The Southeast Asian State of Fisheries and Aquaculture 2022

Southeast Asian Fisheries Development Center

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SEAFDEC Secretariat
Suraswadi Building
Kasetsart University Campus
P.O. Box 1046, Kasetsart Post Office
Bangkok 10903, Thailand
Email: secretariat@seafdec.org

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PREFACE

Information on the status and trends of fisheries is recognized as crucial in serving as the basis for sustainable development and management of fisheries. Southeast Asia is one of the regions that continue to provide a significant contribution to global fishery production. However, countries in the region throughout the recent decades have been confronted with several issues and challenges in ensuring that fisheries could provide a sustainable contribution to meet with the increasing demand, either for domestic consumption or exportation or even for non-food uses. Challenges were also posed from international efforts to ensure that the exploitation of fishery resources is undertaken in a sustainable manner and the resources would be able to provide benefits to the people, not only for the present but also for future generations.

SEAFDEC, throughout the past decades, had undertaken several programs and projects to address fisheries-related issues and challenges that may hinder sustainable development of the fisheries sector, and compile various forms of fishery data and information, *e.g.* regional fishery statistics based on the national statistics data provided by the Southeast Asian countries, among others. In order that such data and information are fully utilized to support the sustainable development of the region's fisheries sector, SEAFDEC started the initiative in developing the publication "The Southeast Asian State of Fisheries and Aquaculture" or "SEASOFIA" with the first issue in 2012, and the subsequent issue in 2017.

The Southeast Asian State of Fisheries and Aquaculture 2022 is the third of a series. This publication was prepared with the collaborative efforts of the SEAFDEC Secretariat and the five technical Departments. It is, therefore, our ultimate hope that this publication would provide useful information on the region's fisheries and aquaculture production and utilization; the recent issues, initiatives, and challenges faced in ensuring sustainable development of fisheries and aquaculture, as well as the future outlook and anticipated challenges. We hope that the publication would contribute to improving science-based policy planning and management of fisheries in order to support countries in achieving sustainable fisheries and enhancing the fisheries' contribution to food security in the years to come.

Malinee Smithrithee
SEAFDEC Secretary-General

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ACDS	ASEAN Catch Documentation Scheme
AFCC	ASEAN Multi-Sectoral Framework on Climate Change
AI	Artificial Intelligence
AIS	Automatic Identification System
ALDFG	Abandoned, Lost or otherwise Discarded Fishing Gear
AMAF	ASEAN Ministers on Agriculture and Forestry
AMR	Antimicrobial Resistance
AMSs	ASEAN Member States
AN-IUU	ASEAN Network for Combating IUU Fishing
APEC	Asia-Pacific Economic Cooperation
AQD	SEAFDEC/Aquaculture Department
APFIC	Asia-Pacific Fishery Commission
AR	Artificial Reef
ASEAN	Association of Southeast Asian Nations
ASPIC	Stock-Production Model Incorporating Covariates
ASWGFi	ASEAN Sectoral Working Group on Fisheries
BOBLME	Bay of Bengal Large Marine Ecosystem
CBFM	Community-based Fisheries Management
CCRF	FAO Code of Conduct for Responsible Fisheries
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CDT	Catch Documentation and Traceability System
CFi	Community Fisheries
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CBD	Convention on Biological Diversity
CBF	Culture-based Fisheries
CBFM	Community-based Fisheries Management
CM	Co-management
CPUE	Catch Per Unit Effort
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security
DOF	Department of Fisheries
EAA	Ecosystem Approach to Aquaculture
EAFM	Ecosystem Approach to Fisheries Management
EC	The European Commission
EEZs	Exclusive Economic Zones
EPRS	Emergency Preparedness and Response System
ETP Species	Endangered, Threatened, and Protected Species
EU	The European Union
FADs	Fish Aggregating Devices
FAO	Food and Agriculture Organization of the United Nations
GAqP	Good Aquaculture Practices
GEF	Global Environment Facility

GIS	Geographic Information System
GMP	Good Manufacturing Practices
GoT	Gulf of Thailand
HABs	Harmful Algal Blooms
HACCP	Hazard Analysis and Critical Control Point
IFRDMD	SEAFDEC/Inland Fishery Resources Development and Management Department
ILO	International Labour Organization
IMTA	Integrated Multi-Trophic Aquaculture
IOTC	Indian Ocean Tuna Commission
IPCC	Intergovernmental Panel on Climate Change
IPOA-Capacity	International Plan of Action for the Management of Fishing Capacity
IPOA-IUU	International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
IUCN	International Union for Conservation of Nature
IUU Fishing	Illegal, Unreported and Unregulated Fishing
JAIF	Japan-ASEAN Integration Fund
JIRCAS	Japan International Research Center for Agricultural Sciences
JTEDs	Juvenile and Trash Excluder Devices
JTF	Japanese Trust Fund
LIFE Fishing	Low Impact and Fuel Efficient Fishing
LMB	Lower Mekong Basin
MCS	Monitoring, Control and Surveillance
MFRD	SEAFDEC/Marine Fisheries Research Department
MFRDMD	SEAFDEC/Marine Fishery Resources Development and Management Department
MMPA	U.S. Marine Mammal Protection Act
MPAs	Marine Protected Areas
MSY	Maximum Sustainable Yield
NACA	Network of Aquaculture Centres in Asia-Pacific
NDFs	Non-detriment Findings
NOAA	U.S. National Oceanic and Atmospheric Administration
NPOA	National Plan of Action
OIE	World Organization for Animal Health
PSM	Port State Measures
PSMA	Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
REBYC	Project on Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management
RES&POA	Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region
RFMO	Regional Fisheries Management Organization

RFVR	Regional Fishing Vessels Record
RPOA-Capacity	Regional Plan of Action for the Management of Fishing Capacity
RPOA-IUU	Regional Plan of Action to Promote Responsible Fishing Practices (including Combating IUU Fishing) in the Region
RPOA-Neritic Tunas	Regional Plan of Action on Sustainable Utilization of Neritic Tunas in the ASEAN Region
RS	Remote Sensing
SDGs	Sustainable Development Goals
SEAFDEC	Southeast Asian Fisheries Development Center
SEASOFIA	The Southeast Asian State of Fisheries and Aquaculture
SIOFA	Southern Indian Ocean Fisheries Agreement
SPS	Sanitary and Phytosanitary
TAC	Total Allowable Catch
TAE	Total Allowable Efforts
TD	SEAFDEC/Training Department
TEDs	Turtle Excluder Devices
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VMS	Vessel Monitoring System
WCPFC	Western and Central Pacific Fisheries Commission
WTO	World Trade Organization
WWF	World Wide Fund for Nature

PART I
Overview of the Status and Trends of Capture Fisheries and Aquaculture in Southeast Asia

1. Global Production and Utilization of Fish

The global fisheries production had continued to grow from 152.8 million metric tons (mt) in 2005 to 213.7 million mt in 2019, with the worldwide trend of fisheries production from both capture fisheries and aquaculture steadily increasing at an annual average rate of 4.35 million mt or about 2.43 % annually (**Table 1**). The utilization of fish for human consumption and non-food uses also increased from 137 million mt in 2005 to 177.8 million mt in 2019 or an increase of 1.89% annually (FAO, 2020a). During the period from 2005 to 2019, the percentage of fish produced for human consumption had increased from 70.2 % to approximately 77.1 %, although there was slight decrease during 2011–2015, but it had remained rather steadily at 76.0 % in 2016, and then slightly declined from 2017 to 2019 (**Table 1**; **Figure 1**). Meanwhile, the human population as major consumer of fish products also increased from approximately 6.5 billion in 2005 to 7.7 billion in 2019, while the per capita fish consumption also increased from an average of 16.5 kg in 2005 to 20.9 kg in 2019 (**Figure 2**). From the aforesaid data, it could be visualized that the increased supply of fish through enhanced fisheries production has contributed to the elevated consumption and other utilization, and as the human population grows the demand for fish and fishery products would surely

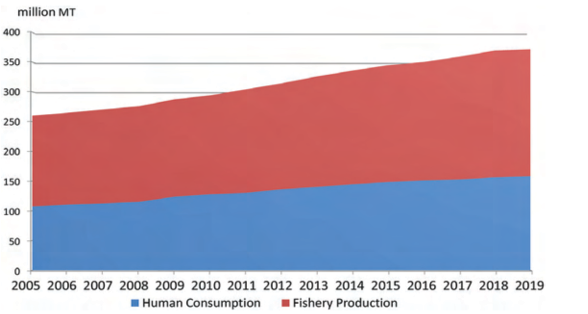


Figure 1. Quantity of fisheries production utilized for human consumption from 2005 to 2019

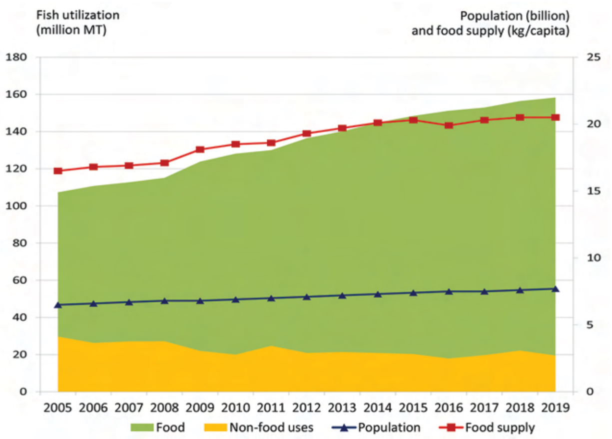


Figure 2. Global fish utilization, food supply and human population from 2005 to 2019

Table 1. World fisheries production and utilization from 2005 to 2019

Year	Production (million mt)*			Utilization**		Human population (billions)**	Percentage of production for human consumption (%)	Per capita fish consumption (kg)**
	Capture	Aquaculture	Total	Human consumption	Non-food uses			
2005	93.7	59.1	152.8	107.3	29.7	6.5	70.2	16.5
2006	91.2	62.9	154.1	110.7	26.3	6.6	71.8	16.8
2007	91.6	66.3	157.9	112.7	27.1	6.7	71.4	16.9
2008	90.7	70.2	160.9	115.1	27.2	6.8	71.5	17.1
2009	90.1	73.8	163.9	123.8	22.0	6.8	75.5	18.1
2010	88.2	78.0	166.2	128.1	20.0	6.9	77.1	18.5
2011	92.7	81.6	174.3	130.0	24.7	7.0	74.6	18.6
2012	89.8	88.2	178.0	136.4	20.9	7.1	76.6	19.3
2013	91.0	95.0	186.0	140.1	21.4	7.2	75.3	19.7
2014	91.6	99.6	191.2	144.8	20.9	7.3	75.7	20.1
2015	92.7	103.9	196.6	148.4	20.3	7.4	75.5	20.3
2016	90.8	108.2	199.0	151.2	17.9	7.5	76.0	19.9
2017	94.3	112.1	206.4	152.9	19.7	7.5	74.1	20.3
2018	97.6	115.8	213.4	156.4	22.2	7.6	73.3	20.5
2019	93.6	120.1	213.7	158.3*	19.5*	7.7	74.1	20.5*

Source: ** FAO Fisheries and Aquaculture Information and Statistics Service*
*** State of World Fisheries and Aquaculture 2018 and 2020*

rise. It is quite clear that for the developing countries, fish consumption trends depend on the availability of local and seasonal supply of fish and fishery products, which also influence the subsequent fish supply chain.

The rapid growth in human population is also likely to continue, and as predicted by the United Nation's Population Division, world population will reach 8.5 billion by 2030 and 9.7 billion by 2050 (UN, 2019), increasing at 10.4 % and 26.0 %, respectively, compared with that in 2019. In 2019, fish consumption had accounted for 74.2 % of the global fisheries production, and is expected to increase in the coming years considering the health benefits that could be derived from fish and fishery products. The world food producing sectors must therefore secure food and nutrition for the growing human population through increased sustainable production. Although records might have shown that the Coronavirus 2019 pandemic has led to dramatic loss of human lives worldwide and presented an unprecedented challenge to public health and food system, the number of people in the world affected by hunger increased in 2020 under the shadow of the COVID-19 pandemic. In fact, after remaining virtually unchanged from 2014 to 2019, the prevalence of under nourishments (PoU) climbed to around 9.9 % in 2020 from 8.4 % a year earlier (FAO, 2021a).

The world fisheries production from 2005 to 2019 by continent (**Table 2**; **Figure 3**) indicated continuous annual increases at an average rate of 2.43 % or 4.35 million mt per year. The major fish producers on one hand, are the countries in Asia (excluding Southeast Asia), contributing 52.8 % to the total production in 2019. On the other hand, the Southeast Asian region, which contributes approximately

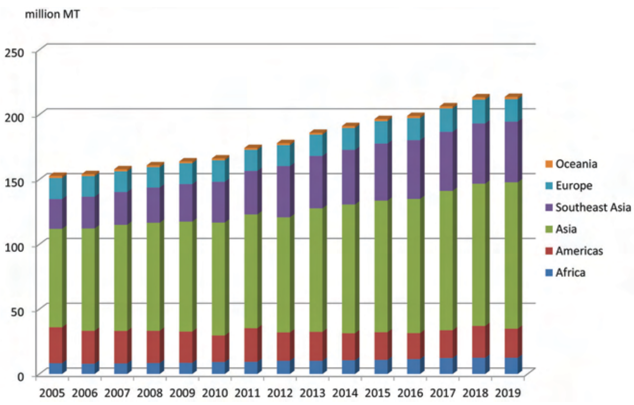


Figure 3. Trends of fisheries production of each continent from 2005 to 2019 by quantity (mt)
*(**Note:** Asia does not include the data of Southeast Asia)*

21.9 % to the world's total fisheries production, had maintained an increasing trend in production from 23.0 million mt in 2005 to 46.8 million mt in 2019 or at an annual average increase of 1.7 million mt or 5.3 % per year. Meanwhile, fisheries production from the Americas had been fluctuating with slight decrease from 27.7 million mt in 2005 to 22.4 million mt in 2019. For Europe, its fisheries production had slightly increased from 16.2 million mt in 2005 to 17.3 million mt in 2019 with highest production peak of 18.4 million mt in 2018.

2. Fisheries Production of Southeast Asia

The Southeast Asian region (**Figure 4**) is bordered to the north by East Asia, to the west by South Asia and the Bay of Bengal, to the east by Oceania and the Pacific Ocean, and to the south by Australia and the Indian Ocean. Southeast Asia

Table 2. Fisheries production of each continent from 2005 to 2019 by quantity (in million mt)

Year	World total* (million mt)	Continents					
		Africa*	Americas*	Asia*	Southeast Asia**	Europe*	Oceania*
2005	**152.8**	8.3	27.7	75.9	23.0	16.2	1.7
2006	**154.1**	7.9	25.4	78.9	24.5	15.9	1.5
2007	**157.9**	8.1	25.1	81.8	25.3	16.0	1.6
2008	**160.9**	8.4	24.9	83.3	27.2	15.7	1.4
2009	**163.9**	8.6	24.1	84.8	28.9	16.1	1.4
2010	**166.2**	9.2	20.5	87.1	31.4	16.6	1.4
2011	**174.3**	9.4	25.9	87.7	33.6	16.3	1.4
2012	**178.0**	10.2	21.8	88.8	36.1	16.2	1.5
2013	**186.0**	10.2	22.3	95.2	40.4	16.5	1.4
2014	**191.2**	10.6	20.8	99.3	42.1	16.9	1.5
2015	**196.6**	10.9	21.3	101.5	44.0	17.3	1.6
2016	**199.0**	11.5	20.0	103.5	45.3	17.0	1.7
2017	**206.4**	12.3	21.4	107.5	45.5	18.1	1.6
2018	**213.4**	12.5	24.5	109.7	46.5	18.4	1.8
2019	**213.7**	12.5	22.4	112.9	46.8	17.3	1.8

Note: *Asia does not include data of Southeast Asia*
* ***Source:*** *FAO Fisheries and Aquaculture Information and Statistics Service*
** ***Source:*** *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Figure 4. Map of Southeast Asia
*(**Source:** Google)*

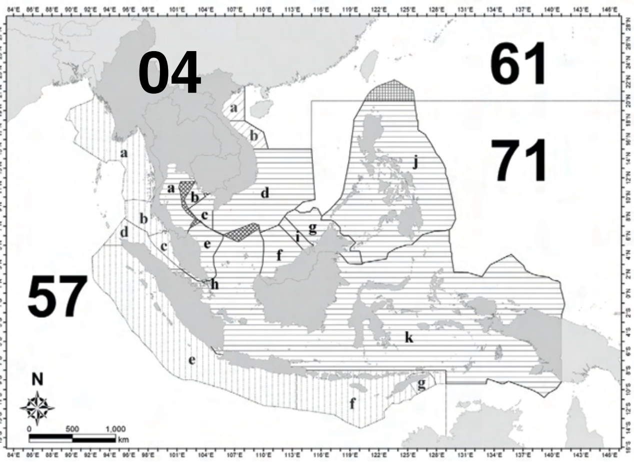


Figure 5. FAO Major Fishing Areas in Southeast Asia
*(**Source:** SEAFDEC, 2008b)*

comprises eleven countries with impressive diversity in religion, culture, and history, namely: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Timor-Leste, Thailand, and Viet Nam. Although Timor-Leste may have its own fisheries data, SEAFDEC has no mandate to include the country's statistics in this publication as the scope of this publication focuses mainly on the ten ASEAN Member States (AMSs). In terms of fishery statistics for both capture fisheries and aquaculture, the total fisheries production of the Southeast Asian region is derived from the waters identified as FAO Major Fishing Area 57 (Indian Ocean, Eastern), 61 (Pacific, Northwest), 71 (Pacific, Western Central), and 04 (Asia, Inland Waters) as shown in **Figure 5**.

All inland waters of the Southeast Asian countries are included in the FAO Major Fishing Area 04 (Asia, Inland Waters) as shown in **Figure 6**. The data presented by Lao PDR, which is the sole landlocked country in the region, are therefore reported under Area 04 only (SEAFDEC, 2008b). There is no sub-area that has been recognized for the collection of catch effort data for the Southeast Asian region. The fisheries production of the Southeast Asian region from 2005 to 2019, summarized in **Table 3**, was compiled by SEAFDEC based on inputs from the AMSs, and published in the Fishery Statistical Bulletin for the South China Sea Area in 2005-2007 and henceforth, in the Fishery Statistical Bulletin of Southeast Asia in 2008–2019.

In compiling the data for the Fishery Statistical Bulletin of Southeast Asia, efforts are being made to come up with as much complete data as possible, by utilizing as additional inputs those data and information that are available from various sources, while utilization of regional inputs is always maximized. These include the data collected

Table 3. Fisheries production of the Southeast Asian countries from 2005 to 2019 by quantity (thousand mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	3.42	546	6,646.96	107.8	1,402.40	2,581.78	4,161.87	7.84	4,132.83	3,397.20	**22,988.10**
2006	2.99	661.54	7,183.59	107.8	1,596.05	2,817.99	4,412.16	11.67	4,051.82	3,656.15	**24,501.76**
2007	3.22	525.1	7,510.77	91.66	1,654.22	2,808.04	4,710.95	8.03	3,675.38	4,315.50	**25,302.87**
2008	2.75	536.32	9,054.87	93.5	1,639.02	3,147.60	4,964.70	5.14	3,204.20	4,559.72	**27,207.82**
2009	2.42	515	10,064.14	105	1,729.00	3,491.10	5,084.67	5.69	3,137.67	4,782.40	**28,917.09**
2010	2.77	550	11,662.31	113	1,806.57	3,901.98	5,155.65	5.23	3,113.32	5,127.60	**31,438.43**
2011	2.45	631.69	13,626.14	129.6	1,665.84	4,149.80	4,973.59	5.95	3,036.53	5,432.90	**33,654.49**
2012	5.08	728	15,420.73	136	1,760.84	4,417.68	4,865.68	6.2	2,991.62	5,816.10	**36,147.93**
2013	3.43	728	19,245.63	164.23	2,018.74	4,715.84	4,695.37	7.21	2,822.08	6,019.70	**40,420.23**
2014	3.95	745.31	20,600.77	150.59	1,985.16	5,040.31	4,681.42	6.69	2,567.80	6,332.50	**42,114.50**
2015	4.35	731.89	22,154.42	158.6	1,998.25	5,316.95	4,645.87	8.16	2,429.86	6,549.70	**43,998.05**
2016	14.11	808.55	23,172.87	166.88	1,987.68	5,598.00	4,350.76	7.35	2,425.90	6,803.90	**45,336.00**
2017	15.43	857.02	22,850.63	180.78	1,897.30	5,675.46	4,312.66	6.99	2,386.92	7,313.40	**45,496.59**
2018	14.71	943.21	23,007.39	179.1	1,672.45	5,877.46	4,613.07	7.01	2,456.29	7,768.50	**46,539.19**
2019	14.66	969.1	22,614.59	183.9	1,872.80	5,931.81	4,413.13	7.25	2,488.83	8,270.20	**46,766.27**

***Source:** Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

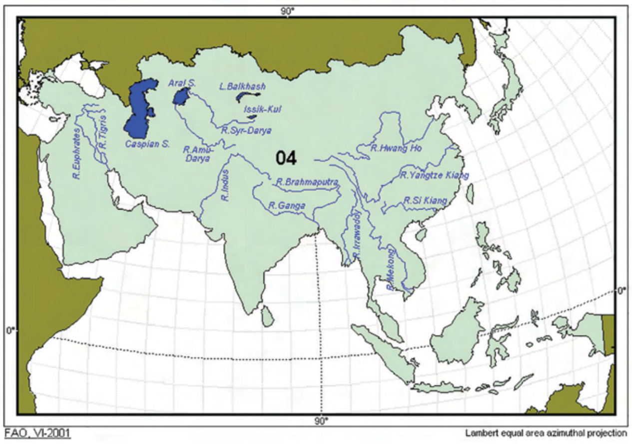


Figure 6. Asia-Inland Waters
*(**Source:** SEAFDEC, 2008b)*

through statistics surveys, as well as statistical records from government and semi-governmental organizations. In addition, data and information derived from recently-conducted statistical research, *e.g.* small-scale surveys are also being sourced to provide additional inputs to the Bulletin.

The total fisheries production of the Southeast Asian region in 2019 reached a record of 46.77 million mt, with an average increase of 6.08 % annually over the past 15 years. By country, Indonesia reported the highest fisheries production in 2019 in terms of volume at 22.6 million mt or nearly 48.3 % of the region's total fisheries production, followed by Viet Nam, Myanmar, Philippines, and Thailand at 8.2 million mt (17.7 %), 5.9 million mt (12.7 %), 4.4 million mt (9.4 %), and 2.5 million mt (5.3 %), respectively. The increased fisheries production in Indonesia could have been due to a number of reasons that include increased abundance of fish in several locations of the country; good weather with waves and wind that support fishing activities; increase in the number of fishing vessels, as well as government support for fishing facilities, *e.g.* distribution of fishing gears in 2018 (KKP, 2019). In contrast, the fishery statistics of Thailand showed declining trends, particularly from 2006 until 2019 at an average rate of 3.4 % annually,

Table 4. Production of the fisheries sub-sectors of Southeast Asia in 2019 by quantity (mt) and value (USD thousand)

Sub-sectors	Quantity (mt)	Value (USD thousand)	Value/ Quantity (USD/mt)*
Marine Capture Fisheries	18,167,839	29,343,867	2,031
Inland Capture Fisheries	3,316,808	4,056,224	1,605
Aquaculture	25,281,627	21,645,304	1,063
Total	**46,766,274**	**55,045,395**	

Source: *Fishery Statistical Bulleting of Southeast Asia 2019 (SEAFDEC, 2022)*
* *Computation of value/quantity excludes the corresponding quantity of production from countries that did not report their production values*

mainly because of the yearly decreases in the production from marine capture fisheries.

Fisheries production of the Southeast Asian region comes from three sub-sectors, namely: marine capture fisheries, inland capture fisheries, and aquaculture. By sub-sector, the total fisheries production of the region in 2019 (**Table 4**) indicated that the largest portion of the production volume

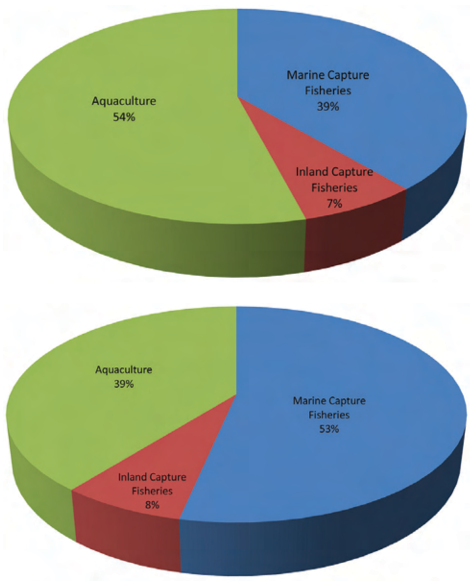


Figure 8. Percentage contribution of the fisheries sub-sectors to the total fisheries production of Southeast Asia in 2019: by quantity in mt *(above)* and value in USD *(below)*

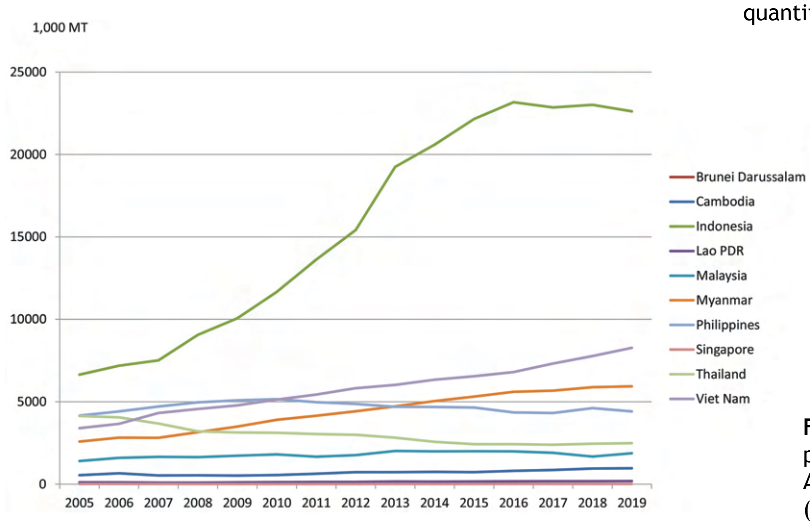


Figure 7. Trends of fisheries production of the Southeast Asian countries by quantity (thousand mt)

Table 5. Production trends of the fisheries sub-sectors of Southeast Asia: 2005 to 2019 by quantity (million mt)

Year	Marine Capture Fisheries		Inland Capture Fisheries		Aquaculture		Total (million mt)
	Production (million mt)	Percentage (%)	Production (million mt)	Percentage (%)	Production (million mt)	Percentage (%)	
2005	13.59	59	1.89	8	7.51	33	**22.99**
2006	13.94	57	2.14	9	8.43	34	**24.50**
2007	14.06	56	2.01	8	9.24	37	**25.31**
2008	13.81	51	2.33	9	11.06	41	**27.20**
2009	14.14	49	2.40	8	12.38	43	**28.92**
2010	14.87	47	2.38	8	14.19	45	**31.44**
2011	15.07	45	2.64	8	15.94	47	**33.65**
2012	15.48	43	2.82	8	17.85	49	**36.15**
2013	16.14	40	2.87	7	21.41	53	**40.42**
2014	16.58	39	3.00	7	22.53	54	**42.11**
2015	16.76	38	3.06	7	24.18	55	**44.00**
2016	17.03	38	3.13	7	25.18	56	**45.34**
2017	17.33	38	3.23	7	24.94	55	**45.50**
2018	18.33	39	3.34	7	24.87	53	**46.54**
2019	18.17	39	3.32	7	25.28	54	**46.77**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

was derived from aquaculture accounting for approximately 54 % followed by marine capture fisheries at about 39 % and inland capture fisheries at 7 % (**Figure 8**). In terms of value, marine capture fisheries contributed the highest production value accounting for 53 % followed by aquaculture at approximately 39 % and inland capture fisheries at about 8 % (**Figure 8**). While the value per volume of marine capture fisheries in 2019 was about USD 2,031/mt, those of inland capture fisheries and aquaculture were about USD 1,605/mt and USD 1,063/mt, respectively (**Table 4**).

The production trends of the fisheries sub-sector of Southeast Asia from 2005 to 2019 signified declining contributions from marine capture fisheries, for although its contribution was about 59 % in 2005, henceforth, this had been constantly decreasing (**Table 5**). Nevertheless, such reduction was compensated by the contribution from aquaculture which increased from 33 % in 2005 to 54 % in 2019. These trends indicated the increasing importance of aquaculture as a source of food fish to meet the increasing demand for fish and ensure food security in the region.

3. Marine Capture Fisheries Production of Southeast Asia

In 2019, the global marine capture fisheries production was reported to be 81.5 million mt, accounting for 38 % of the total fisheries production (213.7 million mt) with Asia (excluding Southeast Asia) and Southeast Asia as the top contributors followed by Americas and Europe (**Table 6**). The slight decrease of the marine capture fishery production from 2005 to 2019 was a result of the severe fluctuations in the production of America and the declining production trend of Asia over the years (**Figure 9**).

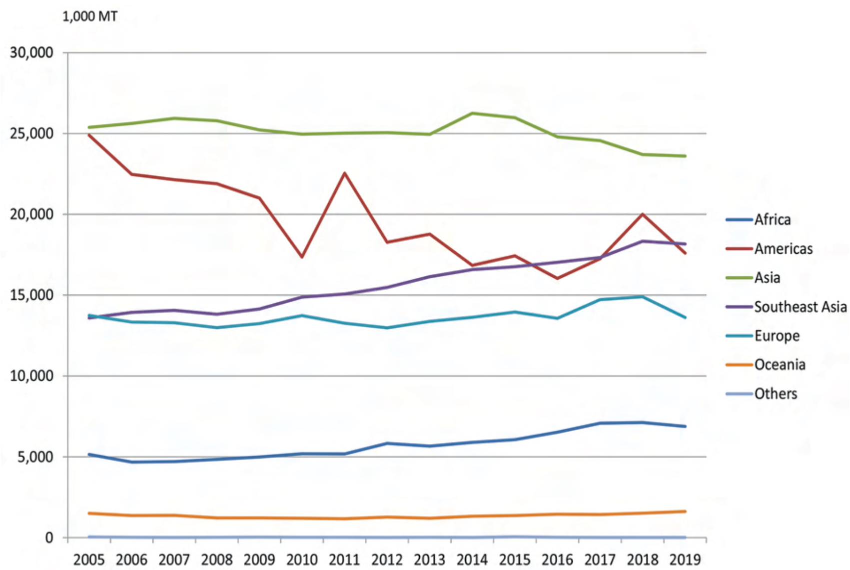


Figure 9. Trends in marine capture fisheries production of each continent by quantity (thousand mt)
(Asia does not include data of Southeast Asia)

Table 6. Marine capture fisheries production of each continent from 2005 to 2019 by quantity (thousand mt)

Year	World total* (thousand mt)	Continents (thousand mt)						
		Africa*	Americas*	Asia*	Southeast Asia**	Europe*	Oceania*	Others*
2005	**84,292**	5,144	24,892	25,380	13,587	13,742	1,502	45
2006	**81,435**	4,676	22,466	25,622	13,939	13,341	1,368	23
2007	**81,521**	4,701	22,141	25,938	14,057	13,290	1,376	18
2008	**80,572**	4,842	21,891	25,782	13,814	12,990	1,224	29
2009	**79,852**	4,987	21,003	25,225	14,140	13,242	1,221	34
2010	**77,342**	5,187	17,360	24,962	14,874	13,736	1,204	19
2011	**82,267**	5,178	22,544	25,017	15,072	13,264	1,168	24
2012	**78,891**	5,830	18,271	25,048	15,479	12,977	1,270	16
2013	**80,135**	5,664	18,772	24,948	16,137	13,383	1,204	27
2014	**80,532**	5,897	16,839	26,246	16,584	13,628	1,326	12
2015	**81,601**	6,059	17,428	25,972	16,762	13,951	1,370	59
2016	**79,410**	6,527	16,031	24,787	17,027	13,567	1,449	22
2017	**82,387**	7,077	17,257	24,557	17,330	14,718	1,435	13
2018	**85,578**	7,124	20,006	23,698	18,330	14,895	1,511	14
2019	**81,503**	6,881	17,600	23,601	18,168	13,623	1,616	14

Note: *Asia does not include data of Southeast Asia*
* ***Source:*** *FAO Fisheries and Aquaculture Information and Statistics Service*
** ***Source:*** *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

For the Southeast Asian region, the trend in marine capture fisheries production showed that it had been increasing from 2005 until 2018, but with slight decrease in 2019 to 18.17 mt from 18.33 mt in 2018 due to the decreased production of Indonesia and the Philippines in 2019 (**Table 7**). Nonetheless, such production in 2019 still accounted for 22 % of global marine capture fisheries production. **Figure 10** shows the generally increasing trend in marine capture fisheries production of the Southeast Asian countries from 13.59 million mt in 2005 to 18.17 million mt in 2019 with an annual average increase of 0.31 million mt or 2.0 % annually. Among the Southeast Asian countries, Indonesia consistently contributed the highest volume to the region's total marine capture fisheries production during 2005–2019 (**Table 7**). Specifically in 2019, Indonesia accounted for the highest production in terms of volume at 6.42 million mt accounting for about 35.3 % of the region's marine capture production, followed by Viet Nam contributing 3.58 million mt (19.72 %), Myanmar at 3.25 million mt (17.89 %), and Philippines at 1.90 million mt (10.46%). Malaysia ranked next contributing 1.45 million mt (8.01 %), and Thailand at 1.41 million mt (7.76 %).

Table 7. Marine capture fisheries production of the Southeast Asian countries in 2005-2019 by quantity (thousand mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR*	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	2.71	60	4,408.50	-	1,209.60	1,375.67	2,122.22	1.92	2,615.56	1,791.10	**13,587.28**
2006	2.28	60.5	4,512.19	-	1,379.86	1,525.00	2,154.80	3.1	2,484.80	1,816.10	**13,938.63**
2007	2.55	54.9	4,734.28	-	1,381.42	1,485.74	2,327.82	3.52	2,079.35	1,987.40	**14,056.98**
2008	2.36	66	4,701.93	-	1,394.53	1,679.01	2,377.51	1.62	1,644.80	1,946.60	**13,814.36**
2009	1.96	75	4,789.41	-	1,391.09	1,867.51	2,418.84	2.12	1,496.16	2,098.30	**14,140.39**
2010	2.35	85	5,039.42	-	1,428.88	2,048.59	2,424.48	1.73	1,617.40	2,226.60	**14,874.45**
2011	2.15	114.69	5,328.64	-	1,373.11	2,169.82	2,171.77	1.62	1,610.42	2,300.00	**15,072.22**
2012	4.52	110	5,400.98	-	1,472.24	2,332.79	2,145.23	1.97	1,500.20	2,510.90	**15,478.83**
2013	2.82	110	5,707.02	-	1,482.90	2,483.87	2,127.37	1.64	1,614.54	2,607.00	**16,137.16**
2014	3.19	120.25	5,967.14	-	1,458.13	2,702.24	2,131.87	1.43	1,488.28	2,711.10	**16,583.63**
2015	3.37	100.98	6,065.06	-	1,486.05	2,854.20	2,094.35	1.26	1,317.22	2,839.90	**16,762.39**
2016	13.29	126.7	6,070.96	-	1,574.45	2,996.74	1,994.34	1.24	1,275.99	2,973.60	**17,027.31**
2017	13.8	121.02	6,268.11	-	1,465.11	3,036.41	1,911.01	1.1	1,300.42	3,213.30	**17,330.28**
2018	13.56	153.6	6,625.37	-	1,448.98	3,152.14	2,145.73	1.31	1,392.93	3,396.70	**18,330.32**
2019	13.72	137.23	6,416.45	-	1,455.45	3,249.70	1,900.21	1.42	1,410.66	3,583.00	**18,167.84**

* *- means magnitude is zero or not applicable. Being a landlocked country, Lao PDR has no marine capture fisheries*
Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

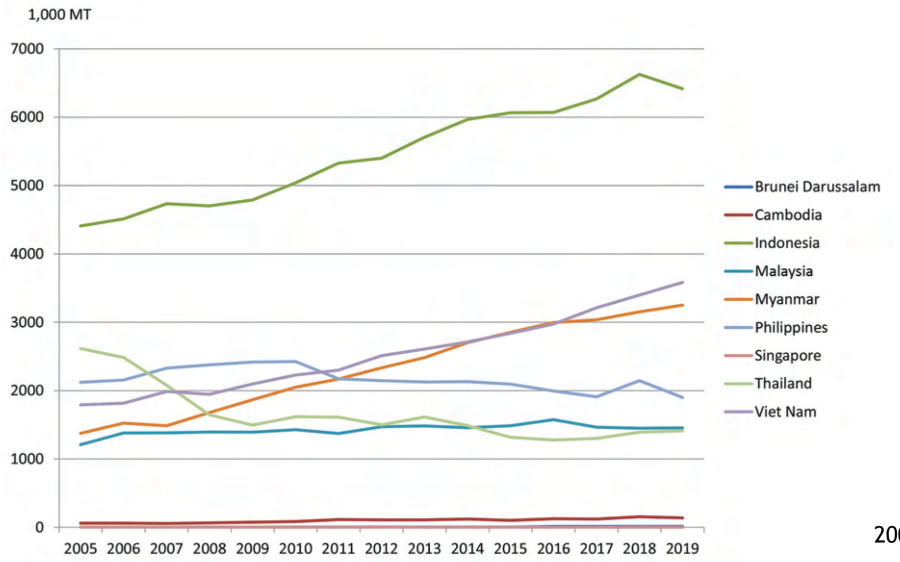


Figure 10. Trends in marine capture fisheries production of Southeast Asian countries in 2005-2019 by quantity (thousand mt)

As shown in **Table 7** and **Figure 10**, Indonesia has been the largest fish producer in the Southeast Asian region from 2005 to 2019 in terms of quantity, which had been increasing from 4.41 million mt to 6.42 million mt or at an annual average rate of increase of 143.43 thousand mt or 2.75 % annually. The marine capture fisheries production of Viet Nam had also been steadily increasing from 1.79 million mt to 3.58 million mt or at an annual average rate of increase of 127.99 thousand mt or 5.12 % annually. Myanmar's marine capture production had increased from 1.37 million mt in 2005 to 3.25 million mt in 2019 with an annual average rate of increase of 133.86 thousand mt or 6.41 % annually. In contrast, the marine capture production of the Philippines showed declining trends from 2.12 million mt in 2005 to 1.90 million mt in 2019 with an annual average rate of decrease of 15.86 thousand mt or 0.60 % annually. Thailand also showed declining trends from 2.61 million mt in 2005 to 1.41 million mt in 2019 with an annual average rate of decrease of 86.06 thousand mt or 3.92 % annually. One of the possible reasons for the declining data on marine capture fisheries production of Thailand could have emanated from the decision of the European Union to declare Thailand in 2015 as having breached the illegal, unreported, and unregulated (IUU) fishing regulations by carrying out inappropriate fishing activities, and to issue a yellow card after giving warning to Thailand for being identified as a non-cooperating country in the fight against illegal, unreported and unregulated (IUU) fishing. Subsequently, Thailand had also been prohibited from exporting fishery products to the EU countries. Nonetheless, Thailand had adopted several measures to combat IUU fishing and controlled the fishing capacity at sustainable level. The yellow card issued to Thailand was finally lifted by the EU in January 2019.

Table 8. Marine capture fisheries production of the Southeast Asian countries in 2005-2019 by value (USD million)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR*	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	10	...	3,726	-	1,147	...	1,681	6	1,534	...	**8,104**
2006	9	...	4,106	-	1,346	...	1,998	12	1,629	...	**9,100**
2007	10	...	4,868	-	1,493	...	2,452	14	1,586	...	**10,423**
2008	9	...	4,957	-	1,691	1,585	2,811	9	1,276	...	**12,338**
2009	5	111	1,687	-	1,888	3,081	2,390	11	1,244	...	**10,417**
2010	7	...	6,558	-	2,015	3,400	2,525	11	1,383	...	**15,899**
2011	8	...	7,100	-	2,268	3,580	3,017	10	1,627	3,784	**21,394**
2012	18	...	4,863	-	2,583	3,849	2,890	12	1,767	4,384	**20,366**
2013	8	...	8,997	-	2,646	4,098	2,997	11	1,829	...	**20,586**
2014	9	...	8,014	-	4,768	4,459	2,787	9	1,608	...	**21,654**
2015	9	...	8,032	-	2,383	4,852	2,710	9	1,486	...	**19,481**
2016	46	...	8,351	-	2,447	5,095	2,410	9	1,582	...	**19,940**
2017	44	...	13,199	-	2,774	5,162	2,389	8	1,716	...	**25,292**
2018	36	...	17,626	-	2,782	3,152	2,599	9	1,919	...	**28,123**
2019	53	...	16,413	-	2,770	5,362	2,607	9	2,130	...	**29,344**

* - *means magnitude is zero or not applicable. Being a landlocked country, Lao PDR has no marine capture fisheries*
Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

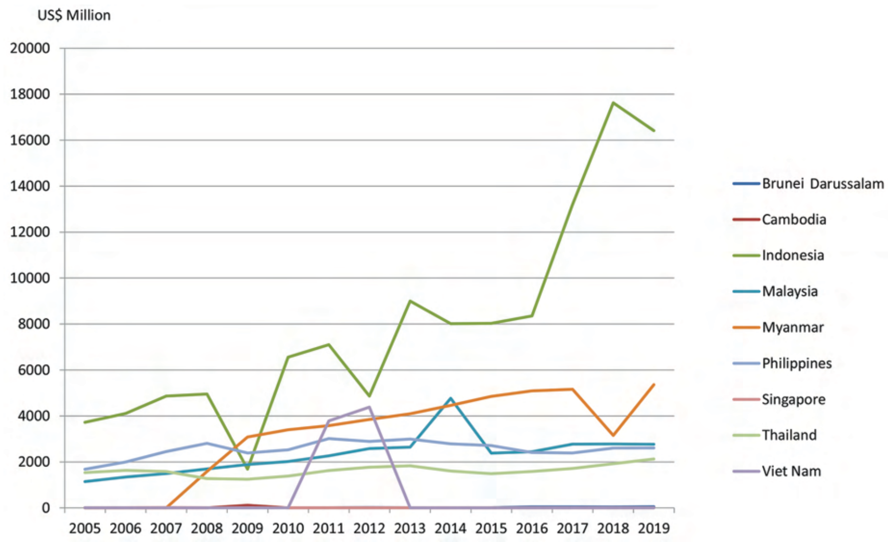


Figure 11. Trends in value of marine capture fisheries production of the Southeast Asian countries in 2005-2019 (USD million)

In terms of value, the total production from marine capture fisheries of the Southeast Asian countries during 2005-2019 as shown in **Table 8**, indicated that the total value of the region's marine capture fisheries production from 2005 to 2019 had increased corresponding to the increasing trend of the quantity of production, although some countries were not able to provide the data. Indonesia which led Southeast Asia's top producing countries, accounted for about 55.9 % of the region's marine capture fisheries production in 2019 in terms of value, with Myanmar emerging second contributing about 18.3 %. Meanwhile, Malaysia which came in the third contributed about 9.4 %, the Philippines came in fourth at 8.8 %, and Thailand at the fifth rank contributed about 7.3 % (**Figure 11**).

In terms of the species of Southeast Asia's marine capture fisheries production, the countries reported a total of 184 aquatic species and/or species groups caught that comprise 143 finfishes, 17 crustaceans, 20 mollusks, and 4 aquatic invertebrates. **Table 9** shows the major groups of species from marine capture fisheries of Southeast Asian countries with the corresponding production in quantity and value in 2019. Nevertheless, it should be noted that the large portion of the production from the region was recorded as "Miscellaneous fishes (45.25 %), meaning that the catches had been recorded without being classified into species or species group. Moreover, the region's production of major species of marine capture fisheries in 2019 indicated that jack, mullets, sauries, etc. contributed the second highest volume at 10.64 % followed by tunas at 10.23 %; herring, sardines, anchovies, etc. at 8.22 %; red fishes, basses, conger etc. at 7.95 %; mackerels at 4.19 %; cuttlefish, squids, etc. at 2.47 %; and miscellaneous crustaceans at 2.36 %.

As the consistent top producer, Indonesia contributed the largest volume of marine capture fisheries in 2019 which included the major groups of marine fishes *nei* at 26.87 %; tunas at 19.8 %; jack, mullets, sauries, etc. at 17.36 %; red fishes, basses, conger etc. at 11 %. The second highest producer, Viet Nam reported production of major groups of species classified as marine fish *nei* at 66.10 %; others at 10.05 %; herring, sardines, anchovies, etc. at 9.34 %; mollusks at 8.65 %.

In terms of production value, it should be noted that although the production volume of Indonesia has been steadily increasing from 2005 to 2019 (**Figure 10**), the corresponding value had been highly fluctuating particularly from 2009 onwards (**Figure 11**) due to the decreasing production values of several major species. Since several Southeast Asian countries were not able provide their respective data on production value, *i.e.* Cambodia, Lao PDR, and Viet Nam although the latter was able to report for some years, the overall regional picture of the value of marine capture fisheries production could not be reported. In the case of Myanmar however, the country started to report the value of its production starting from 2008 to the present, and the trend showed increasing value at an average rate of USD 343 million per year or 16.3 % annually. Nevertheless, the general picture of the region's marine capture fisheries production in terms of value, seemed to indicate a highly fluctuating trend over the years.

The data in **Table 9** also suggest that the production value of lobster as valued per volume is the highest among the major groups of species of marine capture fisheries at USD 5,683/mt, which was produced by Thailand and Indonesia as well as in smaller quantities by Malaysia, Philippines, and Singapore. This was followed by crabs at USD 2,551/mt produced mainly by Indonesia, Thailand, and Viet Nam; cuttlefish, squids, etc. at USD 1,905/mt from Indonesia, Thailand, Malaysia, Philippines, and in small quantities from Brunei Darussalam and Singapore; mackerels at USD 1,369/mt from Indonesia, Philippines, Malaysia, Thailand and in small quantities from Brunei Darussalam and Singapore; shrimps prawns, etc. at USD 1,328/mt from Indonesia, Thailand, Philippines, and Brunei Darussalam; cockles, clams, etc. at USD 1,322/mt from

Table 9. Major groups of species produced by marine capture fisheries of the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Major groups of species	Quantity (mt) by country										Total value (USD thousand)*	Value/ Quantity (USD/mt)*
	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total		
Shads, milkfish, barramundi, etc.	26	…	52,220	35,740	…	2,828	46	827	…	**91,687**	**78,486**	**856**
Flounders halibuts, soles, etc.	7	…	8,177	9,221	…	699	…	4,266	…	**22,370**	**28,215**	**1,261**
Red fishes, basses, congers, etc.	262	…	705,590	299,459	…	304,176	466	134,962	…	**1,444,915**	**1,475,075**	**1,021**
Jack, mullets, sauries, etc.	410	…	1,113,680	216,141	…	415,270	241	186,763	…	**1,932,504**	**1,526,192**	**790**
Herring, sardines, anchovies, etc.	246	…	435,506	87,278	…	394,915	41	239,810	334,800	**1,492,596**	**640,068**	**553**
Tunas	2,217	…	1,275,534	90,751	…	419,243	1	46,397	25,109	**1,859,252**	**1,272,396**	**694**
Mackerels	187	…	300,050	161,255	…	203,430	46	96,309	…	**761,277**	**1,042,279**	**1,369**
Sharks and rays	37	…	20,271	17,379	…	3,969	107	2,562	…	**44,325**	**42,189**	**952**
Misc. fishes	…	104,765	1,724,157	318,837	3,249,700	12,615	151	442,696	2,368,291	**8,221,212**	**5,708,407**	**993**
Crabs	4	…	125,815	15,227	…	30,224	26	50,950	50,360	**272,606**	**566,884**	**2,551**
Lobsters	…	…	1,567	682	…	268	4	1,964	…	**4,484**	**25,483**	**5,683**
Shrimps, prawns, etc.	169	…	92,472	…	…	27,299	…	34,053	…	**153,993**	**204,573**	**1,328**
Misc. crustaceans	9	17,430	129,380	106,517	…	11,196	218	29,072	134,544	**428,366**	**410,575**	**1,485**
Oysters	…	…	334	…	…	7	…	…	…	**341**	**147**	**432**
Mussels	…	…	11,319.00	…	…	24.00	…	…	…	**11,343**	**365**	**32**
Cockles, clams, etc.	…	…	103,702	4,247	…	473	…	26,449	…	**134,871**	**178,325**	**1,322**
Cuttlefish, squids, etc.	91	…	225,657	70,603	…	53,772	72	98,375	…	**448,570**	**854,608**	**1,905**
Mollusks	…	15,030	13,885	…	…	…	…	6,577	309,844	**345,336**	**10,489**	**513**
Invertebrates	…	…	9,651	20,904	…	951	…	8,634	…	**40,140**	**16,128**	**402**
Seaweeds	…	…	67,483	…	…	365	…	…	…	**67,848**	**…**	**…**
Others	10,060	…	…	1,205.00	…	18,486.10	…	…	360,052	**389,803**	**15,262,983**	
Total	**13,725**	**137,225**	**6,416,450**	**1,455,446**	**3,249,700**	**1,900,210**	**1,418**	**1,410,665**	**3,583,000**	**18,167,838**	**29,343,867**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Computation of prices excludes the corresponding production of country not reporting the production value*

Indonesia, Thailand, Malaysia, and in small quantity from the Philippines.

3.1 Economically Important Marine Species

The economically important marine species that provided significant contributions to Southeast Asia's total fisheries production in 2019 include tuna and tuna-like species, small pelagic fishes (*e.g.* scads, mackerel, anchovies, sardines), demersal fish species, crustaceans, mollusks, and seaweeds. Being highly in demand not only within the Southeast Asian region but also in other regions of the world, these species dominate the fishery exports of the Southeast Asian countries.

3.1.1 Tuna and Tuna-like Species

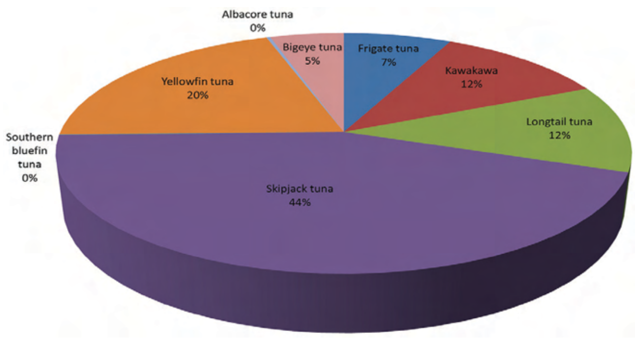
The tuna and tuna-like species include the most economically important species referred to as principal market because of their global economic importance and the intensive international trade generated for canning and sashimi production. Tuna and tuna-like species in Southeast Asian could be taxonomically classified under the family Scrombridae, and broadly categorized into three groups, *i.e.* oceanic tunas which include skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*), albacore tuna (*T. alalunga*), and bluefin tuna (*T. thymus*, *T. orientalis*, and *T. macoyii*); neritic tunas including frigate tuna (*Auxis thazard*), bullet tuna (*A. rochei*), kawakawa (*Euthynnus affinis*), and longtail tuna (*T. tonggol*); and tuna-like species, *i.e.* narrow-barred Spanish mackerel (*Scomberomorus commerson*), Indo-Pacific king mackerel (*Scomberomorus guttatus*), seerfishes (*Scomberomorus* spp.), striped bonito (*Sarda orientalis*), and tuna-like fishes *nei* (Scombroidei). Tuna and tuna-like species are caught by commercial fishing gears, particularly trawl nets, purse seines, falling net, and gill net as well as several other traditional fishing gears.

Table 10. Tuna and tuna-like species production of the Southeast Asian countries in 2019 by quantity (mt)

Species	Countries							Total
	Brunei Darussalam	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam	
Neritic tunas	**135**	**409,978**	**71,297**	**35,759**	**...**	**46,397**	**...**	**563,566**
Frigate tuna (*Auxis thazard*)	121	130,518	2,937	...	...	...	...	133,576
Bullet tuna (*Auxis rochei*)	...	...	...	...	...	...	...	...
Kawakawa (*Euthynnus affinis*)	4	119,930	25,515	35,759	...	29,383	...	210,591
Longtail tuna (*Thunnus tonggol*)	11	159,530	42,845	...	...	17,014	...	219,400
Oceanic tunas	**2,081**	**865,556**	**19,454**	**383,484**	**1**	**...**	**25,109**	**1,295,685**
Skipjack tuna (*Katsuwonus pelamis*)	1,417	527,237	16,107	266,376	1	...	12,000	823,138
Southern bluefin tuna (*Thunnus maccoyii*)	...	1,607	...	...	...	...	...	1,607
Yellowfin tuna (*Thunnus albacares*)	664	265,129	1,862	99,351	...	...	7,700	374,706
Albacore tuna (*Thunnus alalunga*)	...	4,316	485	...	...	...	...	4,801
Bigeye tuna (*Thunnus obesus*)	...	67,267	1,000	17,757	...	...	5,409	91,433
Tuna-like species	**15**	**222,727**	**16,934**	**111,511**	**39**	**9,430**	**334,800**	**695,456**
Narrow-barred Spanish mackerel (*Scomberomorus commerson*)	14	163,855	...	111,511	...	...	...	275,380
Indo-Pacific king mackerel (*Scomberomorus guttatus*)	1	47,910	...	...	...	...	...	47,911
Seerfishes *nei* (*Scomberomorus* spp.)	...	...	16,934	...	39	9,430	...	26,403
Tuna-like fishes *nei* (Scombroidei)	...	10,962	...	...	...	...	334,800	345,762
Total	**2,232**	**1,498,261**	**107,865**	**530,754**	**40**	**55,827**	**359,909**	**2,554,708**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

In 2019, only seven countries provide the statistics on tuna and tuna-like species production by species, namely: Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Viet Nam. Cambodia and Myanmar were unable to report their respective production volumes of tuna and tuna-like species. **Table 10** shows the tuna and tuna-like species production of Southeast Asia in 2019 accounting for approximately 14.06 % of the region's total marine capture fisheries production. The total production volume of oceanic tunas accounted for approximately 50.7 % of the region's total tuna and tuna-like species production, while tuna-like species accounted for approximately 27.2 % of the region's total tuna and tuna-like species production. In 2019, Indonesia which is the top tuna producer in Southeast Asian region contributed to the region's total tuna production by approximately 68.60 %, followed by the Philippines contributing about 22.55 %, Malaysia 4.88 %, Thailand 2.50 %, Viet Nam 1.35 %, and Brunei Darussalam 0.12 %. In terms of species, skipjack tuna (*Katsuwonus pelamis*) contributed the highest production volume accounting for 44.27 %, followed by yellowfin tuna (*Thunnus albacares*) at 20.15 %, and longtail tuna (*Thunnus tonggol*) at 11.80 % (**Figure 12**). In 2019, Viet Nam was the leading producer of tuna-like species in the Southeast Asian region contributing approximately 48.14 % followed by Indonesia at 32.03 %, Philippines at 16.03 %, and Thailand 1.36 %. Nearly half of the catch was reported not by species but only as tuna-like



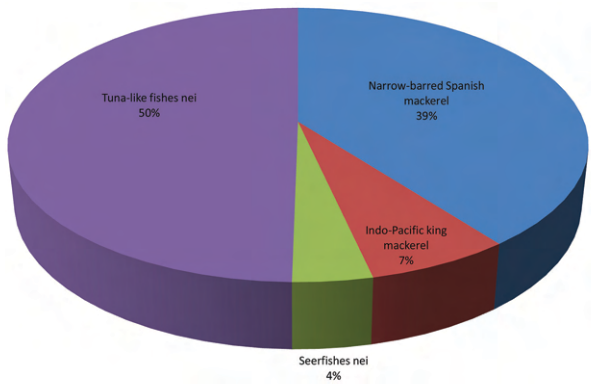


Figure 12. Percentage of tuna species *(above)* and tuna-like species *(below)* production of Southeast Asia in 2019 by quantity

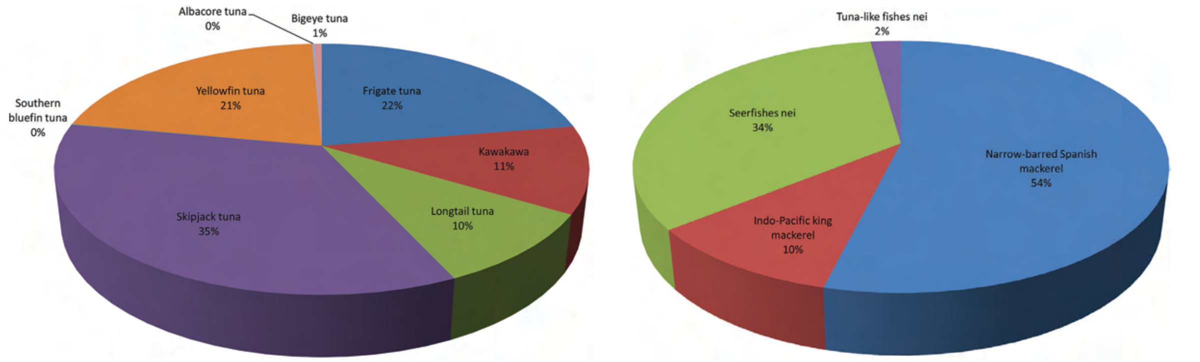


Figure 13. Percentage of tuna species *(left)* and tuna-like species *(right)* production of Southeast Asia in 2019 by value

fishes *nei* (Scombroidei) which accounted for 49.72 % of the region's production of total tuna-like species followed by the narrow-barred Spanish mackerel (*Scomberomorus commerson*) at 39.60 % (**Figure 12**).

In terms of the value of production in 2019, tuna and tuna-like species contributed approximately 2.93 % to the region's total fisheries production or 5.49 % to the region's total marine capture fisheries production. Skipjack tuna (*Katsuwonus pelamis*) provided the highest production value about 34.76 % of the region's total tuna production, followed by frigate tuna (*Auxis thazard*) contributing about 22.37 %, and yellowfin tuna (*Thunnus albacares*) about 21.35 % (**Figure 13**). For the value of production of tuna-like species in 2019, narrow-barred Spanish mackerel (*Scomberomorus commerson*) contributed the highest production value to the region's total value tuna-like species production accounting for 53.87% followed by seerfishes *nei* (*Scomberomorus* spp.) contributing about 33.65 % (**Figure 13**). Data in **Table 11** suggest that seerfishes *nei* (*Scomberomorus* spp.) obtained the highest price among the tuna and tuna-like species group at USD 4,891/mt, followed by frigate tuna (*Auxis thazard*) at USD 2,055/mt, Indo-Pacific king mackerel (*Scomberomorus guttatus*) at USD 824/mt, narrow-barred Spanish mackerel (*Scomberomorus commerson*) at USD 751/mt, yellowfin tuna (*Thunnus albacares*) at USD 679/mt, and Kawakawa (*Euthynnus affinis*) at USD 654/mt.

The region's production of tuna and tuna-like species in 2019 (**Table 11**) was derived mostly from FAO Major Fishing Area 71 (Pacific, Western Central) and 57 (Indian

Table 11. Tuna and tuna-like species production of Southeast Asia in FAO Major Fishing Areas in 2019 by quantity (mt), and value (USD thousand)

Species	Quantity (mt)			Value (USD thousand)			Value/Quantity (USD/mt)*
	Fishing Area 57	Fishing Area 71	Total	Fishing Area 57	Fishing Area 71	Total	
Neritic tuna	**243,515**	**320,052**	**563,567**	**148,718**	**380,575**	**529,293**	
Frigate tuna (*Auxis thazard*)	125,118	8,458	133,576	96,418	178,130	274,548	2,055
Bullet tuna (*Auxis rochei*)	…	…	…	…	…	…	…
Kawakawa (*Euthynnus affinis*)	57,270	153,321	210,591	36,791	100,983	137,774	654
Longtail tuna (*Thunnus tonggol*)	61,127	158,273	219,400	15,509	101,462	116,971	533
Oceanic tuna	**205,677**	**1,090,008**	**1,295,685**	**11,496**	**686,607**	**698,103**	
Skipjack tuna (*Katsuwonus pelamis*)	131,755	691,383	823,138	2,886	423,735	426,621	526
Southern bluefin tuna (*Thunnus maccoyii*)	1,607	…	1,607	835	…	835	520
Yellowfin tuna (*Thunnus albacares*)	51,896	322,810	374,706	4,270	257,791	262,061	714
Albacore tuna (*Thunnus alalunga*)	4,796	5	4,801	1,924	10	1,934	403
Bigeye tuna (*Thunnus obesus*)	15,623	75,810	91,433	1,581	5,071	6,652	77
Tuna-like species	**55,529**	**639,927**	**695,456**	**55,787**	**327,965**	**383,752**	
Narrow-barred Spanish mackerel (*Scomberomorus commerson*)	31,417	243,963	275,380	497	206,226	206,723	751
Indo-Pacific king mackerel (*Scomberomorus guttatus*)	12,440	35,471	47,911	13	39,476	39,489	824
Seerfishes *nei* (*Scomberomorus* spp.)	8,266	18,137	26,403	49,413	79,727	129,140	4,891
Tuna-like fishes *nei* (Scombroidei)	3,406	342,356	345,762	5,864	2,536	8,400	766
Total	**504,721**	**2,049,987**	**2,554,708**	**216,001**	**1,395,147**	**1,611,148**	

* *Computation of prices excludes the corresponding production from countries that do not report their production values*
Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

Ocean, Western). However, most of the production figures were actually based on the areas where tunas were landed and not fished. In 2019, the total value of tuna and tuna-like species production value from Fishing Area 71 was about USD 1,395 million or 86.59 % of the region's total tuna production value, with an average price about USD 825/mt, while the total value of the production from Fishing Area 57 of about USD 428 million provided the remaining 13.41 % at an average price of USD 428/mt. For Fishing Area 71, the species that contributed the highest value to the total production value was skipjack tuna followed by yellowfin tuna, narrow-barred Spanish mackerel, and frigate tuna.

3.1.2 Small Pelagic Fish Species

Small pelagic fish species could be groups of scads, mackerels, sardines, and anchovies which are also main contributors to the fisheries production. In 2019, production from small pelagic fish species contributed approximately 6.42 % to the region's total fisheries production or 16.52 % to the region's total marine capture fisheries production. **Table 12** shows the region's production of small pelagic fish species in 2019 indicating that scads and sardines are the most economically important species contributing about 53.61 % and 23.50 %, respectively. Indonesia as the main producer, contributed 1,326 thousand mt accounting for 44.20 % of the region's total small pelagic production, followed by Philippines at 838 thousand mt (27.92 %), Thailand at 483 thousand mt (16.08 %), Malaysia at 353 thousand mt (11.76 %). Brunei Darussalam and Singapore reported at 753 and 105 mt, respectively.

In 2019, seven species of scads accounted for approximately 53.61 % of the region's total small pelagic species

Table 12. Production of small pelagic fishes of the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Major groups of species	Quantity (mt) by country						Total quantity (mt)	Total value (USD thousand)	Value/ Quantity (USD/mt)*
	Brunei Darussalam	Indonesia	Malaysia	Philippines	Singapore	Thailand			
Scads	**352**	**902,439**	**176,253**	**369,129**	**98**	**160,476**	**1,608,747**	**1,135,507**	**706**
Indian scad (*Decapterus russelli*)	…	513,733	69,746	…	…	50,952	634,431	154,147	
Scads *nei* (*Decapterus* spp.)	262	…	…	194,826	60	…	195,148	278,081	
Bigeye scad (*Selar crumenophthalmus*)	40	62,031	48,310	109,440	…	30,074	249,895	318,533	
Yellowstripe scad (*Selaroides leptolepis*)	…	139,241	9,459	…	…	…	148,700	58,598	
Hardtail scad (*Megalaspis cordyla*)	…	24,792	34,032	13,663	…	22,397	94,884	94,404	
Jacks, crevalles *nei* (*Caranx* spp.)	51	162,642	…	…	22	…	162,715	15,087	
Carangids *nei* (Carangidae)	…	…	14,706	51,200	16	57,053	122,975	216,657	
Mackerel	**172**	**87,178**	**144,321**	**91,084**	**7**	**86,879**	**409,641**	**666,091**	**1,626**
Short mackerel (*Rastrelliger brachysoma*)	74	23,603	…	30,003	…	…	53,680	194,497	
Indian mackerel (*Rastrelliger kanagurta*)	…	63,575	…	61,081	…	62,505	187,161	203,275	
Indian mackerels *nei*	1,271	…	1,403		…	…	2,674	1,349	
(*Rastrelliger* spp.)	98	…	50,318	…	7	24,374	74,797	45,902	
Sardines	**228**	**278,318**	**…**	**334,696**	**…**	**91,989**	**705,231**	**281,267**	**399**
Goldstripe sardinella (*Sardinella gibbosa*)	…	141,722	…	…	…	…	141,722	19,213	
Bali sardinella (*Sardinella lemuru*)	…	90,411	…	247,503	…	…	337,914	135,997	
Sardinellas *nei* (*Sardinella* spp.)	…	…	…	81,878	…	91,989	173,867	105,383	
Spotted sardinella (*Amblygaster sirm*)	82	26,752	…	…	…	…	26,834	10,362	
Rainbow sardinella (*Dussumieria acuta*)	146	19,433	…	5,315	…	…	24,894	10,312	
Anchovies	**…**	**58,570**	**32,440**	**42,900**	**…**	**143,218**	**277,128**	**252,993**	**913**
Stolephorus anchovies (*Stolephorus* spp.)	…	58,570	32,440	42,900	…	…	133,910	143,341	
Anchovies *nei* (Engraulidae)	…	…	…	…	…	143,218	143,218	109,652	
Total	**753**	**1,326,505**	**353,014**	**837,809**	**105**	**482,562**	**3,000,748**	**2,335,858**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
* *Computation of prices excludes corresponding production from countries not reporting their production values*

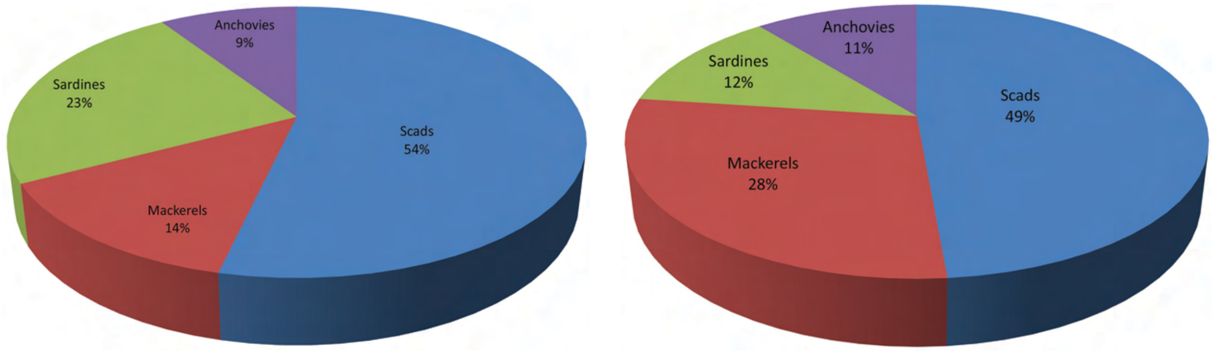


Figure 14. Percentage production of major groups of species of small pelagic fish of Southeast Asia in 2019 by quantity *(left)* and value *(right)*

production (**Figure 14**). These are: the Indian scad (*Decapterus russelli*) which contributed the highest volume to the region's total scads production at 39.44 %, followed by bigeye scad (*Selar crumenophthalmus*) at approximately 15.53 %, scads *nei* (*Decapterus* spp.) at 12.13 %, jacks, crevalles *nei* (*Caranx* spp.) at 10.11 %, yellowstriped scad (*Selaroides leptolepis*) at 9.24 %, carangids *nei* (Carangidae) at 7.64 %, and hardtail scad (*Megalaspis cordyla*) at 5.90 % (**Table 12**).

Sardines which contributed approximately 23.50 % to the total small pelagic species production in 2019 (**Figure 14**) comprise five species, namely: goldstriped sardinella (*Sardinella gibbosa*), Bali sardinella (*Sardinella lemuru*), sardinellas *nei* (*Sardinella* spp.), spotted sardinella (*Amblygaster sirm*), and rainbow sardinella (*Dussumieria acuta*). Bali sardinella (*Sardinella lemuru*) contributed nearly 47.91 % to the region's total sardine production, with Philippines as the largest producer, providing 47.46 % to the region's total sardine production (**Table 12**).

For mackerel, Malaysia, Philippines, Thailand, Brunei Darussalam, and Singapore reported catching four species, comprising short mackerel (*Rastrelliger brachysoma*), Indian mackerel (*Rastrelliger kanagurta*), Indian mackerels nei (*Rastrelliger* spp.), and mackerels *nei* (Scombridae) as shown in **Table 12**. The production of mackerels contributed about 13.65 % to the total small pelagic production of the region (**Figure 14**), with the Indian mackerel (*Rastrelliger kanagurta*) having the highest production that accounted for 45.69 % of the total mackerel production (**Table 12**).

Another important small pelagic is anchovy with total production of 277,128 mt in 2019 (**Table 12**), contributing approximately 9.23 % to the region's small pelagic production (**Figure 13**). Thailand was the main producer providing 51.68 % to the region's total anchovy production (**Table 12**).

In terms of value, scads ranked first accounting for about 48.61 % of the total small pelagic production, followed by mackerels at about 28.52 % (**Figure 14**). The data showed in **Table 12** also suggest that mackerels commanded the highest average value compared to the other small pelagic species at about USD 1,626/mt, followed by anchovies at USD 913/mt, scads at USD 656/mt, and sardines at USD 399/mt.

3.1.3 Demersal Fish Species

Demersal fishes are one of the major components in the marine capture fisheries in Southeast Asian region which live and feed on or near the bottom of seas. The major species groups of demersal fishes found in the Southeast Asian waters include the flounders, halibuts, soles, lizardfishes, sea catfishes, threadfins *nei* (*Nemipterus* spp. and *Polynemus* spp.), snappers (*Lutjanus* spp.), groupers *nei* (*Epinephelus* spp.), sillago whitings, croakers and drums, fusilier (*Caesio* spp.), pony fishes (*Leiognathus* spp.), goatfishes, sweetlips, emperors, etc. Demersal fishes are usually caught by trawl nets, bottom gillnets, longlines, and handlines.

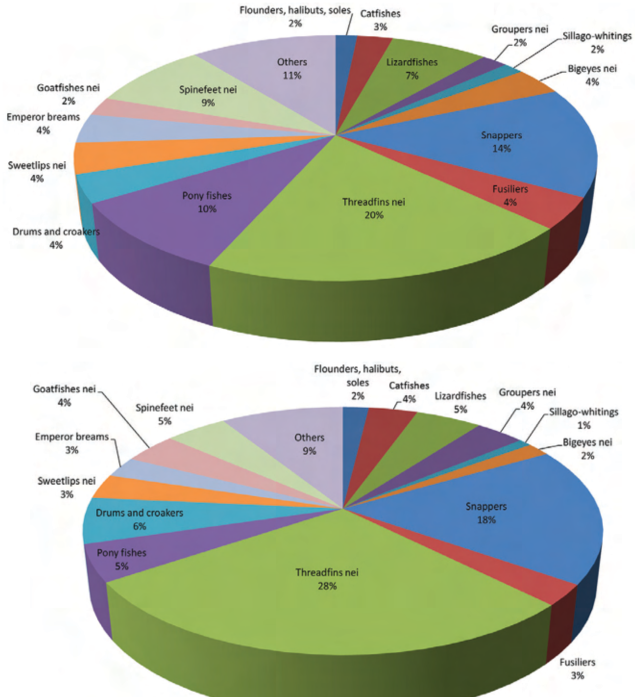


Figure 15. Percentage production of major groups of species of demersal fish of Southeast Asia in 2019 by quantity *(above)* and value *(below)*

Table 13. Major groups of species of demersal fishes produced by the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Major groups of species	Quantity (mt) by country						Total quantity (mt)	Total value (USD thousand)	Value/ Quantity (USD/mt)*
	Brunei Darussalam	Indonesia	Malaysia	Philippines	Singapore	Thailand			
Flounders, halibuts, soles	7	8,177	9,221	933	…	3,746	22,084	28,215	1,278
Catfishes	5	49	29,319	4,542	63	2,580	36,558	53,149	1,454
Lizardfishes	5	16,201	52,488	4,964	0	25,652	99,310	71,791	723
Groupers *nei*	28	17,158	9,319	…	35	…	26,540	53,590	2,019
Sillago-whitings	…	2,343	1,752	13,439	…	3,204	20,738	13,992	675
Bigeyes nei	22	21,841	12,341	…	…	16,348	50,552	25,155	498
Snappers	66	122,903	21,876	35,946	117	18,694	199,602	263,367	1,319
Fusiliers	2	37,282	945	18,661	16	…	56,906	40,478	711
Threadfins *nei*	61	113,128	61,087	44,235	70	52,387	270,968	415,486	1,533
Pony fishes	34	76,656	9,890	46,464	4	…	133,048	70,732	532
Drums and croakers	3	…	42,722	…	43	7,798	50,566	88,299	1,746
Sweetlips *nei*	10	49,580	6,020	…	36	…	55,646	47,096	846
Emperor breams	6	52,023	1,551	…	…	…	53,580	39,713	741
Goatfishes *nei*	0	17,711	16,269	13	…	…	33,993	58,516	1,721
Spinefeet *nei*	9	95,827	1,360	25,282	24	…	122,502	67,363	550
Others	10	80,122	26,781	34,223	24	8,298	149,458	133,268	892
Total	**267**	**711,001**	**302,941**	**228,702**	**432**	**138,707**	**1,382,050**	**1,470,210**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Computation of prices excludes corresponding quantity from countries not reporting their production value*

In 2019, the total demersal fish production in terms of quantity was approximately 1,382,050 mt contributing about 7.61 % to total marine capture fisheries production of the region (**Table 13**). Threadfins *nei* which provided the highest production that accounted for 19.61 % of the total demersal fish production in 2019 (**Figure 15**), snappers gave the second highest at 14.44 % followed by pony fishes at 9.63 %, and Spinefeet *nei* at 8.86 %. By country, Indonesia was the leading producer of demersal fish species, contributing approximately 51.44 % of the region's total demersal fish production, followed by Malaysia at 21.92 %, Philippines at 16.55 %, Thailand at 10.04 %; while Singapore and Brunei Darussalam reported a few volumes. For Indonesia, the main demersal fish species were snappers contributing 17.26 % to the country's total demersal fish production followed by threadfins *nei* at 15.91 %, and spinefeet *nei* at 13.48 %.

In terms of value, threadfin *nei* had the highest value at approximately at USD 415 million or 28.26% of the total demersal fish production value, followed by snappers at USD 263 million or 17.91%, (**Figure 15**). **Table 13** also show that groupers *nei* posted the highest value per volume at about USD 2,019/mt followed by drums and croakers at USD 1,746/mt, goatfishes *nei* at USD 1,721/mt, and threadfin *nei* at USD 1,533/mt.

3.1.4 Crustaceans

Crustacean fisheries have great economic importance in the Southeast Asian region. The commercial crustaceans in the region could be classified into five groups that are crabs, lobsters, penaeid shrimps, metapenaeus shrimps, and marine crustaceans *nei* (species not classified). Brunei Darussalam, Indonesia, Philippines, Singapore, and Thailand reported on their respective production by species, but Cambodia, Malaysia, and Viet Nam had reported by group of crustaceans only for 2019. Thus, in 2019, the production of crustaceans contributed about 4.27 % to the region's marine capture fisheries production. Indonesia was the largest producer contributing 349,234 mt accounting for 44.99 % of the region's total crustaceans, followed by Viet Nam at 23.82 %, Thailand at 11.2 %, Malaysia at 10.33 %, Philippines at 7.36 %, Cambodia at 2.24 %; while Singapore and Brunei Darussalam reported only a few volumes (**Table 14**).

The main crustacean species in the Southeast Asian region include the blue swimming crab (*Portunus pelagicus*), Indo-pacific swamp crab (*Scylla serrata*), lobsters (*Panulirus* spp.), banana prawn (*Penaeus merguiensis*), giant tiger prawn (*Penaeus monodon*), western king prawn (*Penaeus latisulcatus*), green tiger prawn (*Panaeus semisulcatus*), Penaeus shrimps (*Penaeus* spp.), and Metapenaeus shrimps *nei* (*Metapenaeus* spp.). Majority of the crustaceans harvested in the region were reported under marine crustaceans *nei* accounting for 44.55 % of the total crustacean production from marine capture fisheries in 2019 (**Table 14**). Production of blue swimming crab (*Portunus pelagicus*) was the second highest at 23.31 % followed by metapenaeus shrimps *nei* at 11.65 %, marine crabs *nei* at 9.68 %.

Table 14. Major groups of species of crustaceans produced by the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Major groups of species	Quantity (mt) by country								Total quantity (mt)	Total value (USD thousand)	Value/ Quantity (USD/mt)*
	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam			
Blue swimming crab	3.94	...	111,922	...	29,020	...	40,027	...	180,973	432,024	2,387
Indo-pacific swamp crab	...	...	13,893	...	1,204	22	1,332	...	16,451	30,293	1,841
Marine crabs *nei*	...	...	...	15,227	...	3	9,591	50,360	75,181	104,567	4,213
Lobsters *nei*	0.01	...	1,567	682	268	3.88	1,964	...	4,485	25,483	5,682
Banana prawn	10.31	...	10,543	...	...	...	7,281	...	17,834	76,826	4,308
Giant tiger prawn	...	...	10,447	...	924	...	461	...	11,832	15,463	1,307
Western king prawn	...	...	...	...	...	...	799	...	799	3,333	4,171
Green tiger prawn	26.18	...	...	...	...	...	1,699	...	1,725	23,718	13,748
Penaeid shrimps *nei*	121.4	...	...	...	16,690	...	13,897	...	30,708	33,476	1,090
Metapenaeus shrimps *nei*	11.1	...	71,482	...	9,052	...	9,916	...	90,461	51,757	572
Marine crustaceans *nei*	8.85	17,430	129,380	64,251	...	218	...	134,544	345,832	410,575	2,118
Total	**182**	**17,430**	**349,234**	**80,160**	**57,158**	**247**	**86,967**	**184,904**	**776,282**	**1,207,515**	**.**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Computation of prices excludes corresponding production from countries not reporting their production values*

The data in **Table 14** also suggest that the production value of blue swimming crab is the highest among the commodities harvested through crustacean capture fisheries at USD 432 million or 35.78 % of total crustacean value production, followed by marine crustaceans *nei* at USD 411 million or 34.00 %, marine crabs *nei* at USD 105 million or 8.66 %. In terms of value per volume, green tiger prawn (*Panaeus semisulcatus*) posted the highest at about USD 13,748/mt, followed by lobsters *nei* (*Panulirus* spp.) at USD 5,682/mt, banana prawn (*Penaeus merguiensis*) at USD 4,308/mt, marine crabs *nei* at USD 4,213/mt, and western king prawn (*Penaeus latisulcatus*) at USD 4,171/mt.

3.1.5 Mollusks

Mollusks, which are of general importance within the food chains, include such familiar organisms as snails, octopuses, squid, clams, scallops, and oysters. In 2019, the production of mollusks in the Southeast Asian region contributed about 5.17 % to the region's total marine capture fisheries production by quantity, while its contribution in terms of value was nearly 3.56 %. The main mollusk species harvested in the Southeast Asian region include those in the groups of the oysters (*Crassostrea* spp.), green mussels (*Perna viridis*), blood cockle (*Anadara granosa*), clams, etc. *nei* (Bivalvia), common squids *nei* (*Loligo* spp.),

Table 15. Production of major groups of species of mollusks of the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Major groups of species	Quantity (mt) by country								Total quantity (mt)	Total value (USD thousand)	Value/ Quantity (USD/mt)*
	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam			
Oysters	...	...	334	...	7	...	...	...	341	147	432
Green mussel	…	…	11,319	…	24	…	…	…	11,343	365	32
Blood cockle	...	...	100,614	...	...	...	19,122	...	119,736	149,210	1,246
Clams, etc. *nei*	...	...	2,388	4,247	472	...	7,326	...	14,433	28,871	2,000
Common squids *nei*	36.56	…	193,821	…	46,946	35	69,387	…	310,226	470,494	1,517
cuttlefish, bobtail squids *nei*	54.26	…	20,363	20,661	1,478	37	12,901	…	55,494	110,983	2,000
Squids *nei*	…	…	…	48,848	1,594	…	5,839	…	56,281	238,417	4,236
Octopuses *nei*	…	…	11,473	1,094	3,754	…	10,248	…	26,569	34,713	1,307
Marine mollusks *nei*	…	15,030	13,885	…	…	…	6,577	309,844	345,336	10,489	513
Total	**90.82**	**15,030**	**354,197**	**74,850**	**54,275**	**72**	**131,400**	**309,844**	**939,758**	**1,043,689**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Computation of prices excludes corresponding production from countries not reporting their production values*

cuttlefish, bobtail squids *nei* (Sepiidae, Sepiolidae), various squids *nei* (Loliginidae, Ommastrephidae), octopuses *nei* (Octopodidae), marine mollusks *nei* (Molluska). Indonesia was the largest producer contributing 354,197 mt accounting for 37.69 % of the region's total mollusks production followed by Viet Nam at 32.97 %, Thailand at 13.98 %, and Malaysia at 7.96 % (**Table 15**).

The production of common squids *nei* (*Loligo* spp.) of Indonesia, as the largest producer of mollusks in 2019, contributed 54.72 % to the country's mollusks production. This was followed by blood cockle (*Anadara granosa*) accounting for 28.41 %, and cuttlefish, bobtail squids *nei* (Sepiidae, Sepiolidae) at 5.75 %. In the case of Viet Nam, as the second the highest producer of mollusks, their production was reported as marine mollusks *nei* (Molluska). For Thailand, as the third highest producer of mollusks, its main product is the common squids *nei* (*Loligo* spp.) contributing 52.81 % to the country's production of mollusks, followed by blood cockle (*Anadara granosa*) accounting for 14.55 %, cuttlefish, bobtail squids *nei* (Sepiidae, Sepiolidae) at 9.82 %, and octopuses *nei* (Octopodidae) at 7.80 %. For Malaysia, its main production from mollusks comprises various squids *nei* (Loliginidae, Ommastrephidae) which accounted for 65.26 % of the country's production of mollusks, followed by cuttlefish, bobtail squids *nei* (Sepiidae, Sepiolidae) accounting for 27.60 %.

For the production value, the common squids *nei* (*Loligo* spp.) contributed at 40.08 % to the region's total mollusks production value followed by various squids *nei* (Loliginidae, Ommastrephidae) which contributed about 22.84 %, blood cockle (*Anadara granosa*) at 14.30 %, and cuttlefish, bobtail squids *nei* (Sepiidae, Sepiolidae) at 10.63 %. In terms of value per volume of mollusk production in 2019 (**Table 15**), the group of squids *nei* (Loliginidae, Ommastrephidae) posted the highest at about USD 4,236/mt, followed by cuttlefish, bobtail squids *nei* and clams, etc. *nei* (Bivalvia) both at USD 2,000/mt, common squids *nei* (*Loligo* spp.) at USD 1,517/mt, octopuses *nei* (Octopodidae) at USD 1,307/mt, and blood cockle (*Anadara granosa*) at USD 1,246/mt.

4. Inland Capture Fisheries Production of Southeast Asia

Inland capture fisheries have been identified as the main source of livelihoods of peoples living in rural areas and improved incomes of rural households in Southeast Asia, and make use of natural inland waters that include vast river systems and lakes, floodplains, reservoirs, dams, and wetlands. Specifically in Southeast Asia, Indonesia has more than 256 million ha of inland water bodies, followed by Myanmar with more than 82 million ha, Thailand with more than 66 million ha, and the Philippines with more than 12 million ha. Cambodia has the Tonle Sap Great Lake which could expand from 250,000 ha during dry season to more than 1.6 million ha during the wet season (Pongsri *et al.*, 2015). **Figure 16** shows the important rivers and lakes in the region that have been tapped by rural fisherfolks for many years for their subsistence.

From 2005 to 2019, the inland capture fisheries production at global level has continued to grow at an annual average of about 190 thousand mt or 1.81% annually (**Table 16**). Asia and Southeast Asia continued to be the leading inland capture fisheries producers, followed by Africa, Americas, Europe, and Oceania. In 2019, Asia (excluding Southeast Asia) which was the top producing region accounted for 37.64 % of the world's total inland capture fisheries production, followed by Southeast Asia at 27.44 %, Africa at 26.93 %, Americas at 4.60 %, Europe at 3.25 %, and Oceania at 0.14 %.

Table 17 and **Figure 17** show the trend of inland capture fisheries production by quantity during 2005-2019, of which the region's production from inland capture fisheries had increased at about 102 thousand mt/year or 4.26 % annually.

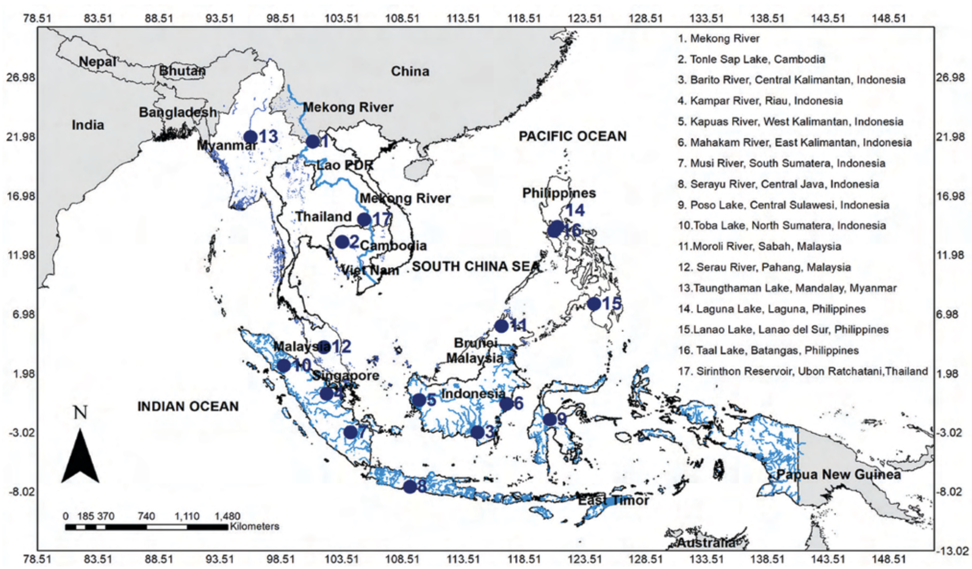


Figure 16. Important rivers and lakes in Southeast Asia
(Muthmainnah D., et al. 2017a)

Table 16. Inland capture fisheries production of each continent from 2005 to 2019 by quantity (mt)

Year	World total* (mt)	Continents					
		Africa*	Americas*	Asia*	Southeast Asia**	Europe*	Oceania*
2005	**9,431,089**	2,449,224	579,892	4,145,770	1,888,279	350,055	17,869
2006	**9,830,788**	2,386,956	596,098	4,350,395	2,133,246	346,256	17,837
2007	**10,074,554**	2,522,207	575,089	4,561,756	2,008,267	389,433	17,802
2008	**10,161,313**	2,502,883	569,356	4,394,762	2,335,711	340,915	17,686
2009	**10,328,235**	2,548,141	566,903	4,427,429	2,397,773	370,462	17,527
2010	**10,864,121**	2,619,728	562,335	4,905,452	2,377,253	381,846	17,507
2011	**10,503,064**	2,711,655	542,180	4,222,323	2,637,300	371,292	18,314
2012	**10,892,468**	2,705,949	547,045	4,425,102	2,817,251	378,812	18,309
2013	**10,939,910**	2,829,389	551,576	4,260,577	2,869,785	409,956	18,627
2014	**11,066,834**	2,854,570	551,495	4,244,752	3,001,099	396,615	18,303
2015	**11,175,063**	2,850,599	574,966	4,242,969	3,058,821	429,678	18,030
2016	**11,385,882**	2,885,002	608,439	4,312,422	3,126,166	435,904	17,949
2017	**11,954,018**	3,021,294	583,379	4,691,932	3,226,154	413,121	18,138
2018	**12,010,137**	3,037,770	638,020	4,569,265	3,337,066	410,032	17,984
2019	**12,088,723**	3,255,405	556,161	4,549,949	3,316,808	392,911	17,489

Note: *Asia does not include data of Southeast Asia*
* ***Source:*** *FAO Fisheries and Aquaculture Information and Statistics Service*
** ***Source:*** *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Table 17. Inland capture fisheries production of the Southeast Asian countries in 2005-2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	0	444,000	297,370	29,800	4,583	631,120	143,806	0	198,800	138,800	**1,888,279**
2006	0	559,642	293,921	29,800	4,164	718,000	165,081	0	214,000	152,325	**2,136,933**
2007	0	420,000	310,457	28,410	4,283	717,640	168,311	0	225,600	133,600	**2,008,301**
2008	0	430,600	497,740	29,200	4,353	814,740	179,491	0	228,600	144,800	**2,329,524**
2009	0	390,000	494,630	30,000	4,469	899,430	188,444	0	245,500	144,800	**2,397,273**
2010	0	405,000	344,972	30,900	4,545	1,002,430	185,406	0	209,800	194,200	**2,377,253**
2011	0	445,000	368,542	34,000	5,695	1,163,159	193,698	0	224,706	202,500	**2,637,300**
2012	0	528,000	393,552	34,105	5,042	1,246,460	195,804	0	219,428	194,500	**2,816,891**
2013	0	528,000	391,324	40,143	5,640	1,302,970	194,615	0	210,293	196,800	**2,869,785**
2014	0	505,005	446,509	60,237	6,520	1,381,030	211,941	0	181,757	208,100	**3,001,099**
2015	0	487,905	455,270	62,635	5,924	1,463,120	203,366	0	181,101	196,500	**3,055,821**
2016	0	509,350	426,874	70,915	5,848	1,580,670	155,509	0	187,300	189,700	**3,126,166**
2017	0	528,493	467,531	70,900	5,177	1,590,360	163,870	0	192,623	207,200	**3,226,154**
2018	0	535,555	612,753	70,900	6,089	1,594,970	162,974	0	143,825	210,000	**3,337,066**
2019	0	524,465	649,978	70,900	5,569	1,600,050	154,681	0	116,465	194,700	**3,316,808**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Myanmar had been the top producer from inland capture fisheries throughout 2005 to 2019, providing 48.24 % to the region's total inland capture fisheries production producing about 1,600,050 mt in 2019. The second highest producer, Indonesia reported production of 649,978 mt in 2019 representing 19.60 % of the region's total inland capture fisheries production, followed by Viet Nam contributing approximately 5.87 %.

In terms of production value, only five countries had reported their figures, namely: Indonesia, Malaysia, Myanmar (since 2008), Philippines, and Thailand. Despite the efforts made by many agencies to improve the compilation of information on inland capture fisheries production in Southeast Asia, the information could still be under reported due to the inadequacy of information gathered, especially on production value of inland capture fisheries. As shown in **Table 18**, the region's total production value from inland capture fisheries in 2019 was USD 4,056 million accounting for 7.37 % of the region's total fisheries production value or 12.14 % of the region's total capture fisheries production value. Myanmar maintains a stable inland capture fisheries production value from 2008-2019 and its production value of USD 2,480 million

Table 18. Inland capture fisheries production of the Southeast Asian countries in 2005-2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	0	...	323,827	...	9,187	...	84,077	0	194,859	...	**611,950**
2006	0	...	264,372	...	8,455	...	101,477	0	222,273	...	**596,877**
2007	0	...	368,247	215,708	9,013	...	125,464	0	266,740	...	**985,172**
2008	0	255,500	521,019	240,334	10,290	788,325	145,912	0	254,057	...	**2,215,437**
2009	0	334,845	616,640	93,168	11,482	1,349,145	155,907	0	273,290	...	**2,834,477**
2010	0	...	546,937	...	13,138	1,503,645	174,479	0	288,277	...	**2,526,476**
2011	0	...	635,754	...	17,978	1,744,738	185,799	0	348,810	...	**2,933,079**
2012	0	...	793,238	...	18,376	1,869,690	196,239	0	359,075	...	**3,236,618**
2013	0	...	741,813	...	20,129	1,954,455	206,569	0	375,993	...	**3,298,959**
2014	0	...	721,042	313,232	19,441	2,071,545	220,480	0	312,798	...	**3,658,538**
2015	0	...	724,041	...	18,353	2,267,836	208,919	0	301,441	...	**3,520,590**
2016	0	...	774,384	...	21,570	2,450,038	152,387	0	298,804	...	**3,697,183**
2017	0	...	1,065,343	...	23,926	2,465,058	161,337	0	302,702	...	**4,018,366**
2018	0	...	1,170,570	...	30,578	2,472,203	167,742	0	272,883	...	**4,113,976**
2019	0	...	1,155,560	...	22,033	2,480,080	172,633	0	225,918	...	**4,056,224**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

in 2019 accounted for 25.61 % of the country's total fishery production value. Indonesia as the second highest in inland capture fisheries production value accounted for 3.71 % of the country's total fishery production value followed by Thailand at 4.08 %, Philippines at 3.41 %, and Malaysia at 0.61 %.

Looking at the contribution from inland capture fisheries to the respective countries' total fisheries productions in 2019, Cambodia ranked first with its production contributing 54.12 % to the country's total fisheries production, followed by Lao PDR at 38.55 %, Myanmar at 26.97 %, Thailand at 4.68 %, and Philippines at 3.51 %. As for Indonesia, although the total inland capture was very high and ranked second after Myanmar, but the total production from inland capture fisheries represented only 2.87 % of the country's total fisheries production (**Table 19**). It should be noted however that such production volumes could not be confirmed as accurate and could be under-reported, considering that most of the countries still need to improve their systems of collecting and compiling their respective fishery statistics, especially with regards to their production form inland capture fisheries.

In terms of production of major species from inland capture fisheries (**Table 20**), only Indonesia, Philippines, and Thailand provided the figure at species levels. The group of freshwater fishes *nei* (Osteichthyes) with no species classification provided the highest production from inland capture fisheries accounting for 72.71 % of the region's total

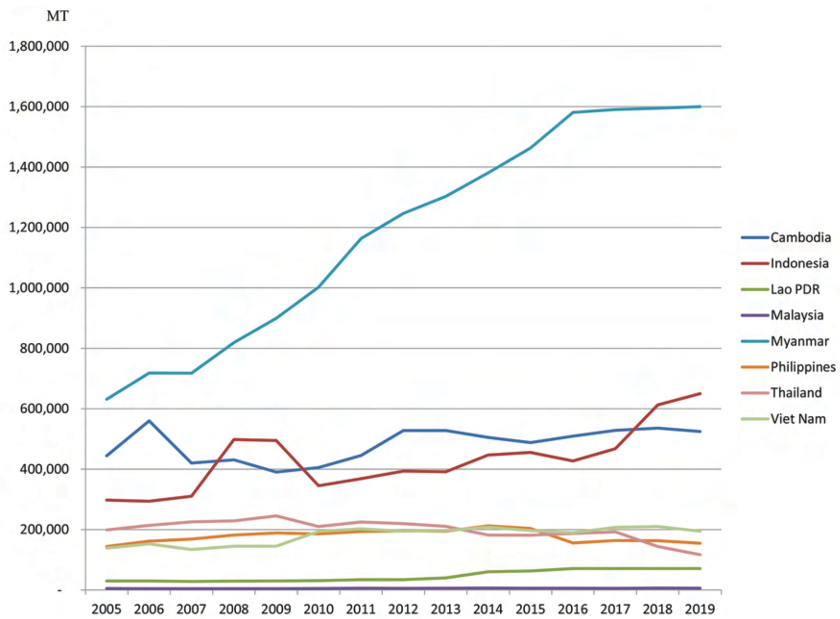


Figure 17. Trends of inland capture fisheries production of the Southeast Asian countries in 2005-2019 by quantity (mt)

Table 19. Contribution of inland capture fisheries production to the respective Southeast Asian country's capture fisheries production and total fisheries production in 2019 by quantity (mt)

Country	Inland capture fisheries production (mt)	Total Capture fisheries production (mt)	Percentage of inland capture fisheries production in total capture fisheries production (%)	Total fisheries production (mt)	Percentage of inland capture fisheries production in total fisheries production (%)
Brunei Darussalam	0	13,725	0	14,658	0
Cambodia	524,465	661,690	79.26	969,098	54.12
Indonesia	649,978	7,066,428	9.20	22,614,595	2.87
Lao PDR	70,900	70,900	100.00	183,900	38.55
Malaysia	5,569	1,461,015	0.38	1,872,797	0.30
Myanmar	1,600,050	4,849,750	32.99	5,931,815	26.97
Philippines	154,681	2,054,891	7.53	4,413,129	3.51
Singapore	0	1,418	0	7,249	0
Thailand	116,465	1,527,130	7.63	2,488,833	4.68
Viet Nam	194,700	3,777,700	5.15	8,270,200	2.35
Total	**3,316,808**	**21,484,647**	**Ave: 15.44**	**46,766,274**	**Ave: 7.09**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

Table 20. Production of major species from inland capture fisheries in Southeast Asia in 2019

Common name	Quantity (mt)	Percentage total quantity of major inland species to total inland capture production (%)	Value (USD thousand)*	Percentage total value of major inland species to total inland capture production (%)	Value/Quantity (USD/mt)**
Nile tilapia	126,268	3.81	209,575	5.17	1,660
Striped snakehead	87,395	2.63	230,402	5.68	2,636
Torpedo-shaped catfishes *nei*	47,647	1.44	60,847	1.50	1,277
Freshwater mollusks *nei*	46,471	1.40	4,727	0.12	102
Snakeskin gourami	44,122	1.33	15,805	0.39	358
Tilapia *nei*	41,802	1.26	51,835	1.28	1,240
Silver barb	36,715	1.11	33,041	0.81	900
Climbing perch	35,452	1.07	87,830	2.17	2,477
Common carp	29,649	0.89	64,455	1.59	2,174
Asian redtail catfish	29,140	0.88	77,285	1.91	2,652
Pangasius djambal	28,397	0.86	40,835	1.01	1,438

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Data not available from Cambodia, Lao PDR, and Viet Nam*
*** Computation of price excludes corresponding quantity from Cambodia, Lao PDR, and Viet Nam*

inland capture fisheries production in 2019. As for the major species, production of Nile tilapia (*Oreochromis niloticus*) was the highest at 3.81 %, followed by striped snakehead (*Channa striata*) at 2.63 %, torpedo-shaped catfishes *nei* (*Clarias* spp.) at 1.44 %, freshwater mollusks *nei* (Molluska) at 1.4 0%, and snakeskin gourami (*Trichogaster pectoralis*) at 1.33 %. As for the production value per volume, the group of freshwater fishes *nei* (Osteichthyes) was valued the highest among the commodities harvested through inland capture fisheries at USD 3,602/mt, followed by the Asian redtail catfish (*Hemibagrus nemurus*) at USD 2,652/mt, striped snakehead (*Channa striata*) at USD 2,636/mt, climbing perch (*Anabas testudineus*) at USD 2,477/mt, and common carp (*Cyprinus carpio*) at USD 2,174/mt.

5. Aquaculture Production of Southeast Asia

Global aquaculture had grown dramatically during the period from 2005 to 2019 at an average rate of about 4.35 million mt per year or 5.21 % annually (**Table 21**). Of the total world's production from aquaculture in 2019, approximately 21.05 % was contributed by the Southeast Asian countries (**Figure 18**). The importance of aquaculture in the Southeast Asian region goes beyond its relatively high contribution to world aquaculture production as fish products are important in the diet in most of Southeast Asian countries' populace. While capture fisheries had grown only slightly over the same period, aquaculture production had increased rapidly. Aquaculture in Southeast Asia therefore plays important roles in providing source of protein, contributing to food security, enhancing people's

Table 21. Aquaculture production of each continent from 2005 to 2019 by quantity (mt)

Year	World total* (mt)	Continents					
		Africa*	Americas*	Asia*	Southeast Asia**	Europe*	Oceania*
2005	59,148,584	727,569	2,192,363	46,418,409	**7,512,534**	2,135,194	162,515
2006	62,933,396	843,195	2,406,779	48,888,916	**8,426,187**	2,193,747	174,572
2007	66,302,271	916,837	2,386,509	51,218,416	**9,237,586**	2,367,132	175,791
2008	70,203,575	1,061,743	2,497,835	53,072,022	**11,063,934**	2,327,891	180,150
2009	70,835,134	1,103,355	2,554,886	52,091,208	**12,379,436**	2,518,903	187,346
2010	77,981,746	1,424,308	2,527,550	57,115,459	**14,186,737**	2,524,939	202,753
2011	81,612,091	1,536,939	2,790,277	58,482,343	**15,944,613**	2,648,469	209,450
2012	88,171,509	1,651,800	2,995,568	62,637,316	**17,852,212**	2,831,536	203,077
2013	94,979,864	1,743,938	2,999,715	65,892,847	**21,413,291**	2,732,994	197,079
2014	99,619,014	1,867,108	3,362,408	68,743,967	**22,529,781**	2,906,952	208,798
2015	103,891,620	1,974,636	3,291,811	71,301,858	**24,176,840**	2,945,782	200,693
2016	108,178,787	2,115,854	3,333,753	74,357,172	**25,182,532**	2,964,175	225,301
2017	112,175,203	2,161,660	3,602,903	78,219,445	**24,940,156**	3,026,451	224,588
2018	115,949,295	2,530,742	3,834,670	81,416,800	**24,871,804**	3,074,713	220,566
2019	120,098,422	2,395,252	4,203,050	84,747,685	**25,281,627**	3,247,536	223,272

Note: *Asia does not include data of Southeast Asia*
* ***Source:*** *FAO Fisheries and Aquaculture Information and Statistics Service*
** ***Source:*** *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

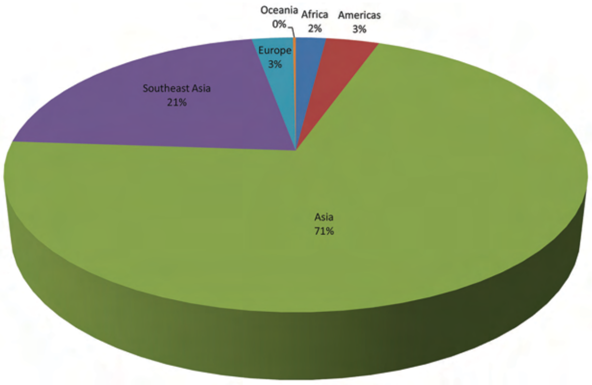


Figure 18. Percentage of continents' aquaculture production to world's production in 2019 by quantity
Note: *Asia does not include data of Southeast Asia*

livelihoods, providing income and employment, as well as improving economic growth.

From 2005 to 2019, the total production of aquaculture in the Southeast Asian region had continued to increase at an annual average rate about 1,269 thousand mt or 9.25 % per

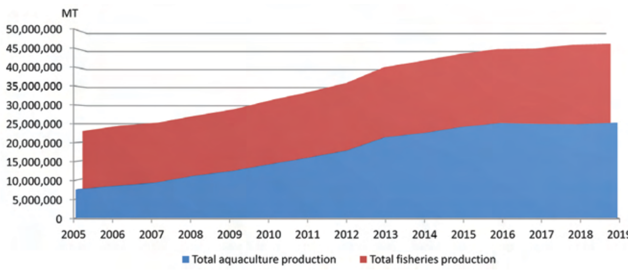


Figure 19. Contribution of the region's aquaculture production to the total fisheries production of Southeast Asia from 2005 to 2019

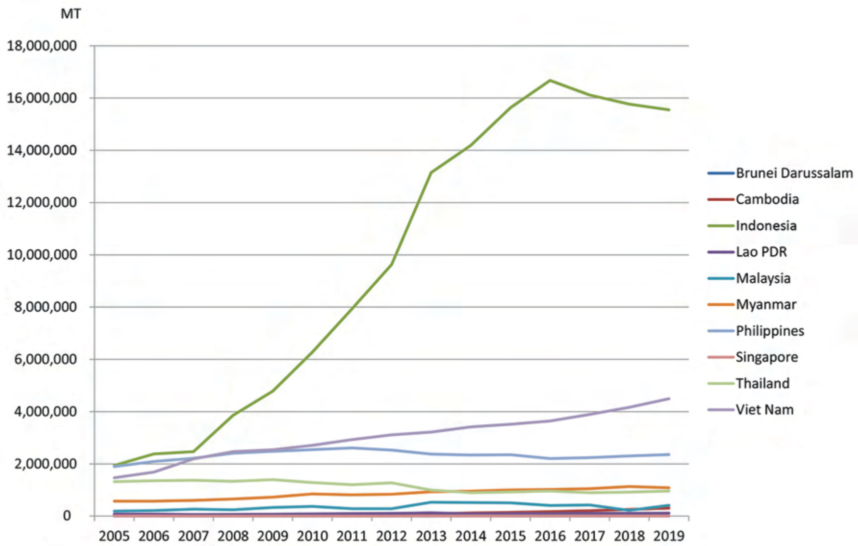


Figure 20. Trends of aquaculture production of the Southeast Asian countries in 2005-2019 by quantity (mt)

Table 22. Aquaculture production of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total (aquaculture production)	Total (fisheries production)
2005	703	42,000	1,941,096	78,000	188,220	574,990	1,895,847	5,917	1,318,461	1,467,300	**7,512,534**	**22,988,103**
2006	700	41,400	2,377,474	78,000	212,028	574,990	2,092,275	8,572	1,353,021	1,687,727	**8,426,187**	**24,501,767**
2007	674	50,200	2,466,030	63,250	268,514	604,657	2,214,826	4,504	1,370,431	2,194,500	**9,237,586**	**25,302,872**
2008	390	39,720	3,855,200	64,300	240,133	653,855	2,407,698	3,518	1,330,800	2,468,320	**11,063,934**	**27,207,826**
2009	460	50,000	4,780,100	75,000	333,445	724,163	2,477,392	3,566	1,396,010	2,539,300	**12,379,436**	**28,917,098**
2010	421	60,000	6,277,923	82,100	373,151	850,959	2,545,765	3,501	1,286,117	2,706,800	**14,186,737**	**31,438,431**
2011	293	72,000	7,928,962	95,600	287,042	816,820	2,608,120	3,974	1,201,402	2,930,400	**15,944,613**	**33,654,492**
2012	556	90,000	9,626,863	101,895	283,559	838,426	2,524,641	3,577	1,271,995	3,110,700	**17,852,212**	**36,147,934**
2013	606	90,000	13,147,288	124,085	530,205	929,000	2,373,386	5,566	997,255	3,215,900	**21,413,291**	**40,420,239**
2014	761	120,055	14,187,124	90,355	520,515	957,041	2,337,605	5,262	897,763	3,413,300	**22,529,781**	**42,114,508**
2015	983	143,000	15,634,093	95,965	506,276	999,630	2,348,159	6,896	928,538	3,513,300	**24,176,840**	**43,998,054**
2016	822	172,500	16,675,033	95,965	407,387	1,020,593	2,200,914	6,112	962,606	3,640,600	**25,182,532**	**45,336,010**
2017	1,632	207,500	16,114,990	109,877	427,015	1,048,692	2,237,787	5,891	893,872	3,892,900	**24,940,156**	**45,496,587**
2018	1,146	254,050	15,769,272	108,200	217,381	1,130,350	2,304,365	5,702	919,538	4,161,800	**24,871,804**	**46,539,195**
2019	933	307,408	15,548,167	113,000	411,782	1,082,065	2,358,238	5,831	961,703	4,492,500	**25,281,627**	**46,766,274**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Table 23. Aquaculture production of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	…	…	2,168,720	…	341,126	…	892,536	9,971	1,353,179	2,945,650	**7,711,182**
2006	…	…	2,341,501	…	351,975	…	1,085,011	9,477	1,990,005	…	**5,777,969**
2007	3,212	58,038	2,447,539	…	352,981	1,862,403	1,334,719	9,052	2,134,592	4,544,750	**12,747,286**
2008	392	61,790	4,222,498	91,141	452,880	782,566	1,718,634	9,262	2,065,301	4,617,700	**14,022,164**
2009	658	87,954	5,189,522	111,801	700,910	853,165	1,720,961	8,793	2,422,630	4,867,779	**15,964,173**
2010	4,950	…	6,980,897	…	793,085	917,706	1,835,308	14,864	2,830,930	…	**13,377,740**
2011	1,671	126,850	7,219,307	...	757,320	740,655	1,984,554	15,039	3,360,317	6,281,507	**20,487,220**
2012	4,730	...	7,635,708		833,156	1,348,346	2,152,326	12,686	3,484,673	6,383,000	**21,854,625**
2013	3,495	...	10,348,414	...	768,026	1,714,315	2,186,360	32,215	2,955,291	...	**18,008,116**
2014	8,884	...	9,503,444	108,426	1,197,902	1,857,360	2,135,384	42,756	2,555,413	...	**17,409,569**
2015	6,165	...	8,775,201	...	804,915	1,643,071	2,135,384	30,511	2,331,558	...	**15,726,805**
2016	4,138	...	10,303,470	...	712,306	1,990,126	1,964,460	55,794	2,488,147	...	**17,518,441**
2017	10,985	...	13,965,299	...	788,655	1,749,584	2,000,639	33,689	2,704,988	...	**21,253,839**
2018	8,518	...	12,159,824	...	762,788	1,498,561	2,082,502	44,576	3,017,966	...	**19,574,735**
2019	6,818	...	13,492,992	...	820,430	1,841,443	2,274,650	35,204	3,173,767	...	**21,645,304**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

year, while its contribution to the region's total fisheries had increased from 32.7 % to 54.1 % (**Table 22**). **Figure 19** shows the constant increase in aquaculture production of the region which could be observed throughout a span of 15 years.

By country, Indonesia as a large aquaculture producer in 2019 contributed about 61.50 % to the region's total aquaculture production, followed by Viet Nam at 17.77 %, the Philippines at 9.33 %, Myanmar at 4.28 %, Thailand at 3.80 %, Malaysia at 1.63 %, and Cambodia at 1.22 % (**Figure 20**).

In terms of value of the region's aquaculture production, the actual trend could not be established as some countries were not able to report their data regularly (**Table 23**). For the available data in 2019, by value per volume, Brunei Darussalam attained the highest average value at USD 7,308/mt followed by Singapore at USD 6,037/mt, Thailand at USD 3,300/mt, Malaysia at USD 1,992/mt, Myanmar at USD 1,702/mt, the Philippines at USD 984/mt, and Indonesia at USD 868/mt (**Table 22** and **Table 23**).

Aquaculture production comes from three culture environments, namely: mariculture, brackishwater culture,

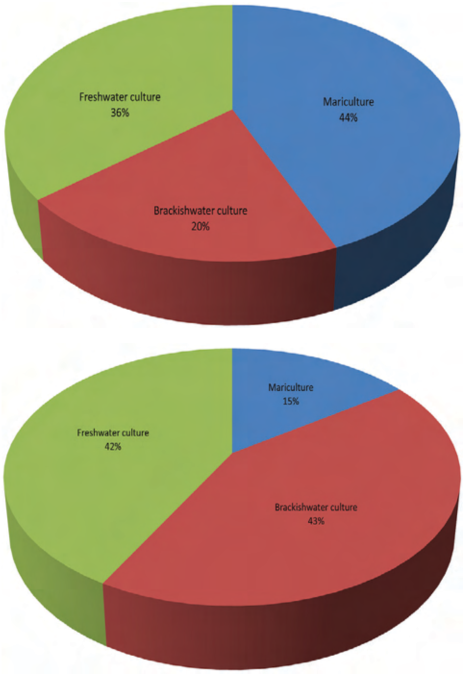


Figure 21. Contribution of the culture environments to the aquaculture production of Southeast Asia in 2019 by quantity *(above)* and value *(below)*

and freshwater culture. In 2019, Indonesia as the top producer of aquaculture products of the Southeast Asian region had the highest production from mariculture, followed by Viet Nam from freshwater culture, Philippines from mariculture, Myanmar from freshwater culture, and Thailand from brackishwater culture (**Table 24**). In terms of volume, aquaculture in marine areas or mariculture provided 44.00 % to the region's total aquaculture production in 2019 while brackishwater aquaculture contributed 20.00 %, and the remaining 36.00 % came from freshwater aquaculture. However, in terms of value, mariculture contributed 15.00 % while freshwater aquaculture production contributed 42.00 %, while brackishwater aquaculture production contributed the highest at 43.00 % (**Figure 21**).

The production of spiny eucheuma (*Eucheuma denticulatum*) of Indonesia as the largest producer of aquaculture product in 2019, contributed 54.50 % to the production volume and 14.30 % to the production value of the country's aquaculture production. This was followed by Nile tilapia (*Oreochromis niloticus*) accounting for 9.00 %, Gracilaria seaweeds *nei* (*Gracilaria* spp.) at 7.90 %, and torpedo-shaped catfishes (*Clarias* spp.) at 6.50 %. In the case of Viet Nam, as the second highest producer from aquaculture, 35.60 % of its aquaculture production came from striped catfish (*Pangasianodon hypophthalmus*), followed by whiteleg shrimp (*Penaeus vannamei*) at 12.80 %, freshwater fishes *nei* (Osteichthyes) at 10.60 %, and cyprinids *nei* (Cyprinidae) at 9.80 % of the country's aquaculture production.

For the Philippines as the third highest producer from aquaculture, its main aquaculture product was the elkhorn sea moss (*Kappaphycus alvarezii*) contributing 60.30 % to the country's production from aquaculture, followed by milkfish (*Chanos chanos*) at 17.40 %, Nile tilapia (*Oreochromis niloticus*) at 7.40 %, Tilapia *nei* (*Oreochromis* (=Tilapia) spp.) at 4.50 %, and spiny eucheuma (*Eucheuma denticulatum*) at 3.20 %. For Myanmar, its main production from aquaculture was roho labeo (*Labeo rohita*) which accounted for 33.40 % of the country's production from aquaculture, followed by common carp (*Cyprinus carpio*) at 28.10 %, and silver barb (*Barbonymus gonionotus*) at 24.00 %. Thailand's main aquaculture product was the whiteleg shrimp (*Penaeus vannamei*) accounting for 39.40 % of the country's production from aquaculture, followed by Nile tilapia (*Oreochromis niloticus*) at 23.80 %, hybrid catfishes (*C. gariepinus* x *C. macrophalus*) at 10.10 %, and barramundi (=giant seaperch) (*Lates calcarifer*) at 4.90 %. In terms of value per volume of production from aquaculture, Brunei Darussalam had the highest average value at about USD 7,308/mt (**Table 24**), followed by

Table 24. Production from aquaculture environments of the Southeast Asian countries in 2019 by quantity (mt) and value (USD thousand)

Country	Quantity (mt)				Value (USD thousand)	Value/Quantity (USD/mt)*
	Mariculture	Brackishwater culture	Freshwater culture	Total		
Brunei Darussalam	336	591	6	933	6,818	7,308
Cambodia	13,888	3,340	290,180	307,408	0	0
Indonesia	8,638,457	2,984,207	3,925,503	15,548,167	13,492,992	868
Lao PDR	0	0	113000	113,,000	0	0
Malaysia	204,839	91,658	115,285	411,782	820,430	1,992
Myanmar	52,849	69,472	959,744	1,082,065	1,841,443	1,702
Philippines	1,688,977	348,284	320,977	2,358,238	2,274,650	984
Singapore	4614	202	1,015	5,831	35,204	6,037
Thailand	88,973	445,781	426,949	961,703	3,173,767	3,300
Viet Nam	368,414	1,140,257	2,983,829	4,492,500	0	0
Total	**11,061,347**	**5,083,795**	**9,136,487**	**25,281,627**	**21,645,304**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
* *Computation of price excludes thee corresponding quantities from Cambodia, Lao PDR, and Viet Nam*

Table 25. Mariculture production of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	37	16,400	890,074	0	98,851	804	1,419,727	5,280	364,061	213,800	**3,009,034**
2006	500	500	1,365,919	0	96,696	…	1,566,056	8,113	317,457	216,200	**3,571,441**
2007	33	16,630	1,509,062	0	144,794	0	1,626,206	4,159	309,497	208,500	**3,818,881**
2008	31	1,370	2,377,382	0	70,407	48,303	1,793,395	3,235	285678	48,420	**4,628,221**
2009	72	4,925	2,537,100	0	77,476	50,464	1,860,462	3,286	316,927	172,003	**5,022,715**
2010	109	2,120	3,514,702	0	89,366	75,441	1,933,396	3,098	270,628	128322	**6,017,182**
2011	121	2,620	4,605,825	0	60,975	3,158	1,992,953	3,448	186,676	318,300	**7,174,076**
2012	201	2810	5,769,736	0	131,005	52,693	1,910,568	3,022	185,860	374,300	**8,430,195**
2013	134	4,633	8,372,817	0	332,236	4,775	1,727,165	4,159	216,577	202,633	**10,865,129**
2014	162	7,416	9,029,843	0	283,930	59,705	1,820,533	4,252	202,732	454,100	**11,862,673**
2015	182	2500	10,275,181	0	278,890	55,524	1,965,099	5,598	194,405	360100	**13,137,479**
2016	107	12,832	11,704,838	0	217,980	60,827	1,821,670	4,748	197,201	284,500	**12,946,303**
2017	371	10500	9,550,781	0	219,173	59,015	1,457,474	4,868	98,256	306,600	**11,707,038**
2018	413	1,810	9,601,972	0	18,431	23,458	1,553,997	4,621	78,203	303,000	**11,585,905**
2019	336	13,888	8,638,457	0	204,839	52,849	1,688,977	4,614	88,973	368,414	**11,061,347**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Table 26. Mariculture production of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	-	-	353,019	0	20,444	-	171,539	7,147	97,215	622,600	**1,271,964**
2006	-	-	220,568	0	17,764	-	216,342	7,381	1,457,754	-	**1,919,809**
2007	-	5,300	432,802	0	23,238	-	270,984	7,980	-	189,500	**929,804**
2008	392	3,890	983,185	0	4,974	641,278	500,275	8,082	-	1,493,750	**3,635,826**
2009	-	19,700	1,297,568	0	40,195	208,905	404,910	7,551	71,837	174,000	**2,224,666**
2010	-	-	1,437,044	0	34,369	193,568	934,081	13,204	110,379	-	**2,722,645**
2011	740	8,070	1,127,599	0	27,785	2,088	535,916	12,986	82,065	2,305,138	**4,102,387**
2012	4,716	-	1,349,055	0	500,888	213,465	649,976	10,028	107,746	2,191,542	**5,027,416**
2013	712	-	1,810,287	0	197,976	17,728	533,742	22,344	122,869	-	**2,705,658**
2014	1,710	-	1,668,006	0	234,956	260,538	665,468	28,724	181,418	-	**3,040,820**
2015	976	-	952,546	0	43,615	330,715	665,468	21,310	137,410	-	**2,152,040**
2016	786	-	2,389,389	0	42,220	548,777	984,226	36,822	138,661	-	**4,140,881**
2017	2,669	-	1,619,760	0	30,209	379,608	861,732	22,668	125,365	-	**3,042,011**
2018	3,453	-	1,418,891	0	24,899	185,917	1,100,797	34,356	162,659	-	**2,930,972**
2019	2,871	-	2,156,005	0	59,339	374,257	550,012	21,843	168,306	-	**3,332,634**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

Singapore at the average of USD 6,037/mt, and Thailand about USD 3,300/mt.

5.1 Mariculture

The growth of mariculture production in the region had been very strong for the past 15 years, resulting mainly from the increased fisheries production of Indonesia. From 2005 to 2019, the region's total mariculture products increased in terms of quantity by about 575 thousand mt per year (**Table 25** and **Figure 22**) and valued at about USD 147 million/year (**Table 26**). In 2019, Indonesia contributed the highest mariculture production in quantity, accounting for 78.10 % of the region's total mariculture production, followed by the Philippines for 15.30 %, Viet Nam for 3.30 %, Malaysia for 1.80 %, Thailand 0.80 %, and Myanmar for 0.50 %. Cambodia, Singapore, and Brunei Darussalam also reported minimal contributions to the region's total mariculture production. In terms of value, Indonesia also led the countries with the value of its mariculture production contributing about 64.70 % to the region's total mariculture production value, followed by Philippines for 16.50 %, Myanmar for 11.20 %, Thailand for 5.00 %, Malaysia for 1.80 %, and Singapore for 0.70 %, while Singapore and

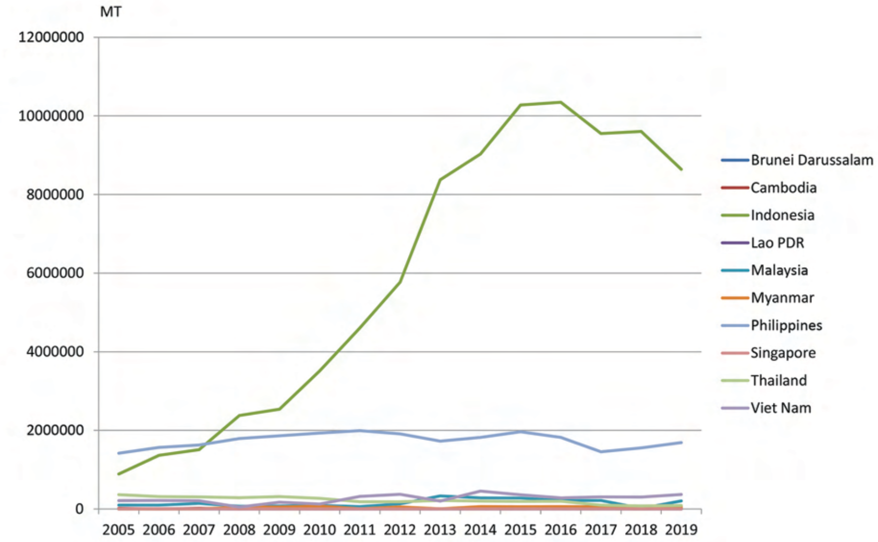


Figure 22. Trends of the quantity (mt) of mariculture production of the Southeast Asian countries in 2005-2019

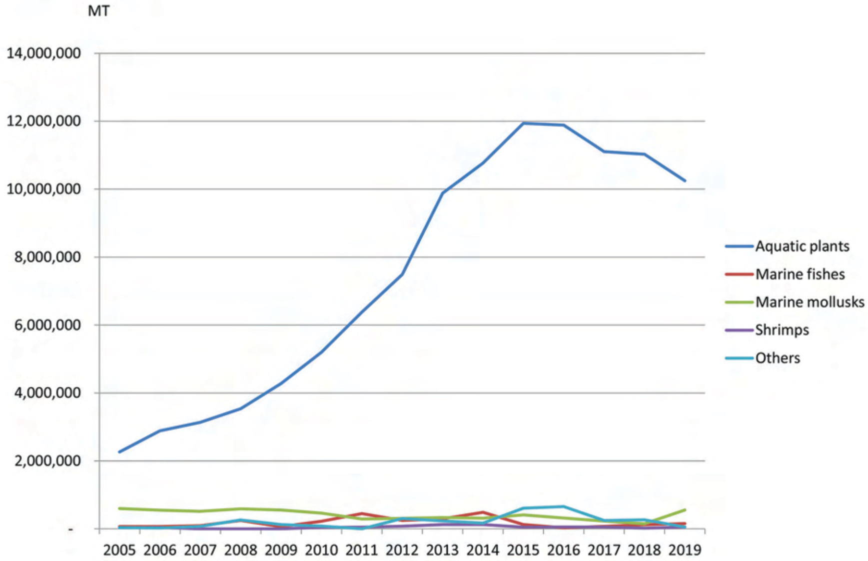


Figure 23. Trends of mariculture production by quantity (mt) of major groups of species of Southeast Asia in 2005-2019

Brunei Darussalam contributed less than 1.00 % to the region's total mariculture production value.

By major groups of mariculture species, namely: aquatic plants, marine fishes, marine mollusks, shrimps, and others, the aquatic plants contributed the largest production to the region's total mariculture production from 2005 to 2019. The total contribution from aquatic plants attained an average increase of at about 570,021 mt/year or 12.03 % annually (**Table 27** and **Figure 23**).

As shown in **Table 28**, by major groups of mariculture species, the aquatic plants contributed about 93.00 % to the region's total mariculture production volume. Indonesia contributed the largest amount from production of aquatic plants, particularly *Eucheuma* spp. which accounted for about 76.60 % of the region's total production volume from mariculture, followed by the elkhorn sea moss (*Kappaphycus alvarezii*) the main mariculture product of the Philippines which accounted for 12.90 %. Specifically for the marine mollusks group, this group contributed

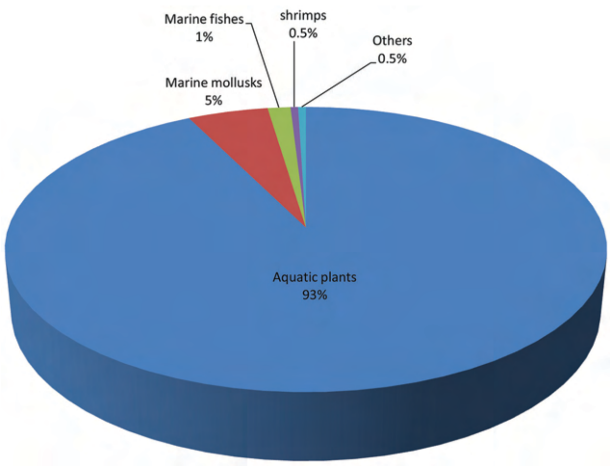


Figure 24. Percentage of mariculture production of major groups of species of Southeast Asia in 2019 by quantity (mt)

Table 27. Mariculture production of major groups of species of Southeast Asia from 2005 to 2019 by quantity (mt)

Year	Major group of species					
	Aquatic plants	Marine fishes	Marine mollusks	Shrimps	Others	Total
2005	2,266,406	70,521	596,837	40,608	34,662	**3,009,034**
2006	2,883,247	69,314	551,143	40,630	27,107	**3,571,441**
2007	3,134,993	91,972	518,330	130	73,456	**3,818,881**
2008	3,534,124	245,967	588,563	…	259,567	**4,628,221**
2009	4,277,095	64,279	553,401	…	127,940	**5,022,715**
2010	5,198,944	224,993	462,158	46,105	84,982	**6,017,182**
2011	6,380,246	449,323	291,382	51,207	1,918	**7,174,076**
2012	7,488,620	244,770	311,560	79,099	306,146	**8,430,195**
2013	9,879,417	292,890	334,836	127,050	230,936	**10,865,129**
2014	10,767,935	485,559	312,452	126,200	170,527	**11,862,673**
2015	11,940,006	128,671	412,832	49,891	606,079	**13,137,479**
2016	11,882,824	29,332	321,493	54,179	658,475	**12,946,303**
2017	11,105,950	71,465	225,451	55,310	248,862	**11,707,038**
2018	11,027,739	120,127	151,920	19,042	267,077	**11,585,905**
2019	10,246,706	157,178	554,145	51,904	53,414	**11,061,347**

Source: *FAO Fisheries and Aquaculture Information and Statistics Service*
Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019

Table 28. Production of major groups of mariculture species of the Southeast Asian countries in 2019 by quantity (mt)

Major groups of species	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Aquatic plants	**...**	**...**	**8,556,708**	**188,110**	**11**	**1,499,877**	**...**	**...**	**...**	**10,244,706**
Eucheuma denticulatum	...	...	...	...	...	75,619	...	...	...	75,619
Eucheuma spp.	...	...	8,476,045	...	...	...	...	...	...	8,476,045
Caulerpa sertularioides	...	...	45	...	...	...	...	...	...	45
Caulerpa spp.	...	...	...	...	...	1,090	...	...	...	1,090
Kappaphycus alvarezii	...	...	...	188,110	11	1,423,168	...	...	...	1,611,289
Sargassum muticum	...	...	80,618	...	...	...	...	...	...	80,618
Marine mollusks	**...**	**11,900**	**59,691**	**16,561**	**...**	**61,615**	**405**	**88,973**	**315,000**	**554,145**
Marine mollusks *nei*	...	11,900	10,864	...	...	...	...	...	315,000	337,764
Perna viridis	...	...	26,080	1,221	...	25,421	403	38,005	...	91,130
Anadara granosa	...	...	11,883	13,772	...	...	...	33,064	...	58,719
Crassostrea gigas	...	...	10,748	...	...	...	2	...	...	10,750
Crassostrea iredalei	...	...	...	...	...	36,194	...	...	...	36,194
Crassostrea spp.	...	...	...	1,568	...	...	...	17,904	...	19,472
Pinctada radiata	...	...	116	...	...	...	...	...	...	116
Marine fishes	**336**	**1,988**	**22,058**	**168**	**934**	**127,485**	**4,209**	**...**	**...**	**157,178**
Marine crustaceans (shrimps)	**...**	**...**	**...**	**...**	**51,904**	**...**	**...**	**...**	**...**	**51,904**
Others	**...**	**...**	**...**	**...**	**...**	**...**	**...**	**...**	**53,414**	**53,414**
TOTAL	**336**	**13,888**	**8,638,457**	**204,839**	**52,849**	**1,688,977**	**4,614**	**88,973**	**368,414**	**11,061,347**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

about 5.00 % to the region's total production volume from mariculture, with Viet Nam providing the highest production of marine mollusks *nei* accounting for about 2.80 %, followed by Thailand whose production of the green mussels (*Perna viridis*) and blood cockles (*Anadara granosa*) contributed about 0.30 % each (**Figure 24**).

In terms of value, the eucheuma seaweeds *nei* (*Eucheuma* spp.) contributed 58.10 % to the region's total mariculture

Table 29. Production of major species from inland capture fisheries in Southeast Asia in 2019

Scientific name (Common name)	Quantity (mt)	Percentage production of major commodities from mariculture to total mariculture production	Value (USD thousand)*	Percentage total value of major commodities production from mariculture to total mariculture value (%)	Value/ Quantity** (USD/mt)
Eucheuma spp. (Eucheuma seaweeds *nei*)	8,476,045	76.6	1,936,894	58.1	229
Kappaphycus alvarezii (Elkhorn sea moss)	1,611,289	14.6	116,154	3.5	72
Marine mollusks *nei*	337,764	3.1	15,927	0.5	700
Chanos chanos (Milkfish)	126,804	1.1	282,610	8.5	2,229
Perna viridis (Green mussel)	91,130	0.8	40,981	1.2	450
Sargassum muticum (Japanese Sargasso seaweed)	80,618	0.7	27,643	0.8	343
Eucheuma denticulatum (Spiny eucheuma)	75,619	0.7	8,587	0.3	114
Crassostrea spp. (Oysters)	66,416	0.6	60,464	1.8	910
Anadara granosa (Blood cockle)	58,719	0.5	176,167	5.3	3,000
Marine crustaceans (Shrimps)	51,904	0.5	362,575	10.9	6,985

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Data not available from Cambodia and Viet Nam*
*** Computation of price excludes corresponding quantity production from Cambodia and Viet Nam*

production followed by shrimps which contributed 10.90 %, milkfish (*Chanos chanos*) which contributed about 8.50 %, and blood cockle ((*Anadara granosa*) that contributed 5.30 %. Moreover, shrimp commenaded the highest value per volume at USD 6,985/mt, followed by blood cockle at USD 3,000/mt, and milkfish at USD 2,229/mt. Meanwhile, the lowest value was obtained for the elkhorn sea moss at USD 72/mt (**Table 29**).

5.2 Brackishwater Aquaculture

The total brackishwater aquaculture production of the Southeast Asian region had increased from 1,901,173 mt in 2005 to 5,083,792 mt in 2019, accounting for an average increase of 227,287 mt/year or 7.96 % annually (**Table 30**). Throughout the 15-year period (**Figure 25**), Indonesia had been the region's top producer with an average increase in production of 167,159 mt/year or 13.80 % annually, followed by Viet Nam at 60,933 mt/year, Thailand at 2,204 mt/year, Philippines at 5,075 mt/years, and Malaysia at 4,593 mt/year.

The value of the brackishwater aquaculture production had increased during 2005–2019 at an average of USD 329 million per year or 12.68 % annually (**Table 31**). Indonesia reported the highest increasing average value of USD 263,157 per year, followed by Thailand at USD 90,844 per year, Philippines at USD 49,396 per year, and Malaysia at USD 22,934 per year. In 2019, Singapore recorded the highest average value of USD 28,267/mt, followed by Brunei Darussalam at USD 6,618/mt, Malaysia at USD 6,087/mt, Thailand at USD 4,866/mt, Philippines at USD 3,523/mt, Indonesia at USD 1,732/mt, and Myanmar at USD 1,300/mt. Cambodia and Viet Nam were not able to report the values of their respective brackishwater aquaculture production in 2019 (**Table 31**).

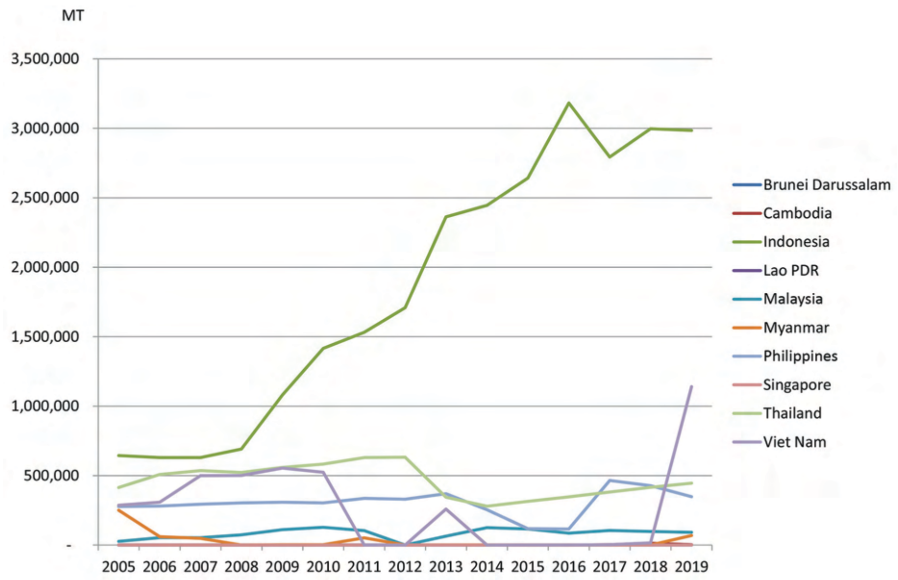


Figure 25. Trends of brackishwater culture production of the Southeast Asian countries in 2005-2019 by quantity (mt)

Table 30. Brackishwater aquaculture production of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	537	100	643,975	0	27,363	250,407	277,230	35	414,926	287,200	**1,901,773**
2006	60	130	629,609	0	53,679	60,000	281,316	34	508,150	309,000	**1,841,978**
2007	629	-	629,797	0	53,656	48,303	294,495	-	535,834	500,500	**2,063,214**
2008	355	-	691,432	0	73,694	-	303,244	-	522,659	501,600	**2,092,984**
2009	-	75	1,080,700	0	11,524	2,926	308,440	-	558,444	554,397	**2,616,506**
2010	293	100	1,416,038	0	128,387	3,122	304,276	-	583,111	524,443	**2,959,770**
2011	159	-	1,531,456	0	103,578	51,965	336,159	-	630,375	-	**2,653,692**
2012	335	160	1,708,110	0	-	-	330,781	96	631,881	-	**2,671,363**
2013	456	91	2,362,480	0	64,577	1,969	369,591	389	344,913	258,867	**3,403,333**
2014	592	-	2,446,031	0	125,801	1,845	254,692	200	279,907	-	**3,109,068**
2015	789	870	2,641,429	0	115,352	-	118,648	237	314,288	-	**3,191,613**
2016	712	-	3,182,105	0	85,802	-	116,237	334	347,382	-	**3,732,572**
2017	1,242	2,720	2,793,437	0	105,195	-	465,274	204	382,353	2,200	**3,752,625**
2018	724	13,630	2,997,350	0	97,681	-	427,770	227	415,498	15,500	**3,968,380**
2019	591	3,340	2,984,207	0	91,658	69,472	348,284	202	445,781	1,140,257	**5,083,792**

Source: *FAO Fisheries and Aquaculture Information and Statistics Service*
Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019

Table 31. Brackishwater aquaculture production of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	-	-	1,483,289	0	236,883	-	535,451	374	897,455	1,463,200	**4,616,652**
2006	-	-	1,736,275	0	254,555	-	611,344	625	-	-	**2,602,799**
2007	3,212	-	1,672,408	0	193,212	714,106	714,106	-	1,523,423	1,692,500	**6,512,967**
2008	-	375	1,840,902	0	323,749	-	831,073	-	1,602,685	467,450	**5,066,234**
2009	658	754	2,156,102	0	409,412	-	897,093	-	1,717,645	1,974,429	**7,156,093**
2010	4,800	-	3,409,438	0	506,555	-	481,441	-	2,066,328	-	**6,468,562**
2011	890	-	2,657,156	0	497,955	1,592	1,044,438	-	2,587,963	-	**6,789,994**
2012	-	-	2,643,864	0	-	-	1,040,218	717	2,570,171	-	**6,254,970**
2013	2,690	-	4,234,648	0	284,912	262,169	1,204,447	6,752	2,003,487	-	**7,999,105**
2014	7,130	-	3,526,200	0	737,340	1,600	1,040,667	5,299	1,610,425	-	**6,928,661**
2015	5,147	-	3,238,667	0	552,192	-	1,040,667	2,952	1,456,921	-	**6,296,546**
2016	3,340	-	2,597,458	0	464,783	-	592,548	6,696	1,615,768	-	**5,280,593**
2017	8,163	-	6,053,092	0	567,328	-	671,957	4,938	1,914,523	-	**9,220,001**
2018	5,014	-	5,496,728	0	520,505	-	509,164	2,044	2,044,098	-	**8,577,553**
2019	3,911	-	5,167,493	0	557,953	90,314	1,226,997	5,710	2,169,268	-	**9,221,646**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

The major groups and species cultured in brackishwater include aquatic plants such as *Gracilaria* spp., crustaceans such as banana prawn (*Penaeus merguiensis*), giant tiger shrimp (*P. monodon*), whiteleg shrimp (*P. vannamei*), and other shrimps, as well as fishes such as milkfish (*Chanos chanos*) and marine fishes, and others. **Table 32** showed that the production of *Gracilaria* spp., whiteleg shrimp (*P. vannamei*), giant tiger shrimp (*P. monodon*), and milkfish (*Chanos chanos*) had increased from 2005 to 2019, where *Gracilaria* spp. attained average increase in production of 84,242 mt/year, followed whiteleg shrimp at 78,567 mt/year, giant tiger shrimp (*P. monodon*) at 4,615 mt/year, and milkfish at 37,019 mt/year. On the other hand, production of banana prawn (*Penaeus merguiensis*) had decreased with an average decrease of 5,503 mt/years from 2005 to 2019. Malaysia was unable to report its production of banana prawn (*Penaeus merguiensis*) since 2008. In 2019, the whiteleg shrimp (*P. vannamei*) provided the highest contribution to the total brackishwater aquaculture production for 33.00 % followed by at *Gracilaria* spp. at 24.10 %, milkfish (*Chanos chanos*) at 19.50 %, and giant tiger shrimp (*P. monodon*) at 9.00 %.

Table 32. Production of major group of species of brackishwater aquaculture of Southeast Asia from 2005 to 2019 by quantity (mt)

Year	Major group of species								
	Aquatic plants (*Gracilaria* spp.)	Crustaceans				Fishes		Others	Total
		Banana prawn (*P. merguiensis*)	Tiger shrimp (*P. monodon*)	Whiteleg shrimp (*P. vannamei*)	Other shrimps	Milkfish (*Chanos chanos*)	Miscellaneous fishes		
2005	44,253	80,613	393,720	578,361	185,271	473,924	139,447	6,184	**1,901,773**
2006	120,000	76,633	366,522	690,062	63,216	439,706	64,790	21,049	**1,841,978**
2007	242,821	86,186	429,295	580,091	72,424	498,437	153,826	134	**2,063,214**
2008	207,470	78,087	522,326	745,948	224,545	219,444	95,164	...	**2,092,984**
2009	171,868	64,534	383,696	571,000	462,671	260,610	552,667	149,460	**2,616,506**
2010	517,605	87,905	455,722	767,653	31,650	683,990	172,012	243,233	**2,959,770**
2011	630,788	73,404	234,053	762,045	17,291	735,667	108,657	91,787	**2,653,692**
2012	776,177	64,258	188,870	825,169	1,419	756,842	25,899	32,729	**2,671,363**
2013	977,635	65,285	297,468	695,665	129,224	977,970	260,086	...	**3,403,333**
2014	1,106,065	74,838	197,571	699,776	12,997	738,605	142,756	136,460	**3,109,068**
2015	1,157,561	1,883	65,931	338,696	548,701	1,009,876	68,965	...	**3,191,613**
2016	1,358,685	1,890	67,860	361,851	677,543	1,141,030	123,713	...	**3,732,572**
2017	1,059,204	3,005	197,231	1,153,741	30,258	1,114,731	152,827	41,628	**3,752,625**
2018	1,338,716	17,707	197,641	875,997	66,303	932,505	415,040	124,472	**3,968,380**
2019	1,223,648	3,565	458,325	1,678,302	95,645	992,195	343,606	288,507	**5,083,792**

Source: *FAO Fisheries and Aquaculture Information and Statistics Service*
Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019

Table 33. Production of major groups of species of brackishwater aquaculture of the Southeast Asian countries in 2019 by quantity (mt)

Major groups of species	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Aquatic plants										
(*Gracilaria* spp.)	-	-	1,223,564	-	-	84	-	-	-	1,223,648
Crustaceans										
Banana prawn	-	-	2,229	-	-	1,176	-	160	-	3,565
Giant tiger shrimp	52.4	-	129,610	3,950	-	45,733	25.3	17,954	261,000	458,325
Whiteleg shrimp		**-**	**664,869**	**38,767**	**-**	**19,152**	**5.58**	**378,508**	**577,000**	**1,678,302**
Other shrimps	202.5	1336	49,399	-	-	498	58.39	151	45,000	96,645
Fishes										
Milkfish	3.9	-	748,167	2,235	-	241,789	-	-	-	992,195
Marine fishes	332	1988	153,803	45,860	69,472	8,530	113	49,008	14,500	343,606
Others	**-**	**16**	**12,566**	**846**	**-**	**31,322**	**-**	**-**	**242,757**	**287,507**
Total	**591**	**3,340**	**2,984,207**	**91,658**	**69,472**	**348,284**	**202**	**445,781**	**1,140,257**	**5,083,792**
Total Value (USD thousand)	**3,911**	**...**	**5,167,493**	**557,953**	**90,314**	**1,226,997**	**5,710**	**2,169,26**	**...**	**9,221,646**

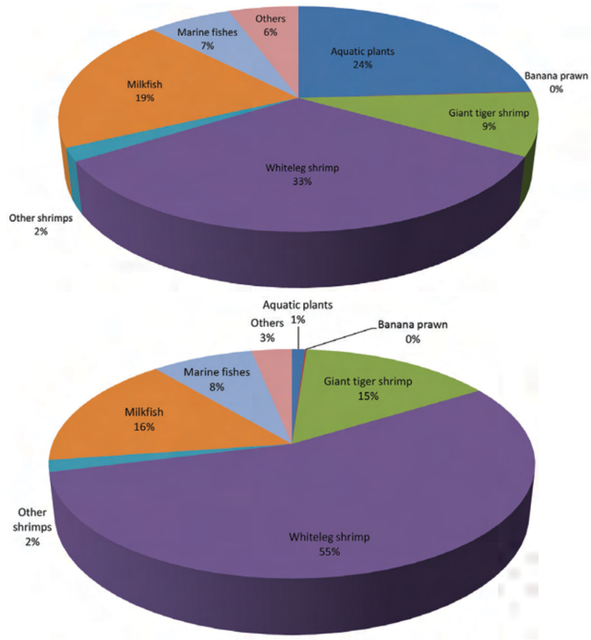
Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

In the production quantity of brackishwater aquaculture in 2019 by the Southeast Asian countries and by major groups and species, production of whiteleg shrimp (*P. vannamei*) was highest and mainly produced by Indonesia (39.60 %), Viet Nam (34.40 %), and Thailand (22.50 %). The second highest production was generated by aquatic plants or *Gracilaria* spp. mainly produced by Indonesia which contributed the highest to the region's total brackishwater aquaculture production of aquatic plants at 99.90 %, and the third highest was from milkfish (*Chanos chanos*) mainly produced by Indonesia (75.40 %) and Philippines (24.40 %), and followed by giant tiger shrimp (*P. monodon*) mainly produced by Viet Nam (56.90 %), Indonesia (28.30 %), Philippines (10.00 %), and Thailand (3.90 %) (**Table 33**). In terms of production value, the whiteleg shrimp (*P. vannamei*) contributed the highest value of about 54.80 % followed by milkfish (*Chanos chanos*) at 16.10 %, giant tiger shrimp (*P. monodon*) at 15.10 %, and marine fishes at 8.00 %. Although aquatic plants attained the second highest production volume (24.00 %), its contribution in terms of value was only 1.00 % (**Figure 26**).

Table 34. Major brackishwater species cultured in the region (as of 2019)

Common name	Quantity (mt)	Percentage brackishwater culture production of major commodities to total brackishwater culture production	Value (USD thousand)*	Percentage total value of major commodities production from brackishwater culture to total brackishwater culture value (%)	Value/ Quantity** (USD/mt)
Whiteleg shrimps	1,678,302	33.0	5,056,968	54.8	4,592
Gracilaria seaweeds	1,223,648	24.1	94,800	1.0	77
Milkfish	992,195	19.5	1,483,073	16.1	1,495
Giant tiger shrimp	458,325	9.0	1,392,428	15.1	7,057
Fishes	343,606	6.8	736,466	8.0	2,238
Shrimps	96,645	1.9	152,959	1.7	2,962

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Data not available from Cambodia and Viet Nam*
*** Computation of price excludes corresponding quantity production from Cambodia and Viet Nam*



Figures 26. Production of major group of species from brackishwater aquaculture of Southeast Asia in 2019 by quantity *(above)* and value *(below)*

On the average value per volume of production from brackishwater aquaculture, considering only the countries that reported their respective production values, Singapore posted the highest at USD 28,267/mt followed by Brunei Darussalam at USD 6,618/mt, Malaysia at USD 6,087/mt, Thailand at USD 4,866/mt, Philippines at USD 3,523/mt, Indonesia at USD 1,732/mt, and Myanmar at USD 1,300/mt. Cambodia and Viet Nam did not report their respective production value from brackishwater aquaculture (**Table 33**). The highest value per volume of production was attained by the giant tiger shrimp (*P. monodon*) at USD 7,057/mt followed by whiteleg shrimp (*P. vannamei*) at USD 4,592/mt, other shrimps at USD 2,962/mt, group of fishes at USD 2,238/mt, milkfish (*Chanos chanos*) at USD 1,495/mt, and *Gracilaria* spp. at USD 77/mt (**Table 34**).

5.3 Freshwater Aquaculture

Freshwater aquaculture had continued to play an increasingly important role in food security in many countries in the Southeast Asian region, with policies evolving in several countries to address the anticipated short-fall in fishery products from capture fisheries. In less developed countries of the sub-region such as Viet Nam, Myanmar, Cambodia, and Lao PDR, recognition is given to fish production for food security and rural development, as the governments promoted aquaculture as means of alleviating poverty and ensuring food supply in many rural areas (FAO, 1997a). This is clearly reflected in the continued increases in production from freshwater aquaculture in the respective countries.

The region's total production from freshwater aquaculture in 2019 was reported to be 9,136,488 mt accounting for about 36.00 % of the region's total production from aquaculture. Indonesia had the highest production from freshwater aquaculture at 3,925,503 mt or 43.00 % to the region's total freshwater aquaculture production, followed by Viet Nam at 2,983,829 mt or 32.70 %, Myanmar at 959,744 mt or 10.50 %, Thailand at 426,949 mt or 4.70 %, and Philippines at 320,977 mt or 3.50 % (**Table 35**).

The trend of freshwater aquaculture in the Southeast Asian countries from 2005 to 2019 as shown in **Figure 27** indicates a large increase of approximately 466,769 mt per year or 9.70 % annually. In terms of value, production from freshwater aquaculture provided 42.00 % to the regions' total aquaculture production value (**Table 36**). This information however, could be underestimated considering that the corresponding production value from Cambodia, Lao PDR, and Viet Nam have not yet been reported.

Table 35 and **Table 36** showed that Singapore posted the highest average value at USD 7,538/mt in 2019 followed by Brunei Darussalam at USD 6,050/mt, Thailand at USD 1,959/mt, Malaysia at USD 1,762/mt, Indonesia at USD 1,572/mt, Philippines at USD 1,550/mt, and Myanmar at

Table 35. Freshwater aquaculture production of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	129	25,500	407,047	78,000	62,006	323,779	198,890	602	539,474	966,300	**2,601,727**
2006	140	40,770	381,946	78,000	61,653	514,990	244,903	425	527,414	1,162,527	**3,012,768**
2007	12	33,570	327,171	63,250	70,064	556,354	294,125	345	525,100	1,485,500	**3,355,491**
2008	4	38,350	786,386	64,300	96,032	605,552	311,059	283	522,463	1,918,300	**4,342,729**
2009	34	45,000	1,162,300	75,000	144,445	670,773	308,490	280	520,639	1,812,900	**4,739,861**
2010	19	57,780	1,347,183	82,100	155,398	772,396	308,093	403	432,378	2,054,035	**5,209,785**
2011	13	69,380	1,791,681	95,600	122,489	761,697	279,008	526	384,351	2,612,100	**6,116,845**
2012	20	87,030	2,149,017	101,895	152,554	785,733	283,292	459	454,254	2,736,400	**6,750,654**
2013	16	85,276	2,411,991	124,085	133,392	922,256	276,630	1,018	435,765	2,754,400	**7,144,829**
2014	7	112,639	2,711,250	90,355	110,784	895,491	262,380	810	415,124	2,959,200	**7,558,040**
2015	12	139,630	2,717,483	95,965	112,034	944,106	264,412	1,061	419,845	3,153,200	**7,847,748**
2016	3	159,668	3,146,490	95,965	103,605	959,766	263,007	1,030	418,023	3,356,100	**8,503,657**
2017	19	194,280	3,770,772	109,877	102,647	989,677	315,039	819	413,263	3,584,100	**9,480,493**
2018	9	238,610	3,169,950	108,200	101,269	1,106,892	322,598	854	425,837	3,843,300	**9,317,519**
2019	6	290,180	3,925,503	113,000	115,285	959,744	320,977	1,015	426,949	2,983,829	**9,136,488**

Source: *FAO Fisheries and Aquaculture Information and Statistics Service*
Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019

Table 36. Freshwater aquaculture production of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	...	...	332,412	...	83,799	...	185,546	2,450	358,509	859,850	**1,822,566**
2006	...	...	384,658	...	79,656	...	257,325	1,471	532,251	...	**1,255,361**
2007	...	52,738	342,329	...	136,531	1,148,297	349,629	1,072	611,169	2,662,750	**5,304,515**
2008	...	57,525	1,398,411	91,141	124,157	141,288	387,286	1,180	462,616	2,656,500	**5,320,104**
2009	...	67,500	1,735,852	111,801	251,304	644,260	418,956	1,242	633,148	2,719,350	**6,583,414**
2010	150	...	2,134,415	...	252,161	724,138	419,786	1,660	654,223	...	**4,186,533**
2011	41	118,780	3,434,552	...	231,579	736,975	404,200	2,053	690,290	3,976,369	**9,594,839**
2012	14	...	3,642,789	...	332,268	1,134,881	462,132	1,941	806,756	4,191,458	**10,572,239**
2013	93	...	4,303,479	...	285,138	1,434,418	448,171	3,119	828,935	...	**7,303,353**
2014	44	...	4,309,238	108,426	225,606	1,595,222	429,249	8,733	763,570	...	**7,440,088**
2015	42	...	4,583,988	...	209,108	1,312,356	429,249	6,249	737,227	...	**7,278,219**
2016	12	...	5,316,623	...	205,303	1,441,349	387,686	12,276	733,718	...	**8,096,967**
2017	153	...	6,292,447	...	191,118	1,369,976	466,950	6,083	665,100	...	**8,991,827**
2018	51	...	5,244,205	...	217,384	1,312,644	472,541	8,176	811,209	...	**8,066,210**
2019	36	...	6,169,494	...	203,137	1,376,872	497,641	7,651	836,193	...	**9,091,025**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

USD 1,435/mt. Cambodia, Lao PDR, and Viet Nam were not able to report the values of their respective countries' freshwater aquaculture production in 2019.

In the Southeast Asian region, more than 40 major groups and species are being cultured in freshwater environment, about one-half of which are non-indigenous fish species such as common carp, tilapia, roho labeo, African catfish, mrigal carp, giant freshwater prawn, and so on. A portion of the alien fish species have established self-sustaining populations in the nature, while a few have become invasive. These successful fish invaders have posed serious threats not only to the freshwater aquaculture sector and the native species, but also to the countries' economies. While Brunei Darussalam, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam were able to report their production from freshwater aquaculture by species, the other countries reported production by major groups only, such as freshwater fish *nei*, without providing the details at species level. From 2005 to 2018, the freshwater aquaculture production of major groups of species indicated that tilapia and other cichlids groups posted the largest production followed by carps, barbells, and other cyprinids group, and the catfishes group. In 2019, the catfishes group accounted for 35.00 % of the region's total production from freshwater aquaculture, followed

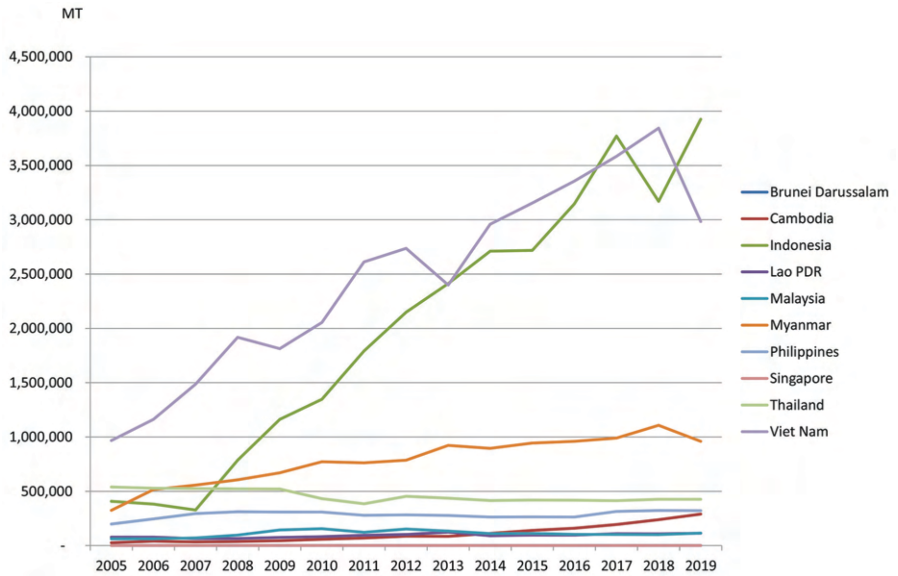


Figure 27. Freshwater aquaculture production trend of Southeast Asia in 2005-2019 by quantity (mt)

Table 37. Production of major groups of species of freshwater aquaculture of Southeast Asia from 2005-2019 by quantity (mt)

Year	Major group of species								
	Carps, barbells and other cyprinids	Catfishes	Freshwater crustaceans	Gouramis	Freshwater fishes *nei*	Tilapia and other cichlids	Milkfish	Others	Total
2005	300,195	667,154	46,141	44,418	1,014,347	504,195	25,277	0	**2,601,727**
2006	495,534	756,841	32,294	44,971	1,117,711	530,852	34,565	0	**3,012,768**
2007	428,692	1,001,873	113,873	32,333	1,161,877	575,560	41,283	0	**3,355,491**
2008	680,758	1,462,884	37,378	37,883	1,463,682	615,705	44,439	0	**4,342,729**
2009	636,003	1,334,894	42,159	37,438	1,994,409	540,508	43,115	111,335	**4,739,861**
2010	1,080,784	637,766	61,254	91,922	2,337,286	957,984	42,789	0	**5,209,785**
2011	1,147,753	792,513	51,631	97,505	2,901,796	1,083,395	42,252	0	**6,116,845**
2012	1,228,141	1,018,284	443,334	124,198	2,459,289	1,226,926	41,524	208,958	**6,750,654**
2013	1,336,381	1,215,705	510,616	137,358	2,457,258	1,385,695	42,426	59,389	**7,144,829**
2014	1,341,130	1,324,607	567,299	160,093	2,472,650	1,462,229	36,921	193,112	**7,558,040**
2015	1,337,999	1,315,651	645,644	132,193	2,720,464	1,600,711	85,753	9,333	**7,847,748**
2016	1,378,567	1,558,243	689,606	167,022	2,867,812	1,706,567	92,826	43,015	**8,503,657**
2017	1,300,333	1,686,016	796,028	246,384	3,410,935	1,803,775	114,357	122,666	**9,480,493**
2018	1,595,751	1,352,962	885,367	147,802	3,442,447	1,612,698	102,331	178,162	**9,317,519**
2019	2,237,568	3,174,256	91,431	202,405	969,794	2,230,460	118,226	112,348	**9,136,488**

Source: *FAO Fisheries and Aquaculture Information and Statistics Service*
Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to2019

by carps, barbells and other cyprinids group accounting for 25.00 %, tilapia and other cichlids group for 24.00 %, and freshwater fishes *nei* for 11.00 %. (**Table 37** and **Figure 28**). It should however be noted that Indonesia had reported its milkfish aquaculture production under inland water environments since 2015.

In terms of production volume from freshwater aquaculture by species of the Southeast Asian countries (**Table 38**), pangas catfishes *nei* (*Pangasius* spp.) accounted for 21.90 % of the region's total production from freshwater aquaculture, which was contributed mainly by Viet Nam. This was followed by Nile tilapia (*Oreochromis niloticus*) which accounted for 19.70 % and contributed mainly by

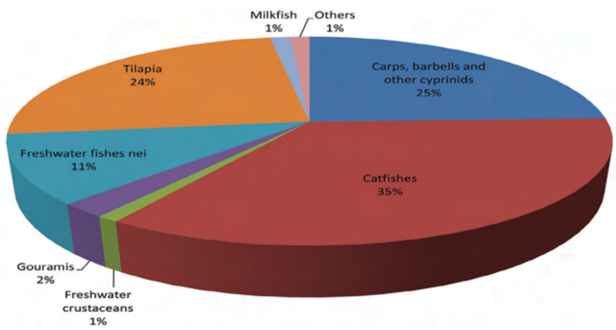


Figure 28. Percentage of production of major groups of species in freshwater aquaculture of Southeast Asia in 2019 by quantity (mt)

Table 38. Production of major groups of species from freshwater aquaculture of the Southeast Asian countries in 2019 by quantity (mt)

Major groups of species	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Pangas catfishes *nei*	-	-	383,836	-		-	-	19	13,316	1,600,000	**1,997,171**
Nile tilapia	5	-	1,399,136	-	3715	-	169,594	75.5	228,601	-	**1,801,127**
Torpedo-shaped catfishes	-	-	1,011,083	-	28,464	-	4,874		12,500	-	**1,056,921**
Common carp	-	-	605,091	-	1,562	303,731	-	-	980	134,312	**1,045,676**
Tilapias *nei*	-	-	42,982	-	31,845	-	91,321	-	79	263,107	**429,334**
Cyprinids *nei*	-	-	-	-	-	-	12,819	-	-	400,000	**412,819**
Roho labeo	-	-		-	8908	361,345	-	-	1744	-	**371,997**
Silver barb	-	-	21,757	-	990	259,542	-	-	21,767	-	**304,056**
Giant gourami	-	-	181,960	-		-	87	-	11,150	-	**193,197**
Catfishes, hybrid	-	-	-	-		-	-	-	97,151	-	**97,151**
Misc. freshwater fishes	-	289,750	76,149	112,920	1,746	-	200	0.16	13,092	475,937	**969,794**
Milkfish	-	-	76,370	-	543	-	41,314	-	-	-	**118,227**
Giant river prawn	1.26	-	5,829	-	206	9509	1	0.1	31,984	20,129	**67,659**
Others*	-	430	121,310	80	37,306	25,617	767	920.47	7,085	77,844	**271,359**
Total	**6**	**290,180**	**3,925,503**	**113,000**	**115,285**	**959,744**	**320,977**	**1,015**	**426,949**	**2,983,829**	**9,136,488**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
**Others including other fishes, frogs, turtles, etc.*

Table 39. Major brackishwater species cultured in the region (as of 2019)

Common name	Quantity (mt)	Percentage freshwater culture production of major commodities to total freshwater culture production	Value	Percentage total value of major commodities production from brackishwater culture to total brackishwater culture value (%)	Value/ Quantity** (USD/mt)
Pangas catfish	1,997,171	21.9	548,074	6.0	1,380
Nile tilapia	1,801,127	19.7	2,956,238	32.5	1,641
Torpedo-shaped catfishes	1,056,921	11.6	1,258,394	13.8	1,191
Common carp	1,045,676	11.4	1,529,652	16.8	1,678
Tilapias *nei*	429,334	4.7	278,391	3.1	1,675
Cyprinid *nei*	412,819	4.5	6,160	0.1	481
Roho labeo	371,997	4.1	628,625	6.9	1,690
Silver barb	304,056	3.3	321,284	3.5	1,057
Giant gourami	193,197	2.1	446,744	4.9	2,312
Catfishes, hybrid	97,151	1.1	144,193	1.6	1,484
Misc. freshwater fishes	969,794	10.6	119,378	1.3	1,309
Milkfish	118,227	1.3	169,377	1.9	1,433
Giant river prawn	67,659	0.7	332,987	3.7	7,006

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*
** Data not available from Cambodia, Lao PDR, and Viet Nam*
*** Computation of price excludes corresponding quantity production from Cambodia, Lao PDR, and Viet Nam*

Indonesia, followed by torpedo-shaped catfishes (*Clarias* spp.) at 11.60 % contributed mainly by Indonesia, common carp (*Cyprinus carpio*) at 11.40 % contributed mainly by Indonesia, Myanmar, and Viet Nam, tilapias *nei* (*Oreochromis*(=Tilapia) spp.) for 4.70 % contributed mainly by Viet Nam, cyprinids *nei* for 4.50 % accounted mainly by Viet Nam, roho labeo (*Labeo rohita*) at 4.10 % contributed mainly by Myanmar, silver barb (*Barbonymus gonionotus*) at 3.30 % accounted mainly by Myanmar, giant gourami (*Osphronemus goramy*) accounted for 2.10 % contributed mainly by Indonesia, and Africa-bighead catfish, hybrid (*Clarias gariepinus* x *C. macrocephalus*) at 1.10 % contributed mainly by Thailand.

On production value, the highest contributor to the region's total production value from freshwater aquaculture in 2019 was Nile tilapia (*Oreochromis niloticus*) which accounted for 32.50 % of the region's total production from freshwater aquaculture, followed by common carp (*Cyprinus carpio*) at 16.80 %, torpedo-shaped catfishes (*Clarias* spp.) at 13.80 %, roho labeo (*Labeo rohita*) at 6.90 %, pangas catfishes *nei* (*Pangasius* spp.) at 6.00 %, giant gourami (*Osphronemus goramy*) at 4.90 %, giant river prawn (*Macrobrachium rosenbergii*) at 3.70 %, and tilapias *nei* (*Oreochromis*(=Tilapia) spp.) at 3.10 %. For the value per volume of major freshwater aquaculture species, the highest was earned by giant river prawn (*Macrobrachium rosenbergii*) at USD 7,006/mt followed by giant gourami (*Osphronemus goramy*) at USD 2,312/mt, roho labeo (*Labeo rohita*) at USD 1,690/mt, common carp (*Cyprinus carpio*) at USD 1,678/mt, tilapias *nei* (*Oreochromis*(=Tilapia) spp.) at USD 1,675/mt, Nile tilapia (*Oreochromis niloticus*) at USD 1,641/mt, Africa-bighead catfish, hybrid (*Clarias gariepinus* x *C. macrocephalus*) at USD 1,484/mt, milkfish (*Chanos chanos*) at USD 1,433/mt, pangas catfishes *nei* (*Pangasius* spp.) at USD 1,380/metric mt, miscellaneous freshwater fishes at USD 1,309/mt, torpedo-shaped catfishes (*Clarias* spp.) at USD 1,191/mt, silver barb (*Barbonymus gonionotus*) at USD 1,057/mt, and cyprinids *nei* at USD 481/mt (**Table 39**).

6. Fishing Vessels

In the Southeast Asian countries, the number of fishing vessels reported is only for those vessels that had been registered, except for Cambodia and Lao PDR which did not report their respective number of registered fishing vessels in 2019. Based on the data available as of 2019, Indonesia had the highest number of vessels at 625,708, followed by Malaysia with 50,945 vessels of which 6,303 were non-powered while 44,642 were powered. The third highest number was reported by Viet Nam at 35,382, followed by Myanmar with 22,410 vessels of which 5,122 were non-powered while 17,288 were powered, Thailand with 10,530, Philippines with 7,646, Brunei Darussalam with 1,286, and Singapore with 34 vessels (**Table 40**).

Table 40. Number of fishing vessels in Southeast Asia in 2019

Country	Powered boats		Non-powered boats	Total
	Out-board	In-board		
Brunei Darussalam	1,158	44	84	1,286
Indonesia	...	...	...	625,708
Malaysia	29,227	15,415	6,303	50,945
Myanmar	14,077	3,211	5,122	22,410
Philippines	...	7,646	...	7,646
Singapore	26	8	...	34
Thailand	...	10,530	...	10,530
Viet Nam	...	...	...	35,382
Total	**44,488**	**36,854**	**11,509**	**753,941**

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

Table 41. Number of fishing vessels in the Southeast Asian countries from 2005 to 2019

Year	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	...	40,600	311,110	36,136	16,375	...	146	13,627	20,537	**438,531**
2006	...	...	340,362	38,276	1,881	...	125	12,552	-	**393,196**
2007	...	...	348,425	39,221	...	...	...	13,056	21,552	**422,254**
2008	3,184	...	604,847	40,959	31,371	...	142	12,920	22,729	**716,152**
2009	2,750	108,145	596,230	48,745	30,428	...	133	16,891	24,990	**828,312**
2010	2,743	...	570,827	49,756	32,824	...	39	15,381	25,346	**696,916**
2011	2,607	...	581,845	53,002	30,848	...	39	17,203	28,424	**713,968**
2012	2,627	...	616,690	54,235	30,349	...	144	18,089	27,988	**750,122**
2013	46	...	603,318	57,095	27,638	...	155	16,548	30,132	**734,932**
2014	38	...	651,966	57,972	28,958	6,317	158	23,556	31,235	**800,200**
2015	36	98,693	625,708	56,211	29,455	6,371	30	25,002	28,719	**870,225**
2016	1,449	...	568,329	72,786	26,414	6,901	30	11,237	30,976	**718,122**
2017	1,415	...	543,845	52,648	29,884	1,025	32	10,913	32,878	**672,640**
2018	921	...	563,239	52,556	25,105	6,578	34	10,645	34,563	**693,641**
2019	1,286	...	625,708	50,945	22,410	7,646	34	10,530	35,382	**753,941**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019*

The Regional Classification of Fishing Vessels was developed to be able to compile the statistics on the fishing units considering the extent of existing fishing operations in Southeast Asia (SEAFDEC, 2008b). **Table 41** shows that Indonesia had the highest number of fishing vessels during 2005–2019 followed, by Malaysia, Viet Nam, Myanmar, and Thailand. The data on fishing vessels by Indonesia indicated some increases in terms of the numbers from 2005 to 2008, but with slight decreases in 2009–2011, slightly increasing again in 2012–2015, and slightly decreasing again in 2016–2017, after that the number slightly increased since 2018. The second highest number was reported by Malaysia, which indicated some increases from 2005 to 2014 with slight decrease in 2015 and an increase again in 2016, but decreased again in 2017 and afterwards. It should be noted that reductions in the number of fishing vessels could be due to several reasons, such as natural disasters, issues on vessel and gear licensing/registration, as well as the respective countries' policies toward the reduction of fishing vessels in commercial fishing operations, *e.g.* in the case of Thailand, to control the level of fishing capacity within sustainable level.

7. Fishers and Fish Farmers

From 2005 to 2019, the trend in the number of fishers and fish farmers in the Southeast Asian countries varied among countries. Indonesia had the highest number followed by Myanmar, Viet Nam, Philippines, Cambodia, Thailand, and Malaysia (**Table 42**). Although Brunei Darussalam and Singapore reported the minimal numbers of fish workers in their respective countries, but Lao PDR was not able to provide the information on the number of fishers and fish farmers during the past 15 years. Efforts had been made by the countries to improve the availability of relevant data and statistics, but support to the countries would still necessary to be able to compile the data and information. It has therefore become necessary that the countries' systems of collecting data and reporting of the statistics, especially for the number of fishers and farmers, should be improved, and in some instances, this could be achieved through the conduct of census and surveys using questionnaires. This approach would also enable the countries to compile the necessary data and information on fisheries not only on the number of fishers and fish farmers but also on the number of fishing vessels actively engaged in fishing operations.

Table 42. Number of fishers and fish farmers in the Southeast Asian countries from 2005 to 2019

Year	Brunei Darussalam	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	4,124	765,124	5,120,414	115,100	2,991,000	2,201,000	...	452,300	2,100,730	**13,749,792**
2006	4,109	...	4,975,481	...	3,024,500	...	...	...	...	**8,004,090**
2007	5,541	...	5,099,977	...	3,080,600	...	...	...	...	**8,186,118**
2008	5,441	...	5,495,983	140,358	3,201,923	...	...	...	...	**8,843,705**
2009	4,078	...	5,135,160	152,014	3,261,199	...	460	...	...	**8,552,911**
2010	3,907	673,963	5,782,524	155,913	3,160,070	2,338,435	514	430,000	2,640,852	**15,186,178**
2011	3,910	657,269	6,099,112	162,709	3,164,627	...	500	...	...	**10,088,127**
2012	4,054	...	7,276,746	166,008	3,193,645	...	651	435,000	1,530,000	**12,606,104**
2013	4,393	578,468	6,473,657	170,821	3,196,289	...	699	435,000	2,565,525	**13,424,852**
2014	3,938	578,468	6,478,198	169,937	3,201,336	...	725	435,000	2,560,800	**13,428,402**
2015	3,126	...	6,443,192	210,399	3,216,300	...	643	456,960	2,602,340	**12,932,960**
2016	2,893	...	6,593,592	158,749	3,247,646	...	766	456,960	2,619,550	**13,080,156**
2017	2,678	...	6,761,204	153,517	3,205,805	...	811	456,960	2,619,550	**13,200,525**
2018	2,923	...	6,860,861	151,148	2,321,957	...	826	456,960	2,619,550	**12,414,225**
2019	402	...	5,508,642	149,269	...	...	756	...	...	**5,659,069**

Source: *Fishery Statistical Bulletin for the South China Sea Area 2005-2007 (SEAFDEC, 2008a; 2009; 2010a) for data from 2005 to 2007, and Fishery Statistical Bulletin of Southeast Asia 2008-2019 (SEAFDEC, 2010b; 2011; 2012; 2013, 2014, 2015; 2016; 2017a; 2018; 2020a; 2020b; 2022) for data from 2008 to 2019 FAO Yearbook 20016-2018*

Table 43. Number of fishers and fish farmers in the fisheries sub-sectors of Southeast Asia in 2019 by working status

Country	Marine Capture Fisheries		Inland Capture Fisheries		Aquaculture		Total
	Full-time	Unspecified	Full-time	Unspecified	Full-time	Unspecified	
Brunei Darussalam	...	...	402	...	...	...	402
Indonesia	...	2,296,746	...	515,545	...	2,696,351	5,508,642
Malaysia	126,595	...	3,205	...	19,469	...	149,269
Singapore	64	...	...	...	692	...	756

Source: *Fishery Statistical Bulletin of Southeast Asia 2019 (SEAFDEC, 2022)*

In 2019, Indonesia had the highest number of fishers and fish farmers at 5,508,642 of which 48.90 % were involved in aquaculture, 41.70 % in marine capture fisheries, and 9.40 % in inland capture fisheries. Malaysia had the second highest number of fishers and fish farmers at 146,269 with 84.80 % in marine capture fisheries, 13.00 % in aquaculture, and 2.20 % in inland capture fisheries (**Table 43** and **Figure 29**). Although minimal, Singapore and Brunei Darussalam also reported their respective number of fishers and fish farmers, however, Cambodia, Lao PDR, Myanmar, Philippines, Thailand, and Viet Nam were not able to provide the information on their respective numbers of fishers and fish farmers.

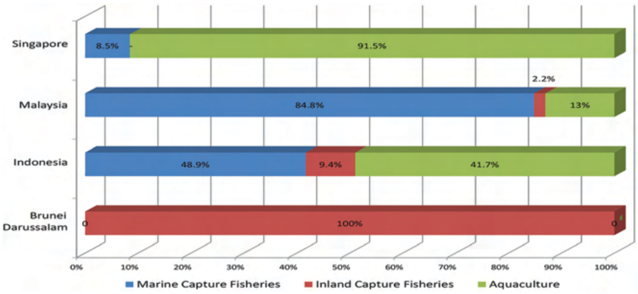


Figure 29. Percentage of fish workers in the fisheries sub-sectors of Southeast Asia in 2019

8. Fish Processing Industry

The fishing industry plays a vital role in the lives of millions of people in the world, and is the main source of food and livelihood for many. It accounts for a significant percentage in global trade of agriculture commodities. Although capture fisheries production from 2005 to 2019, had grown at a slow rate and which had a tendency to be stagnant, aquaculture production had grown dramatically to serve the demand of the world. Such a scenario had enabled the fishing industry to improve the fish supply for local consumption, which was decreasing because of increases in world population and the rising export growth. According to FAO (2020a), 87.60 % (156 million mt) of the global fish production in 2018 was used for human consumption. Of the portion not consumed by human, 12.40 % (22.1 million mt) was destined from non-food products. **Figure 30** showed that about 39.00 % of the catch reached the market as live and fresh fish, 30.00 % as frozen fish, while 10.00 % is used as raw materials for canning and another 10.00 % for reduction, and 9.00 % for curing. The remaining fish supply (2.00 %) is used for miscellaneous purposes.

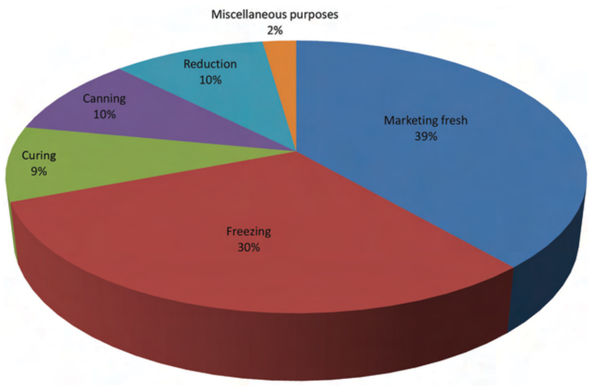


Figure 30. Percentage of disposition of the world fisheries production in 2018

The fisheries and fish processing industry in Southeast Asia had shown tremendous growth over the past decades, because of the extension of cold chain distribution systems, diversification of fish processing techniques, and advances in quality control hygiene and sanitation management. However, the progress varied from country to country, with changes taking place rapidly in some and slowly in other countries (Miwa, 1991). The main species being processed are freshwater fishes, for example, in Viet Nam which is the largest exporter of catfish, in fillets and frozen forms running to 541,560 mt. On the other hand, skipjack tuna is prepared and preserved in Thailand, and comes as the second highest exported products of the country at 427,389 mt. FAO (2020b) indicated that in many developing countries, fish processing had evolved from traditional methods to more advanced value-adding processes, depending on the commodity and market value. Growth was observed in the share of production destined for human consumption in frozen form and in prepared or preserved forms. Fish commercialized in live form is principally appreciated in East and Southeast Asia, and in niche markets in other countries, mainly among the Asian communities. In some cases, fish is also used to produce traditional fish products of the Southeast Asian region, *i.e.* fermented fish and fish sauce. Nonetheless, information on the region's data on disposition of its fisheries production, is not complete because only two countries provide the relevant information, namely: Brunei Darussalam and Indonesia, as shown in **Table 44**.

Table 44. Disposition of fisheries production of the Southeast Asian countries in 2019 by quantity (mt)

Disposition	Brunei Darussalam	Indonesia	Total
Marketing fresh	...	299,147	299,147
Freezing	3,433	1,389,022	1,392,455
Curing	7	3,615,115	3,615,122
Canning	...	285,486	285,486
Reduction	514	88,152	88,666
Misc. purposes	2	...	2
Unspecified	160	1,168,384	1,168,544
Total	**4,116**	**6,845,306**	**6,849,422**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

Moreover, several countries in Southeast Asia are exerting efforts not only on the improvement and development of fish processing but also in the development of new fishery products. This is meant to enhance the awareness of consumers on the importance of fish in human diet and also to promote the utilization of low cost and the so-called secondary species of fish into comminuted products.

9. Fish Trade

Seafood is one of the most traded food commodities in the world, and the trend of seafood trade keeps on growing. In 2019, fisheries production reached 213.7 million mt including about 93.6 million mt from capture fisheries and 120.1 million mt from aquaculture. While the export volume of fish and fishery products reached 41.6 million mt or 19.50 % of the world's total fisheries production, the total import accounted for about 40.9 million mt or 19.10 % of world's total fisheries production, posting a trade balance of 748,489 mt (**Table 45**). Therefore, fish is still fish available for fish for human consumption, which has reached an annual average of about 20.9 kg per capita.

Europe had been the top exporter and importer of fish and fishery products in 2019, accounting for 35.70 % of the total exports and 35.10 % of the total imports, followed by Asia which excludes Southeast Asian countries, at 21.50 % of the total exports and 31.60 % of the total imports. In the Southeast Asian region, the export of fish and fishery products in 2019 represented about 5,551,727 mt or 11.90 % of the regions' total fisheries production, while import was 4,009,160 mt, posting a trade balance of 1,542,567 mt.

9.1 Global Trading of Fish and Fishery Products

From 2005 to 2019, the world's export of fish and fishery products increased in terms of quantity by about 753,008 mt/year or 2.10 % annually (**Table 46** and **Figure 31**), and in terms of value by about USD 6,005 million/year or 5.60 % annually (**Table 47**). Europe is the top exporter of fish and fishery products during the past 15 years, and in 2019, Europe's export of fish and fishery products accounted for about 35.70 % in terms of quantity and 35.90 % in value of the world's total export of fish and fishery products (**Figure 32**). Asia (excluding Southeast Asian countries) which ranked second, accounted for about 21.50 % in terms of quantity and 23.40 % in value, then the Americas with about 19.20 % in terms of quantity and 20.30 % in value. The next highest exporter of fish and fishery products is the Southeast Asian region which accounted for 13.30 % of global export quantity and 13.60 % of the global export value.

Table 48 shows that China was the largest exporter of fish and fishery products in 2019 contributing about 12.40 % to the global export value, followed by Norway providing about 7.40 %. Among the Southeast Asian countries, Viet Nam also exported very large amounts of fish and fishery

Table 45. World fisheries trade of fish and fishery products of each continent in 2019 by quantity (mt)

	Total fisheries production	Trade of fish and fishery products		Trade balance (export-import)
		Export	Import	
World	**213,690,416**	**41,633,173**	**40,884,684**	**748,489**
Africa	12,531,080	3,352,176	4,106,189	-754,013
Americas	22,359,201	8,017,771	5,078,807	2,938,964
Asia*	112,899,095	8,955,366	12,912,377	-3,957,011
Southeast Asia	46,766,274	5,551,727	4,009,160	1,542,567
Europe	17,263,623	14,849,258	14,355,274	493,984
Oceania	1,856,733	906,875	422,877	483,998
Others	14,410	...	...	...

Source: *FAO Fishery and Aquaculture Information and Statistics Service*
**Asia does not include data of Southeast Asia*

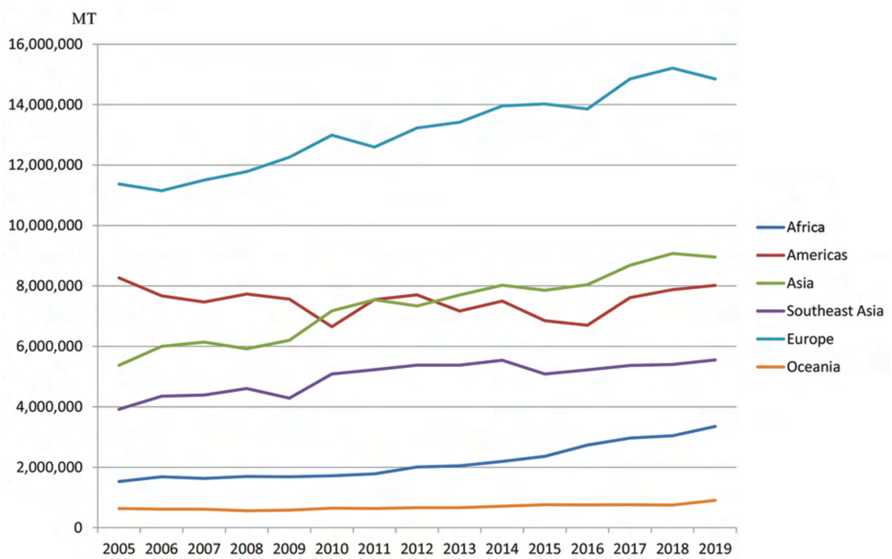


Figure 31. Trend of export of fish and fishery products of each continent from 2005 to 2019 by quantity (mt)

Table 46. Export of fish and fishery products of each continent from 2005 to 2019 by quantity (mt)

Year	World total	Continents					
		Africa	Americas	Asia*	Southeast Asia	Europe	Oceania
2005	**31,091,064**	1,524,564	8,266,534	5,371,442	**3,919,407**	11,375,261	633,856
2006	**31,469,860**	1,686,470	7,671,912	6,000,078	**4,348,364**	11,152,719	610,317
2007	**31,744,010**	1,630,255	7,467,034	6,144,031	**4,388,903**	11,500,230	613,557
2008	**32,291,817**	1,692,927	7,730,209	5,922,093	**4,606,151**	11,783,837	556,600
2009	**32,573,026**	1,682,669	7,565,847	6,198,749	**4,285,608**	12,257,814	582,339
2010	**34,268,241**	1,717,805	6,648,043	7,175,185	**5,088,794**	12,991,032	647,382
2011	**35,326,566**	1,781,927	7,549,158	7,540,460	**5,225,911**	12,596,873	632,237
2012	**36,318,722**	2,007,441	7,703,801	7,335,224	**5,381,089**	13,228,061	663,106
2013	**36,368,650**	2,044,822	7,168,953	7,697,828	**5,376,674**	13,417,913	662,460
2014	**37,925,911**	2,191,929	7,498,829	8,025,325	**5,543,781**	13,956,713	709,334
2015	**36,936,193**	2,359,614	6,850,987	7,855,104	**5,086,043**	14,026,383	758,062
2016	**37,310,085**	2,733,503	6,698,705	8,040,153	**5,224,608**	13,858,718	754,398
2017	**40,238,424**	2,964,765	7,612,109	8,686,568	**5,365,920**	14,850,528	758,534
2018	**41,356,327**	3,043,038	7,878,808	9,071,380	**5,402,922**	15,209,718	750,461
2019	**41,633,173**	3,352,176	8,017,771	8,955,366	**5,551,727**	14,849,258	906,875

Source: *FAO Fishery and Aquaculture Information and Statistics Service*
* *Southeast Asia data excluded from Asia data*

Table 47. Export of fish and fishery products of each continent from 2005 to 2019 by value (USD thousand)

Year	World total	Continents					
		Africa	Americas	Asia*	Southeast Asia	Europe	Oceania
2005	**79,228,696**	3,828,723	17,785,236	15,420,204	**11,045,661**	28,961,282	2,187,590
2006	**86,760,552**	4,076,908	19,112,854	16,730,678	**12,527,626**	32,139,612	2,172,874
2007	**94,214,013**	4,589,519	19,762,842	17,700,239	**13,707,701**	36,150,048	2,303,664
2008	**103,087,500**	5,023,878	21,384,222	18,999,159	**16,134,748**	39,218,279	2,327,214
2009	**97,105,931**	4,841,328	19,287,161	19,290,164	**14,989,838**	36,480,871	2,216,569
2010	**111,415,939**	5,042,616	20,973,896	24,243,232	**17,437,088**	41,187,312	2,531,795
2011	**130,508,288**	5,319,936	25,423,670	30,067,489	**20,441,521**	46,450,822	2,804,850
2012	**130,656,421**	5,793,192	25,472,804	31,006,255	**20,966,895**	44,552,941	2,864,334
2013	**139,299,827**	6,028,941	27,082,621	33,357,869	**21,040,188**	48,930,350	2,859,858
2014	**148,705,197**	6,381,931	29,477,606	35,763,633	**22,020,221**	51,979,914	3,081,892
2015	**133,431,817**	5,953,576	26,479,127	32,993,255	**18,686,790**	46,401,253	2,917,816
2016	**143,078,027**	6,540,131	27,602,531	34,896,006	**19,713,063**	51,307,119	3,019,177
2017	**157,729,008**	7,282,520	31,643,157	38,326,430	**21,739,500**	55,445,374	3,292,027
2018	**166,578,997**	8,068,646	33,015,340	39,969,241	**22,530,393**	59,662,218	3,333,159
2019	**163,304,921**	7,638,817	33,180,024	38,239,304	**22,163,504**	58,624,265	3,459,007

Source: *FAO Fishery and Aquaculture Information and Statistics Service*
* *Southeast Asia data excluded from Asia data*

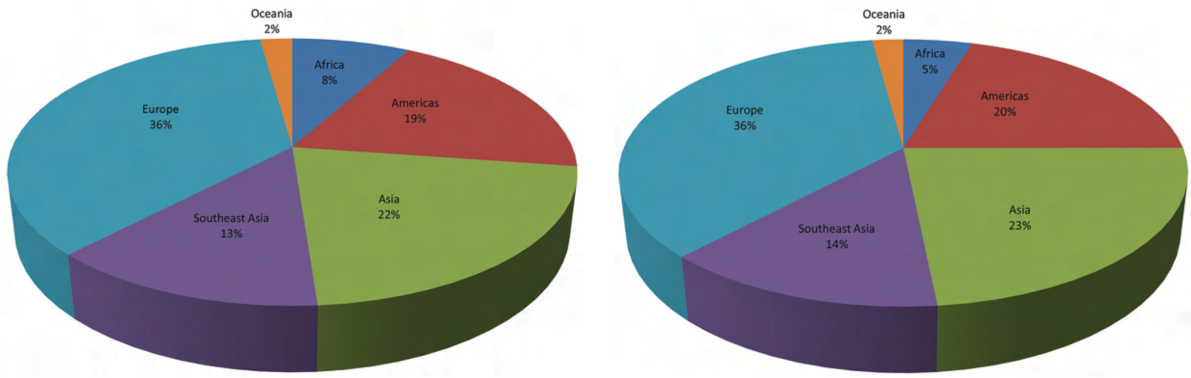


Figure 32. Percent share of world's export of fish and fishery products by each continent in 2019, quantity *(left)* and value *(right)*

Table 48. World's top ten exporters and importers of fish and fishery products in 2019 by value (USD thousand)

Exporter	Export value (USD thousand)	Importer	Import value (USD thousand)
1. China	20,256,429	1. USA	23,520,523
2. Norway	12,022,775	2. China	18,340,891
3. Viet Nam	8,694,596	3. Japan	15,492,562
4. India	6,857,128	4. Spain	8,139,488
5. Chile	6,675,177	5. France	6,733,949
6. Thailand	5,864,824	6. Italy	6,618,714
7. Netherlands	5,723,789	7. Germany	5,886,863
8. Canada	5,612,407	8. Republic of Korea	5,620,605
9. Ecuador	5,520,234	9. Sweden	5,270,508
10. Russia	5,490,671	10. United of Kingdom	4,600,952

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

products the value of which contributed 5.30 % to the world's total export value, while Thailand provided about 3.60 %.

Meanwhile, the world's import of fish and fishery products during the past 15 years had increased in terms of quantity by about 637,604 mt/year or 1.80 % annually (**Table 49**) and in value by USD 5,604 million per year or 5.10 % annually (**Table 50**). In 2019, Europe imported the largest quantity representing 35.10 % of the world's total import volume and 39.60 % of the world's total import value. The second largest importer was Asia (excluding Southeast Asia) contributing about 31.60 % in terms of quantity and 30.60 % in value (**Figure 33**). The United States of America was the largest importing country, the value of which accounted for 14.50 % followed by China for about 11.30 %, and Japan for about 9.60 % of the world's total import value (**Table 48**).

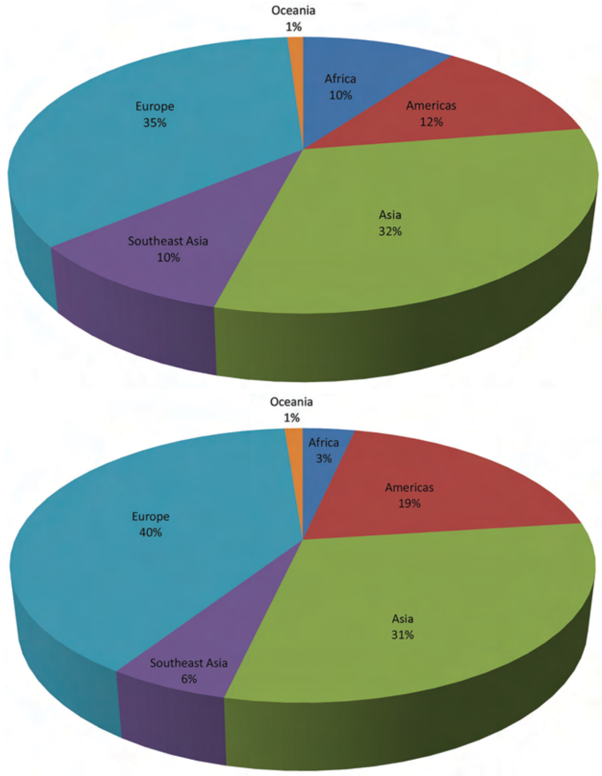


Figure 33. Percent share of the import of fish and fishery products by each continent in 2019, quantity *(above)* and value *(below)*

9.2 Trading of Fish and Fishery Products in Southeast Asia

The growth of international trade in fish and fishery products in Southeast Asian countries had been dramatic during 2005-2019 with significant export volumes contributing significantly to the foreign exchange earnings of the countries (**Table 51** and **Figure 34**). Overall, the Southeast

Table 49. Import of fish and fishery products of each continent from 2005 to 2019 by quantity (mt)

Year	World total	Continents					
		Africa	Americas	Asia*	Southeast Asia	Europe	Oceania
2005	**31,958,232**	2,430,783	3,866,634	9,782,850	**2,590,590**	12,914,986	372,389
2006	**32,647,088**	3,085,191	4,047,547	9,407,415	**2,705,785**	13,012,584	388,566
2007	**33,179,097**	2,963,342	4,190,437	9,385,655	**2,648,609**	13,602,710	388,344
2008	**33,300,170**	2,973,777	4,208,994	9,474,597	**2,811,534**	13,432,910	398,358
2009	**33,767,431**	3,275,438	4,158,995	9,350,489	**2,991,021**	13,621,570	369,918
2010	**34,956,139**	3,484,414	4,464,453	9,884,535	**3,056,568**	13,675,899	390,270
2011	**35,976,640**	4,038,104	4,578,331	10,380,008	**3,169,205**	13,396,764	414,228
2012	**35,695,339**	3,456,636	4,563,853	10,434,844	**3,192,797**	13,587,945	459,264
2013	**35,407,919**	3,380,678	4,646,270	10,205,432	**3,236,097**	13,494,234	445,208
2014	**37,526,567**	4,141,080	4,903,681	10,657,469	**3,303,514**	13,999,120	521,703
2015	**36,664,624**	4,050,298	4,833,146	10,540,209	**3,317,990**	13,452,963	470,018
2016	**36,997,760**	3,744,071	4,938,597	10,423,050	**3,630,381**	13,811,826	449,835
2017	**38,696,543**	3,624,861	5,062,595	11,445,019	**4,010,542**	14,121,866	431,660
2018	**39,720,822**	3,830,130	5,171,941	11,749,913	**4,096,609**	14,445,813	426,416
2019	**40,884,684**	4,106,189	5,078,807	12,912,377	**4,009,160**	14,355,274	422,877

Source: *FAO Fishery and Aquaculture Information and Statistics Service*
** Southeast Asia data excluded from Asia data*

Table 50. Import of fish and fishery products of each continent from 2005 to 2019 by value (USD thousand)

Year	World total	Continents					
		Africa	Americas	Asia*	Southeast Asia	Europe	Oceania
2005	**83,718,314**	2,008,310	16,212,435	24,784,946	**3,283,879**	36,375,305	1,053,439
2006	**92,181,249**	2,405,732	18,062,825	25,324,989	**3,494,683**	41,751,400	1,141,620
2007	**100,364,239**	2,887,837	19,160,452	25,782,122	**3,868,229**	47,337,018	1,328,581
2008	**109,644,614**	3,106,472	20,551,914	28,725,502	**4,827,561**	51,036,452	1,396,713
2009	**101,292,165**	3,399,002	19,189,832	26,824,946	**4,439,163**	46,124,358	1,314,864
2010	**112,722,133**	3,580,730	21,625,453	31,328,649	**5,006,502**	49,632,326	1,548,473
2011	**131,903,507**	5,432,114	24,714,400	37,164,443	**6,334,802**	56,383,254	1,874,494
2012	**130,891,716**	5,389,238	25,022,982	38,038,463	**6,882,109**	53,538,326	2,020,598
2013	**135,594,983**	5,301,345	27,102,139	36,365,910	**7,036,958**	57,737,167	2,051,464
2014	**143,636,832**	5,870,074	29,997,819	37,543,005	**7,086,735**	60,848,230	2,290,969
2015	**129,791,833**	5,335,018	27,393,206	35,898,900	**6,719,576**	52,565,495	1,879,638
2016	**137,225,327**	4,773,373	28,067,373	37,451,768	**7,466,942**	57,586,659	1,879,212
2017	**148,606,749**	5,020,911	29,857,962	41,257,570	**8,608,805**	61,791,403	2,070,098
2018	**162,062,767**	5,617,553	32,235,679	46,673,153	**9,282,293**	66,224,808	2,029,281
2019	**162,176,791**	5,603,490	31,616,170	49,687,029	**9,101,078**	64,234,605	1,934,419

Source: *FAO Fishery and Aquaculture Information and Statistics Service*
* *Southeast Asia data excluded from Asia data*

Asian region has become large fish exporter, and from 2005 to 2019, fish export showed a gradually increasing surplus in quantity and value (**Table 51** and **Table 52**) as the total quantity of export from the Southeast Asian countries had grown at about 116,594 mt/year or 2.70 % annually. The export value of the region's fish and fishery products also increased from 2005 to 2019 at about USD 794,132 per year or 5.50 % annually.

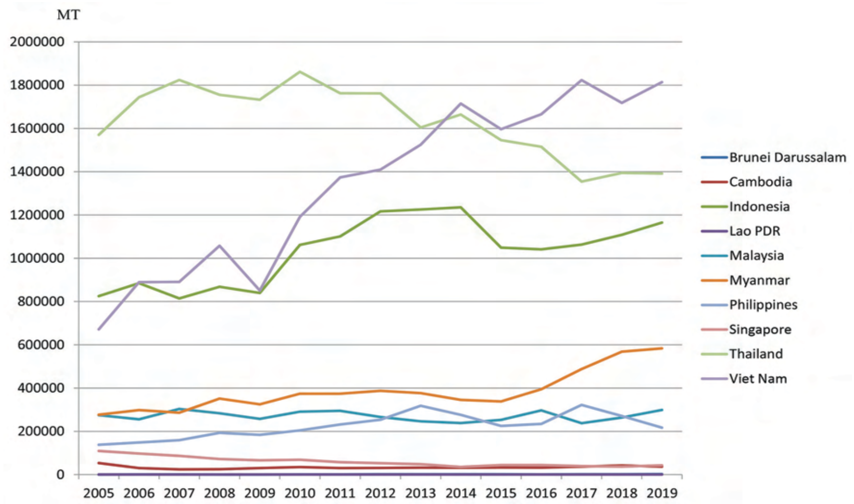
In 2019, Viet Nam was the largest exporter of fish and fishery products among the Southeast Asian countries. Its export represented about 21.90 % of the country's total fisheries production by quantity. Following Viet Nam is Thailand, its export quantity was about 55.90 % of its total fisheries production, and then Indonesia at about 5.10 % of its total fisheries production (**Figure 35**).

In 2019, Singapore reported the highest average value of its exported products at USD 7,446/mt followed by Viet Nam at USD 4,793/mt, Thailand at USD 4,214/mt, Indonesia at USD 4,070/mt, Philippines at USD 3,864/mt, Malaysia at USD 3,012/mt, Brunei Darussalam at USD 2,632/mt, Lao PDR at USD 2,500/mt, and Cambodia at USD 2,035/mt. Meanwhile, Myanmar posted the lowest average value of its exported products at USD 1,247/mt (**Table 51** and **Table 52**).

Table 51. Export of fish and fishery products of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	452	53,266	824,823	0	275,006	276,699	137,789	109,564	1,570,762	671,046	**3,919,407**
2006	736	30,120	885,031	1	255,890	298,071	148,297	96,978	1,743,974	889,266	**4,348,364**
2007	568	24,100	814,161	0	303,461	286,054	159,406	86,493	1,823,612	891,048	**4,388,903**
2008	298	25,000	868,349	1	283,494	351,652	192,982	71,721	1,755,255	1,057,399	**4,606,151**
2009	379	30,000	839,803	2	257,413	324,710	183,801	66,030	1,732,874	850,596	**4,285,608**
2010	535	35,043	1,061,945	1	290,662	374,187	204,375	68,667	1,862,012	1,191,367	**5,088,794**
2011	730	30,000	1,100,869	0	295,022	373,898	231,711	57,363	1,762,955	1,373,363	**5,225,911**
2012	1271	31,025	1,216,681	119	266,469	387,371	253,838	52,931	1,762,131	1,409,253	**5,381,089**
2013	1497	32,000	1,225,276	43	246,146	376,848	317,973	48,189	1,604,445	1,524,257	**5,376,674**
2014	1724	31,684	1,235,452	130	238,458	345,247	276,455	35,558	1,664,372	1,714,701	**5,543,781**
2015	1540	32,664	1,049,218	52	252,748	338,284	225,190	44,219	1,545,968	1,596,160	**5,086,043**
2016	892	32,201	1,041,066	16	296,626	394,397	234,418	43,757	1,515,437	1,665,798	**5,224,608**
2017	1,299	37,007	1,062,697	9	237,516	487,886	321,989	39,738	1,354,237	1,823,542	**5,365,920**
2018	1,505	41,969	1,108,207	6	263,616	568,224	270,879	36,584	1,394,091	1,717,841	**5,402,922**
2019	2,345	36,957	1,164,572	0.4	298,955	583,675	216,885	42,439	1,391,701	1,814,198	**5,551,727**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*



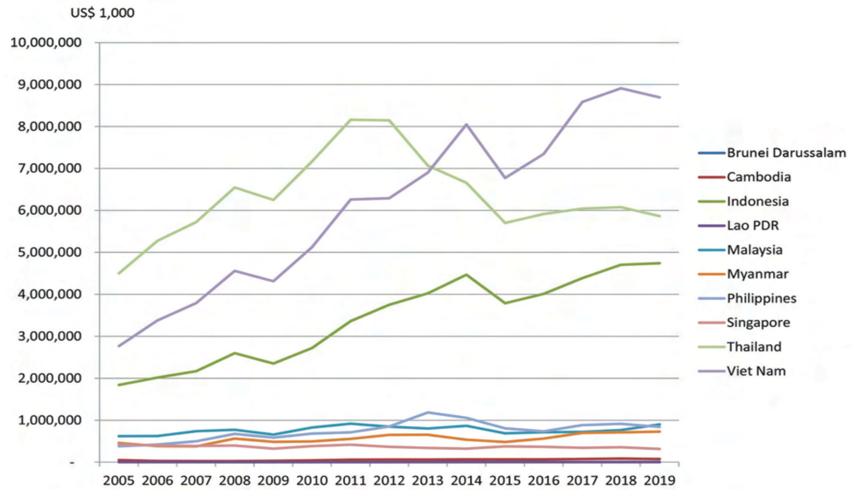


Figure 34. Trend of export of fish and fishery products by the Southeast Asian countries, quantity in mt *(above)* and value in USD thousand *(below)*

From 2005 to 2019, fish remained the most important exported fishery commodity with its fresh, chilled or frozen forms contributing the highest export. Crustaceans and mollusks were the second largest exported fishery commodity with their live, fresh, chilled forms generating high export, and the export of aquatic plants had been rapidly increasing during the past 15 years (**Table 53** and **Figure 36**). In 2019, fish was reported as the highest

Table 52. Export of fish and fishery products of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	3,053	48,551	1,841,643	17	619,653	456,919	380,094	427,544	4,502,821	2,765,366	**11,045,661**
2006	5,305	26,835	2,017,273	3	624,015	382,951	419,552	396,388	5,275,349	3,379,955	**12,527,626**
2007	5,038	23,285	2,167,839	3	738,535	376,315	499,539	385,455	5,721,525	3,790,167	**13,707,701**
2008	2,477	24,679	2,598,922	6	770,273	560,568	672,813	398,016	6,547,742	4,559,252	**16,134,748**
2009	1,613	30,362	2,350,376	7	657,479	483,230	585,044	321,098	6,248,891	4,311,738	**14,989,838**
2010	1,797	40,011	2,718,099	9	827,565	495,454	680,905	384,518	7,166,020	5,122,710	**17,437,088**
2011	1,701	60,000	3,360,923	0	916,456	555,515	711,155	416,370	8,159,613	6,259,788	**20,441,521**
2012	2,435	61,020	3,752,294	247	846,169	651,129	850,344	367,196	8,144,920	6,291,141	**20,966,895**
2013	4,311	62,500	4,025,024	107	801,685	652,840	1,185,788	339,621	7,067,700	6,900,612	**21,040,188**
2014	4,146	63,900	4,467,564	355	866,068	536,255	1,054,800	323,114	6,657,459	8,046,560	**22,020,221**
2015	3,342	66,046	3,788,795	138	688,356	482,237	805,286	376,654	5,701,788	6,774,148	**18,686,790**
2016	3,057	65,442	4,009,356	73	712,732	561,826	735,786	365,690	5,914,988	7,344,113	**19,713,063**
2017	5,819	75,361	4,386,795	45	720,688	696,302	883,537	342,992	6,041,469	8,586,492	**21,739,500**
2018	4,169	85,306	4,705,215	22	764,999	711,717	912,387	357,504	6,077,436	8,911,638	**22,530,393**
2019	6,172	75,192	4,740,035	1	900,446	728,080	838,146	316,012	5,864,824	8,694,596	**22,163,504**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

Table 53. Fish and fishery products exported by Southeast Asia from 2005 to 2019 by FAO major group, quantity (mt)

Year	Total	Major group of species								
		Fish				Crustaceans and mollusks			Aquatic plants	Others
		Total	Fresh ,chilled, or frozen	Dried, salted, and smoked	Prepared or preserved	Total	Live, fresh, chilled	Prepared or preserved		
2005	3,919,407	2,402,471	1,450,922	124,968	826,581	1,279,458	1,042,957	236,501	97,119	140,359
2006	4,348,364	2,649,362	1,623,658	142,659	883,045	1,390,211	1,093,956	296,255	122,207	186,584
2007	4,388,903	2,641,577	1,607,483	139,474	894,620	1,419,067	1,115,866	303,201	110,338	217,921
2008	4,606,151	2,963,573	1,863,329	121,924	978,320	1,378,058	1,061,544	316,514	118,055	146,465
2009	4,285,608	2,725,780	1,604,633	122,923	998,224	1,300,918	965,850	335,068	108,504	150,406
2010	5,088,794	3,175,302	2,014,480	145,185	1,015,637	1,458,696	1,097,872	360,824	144,697	310,099
2011	5,225,911	3,205,151	2,000,322	138,255	1,066,574	1,560,148	1,166,893	393,255	191,153	269,459
2012	5,381,089	3,514,471	2,179,460	150,312	1,184,699	1,361,641	1,006,847	354,794	198,219	306,758
2013	5,376,674	3,477,299	2,125,663	143,622	1,208,014	1,294,257	955,476	338,781	217,046	388,072
2014	5,543,781	3,449,504	2,114,137	139,203	1,196,164	1,404,974	1,049,086	355,888	222,375	466,928
2015	5,086,043	3,154,609	1,895,588	127,587	1,131,434	1,265,618	928,639	336,979	229,436	436,380
2016	5,224,608	3,214,862	1,974,944	133,772	1,106,146	1,325,904	988,159	337,745	198,284	485,558
2017	5,365,920	3,365,214	2,097,838	129,653	1,137,723	1,420,147	1,083,491	336,656	199,731	380,828
2018	5,402,922	3,451,815	2,155,967	128,434	1,167,414	1,334,055	1,012,471	321,584	214,172	402,880
2019	5,551,727	3,509,370	2,201,222	130,359	1,177,789	1,402,569	1,070,565	332,004	221,397	418,391

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

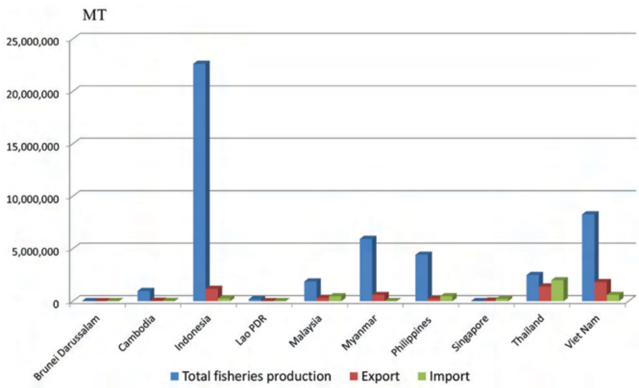


Figure 35. Trade of fish and fishery products in the Southeast Asian countries by quantity (mt)

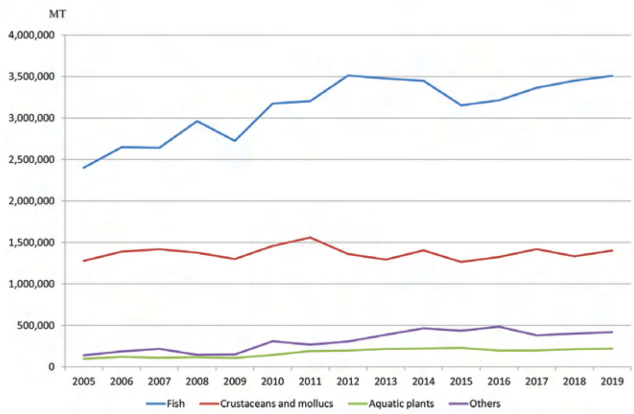


Figure 36. Export of fish and fishery products from Southeast Asia (2005 to 2019) by quantity (mt)

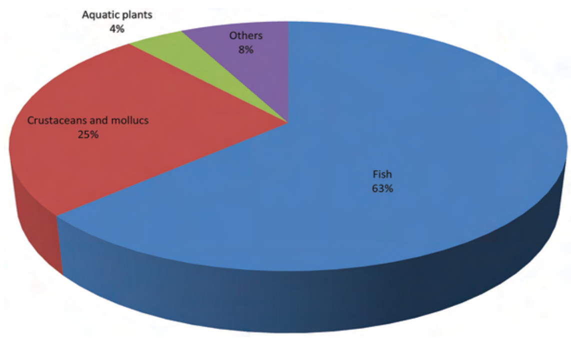


Figure 37. Percent share of major groups species exported by Southeast Asia in 2019

exported commodity accounting for 63.00 % of the total export of fish and fishery products of the region, in terms of quantity, followed by crustaceans and mollusks contributing 25.00 %, and aquatic plants contributing 4.00 % (**Figure 37**). In the case of Viet Nam, which is the largest exporter in the region, catfish in fillets and frozen forms, was the highest exported commodity contributing about 541,560 mt, followed by skipjack prepared and preserved in Thailand contributing about 427,389 mt.

As the largest importing country in Southeast Asia, Thailand posted a negative trade balance of 596,442 mt in 2019. Meanwhile, Viet Nam posted positive trade balance of about 1,221,989 mt, while the Philippines posted a negative trade balance at 247,803 mt, and Malaysia also posted a negative trade balance at 158,409 mt. Indonesia posted a positive trade balance at 915,611 mt, and Cambodia with a positive trade balance at 16,665 mt. Brunei Darussalam

Table 54. Trade of fish and fishery products of the Southeast Asian countries in 2019 by quantity (mt)

	Total fisheries production	Trade of fish and fishery products		Trade balance (Export-import)
		Export	Import	
Brunei Darussalam	14,658	2,345	13,030	-10,685
Cambodia	969,098	36,957	20,292	16,665
Indonesia	22,614,595	1,164,572	248,961	915,611
Lao PDR	183,900	0.4	5,878	-5,878
Malaysia	1,872,797	298,955	457,364	-158,409
Myanmar	5,931,815	583,675	13,847	569,828
Philippines	4,413,129	216,885	464,688	-247,803
Singapore	7,249	42,439	204,748	-162,309
Thailand	2,488,833	1,391,701	1,988,143	-596,442
Viet Nam	8,270,200	1,814,198	592,209	1,221,989
Total	**46,766,274**	**5,551,727**	**4,009,160**	**1,542,567**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

Table 55. Import of fish and fishery products of the Southeast Asian countries from 2005 to 2019 by quantity (mt)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	7,215	6,664	128,431	1,454	400,766	1,826	180,945	253,553	1,445,348	164,388	**2,590,590**
2006	7,694	3,731	165,195	1,206	440,135	1,354	170,834	244,644	1,470,636	200,356	**2,705,785**
2007	6,617	3,543	126,281	1,175	440,270	1,668	193,578	239,688	1,407,414	228,375	**2,648,609**
2008	6,505	2,942	198,980	1,251	386,051	2,400	200,331	225,704	1,533,690	253,680	**2,811,534**
2009	5,848	5,767	252,976	872	411,544	2,827	273,623	221,987	1,585,850	229,727	**2,991,021**
2010	7,336	4,970	301,569	521	424,032	4,840	195,037	223,131	1,586,764	308,368	**3,056,568**
2011	7,729	6,755	355,684	608	365,460	6,102	203,682	223,138	1,668,020	332,027	**3,169,205**
2012	10,037	10,776	270,450	468	417,029	6,592	268,477	215,681	1,662,766	330,521	**3,192,797**
2013	14,116	12,564	266,027	363	463,242	5,414	257,910	209,369	1,667,820	339,272	**3,236,097**
2014	12,310	26,766	238,428	520	469,716	7,254	302,917	207,398	1,624,879	413,326	**3,303,514**
2015	9,510	19,890	212,981	804	424,316	6,009	384,843	207,868	1,620,659	431,110	**3,317,990**
2016	10,565	24,482	206,729	570	408,251	6,542	417,022	209,231	1,868,170	478,819	**3,630,381**
2017	10,797	24,118	295,386	5,297	425,901	5,410	493,535	199,087	1,924,537	626,474	**4,010,542**
2018	12,041	18,937	273,093	5,465	431,308	7,907	473,963	198,175	2,129,606	546,114	**4,096,609**
2019	13,030	20,292	248,961	5,878	457,364	13,847	464,688	204,748	1,988,143	592,209	**4,009,160**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*

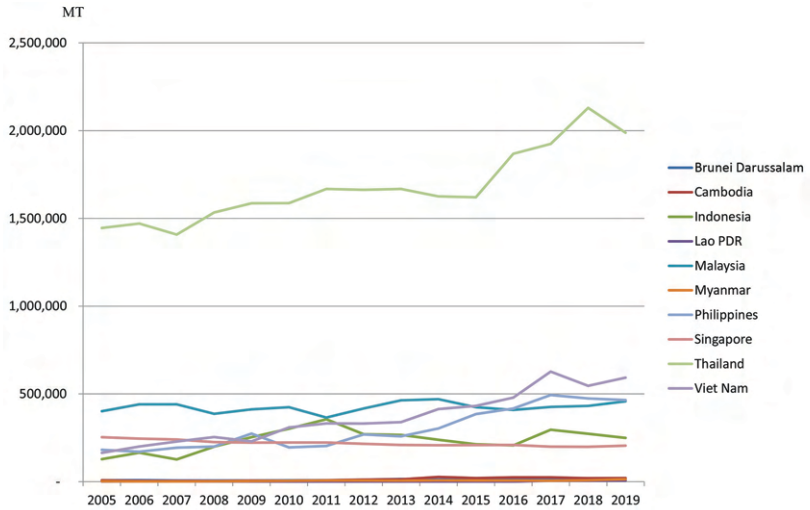
with the least fisheries production posted a negative trade balance of 10,685 mt and Singapore also with a negative trade balance of 162,309 mt (**Table 54**).

The quantity of fisheries import of the Southeast Asian region had been increasing from 2005 to 2019 at the rate about 101,326 mt/year or 3.20 % annually (**Table 55** and **Figure 38**), posting a trade balance of about 1,542,567 mt in 2019 (**Table 53**). The value of the fishery products imported by the Southeast Asian countries increased by about USD 415,514/year or 8.00 % annually (**Table 56** and **Figure 38**). In terms of the average value of imported products, Singapore posted the highest value at USD 5,504/mt, followed by Brunei Darussalam at USD 3,918/mt, Viet Nam at USD 3,569/mt, and Malaysia at USD 2,524/mt. While Thailand as the largest importer among the Southeast Asian countries, posted the value of its imports at USD 1,898/mt, and Myanmar's import was the lowest at about USD 1,162/mt.

Table 56. Import of fish and fishery products of the Southeast Asian countries from 2005 to 2019 by value (USD thousand)

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
2005	17,316	9,602	106,330	2,001	530,863	3,186	103,680	776,389	1,457,936	276,576	**3,283,879**
2006	25,813	4,206	142,742	1,599	580,337	2,533	103,126	757,944	1,573,958	302,425	**3,494,683**
2007	20,987	3,626	118,966	1,735	644,881	2,914	132,922	818,704	1,750,024	373,470	**3,868,229**
2008	20,054	2,973	202,029	2,499	594,255	5,189	176,815	914,863	2,447,759	461,125	**4,827,561**
2009	20,374	5,163	234,531	1,611	683,818	6,376	203,336	824,248	2,026,369	433,337	**4,439,163**
2010	27,641	4,573	326,108	1,519	790,291	10,996	148,552	971,041	2,195,932	529,849	**5,006,502**
2011	32,700	6,250	411,209	2,072	998,720	13,666	193,314	1,162,463	2,788,193	726,215	**6,334,802**
2012	42,875	12,739	358,946	1,451	1,071,037	13,505	263,038	1,074,992	3,205,597	837,929	**6,882,109**
2013	51,417	15,436	379,626	1,634	1,070,213	10,944	278,737	1,073,334	3,238,637	916,980	**7,036,958**
2014	46,034	27,491	355,529	2,347	1,134,550	15,187	266,158	1,109,339	2,840,281	1,289,819	**7,086,735**
2015	40,776	17,363	318,615	3,811	948,710	10,563	369,746	1,093,000	2,616,038	1,300,954	**6,719,576**
2016	39,853	20,571	365,836	2,042	955,990	9,147	398,264	1,129,644	3,179,244	1,366,351	**7,466,942**
2017	43,624	28,748	398,007	7,846	1,003,884	9,724	585,047	1,096,665	3,669,269	1,765,991	**8,608,805**
2018	49,136	26,991	423,664	7,655	1,066,537	11,704	605,809	1,162,525	4,068,941	1,859,331	**9,282,293**
2019	51,057	31,213	421,635	10,208	1,154,374	16,097	626,626	1,126,942	3,774,411	1,888,515	**9,101,078**

Source: *FAO Fishery and Aquaculture Information and Statistics Service*



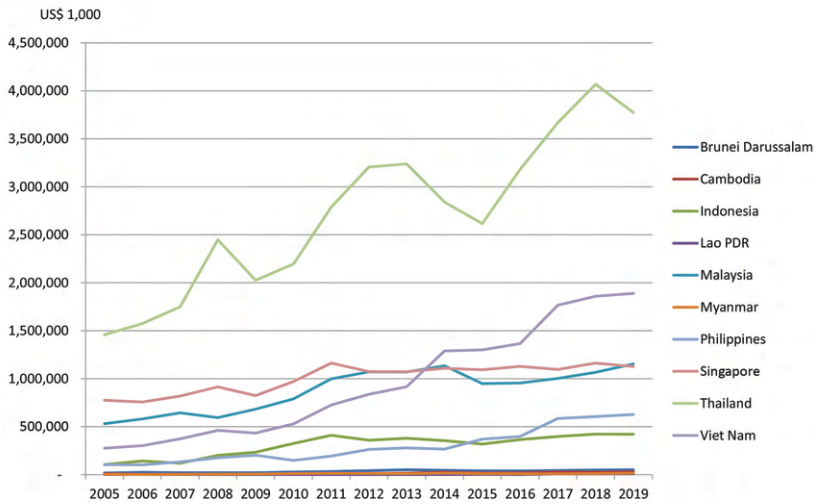


Figure 38. Trend of fisheries import by the Southeast Asian countries in 2005-2019, quantity in mt *(above)* and value in USD thousand *(below)*

PART II
Issues and Challenges in Sustainable Development of Fisheries and Aquaculture of the Southeast Asian Region

1. Marine Fishery Resources

1.1 Status, Issues, and Concerns

1.1.1 Tuna and Tuna-like Species

Tunas and tuna-like species are categorized into three groups, *i.e.* neritic tunas, oceanic tunas, and tuna-like species. Neritic tunas are likely found in the seas of Southeast Asia particularly in the Andaman Sea (AS) and South China Sea (SCS), while oceanic tunas migrate over a thousand kilometers. **Figure 39** shows the production of tuna and tuna-like species of Southeast Asia, from Fishing Area 57 (Indian Ocean, Eastern) and Fishing Area 71 (Pacific, Western Central) during 2008–2019. Based on the information provided by the ASEAN Member States (AMSs), neritic tunas include frigate tuna (*Auxis thazard*), bullet tuna (*Auxis rochei*), kawakawa (*Euthynnus affinis*), longtail tuna (*Thunnus tonggol*); oceanic tunas include skipjack tuna (*Katsuwonus pelamis*), southern bluefin tuna (*Thunnus maccoyii*), yellowfin tuna (*Thunnus albacares*), albacore tuna (*Thunnus alalunga*), and bigeye tuna (*Thunnus obesus*); and tuna-like species include narrow-barred Spanish mackerel (*Scomberomorus commerson*), Indo-Pacific king mackerel (*Scomberomorus guttatus*), seerfishes *nei* (*Scomberomorus* spp.), and tuna-like fishes *nei* (Scombroidei). For Fishing Area 57, the average production during the twelve-year period from 2008 to 2019, was about 0.41 million metric tonnes (mt) per year with the lowest at 0.32 mt in 2017 and highest at 0.54 mt in 2010. For Fishing Area 71, the average production was about 1.64 mt per year with the lowest at 1.28 mt in 2010 and highest at 2.05 mt in 2019. Overall, the production of Fishing Area 71 was almost four times higher than that of Fishing Area 57.

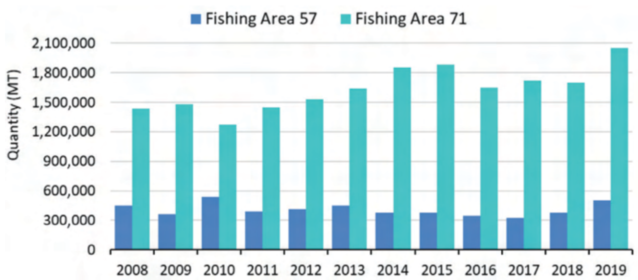


Figure 39. Production of tunas and tuna-like species of Southeast Asia between 2008 and 2019 from Fishing Area 57 and Fishing Area 71 by quantity (mt)

Source: *SEAFDEC, 2022*

RPOA-Neritic Tunas

For the AMSs, neritic tunas are vital fisheries commodities providing food for domestic consumption, generating job opportunities, and bringing about high economic revenues for many countries through their export endeavors since neritic tunas offer high prices for the fish processing industries. However, being concerned that the insufficiency of data and information as well as the unclear stock status of neritic tunas in the Southeast Asian region could possibly lead to the overexploitation of the resources, SEAFDEC/MFRDMD in collaboration with SEAFDEC Secretariat and SEAFDEC/TD organized series of consultations with the AMSs to examine the issues related to the stock status of neritic tunas in Southeast Asia. This led to the development of the Regional Plan of Action on Sustainable Utilization of Neritic Tunas in the ASEAN Region (RPOA-Neritic Tunas) by the AMSs in collaboration with SEAFDEC, and subsequent endorsement of the RPOA-Neritic Tunas during the Forty-seventh Meeting of the SEAFDEC Council in 2015 and the 23rd Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi). The main features of the RPOA-Neritic Tunas are shown in **Box 1**.

Box 1. Main features of the RPOA-Neritic Tunas

Objectives	Issues	Action plan
Determining available data and information, improving data collection, and developing the key indicator	Insufficient data and information	Improve data collection and analysis for neritic tunas
Improving sustainable fisheries management	Inadequate understanding of management and conservation measures	Enhance understanding of management and conservation measures of neritic tunas
Improving compliance to rules and regulations and access to markets	Illegal, unreported and unregulated (IUU) fishing	Combat IUU fishing occurring in the Southeast Asian region
Enhancing regional cooperation	Insufficient information on status and trends of neritic tunas at sub-regional level	Assessment of the status and trends of neritic tunas at sub-regional level

One of the key actions of the RPOA-Neritic Tunas requires the need to enhance regional cooperation for the development of sub-regional Action Plans for neritic tuna fisheries, as well as to support the assessment of the stock status and trends of neritic tuna at the regional level. As also called for in the RPOA-Neritic Tunas, the Scientific Working Group on Neritic Tuna Assessment (SWG-Neritic Tuna) was established which convenes their meetings annually or biannually to continue discussions on the stock status of neritic tunas in the Southeast Asian region.

Stock Assessment of Neritic Tunas

The second series of stock assessments of neritic tunas was conducted by SEAFDEC in cooperation with the Member Countries in February 2020, focusing on kawakawa (*Euthynnus affinis*) and longtail tuna (*Thunnus tonggol*), with the conjecture that these species inhabited Fishing Area 57 and Fishing Area 71. The results of the second assessment were compared to the previous assessment in 2016 which was conducted using A Stock-Production Model Incorporating Covariates (ASPIC), Kobe Plot I-II, and risk assessment (MFRDMD, 2021).

- *Kawakawa*

Indian Ocean

In the Indian Ocean, the stock status of kawakawa had changed from green zone (safe) in 2014 to red zone (unsafe) in 2018, as shown in **Figure 40**. Although kawakawa stock was in a safe condition in 2014, it was recommended that fishing pressure and catch should not exceed the 2014 level, since the 2014 Kobe plot already exhibited 53 % of uncertainties (red, orange, and yellow zones) with only 47 % in the green zone. Meanwhile, the Kobe plot in 2018 revealed a high probability that the stock status of kawakawa is 76 % in the red zone, indicating that serious overfished and overexploitation situations had occurred. Therefore, as shown in **Figure 41**, the current catch of 62,000 mt should be reduced by 60 % (25,000 mt) to avoid the 50 % risks that the total biomass (TB) and fishing mortality (F) would violate their MSY levels.

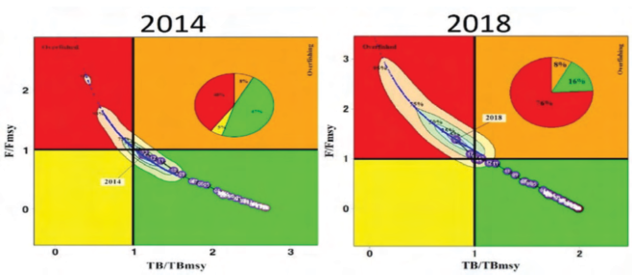


Figure 40. Status of kawakawa in the Indian Ocean in 2014 and 2018 based on Kobe Plot

11 catch scenarios (tons)	0% (-100%)	20% (-80%)	40% (-60%)	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	91% (-9%) MSY level	100% Current catch (*)	110%	120%
	0	12,312	24,624	36,936	43,092	49,248	55,404	55,850	61,560	67,716	73,872
TB2021 < TBmsy	56	58	61	67	70	73	76	76	80	84	87
F2021 > Fmsy	0	48	51	56	60	66	75	76	86	98	100
TB2028 < TBmsy	41	48	50	54	57	61	71	72	84	95	100
F2028 > Fmsy	0	48	50	54	57	60	70	72	88	100	100

(*)The current catch levelis the average catch in 3 recent years(2016–2018).

Figure 41. Risk assessment of kawakawa in the Indian Ocean

Pacific Ocean

As shown in **Figure 42**, the stock status of kawakawa in the Pacific Ocean remains in a safe situation, as it is in the green zone. The 2013 Kobe plot showed that there was no probability for uncertainties to fall under the unsafe zone (red, orange, and yellow zones). Thus, it was then recommended that the current catch and fishing pressure (F-fishing mortality levels) should be maintained under their MSY levels, *i.e.* at 185,000 mt and 0.43, respectively. Moreover, since the 2018 Kobe plot also revealed that the stock status of kawakawa in the Pacific Ocean side is still in the green zone (safe) with a probability of 84 %, this indicates that kawakawa is not exploited. However, it is still necessary that the current catch of 205,000 mt should be reduced by 20 % (164,000 mt) to avoid a 50 % risk of the TB and F violating their MSY levels as indicated in **Figure 43**. Specifically, even if the stock status is in the green zone or the 2018 current catch is higher than the MSY level, the catch should still be reduced in order that the stock status remains in a safe condition.

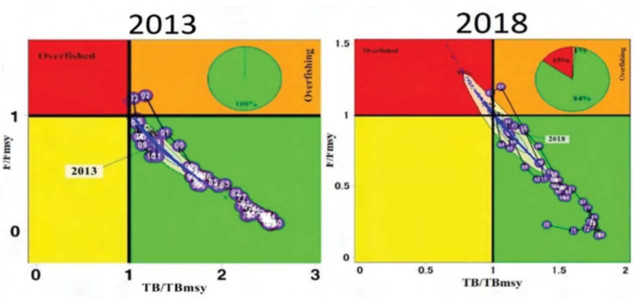


Figure 42. Status of kawakawa in the Pacific Ocean in 2013 and 2018 based on Kobe Plot

10 catch scenarios (tons)	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	98% (-2%) MSY level	100% Current catch (*)	110%	120%	130%	140%
	122,743	143,200	163,658	184,115	200,600	204,572	225,029	245,486	265,944	286,401
TB2021 < TBmsy	62	68	72	76	79	80	83	87	90	93
F2021 > Fmsy	7	18	40	66	78	82	94	98	100	100
TB2028 < TBmsy	35	40	49	66	80	84	95	98	100	100
F2028 > Fmsy	7	14	27	56	80	86	98	100	100	100

(*)The current catch levels the average catch in 3 recent years(2016–2018).

Figure 43. Risk assessment of kawakawa in the Pacific Ocean

- *Longtail tuna*

Indian Ocean

For longtail tuna in the Indian Ocean, the stock status seemed to have recovered from being in the red zone in 2014 to be in the green zone in 2018 as shown in **Figure 44**. In 2014, its Kobe plot showed very high uncertainties of being in the red, orange, and yellow zones with 78 % probability, indicating that the stock was already overfished, yet fishing activities continued. Thus, it was recommended to reduce the catch and fishing mortality (F) to their MSY levels at 37,000 mt and 0.51, respectively. However, the 2018 Kobe plot revealed that the stock status of longtail tuna in the Indian Ocean is already in the green zone (safe) with 63 % probability. It is therefore suggested that the current catch in 2018 at 124,000 mt could be increased to the MSY level of 167,000 mt, considering that the probability of the total biomass and fishing mortality violating their MSY levels is less than 50 % (**Figure 45**).

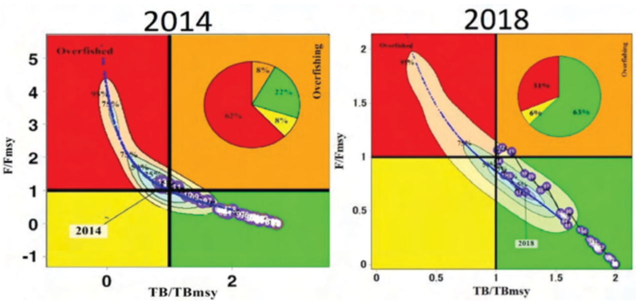


Figure 44. Status of longtail tuna in the Indian Ocean in 2014 and 2018 based on Kobe Plot

	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	100%	110%	120%	120%	130%	140%
					Current catch (*)		MSY level			
10 catch scenarios (tons)	19,993	23,325	26,658	29,990	33,322	36,654	40,130	39,986	43,319	46,651
TB2021 < TBmsy	27	28	29	30	32	34	36	36	38	40
F2021 > Fmsy	18	20	22	23	26	30	37	37	46	59
TB2028 < TBmsy	18	19	21	23	25	32	44	44	62	73
F2028 > Fmsy	17	18	20	22	24	30	44	44	66	82

(*)The current catch levels the average catch in 3 recent years(2016–2018).

Figure 45. Risk assessment of longtail tuna in the Indian Ocean

Pacific Ocean

In the Pacific Ocean, the stock status of longtail tuna in 2013 was in the green zone (safe) as shown in **Figure 46**, indicating zero probability of uncertainties to be in red, orange, and yellow zones. It was then suggested to increase the catch and fishing pressure but should be less than their MSY and Fmsy levels, that is at 200,000 mt and 1.07, respectively. Since the 2018 Kobe plot also showed that the stock status of longtail tuna remained healthy with a 100 % probability of being in the green zone (safe), it is therefore suggested that the current catch at 124,000 mt could be increased to the MSY level of 167,000 mt, because the probability of total biomass and fishing mortality violating their MSY levels is less than 50 % as shown in **Figure 47**.

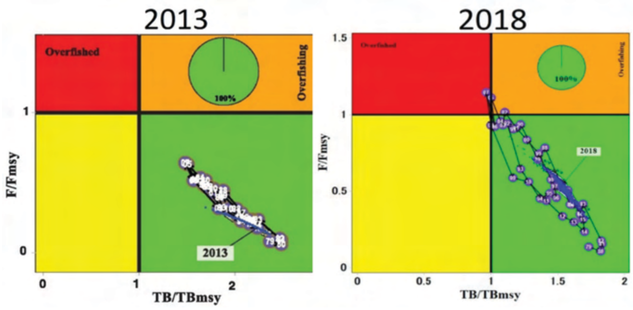


Figure 46. Status of longtail in the Pacific Ocean in 2013 and 2018 based on Kobe Plot

	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	100%	110%	120%	130%	135%	140%	150%	200%	250%	300%
					Current catch (*)				MSY level					
14 catch scenarios (tons)	74,259	86,636	99,012	111,388	123,765	136,142	148,518	160,894	166,800	173,271	185,648	247,530	309,412	371,295
TB2021 < TBmsy	21	22	24	26	27	29	32	34	35	35	38	51	63	75
F2021 > Fmsy	0	0	0	4	9	16	24	33	38	42	54	90	99	100
TB2028 < TBmsy	18	20	22	24	27	32	37	46	54	63	78	99	100	100
F2028 > Fmsy	0	0	0	4	9	17	26	43	56	68	86	100	100	100

(*)The current catch levels the average catch in 3 recent years(2016–2018).

Figure 47. Risk Assessment of longtail tuna in the Pacific Ocean 2018

Stock Assessment of Tuna-like Species

In 2018, the SEAFDEC Secretariat in collaboration with SEAFDEC/TD organized the "Practical Workshop on Stock Assessments of Indo-Pacific King Mackerel and Narrow-barred Spanish Mackerel in the Southeast Asian Waters" at SEAFDEC/TD in Samut Prakan, Thailand, which was attended by representatives from the AMSs. The training course aimed to enhance the knowledge of the participants on the stock and risk assessments of the Indo-Pacific king mackerel (*Scomberomorus guttatus*) and narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the waters of Southeast Asia (SEAFDEC, 2019).

- *Narrow-barred Spanish mackerel*

Indian Ocean

Results of the assessments showed that the stock status of the narrow-barred Spanish mackerel in the Indian Ocean is in the green zone but very close to the MSY (TB and F) while the probability of getting into the red zone is 71 % (**Figure 48**). Thus, the stock is still not safe even if the stock status of 2016 is in the green zone. Based on the results of the risk assessments (**Figure 49**), the current catch level should be reduced by 20 % (43,300 mt), so the probabilities of violating the MSY (TB and F) would be less than 50 % in 10 years (2026).

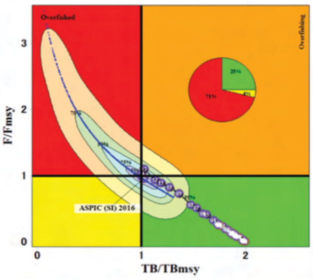


Figure 48. Status of narrow-barred Spanish mackerel in the Indian Ocean in 2016 based on Kobe Plot

	0%	20%	40%	60%	70%	80%	90%	100% Current Catch (*)	102% MSY level	110%	120%	130%
10 catch scenarios (tons)	0	10,818	21,636	32,454	37,863	43,272	48,681	54,090	55,170	59,499	64.908	70,317
TB2019< TBmsy	33	38	42	27	50	54	57	61	62	67	71	76
F2019 > FMSY	0	27	29	35	39	43	51	60	63	74	91	100
TB2026 < Tbmsy	13	27	29	33	36	41	46	59	63	80	95	100
F2026 > FMSY	0	27	29	33	36	40	46	59	64	84	100	100

(*) The current catch levels the average catch in 3 recent year (2014-2016)

Figure 49. Risk assessment of narrow-barred Spanish mackerel in the Indian Ocean

Pacific Ocean

The resultant Kobe plot (**Figure 50**) indicates that the stock status in 2016 was in the red zone (serious situation), and based on the risk assessments, the current catch should be reduced by at least 80 % (32,800 mt) to secure the MSY levels for both TB and F at the probability of 50 % or more in 3–10 years. However, even with the 80 % reduction, the probability of violating the MSY (TB and F) would still be more than 50 %. As the 80 % reduction is too much and too critical for the fishing and processing industries, the SEAFDEC-organized workshop suggested that step-wise reductions could be adopted, *i.e.* for example, by 40 % reduction (98,300 mt) as the first step for a few years, afterward, reduction levels would be adjusted depending on results of the next stock and risk assessments (**Figure 51**).

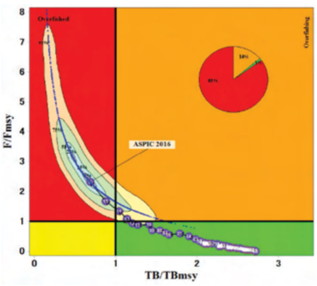


Figure 50. Status of narrow-barred Spanish mackerel in the Pacific Ocean in 2016 based on Kobe Plot

	0%	20%	40%	60%	70%	79% MSY level	80%	90%	100% Current Catch (*)	110%
10 catch scenarios (tons)	0	32,758	65,516	98,274	114,653	129,200	131,032	147,411	163,790	180,169
TB2019< TBmsy	81	86	90	94	96	96	97	98	99	100
F2019 > FMSY	0	68	75	86	91	96	96	100	100	100
TB2026 < Tbmsy	2	67	72	80	86	91	91	97	100	100
F2026 > FMSY	0	67	72	80	56	91	91	98	100	100

(*) The current catch levels the average catch in 3 recent year (2014-2016)

Figure 51. Risk assessment of narrow-barred Spanish mackerel in the Pacific Ocean

- *Indo-Pacific king mackerel*

Indian Ocean

The stock status of the Indo-Pacific king mackerel in the Indian Ocean (**Figure 52**) is in the green zone and is in a very healthy situation as the TB and F in 2016 are far away from their MSY levels and the probability of uncertainties in the green zone is 97 %. Moreover, as shown in **Figure 53**, it is suggested that the current catch level could be increased by 15 % to the MSY level (21,500 mt), for even with the increase to MSY levels, the probabilities violating the MSY (TB and F) would be less than 50 % in 10 years (2026).

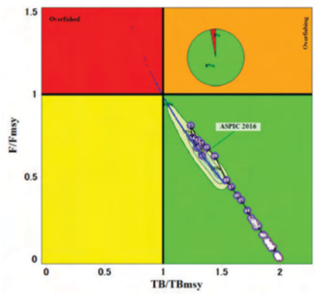


Figure 52. Status of Indo-Pacific king mackerel in the Indian Ocean in 2016 based on Kobe Plot

	60%	70%	80%	90%	100% Current Catch (*)	110%	115% MSY level	120%	130%	140%
10 catch scenarios (tons)	11,231	13,103	14,975	16,847	18,719	20,591	21,500	22,463	24,335	26,207
TB2019< TBmsy	1	2	3	5	8	12	14	16	23	30
F2019 > FMSY	0	0	0	0	3	11	20	29	63	97
TB2026 < Tbmsy	0	0	0	1	8	34	52	70	96	100
F2026 > FMSY	0	0	0	0	5	31	53	76	100	100

(*) The current catch levels the average catch in 3 recent year (2014-2016)

Figure 53. Risk assessment of Indo-Pacific king mackerel in the Indian Ocean

Pacific Ocean

As shown in **Figure 54**, the stock status of Indo-Pacific king mackerel in the Pacific Ocean indicates that the stock status in 2016 is in the green zone (TB/TBmsy = 1.45 and F/Fmsy = 0.63). This suggests that the stock status is in a very safe situation as TB and F in 2016 are far away from their MSY levels. Based on the risk assessment (**Figure 55**), it is suggested that the current catch level could be increased by 31 % to the MSY level (15,100 mt). Even with increases

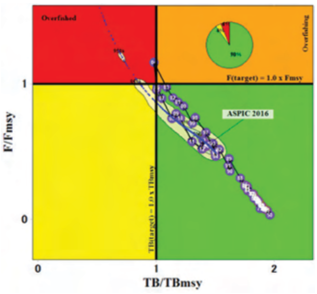


Figure 54. Status of Indo-Pacific king mackerel in the Pacific Ocean in 2016 based on Kobe Plot

	60%	70%	80%	90%	100% Current Catch (*)	110%	120%	130%	131% MSY level	140%
10 catch scenarios (tons)	6,955	8,114	9,274	10,433	11,592	12,751	13,910	15,070	15,130	16,229
TB2019< TBmsy	5	5	6	6	6	7	8	8	8	9
F2019 > FMSY	2	2	2	3	4	5	6	8	9	16
TB2026 < Tbmsy	2	2	2	2	3	5	7	33	38	87
F2026 > FMSY	2	2	2	2	3	4	6	36	42	97

(*) The current catch levels the average catch in 3 recent year (2014-2016)

Figure 55. Risk assessment of Indo-Pacific king mackerel in the Pacific Ocean

in the MSY levels, the probability of violating the MSY (TB and F) would be less than 40 % in 10 years (2026).

Life History of Tunas

In 2020, a study of the life history of kawakawa (*Euthynnus affinis*) was conducted using the hard part analysis method by estimating the annual ring or age using the otolith. In estimating the fish age, the otolith's growth is related to the fish size and generally follows an allometric increase in dimensions. The results of using the otolith in determining the age of *E. affinis* indicated that the age of kawakawa having 240–640 mm fork length could be 1–7 years old.

Genetic Population Study

From 2016 to 2018, SEAFDEC/MFRDMD with funding support from the SEAFDEC-Sweden Project carried out the "Population Study of *Thunnus tonggol* (Bleeker, 1851) in the Southeast Asian Region," using full-length sequences of the mitochondrial displacement loop (D-loop) and cytochrome b (*Cyt b*). A total of 548 samples from 12 sites in the Southeast Asian region (**Figure 56**) was collected from May 2017 to July 2018. The pairwise FST comparison analysis among the sampling sites showed no significant difference for D-loop, but for *Cyt b*, Banda Aceh and Pemangkat in Indonesia showed significant differences from the other sites. The phylogenetic reconstruction defines the haplotypes into genetically homogenous gene trees among all sampling sites based on the homogeneous, single-clade gene trees and complex reticulation of the median-joining network.

Furthermore, the high contribution of within-localities variation through AMOVA firmly proposed that *T. tonggol* in the Southeast Asian region are genetically identical with ambiguous genetic structure, which is likely due to high genetic connectivity. Although the haplotype diversity is high, there is low nucleotide diversity among *T. tonggol* populations in the studied populations, suggesting population expansion of *T. tonggol* in the region due to the lack of geographical structure inferred by both markers.

Using the same samples, the other study in 2019 "Genotyping of microsatellite markers to study the genetic structure of the longtail tuna, *T. tonggol* in the Southeast Asian region," which was funded by the Department of Fisheries Malaysia, had supported the previous study of SEAFDEC/MFRDMD which found that *T. tonggol* in the region is a single stock. Besides, other studies have also reported that in their studied locations, there exists a single stock structure for the same species (Kunal *et al.*, 2014; Willette *et al.*, 2016; Kasim *et al.*, 2020).

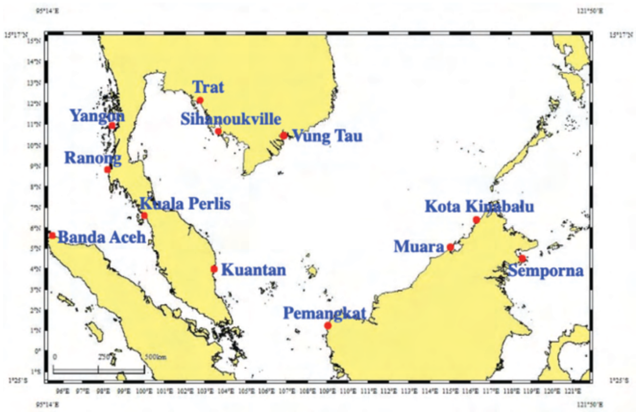


Figure 56. Sampling locations for the genetic study on *Thunnus tonggol* in the Southeast Asian region

Issues and Challenges

The optimum catch level (suggested total allowable catch (TAC)) for the neritic tuna species had been developed based on the results of the stock and risk assessments. However, this TAC is a reference for the SEAFDEC Member Countries, especially those that exploit the tuna resources on a large scale. Moreover, since SEAFDEC cannot provide legally binding TAC recommendations because this is beyond its scope for not being an RFMO, it could only provide recommendations, which the concerned countries and relevant agencies and organizations could consider and take a good look for the sustainability of the tuna resources in the Southeast Asian region.

It should also be noted that the optimum catch levels are not different by species, *i.e.* catch of kawakawa in the Indian Ocean (unhealthy stock) and kawakawa in the Pacific Ocean (safe but close to red zone) needs to be reduced from the current levels. In contrast, longtail tuna catch in the Pacific

Ocean and Indian Ocean could be increased. Even so, if the catch of longtail tuna (healthy stock) is increased as suggested, the stock status of kawakawa could be worse because kawakawa and longtail tuna are being exploited by multi-gears and multi-species fisheries in the same ecosystems. Thus, the increase or reduction of catch would be difficult to attain because the gears used in the fisheries could catch the other species with healthy and unhealthy stock status. Therefore, catch reduction strategies should be developed based on the species composition, stock status, fishing seasons, fishing ground, commercial values, and seasonal closures. Each Member Country should consider developing their respective strategies based on their unique situation and factors.

Way Forward

Currently, the activities carried out by the SWG-Neritic Tuna are under the JTF VI Phase 2 Project "Fisheries Management Strategies for Pelagic Fish Resources in the Southeast Asian Region" implemented by SEAFDEC/MFRDMD. The ongoing project activities include assessment of the stock status of neritic tunas, clarification of the stock structure by molecular methods (genetic study), and life history (otolith) study for neritic tunas in the region. Moreover, the following are the future endeavors of SEAFDEC in collaboration with the AMSs.

- Strengthen the cooperation and coordination with IOTC and WCPFC to avoid duplication of works
- Explore the possibility of organizing training courses on stock assessments of neritic tunas and economically important small pelagic species
- Enhance the knowledge on environmental factors that affect the abundance of neritic tunas and small pelagic species
- Continue the activities under the RPOA-Neritic Tunas focusing on longtail tuna and kawakawa, including the genetic study

1.1.2 Scads

Scads are small pelagic fishes under the family Carangidae, that often have a yellow stripe running from head to the caudal peduncle. Mainly feeding on copepods, scads also consume the larvae of pteropods, ostracods, and gastropods (Pastoral *et al*., 2000). Scads normally inhabit the warm coastal waters usually down to 20 m and are distributed around the Andaman Sea, South China Sea, East China Sea, Gulf of Tonkin, Gulf of Thailand, Strait of Malacca, and Java Sea. In the South China Sea, scads are distributed over the continental shelf but concentrated towards the coastal zone (Albert *et al*., 2003). These species are known as migrating species; thus, it is considered that the stocks are shared, especially from the Gulf of Thailand to Sunda Shelf, Straits of Malacca, Eastern South China Sea, and the Gulf of Tonkin (SEAFDEC, 2017b). Wahidah *et al*. (2013) reported that the population of Japanese scads (*Decapterus maruadsi*) in the South China Sea is partially shared with moderate genetic variation, while Noorul *et al*. (2020) found a genetic homogeneity within the Sundaland region's population (Andaman Sea and South China Sea), including the populations found in Rosario, Philippines, and Ranong, Thailand (Andaman Sea) but with different stock structures to that of the Northern Viet Nam populations (Nghe An and Cat Ba).

Although their value is less than the other pelagic species, scads are among the commercially important marine species (Abu-Talib *et al*., 2013; Ahmadi, 2020). In the region, scads are mainly caught using purse seine, especially in the Gulf of Thailand (SEAFDEC, 2014). The types of purse seine are either with the use of luring light in Thailand or fish aggregating devices (FADs) in the Philippines and East Coast of Peninsular Malaysia. Other fishing gears used include trawl net, drift net, ring net, scoop net, and hook and line. In the Southeast Asian region, the production of scads including the Indian scad (*Decapterus russelli*), scads *nei* (*Decapterus* spp.), bigeye scad (*Selar crumenophthalmus*), yellowstripe scad (*Selaroides leptolepis*), hardtail scad (*Megalaspis cordyla*), jacks, crevalles *nei* (*Caranx* spp.), and Carangids *nei* (Carangidae) in the Fishing Area 71 was more than three times higher than in Fishing Area 57 (**Figure 57**). Between 2008 and 2019, the average production was around 0.31 mt per year in Fishing Area 57 and 1.14 mt per year in Fishing Area 71.

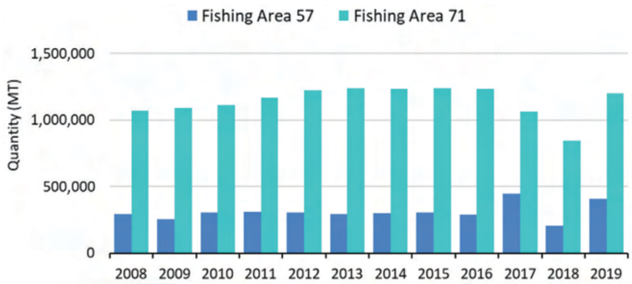


Figure 57. Production of scads of Southeast Asia between 2008 and 2019 from Fishing Area 57 and Fishing Area 71, by quantity (mt)

Source: *SEAFDEC, 2022*

Exploitation rate

The exploitation rate (E) value of more than 0.50 demonstrates that the fishery resource in such an area is exploited more than the optimum level (Gulland, 1983). In the South China Sea, the highest E value was recorded for *D. macrosoma* (0.86) and *D. maruadsi* (0.86) in the waters of Brunei Darussalam. In the Andaman Sea, the highest E value was recorded for *D. maruadsi* at 0.71 in the Andaman Sea coast of Thailand (**Table 57**).

Issues and Challenges

- Insufficient historical time series data and lack of regular collection of data and information
- The validity and reliability of some data submitted

Table 57. Estimated exploitation rate (E) of scads in the South China Sea and Andaman Sea (E- Exploitation rate, F-Fishing mortality; Z-Natural mortality, FMA 711-Fisheries Management Area 711, WCPM-West Coast of Peninsular Malaysia)

Country	Fishing ground	Species	Year	Exploitation rate (E=F/Z)	Reference
South China Sea					
Brunei Darussalam	Brunei waters	*Decapterus macrosoma*	2003–2005	0.86	Matzaini *et al*., 2007
	Brunei waters	*D. maruadsi*	2003–2005	0.86	Matzaini *et al*., 2007
Indonesia	Pekalongan Pemangkat	*D. russelii*	2005	0.55	Wudianto *et al*., 2007
	FMA 711 SCS		2015	0.37	Duto, 2016
	Pekalongan Pemangkat	*D. macrosoma*	2005	0.48	Wudianto *et al*., 2007
	FMA 711 SCS		2015	0.72	Duto, 2016
Malaysia	Tok Bali	*D. macrosoma*	2003–2005	0.59	Samsudin, 2007
	Kuantan		2003–2005	0.73	
	Kota Kinabalu		2003–2005	0.50	Ahemad & Irman, 2007
	Kudat		2003–2005	0.82	
	Tok Bali	*D. maruadsi*	2003–2005	0.75	Samsudin, 2007
	Kuantan		2003–2005	0.70	
	Sarawak waters		2003–2005	0.76	Hadil, 2007
	Kota Kinabalu		2003–2005	0.27	Ahemad & Irman, 2007
	Kudat		2003–2005	0.59	
Philippines	Tayabas Bay	*D. macrosoma*	2011	0.32	Ramos *et al*., 2018
		D. maruadsi	2013	0.23	
		D. macrosoma	2012	0.52	
Thailand	Gulf of Thailand	*D. maruadsi*	2018	0.71	Yamrungrueng *et al*., 2018
Andaman Sea					
Indonesia	Palembang	*D. russelli*	2005	0.53	Wudianto *et al*., 2007
		D. macrosoma	2005	0.55	
Malaysia	WCPM	*Decapterus spp.*	2003–2005	0.59	Sallehudin *et al*., 2016
Thailand	Andaman Sea Coast of Thailand	*D. maruadsi*	2007	0.71	Boonsuk *et al*., 2010

- Lack of statistical database system for catch and effort
- Lack of specific fisheries management plan for scads fisheries including fishing effort, fishery regulation, traceability system, cooperation, among others

Way Forward

The ongoing project "Fisheries Management Strategy for Pelagic Fish Resources in the Southeast Asian Region" (2020–2024) under the JTF VI Phase II project is being implemented by SEAFDEC/MFRDMD and the activities include stock and risk assessments for scads.

1.1.3 Mackerels

Mackerels are under the family Scombridae that feed on plankton, crustaceans, mollusks, fish eggs, and small fishes, and could be found at water depths between 20 m to 90 m, *e.g.* short mackerel (*Rastrelliger brachysoma*) are mostly in the inshore areas while the Indian mackerel (*Rastrelliger kanagurta*) are at the offshore areas (Hadil & Richard, 1991). A study conducted in the South China Sea and the Andaman Sea has voted for a single unit stock for the management purpose of the Indian mackerel (*R. kanagurta*) since the fish species in the South China Sea and the Andaman Sea share the same stock with high genetic variation (Akib *et al*., 2015; Wahidah *et al*., 2013). A single genetic stock of *R. brachysoma* has also been identified in the Gulf of Thailand. The mixed-stock analysis revealed that the Samut Songkhram population has been the major contributor (52.71 %) to the total catch from the Inner Gulf of Thailand. The Surat Thani population dominantly contributes 46.23 % to the total catch from the lower part of the Central Gulf of Thailand, where the fishing ground surrounds its spawning ground. The populations from Cambodia and Malaysia corporately contribute 70.95 % and 87.88 % to the total catches from the Eastern Gulf of Thailand and upper part of the Central Gulf of Thailand, respectively (Kongseng *et al*., 2021). A study on the distribution and density of mackerel larvae *Rastrelliger* spp. in the northwest coast of Peninsular Malaysia (Yan, Kedah) found that the highest density occurs in September compared to August and October (Nur-Hidayah *et al*., 2020).

The production of mackerels including the Indian mackerel (*R. kanagurta*), short mackerel (*R. brachysoma*), Indian mackerels *nei* (*Rastrelliger* spp.), and mackerels *nei* (Scombridae) of Southeast Asia between 2008 and 2019 is shown in **Figure 58**. In Fishing Area 57 (Indian Ocean, Eastern), the production trend was stable with an average of 291,836 mt/year in 2008–2018 but declined significantly to 178,512 mt in 2019. Production in Fishing Area 71 (Pacific, Western Central) had a gradually increasing trend from 2008 (432,259 mt) to 2013 (548,629 mt), but the production decreased significantly in 2019 (231,130 mt).

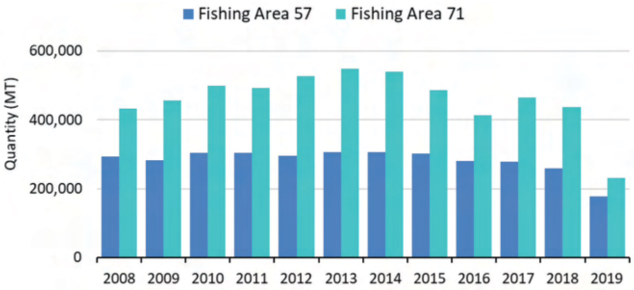


Figure 58. Production of mackerels of the Southeast Asian countries between 2008 and 2019 from Fishing Area 57 and Fishing Area 71 by quantity (mt)

Source: SEAFDEC, 2022

Table 58. Estimated exploitation rates of mackerels (*R. kanagurta* and *R. brachysoma*) in the South China Sea and Andaman Sea

Country	Site	Year	Species	Exploitation rate	References
South China Sea					
Brunei Darussalam	Brunei waters	2003–2005	*R. kanagurta*	0.72	Matzaini *et al.*, 2007
Malaysia	Tok Bali, Kelantan	2003–2005	*R. kanagurta*	0.65	Samsudin, 2007
	Tok Bali, Kelantan	2016–2020	*R. kanagurta*	0.64	Mohammad-Faisal *et al.*, 2021a
	Kuantan, Pahang	2003–2005	*R. kanagurta*	0.68	Samsudin,2007
	Endau, Johor	2017–2018	*R. kanagurta*	0.41	Mohammad-Faisal *et al.*, 2021b
	Kota Kinabalu, Sabah	2003–2005	*R. kanagurta*	0.65	Ahemad & Irman, 2007
	Kudat, Sabah	2003–2005	*R. kanagurta*	0.77	Ahemad & Irman, 2007
	Kunak, Sabah	2003–2005	*R. kanagurta*	0.70	Ahemad & Irman, 2007
	Marudu Bay, Sabah	2013	*R. kanagurta*	0.45	Amin *et al.*, 2014
	Sarawak waters	2003–2005	*R. kanagurta*	0.75	Hadil, 2007
	Sarawak waters	2003–2005	*R. brachysoma*	0.86	Hadil, 2007
Philippines	Davao Gulf	2004	*R. kanagurta*	0.64	Armada, 2004
	Davao Gulf	2004	*R. brachysoma*	0.59	Armada, 2004
	Rosario	2003–2005	*R. brachysoma*	0.64	Rafael *et al.*, 2007
	Rosario	2003–2005	*R. kanagurta*	0.74	Rafael *et al.*, 2007
	Navotas	2003–2005	*R. brachysoma*	0.61	Rafael *et al.*, 2007
	Navotas	2003–2005	*R. kanagurta*	0.69	Rafael *et al.*, 2007
	Dagupan	2003–2005	*R. brachysoma*	0.54	Rafael *et al.*, 2007
	Dagupan	2003–2005	*R. kanagurta*	0.41	Rafael *et al.*, 2007
	Manila Bay	2017	*R. brachysoma*	0.70	Santos *et al.*, 2017
Thailand	Gulf of Thailand	2012	*R. kanagurta*	0.52	Thongsila *et al.*, 2012
	Eastern Gulf of Thailand	2017	*R. kanagurta*	0.56	Koolkalya, 2017
Andaman Sea					
Indonesia	Malacca Strait	2014	*R. brachysoma*	0.79	BOBLME, 2015
	Malacca Strait	2014	*R. kanagurta*	0.62	BOBLME, 2015
Malaysia	Northern Part of West Coast of Peninsular Malaysia	2016–2020	*R. brachysoma*	0.78	Effarina & Fathul, 2021
	Northern Part of West Coast of Peninsular Malaysia	2016–2020	*R. kanagurta*	0.86	Effarina & Nor-Bariah, 2021

Exploitation Rate

Several studies on the exploitation rates of *R. kanagurta* and *R. brachysoma* had been carried out in various sites of the countries around the South China Sea and Andaman Sea. The results (**Table 58**) show that in the South China Sea, the highest exploitation rate of *R. kanagurta* (0.77) was recorded in Kudat, Sabah in 2003-2005, and the highest exploitation rate of *R. brachysoma* (0.86) was recorded in Sarawak, Malaysia in 2003-2005. In the Andaman Sea, the highest exploitation rate of *R. kanagurta* (0.86) was recorded in the Northern Part of West Coast of Peninsular Malaysia, Malaysia in 2016–2020, and the highest exploitation rate of *R. brachysoma* (0.79) was recorded in Malacca Strait, Indonesia in 2014. Most of the exploitation rate values are higher than the optimization (E_{opt}) criterion of 0.5 (Gulland, 1983) for sustainable exploitation of the fisheries. Based on the results, both *R. kanagurta* and *R. brachysoma* had been fully exploited by fishing activities in the South China Sea and Andaman Sea during the study period except for Endau (Johor, Malaysia), Dagupan (Philippines), and Marudu Bay (Sabah). Therefore, management strategies must be urgently implemented to ensure sustainable exploitation and enhance the management of the fisheries.

Regional Action Plan for Management of Indo-Pacific Mackerel

The ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region (RES&POA), the first of which was adopted by the ASEAN-SEAFDEC Member Countries in 2001, the second in 2011, and the third in 2020, recognize the need to strengthen cooperative efforts among countries toward the sustainable utilization of Indo-Pacific mackerel, a critical transboundary resource in the Gulf of Thailand. The series of RES&POA had also paved the way for the development of the "Regional Action Plan (RAP) for Management of Transboundary Species: Indo-Pacific Mackerel (*Rastrelliger brachysoma*) in the Gulf of Thailand Sub-Region," which was approved and endorsed by the SEAFDEC Council during its Fifty-second Meeting in 2021 with the goal of achieving sustainable Indo-Pacific mackerel fisheries in the Gulf of Thailand sub-region through science-based management for the shared benefit of the other AMSs by 2030. The RAP for Management of Indo-Pacific Mackerel is a non-legal binding document which is meant to serve as a foundation to identify the practices and processes that support the implementation of the relevant RES&POA. The expected outcomes of the RAP for Management of Indo-Pacific Mackerel include: 1) healthy Indo-Pacific mackerel resources through the implementation of the fishery management plan of the Gulf of Thailand; 2) accurate and comprehensive information on Indo-Pacific mackerel of the Gulf of Thailand, and 3) model for the development of management plan for Indo-Pacific mackerel that could be applicable to other sub-regions. The actions would focus on the dimensions of governance, social, economic, ecosystem, and climate change that are aligned with the concept of the ecosystem approach to fisheries management (EAFM) as in **Box 2**.

Box 2. Actions for the RAP for Management of Indo-Pacific Mackerel

1. Governance Dimension		
Objectives	**Knowledge Gaps/Issues**	**Actions**
Fisheries management mechanism developed and approved (including fisheries management plan and arrangement, the effect of regulation)	Fisheries Management Mechanism (including fisheries management plan and arrangement, the effectiveness of the regulation)	Develop fisheries management plan for short mackerel at national and subregional levels
		Initiative on development of harvesting strategy
		Establish regional cooperation on monitoring, control and surveillance
		Raise awareness of both small-scale fishers and commercial-scale fishers • Policy and regulations • Management measures • Sustainable utilization • Involvement the participation, considering gender sensitivity
		Promote stakeholders' consultations among researchers, managers and stakeholders on EAFM
		Conduct habitat conservation and rehabilitation and conduct stock enhancement programs
	Flexibility of regulations to respond to science advice	Encourage periodic evaluation of policies and regulations
	Management schemes/arrangements including transboundary aspects	Develop management schemes/arrangements at sub-regional areas including transboundary aspects
		Support establishment of regional cooperation/ management mechanism (non-legal binding and scientific advisory committees)

Box 2. Actions for the RAP for Management of Indo-Pacific Mackerel *(Cont'd)*		
Data management system is enhanced and considered and regional/sub-regional standardization data management system in place	Insufficient catch and landing data	Develop the SOP/technical guidance for data collection (including catch data, biological data
		Further develop catch documentation
		Harmonization/standardized on data collection and develop database system
Standard for assessing fishing effort for large, medium and small-scale fishery agreed	Insufficient biological data collection	Conduct capacity building program on data collection for enumerators, scientists, researchers
		Conduct time series data collection based on standardized methods
Understanding of national laws and management schemes within the sub-regional which are communicated and applied	Insufficient data on fishing effort (include commercial and small scale)	Link to catch documentation (include commercial and small-scale fishery (as available))
		Regular monitoring and data collection on fishing effort, capture production (include commercial and small scale)
Impact of unregulated and unreported fishing assessed	Understanding national laws and regulations	Comparative review of national laws and regulations, (including local wisdom)
		Disseminate knowledge and information on the conservation and management of Indo-pacific mackerel to fisheries communities and students
Catch documentation system applied as a tool to improve traceability of the short mackerel fishery	Illegal, Unregulated and Unreported Fishing	Assess the impact of illegal, unregulated and unreported fishing
		Strengthen the Monitoring, Control and Surveillance network against illegal fishing (none legal binding)
	Traceability system for fish and fishery products (using electronic logbook, etc.)	Develop catch documentation suitable for traceability system, *e.g.* electronic logbook, etc.
2. Social Dimension		
Objectives	Knowledge Gaps/Issues	Actions
Understanding the social condition of people involved in the fishery at the local and national levels	Social and economic aspect at local and national levels	Conduct a baseline survey based on available information on social and economic at local and national levels
	Traditional fishing (indigenous knowledge and social responsibility)	Improve and disseminate the best practice to others (*e.g.* indigenous people)
Increased participation and involvement of stakeholders at various levels.	People engagement in fishery activity (include small scale fishery and large scale/commercial fishery, processing)	Conduct stakeholder analysis for understanding the important and influence of stakeholder in various level
	People engagement in policy making (fisherfolk organization, academy, private sector	Promote Public Private Partnership
		Promote multi stakeholder engagement in policy making
	Social structure (community small scale and large scale, gender, migrant labor, and fisher)	Encourage gender equality based on understanding of social structure in communities
Resolved conflict on land and resource use	Conflict on land and resource use	Promote stakeholder consultation
		Promote marine spatial planning and coastal zone management
Awareness and capacity at all level built	Awareness raising	Distribute brochures or any media (*e.g.* digital media) to promote fisheries management and regulations)
		Capacity building and experts exchange
		Fishing gear technology for eco-friendly (reduce bycatch, cost and expenditures)
3. Economic Dimension		
Objectives	Knowledge Gaps/Issues	Actions
National government and private sector commitment for long-term funding and support ensured	Funding	To ensure the national government commitment for long-term funding and support
		Explore various potential donor
		Promote capital access through microfinance scheme
		Promote corporate social responsibility

Box 2. Actions for the RAP for Management of Indo-Pacific Mackerel *(Cont'd)*		
Understanding of the structure and ownership of assets within the fishing industry (large, medium, and small scale) raised	Structure and ownership of asset within the fishing industry (large and small scale)	Review structure and ownership of assets within the fishing industry (large, medium and small scale) for management responses
Maximized economic benefit return for management response and reduced unequal distribution	Benefits and economic returns and unequal distribution	Assess benefit and economic returns throughout the value chain
	Increase of cost (fuel and other inputs)	To ensure the fuel and other inputs exist for local fishermen
	Fisheries employment revenue	To create the alternative work
		Require the contract among people engaged in fishing
4. Ecosystem Dimension		
Objectives	Knowledge Gaps/Issues	Actions
Current status understood and knowledge of short mackerel resources improved for scientific-based management	Migratory route	Conduct tagging program, e-DNA, DNA
	Spawning and nursery grounds (including dispersion and distribution of fish larvae)	Conduct comprehensive larvae survey (*e.g.* ichthyoplankton)
	Seasonal changes	Conduct comprehensive larvae survey (*e.g.* ichthyoplankton)
		Conduct reproductive biology study
	Stock structure	Conduct DNA study, otolith, tagging, etc.
	Stock status at national and regional of *R. brachysoma* (distribution and abundance)	Conduct stock assessment at national, sub-regional or regional level
		Share data, information and findings from scientific research to relevant stakeholders
		Standardized data collection for regional stock assessment
		Develop modelling for stock assessment
	Species identification	Provide capacity building on species identification of small size (juvenile) and larval fishes
	Status and Trends	Investigate the trend of short mackerel catch at national, sub-regional levels
	Population dynamics (Growth parameters, mortalities etc.	Conduct survey on fisheries biology
	Impact of fishing effort on stock structure (multi-fishing gears to harvest)	Conduct study on impact of fishing effort on stock structure (Multi-fishing gears to harvest) to improve the fishery management
	Stock assessment and distributions for transboundary species	Enhance the cooperation for information sharing among the bordering countries
	Capacity building and experts exchange	Training, workshop, conference and experts exchange
Various habitats of short mackerel throughout its life cycle understood	Migratory route	Update, further define and confirm the migratory route at national, sub-regional or regional area
	Spawning and nursery grounds (including dispersion and distribution of fish larvae)	Study on critical habitats
	Physical and chemical oceanographic conditions and ocean circulation	Conduct oceanography survey
		Develop oceanographic modelling
		Conduct satellite imagery (GIS, remote sensing) analysis
	Impact of fishing effort on stock structure (Multifishing gears to harvest)	Enhance Fishing gear technology for ecofriendly (Reduce bycatch, cost and expenditures)
	Capacity building and experts exchange	Training, workshop, conference and experts exchange

Box 2. Actions for the RAP for Management of Indo-Pacific Mackerel *(Cont'd)*		
5. Climate Change Dimension		
Objectives	Knowledge Gaps/Issues	Actions
Adaptive management measures **in place** in response to the impact of climate change and disaster on short mackerel fisheries and habitats	Impact of climate change to fish migration route	Assess the impact of climate change/disaster/anthropogenic activities to fish migration route, habitat and behavior
		Study effect of environmental changes on the migratory pattern and spawning patterns based on climate change
	Sensitivity of species on critical habitats and environment impact to ecosystem (pollution, climate change, etc.)	Conduct study on sensitivity of species on environment change (pollution, climate change, etc.) to support the management response
		Study on the critical habitats (spawning and grounds)
		Study effect of environmental changes on the migratory pattern and spawning patterns
		Data sharing (assign focal person to share information)
	Capacity building and experts exchange	Training, workshop, conference and experts exchange on CC impacts
Mitigation and precautionary measures **adopted** to compensate for the effects of climate change	Impact of climate change to fish migration route	Share information from the findings of scientific research to both fisheries managers and fishers
	Capacity building and experts exchange	Training, workshop, conference and experts exchange on CC impacts

Issues and Challenges

- Inadequate regular collection of data on capture fishery production
- Insufficient data and information on fishery characteristics including catch and effort and biology
- Inadequate information on stock status and population dynamics including distribution and abundance
- Changing of fishing gear used to catch pelagic fishes especially mackerel
- Absence of fisheries management plan including fishery regulations, co-management, traceability system, among others
- Need for strengthened regional cooperation on standardized and integrity of data collection for regional stock assessment, data sharing, management body to develop the transboundary management plan

1.1.4 Anchovies

Anchovies are small pelagic fishes that belong to the family of Engraulidae, under the order of Clupeiformes which has 151 species and 17 genera (Eschmeyer *et al*., 2017). Like other small pelagic fishes, anchovies are widely distributed in the Southeast Asian region. Anchovies are found in the neritic zone or shallow coastal waters where the shorthead anchovy (*Encrasicholina heteroloba*) and Indian anchovy (*Stolephorus indicus*) are the two dominant species found in the Southeast Asian region. Fishing grounds are located in the South China Sea and the Andaman Sea. The South China Sea had higher production compared to the Andaman Sea. Indonesia, Malaysia, Philippines, Singapore, and Thailand are the countries that catch anchovies in the South China Sea. Meanwhile, the countries that fish for anchovies in the Andaman Sea are Indonesia, Malaysia, Myanmar, and Thailand. Anchovies have ecological importance due to the large biomass in the food web in coastal areas and the transfer of energy from plankton and small organisms to large-sized fish (Ganias, 2014). Most species of anchovies are commonly found in coastal areas (Young *et al*., 1995) and are usually present in shallow waters from 5 m to 35 m depths with the highest densities around island areas (Fricke *et al*., 2011).

The production of anchovies including the Stolephorus anchovies (*Stolephorus* spp.) and anchovies nei (Engraulidae) of the Southeast Asian region during 2008–2019 is shown in **Figure 59**. In Fishing Area 57 (Indian Ocean, Eastern), the production trend was constant with an average of 107,561 mt/year ranging from 44,492 mt in 2019 to 143,626 mt in 2017. In Fishing Area 71 (Pacific, Western Central), the production had an average of 312,088 mt per year with the range between 232,636 mt in 2019 and 356,446 mt in 2009.

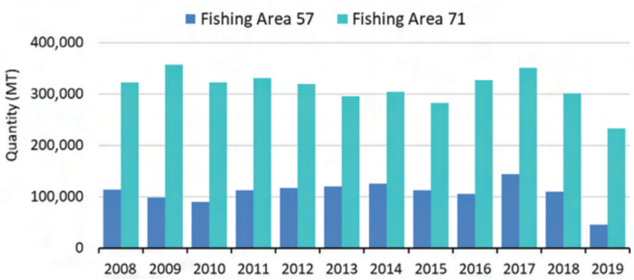


Figure 59. Production of anchovies of the Southeast Asian region between 2008 and 2019 from Fishing Area 57 and Fishing Area 71 by quantity (mt)
Source: *SEAFDEC, 2022*

Issues

Globally, due to the pandemic COVID-19, the impacts on fish catches have varied with many countries seeing sharp drops in production during the first weeks of the crisis followed by improvements as the sector adapted (FAO, 2020c). Although many vessels are not going out for fishing during pandemic COVID-19, overfished fish stocks need as much as 10–15 years of reduced fishing to permit depleted stocks to recover. So, in the absence of governance and management reforms that sustain reduced pressure, such recoveries seem unlikely to date (UNDP, 2020).

According to FAO (2020c), most surveys to collect data for fisheries stock assessment processes have been postponed or canceled in some countries. The situation during this pandemic, with restrictions of movement and number of persons that can work near each other, with working from home policies in many countries and even some crew members or researchers becoming infected, suggest that canceling stock assessment activities is the only possible solution. In these circumstances, estimating the stock sizes for long-lived fish species may be possible for some species by using trends or the same results as the year(s) before. However, this situation could be challenging for some short-living species (one to three years) and result in highly uncertain total allowable catches (TACs) for fish stocks. The results for stock status may be affected where a TAC is overestimated, or a decrease in potential production where a TAC is underestimated.

There are some issues concerning fisheries in Viet Nam, such as the decreasing marine fishery resources in all waters of Viet Nam, underdeveloped fishing techniques, insufficient funds for research of fish stocks, while biological information for target species and implementation of fisheries management regulations are limited at fishermen's communities, and the ineffective fisheries management tools for purse seine fisheries (Tuyen & Tam, 2018). Meanwhile, in Thailand there have been some issues, such as those on IUU fishing, catching large quantities of juvenile fish of larger commercial species which could grow bigger, conflicts between artisanal and commercial fishers, degraded critical habitats, and inadequate fisheries data and information.

Way Forward

The status of the anchovy resources is important for management purposes. Therefore, continuous studies should be conducted for 5–10 years and the strong support of governments would be necessary such as allocation of sufficient budget, especially for collaborative and comprehensive studies. Biological information of anchovies such as species composition, density, biomass, population dynamic parameters should be obtained from the conducted surveys. Information on the early life history of anchovies including their habitats, gonad maturity, spawning season, and their route should also be studied to enable to establish closed areas or closed seasons (**Table 59**). Public awareness campaigns for fishers and other stakeholders should be frequently undertaken to educate them on the need to sustain the resource through an ecosystem approach. Capacity building is necessary to achieve the above targets and raise knowledge, especially for coastal fishermen's communities, which should be undertaken continuously. Strengthening the capacity for various stakeholders (scientists, managers, policymakers, fishers, etc.), the conduct of stock assessment courses for the anchovy resources as well as biosocioeconomics should be introduced at the university level. The pool of knowledgeable graduates would ensure the continuity of expertise capable of estimating the status and trends of anchovies in the region.

Table 59. Way forward for anchovies

1. Long-term research activities • Resource status through anchovy resource survey for each three years • Biological study to determine species and distribution pattern • Fishery biosocioeconomics
2. Capacity Building • Training on stock assessment of anchovies for research staff • Establishment of programs on anchovy stock assessments at local university
3. Fishing Capacity • Standardization of vessel parameters • Review of the number of vessels operating in each fishing area
4. Establishment of closed seasons • Closed season or closed area during the peak spawning months every year • No fishing activities in the conservation zones (0-1 nm), which are the nursery grounds for larvae and juveniles
5. Public awareness on EAFM • Raising the stakeholders and fishers' awareness in sustaining anchovy resources
6. Fisheries Management Plan for Anchovies (FMP for Anchovies) • This management body should be supported and implemented • FMP will set the management indicators such as stock status, catch per unit effort (CPUE), economic indicators • FMP would be reviewed and action is taken based on stock assessment and assessment of ecosystem impacts

1.1.5 Sardines

Sardines are under the Family Clupeidae, subfamily Clupeinae, and are small pelagic fishes feeding on phytoplankton and zooplankton. The species are distinguishable from other small pelagics through their rounded upper lip and two pronounced supra-maxillae at the proximal end of the mouth (Whitehead, 1985). Clupeids have short life spans generally ranging 1–4 years, typically reaching maturity by 12 months, occupying low trophic levels, and occurring in continental shelf waters, and each species differ in maximum size, size at maturity, habitat preferences, seasonal or life-cycle migration patterns and response to climate ocean variation (Hunnam *et al.*, 2021).

The production of sardines including the goldstripe sardinella (*Sardinella gibbosa*), Bali sardinella (*S. lemuru*), sardinellas *nei* (*Sardinella* spp.), spotted sardinella (*Amblygaster sirm*), rainbow sardinella (*Dussumieria acuta*) of the Southeast Asian region from Fishing Area 57, and Fishing Area 71 during 2008–2019 is shown in **Figure 60**. In Fishing Area 57, the average production was 106,577 mt per year with the highest at 206,967 mt in 2008 and the lowest at 46,098 mt in 2016. In Fishing Area 71, the average production was 669,346 mt per year with the highest at 968,597 mt in 2018 and 491,253 mt in 2017.

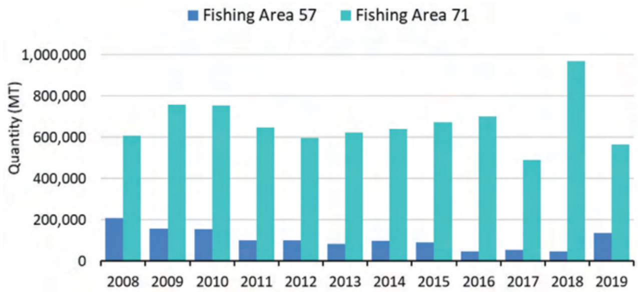


Figure 60. Production of sardines of the Southeast Asian region between 2008 and 2019 from Fishing Area 57 and Fishing Area 71 by quantity (mt)

Source: *SEAFDEC, 2022*

Exploitation Rate

Table 60 shows the exploitation rates of sardines in selected fishing grounds of the Philippines and Thailand. The high exploitation rates of 0.76 and 0.78 for *S. gibbosa* were recorded in the Gulf of Thailand and Manila Bay, respectively. Meanwhile, *S. fimbriata* had an exploitation rate value of 0.66 in Manila Bay. In general, the stock of sardines is overfished (E = 0.66 - 0.78) in the western side of the South China Sea and moderately fished or underfished (E = 0.44) in the northern and central Philippines.

Genetic Stock Structure

SEAFDEC/MFRDMD, with support from the Japanese Trust Fund VI, conducted the genetic population study of *Amblygaster sirm* by using mitochondrial DNA (mtDNA) markers to ascertain its genetic structure in the South China Sea and Andaman Sea, and to confirm whether there is a single stock or more for management purposes. *A. sirm* is one of the economically important sardine species in the region. A total of 498 samples of *A. sirm* were collected during 2014–2018 from the different sampling sites in the region (**Figure 61**). It was found that this species does not occur in the Strait of Malacca. Based on the genetic analysis, both mtDNA markers, Cytochrome B (*Cyt b*) (**Figure 62A**) and Cytochrome C Oxidase Sub-unit I (COI) (**Figure 62B**), it has been established that there are two highly divergent genetic stocks. One stock is in the northern Andaman Sea (*i.e.* Ranong in Thailand) while the rest of the populations could be found in the South China Sea (*i.e.* Muara in Brunei Darussalam; Kuantan, Kuching, and Kudat in Malaysia; Palawan and Zambales in the Philippines; and Songkhla in Thailand), southern Andaman Sea (Banda Aceh in Indonesia), and Java Sea (Pekalongan in Indonesia). As *A. sirm* could not be found in the Strait of Malacca, this suggests that each stock should be managed independently. Nonetheless, further studies should be carried out to confirm the genetic stock structure of the spotted sardinella being a cryptic species in Ranong (Wahidah *et al.*, 2020).

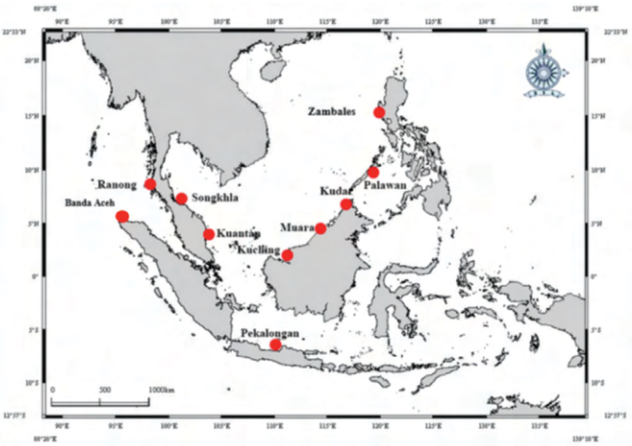


Figure 61. Sampling sites for the genetic population study of *Amblygaster sirm* in the Southeast Asian region

Issues and Concerns

- Failure to control overfishing
- Variation in local names of one species of sardines in one country across the region
- Limited knowledge and understanding of fishers relevant to managing the sardine fishery including seasonality, habitat, interannual variation in landings, movements as well as post-harvest characteristics in relation to perishability

Table 60. Exploitation rate of sardines in the Philippines and Thailand waters

Country	Fishing ground	Species	Year	Exploitation rate (E=F/Z)	Reference
Philippines	Manila Bay	*Sardinella fimbriata*	2012-2015	0.66	Santos *et al.*, 2017
	Tayabas Bay	*S. gibbosa*	2018	0.44	Ramos *et al.*, 2018
	Manila Bay	*S. gibbosa*	2012-2015	0.76	Santos *et al.*, 2017
Thailand	Gulf of Thailand	*S. gibbosa*	2012	0.78	Boonjorn *et al.*, 2012

A.

B.

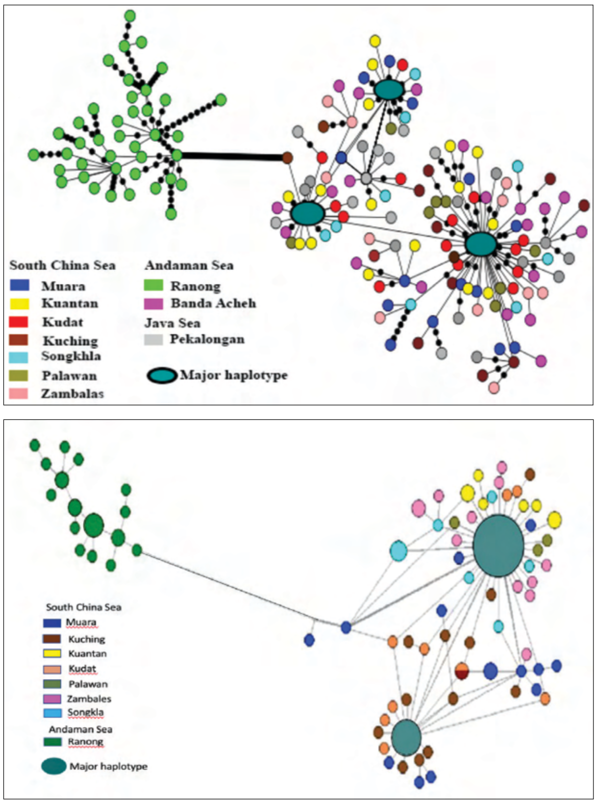


Figure 62. Minimum Spanning Network (MSN) inferred from mtDNA *Cyt b* (A) and *COI* (B) genes

- Misidentification of most common sardine species; thus, there is a need for morphologic, meristic, and molecular genetic tools to identify at the species level

Way Forward

The ongoing project of SEAFDEC/MFRDMD "Fisheries Management Strategy for Pelagic Fish Resources in the Southeast Asian Region" (2020–2024) under the JTF VI Phase II is developing the sustainable management strategy for pelagic fisheries including the fishery of sardines. For the AMSs, the Philippines as the leading sardine producer in the region through its Bureau of Fisheries and Aquatic Resources (BFAR), has initiated the National Sardines Management Plan (NSMP) 2020–2025 which envisions "A sustainable and equitably-shared sardine fishery that contributes to food security and increased income through responsible management." To contribute to this vision, the Plan aims to: 1) establish (reference points) and monitor progress with respect to biomass-based and fishing mortality-based reference points for the top three sardine species by 2023; 2) reduce juvenile catch by 10 % by 2025 in five priority sardine fishing areas by 2022; and 3) reduce poverty incidence of sardines fishers by 5 % (BFAR, 2020).

1.1.6 Marine Shrimps

In the Southeast Asian region, the economically important marine shrimps from capture fisheries include the tropical spiny lobsters *nei*, flathead lobster, slipper lobsters *nei*, banana prawn, giant tiger prawn, western king prawn, green tiger prawn, *Penaeus* shrimps *nei*, endeavour shrimp, *Metapenaeus* shrimps *nei*, and sergestid shrimps *nei*. Shrimps are mainly caught by beam trawls with relatively small mesh size, while in Brunei Darussalam and Singapore, *Penaeus* spp. are mainly caught by gill nets and trawls, respectively (SEAFDEC, 2020a).

The average production of marine shrimps from capture fisheries of the region during 2008–2019 was around 288,057 mt per year (**Figure 63**). In Fishing Area 57, the average production between 2008 and 2019 was around 95,815 mt with the highest at 118,445 mt in 2011 and lowest at 74,307 mt in 2019. On the other hand, in Fishing Area 71 production between 2008 and 2019 reached an average of 192,242 mt per year, with the highest in 2018 at 248,170 mt, and the lowest was in 2017 (157,786 mt).

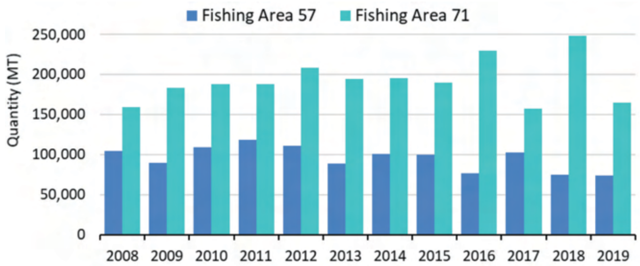


Figure 63. Production of marine shrimps from capture fishery of Southeast Asia from 2008 to 2019 by quantity (mt) (SEAFDEC, 2022)

1.1.7 Seaweeds

Seaweeds are aquatic plants that could be commonly differentiated by the predominant color of its pigments, *i.e.* red (*Rhodophyta*), green (*Chlorophyta*), and brown (*Ochrophyta*). Seaweeds have been traditionally exploited for centuries and generally collected from the wild as a source of food particularly in Asia. However, in the last 50 years, the increased demand for seaweeds and its by-products has led to the commercial exploitation and expansion of farming areas in tropical and temperate countries. The exponential increase in production of the eucheumatoid seaweeds in the Southeast Asian region has been attributed to the increased demand for carrageenan, an extract valued for its hydrocolloid polysaccharides. Carrageen-producing red algal seaweeds of the genera *Kappaphycus* and *Eucheuma* are the leading seaweeds being cultured in the region. Carrageenan is classified into three types, namely: kappa, iota, and lambda carrageenan. Kappa carrageenan is the hard-gelling type and comes from *Kappaphycus* spp; iota-carrageenan is a soft-gelling carrageenan sourced from *E. denticulatum*; and lambda is a non-gelling carrageenan usually used as a thickener in dairy products. Moreover, the red alga *Gracilaria* is known as an important source of agar. The discovery of other uses of seaweeds and its by-products other than food applications, including nutraceuticals, pharmaceuticals, and biofuels, contributed to the high demand for seaweeds.

History of Seaweed Farming in Southeast Asia

The experimental cultivation of *Kappaphycus* (=*Eucheuma*) in the mid-1960s in Tawi-Tawi, Philippines, through the collaboration between Marine Colloids Inc. and *Dr. Maxwell Doty* of the University of Hawaii has become commercial success (Doty & Alvarez, 1975). Red seaweeds with high-yielding carrageenan were identified including the genera *Kappaphycus* and *Eucheuma* which are commercially known as "cottonii" and "'spinosum," respectively. The successful cultivation of tropical eucheumatoid seaweeds was later introduced and expanded to other areas of the Philippines including Luzon, Visayas, and Mindanao. The commercial production technique in the seaweed farms in the Philippines was replicated in neighboring countries such as Indonesia and Malaysia. The simple production technique (*e.g.* vegetative planting), low production costs involved in the eucheumatoid seaweed farming, and high demand for carrageenan resulted in its commercial exploitation and introduction to other counties and regions (Ask *et al*., 2003).

The two dominant genera of red seaweeds being cultured in the Southeast Asian region are the *Kappaphycus* spp. and *E. denticulatum*. *Gracilaria* spp. is another important species of red seaweed being commercially cultivated but at a lesser production volume. The green alga *Caulerpa* spp. (sea grapes) is cultivated mainly for direct human consumption, while *Sargassum* spp. is primarily collected from the wild, thus, the production volume is lower than the cultivated red seaweeds. Factors such as availability of raw materials for seedling purposes, low labor cost, favorable weather conditions, and high acceptability of seaweed as a source of food are the several reasons for the region's emergence as the center of global seaweed production.

Among the thousands of red seaweed species, only a few genera including *Kappaphycus*, *Eucheuma*, and *Gracilaria*, have been successfully introduced to other tropical and subtropical regions (Ask *et al*., 2003). Of these, *Kappaphycus alvarezii*, *K. striatus*, and *Eucheuma denticulatum* have been reportedly farmed in over 20 countries in Southeast Asia, South Pacific, Latin America, and the Indian Ocean (Sulu *et al*., 2004; Pickering, 2006; Hurtado *et al*., 2014b; Msuya *et al*., 2014; Hayashi *et al*., 2017; Shanmugam *et al*., 2017; Alemaña *et al*., 2019). These red seaweeds are important sources of carrageenan and agar. Initially, carrageenan was extracted solely from *Chondrus crispus* (Irish moss) but was collected primarily from the wild. As the demand for carrageenan increases, the search for other sources of carrageenan has led to the exploration of tropical red seaweeds.

Seaweed Production of Southeast Asia

Seaweed farming has been considered the fastest growing industry of the aquaculture sub-sector globally with an annual growth rate of 10 percent. In 2019, FAO (2021) reported that seaweeds and other aquatic plants contributed 34.68 million mt wet weight to the world fishery production, and 96.52 percent of the total seaweed production was concentrated in Asia particularly East Asia and Southeast Asia. For Southeast Asia, the region produced 11.62 million mt or 33.52 percent of the world's seaweed production. During the last two decades, some AMSs, namely: Indonesia, Philippines, and Malaysia contributed significantly to the world production of seaweeds; while Viet Nam, Cambodia, and Myanmar were also seaweed producers (**Figure 64**).

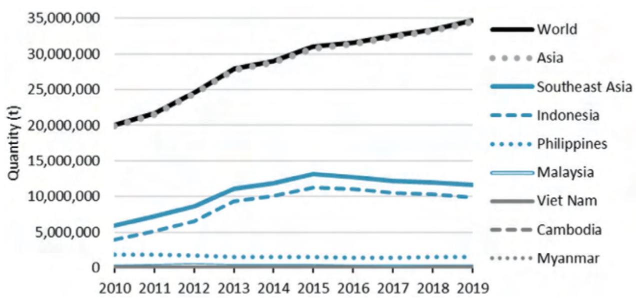


Figure 64. Production of seaweeds (including other aquatic plants) of the world, Asia, Southeast Asia, and ASEAN Member States by quantity (mt, wet weight) from 2010 to 2019 (FAO, 2021b)

Indonesia is the world's most significant contributor of aquatic plants (mostly red seaweeds) producing 9.92 million mt in 2019; and it is the only country besides China that produced over 100,000 mt of farmed *Gracilaria* (FAO, 2021b). Also, Indonesia is the world's largest producer of red seaweeds, including *Kappaphycus* and *Eucheuma*. The major production areas are located in Sulawesi, Maluku, West and East Nusa Tenggara, Northern Kalimantan, and East Java (FAO, 2018). Cai *et al*. (2021) indicated the factors that contributed to the success of the seaweed industry in Indonesia, which include 1) conducive climate conditions for tropical seaweed farming; 2) abundant suitable cultivation sites in the vast archipelago made accessible by effective community-based coastal management; and 3) large labor force in rural fishing communities looking for alternative activities to support livelihoods threatened by overfishing.

The Philippines was the largest producer of farmed eucheumatoid seaweeds from the start of its commercial production in the early 1970s until Indonesia overtook in 2008 (Bixler & Porse, 2011; Hurtado *et al*., 2014a). The seaweed production of the country reached its peak in 2011 with 1.84 million mt; however, there was a notable decline in the production in the succeeding years. Nonetheless, the country's aquaculture production has been dominated by seaweeds in recent years. In 2019, the aquaculture production of the Philippines was 2.36 million mt, and 63 percent (1.49 million mt) of this was from seaweeds amounting to around USD 250 million (BFAR, 2019). The country mainly produced *Kappaphycus* and *Eucheuma* which are processed as alkali-treated chips (ATC), semirefined carrageenan (SRC), and refined carrageenan. Also, the Philippines is the leading producer of *Caulerpa* spp. at 1,090 mt in 2019. Seaweed production has been documented in 15 of the 17 administrative regions of the Philippines. The bulk of production was recorded in the Sulu archipelago including Sulu and Tawi-Tawi Provinces with 0.70 million mt or 46.5 percent of the total seaweed production in 2019 (BFAR, 2019). Also, Region IV-B including Palawan, Zamboanga Peninsula, Western Visayas, and Central Visayas regions contributed significantly to the seaweed production of the country (BFAR, 2019).

After Indonesia and Philippines, Malaysia is the third-largest producer of seaweeds in Southeast Asia producing 0.19 million mt in 2019. The majority of seaweeds produced in the country are *Kappaphycus* and *Eucheuma*. The total area for seaweed cultivation in the country is 9,836 ha (DOF, 2019). Nearly all the seaweed production in Malaysia is concentrated in Sabah particularly in Semporma, Tawau, Kunak, and Lahad Datu as the four major seaweed growing areas.

In Viet Nam, the seaweed industry is still in the developing stage where the production volume is in limited quantity and mostly harvested from the wild. In 2019, the country produced more than 10,000 mt of *Gracilaria* (FAO, 2021b). The two main seaweeds of commercial importance are *Gracilaria* and *Sargassum* for agar and alginate processing, respectively; while *Sargassum* is mainly used as fertilizer (FAO, 2018). Seaweed processing centers are already present in the country, particularly in Haiphong, Ho Chi Minh City, and Danang.

Other AMSs including Cambodia, Myanmar, and Thailand produced seaweeds on a limited production scale (FAO, 2021b). In 2019, Cambodia and Myanmar produced 2,000 mt and 11 mt of seaweeds, respectively (FAO, 2021b). Most of the production was from the wild and mainly for local consumption. In Thailand, FAO (2018) reported that seaweed productions are mainly from *Gracilaria*, *Hypnea*, *Porphyra*, *Acanthopora*, and *Caulerpa*. Most of these seaweeds are wild-caught and in limited volume. Among these, *Gracilaria* is considered the most important species, mainly used for human consumption and agar processing. To fill the requirements for the local needs, raw and processed seaweeds are being imported from China, Japan, and Republic of Korea.

Seaweed Farming

Kappaphycus and *Euchuema* can be grown in shallow and deep-sea areas. In shallow areas, the fixed off-bottom is the most common method used, while hanging long-line, free swing, hanging basket, multiple raft-long lines, single raft long-line, spider web, and triangular are the methods used in deeper waters. The most adopted method in Indonesia, Malaysia, and Philippines are the fixed off-bottom, single floating raft, and hanging long-line (Luxton, 1993; Yasir, 2012; Hurtado *et al*., 2013). In Sabah, Malaysia, the hanging basket method is used in deeper areas. In the Philippines, the methods used to culture *Kappaphycus* that were first introduced were the fixed off-bottom, broadcast, floating bamboo, net system, and tubular net. Particularly in the Zamboanga Peninsula and Sitangkai, Tawi-Tawi, the multiple raft long lines, spider web, and free-swing are the culture methods used in deeper waters.

Problems and Challenges

Seaweeds had been in a bright spot in aquaculture production, benefiting many countries by improving the socioeconomic status of many coastal communities engaged in seaweed cultivation. However, in recent years, several seaweed farming nations, including the AMSs, have experienced a declining trend in production (**Figure 64**). Several factors have been linked to the decline in seaweed production, which include natural calamities, seaweed quality deterioration, seaweed health problems, and biosecurity issues. For the sustainability of the seaweed industry, addressing these problems and challenges should be taken into consideration.

- *Natural calamities*

Seaweed farming is usually done in shallow water areas making the farms vulnerable to fluctuating weather conditions. Natural calamities such as typhoons, earthquakes, volcanic eruptions, and drought, among others could affect the farming areas and, ultimately, loss in biomass production. These natural calamities constituted significant threats to the farming communities that rely on seaweed farming as their source of livelihood. In the last decade, typhoons had frequented the Philippines and were observed to be stronger which destroyed the seaweed farming areas around the country, and losses of income and livelihood opportunities. Unlike Indonesia and Malaysia, Philippines is located in the typhoon belt area where strong winds and storm surges happen regularly, damaging the seaweed farms and preventing production throughout the year (Valderrama *et al*., 2013; Hurtado, 2013). Also, earthquakes and volcanic eruptions can disrupt seaweed farming and operations, thereby affecting production. Moreover, changing weather patterns brought about by climate change (*i.e. El Niño* and *La Niña*) make seaweed farming in the shallow water areas more challenging as the fluctuations of environmental parameters could affect seaweed health.

- *Deterioration of seaweed quality*

Vegetative cutting or the cut and plant is the most commonly used and conventional method in seaweed farming. This method uses healthy thallus of seaweeds which is used as the seedling materials for the subsequent cropping. However, the repetitive use of this method results in the slow growth of seaweeds and makes the seaweeds "less vigor" (Hayashi *et al.*, 2010) and more susceptible to diseases and pests because of the changing environment brought about by climate change.

- *Seaweed health problems*

It was reported that diseases and pest outbreaks in farmed seaweeds had resulted in decreases in production, not only in Southeast Asia but also in other major seaweed producing countries including in Zanzibar, Tanzania (Largo *et al.*, 2020), and China (Pang *et al.*, 2015). In the Philippines, disease and pest outbreaks and other factors resulted in yearly average production losses of 16.8 percent from 2012 to 2018 compared to its peak of production in 2011 at 1.84 million mt (PSA, 2013, 2015, 2019).

Specifically, the ice-ice disease (IID) and epiphyte outbreaks affected the biomass production and carrageenan quality of farmed seaweeds (Uyenco *et al.*, 1981; Largo *et al.*, 1995; Vairappan *et al.*, 2008; Hurtado *et al.*, 2019; Ward *et al.*, 2020). The IID initially manifests gradual depigmentation or loss of color, from pinkish to whitish, notably at the primary and secondary branches, followed by softening of the thallus; and finally, the breaking off of the infected tissues from the main cultivation line (**Figure 65A**). Such breaking-off of the thallus eventually results in the loss of biomass. The recent survey conducted by Faisan *et al.* (2021) found that IID was prevalent in farms in major seaweed cultivating areas in the Philippines, suggesting that IID already affects many farming areas encompassing different cultivar farming techniques and locations. Several studies suggest that the causative agents of IID, isolated from the diseased seaweeds, are microbes including the gram-negative bacteria (*Vibrio* sp., *Cytophaga-Flavobacterium* complex, *Alteromonas*, *Pseudoalteromonas*, and *Aurantomonas*), and fungi (*Aspergillus*, *Ochraceus*, *A. tereus*, *Phoma* sp.) (Largo *et al.*, 1995; Solis *et al.*, 2010; Syafitri *et al.*, 2017). However, these findings, in addition to the earlier report of Uyenco (1981), suggest that no particular species of microbes were associated with each incidence of IID but instead might be a combination or complex of the abovementioned microbes.

Furthermore, epiphytic filamentous algae (EFA) are red seaweeds that damage the host plant by infiltrating the cortical and medullary cells (**Figure 65B**). EFA-affected seaweeds result in tissue injury, thus allowing pathogenic microbes to infect the host plant. Outbreaks caused by EFA have been recorded in the Philippines since 1975 (Doty & Alvarez, 1975). Hurtado *et al.* (2006) described the EFA outbreaks affecting *K. alvarezii* farm in Camarines Norte, Philippines, resulting in massive losses and stoppage of culture for several years. The same results were also observed in the study of Vairappan (2006), where seasonal occurrences of mostly *Neosiphonia savatiere* infecting *K. alvarezii* farms in Malaysia.

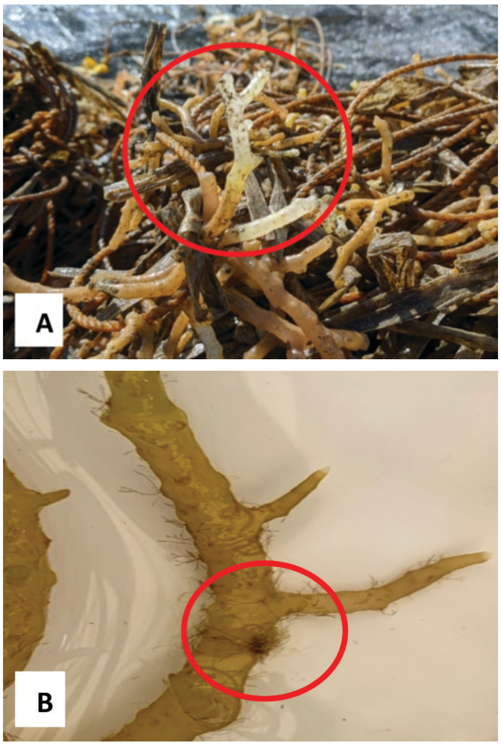


Figure 65. (A) Ice-ice disease (IID) and (B) epiphytic filamentous algae (EFA) affecting farmed eucheumatoid seaweeds (*Kappaphycus*).

Photos by JP Faisan

Seasonal occurrence of other seaweeds, such as the brown algae Sargassum, green algae *Ulva*, and red algae *Gracilaria*, could be observed to grow on the surface of farmed seaweed plants. These macro-epiphyte seaweeds are often observed either loosely attached or entangled on the main cultivating lines. The presence of these macro-epiphytes can potentially affect the growth of farmed seaweeds by competing for light and nutrients. The high prevalence of these macro-epiphyte seaweeds could also be attributed to environmental factors such as slow water movement that prevented these seaweeds from disentangling from the seaweed line or high nutrient availability due to anthropogenic eutrophication (Faisan *et al.*, 2021). Certain grazing incidences could also be observed on the soft tissues at the apex of the thallus region of the seaweed plants. Often, signs of grazing are manifested by the absence of tips which is mainly related to the seasonal abundance of juvenile herbivorous fish (*e.g.*, siganids). Mechanical damage on the thallus makes the seaweed tissues susceptible to disease occurrence secondary to microbial infection. Tan *et al.* (2020) found that grazing damage to seaweeds could significantly shift the microbial community structure. Grazing incidence in farms could potentially affect biomass yields, especially on the nursey phase of cultivation where seaweeds are used for seedlings propagation.

Seaweed health problems result in major losses in terms of production yields. However, disease and pest diagnosis in eucheumatoid seaweeds at the farm level remain dependent on personal observation of the farmers, mostly unsupported by scientific knowledge or standardized guidelines (Marino *et al*., 2019; Kambey *et al*., 2020). Research on diagnostic tools to prevent the spread and outbreaks of seaweed health problems should be considered with utmost priority.

- *Biosecurity issues*

The exponential demand for seaweeds (*Kappaphycus* and *Eucheuma*) and its derivatives resulted in the introduction and commercial expansion of seaweed farms in many countries. However, the introduction of non-native seaweeds to other localities or countries inevitably resulted in the introduction of diseases and pests. Compared to other important commodities (both aquatic and terrestrial), biosecurity measures on seaweeds have been absent or not strictly implemented, from the source of the seedlings to the farm (Mateo *et al*., 2020). Policies on seaweed biosecurity have been a major constraint and lacking in many seaweed-producing countries. Although seaweeds had been a major contributor to aquaculture production worldwide, the biosecurity initiatives of the seaweeds industry, particularly in developing countries, remain lagging behind other industries of the aquaculture sub-sector (Cottier-Cook *et al*., 2016).

Concerning the global seaweed industry, Campbell *et al*. (2020) reported the significant challenges in biosecurity policies which include: 1) inconsistent terminology for the inclusion of seaweeds in regulatory frameworks; 2) limited guidance for the responsibility of implementation of biosecurity measures; 3) insufficient evidence to develop disease and pest-specific policies; and 4) lack of coherent approach to seaweed biosecurity risk management in international policies. These issues have also been reflected in the national biosecurity-related regulations and policies in Indonesia and Philippines. Both countries have similar issues in the seaweed industry and there is a need to strengthen the biosecurity policies to ensure the protection of this important commodity. Policies and legislation on seaweeds should be strictly followed and enforced to manage the risk of transboundary transfers of unchecked cultivars and decrease the risks of disease and pest outbreaks.

The inadequate legislation and policies related to seaweed biosecurity issues experienced by the seaweed industry of Indonesia include 1) unspecific allocation of seaweed aquaculture in biosecurity frameworks; 2) limited variety of biosecurity approaches; 3) limited scientific information in seaweed framework; and 4) limited guidance for the use of precautionary principle (Kambey *et al*., 2020). Also, Kambey *et al*. (2020) listed key policy recommendations to improve the national biosecurity frameworks in Indonesia, such as: 1) support further research to develop a strong evidence base, upon which national strategic decisions could be made on the management of the seaweed cultivation; 2) establish seaweed-specific regulations and policies, providing appropriate management strategies that can be effectively enforced; 3) establish national database that reports on the species of seaweeds being produced and where any pest and disease outbreaks occur, and should be followed up with regular evaluation so that the risks could be assessed by the national government and each district, where possible; 4) provide support for farmers to invest in the biosecurity management of seaweed cultivation systems including health monitoring equipment, training on management procedures, regional facilities for farmers to use for quarantine of seedlings or crop stock and surveillance systems; 5) develop risk assessment procedures for the expansion of farms into new and disease-free areas; and 6) make clarifications on the competent authority that is tasked to regulate and support the seaweed industry.

In the Philippines, Mateo (2020) highlighted the key gaps in the legislation and policies governing the seaweed industry, which include: 1) inadequate seaweed specific frameworks; 2) insufficient binding policies for seaweeds aquaculture; 3) limited biosecurity approaches; 4) absence of competent authority; 5) limited involvement of experts in framework development; and 6) insufficient guidance for the use of the precautionary principle. The updating and inclusion of these gaps in the Code of Good Aquaculture Practices for Seaweeds (GAqP-S) by the Philippine National Standards/ Bureau of Fisheries Standards (PNS/BAFS, 2017) including biosecurity protocols on disease prevention and management should be strictly implemented.

Way Forward

The repetitive use of a limited number of cultivars for planting materials in the last several decades has resulted in seaweed biomass quality and quantity deterioration. To improve the quality of seaweed plantlets, micropropagation or in vitro clonal propagation has been developed to produce large numbers of individuals in a short period (Yokoya & Yoneshigue-Valentin, 2011). Aharon Gibor did the first attempt to cultivate seaweed explants under axenic conditions in the 1950s (Polne-Fuller, 1988), while Luhan and Mateo (2017) presented a simple method of producing propagules within a shorter period in media using inorganic nitrogen compared to Grund medium or *Ascophyllum nodosum* only. Several studies in the laboratory were also conducted to renew existing stocks and to culture propagules of *Kappaphycus alvarezii* (Dawes & Koch 1991; Dawes *et al*., 1993). Hurtado and Biter (2007) used smaller sections of seaweeds for tissue culture and then for grow-out farming. The culture of seaweed microcuttings in suspension is a more efficient and cost-effective method to produce clones of *K. alvarezii* for mass production (Luhan & Mateo, 2017). Besides, research on finding seaweed cultivars or strains from the wild populations and their progenies as a new source of planting materials is being developed (Luhan & Sollesta, 2010; Hinaloc & Roleda, 2021).

The full potential of seaweed farming in the AMSs has not been fully tapped as offshore areas of many countries are potentially emerging production sites for farming. Also, the inclusion of seaweeds in the integrated multi-tropic aquaculture (IMTA) system in offshore locations has been explored (Buck *et al*., 2018), potentially maximizing the benefits and production yields. In addition, the use of large-scale seaweed aquaculture as a tool for carbon sequestration to reduce the impacts of climate change has been recently advocated (Duarte *et al*., 2017). The SEAFDEC Aquaculture Department (SEAFDEC/AQD) has been an active partner in supporting the development of seaweed aquaculture by carrying out research and innovation activities. SEAFDEC/AQD is providing quality seaweed plantlets to seaweed growers in the Philippines, and in addition, it also provides technical support through online seminars and on-site training sessions that cater to the needs of seaweed stakeholders.

1.2 Challenges and Future Direction

In the Southeast Asian region, the productivity of the marine fishery resources comes from fishing activities either within or outside the exclusive economic zones (EEZs) of the respective countries or in high sea areas. Although the contribution of the harvests from marine fishery resources from the AMSs overall, has continuously increased during the past decades, the stock status of several commercially exploited marine species has been of major concern. This is especially true for marine pelagic fishery resources that migrate across waters of several countries and into the high sea areas, the management of which requires close cooperation among the concerned countries and with relevant international/regional organizations. In addition to the pelagic species, other important marine fishery resources that are exploited by countries in the region include the demersal fishes, reef fishes, crustaceans, mollusks, and seaweeds, which also require management interventions to ensure their sustainable utilization. Efforts to ensure the sustainable utilization of marine resources should therefore be continued and further intensified by the AMSs to make sure that the productivity of these marine fishery resources would continue to substantially contribute to achieving the target of the UN Sustainable Development Goals (SDGs) in particular the SDG 14: "life below water" which stipulates the ambition to "*conserve and sustainably use the oceans, seas and marine resources*." Therefore, to ensure the sustainable utilization of the marine fishery resources, the following aspects should be considered by the concerned AMSs, and relevant institutions and organizations:

Supporting the management of highly migratory species in cooperation with relevant RFMOs

- Management of oceanic tunas is currently undertaken by relevant RFMOs, *e.g.* the IOTC in the Indian Ocean and the WCPFC in the western and central Pacific Ocean, while the management of neritic tunas and some tuna-like species are also covered by the IOTC. The development of management recommendations for species under the competence of the RFMOs is undertaken through the data collection schemes of the respective organizations. While countries that are members of the respective RFMOs are already complying with their regulations, countries that are non-members have been encouraged to also cooperate as non-contracting parties to ensure sustainable utilization of the marine fishery resources in such RFMO areas.

- Other relevant international/regional organizations and institutions should also consider continuing their support through the conduct of stock and risk assessments of neritic tunas and tuna-like species in the Southeast Asian region. In cases where such organizations do not have specific management mandates, the results of their efforts should be conveyed to the relevant RFMOs, *e.g.* the results of the stock and risk assessments of some neritic tunas and tuna-like species undertaken by SEAFDEC in collaboration with concerned AMSs.

Improving data collection and stock assessment on marine fishery resources

- The AMSs should continue to improve their respective systems of long-term data collection on the status and production trend of major commercially important species, *e.g.* statistics on catch/landings of important marine species including the data from fishing logbooks, statistics on fishing efforts, data on catch per unit effort (CPUE), among others, as these are necessary to support the efforts in carrying out stock and risk assessments of such species.

- Relevant international/regional organizations should also consider enhancing their activities related to the development of appropriate methodologies/models, and extending the capacity building to the AMSs on stock assessment of major species under the data-poor situation of Southeast Asia, the appropriate reference points for multi-species fisheries of the region, as well as the appropriate methodologies and techniques for population genetics study. The results of these efforts are necessary to support the development of appropriate management plans of such resources.

- The AMSs and concerned agencies and institutions should consider establishing collaborative arrangements, especially with respect to undertaking studies on important shared stocks or migratory species, *e.g.* species distribution, life cycle, migration, stock assessment, genetics, among others, considering that one country alone could not come up with the complete information on such particular species.

Managing the sustainable utilization of marine fishery resources

- The AMSs should consider establishing their respective management schemes to ensure the sustainable utilization of the marine fishery resources based on the best scientific evidence and appropriate reference points, *e.g.* maximum sustainable yield, total allowable catch, total allowable effort, closed season or closed areas during spawning seasons, which should be backed up with awareness-building programs for concerned fishers and other stakeholders. Management recommendations should also consider the nature of several fishing gears that target the multi-species resources, *e.g.* purse seines, trawls, and so on.

- The existing frameworks such as the "Regional Plan of Action on Sustainable Utilization of Neritic Tunas in the ASEAN Region (RPOA-Neritic Tunas)" and the "Regional Action Plan (RAP) for Management of Short Mackerel (Indo-Pacific Mackerel) in the Gulf of Thailand Sub-region" should be promoted to enhance regional cooperation for sustainable utilization of the marine resources shared by more than one country.

Developing aquaculture technologies to reduce pressure on marine fish resources

- Appropriate aquaculture technologies for some marine species, *e.g.* marine shrimps, reef fishes, should be developed and promoted with a view to reducing the threats to natural populations and increasing production of marine species to commensurate the increasing demand. Large-scale aquaculture of seaweeds is another area that should be explored considering that this could contribute to multi-faceted benefits, *e.g.* providing products for a variety of food and non-food uses, serving as shelters and habitats for aquatic animals, and reducing carbon absorption to mitigate the impacts of climate change, among others.

2. Inland Fishery Resources

2.1 Status, Issues, and Concerns

2.1.1 Contribution of Inland Fisheries to Food Security and Poverty Alleviation

Inland fisheries play a very important role in providing food and income, particularly in developing countries, and as a source of animal protein for local communities. Inland fish is usually more affordable than the other animal food sources and is often available even in remote areas. Fish contains high essential vitamins and minerals that are important for alleviating micronutrient deficiencies, childhood stunting, and some health conditions (Bennett *et al.*, 2018). Thus, the sustainable development of inland fisheries ensures that people in the rural areas could access affordable fish as a source of their protein requirements.

Inland capture fisheries are practiced in various scales, from artisanal and subsistence, to small-scale and large-scale fisheries. This sub-sector also engages a large number of persons who work in the processing, marketing, transport, and related industries. It is estimated that about 4 million people are engaged, full- or part-time, in the primary activities of inland capture fisheries or in fish farming. Four to five times that number are employed in secondary industries such as processing, distribution, and trade (FAO, 2000).

Despite its importance, inland fisheries are usually underrepresented in national and international policy discussions, and more often than not, the role of this sector is overshadowed by the higher-profile interest in marine fisheries issues (Funge-Smith & Bennett, 2019). Due to environmental degradation, heavy fishing pressure, and conflicts with other land and water users, it is possible that the production from inland capture fisheries is on the declining trend (FAO, 2000; Funge-Smith & Bennett, 2019). This is contrary to published statistics on inland capture fisheries which show an increasing trend over the past 15 years, as such reported production volumes may not be accurate because of the deficient systems of collecting and compiling statistics especially from small-scale inland capture fisheries of the respective Southeast Asian countries.

Nonetheless, there is a need to sustain the production of inland capture fisheries, as well as improve the systems of data collection on inland fisheries in general. Future attention should therefore be directed towards protecting and rehabilitating the inland aquatic habitats in order that these could continue to provide the enabling environment for sustaining fish production for the rural populace. The profile of inland capture fisheries should also be raised by sharing information and data with the other relevant sectors that compete for the utilization of the same resources and also by providing the best information to policymakers and planners.

In the Southeast Asian region, efforts are being made to establish and promote the priority actions that would ensure the sustainable contribution of inland capture fisheries to the socioeconomic development of rural communities, especially on their food security and poverty alleviation. These are specified in the adopted Plan of Action for Sustainable Fisheries for Food Security for the ASEAN Region Toward 2030, such as:

> Plan of Action No. 45 to "*Monitor and assess the impacts of the construction/operations of man-made structures that could alter the waterways and affect migration and spawning of aquatic animals,*

particularly those at risk of overexploitation, and develop mitigating measures and appropriate conservation and management measures for such impacts through consultative processes that may involve collaboration with regional organizations";

Plan of Action No. 46 to "*Encourage coordinated planning and management on the use of inland water bodies including rivers, floodplains, wetlands, etc. through (i) resource enhancement programs; (ii) inland fisheries management programs; (iii) environmental impact assessment of structures on the aquatic resources; and (iv) restocking of indigenous and/or commercially-important aquatic animals species taking into consideration concerns on genetic diversity; and build/improve the capacity of human resources and institutions in the implementation of such programs*"; and

Plan of Action No. 47 to "*Formulate guidelines to promote the use of practical and simple indicators for inland/floodplain fisheries within the national inland fisheries management framework, to facilitate (i) timely local level fisheries management decisions with due respect to the large number of people/farmers that take part in fishing; (ii) dialogues to ensure that the inter-connectivity of fish migration path is kept as a tool for management/conservation measures; and (iii) adaptation to the effects of climate change within water bodies*"

The AMSs are therefore enjoined to mainstream the abovementioned action plans that were adopted by the authorities of the ASEAN and SEAFDEC, in the respective countries' plans and programs in order that the inland capture fisheries would continue to provide food fish and incomes to the rural fishing communities. Thus, this sub-sector could continue to contribute to food security and poverty alleviation in the AMSs.

2.1.2 Data Collection on Inland Fisheries

Data and information are the basis for proper management, while information on fish and fishers is the essential component of any fisheries. In the case of inland capture fisheries, data collection is usually weak while the compiled data are generally insufficient for generating the kinds of decisions needed. Furthermore, the catch statistics on inland fisheries are fragmented and discontinuous, contributing to the poor picture of the status of the inland fishery resources around the world.

The inland fisheries sub-sector is very complex, comprising many small-scale fishers with catches that vary not only in size but also in species which could be multiple. Meanwhile, fishing gears used are also multiple, and fishing is highly seasonal (Fitzgerald *et al*., 2018; Muthmainnah *et al*., 2020). The majority of activities in inland fisheries are not licensed, operated at semi-commercial or subsistence level, and widely dispersed along with the numerous water bodies (FAO, 2010a). Most of the catches of inland fish are unrecorded as sometimes the catch is bought directly from landing spots or informal local markets. The existence of inland landing sites or major markets is very rare, making it difficult to collect the necessary data and information. Moreover, the importance of inland catch statistics is less valued by most authorities in many countries.

In the Southeast Asian region, some nations have established their national strategies and tools with respect to gathering information on inland capture fisheries, *e.g.* inland fisheries databases had been developed in the Philippines and Indonesia. The National Stock Assessment Program (NSAP) of the Philippines makes use of a standardized method of data collection to come up with science-based policy recommendations for the conservation and management of the fishery resources in the Philippines. While for Indonesia, the One Data Policy (ODP) is the database system used for integrated data compilation. The ODP uses data processors (or enumerators) assigned to visit the respondents and to record and input the data collected (Muthmainnah *et al*., 2017b).

Another issue with regard to the collection of inland capture fisheries data and information is the high cost that could be incurred as this requires people who would be paid for their services, and expenses for the cost of transportation and communication system to be effective (FAO, 1997b). Nevertheless, SEAFDEC/IFRDMD is currently establishing a mobile application known as "Data Collection for Fishery Activities" or DACOFA for short, designed to make sure that fishers or users input the necessary data quickly and efficiently. An android system was chosen considering its convenience and ease of running the application as well as the affordability of the phones. One of the main advantages of using the data collection application is that the data could be gathered easily. The enumerators who are on the go or in a location where internet connection could be unreliable can still input the data. Offline modes would allow the fishers to store a backup of their data on their mobile devices and upload it once an internet connection is available. Automatically, the data will be recorded in the database system. By using this mobile system of data collection compared to paper-based forms, the number of data collected had been enhanced in quality and increased in quantity. This gives the option for the data collectors to use as it suits best their purposes (Muthmainnah *et al*., 2020).

Improving data collection on inland capture fisheries

Strengthening the system of collecting capture fisheries data from inland fisheries has become essential, especially in terms of information on fishery household and production. The availability of complete and valid fisheries data would facilitate the formulation of policies that benefit the inland fisheries subsector, as policymakers could optimize the utilization of such updated and real-time data in formulating policies that could be appropriately enforced according to the conditions of each inland resource location.

While the important roles of data in various aspects of fisheries, from planning, policy formulation to evaluation are recognized, the insufficiency of data on inland capture fisheries makes it difficult for policymakers to give due recognition on the importance of this sub-sector. Furthermore, when the data on the importance and socioeconomic value of inland fisheries is unrecorded or under-reported, decision-makers would have the tendency to value more the other water uses with known value to the economy over the inland fisheries sub-sector. Therefore, strengthening data collection and compilation should form part of an important component in policy formulations as good data could be used as a basis for policy-making in every program and activity. Moreover, this would also require the identification of appropriate indicators and compilation of local/indigenous knowledge to back up the information on the status of inland fishery resources. It is also a challenge to come up with novel methods of data collection, analysis, and dissemination, including the use of mobile applications for data collection, as these would make data collection more convenient.

2.1.3 Impact and Mitigation of Impacts of Water Barrier Construction on Inland Fisheries

The role of the inland fisheries sub-sector as a significant contributor to the economic development of many countries, alleviating poverty and ensuring food security in rural communities, has recently been well-recognized. Nonetheless, the sustainability of inland fisheries is dependent on the quality of the freshwater resources, aquatic habitats, and the ecosystem. In attaining such sustainability, strategies are necessary to strike a balance between maintaining the quality of the freshwater fishery resources and aquatic habitats, and utilization of the water resources by the non-fisheries sectors.

One of the important developments that have resulted in drastic impacts on the inland aquatic habitats and ecosystems is the construction of infrastructures along rivers and other bodies of water for economic development, which includes dams and weirs. Large-scale water construction projects such as hydropower structures could promote progress and development such as road construction, deforestation, mining, and urban development in the surrounding areas, but the impacts of such construction on the aquatic biodiversity of the inland water environments should also be taken into consideration (Arantes *et al*., 2019). Environment and socioeconomic impacts are generally assessed only in some areas near the infrastructure projects, *e.g.* hydropower structures, but not in the upstream and downstream areas where many people are dependent on the whole river ecosystem for their livelihoods. Dams and weirs are the main structures that could greatly improve the performance of an irrigation system as they help retain water in catchment areas during the rainy season and store water for utilization throughout the entire year for irrigating the agricultural lands. Constructing dams and weirs in rivers could therefore contribute to economic growth, poverty alleviation, crop productivity, water availability, and electricity generation. However, these water infrastructures could also cause depletion of the inland fishes because as water barriers, they could cause interruptions of the fish migration routes to complete their life cycles. When the fish route is blocked by such barriers, fishes are unable to access their habitats to complete the critical stages of their life cycle. Although species with short life cycles may be able to adapt to such conditions, but as a consequence, other fish populations in the upstream and downstream waters could be severely affected, especially in terms of their genetic makeup. Dams fragment the aquatic ecosystems by blocking the fish migration routes, sediments, nutrients, wood debris, and aquatic organisms in general (Zielinski & Freiburger, 2020). The impact of such ecosystem fragmentation generally affects not only the migratory fish species but also the non-migratory aquatic species as well.

Strategies should therefore be developed and promoted to mitigate such impacts of ecosystem fragmentation, especially through the construction of fish passage that allows the upstream waters of rivers to reconnect with the downstream waters. Fish passage or fishway facilitates fish migration from downstream to upstream or vice-versa. Fish that swim from downstream can enter the fishway inlet located downstream of a dam. Knowledge of fish passage construction has been used globally to maintain river connectivity. However, the appropriate design of fish passage must be based on the local fish that inhabit the particular water systems.

According to Bunt *et al*. (2012), the efficiency of fishways consists of attraction and passage efficiencies and constitutes the proportion of a fish stock present downstream that enters and successfully passes through the fishway with minimal delay. Effective fishway design requires extensive integration of biological and hydraulic data (Castro-Santos *et al*., 2009). As the variation of fish morphology is large among species, the hydraulic structure should consider the morphology of the fish in producing a selective passage. Several morphological characters such as body length, body shape, and structure of fins affect the fish swimming functions and performance. To be effective, a fishway must allow target fish to successfully pass, this implies that good knowledge of the swimming capabilities of the target fish is crucial for an effective and efficient fishway design (Katopodis *et al*., 2019).

Research should therefore be undertaken with the collaboration of fish passage biologists and engineers, emphasizing on the ecohydraulic concepts that consider both biological and hydraulic components relevant to fish passage. Scientists and engineers should implement the fish passage technologies that are developed from past experiments and should be annually monitored, evaluated, and adjusted during the subsequent years. When a water barrier is built, scientists should optimize the various sorting technologies and techniques below the barrier to maximize the passing efficiency of desirable fishes and remove invasive fishes (Zielinski & Freiburger, 2020).

A primary measure of a successful migration is that the aquatic animals arrive at their habitat with sufficient energy reserves to spawn successfully. Stress in fish is known to affect the timing of reproduction, behavior during spawning, and the survival of offspring (Schreck *et al*., 2001). A more generalized approach is to define the ideal fishway, which should aim for the main goal of optimizing designs that consider both biological and operational ideals. Fish passage structures should be designed on a site-specific basis and rely on comprehensive knowledge to adapt the structures to local conditions. Knowledge of fish response to certain conditions and factors that attract and repel them is also critical for a successful fish passage design (Williams *et al*., 2012). A comprehensive assessment of the applicability of the available fishways requires biological monitoring of the current fish assemblages of concern to determine the type, number, and biological characteristics of fish that are expected to pass the fishways. Different species will have different requirements for fish passage and different responses to upstream and downstream conditions.

Fishways that do not take into account the behavior and physiology of the target fish species could lead to poor passage rates of fish as their swimming ability would be quite slow and delayed, and they could end up failing to migrate during their migrating time. These conditions affect the fish survival and reproductive ability. Therefore, it is significant to understand the fish migration behavior and the swimming ability of the resident native fish species. In addition, the selection of fishway type must also be based on priorities by taking into consideration the conditions of the river and the transverse structures or barriers. In consideration of providing a fish passage or fishway, a technical solution should be arrived at ensuring that the negative impact of reduced connectivity between the upstream and downstream waters is avoided.

In the Southeast Asian region, the techniques to install effective fish passage had already been established and largely developed in Lao PDR. However, for other countries in the region, their capacity to adapt such techniques is rather still limited. Therefore, one of the initiatives promoted by SEAFDEC through the SEAFDEC/TD with support from the Southeast Asian countries, especially those in the Lower Mekong River Basin, is the implementation of activities through the Project "Implementing the Lower Mekong Fish Passage Initiative in Cambodia, Thailand, and Vietnam" from 2018 until 2021, which is being implemented by SEAFDEC/TD in collaboration with the US Department of Interior (US-DOI). Through this Project, one demonstration fish passage had been installed in each of the participating countries. The working teams in the respective participating countries, comprising personalities who have expertise in biology and engineering as well as local knowledge, had undertaken barrier assessment procedures followed by construction of the demonstration fish passage with technical assistance from the USAID in partnership with the Australian Centre for International Agricultural Research (ACIAR). The lessons learned from such activities demonstrated that partnership is crucial for the successful implementation of fish passage by engaging the local communities, local officers, local and national governments, and partner agencies (Theparoonrat, 2021).

In Indonesia, the focus has been made on raising the awareness of stakeholders on the importance of the fish ladder, and research is also currently being carried out on this aspect with the support of several donors. In addition to the benefit of fishways to facilitate general upstream and downstream migration of fish, a specific fish ladder is also necessary for certain aquatic species to maintain their survival. For example, a "fish way" for eels in Sulewana Poso functions as a refuge during eel migration, as both migrating parents (adult eel) and chicks (elvers) that go to the sea, will subsequently migrate upstream towards Lake Poso in Sulewana (Krismono, 2012). The design of the "eel ladder" in this case is special and is not the same as the "fish way" which is for other types of fishes such as salmon, but for eels, the fish ladder must be adapted to the biological nature and swimming ability of eels (Porcher, 2002).

Improving interconnectivity of inland aquatic habitats

It is recognized that in the Southeast Asian region, inland capture fisheries are increasingly threatened by riverine development projects including the construction of cross-river obstacles that create barriers to fish migration. As mentioned above, the effect of such barriers could be mitigated by the establishment of fishways or fish passages. Although fishways have been set up in many riverine development projects worldwide and helped mitigate the factors that hinder the sustainability of inland fisheries globally, it is important that the criteria for fishway design are established to cater to local aquatic species, and not just adapted from studies conducted elsewhere. Moreover, it should also be recognized that structures that create disconnectivity to habitats are not only dams and weirs, but also other structures such as roads, flood gates, and the like, that also inhibit fish movements and larval dispersal which should also be investigated, the results of which should be conveyed to relevant agencies and authorities for the development of appropriate mitigation measures.

In promoting the application of fishways or other mitigation measures, an investigation should be made to evaluate and enhance their effectiveness. Furthermore, methodologies for analyzing the cost-benefit analysis of fishways should also be developed considering the costs of construction, operation, and maintenance of the facilities; the expected increased incomes from harvests of the fishery resources; and their benefits to human health, as well as other ecosystem services that could be rendered from the improved connectivity of habitats through the fishways.

It should also be noted that a better understanding of the significant contribution of inland fishery resources on socioeconomic development could influence the direction of general development policies for aquatic systems. Specifically, a better illustration of the roles of inland fisheries in generating livelihoods and ensuring food security of people would result in sufficient consideration by authorities during the development of plans for new civil works on rivers, particularly those that concern hydropower and irrigation investments in the future.

2.1.4 Increased Production through Culture-based Fisheries and Mitigation Impacts from Aquaculture

The fisheries sector of developing countries has been seeking to take up approaches that improve environment-friendly fish production for fishery resource enhancement and/or recovery. In this regard, one of the approaches being considered is the promotion of aquaculture-based capture fisheries or culture-based fisheries (CBF) technology (De Silva, 2003; Lorenzen *et al*., 2001) that could be adopted as a form of fish resource recovery technology (Kartamihardja, 2012). Previously, CBF has been underutilized as means of increasing production from fisheries, but over time, a number of developing countries have started to recognize CBF as among the key strategies in improving food security and household economies. For example, Indonesia promotes and uses the CBF technology in its development programs related to improving fisheries production through fish restocking as well as enhancing the fishery resources (De Silva *et al*., 2015).

Culture-based fisheries in the Southeast Asian region

CBF is a form of stocking of fish that is applied in waters with fish production that is experiencing a decline or in waters with poor fish resources or when the type and stock of fish is not much or is low in diversity but has medium to high fertility. In such cases, the stocked fishes could be managed and owned individually and/or collectively by the fishers or fishers' groups, as the case may be (FAO, 2015a). Examples of great success in CBF development have been observed in small reservoirs in Sri Lanka, which has been promoting CBF since it was first introduced by Mendis and Indrasena in 1965 (De Silva *et al*., 2015). Similarly, in the case of Indonesia, after the CBF model had been implemented in small reservoirs, the fish catch from such reservoirs had significantly increased.

There are strategies for undertaking stock enhancement in lakes, reservoirs, and other inland water bodies, *e.g.* identification of suitable water bodies where fish stocks should be improved, selection of fish species to be stocked taking into consideration their biological, social, and economic aspects, and ensuring that the type of fish to be introduced must be plankton feeders and/or herbivores as the stocked fish should primarily take advantage of natural food and the planktons present in the water bodies. In addition, the development of local hatcheries to provide seeds or seedlings, establishment and promotion of regulations on fishing in stocked areas, development of co-management schemes and strengthening coordination between and among users, preparation of technical instructions for the socialization of fishers (Kartamihardja, 2015) would contribute to the sustainability of CBF. Such strategies could be adapted in other Southeast Asian countries, especially the countries that have similar conditions as those of Indonesia. However, the countries should also consider that the implementation of CBF requires institutional strengthening, clear technical guidance, well-socialized fishers, and strengthened role of seed provider institutions (Kartamihardja, 2015; Aisyah *et al*., 2019).

For centuries, Indonesia has been practicing stock enhancement and restocking of fish in inland waters as a positive fisheries management tool although the country's stock enhancement activities in the past had been technologically based and focused mainly on increasing the production of fish, resulting in limited or no demonstrated successes with respect to the impacts of the stock enhancement. Since 1999 however, the country's stock enhancement and restocking practices had been focused on the establishment of scientific evidence and included the establishment of the bio-limnological characteristics of water bodies, *e.g.* productivity and ecological niche of the water bodies, structure of fish communities, life cycle and biology of the fish stocks. In addition, fisheries co-management had been promoted in the country, focusing on the so-called local wisdom or local knowledge approach. Thus, the fish species used for stock enhancement had been closely reviewed, and the causes of successes or failures were compiled and analyzed to determine the best approach for future restocking. Nevertheless, recent successes in the country's fish stock enhancement activities have been realized through the use of species that can reproduce naturally in inland water bodies.

In Cambodia, free access to the fisheries, establishment of conservation zones, and promotion of feasible strategies have been used as the basis for assessing the need to improve CBF management. The Fishery Regulations of Cambodia allow free access to fish in any type of water body. Equally, and unlike in most other countries in the region, the communities living close to water bodies capable of practicing CBF are not organized to take up water-use management, for example, the practice of fish culture in the downstream areas. As in most countries, the key to successful CBF is for the already operational community organizations and/or their representatives to be also engaged in CBF management (Wijenayake *et al*., 2005; Nguyen *et al*., 2001; Kularatne *et al*., 2009; Saphakdy *et al*., 2009). Consequently, even though the communities existing in the vicinity of a water body could be organized into suitable CBF management units, as in the case of Cambodia and in other countries, under the existing Fishery Law of Cambodia, such units do not have the power to stop free access to fishing even immediately after stocking or restocking. The situation is further exacerbated by the fact that fishing in relatively easily accessible water bodies, is allowed to meet the daily food fish needs of the communities, a traditional and cultural practice in rural Cambodia. As such, very high proportions of the stocked seeds do not reach the table or marketable size, and in the end, the overall yield is considerably reduced.

Demarcation of the conservation zones in every water body of Cambodia, irrespective of their scientific merits, was introduced in 2010. A conservation zone is indicated very conspicuously with appropriate signages, and overall, the community abides by this regulation by refraining from fishing in the indicated zones. The area of the conservation zone in a water body could vary from 10 % to 30 % of the area at full supply level and is often wooded and/or planted with rooted vegetation such as water lilies or lotus (*Nymphea* spp.), which should not be harvested. A community belief that the conservation zones provide spawning grounds for some native species is respected, although the explicit scientific evidence in this regard is yet to come forth.

As in the case of Cambodia, any strategy that would enhance CBF production in small water bodies should comply with the existing fishery regulations. Nevertheless, the most direct and logical way of increasing production from CBF practices will be to provide time for the stocked fish seeds to grow to larger or marketable size, *i.e.* reduce the probability of recently stocked fry and/or fingerlings from being captured relatively early in their growth cycle. Accordingly, seed stocks of whatever stage at the time of purchase, which should generally be advanced fry stages or early fingerlings, be released into the conservation zones that are appropriately cordoned off using nettings or fenced. Furthermore, brush parks could also be introduced into such zones prior to stocking. The netting or fence could be gradually removed in stages, based on observations on the rate of growth of the stocked fishes. Needless to say, there are a host of unknowns that have to be researched in order to adopt this strategy to optimize fish yield from CBF in small water bodies. The application of culture-based fisheries in Cambodian waters commenced with the initiation of a project under the auspices of the Australian Centre for International Agricultural Research (ACIAR) and coordinated by the Network of Aquaculture Centres in Asia-Pacific (NACA).

Meanwhile, in Lao PDR, the CBF technology has been sustained over five to six cycles, and there is an increasing number of communities adopting CBF to augment their income and wellbeing (Phomsouvanh *et al*., 2015). In view of the successful promotion of CBF in rural communities, the Government of Lao PDR has incorporated its popularization as a major feature in the country's strategic agricultural development plans (Ministry of Agriculture and Forestry, 2010) and the recently enacted Fisheries Law of Lao PDR (Department of Livestock and Fisheries, 2010). One of the most interesting aspects of the CBF practiced in Lao PDR is the adoption of the different strategies of management and the resulting benefit of sharing protocols, which had been previously dealt with only briefly (Saphakdy *et al*., 2009). Even though communities practicing CBF are in close communication with each other and with the Central Government authorities (NACA, 2013), each of the communities has retained its management protocol and the associated benefits of the sharing procedures. This is perhaps indicative of the fact that each community is satisfied with the management style practiced, which as the data show, has resulted in increased production and monetary benefits with time.

In the case of Lao PDR, as in most countries in Asia that successfully practice CBF (*e.g.* Sri Lanka, Viet Nam), a number of exotic species had been used. However, to date, there is no explicit evidence to demonstrate that the use of exotic species in CBF practices has created negative impacts on the countries' fisheries, including in Lao PDR (Arthur *et al*., 2010). Furthermore, it should be noted that the exotic species currently used in CBF practices in Asian countries have been introduced for other purposes, including other forms of aquaculture.

The positive impacts of culture-based fisheries had been obvious in terms of enhancing production from aquatic resources in their natural habitats. Nevertheless, it is also necessary for countries to put in place appropriate management, *e.g.* appropriate harvesting regulations, equitable sharing of benefits among stakeholders, and with due consideration given to the need to avoid factors that could possibly cause a decline in conditions of the inland fishery resources, *e.g.* environmental impacts, as well as changes in biodiversity and genetic diversity of aquatic species.

Mitigating the impacts of freshwater aquaculture on the environment

It is not only culture-based fisheries in aquatic habitats that could create negative impacts on the environment and aquatic species, but freshwater aquaculture through the culture facilities also creates significant impacts on the environment if not properly managed. Aquaculture is the fastest-growing food production sub-sector and an important component in many programs on poverty alleviation and food security (Taylor *et al*., 2016). Aquaculture technologies had been developed not only to meet the demands of domestic and export-oriented markets but also as means of preserving the endemic fish for local communities. There are many fish culture techniques that could be promoted in inland water bodies, one such aquaculture system that is widely practiced in the region is cage culture where fishes are stocked and raised in cages in natural waters until marketable size. While it is already a challenge to make this aquaculture activity profitable, such system could also pose risk when the cultured species (which could be non-indigenous) escape into the natural habitats resulting in disruption of the ecological balance of the food chain, as well as changes in biodiversity and genetic diversity of the aquatic species. The rapid development of floating net cages with overfeeding has also caused a lot of leftover food to accumulate at the bottom of the water bodies (Makmur *et al*., 2020). It is estimated that around 50–70 mt of feed are spread per day in water bodies where floating net cage culture systems are practiced. Besides, fish feces also accumulate at the bottom of the water bodies, where the organic materials are then broken down by microbes exposing a lot of oxygen, making the lake bottom run out of oxygen (anoxic) and resulting in the production of toxic sulfides.

Change in the weather also causes the hydrological conditions to be altered, and as the phenomenon lifts the inner layer of the lake bottom (overturn), the fish on the surface will die massively because of depleted oxygen and poisoning. Mass fish kills then repeatedly occur, causing enormous economic losses. Because of the presence of sulfur, the increasing number of leftover deposits and metabolism occurring at the bottom of the lake will cause a slight reversal of the water mass. As the weather changes again, repealing the water mass, it becomes toxic to fish, especially those in the floating net cages.

Nevertheless, inland aquaculture or freshwater aquaculture could still be promoted toward sustainability by taking into consideration environmental and social aspects. Environmental aspects comprise the important factors that should be considered while doing aquaculture. These factors could include the natural systems which consist of fish, ecosystem quality, and biophysical environment. Nonetheless, freshwater aquaculture should not in any way, impact the freshwater environment by the adoption of good aquaculture practices. Meanwhile, the social aspects include the human system that comprises the fishers, processors and the fishing community as a whole. It is necessary that inland aquaculture practices should benefit the stakeholders from the producers to the consumers by producing wholesome cultured fish. After identifying the elements of these two aspects, a fishery management system could be adopted, including the planning of the culture systems, management, and research. Factors that could possibly cause the decline of the condition of the inland fishery resources should be avoided during freshwater aquaculture operations through the adoption of sustainable fisheries management strategies. Such freshwater aquaculture should therefore remain sustainable in order that it would be able to provide beneficial results to all stakeholders.

2.1.5 Conflicts on Use of Inland Water Resources among Various Sectors

In several countries, inland water resources are being tapped for food security, poverty alleviation, cultural services, and the preservation of biodiversity (Funge-Smith & Benneth, 2019). The future of inland fisheries is linked to the successful management of inland waters, such as rivers, swamps, lakes, and other wetlands (Funge-Smith & Benneth, 2019). In this regard, it has become necessary that inland fisheries management be considered as part of a larger environmental and socioeconomic scale that involves multistakeholder and sectors sharing and competing over the same water resources.

The inland fisheries sub-sector has been facing serious challenges between conserving fish biodiversity and fish production for food security. Management of inland fisheries through regulations and interventions can contribute to socioeconomic benefits, increase productivity, and preserve biodiversity. In developed countries, inland waters are used not only by the fisheries sector but also by other sectors that demand water (*e.g.* hydropower, agriculture, tourism, industry, or transportation), and thus, would require a lot of efforts to synergize between freshwater fisheries and other users that compete for the same inland waters through an ecosystem approach that involves cooperation among the stakeholders from all sectors to formulate the most appropriate comprehensive and inherent policies. Conflicts can arise because the users have differences in priorities, as a result, direct conflicts often exist between fisheries and other sectors because they use the same resource base, although many studies indicate that fisheries, agriculture, tourism, infrastructure, and other sectors would be able to co-exist in well-managed inland waters.

Water construction developments like dams and weirs for hydropower generation or agriculture, modification of environmental form and function, industrial and land-use practices including forestry and recreational use, can cause significant impacts on inland fisheries. Dams and weirs can block fish migration and environmental modification for some purposes can eliminate critical habitats, sedimentation, and water quality degradation. Dam construction has almost always created conflicts between energy supply and related economic interests, versus their social and environmental impacts (King *et al*., 2007).

Modern approaches to fisheries management are needed and have proved successful in promoting close integration between the fisheries and irrigation sectors. There is a

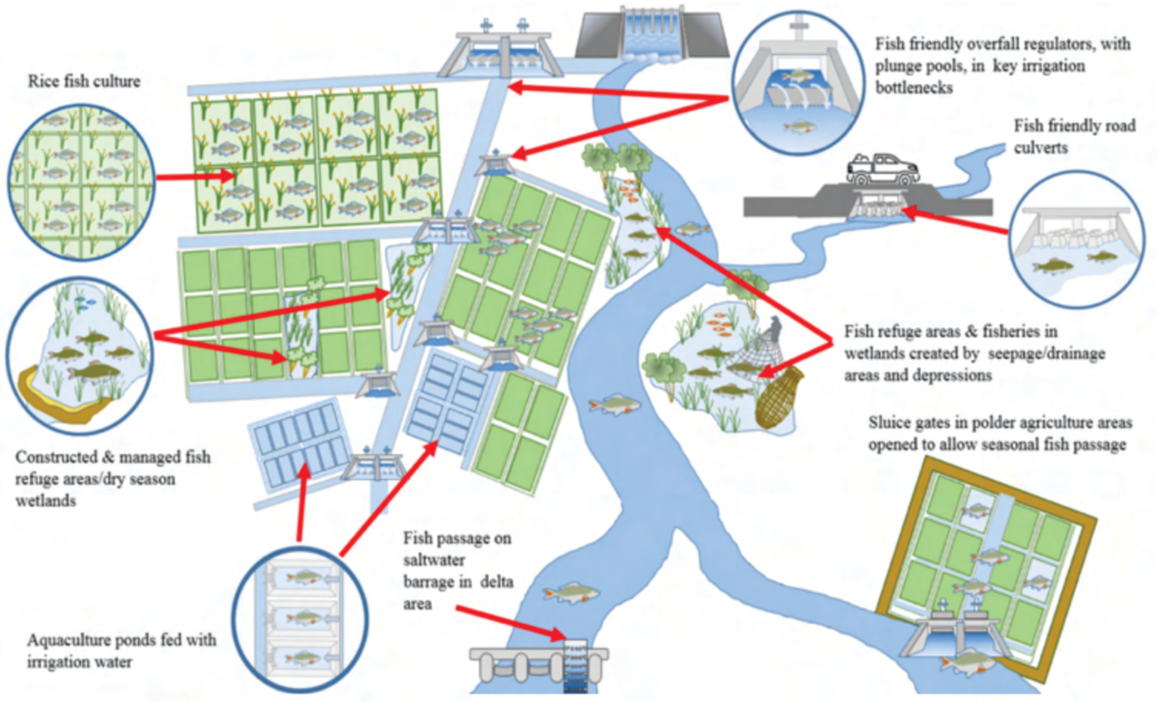


Figure 66. Fisheries, aquaculture, and irrigation integration (Gregory *et al.*, 2018)

tendency to integrate the management of natural resources in Southeast Asian countries but this would need deeper involvement of communities in the planning and co-management of natural resources. These trends offer opportunities for the various natural resources departments and sectors to work together. In order to achieve such a goal, the integration process proposed would require the collaboration of irrigation, agriculture, and fisheries sectors (**Figure 66**) (Gregory *et al*., 2018).

Fisheries stakeholders, therefore, need to interact and make alliances with the multi-stakeholder environment to minimize aquatic ecosystem damage and to promote conservation activities. Welcomme *et al*. (2010) suggested five main actions that could usually address the challenges for inland fisheries managers and stakeholders relative to the environment. These actions could aim for the establishment of policies relevant to: 1) creation of reserves or refuge areas; 2) pollution prevention and control; 3) maintaining environmental flows; 4) freedom of passage for fish; and 5) rehabilitation of degraded habitats.

Moreover, the fact that several rivers and lake basins lie within the territories of more than one country, and fish often migrate from one country to another for breeding, feeding, or refuge, any human activities in one country, *e.g.* pollution control, water obstruction, and damming, can also affect those of the other countries. Common approaches should therefore be adopted for their management using the ecosystems (river or lake basin) approach. Many international mechanisms for such collaboration exist in the form of river and lake basin commissions, but these usually address developmental issues such as water supply, power generation or navigation, and rarely consider the fisheries aspects (Welcomme *et al*., 2010)

Establishment of regulations and management of inland fishery resources

General policies are necessary for regulating and managing the inland waters properly. The establishment of regulations is very crucial, which should be raised as a priority action because inland waters produce significant economic commodities. Without proper management, the inland water resources would be gradually depleted. A better understanding of the significance of sustainable resources of inland waters could influence the direction of general policies, particularly in maintaining the relationship between fisheries and with other sectors such as agriculture, tourism, infrastructure development, and transportation.

As for the fisheries sector, the practice of managing the fishery resources in inland waters had been carried out for a long time by the local people. Such practice includes habitat conservation which is actually not something new for local people had ever since practiced conserving and protecting the fish habitats, either temporarily or permanently, and had been doing this for hundreds of years. Habitat conservation could refer to an area of public waters with a certain portion that is protected also known as reserve or refuge, as a habitat for fish to live and complete their life cycle. Currently, the existing habitat conservation has various forms, management rules, and regulations. This is because most of the management strategies had been developed by local people having different customs and cultures. In some areas, traditional fishing communities usually have their own forms of fisheries management, one of which is designating an area in inland waters as a protected area to be free from any form of fishing activities. Protection and/or prohibition of any fishing activities in such an area could be carried out continuously or temporarily. Nevertheless, in inland fisheries management, determining the areas for fishery reserves could be difficult to realize, because there are already a good number of protected areas in inland waters that have so far been managed by local communities.

In order to manage the reserved areas or refuges in a sustainable manner, it is necessary to have an institution consisting of the elements of human resources as the manager of the habitat conservation, as well as plans and rules for managing such habitats being conserved and/or protected. Moreover, in order to succeed in habitat conservation, the human resources for its management should come from the local government and representatives from the local fishing communities. The habitat conservation group should have an organizational structure consisting of a chairman, secretary, and members.

2.2 Challenges and Future Direction

The importance of inland capture fisheries to food security, as well as improved livelihoods and socioeconomic well-being of the Southeast Asian countries, is well recognized. The inland fisheries sector also contributes to recreational services, biodiversity conservation, and ecotourism. Nevertheless, the sector has been facing challenges brought about by competition of several sub-sectors that may result in deterioration (including disconnectivity) of the resources and habitats, as well as conflicts in the utilization of inland aquatic resources, that may continue to threaten the sustainability of inland capture fisheries. It is therefore necessary that inland fisheries should be properly and sustainably managed by the AMSs for the food security of their peoples, especially those in the rural areas. Inland fisheries also make substantial contributions towards achieving several SDGs, particularly SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 12: Sustainable Consumption and Production; and SDG 15: Life on Land. To enhance the sustainable contribution of the inland fishery resources to the socioeconomic well-being of peoples in the region, the following aspects should be considered by the AMSs and relevant institutions and organizations:

Developing new methods of data collection, analysis, and dissemination

- The AMSs and relevant organizations/institutions should consider examining new methodologies for data collection and analysis appropriate for the small-scale and multispecies characteristics of inland capture fisheries, especially coming up with data that could substantiate the socioeconomic value and the important contribution of inland capture fisheries to food security and livelihoods of people, for dissemination to planners and policymakers, not only for the fisheries but also other relevant sectors. This is considering that improvement of conventional catch/landing data collection is not always possible as it requires a large number of enumerators and high cost due to the dispersed characteristics of inland capture fisheries activities.
- The AMSs and relevant organizations/institutions should continue to pursue the development of novel and innovative methodologies, using appropriate indicators and local/indigenous knowledge, for conducting research studies on the status of inland fishery resources, taking into consideration the specificity of inland capture fisheries. Strengthening international cooperation should be explored when undertaking research studies on inland aquatic species and habitats that are transboundary, considering that one country alone could not come up with complete information on the species or habitat.
- Relevant institutions/agencies should consider developing an application-based system for mobile phones, *e.g.* in an android system, to support efficient and effective data collection from inland capture fisheries. The application should also allow offline data inputting when the internet connection is unreliable or unstable or unavailable, in order that the data could be uploaded into the database once the internet connection is restored or available.

Sustaining inland aquatic habitat conservation and restoration

- The AMSs and relevant organizations and institutions should enhance the promotion of appropriate habitat conservation and restoration measures, *e.g.* establishing fish refuge areas, as a habitat for fish to live and complete their life cycle, or deep pools; as well as appropriate management, *e.g.* by habitat conservation groups comprising members of local governments and representatives from local fishing communities, and so on. Identification of fish refuge areas could be based on the best scientific evidence including local indigenous knowledge on inland fisheries habitats in association with economically important aquatic species.
- The AMSs should consider formulating technical policies for prevention, control, and rehabilitation of habitats and their environment; investigating the carrying capacity of waters for fishery activities, including restocking, introduction, and control of alien species; and pursuing culture-based fisheries, species/genetic conservation, and conservation-based capture fisheries, with a view to supporting the sustainability of the utilization and preservation of the fishery resources and their environment

Mitigating the impacts of other sectors on the inland fishery resources

- The AMSs and relevant organizations/institutions should consider pursuing the use of appropriate designs of fishways or fish passes suitable for mitigating the impacts of cross-water obstacles on indigenous aquatic species, especially those that need upstream/downstream migration to complete their life cycles, *e.g.* anguillid eels, among others; promoting the application of fishways upon evaluating their effectiveness and investigating their cost-benefits and returns to demonstrate the benefits of fishways to fishers' incomes, food security, ecosystem services; and enhancing the awareness of policymakers, and relevant agencies and stakeholders on the ecological advantages of constructing fishways or fish passes.

- In addition to mitigating the impacts of dams and weirs on the sustainability of freshwater fishery resources, the effects of constructing other obstacles, *e.g.* roads, flood gates, that also inhibit fish movements and larval dispersal, should also be investigated. Results of such investigations should be conveyed to relevant agencies for the development of appropriate mitigation measures.

- The AMSs should enhance inter-agency coordination among their respective national agencies, *i.e.* between agencies responsible for fisheries and other agencies involved in the utilization of the inland water resources, *e.g.* irrigation, hydro-power generation. The development of measures to mitigate the impacts of cross-water infrastructures on the freshwater fishery resources is necessary and should not only be limited to the construction of fish passes but also to the proper and efficient operations of the structures, *e.g.* of irrigation weirs, hydropower dams, flood gates, to ensure that the excessive discharge of water is avoided or vice versa.

Mitigating the impacts of freshwater aquaculture on the environment

- The AMSs should promote freshwater aquaculture including culture-based fisheries with appropriate management, with due consideration given on the need to avoid factors that could possibly cause a decline in the condition of the inland fishery resources, *e.g.* environmental impacts.

- The AMSs should give due consideration to ensuring that the escape of fish from cages or other culture facilities should be prevented, as the escapees could disrupt the ecological balance of the food chain, as well as result in changes of the biodiversity and in the genetic diversity of aquatic species.

3. Aquatic Species under International Concern

3.1 Status, Issues, and Concerns

3.1.1 Sharks and Rays

The class of chondrichthyans includes the cartilaginous fishes that have skeletons primarily composed of cartilage. The chondrichthyans are divided into two subclasses: Elasmobranch (sharks and batoids (rays and skates)) and Holocephali (chimaeras). The Southeast Asian region has a rich biodiversity of elasmobranch species, and as had been recorded, there are at least 196 species of sharks, 160 species of rays, 30 species of skates, and seven chimaeras that inhabit the Southeast Asian region from freshwater environments to the deep seas (Ahmad *et al.*, 2018; SEAFDEC, 2017b; Wanchana *et al.*, 2016). New species are continuously discovered, the number of which could increase in the future, but some recorded species could turn into extinct species. The numbers of species of sharks, batoids, and chimaeras found in nine Southeast Asian countries are shown in **Figure 67**. However, several species could have been probably misidentified and still need to be confirmed. The average production of sharks and rays of Southeast Asia during 2008–2018 was approximately 62,409 mt per year and 95,265 mt per year, respectively (**Figure 68**).

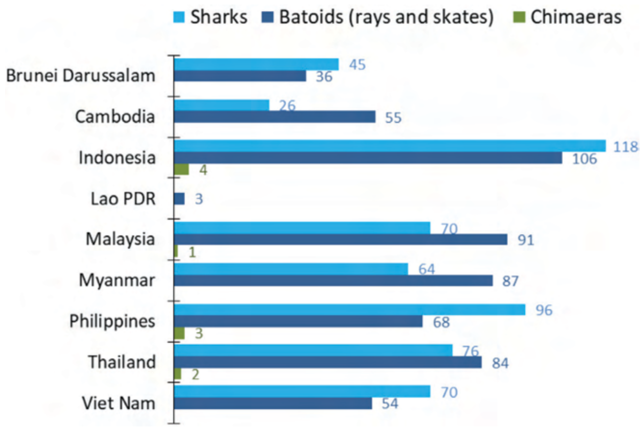


Figure 67. Number of species of sharks, batoids, and chimaeras in the Southeast Asian countries (Ahmad *et al.*, 2018, Wanchana *et al.*, 2016)

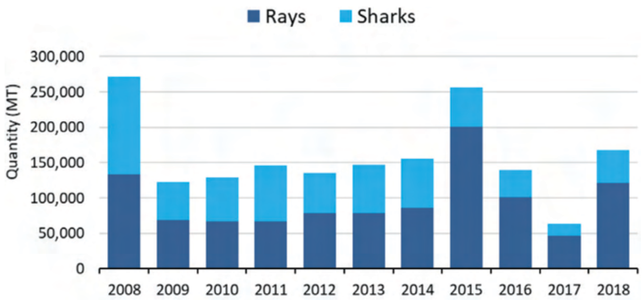


Figure 68. Production of sharks and rays of Southeast Asia from 2008 to 2018 by quantity (mt) (SEAFDEC, 2020a)

Trade of elasmobranchs

SEAFDEC/MFRDMD in collaboration with the Center for Fisheries Research of Indonesia conducted the survey on marketing and trade of sharks and rays in Java and Sumatera, Indonesia in 2018 and in Kalimantan, Indonesia in 2019. It was found that there was a high diversity of products from sharks and rays (excluding fin) such as meat, skin, cartilage, teeth, intestine, and stomach. Almost no parts of sharks and rays are wasted. The sharks and rays resources had therefore been generating livelihoods for fishers, boat owners, exporters, collectors, wholesalers, retailers, processors, and various labor workers in different levels of marketing channels including factories, ports, and transportation (Dharmadi *et al*., 2020).

In 2021, several species of sharks and rays were listed under the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Considering that some species such as the hammerhead sharks, mobula rays, and thresher sharks are common in some countries in the region, there is a need to conduct NDFs study if the products of such species are for export purposes.

Table 61. Species of sharks and rays under the CITES Appendices

Appendix I	Appendix II	Appendix III
Sawfishes	Requiem sharks	Freshwater stingrays
• *Pristidae* spp.	• *Carcharhinus falciformis*	• *Paratrygon aiereba*
	• *Carcharhinus longimanus*	• *Potamotrygon* spp.
		• *Potamotrygon constellata*
	Hammerhead sharks	• *Potamotrygon magdalenae*
	• *Sphyrna lewini*	• *Potamotrygon motoro*
	• *Sphyrna mokarran*	• *Potamotrygon orbignyi*
	• *Sphyrna zygaena*	• *Potamotrygon schroederi*
	Thresher sharks	• *Potamotrygon scobina*
	• *Alopias* spp.	• *Potamotrygon yepezi*
	Basking sharks	
	• *Cetorhinus maximus*	
	Mackerel sharks	
	• *Carcharodon carcharias*	
	• *Isurus oxyrinchus*	
	• *Isurus paucus*	
	• *Lamna nasus*	
	Eagle and mobulid rays	
	• *Manta* spp.	
	• *Mobula* spp.	
	Whale sharks	
	Rhincodon typus	
	Guitarfishes	
	• *Glaucostegus* spp.	
	Wedgefishes	
	• *Rhinidae* spp.	

Capacity building on species identification and data collection of elasmobranchs

SEAFDEC/MFRDMD in collaboration with SEAFDEC/TD had organized a series of training sessions on chondrichthyan taxonomy, biology, data collection, and report presentation in 2016, 2017, and 2019 and workshops on the identification of sharks and rays in 2017 and 2019. These capacity-building activities had been meant to enhance the knowledge and experience of the human resources responsible for collecting data and information on sharks and rays landings. Also, DNA samples had been collected from various sites throughout the region since 2013 for barcoding. A total of 145 sharks, 250 rays, and 20 skate specimens were successfully sequenced for DNA barcoding comprising 39 species of sharks, 42 species of rays, and five species of skates. Using DNA barcoding, for example, all samples identified at first as *Neotrygon kuhlii* were confirmed as *N. varidens* and *N. caeruleopunctate* according to the DNA sequence by Last *et al*. (2016). Therefore, DNA barcoding could support and verify the taxonomy of sharks and rays using morphometric and meristic data. Furthermore, some publications on the identification of sharks and rays, as well as on data collection that had been used in the capacity building activities, are listed in **Box 3** below:

Box 3. List of publications on sharks and rays identification and data collection

- Data Collection on Sharks and Rays by Species in Malaysia (August 2018-July 2019) (2021)
- Data Collection on Sharks and Rays by Species in Malaysia (August 2017-July 2018) (2021)
- Data Collection on Sharks and Rays by Species in Malaysia (August 2016-July 2017) (2020)
- Data Collection on Sharks and Rays by Species in Malaysia (August 2015-July 2016) (2017)
- Terminal Report: Regional Sharks, Rays and Skates Data Collection (2020)
- Terminal Report: Data Collection on Sharks and Rays by Species in Tawau, Sabah (Phase I) October 2018-September 2019 (2020)
- Standard Operation Procedures (SOP) for Sharks, Rays and Skates Data Collection in the Southeast Asian Waters (2017)
- Identification Guide to Sharks, Rays and Skates of the Southeast Asian Region (Volume 2) (2020)
- Identification Guide to Sharks, Rays and Skates of the Southeast Asian Region (2017)
- Guidebook to Cartilaginous Fishes of Thailand and Adjacent Waters (2019)

Stock assessment of elasmobranchs

In 2018, SEAFDEC/TD organized the "Training on Shark and Ray Stock Assessment using yield per recruit (YPR) model," and in conjunction with the regional sharks, rays, and skates data collection during 2015–2016, stock assessment of elasmobranch in Southeast Asia using yield per recruit (YPR) and spawning per recruit (SPR) analysis was undertaken in 2021 using 32 stocks of sharks and rays from six landing sites in Cambodia, Malaysia, Myanmar, and Thailand. The growth parameter estimation showed that 27 stocks had rapid growth rates, four stocks had average growth rates, and one stock of female whitespotted whipray (*Maculabatis gerradi*), the largest stingray found in this study, had a slow growth rate. The results of both YPR and SPR showed that in 5 stocks (16 %) current fishing mortality (F_{curr}) exceeded the limit biological reference points (BRPs), while 12 stocks (37 %) were acceptably exploited with F_{curr} lower than the limit BRPs, and 15 stocks (47 %) were identified as the low exploited stock with F_{curr} lower than all BRPs. For the selected stocks, the sub-region with the lowest exploitation rate was the South China Sea, represented by only one country with a specific fishing ground. Based on the study results, three management measures suggested: fishing gear adaptation, establishment of marine protected areas, and zonation improvement to adjust either age at first capture (tc) or fishing mortality (F) or both at the same time (Pattarapongpan, 2021).

Age determination of elasmobranchs

SEAFDEC/TD organized in 2019 the Training Course on Age Determination Using the Vertebra of Sharks and Rays with support from the Japanese Trust Fund. The training included lectures on the status of elasmobranch fisheries in Southeast Asia, sensitivity of the YPR model, and estimation of the growth parameters. The training also included practical sessions in groups to practice step by step including Species Identification (Species and Sex), Measurements (total length, precaudal length, and body width and weight), Vertebra Removal (boiling and bleaching to clean vertebra, vertebra staining, embedding in epoxy), and Sectioning.

Issues and Challenges

The studies and data on sharks and rays are limited in many countries in the region such as Brunei Darussalam, Myanmar, Cambodia, and Viet Nam. Only a few countries such as Indonesia, Malaysia, and Thailand have the historical data and more comprehensive studies on this group of aquatic species. Most countries in the region still record the landing of sharks and rays by groups (sharks and rays) not up to their species level. Some countries still do not include sharks and rays landings in their national statistics. Other information such as biological data, stock structure, and spatial and temporal distribution of sharks and rays are still lacking in some countries. Furthermore, there is a lack of information on trends in species composition of shark production, while utilization of shark fins and shark meat is not recorded in international trade, global utilization of products other than shark fins and shark meat, and in trade statistics.

Way Forward

For CITES, the Animals Committee had encouraged Parties to:

- provide information on any national management measures that prohibit the commercial take or trade of sharks and rays
- provide a report in accordance with their national legislation about the assessment of stockpiles of shark parts and derivatives for CITES-listed species stored and obtained before the entry into force of their inclusion in CITES to control and monitor their trade, if applicable
- inspect, to the extent possible under their national legislations, shipments of shark parts and derivatives in transit or being transshipped, to verify the presence of CITES-listed species and verify the presence of a valid CITES permit or certificate as required under the Convention or to obtain satisfactory proof of its existence; and
- continue to support the implementation of the Convention for sharks and consider seconding staff members with expertise in fisheries and the sustainable management of aquatic resources to the Secretariat.

In the Southeast Asian region, the ongoing project “Research for Enhancement of Sustainable Utilization and Management of Sharks and Rays in the Southeast Asian Region” (2020–2024) under the JTF VI Phase II project is being implemented by SEADEC/MFRDMD. The planned project activities include capacity development in taxonomy, new species/record identifications, and management of major shark species; confirmation of stock structures for at least two common species of sharks/rays (*Chiloscyllium hasseltii*, *Carcharhinus sorrah*) and one CITES-listed species (*Sphyrna lewini*) in participating countries; and development of socioeconomic studies for the collection of information on marketing and trade, and channels of sharks and rays, as well as the development of NDF documents for selected CITES-listed species that are widespread in the region.

3.1.2 Anguillid Eels

Anguillid eel resources are among the highest economically important inland fishery resources in Southeast Asia. Although Anguillid eels are migratory fish species, their life cycle is mainly spent in freshwater environments. Southeast Asia is home to several tropical Anguillid eel species (Arai *et al*., 1999). Among the total 19 species/subspecies (16 species and 3 subspecies) that exist worldwide (Pacific, Atlantic, and the Indian Ocean), 13 species/subspecies are distributed in the Indo-Pacific Region, of which eight species/subspecies inhabit in Southeast Asia region (**Figure 69**). The most economically important eel species in Southeast Asia are the *Anguilla bicolor* and *Anguilla marmorata*. In this region, six countries have anguillid eel

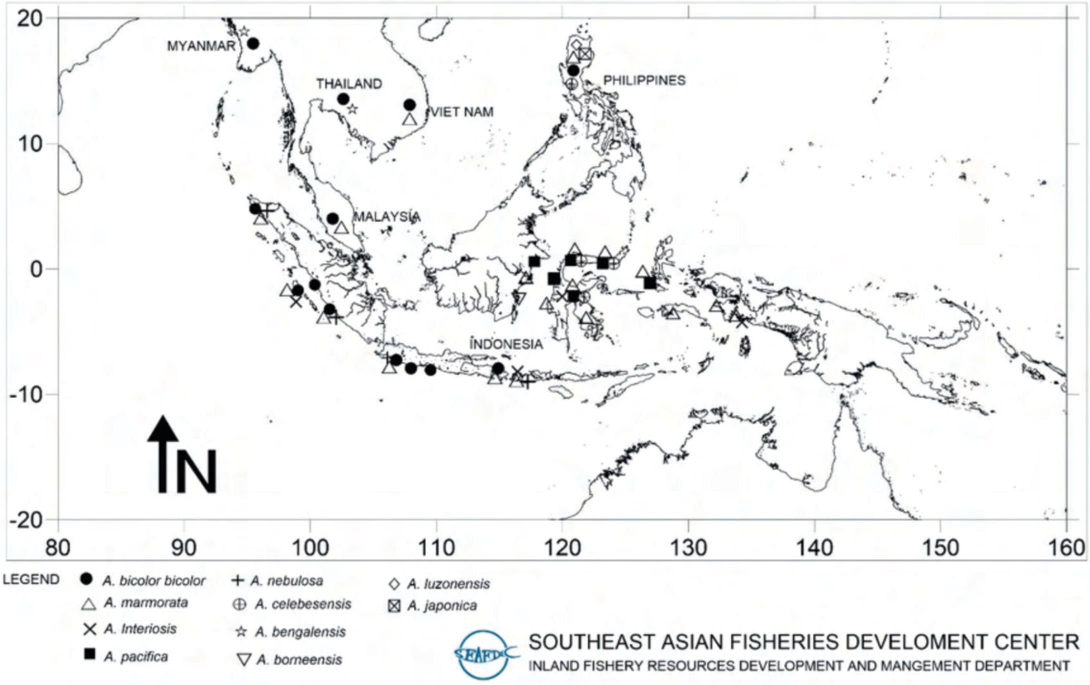


Figure 69. Distribution of *Anguilla* spp. in Southeast Asia

fisheries in place, namely: Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam.

Studies and surveys on the fisheries and aquaculture of Anguillid eels are being carried out in the Southeast Asian region to conserve the Anguillid eel resources and ensure the sustainability of their fisheries management. Such studies are meant not only to save the Anguillid eel resources from getting extinct and prevent the listing of Anguillid eel species in the CITES Appendices as the demand for tropical Anguillid eels has been increasing in the world market but also to secure the economic benefits that the future generation could gain from this commercially important commodity.

Status and Trends

In the Southeast Asian region, information on eels is still very limited, especially for the Anguillid eels. Collecting information and data statistics on the production of Anguillid eels and their utilization is therefore critical and urgent. Nonetheless, despite limited data, the current status and recent trend of eel fisheries and eel resources in the Southeast Asian region could be established (**Figure 70**) focusing on eel landings in Indonesia and the Philippines. Moreover, through the efforts of SEAFDEC/IFRDMD, some information had been obtained regarding the amount and trend of eel trading in Indonesia, Philippines, Viet Nam, Myanmar, and Thailand (**Figure 71**).

SEAFDEC/IFRDMD has also been conducting regular surveys, field observations, and interviews of relevant stakeholders from the AMSs. Although Indonesia, Myanmar, Philippines, and Viet Nam are the contributors

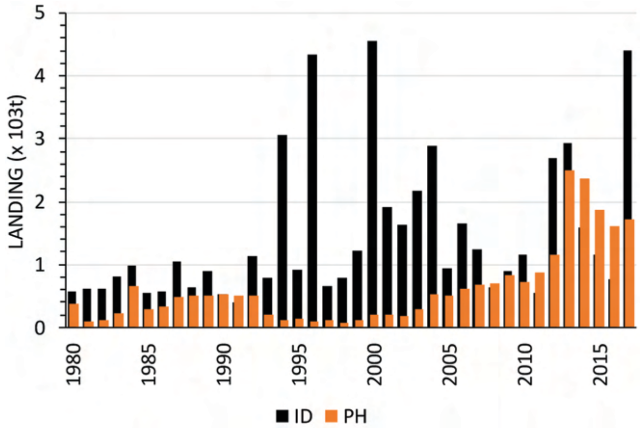


Figure 70. Annual landing data of Anguillid eels nei in Indonesia and Philippines

Source: *SEAFDEC (2019)*

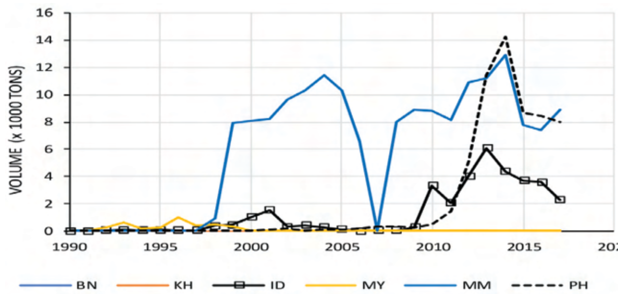


Figure 71. Annual export of eels and live elvers by some ASEAN Member States during 1990-2017

Source: *SEAFDEC (2019)*

of data from wild Anguillid eel fisheries, but the data could not be used to conclude any trend on the status or condition of the fisheries in each AMS due to a number of missing data. Nevertheless, some baseline information could be drawn to strengthen the collaborative efforts in assessing the status and trend of the tropical Anguillid eels in some AMSs, as described in the following.

Indonesia

In Indonesia, Palabuhan Ratu in Sukabumi Regency is the main fishing ground for the glass eel of *A. bicolor*, while Poso Lake and its adjacent waters are located in the Central Sulawesi Province is the main fishing ground for *A. marmorata*. The estimated catch in Palabuhan Ratu ranged from 0.09 million to 1.5 million g/year (**Figure 72**), and the seven-year data on landing indicated that the average daily landing was higher during the early and last quarter than during the other parts of the year except in 2018 when high catch occurred in the middle of the year (**Figure 73**).

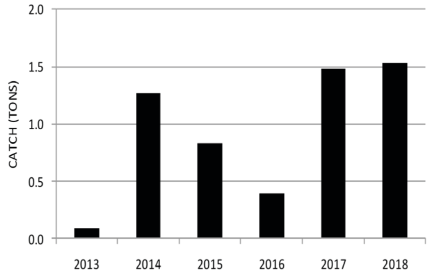


Figure 72. Annual catch of glass eels in Palabuhan Ratu, Indonesia

Source: *SEAFDEC (2019)*

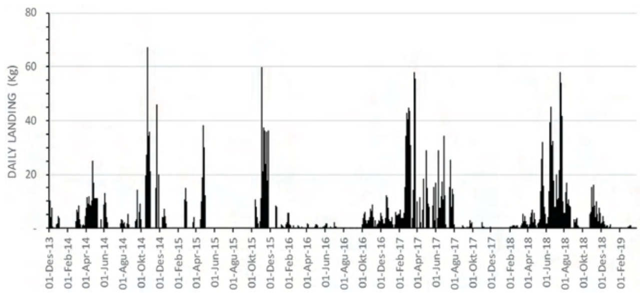


Figure 73. Daily landings of glass eels in Palabuhan Ratu, Indonesia

Source: *SEAFDEC (2019)*

In Poso Lake and its adjacent waters, the fifteen-year harvest data indicated that the volume had decreased during the last two years (**Figure 74**). Although the maximum volume of monthly harvest decreased, the data on glass eels available

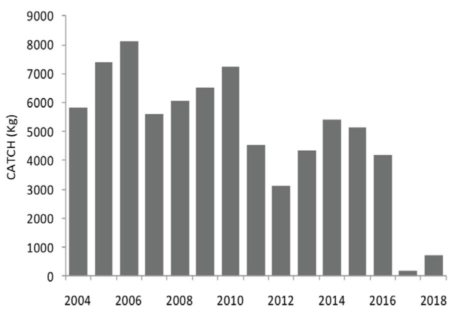


Figure 74. Annual trend of the catch of elvers and yellow eels in Poso Lake, Indonesia

Source: *SEAFDEC (2019)*

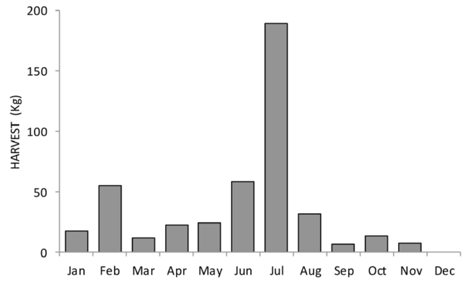


Figure 75. Monthly catch of glass eels in Poso, Central Sulawesi, Indonesia

Source: *SEAFDEC (2019)*

for 2018 indicated that the highest monthly data on harvest occurred in July with a volume of around 1900 kg, while during the other months the volume fluctuated from 7 to 55 kg/month (**Figure 75**).

Myanmar

In Myanmar, the available information from 2017 to 2018, and until early 2019 showed that the total estimated catch was relatively maintained at the same volume. However, further analysis of these data indicated that the landings of A. marmorata were more than that of *A. bicolor* (**Figure 76**). There is a regulation in Myanmar on closed season regarding inland capture fisheries (including Anguillid eel fisheries).

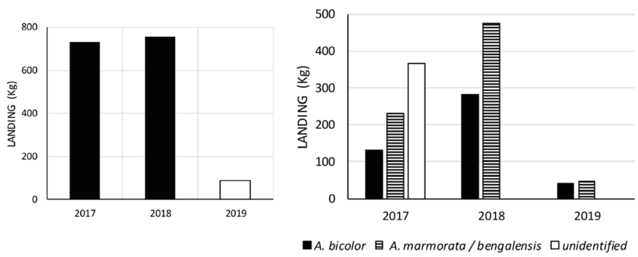


Figure 76. Annual landings of *Anguilla* spp. *(left)*, and annual landing by species *(right)* in Myanmar

Source: *SEAFDEC (2019)*

Philippines

The Philippine data on glass eels was available from 2007 to 2018 except from 2012 to 2015. The monthly data in 2007–2011 and 2016–2018 indicated the maximum catch in different months, while the highest catch occurs in November 2011 at 394 kg, and the estimated maximum CPUE of 1.9 kg/fisher was also noted in November 2011 (**Figure 77** and **Figure 78**). Although there is limited information on the catch of glass eels from the Cagayan River in the northern Philippines, the trend could be established for 2017–2019 (**Figure 79** and **Figure 80**).

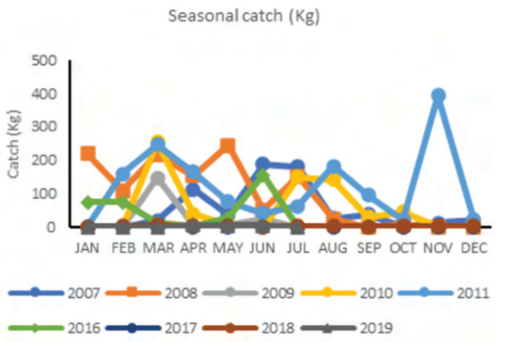


Figure 77. Seasonal catch of glass eels in the Philippines

Source: SEAFDEC (2019)

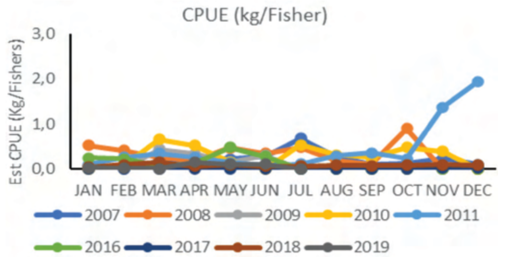


Figure 78. CPUE (kg/fisher) of glass eels in the Philippines

Source: SEAFDEC (2019)

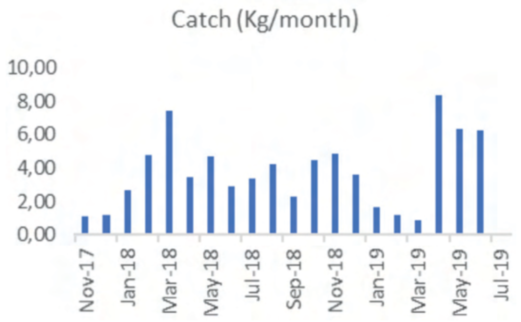


Figure 79. Catch data (kg/month) of glass eels in Cagayan River in 2017-2019

Source: SEAFDEC (2019)

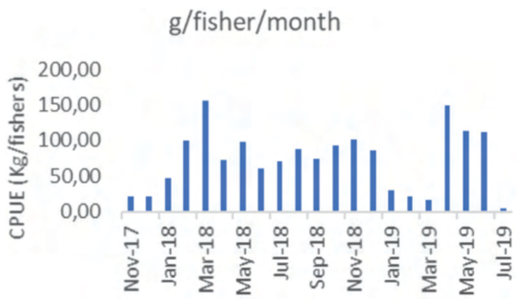


Figure 80. CPUE (g/fisher/month) in Cagayan River in 2017-2019

Source: SEAFDEC (2019)

Viet Nam

Based on the available information from January 2018 up to early 2019, there is not sufficient data to determine the status and trend based on the two-year limited data of Viet Nam. However, the catch data on glass eels and elvers/yellow eels could be established as shown in **Figure 81**.

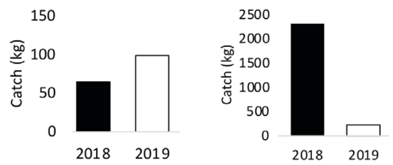


Figure 81. Catch data on glass eels *(left)* and elvers/yellow eels *(right)* of Viet Nam

Source: SEAFDEC (2019)

Issues and Challenges

- *Conservation of Anguillid Eel as Protected Species*

Restocking activities could be an option to preserve the eel stocks in nature, as it could also enhance the stakeholders' awareness of the need to conserve the eel resources. Many factors led to the deteriorating state of the habitats of eels, such as the conversion of their habitats into other development structures and installations, overexploitation, diseases, climate change, and water pollution. The construction of dams/weirs in many rivers to supply the water needed for crop irrigation and for running the hydroelectric power plants creates a blockage of the water flow. Some of the factors that threaten the Anguillid eel population include overexploitation due to the use of non-selective fishing gears and unsustainable fishing methods and practices. The absence of any regulatory management on the maximum number and the distance between the gears would lead to the decreasing populations of the Anguillid eels that migrate to the oceans.

A region-wide study on the population structure of *A. bicolor pacifica* by Marini *et al.* (2021) showed that there is no significant genetic structure of *A. bicolor pacifica* among the three sampling areas in the Southeast Asian region using mt-DNA control region sequences, suggesting that the populations are panmictic. However, such genetic study was limited to the use of a single marker, and given the pronounced genetic divergence, the genetic mosaic may indicate cryptic species. Thus, the use of other strategies like nuclear markers, such as microsatellites, or next-generation sequencing, which may be more sensitive in detecting genetic population structure, could be explored.

The Southeast Asian countries are undertaking sustainable management measures for the tropical Anguillid eel resources. Several regulations had been enforced to prohibit the exportation of eel seeds, including glass eels, to avoid overexploitation of the species. However, several issues on the conservation and management of tropical eels that have been identified by many Southeast Asian countries should be addressed. These include inadequate statistical data on utilization of the eel resources such as catch data as well as a systematic data collection scheme, limited information on eel aquaculture, insufficient data on the geographic range of the Anguillid eels, limited stock assessment studies, inadequate effective conservation and management measures, and mixed statistical data on international trade of eel species.

- *Aquaculture of Anguillid eels*

Although technically feasible, the current status of the technology for artificial seed production of *A. japonica* is not yet economically viable due to the very low survival of the larval stages in the hatchery. Research is still ongoing to address the problems in artificial seed production of the species. The culture industry of anguillid species is still dependent on the supply of glass eels in the wild. In Southeast Asia, Viet Nam, Indonesia, and Philippines are the dominant countries that culture the tropical Anguillid eels from the glass eel stage. Other countries like Myanmar and Cambodia start their culture using yellow eel, also sourced from the wild.

In the Philippines, many glass eel fishers could be found in the northern part of the country, particularly in Cagayan Province where the mouth of the Cagayan River in Aparri Municipality is the traditional fishing ground for glass eels. In the south, among the dominant sources of glass eels are the rivers in Sarangani Province, North Cotabato, and Zamboanga del Sur. Other areas in the Philippines where eels are known to be abundant are in Albay and Camarines Norte (eastern Luzon), and in Iloilo and Negros Occidental (central Philippines). Glass eel consolidators who act as middlemen collect glass eels from the fishers for eventual distribution to buyers. The number of glass eels per kilogram could range from 5,000 to 6,000 pcs.

SEAFDEC/AQD has done rearing trials in 2019 to improve growth and survival. Since eel culture from glass eels to elvers is done in tanks, site selection is not as restrictive compared to earthen pond production systems. Like any aquaculture facility, a sufficient source of good quality water is essential to enable appropriate management.

Nursery of glass eels to elvers can be done in freshwater. Rearing tanks can be circular or rectangular. Size and volume depend on target production. In the Philippines, tank sizes range from as small as 4 m^3 to 500 m^3. Tank materials vary depending on the available capital. Tanks may be made of concrete, polyethylene, and fiberglass or marine plywood lined with canvass or tarpaulin. Concrete tanks are the most common type. Volume depends on the farm area as well as the target volume of production.

Nursery farms in the Philippines have a wide range of initial stocking densities from 1 pc to 12 pcs per liter. However, stocking no more than 5 pcs per liter (1 kg glass eel in 1,000 L of water) is recommended. Natural food is the preferred feed of newly stocked glass eels. Nurseries give live blood worm, *Tubifex* sp. up to the first two weeks or until glass eels reach 0.3 g body weight before being gradually weaned to commercially formulated diets. Feeding minced octopus flesh to *A. marmorata* glass eels as an alternative starter feed to blood worms is practiced in Chinese eel farms. Brine shrimp or *Artemia* nauplii is also used when available although growth rates of glass eel given this live feed is not satisfactory.

Commercially formulated diets for eels are available from a local fish feed manufacturer. Many farms import feeds from Japan, Korea, Taiwan, and China as the growth performance is better than locally manufactured feed, based on experience by local farmers. The daily feed ration for glass eels using dry feed is at 5 % to 10 % of total biomass. Using moist feed, the daily feed ration is at 50 % of total biomass. However, depending on the water temperature and feed consumption, the feed ration should be adjusted accordingly. *A. bicolor pacifica* grow well at 30 °C while *A. marmorata* requires a temperature of 28 °C for optimal growth.

Way Forward

- *Aquaculture*

Success in the culture of eels is dependent on nutritional needs, feeds, and feeding practices. Information on the nutrient requirements of tropical anguillid eels is limited. Therefore, the development of an artificial diet for tropical anguillid eels may be based on the known nutrient requirements of closely related species. Most of the information on vitamin requirements has been derived from experiments using juveniles. Using DL-a-tocopheryl acetate as the dietary vitamin E source, a vitamin E requirement has been estimated to be between > 21.2 mg/kg diet and < 21.6 mg/kg diet. The dietary vitamin C requirement of eels, using L-ascorbyl-2- monophosphate as vitamin C source, ranges from 41.1–43.9 mg/kg diet.

Glass eels are reared to an elver size of about 15 mm (approximately 10 g) and survival may vary depending on-farm management. The most common cause of mortalities in the nursery are poor water quality management and diseases. Growth of glass eels to 15 mm elvers typically takes from 6 to 8 months. *A. bicolor pacifica* grows faster than *A. marmorata* and has better survival rates. Anguillid eels can be infected with parasites, fungi, bacteria, and viruses such as *Trichodina* spp., monogeneans, *Ichthyopthirius multifilis*, *Aeromonas* spp., *Pseudomonas* spp., *Vibrio* spp. The most common fungal disease in eel culture is Saprolegniasis, also known as water mold, skin fungus, or cotton wool disease. It is caused by a group of oomycetes fungi consisting of *Saprolegnia*, *Aphanomyces*, *Achyla*, *Pythium*, and *Dichtyuchus*. Based on researches, the three most common viruses which cause disease in Anguillid eels are Eel Virus European (EVE), Eel Virus American (EVA), and Eel Virus European X (EVEX) and Anguillid Herpesvirus 1 (AngHV1).

- *Management*

The world market demand for Anguillid eel is high, which is reported to be around 58,000 mt. Since the Japanese eel and European eel are under the control of the IUCN, the development of sustainable Anguillid eel fisheries could be an excellent prospect to increase the source of income of small-scale fishers. The eel fishery business chain could be connected institutionally between supply and demand. However, the challenge that needs to be confronted is the damage created to the watersheds threatening the sustainability of eel seeds for aquaculture, which is still capture-based. The critical point that policymakers need urgent attention to is the protection of the eel ecosystems by minimizing the injuries to lakes or watersheds, pollution of public waters, development of dams, and controlling seed consumption.

Box 4. Issues that identified during the October 2018 Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia
Inadequate statistical data on eel resource utilization and systematic data collection scheme Harmonized data on catch, species, life stages, fishing gear, and fishing effort (*e.g.* duration of fishing operation, number of fishing gears, number of fishers, biological data) should be compiled to understand the current status of glass and elver/ yellow eel fisheries, and for stock assessment
Limited information on eel farming and the quantity of glass eels used Data collection system for eel aquaculture activities (*e.g.* number of eel farmers, eel culture production, quantity of glass or elver eels used as inputs) should be established by developing and promoting registration schemes including licensing and reporting system for eel farmers
Geographic range of information on tropical anguillid eel species is insufficient Information on natural habitat, spawning ground, and migration routes are fundamental for conservation and management of the eel stocks, thus, the geographic range of the tropical anguillid eel species in the region should be examined based on the description of fishing areas, reproductive biology, and migration patterns
Limited stock assessment studies on tropical anguillid eels Stock assessment, *e.g.* using CPUE analysis as an abundance index, should be conducted for tropical anguillid eels, and that the appropriate level of exploitation and indicators for managing eel stocks should be established
Limited effective conservation and management measures for tropical anguillid eels Development of conservation and management measures for tropical anguillid eels should be established for each country taking into consideration the results of the abovementioned stock assessment studies
Mixed statistics on international trade of tropical anguillid eels Existing trade data on anguillid eel species under the UN Comtrade Database include other eel species like swamp eel and snake eel, there is a need to disaggregate such data to improve the trade statistical data reports by harmonizing trade data collection, coding, and reporting and by segregating tropical Anguillid eels from other eel species which require capacity building on eel species identification

In order to establish effective and sound conservation and management of tropical anguillid eel resources in the ASEAN region, the ASEAN Member States and SEAFDEC should address several issues that were identified during the Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia organized in October 2018 (**Box 4**).

3.1.3 Sea Cucumbers

Sea cucumbers are commercially important marine invertebrates. Dried sea cucumbers or *beche de mer* or *trepang* fetch high prices in Chinese markets, especially in Hong Kong, Taiwan, and Singapore. The prices are primarily based on the type of species, size, and processing quality. However, during the COVID-19 pandemic, sea cucumber prices went up due to the decreasing supply and high demand (Godfrey, 2019). Efforts on the sustainable management of wild sea cucumber resources have become more crucial than ever. Purcel *et al*. (2013) mentioned that the ineffective management of sea cucumber fisheries has led to the decline of stocks, especially in developing tropical countries where sea cucumber fisheries are considered small-scale. High demand and prices in global markets for luxury seafood, like *trepang*, caused extra pressure on wild harvest which is anticipated to even increase in the near future.

Sea cucumber production

- *Capture fishery*

According to the current data from FAO (2019) for Southeast Asia, only Indonesia and Philippines have shown consistent and active capture fisheries production of sea cucumbers since 1950. At present, Indonesia is the top producer of wild sea cucumbers, with a generally increasing trend since 1986 at record high harvests of more than 7,000 mt in 2005 and 2017 (**Figure 82**). Tuwo (2004) highlighted that harvesting sea cucumber rapidly increased after the 1990s, where the number of fishing vessels targeting sea cucumbers multiplied by more than 10-fold in 2003; however, the catch per unit effort (CPUE) decreased from about 500 sea cucumbers per vessel per day in 1997 to only about 33 sea cucumbers per day in early 2003. In terms of total volume, however, Indonesia still holds a significant chunk in global exports, although not consistently increasing year after year.

From 1985 to 1993, Philippines was the top producer of wild sea cucumber at 3,000–4,000 mt (**Figure 82**). This high production has contributed about 16 percent to the volume of the globally traded sea cucumbers at that time (Akamine, 2005). However, wild sea cucumber production declined

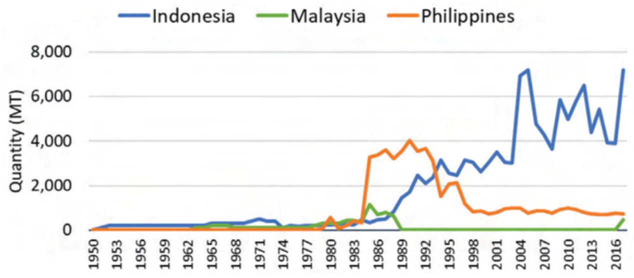


Figure 82. Capture fisheries of production of sea cucumbers in Southeast Asia by quantity (mt) from 1950 to 2017 (FAO, 2019a)

dramatically to 600–800 mt from 1998 to the present. Also, because most of the catches were considered low quality (*e.g.* low-value species, small sizes, poor processing practices), export prices have declined.

In Malaysia, there seem to be no recorded harvests since 1989 according to the FAO data, but sea cucumbers, especially those from the genus *Stichopus*, locally called *gamat*, had been constantly targeted to produce cosmetic products like soap. Although based on the local Annual Fisheries Statistics of 2009–2020, Malaysia produced less than 1,000 mt per year since 2015, those catches from such fisheries had not been reflected in global statistics, such as FAO, because the collection activity in Malaysia is only considered as "by-catch" from other fishing activities, and licenses that are specific for sea cucumbers have not yet been awarded.

Furthermore, the current FAO capture fisheries database also failed to show possible significant wild sea cucumber harvests from the other AMSs, like in Cambodia, Myanmar, Thailand, and Viet Nam, even though, all these countries have long history of sea cucumber harvesting. In Thailand, for example, the collection of sea cucumber had been practiced for many years, especially along the coasts of the Gulf of Thailand and Andaman Sea. However, despite no reliable data and information on the actual status of sea cucumber populations in the country, the decrease in the number of animals has become more apparent in recent years (Viyakarn *et al*., 2020). Because of this, the Ministry of Agriculture and Cooperatives has requested the Department of Fisheries in early 2000 for information on the status of the sea cucumber fishery in Thailand (Bussarawit & Thongtham, 1999). Among the many sea cucumber species in Thailand, 11 of the 102 listed species were considered economically important, with *Holothuria scabra* being the most valuable (Munprasit, 2009). In Viet Nam during the early 1990s, a single fishing vessel can catch about 1.4 mt of sea cucumbers during a single month's voyage from the Truong Sa Archipelago in the South China Sea. However, a recent survey in 2019 revealed that in Kien Giang Province located at the Gulf of Thailand, sea cucumber catches has declined by 60–90 percent compared to 10 years ago (Van Khanh *et al*., 2020).

- *Aquaculture*

The aquaculture of sea cucumbers started before the 1980s in China, Japan, and India. In Southeast Asia, the small-scale culture of sea cucumbers began in intertidal areas using wild-caught juveniles. However, the advent of the early hatchery technology for the sandfish *H. scabra* in the early 2000s has jumped-started some of the earliest aquaculture ventures using hatchery-bred juveniles in the region. Current FAO data reports that only Indonesia, Malaysia, and Viet Nam have aquaculture production of sea cucumbers, with Indonesia being on top with about 2,000 mt in 2015 but declined to < 500 mt starting 2016 onwards (**Figure 83**). Meanwhile, Malaysia and Viet Nam were producing less than 100 mt annually since 2011. However, actual production volumes may not have all been reflected in the FAO database.

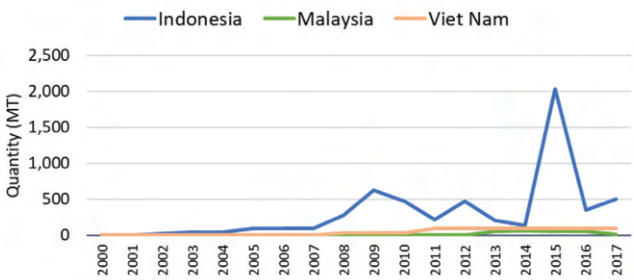


Figure 83. Aquaculture production of sea cucumbers in Southeast Asia by quantity (mt) from 2000 to 2017 (FAO, 2019a)

The farming of sea cucumbers in Indonesia has not been widely documented, although many of the aquaculture efforts and studies were published in the local Bahasa language. However, some recent studies already discussed the development of sea cucumber aquaculture in the country in the recent decade, especially after the establishment of the sandfish hatchery in 2011 at the Marine Bio Industry (LIPI) in north Lombok, Indonesia, and attempts of pond culture have been demonstrated in Sekotong, West Lombok (Indriana & Firdaus, 2020). Although it is interesting to see the FAO aquaculture data for Indonesia as early as 2005, this may suggest that early aquaculture ventures in Indonesia made use of wild-sourced juveniles for farming.

In Malaysia, the Department of Fisheries (DOF) had been conducting successful studies on hatchery production of three species of sea cucumbers, namely: *Stichopus horrens*, *S. vastus*, and sandfish *H. scabra* (Zaidnuddin, 2009; Vaitilingon *et al*., 2016). Farming activities in pens only involved the sandfish species and were carried out only in the waters of northern Sabah from Kudat to Sandakan. However, production levels are on a subsistence scale because these areas were mostly still dependent on wild-caught juveniles. Currently, the Government of Malaysia is investing in hatchery developments, and an example of this is the DOF hatchery in Bukit Malut, Langkawi Island, Malaysia which was completed in 2015. Efforts for pond culture of sandfish were also tested in partnership with private partners within the last decade but were eventually discontinued, primarily because of high investment costs but with low potential yields.

In the Philippines, hatchery production and aquaculture development for sea cucumbers, particularly for the sandfish *H. scabra*, started in the mid-2000s and intended to restore the depleted wild populations through sea ranching and stock enhancement, as well as to increase the supply of good-quality *trepang* through integrated and adaptive culture-based systems (Juinio-Meñez *et al*., 2017). Hatchery production of sandfish juveniles has been established by research institutions and universities in strategic locations in the country. SEAFDEC/AQD was also at the forefront of aquaculture technology development and refinement (SEAFDEC, 2017b). The Philippines also pioneered the development, design, and culture protocols for the ocean-based floating nursery system for sandfish using hapa nets (Juinio-Meñez *et al*., 2012; Altamirano & Noran-Baylon, 2020; Altamirano *et al*., 2021). The farming of sandfish in a sea ranch by local communities was demonstrated in a five-hectare pilot site in Bolinao, Pangasinan in northern Philippines in 2009 with technical support from the Marine Science Institute (MSI) of the University of the Philippines Diliman (Juinio-Meñez *et al*., 2013). Although the economic benefits from the demonstration site were very modest at that time, it showed the prospects of scaling up production using sea ranch networks across coastal communities in the country. The Government of the Philippines, through the Department of Science and Technology (DOST), had been investing resources for research and development on sea cucumbers as an emerging species since the early 2000s, covering fields in aquaculture development, genetics, environmental science, and biotechnology (Juinio-Meñez *et al*., 2017; Ravago-Gotanco & Kim, 2019). Recently, sea ranch sites are multiplying in the central and eastern Philippines and the southern region of Mindanao, although no commercial-scale harvests have been officially recorded yet.

Similar to most ASEAN countries, the culture of sea cucumber in Thailand has been equally challenging. Although no dedicated facilities had been made exclusively for sea cucumber production, the hatcheries at the Shrimp Genetic Improvement Center (SGIC) in Chaiya District, Surat Thani, Thailand, had been producing sandfish *H. scabra* juveniles at experimental scales from 2012 (Sithisak *et al*., 2013).

Local farmers in Viet Nam has already been producing sandfish at 2.6 to 2.8 mt per hectare of marine ponds by alternately culturing with shrimps from 2008 to 2009 (Duy, 2012). This progress was made possible because sandfish juveniles were already being produced, albeit on a small scale, in the hatcheries of the Research Institute in Aquaculture (RIA) 3 in Nha Trang, Viet Nam. Recent aquaculture efforts in Viet Nam are in the co-culture of sandfish with other high-value crops like the Babylon snail (*Babylonia areolata*) and sea grapes (*Caulerpa lentillifera*) – all with good economic prospects (Dobson *et al*., 2020).

Trade

From 1996 to 2011, Indonesia (17 %) and the Philippines (13 %) were the top two exporters of dried and frozen sea cucumbers to Hong Kong, while the remaining 70 percent was a collective of other 101 countries worldwide (To & Shea, 2012). However, the same report also showed that there was a dramatic decline in volume from 1996 versus 2011 with a 67 percent reduction for Indonesia and 40 percent reduction for Philippines. In addition, a more recent report during 2012–2016 revealed that Japan was the number one exporter of dried sea cucumbers to Hong Kong at 11.5 percent, followed by Indonesia as the second (10.4 percent), and Philippines (6.0 percent) at fourth place. Fiji came in at third with 7.2 percent and Madagascar entered fifth with 5.6 percent (To *et al*., 2018). This decline for Indonesia may be attributed to the relatively low quality of *trepang*, often classified as moderate to low, caused by poor processing methods and technology like those being traditionally used in Sulawesi, Indonesia (Aprianto *et al*., 2019).

In most Southeast Asian countries, the preferred high-value sea cucumber species are *H. scabra* and *Stichopus horrens*. The top 10 commercially important sea cucumber species in the region are listed in **Table 62**. However, most of these commercially important species were already considered endangered by the International Union of Conservation of Nature (IUCN), namely: *Thelenota ananas*, *H. lessonii*, *H. whitmaei*, *H. fuscogilva*, and *H. nobilis* (Purcell *et al*., 2014). In fact, the latter three species belonging to the teatfish group were recently included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) with strict trade regulations (Shedrawi *et al*., 2019).

Table 62. Most valuable sea cucumber species in Southeast Asia (SEAFDEC, 2017b)

Scientific Name	Common name	Local price (USD/kg, dried)
H. scabra	sandfish	*30–105*
H. nobilis/H. whitmaei	black teatfish	*17–105*
Holothuria fuscogilva	white teatfish	*17–88*
Actinopyga lecanora	stonefish	*7–66*
Stichopus horrens	dragonfish	*24–58*
Stichopus hermanni	curryfish	*58*
Actinopya echinites	deepwater redfish	*12–54*
Thelenota ananas	prickly redfish	*12–51*
Thelenota anax	amberfish	*4–51*
Bohadschia argus	leopardfish	*9–27*

The actual market prices for sea cucumbers are based not only on the type and species of the product but also on the size and processing quality. Harvested sea cucumbers are processed and dried into what is called *beche de mer* or *trepang* before they can be sold and exported. Unfortunately, the declining supply and high demand for sea cucumber have driven local fishers to harvest even the smallest size that only sells for a very meager amount. Besides, prices of such small animals even drop because of inferior processing methods. Generally, smaller sandfish (*e.g.* < 300 g) warrant a much lower overall price tag than larger (*e.g.* > 500 g) animals. When sold, the larger sandfish will elicit much higher product recovery after processing, larger marketable dry weight, and much higher premium prices of about 180 percent more than small sizes (Pardua *et al*., 2018).

Issues and Challenges

In most countries of the Southeast Asian region, wild sea cucumbers are harvested by multiple methods including simple hand collection, diving with the use of artificial breathing devices, and using fishing vessels (*i.e.* trawlers). In the past, traditional sea cucumber collection by hand-picking during low tide may have had the lowest impact on the sea cucumber population. Nonetheless, the localized impact could be multiplied exponentially when the whole village and their families are involved (Choo, 2012). In addition, such impacts are aggravated by other causes like habitat destruction, pollution, and overexploitation.

In Malaysia, the increase in total sea cucumber landings in 2011 was associated with trawlers when the modified nets were introduced to specifically target sea cucumbers. The bottom rubber rollers of traditional trawl nets were replaced by heavier bottom sinkers, which can plow deeper into the sea bottom and dig out more sea cucumbers. Such fishing vessels are also equipped with a facility for boiling sea cucumbers. Consequently, fishery statistics have shown that the population of sea cucumbers has declined in various locations in Malaysia, especially in the recent decades (Ibrahim & Zaidnuddin, 2015).

In the Philippines, the government has imposed since 2013 a regulation on sea cucumbers harvesting, at least for the sandfish. There is now a set of standards on the quality of dried sea cucumbers, and imposing a 5-cm minimum size limit for the dried sandfish product (BFAR, 2013), which translates to about 350 g of live animal. However, the implementation across the country has been relatively loose because sea cucumbers have remained to be open access resource (Jontila *et al*., 2018). Also, Deauna *et al*. (2021) indicated that the sea cucumber resource in the Philippines is in a state of overexploitation, but the capacity to enforce the necessary regulations is quite low.

In Viet Nam, sea cucumber harvesting has been done for years, especially around the island of Phu Quoc, which is at the border with Cambodia in the Gulf of Thailand. In that area, it is a common knowledge that sea cucumbers had been harvested at 3 mt per day in the past decade. However, at present, it was reduced to only 300 kg per day. Another productive area is the Truong Sa Archipelago in the South China Sea, where a single boat in the early 1990s can catch about 1.4 mt during a single month's voyage. Now, huge declines in catch have been reported because of high harvesting rates (Hung & Dinh, 2008).

Due to the declining populations of the high-value species in the recent decade, local fishers were forced to harvest even the less economically valuable species. In Thailand, for example, it was recorded that in the late 1990s, low-value species like *H. atra*, *H. leucospilota*, *Stichopus chloronatus*, *S. variegatus*, and *Bohadschia marmorata* had been harvested (Bussarawit & Thongtham, 1999). Similarly, a 2019 survey in Viet Nam showed that almost 80 percent of catch from the coasts of Kien Giang Province are now composed of medium to low-value species like *H. leucospilota* and *H. atra*, an indication that the high-value species are already overfished (Van Khanh *et al*., 2020). In Lyson Island on the central coast of Viet Nam, 30 percent of fishers are now exclusively targeting sea cucumbers at Truong Sa using scuba diving as the primary fishing method (Hung & Dinh, 2008), which will further put pressure on wild sea cucumber populations.

Conservation Efforts

The main challenge in the conservation of sea cucumber resources in the Southeast Asian region is the lack of reliable quantitative data on the existing and past status of the resource. The declining trends of populations of various sea cucumber species in the region are often reported anecdotally because of the inherent difficulty in monitoring within the vast coastal areas of the countries that are mostly archipelagic. Fortunately, many assessment studies of the natural populations of sea cucumbers have been recently conducted using inventory assessments and population genetics in Indonesia (Rahardjanto *et al*., 2020), Philippines (Ravago-Gotanco & Kim, 2019; Lal *et al*., 2021), Thailand (Ninwichian & Klinbunga, 2020; Viyakarn *et al*., 2020), and Viet Nam (Van Khanh *et al*., 2020). Data from these studies can fill in the critical gaps in the quantitative information that is relevant in the management of fisheries, aquaculture, and conservation of sea cucumber resources. It is also seen that many more such surveys and fisheries impact assessments will be conducted in the future.

Way Forward

In the past decade, there has been a significant increase in terms of research and development devoted to sea cucumbers in various fields. In Indonesia, the aquaculture for sandfish is still being evaluated in ponds at various sites in Lombok and Sulawesi (Indriana & Firdaus, 2020; Tuwo *et al*., 2020). Efforts to evaluate the economics of the small-scale fisheries in the southern islands of Indonesia had also been promoted (Prescott *et al*., 2017). An important aspect of sea cucumber processing methods and technologies have also been explored, especially in the Sulawesi area, where *trepang* production is significantly important (Aprianto *et al*., 2019). Future directions in research and development in Indonesia is seen to focus more on the seed production and farming of sea cucumbers.

Similarly, research will continue on hatchery production in Malaysia for *Stichopus horrens*, *S. vastus*, and sandfish *H. scabra* with support from the government. Further activities on the demonstration of farming in pens and ponds is seen to continue for sandfish, especially in Sabah with potential engagements of the private sector.

In the Philippines, the trend of research has been in aquaculture production, primarily for the sandfish *H. scabra*. Recent studies had focused on the refinement of hatchery and nursery techniques for sandfish through the enhancement of larval and juvenile feeds (Sibonga *et al*., 2021; Magcanta *et al*., 2021). Refinement of floating hapa nursery systems for juvenile culture have been studied by assessing the various environmental factors such as quality of biofilm as early food sources, and evaluating the best practices and operational management (Altamirano & Noran-Baylon, 2020; Altamirano *et al*., 2021; Gorospe, *et al*., 2021; Sinsona & Juinio-Meñez, 2019). Also, studies and assessments for grow-out systems in pens and sea ranching had been conducted (Dumalan *et al*., 2019; Villamor *et al*, 2021). Foreign assistance, especially in collaborative research, is also active for sea cucumbers in the country, especially those from the Australian Centre for International Agricultural Research (ACIAR). In addition, the focus of research has expanded to other sea cucumber species like *Stichopus horrens*, *Holothuria fuscogilva*, and *Phyllophorus* sp. The Government of the Philippines also established the Niche Center in the Regions (NICER) Program specific for sea cucumbers to enhance further research and development for these commodities (de la Peña, 2020). In particular, SEAFDEC/AQD in the Philippines will be continuing its efforts in optimizing seed production and farming protocols for the sandfish and targeting to publish practical manuals on sandfish production operations. Research and development studies in collaboration with national institutions and international funding partners will continue in addressing knowledge gaps in various phases of the culture of sandfish.

Although the farming of sandfish in ponds has been demonstrated for almost two decades in Viet Nam, farmers still resorted to the culture of shrimps because of relatively shorter culture periods and higher profits. Recently, aquaculture in ponds using multiple species has shown some very good prospects and increased income by integrating sea grape (*Caulerpa lentillifera*) and Babylon snail (*Babylonia areolata*) into the culture with the sandfish *H. scabra* (Dobson *et al*., 2020). Future efforts on sea cucumber aquaculture will be towards the diversification of farming methods, whether intercropping among various species or co-culture in the same culture pond. Also, there have been advancements in the hatchery technology for sandfish by using micro-algae concentrates in larval rearing of sandfish in the hatchery, which can significantly reduce the overall operational and production costs (Duy *et al*., 2016).

In Thailand, the current research on sea cucumbers seems to focus more on the physiological aspects like the study on the functions of sex steroids in gonad maturation and neurotransmitters in larval development and growth (Thongbuakaew *et al*., 2021; Nontunha *et al*., 2020). Research on aquaculture of sea cucumber is being conducted including those that evaluated the co-culture trials for sandfish with red tilapia in experimental inland tanks (Sithisak *et al*., 2013). Recent research also focused on some bioactive compounds from sea cucumbers with potential medical applications, particularly for critical diseases like cancer (Yurasakpong *et al*., 2020) and Parkinson’s disease (Chalorak *et al*., 2018).

The Southeast Asian region has seen some promising developments in sea cucumber resources in the past few years. With the increasing demand for sea cucumber products, more efforts are now being dedicated to the aquaculture and farming of these species and would continue in the coming decades. The preliminary results of pilot farming sites in countries like the Philippines, Malaysia, and Indonesia are viewed to increase and scale up, while production of sandfish in ponds of Viet Nam is bound to increase even more. Meanwhile, efforts on establishing accurate statistics on wild sea cucumber resources in the region will be instrumental in implementing the crucial conservation and management interventions of the threatened wild stocks across Southeast Asia.

3.1.4 Seahorses

Seahorse trade is significant in Southeast Asia for traditional Chinese medicine (TCM) and thus, seahorses are being exported mainly to Hongkong Specialist Administrative Region (SAR), Taiwan, and mainland China (Foster *et al*., 2017; Foster *et al*., 2021; Kuo *et al*., 2018; Stocks *et al*., 2019). Seahorses *Hippocampus* spp. were among the first marine species to come under global restrictions listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). All seahorses are allowed for export provided that the specimens are sourced sustainably and legally within CITES rules. Nevertheless, the global trade of seahorses from 2016–2017 defied export bans under the

CITES action and national legislations of countries with Thailand followed by Philippines as the top sources of dried seahorses (95 %) exported to Hong Kong SAR based on interviews with traders in Hong Kong SAR (Foster *et al*., 2019). According to CITES data, two-thirds of live trade from 2005–2014 went to the USA and 11 % to France. Seahorses born in captivity to wild parents—and traded live—made up 90 % of reported wild exports in the CITES database for 2008–2014.

Issues and Challenges

Exploitation for trade is one of the biggest threats to many species, especially for marine species (Kuo, *et al*., 2018). Effective trade regulations should facilitate the conservation of marine fish populations. However, the illegal trade of seahorses continues even with the implementation of export bans (O'Donnell *et al*., 2012; Foster & Apale, 2016; Foster *et al*., 2017). Based on field surveys carried out in 1998–2001, Philippines was confirmed as the major exporter of dried and live seahorses with an estimated catch for the dried trade at 10,000 kg/year, but highly variable estimates of catch for the aquarium trade ranged from an average of 145,000–1,000,000 seahorses/year depending on the data source (Pajaro & Vincent, 2015). Seahorses are obtained by fishers via free or compressor diving and scoop/push nets and some are caught in non-selective fishing gears including trawls, beach seines, and push nets. Information on the biology, fisheries, and trade of seahorses had been gathered in the Philippines by conducting interviews with fishers and traders across 17 coastal provinces, where fishers reported that the mean catch per unit effort was between one and ten seahorses per day for gleaners, spear/skin divers, compressor divers, and fish nets, and up to as high as 100 seahorses for micro-trawlers (Foster *et al*., 2021).

A case study of the dried seahorse trade in Thailand conducted by Kuo *et al*. (2018) suggested that the trade may be underreported based on the economic value of the seahorses and the large discrepancy between declared export volumes and catch estimates. External datasets from the CITES trade database (2004–2013), the Census and Statistics Department of Hong Kong SAR (1998–2014), and from the Customs Administration of Taiwan (1983–2014) had been used to examine the changes in international trade of seahorses from Thailand. The estimated value of dried seahorses could be worth USD 26.5 million per year versus the total declared annual export value of around USD 5.5 million and USD 1.0 million in 2013. In Viet Nam, Foster *et al*. (2017) reported the complex trade of seahorses due to large domestic consumption for seahorse wine and tonics, and a sizable amount for export. The reported purchase volume of dry seahorses was more than three times of wet seahorses.

The extraction rate of seahorses may be unsustainable and prone to overfishing due to the slow-moving, limited home ranges, and low fecundity of seahorses (Foster & Vincent, 2004; Vincent *et al*., 2011). Seahorses are sensitive to habitat destruction brought about by large-scale environmental impacts including coral bleaching, frequent typhoon, tsunami, and earthquake damages that could impede the recovery of their populations (Shimozomo *et al*., 2015; Anticamara and Go, 2017). Consequently, population recovery of seahorses may be further impeded due to habitat destruction brought about by large-scale environmental impacts including coral bleaching, frequent typhoon, tsunami, and earthquake damages (Shimozomo *et al*., 2015; Anticamara & Go, 2017). Furthermore, heavy degradation of the world's ocean caused by anthropogenic activities is harming the species and habitats across both terrestrial and aquatic ecosystems due to land-based pollution, over-extraction of resources, and changing environmental conditions (Butchart *et al*., 2010; Halpern *et al*., 2015; Maxwell *et al*., 2016; Mora *et al*., 2006). The exploitation of seahorses using trawlers combined with damaged and degraded habitats had been reported in the Philippines, Thailand, and Viet Nam (Foster & Apale, 2016; Foster *et al*., 2018; Foster *et al*., 2019; Foster *et al*., 2021; Stocks *et al*., 2019).

- *Breeding of Seahorses*

Commercial breeding of seahorses started in China in the 1970s, but technical problems on their vulnerability to diseases and correct diet were encountered. Moreover, economic failure in the 1980s led to the widespread closure of seahorse farms in China. In Southeast Asia, Viet Nam started to culture *H. kuda* (Pham, 1993). Research in India on the rearing of *H. trimaculatus* used 2,000 l tanks for broodstocks and 30 l larval rearing tanks (Murugan *et al*. 2009), while in the Philippines illuminated floating bamboo and nylon mesh cages had been used for grow-out (Garcia & Hilomen-Garcia, 2009).

The reproductive biology of seahorses has been explored by offering various types of feed. In Malaysia, Nur *et al*. (2015) reported that while post-larvae shrimp gave the best reproductive performance of *H. barbouri*, frozen mysid can also be used as feeds. In the Philippines, trials conducted at SEAFDEC/AQD showed improved reproductive performance of *H. comes* fed with mysid shrimp alone or in combination with *Artemia* and *Acetes* (Buen-Ursua *et al*., 2015). Significantly higher brood sizes and shorter parturition intervals were obtained from seahorses fed with mysid shrimps as a single diet or combined with either *Artemia* or *Acetes*. In Viet Nam, Troung (2011) reported on the successful culture of seahorses and feeding them with frozen *Mysids* and *Acetes* with some vitamins A, C, and E added to the feed to improve gonad quality and strengthen fish larvae. In India, Murugan, *et al*. (2009) observed significantly higher reproductive efficiency and a lower number of deformed larvae when *H. trimaculatus* were fed with amphipods.

Technologies developed by SEAFDEC/AQD for the larval rearing of newborn and juvenile seahorse, *H. comes* include the use of UV-treated seawater and copepods as a replacement for brine shrimp as food for newborn seahorses (Buen-Ursua *et al*., 2011). The survival of 2–6 months old juveniles has also improved with mysid shrimps and *Acetes*. In Viet Nam, Troung (2011) reported feeding the seahorse with copepod three times per day from birth to 40 days old, while enriched *Artemia* nauplii were fed to fry from 10 days onwards. In India, Murugan *et al*. (2009) used copepodites to improve survival rates in 9 and 12 days old juvenile *H. trimaculatus*. Rearing *H. barbouri* in illuminated cages showed that the seahorse fed on copepods attracted to the night illumination (Garcia *et al*., 2012). From 2009 to 2011, the demonstration project in Sulawesi, Indonesia examined the potential to culture *H. barbourin* as an ornamental marine species for coastal management and conservation efforts (Williams *et al*., 2014). Culture units (8 m × 5 m) had been constructed in the family's yard areas to enhance the incomes for the families.

- *Resource Enhancement and Management*

SEAFDEC/AQD has conducted studies on the development of resource enhancement strategies for seahorses. Results of the transport trials for 5–7 cm in stretched height (SH) juveniles suggested an optimum stocking density of 3 ind/l for transport duration up to 12 h. In the Philippines, baseline assessment of the natural stock of seahorses showed an increasing number of stocks over the years (2012–2019), wherein the communities have played important roles in the stewardship of the protected areas. Appropriate protection of the natural habitat suggests the possible sustainability of the wild seahorse stocks. The fishing communities are being involved through information, education, and communication (IEC) and hands-on training during field sampling, seed production, and nursery rearing of seahorses (Buen-Ursua, unpublished).

The exploitation of seahorses is unsustainable, prompting urgent management of the natural resources. To reduce pressure on seahorse populations, management is required for both target fishers of seahorses and incidental catch. It is necessary to reduce the impact of the large trawl fleet which is consistently catching seahorses while simultaneously destroying habitats (Stocks *et al*., 2017; Foster *et al*., 2018). Marine reserves are also essential and should be well implemented. The Project Seahorse, an interdisciplinary and international organization committed to conservation and sustainable use of the world's coastal marine ecosystems, has made significant contributions to seahorse conservation being the first to study seahorses underwater, discover their huge trade, identify the threatened status of seahorses and the first to launch the seahorse conservation measures. One conservation measure targeting behavior to mitigate wildlife trade is reducing consumers' demand. On a smaller scale, seahorse conservation efforts could include persuading artisanal fishers to catch a minimum size of > 10 cm in height and release smaller sizes (Foster & Vincent, 2005).

Thailand has several fisheries regulations already in place, but conversations with local communities indicated that enforcement of these restrictions may still be an issue. Although the Government recently enacted strict measures against illegal commercial fishing, grounding unregistered trawlers, and banning illegal fishing gear, addressing these biodiversity losses would require extensive fisheries regulations, policy action, and enforcement of existing laws to protect natural resources (Loh *et al*., 2016).

In Viet Nam, exploitation of seahorses had caused declines in their populations, thus requiring the development of adaptive management measures (Giles *et al*., 2006; Stocks *et al*., 2017). Management interventions are necessary to reduce the impact of trawl fleet that catch seahorses and destroy habitats; surveys at major ports by border guards and fisheries surveillance officers; well implemented marine reserves; and reductions in fishing effort, whether seasonally or permanently (Foster & Vincent 2016; Stocks *et al*., 2019).

Way Forward

The exploitation for the trade of seahorses has led to the decline of their wild populations. Trade regulations had been undermined by the persistence of indiscriminate extraction as target species or by bottom trawls. Seahorses are vulnerable to exploitation due to their inherent biology of being slow-moving, limited home range, and low fecundity, which is further aggravated by various natural disasters that cause damage to the habitats. Urgent management of the natural resources is required to mitigate the exploitation of this species. Strict compliance with fishing regulations must be put in place such as the banning of trawlers and other illegal fishing gear. Reducing consumers' demand may also contribute to fishing pressure by implementing a minimum size of at least 10 cm. Survey and monitoring of seahorse catch need strong cooperation with concerned authorities of the respective AMSs. Measures would certainly require prompt cooperation and willing compliance by the fishers and the implementing authorities.

3.1.5 Corals

Coral reefs are the most structurally complex and taxonomically diverse marine ecosystems on earth (Knowlton, 2001; Jackson *et al*, 2001), and occur in more than 100 countries and territories (Souter *et al*., 2020a). Although coral reefs cover only 0.2 % of the seafloor, they support at least 25 % of marine species, providing habitat for tens of thousands of associated fishes and invertebrates (Knowlton, 2001; Jackson *et al*., 2001) and underpin the safety, coastal protection, well-being, food, and economic security of hundreds of millions of people (Souter *et al*., 2020a).

Southeast Asia is the global center or the heart of this incredible diversity and a global hotspot for coral reefs (Kelleher *et al*., 1995), embracing the largest area of coral reefs, *i.e.* nearly 100,000 km^2, almost 34 percent of the world total (Tun *et al*., 2008) but cover only 2.5 % of the earth's ocean surface (Chou, 1994). The region's coral reefs hold more than 77 % or over 600 of the almost 800 reef-building coral species that have been described by scientists (Burke *et al*., 2002, Tun *et al*., 2008), and more than 1300 reef-associated fish species. Most coral reefs within Southeast Asia are located on the continental Sunda and Sahul Shelves, which also have all types of reefs, *i.e.* fringing, platform, barrier reefs, and atolls. More than 60 % of the 557 million people of Southeast Asia live within 60 km of the coasts, many of which are intrinsically linked to natural resources, especially coral reefs. Although many cities in Southeast Asia are developing and growing rapidly, most people of Indonesia, Philippines, Thailand, Viet Nam, and Cambodia remain highly dependent on coastal resources for their livelihoods, especially through fisheries (Tun *et al*., 2008).

The Coral Triangle which includes some or all of the land and seas of three Southeast Asian countries, namely: Indonesia, Malaysia, and the Philippines, and together with Papua New Guinea, Solomon Islands, and Timor-Leste, comprises a biodiversity 'hot spot' that harbors 76 % of the 798 known coral species (Veron, 2000) or at least 590 species of corals (ADB, 2014) and 37 % of the 6,000 worldwide coral reef fish species (Allen, 2008) or 2,057 species of fish (ADB, 2014). Although the Coral Triangle occupies only about 1.6 % of the world's oceans, it covers the largest single coral reef extent of nearly 73,000 km^2 or 29 % of the global coral reef area (Burke *et al*., 2012). This high diversity and extensive habitat, and its associated ecosystems support the lives and livelihoods of an estimated 120 million people.

Coral Reef Diversity

Hard coral diversity remains high in Indonesia, the Philippines, Malaysia, and Viet Nam, with almost 600 species recorded in Indonesia. Many site-specific hot spots of coral diversity (with more than 200 species of hard coral) occur in all Southeast Asian countries, with most hot spot areas occurring on deeper offshore reefs (Tun *et al*., 2008). Veron *et al*. (2009) found that the highest zooxanthellate coral species richness is found at the Bird's Head Peninsula in Raja Ampat archipelago of Indonesia, with 553 species (equivalent to 69 % of the world's total species complement) and individual reefs supporting up to 280 species/ha. Compared with some adjacent areas of the countries bordering the South China Sea, the scleractinian reef-building corals in the south of Viet Nam are diverse and more or less similar to those found in the west of Luzon (433 species) and the south of Palawan (398 species) of the Philippines, and the east of Peninsular Malaysia with 398 species (Huang *et al*., 2014).

Status of Coral Reefs in the Southeast Asian Region

The trends in hard coral cover among the different areas in the regions are varied, indicating some heterogeneity in exposure to disturbance and subsequent recovery. Average hard coral cover in all areas except in the Andaman Sea and Western Sumatera are undergoing considerable fluctuations, while the Andaman Sea and Western Sumatera subregions show a progressive increase in coral cover. In general, the cover of algae had decreased regionally, *i.e.* a substantial decrease in the Philippines until the Straits of Melaka subregion, and a progressive decline in the southern Java until the Andaman Sea subregion (Souter *et al*., 2020b).

Threats to Coral Reefs and Corals

Large-scale coral bleaching events are the greatest disturbance to the world's coral reefs. The mass bleaching event in 1998 wiped out approximately 8 % of the world's corals. Subsequent disturbance events that occurred between 2009 and 2018 have killed about 14 % of the world's corals, more than all the corals currently inhabiting the Australian coral reefs (Souter *et al*., 2020a), and killed up to 100% of corals in several areas in Indonesia (Setiasih *et al*., 2014). Since 2011, the amount of algal cover on the world's coral reefs has increased by about 20 %, mirroring the decrease in hard coral cover. However, Southeast Asia includes the Coral Triangle and contains 30 % of the world's coral reefs, and is the center of global hard coral diversity, showing distinctly different trends from all other regions. This is the only region where the coral cover is substantially greater in 2019 (36.8 %) than when the earliest data contributed to this analysis were collected in 1983 (32.8 %). Also, in contrast with other regions, the cover of algae progressively decreased, resulting in an average of five times more corals than algae on these reefs (Souter *et al*., 2020a).

The influences of local or regional disturbances, such as coral diseases, crown-of-thorns starfish outbreaks, tropical storms, overfishing and destructive fishing, and poor water quality resulting from land-based pollution have undoubtedly also played certain roles in the decline of coral reefs (Souter *et al*., 2020a). Widespread destruction of Southeast Asia's coral reefs was reported throughout the last half of the past century (McManus 1988; Wilkinson *et al*., 1993; Chou, 2000). The 2004 Asian tsunami showed that coral reefs provided some level of coastal protection by absorbing some of the tidal energy while damage to the reefs depended very much on the location and coastal bathymetry (Wilkinson *et al*., 2005). Most of the Southeast Asian reefs escaped the impact, except for those in the Andaman Sea closer to the earthquake's epicenter that started off Sumatra (Chou, 2013).

Overfishing, destructive fishing (blast and poison fishing), sedimentation and pollution, coastal development, and global climate change are threats to the coral reefs (Setiasih *et al*., 2014). Overfishing and unsustainable fishing practices have led to declining fish stocks in almost all Southeast Asia countries, pushing many fishers to resort to destructive fishing practices like the use of dynamite (bomb) and cyanide fishing to obtain food and fish to sell. This is especially evident in Indonesia, Philippines, Thailand, Malaysia (Sabah), and Viet Nam (Tun *et al*., 2008). The poison causes mortality to corals and anemones at low dosages, and brief exposure could result in long-term damage to corals and their zooxanthellae (Cervino *et al*., 2003).

Corals Listed in CITES Appendices

Appendices I, II, and III to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) contain the list of species afforded different levels or types of protection from over-exploitation. The CITES lists some species of corals including the stony corals as well as other types of corals such as the blue corals, organ-pipe corals, and deep-sea corals, as shown in **Table 63**.

Table 63. Species of corals listed in the CITES Appendices

Species	CITES Appendix*	Distribution**	Trade Purpose**
Black corals			
Antipatharia spp.	II	nearshore zones of islands and continents; cosmopolitan in distribution in temperate and tropical areas	Aquarium trade; bycatch of trawls; impacted by global climate change
Red and pink corals			
Corallium elatius (China)	III	West Coast of Japan; Western Pacific	For curio and jewelry trade; used in preparation of traditional medicines in Asian countries; impacted by dredges and trawls
Corallium japonicum (China)	III	West Coast of Japan; Western Pacific	For curio and jewelry trade; used in preparation of traditional medicines in Asian countries; impacted by dredges and trawls
Corallium konjoi (China)	III	West Coast of Japan; Western Pacific	For curio and jewelry trade; used in preparation of traditional medicines in Asian countries; impacted by dredges and trawls
Corallium secundum (China)	III	West Coast of Japan; Western Pacific	For curio and jewelry trade; used in preparation of traditional medicines in Asian countries; impacted by dredges and trawls
Blue corals			
Heliopora coerulea (Fossils are not subject to the provisions of CITES)	II	Shallow reef, exposed reef locations, reef flats and intertidal zones; Indian Ocean – eastern & western; Pacific – eastern central, northwest, southwest & western central	For curio and jewelry trade, and aquarium trade; impacted global climate change
Stony corals			
Scleractinia spp. 13 genera and 42 species (Fossils are not subject to the provisions of CITES)	II	Primary reef-builders; shallow tropical waters; restricted to shallow, well-lit, warm water with moderate to brisk turbulence and abundant oxygen; Indo-West Pacific	For curio and jewelry trade, and aquarium trade; impacted by global climate change
Organ-pipe corals			
Tubiporidae spp. 1 genera and 10 species (Fossils are not subject to the provisions of CITES)	II	Indo-West Pacific; west Pacific, to the south of Japan, west to Africa's east coast, and throughout the Red Sea	For ornaments and jewelry; popular species in aquariums and fairly tolerant of aquarium conditions; impacted by destructive fishing methods that physically devastate the reef
Fire corals			
Milleporidae spp. 1 genera and 29 species (Fossils are not subject to the provisions of CITES)	II	Tropical and subtropical waters; Indian, Pacific and Atlantic Oceans and the Caribbean Sea	For curio and jewelry trade, and the aquarium trade; impacted by global climate change
Lace corals			
Stylasteridae spp. 46 genera, 3 subgenera and 422 species (Fossils are not subject to the provisions of CITES)	II	Pacific -temperate southwest, tropical southwest & northwest Atlantic; Arctic; Antarctic sector of the Indian Ocean & Mediterranean	For curio and jewelry trade, and the aquarium trade; impacted by global climate change

**https://cites.org/eng/app/appendices.php*
***Krishnakumar* et al.*, 2013*

Challenges and Future Direction

Southeast Asia harbors some of the world's most important and extensive coral reefs. Yet they are the most threatened coral reefs in the world — a threat that imperils the social and economic well-being of millions of people. Action is urgently needed to reverse the current trends, reduce degradation, and move toward sustainable management of coastal resources. In order to reverse the decline of coral reefs, governments, the private sector, resource users, and the general public must be well-informed and assured of the value of well-managed reefs (Burke *et al*., 2002). Efforts at local, national, and international levels are therefore needed to address the problems plaguing the Southeast Asian reefs and for the successful management of the region's coral reefs (**Box 5**).

Box 5. Measures to address the issues that plague the Southeast Asian coral reefs
Management and Planning
• **Improve Management and Conservation Measures** - status of coral reefs is largely unknown, therefore mid- to long-term plans should be established to assess the coral reefs, and recommend management measures to conserve these reefs - assistance should be provided for mid- (5 years) to long- (10 years) term monitoring programs supported by in-country commitment - conservation strategies should be undertaken, focusing on safeguarding, restoring and rehabilitating marine habitats and species, should be implemented
• **Improve Management of Coastal and Fisheries Resources** - implement a broad approach for management of coral reefs that is ecosystem-based, respecting biophysical boundaries so that efforts to conserve coral reefs are comprehensive - no single management strategy will be right for all locations under all conditions, but it is crucial to enhance the participation of a variety of stakeholders - strengthen the existing although few coral reef management plans that also assess the management, performance indicator, impact evaluation, and systematic evaluation as many management plans focus more on ambient monitoring and are mostly ecological - avail of the variety of management strategies coordinated and implemented across larger spatial scales that can provide an effective network to enhance all efforts at arresting and reversing reef degradation
• **Establish a Scientific Basis for Sustainable Use and Management of High-Priority Coral Reef Areas** - the role of science in the management of coral reefs should be improved - make use of the advances in the scientific understanding of coral reef processes to support the more effective management strategies - studies to improve understanding and build a scientific basis for coral reef management at a range of locations should be carried out - facilitate better understanding of the structure, functions, ecological processes, and causes of coral reef degradation as these are important for increasing coral reef management effectiveness
• **Strengthen Research Capacity and sustainable Management of Coral Reef Resources** - resources for sustainable coral reef management should include personnel, property, and finances for supporting research activities and management - close the large gaps in knowledge by compiling the coral reef inventory data that have largely been collected as part of small projects - ensure that technical facilities and equipment for coral reef research are adequate - build capacity for existing coral reef management and research offices by modernizing research equipment, recruiting additional research personnel, and enhancing management capacity for agencies at all levels
• **Improve the Management of Existing MPAs** - build the capacity of the staff and resources for effective management notwithstanding the many marine protected areas have been created in Southeast Asia - enhance community involvement, capacity for monitoring, and enforcement of regulations
• **Expand the Protected Areas Network** - expand the extent of coastal waters under protection — whether through marine reserves or multiple-use MPAs — to protect an ecologically representative sample of the region's biodiversity, sources of larvae, and habitat essential to fisheries - ensure that MPAs can protect valuable goods and services and provide a regional resource critical to ecosystem recovery in other areas following major impacts through proper administration and management
• **Establish Management Models and Coral Reef Monitoring System** - establish a management approach to improve management and to monitor coral reef status - undertake an assessment and monitoring of coral reef status to increase awareness and to support the minimization of negative impacts to coral reef ecosystems
Interventions
• **Halt the Use of Destructive Fishing Practices** - stop the practice of destructive fishing as is most damaging to the coral reefs of Southeast Asia, putting an estimated 50 percent of the region's reefs at risk - enhance the enforcement and awareness as well as educate fishers, train them to use alternative fishing methods, and provide them with options for alternative livelihoods, which are essential components in reducing the prevalence of destructive fishing practices

Box 5. Measures to address the issues that plague the Southeast Asian coral reefs *(Cont'd)*
• **Reduce Overfishing** - mitigate the effects of overfishing by making sure that major endeavors are focused on not only on reducing fishing effort but also developing alternative livelihoods for fishers considering that overfishing is the most pervasive threat evaluated for Southeast Asia - reducing the fishing effort as this would result in higher catches per fishing hour and higher incomes for those still engaged in fishing. In some cases, no-take zones need to be established around breeding areas and fish migration paths
• **Regulate the International Trade in Live Reef Organisms** - Regulating the trade in live reef organisms must be done at many levels: at the local level, by retraining fishers on the disadvantages of using destructive fishing practices; and at the national level, testing and monitoring are essential and should be improved in both exporting and importing countries so that regulators can identify and endorse "sustainably" caught species
Management and Planning
• **Develop Tourism Sustainably** - properly implement tourism projects as these can provide important incentives for effective management and conservation of coral reefs - promote the development and use of certification schemes, accreditation, and awards that facilitate best practices for hotels, dive operators, and tour operators as these could provide incentives for eco-friendly development
• **Adopt Policies to Reduce Greenhouse Gas Emissions and Climate Change** - adopt measures that reduce coral bleaching for although most corals are already living in water temperatures near the upper limit of their tolerance, climate change threatens to push water temperatures to levels at which the frequency of mass coral bleaching and mortality could increase - take actions to reduce greenhouse gas emissions as this is critical to mitigating the effects of global climate change on Southeast Asian reefs considering the uncertainty associated with climate projections
Information and awareness
• **Improve Mapping, Monitoring, and Networking of Information on Coral Reefs to Support Better Management** - ensure that managers and communities receive the information and management tools necessary to make sound management decisions - monitoring programs on coral reefs should be linked with monitoring of population and development, including upland activities, because this integration of information is a key to understanding changes in coral reef status and to managing the resources - better organization and collection of information, including the establishment of a centralized information node, is crucial as this would enable the whole region to adopt to improved strategic approaches to protecting reefs
• Raise Public Awareness - ensure that the economic and ecological values of coral reefs and the degree to which corals are currently being damaged by human activities are widely understood - the use of models in the implementation of sustainable coral reef management is largely ineffective because of inadequate education and awareness of laws, management strategies, and general understanding of marine resource management issues - introduce to - promote major awareness-raising campaign to change behavior and create political will among the managers and general public on the aspects of policy change

3.1.6 Inland Species

Irrawaddy Dolphin

The Irrawaddy dolphin (*Orcaella brevirostris* Owen in Gray, 1866) is a species of dolphin found near the coasts and in estuaries in some parts of Southeast Asia. It is usually 1.0 m long weighing about 10 kg at birth but could reach 2.3 m long at full maturity. An adult can weigh more than 130 kg and its life span is about 26–30 years (Tun, 2007). Due to its decreasing population, urgent conservation measures are appropriate and being called for to ensure their sustainability. Irrawaddy dolphins are listed as globally endangered by the IUCN Red List Authority (Minton *et al*., 2017). The Irrawaddy dolphin is also in Appendix I of CITES which disallows all commercial trade in species that are threatened with extinction.

The Irrawaddy dolphin belongs to a group of migratory mammals in foraging habitats in the Southeast Asian region and India. The species' movement is seasonally changing depending on the water level and food supply. These freshwater dolphins inhabit the far upstream not only in nearshore marine waters, as opposed to the other members of their species. In Southeast Asia, their distribution is in the Mekong River in Cambodia and Lao People's Democratic Republic, the Ayeyarwady River in Myanmar, Mahakam in Kalimantan of Indonesia, and two brackish lagoons in Songkhla, Thailand (**Figure 84**). Spatial distribution of freshwater dolphin in East Kalimantan, Indonesia is found in Kaman, Pela Kecil, Bank of Pela Besar Rivers, Semayang, and Melintang Lakes. Freshwater dolphins have been used as ecotourism attractions for local and foreign tourists. Some efforts have been made to conserve the freshwater dolphins in East Kalimantan, Indonesia, namely: habitat protection from pollution and sedimentation, fisheries area protection to provide natural food, and increased local people's role in conserving the existence of these dolphins (Dharmadi *et al*., 2008).

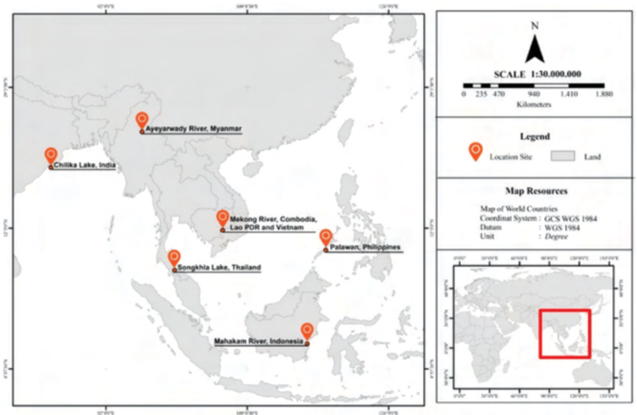


Figure 84. Distribution of Irrawaddy Dolphins in Southeast Asia

Traditional fishing in the Ayeyarwady River of Myanmar avails of a cooperation fishing between the Irrawaddy dolphins and cast-net fishers that have never been described in any world fisheries record. The Irrawaddy dolphins, which are respected by the fishers living on the shores of Ayeyarwaddy River, help the fishers in their cast-net fishing in a cooperative way. The dolphins give the signal for the fishers to row their canoes back and forth, and when the dolphins show their flukes up the water surface pointing straight to the sky, it means that fishers should stop their canoes and wait for another signal for the proper time to throw their nets (Tun, 2007).

Several factors affect the declining population of freshwater dolphins, one of which is habitat degradation. The gillnet entanglement incidents in Cambodia and electric fishing practices in Myanmar are the most critical threats that confront the dolphin population. Furthermore, dolphin-watching tourism has also become a threat to some populations due to harassment and collisions with tourists' vessels (Smith *et al*., 2007). In Mahakam, Indonesia, dolphin movements are being obstructed by large barges transporting coal. Their natural food supply that has been dwindling in their habitats also adds to the factors, since the supply of Irrawaddy dolphins' main food which includes fish, crustaceans, and squids, especially white fishes, have also decreased. Therefore, the supply of food for the dolphins in their habitats should be managed for their sustainability.

Most Southeast Asian countries had already established their respective national laws on protecting and conserving the freshwater dolphin as well as developed their own National Plan of Action (NPOA) on Conserving and Protecting Freshwater Dolphins and their Habitats. In Indonesia, the Irrawaddy dolphin has been considered a protected animal based on the Ministerial Decree of Agriculture No. 35 in 1975. This recognition has been considered during the development of the country's National Plan of Action (NPOA) on marine mammals including the freshwater dolphin based on the Ministerial Decree of Marine Affairs and Fisheries No. 79. In the Philippines, the Irrawaddy dolphin is protected under FAO 185-1 and by other legislation protecting the Malampaya Sound such as the Philippine Wildlife Act and Presidential Proclamation 342 which declared Malampaya Sound as a Protected Landscape and Seascape. Myanmar created a new protected area for the population of critically endangered Irrawaddy dolphins living in the Ayeyarwady River of central Myanmar. In 2012, the Government of Cambodia issued the sub-decree "Mekong Dolphins Managerial Protection Area" which bans and restricts any use of gillnets either entirely or during certain times of the year (WWF, 2017). Furthermore, the Government of Thailand declared that the Tarutou Island is the largest Marine National Park in Southern Thailand for biodiversity protection including that of the Irrawaddy dolphins.

Asian Arowana

The Asian Arowana has been listed in Appendix I of CITES since 1 July 1975 and is endangered by the IUCN Red List (Larson & Vidthayanon, 2019) due to its high demand and low population, and its trading is banned except for captive breeding. In Indonesia, since January 2021 as mentioned in the Ministry of Marine Affairs and Fisheries Decree, the Arowana *Scleropages formosus* is defined as a protected fish species with full protection status. The wild population of this species is low and has low fecundity, and the species has strong schooling behavior that needs specific requirements for developing the management measures necessary for their long-time survival.

The Asian Arowana or Asian bony tongue (*Scleropages formosus*, Muller & Schlegel 1840) is a valuable ornamental freshwater fish with some varieties. These species are very popular as aquarium fish due to their symbols of good luck and prosperity, influenced by the Chinese culture. There are four color variances of Arowana: Super Red, Red Tailed-Golden, Green, and Silver Asian. The highest price goes to the Arowana Super Red and the lowest to the Green Arowana.

Habitat degradation is a major threat to the declining population of Asian Arowana in Southeast Asia. Also known as dragonfish, Arowana is native in Southeast Asia and is distributed from Cambodia, Indonesia, Southern Myanmar to the Malay Peninsula, and Viet Nam (**Figure 85**).

These species inhabit the backwaters, swamps, and flooded forests, but also occur in lakes, rivers, reservoirs, and waterways. In Malaysia, they spend the day in *Pandanus* roots and other structures, and are active at night, being nocturnal, for feeding (Scott, 1976). The spawning season of *S. formosus* in Cambodia begins towards the end of the dry season (March–April) and usually takes place in approximately three months (Rowley *et al*., 2008).

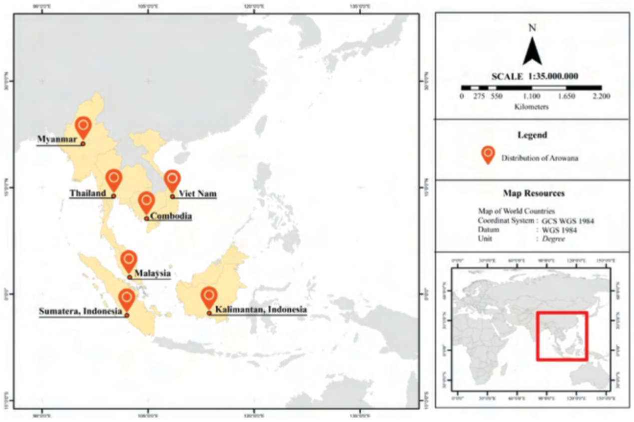


Figure 85. Distribution of Arowana in Southeast Asian

Arowana breeding and farming are being practiced in many Southeast Asian countries such as Indonesia, Malaysia, and Singapore. The First successful artificial breeding of Asian Arowana was in the Sembawang Field Experimental Station (PPD, Singapore) in 1981 (Yue *et al*., 2004). Domestication of the Super Red Arwana has been successfully carried out by the private sector in Indonesia (Mustarudin *et al*., 2012).

3.2 Challenges and Future Direction

Several aquatic species inhabiting the waters in the Southeast Asian region (both marine and inland) have been exploited through commercial fishing operations leading toward the over-exploitation of most species. Some species are also vulnerable to exploitation because of their very nature and characteristics, and the fishing practices used that threaten their continued existence, thus, requiring the establishment of measures or regulations to control their catch and trade. While the conservation and sustainable utilization of species inhabiting national waters could be effectively regulated mainly through national legislation, there are species that due to their nature, have stocks/resources that are shared among or migrate across territorial waters of two or more countries, or even undergo long-distance migration until the high sea areas. When their existence is being threatened, then such species become an international concern. During the past decades, several commercially-exploited aquatic species have been placed under international concern, *e.g.* tunas, sharks and rays, anguillid eels, sea cucumbers, among others, requiring the countries and organizations in the Southeast Asian region to cooperate in exchanging information as well as pursue the development of coordinated directions to address the emerging issues and challenges that confront the sustainability of those species. Considering therefore that several aquatic species of international concern are commercially exploited by the AMSs, the concerned countries, as well as relevant institutions and organizations, should consider the following aspects in developing their future directions on the sustainable utilization of such species:

Monitoring global discussion and facilitating the development of regional positions

- The AMSs and relevant organizations should follow-up on the results of discussions at the international fora, such as the CITES on the possible listing of commercially-exploited aquatic species into the Appendices, *e.g.* the upcoming session of the Conference of the Parties and discussion by relevant CITES Committees; recent regulations put into practice by importing countries, such as the U.S. Marine Mammal Protection Act (MMPA), among others.

- Relevant regional organizations, *e.g.* ASEAN and SEAFDEC, should consider initiating discussions among their member countries on the status of aquatic species under international concern that are subjects for discussion at relevant international fora and supporting the development of common/coordinated positions among the AMSs to be reflected at such relevant fora.

Improving data collection on aquatic species under international concern

- The AMSs should continue collecting data and information through various means, on species protected under their respective national legislations and those listed under CITES Appendices, considering that the catch data of such species are no longer compiled resulting in unavailability of data to support research studies related to the stock status of the species, and to be used as a reference during the development of Non-detriment Finding Documents required for the trade of the species (listed under the CITES Appendices) or other documents required by importing countries.

- Relevant organizations/institutions should consider sustaining their capacity building activities for relevant officers or enumerators on species identification, *e.g.* species identification based on the external morphology at landing ports, species identification by the customs for imported and exported products, based on products' various post-harvest forms (*e.g.* shark fins, dried seahorses, dried sea cucumbers).

- Relevant organizations/institutions should consider introducing and providing capacity building on appropriate methodologies for stock assessment of species under international concern to come up with information on the status and trends of such species.

- Considering the insufficient information on population, species distribution, behavior, and migration of marine mammals in the region, relevant organizations/institutions should introduce and provide capacity building activities on appropriate methodologies for the collection of such information to ensure that the species and their habitats would not be impacted by fishing activities, and on the development and management of the coastal and marine resources.

Developing aquaculture technologies to reduce pressure on species under international concern

- Relevant institutions should consider developing technologies for aquaculture of species under international concern, *e.g.* seahorses, sea cucumbers, anguillid eels, with a view to reducing the threats from fishing to the natural population of the species.

Enabling trade of aquatic species under international concern

- Relevant organizations should provide capacity building on the development of documents required for the trade of fish and fishery products, *e.g.* NDF document for the trade of species listed under the CITES Appendices, or other documentary evidence showing that the harvest of certain fish and fishery products are conducted in a way that no harm was created to the specific species that are subject to the trade-related regulations.

4. Responsible Fishing Practices

4.1 Status, Issues, and Concerns

4.1.1 Reduction of Impacts of Fishing on the Environment

The conduct of fishing activities can create impacts not only on the targeted species and resources but also on the other resources associated with the existence of the dependent species. These include the benthic communities at the bottom of the oceans where bottom-towed fishing gear is operated to target the pelagic resources. Moreover, endangered, threatened, and protected (ETP) aquatic species including sea turtles and marine mammals could also be impacted by fishing gear being operated at the surface and sub-surface water columns. Since the 1990s, several regional studies had been undertaken by researchers to determine the impacts on the resources, of fishing activities that catch juveniles or non-target species and bring about bycatch and discards. Fishing activities could also result in degradation of the environment and habitats due to the very nature of the fishing techniques used, *e.g.* use of dynamite or poison, or the inappropriate use of otherwise acceptable gear, *e.g.* using trawls in coral reefs or seagrass beds.

Impacts of Fishing on the Fishery Resources

Fishing activities can have direct and indirect impacts on the abundance and spawning potentials of the fishery resources, and possibly on population parameters, *e.g.* growth, maturation, among others. Fishing could also modify the structure of fish populations, such as size, sex ratio, species composition, not only of the target species or resources but also of their associated and dependent species, as well as other ETP species living in the ecosystems. FAO (2010a) described the impacts of fishing on biodiversity, which could occur in the following forms: (i) modification of community structure, *e.g.* trophic structure; (ii) reduction in species richness or other taxonomic diversity indices; and (iii) risk of local extinction, *i.e.* severe reduction of the impacted populations to the extent of becoming threatened, endangered, or even locally extinct.

The negative impacts of fishing activities on the fishery resources could occur in all fishing practices without appropriate fisheries management to control fishing capacity as well as IUU fishing (FAO, 2010a). Excessive fishing activities could result in overfishing categorized into three common types as shown in **Box 6** (Froese & Pauly, 2022). Increased fishing pressure beyond the level that can be tolerated by the system, for a protracted period of time, carries the risk of reaching the destructive levels of fishing. Measures to counteract overfishing should therefore be established by policymakers and promoted to the stakeholders before fishing activities reach the unsafe and unsustainable level.

Box 6. Common types of overfishing
Growth overfishing When the range of fishing mortality is above the rate of Fmax, and the loss in weight from total mortality exceeds the gain in weight due to growth.
Recruitment overfishing When the rate of fishing is above the recruitment of the exploitable stocks that becomes significantly reduced. This is characterized by a greatly reduced spawning stock and decreased proportion of mature fish in the catch. Generally, very low recruitment year after year could lead to stock collapse if prolonged and combined with poor environmental conditions.
Ecosystem Overfishing Occurs when the species composition and dominance of an ecosystem is significantly modified by fishing, *e.g.* with reductions of large, long-lived, demersal predators and increases of small, short-lived species at lower trophic levels.

Highly-efficient fishing gear, *e.g.* trawl on benthic community structures, could negatively affect the infaunal and epifaunal communities, and its effect tends to increase with the depth and stability of the substrates (Jennings & Kaiser, 1998). For example, the chronic impact of the iron dredge clam fishing includes the transformation of the benthic organism population from being a group of economic fishery species (clam) to being decomposer and scavenger (*e.g.* of the polychaetes, starfishes, sea urchins) Meanwhile, FAO (2022) summarizes the impacts of major fishing gears on the fishery resources as shown in **Box 7**.

Box 7. Impacts of major fishing gears on the fishery resources
Purse seines • Small pelagic purse seines operated with light attraction, could lead to incidental catch/bycatch of very small fishes, juveniles, or even the endangered species • The increasing practice of using encircling floating objects, including man-made FADs, increases the chances of capturing small-sized and immature fishes that aggregate around those floating objects • Incidental capture of dolphins and small cetaceans by tuna purse seines in certain fishing areas with free-swimming schools of tunas, is considered an irresponsible fishing practice, thus, special techniques have been developed to reduce bycatch of dolphins and small cetaceans, such as the Medina Panel and "back down" procedure, used to create an escape route that ensures the safety of dolphins and small cetaceans after being encircled by the purse seines
Trawls • Bottom trawls capture and frequently discard non-target sizes and species, both of fish and non-fish species
Falling nets and lift nets associated with light • The impact of lift nets and falling nets on the fishery resources depend on the selectivity of fishing net, but the major negative impact is caused by the aggregating of the fishes that are mainly attracted to the light • In addition to the target species, certain species or juvenile fishes can be attracted by the light, as well as the bycatch and sometimes discarded fishes could also be attracted, although these species could be released to safety if necessary
Gillnets and entangling nets • Gillnets and entangling nets can apply selectivity to target the size of the fish to be caught, which directly depends on the size of the mesh • Incidental catch of a number of endangered species such as turtles, sharks, marine mammals or seabirds, by gillnet and entangling net in certain areas is a matter of growing concern • Loss of gillnets generates incidences of ghost fishing, while drifting or sinking of the gear in the sea bottom is a serious concern
Traps/Pots • Juveniles or undersized species caught by traps/pots could be released alive, while the mesh size in the trap could also be adjusted to make sure that small sized individuals are released to safety • The serious issues on traps/pots are mainly focused on the lost traps/pots that would transform them into ghost gear that continues to do fishing, also known as "ghost fishing"
Longlines • Bycatch of sharks, sometimes turtles, and catch of seabirds are the main negative impacts of the pelagic and bottom longlines

During the online Meeting on Reducing Negative Impact to Ecosystem, Optimizing Energy and Fuel Consumption, and Enhancing Safety in Fishing Practices in Southeast Asia organized by SEAFDEC/TD in September 2020, the regional perspectives of the negative impacts of fishing on the fishery resources were established. Trawls had been considered by the AMSs as the topmost destructive fishing gear creating negative impacts on the fishery resources. Trawl fishing can catch various bycatch, *e.g.* juveniles and ETP species, as trawls are non-selective fishing gear whether operated in midwater and sea bottom, impacting especially on the most sensitive protected areas. In addition, some fishing gears associated with luring light except those used for squid fishing, in particular, the anchovy purse seine with luring light is also among the top destructive fishing gear which has negative impacts on the fishery resources, as operating this gear could generate catch that contains a high proportion of immature fishes. Moreover, drifting gill net with mesh size more than 10 inches has been banned in Malaysia to protect the mature size sea turtles. For the same reason, this gear with such mesh size is also not allowed to be operated in Thailand.

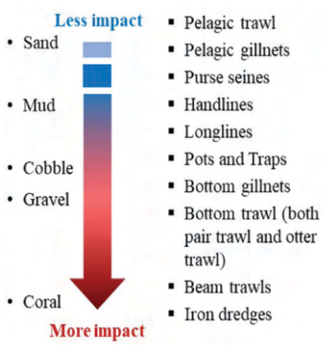
Furthermore, since ETP protected species, *e.g.* turtles, sharks, marine mammals, and seabirds can be mostly affected by some fishing gear, both active gear and ghost gear, modifications of such fishing gear, and improving the associated fishing practices could possibly reduce bycatch of the ETP species. FAO Technical Guidelines, *e.g.* International Guidelines on Bycatch Management and Reduction of Discards, Technical Guidelines to Prevent and Reduce Bycatch of Marine Mammals in Capture Fisheries, and so on, could support the development and implementation of policies and technical interventions to address the bycatch of ETP species in fishing operations.

Impacts of Fishing on the Habitats

Fishing activities can result in changes in the living and non-living environments. FAO (2010a) described the major concerns related to the impacts of fishing on the environment, especially on the bottom habitats. Bottom-towed fishing gears, such as trawls, dredges, and seines that are used to catch target species that live in, on, or in association with the seabed, can result in damages due to bottom abrasion and turbidity. Jennings & Kaiser (1998) concluded that the direct effects of such fishing vary according to the gears used and the habitats being fished, but the results usually include the scraping, scouring, and resuspending of the substratum that occurs against the background of natural disturbance. The damages are also caused by the fishing frequency, gear weight, and rigging. FAO (2022), AFMA (2022), and Seafish (2022) summarized the impacts of some fishing gears on the habitats as shown in **Box 8**.

Box 8. Impacts of some fishing gears on the habitats
Purse seines • This gear does not impact on the environment because of its characteristics, and there is also no impact on the bottom habitats except when the water depth is less than the height of the seine during the fishing operations and when the lower edge of the gear swipes the sea bottom[1]
Bottom trawls • Bottom otter trawls interact physically with the bottom sediments, which could result in removal or damage of sedentary living organisms (*e.g.* seaweeds, corals) and in the case of uneven bottom, the effect could include surface displacement of stones or other larger objects, while on flat sandy/muddy bottom, the sediments could be whirled up into the water masses and suspended • The short and long-term impacts of bottom trawl on the bottom environment is still poorly documented, thus, more research on this aspect is urgently needed1 • It is not physically possible to trawl on reef structures as significant damage can occur if sensitive habitat areas like coral reefs, sponge beds, and seagrass beds are trawled, and to ensure that these sensitive habitat areas are protected from trawling, management arrangements such as area closures are extensively used[2]
Dredges • Fishing with the use of the harvester method impacts on the species and the environment on the sea floor, for example, scallop harvester should only be used on mud and sand at the sea floor to limit its environmental impacts[2]
Pots • Impacts of pots and traps on the seabed could be limited to the light contact of the traps and minimal penetration in the seabed of the small anchors or weights that are used at the end of the operations of some gears • Although there might be some movements of the gear and the ropes on the seabed particularly in poor weather conditions, but this will not have much effect on the seabed[3]
Gillnets • Contact of gillnets on the seabed is limited to very light contact by the footrope and minimal contact from the small anchors at each end of the gear • As the gear is not towed over the seabed, very little abrasion3 could be created on the seabed

Nevertheless, the impacts of some gears on the habitat depend not only on the gear itself but also on the sediment type. Highly dynamic, soft bottoms (*e.g.* coarse sand, hydraulic dunes) may suffer limited damage even when exploited by heavy dredges including the hydraulic dredge. On the contrary, stable, hard, and highly structured habitats (such as coral reefs, seagrass beds, sponge beds) would be easily damaged.



(Garcia & FAO, 2003).

During the September 2020 Online Meeting on Reducing Negative Impact to Ecosystem, Optimizing Energy and Fuel Consumption, and Enhancing Safety in Fishing Practices in Southeast Asia, FAO Expert, Dr. Pinguo He recommended some technical measures to mitigate the impacts of fishing on the environment. These include:

- Closing the most sensitive areas for certain fishing (*e.g.* coral reefs, seagrass beds, nursery grounds)
- Fishing where the fish is, *i.e.* increase fishing efficiency and reduce fishing time
- Modify fishing gear and their operating methods
  - Light gears (reduce the weight of fishing gear on the seabed)
  - Semi-pelagic and pelagic fishing
- Replace intrusive fishing gears with the more habitat-friendly gears

Regional Policy Frameworks and Initiatives to Reduce the Impacts of Fishing on the Environment

The AMSs were of the consensus that it is necessary to obtain understanding and mitigate the impacts of fishing on fishery resources and the environment. Thus, the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 adopted by SEAFDEC and the ASEAN, stipulated the need to "*Promote sound management of fishing capacity and use of responsible fishing technologies and practices*…" (Resolution No. 7); "*Intensify research on the impacts of various fishing gear types and methods on the ecosystem and populations of aquatic animals, and develop and promote environment-friendly fishing practices,* e.g. *low impact and fuel efficient (LIFE) fishing gears/methods*" (Plan of Action No. 33), "*Mitigate bycatch and discard concerns including excessive catch of juvenile fish by promoting the adoption and implementation of relevant regional and international guidelines,* e.g. *FAO International Guidelines on Bycatch Management and Reduction of Discards*" (Plan of Action No. 34).

Box 9. Improving the selectivity of fishing gears

Fishing gear	Studies	Outcome/Constraints
Bottom trawls	• **1996:** Experiments to develop suitable Turtle Excluder Device (TED) for use in shrimp trawls, and development of the Thai Turtle Free Devices (TTFD) suitable for bottom trawl net in the Southeast Asian countries (in collaboration with the AMSs)	• Use of the Turtle Excluder Devices (TEDs) in shrimp trawl fisheries promoted in Sabah, Malaysia by the DOF Sabah and NGOs supported by DOF Malaysia
	• **2003:** Experiments to develop Juvenile and Trash Excluder Device (JTED) to reduce bycatch from shrimp trawling in Southeast Asian countries (in collaboration with the AMSs) while sorting grid was also designed to suit the bottom trawl net operated in Southeast Asia	• Enforcement of Fisheries Administrative Order No. 237 (2010) of the Philippine Bureau of Fisheries and Aquatic Resources Requiring the Installation of Juvenile and Trashfish Excluder Device (JTED) in trawls operating in Philippine waters
	• **2016:** Experiments on the use of 40 mm codend mesh size for trawl fishing in the Gulf of Thailand (in collaboration with the Department of Fisheries of Thailand)	• Enforcement of Section 67 of the Royal Ordinance on Fisheries BE 2560 (2017)
Tuna longlines	• **2004:** Experiments and promotion on the efficiency of Circle Hook (compared with J-shape hook) in longline fishing operations to mitigate the impacts of J-hook on incidental catch of sea turtles	• Since C-hooks are no longer manufactured in the region, the fishing hooks had to be ordered from outside the region where it is not convenient to order the circle hooks in small quantities
Tuna purse seines	• **2003:** Modification of the drifting fish aggregating devices (DFADs) to mitigate sea turtle mortalities in tuna purse seine fishing operations	• AMSs operate purse seines with anchored fish aggregating devices (AFAD) but it is rare to assemble the old fishing net sheet with AFAD • DFADs for tuna purse seine are deployed in the high seas, so the SEAFDEC study could be applied to support the management of tuna by RFMOs

Over the decades, SEAFDEC/TD in collaboration with the AMSs has conducted a number of experiments to improve the selectivity of several fishing gears, *e.g.* trawl, tuna longline, and tuna purse seine, as shown in **Box 9**.

From the Project "Strategies for Trawl Fisheries Bycatch Management (REBYC-II CTI)" implemented from 2013 to 2018 as a collaborative effort between SEAFDEC/TD and FAO, the lessons learned had been disseminated through the various publications that are accessible through the SEAFDEC website. Specifically, the lessons learned from the REBYC-II CTI could be summarized as follows:

- Policy, legal and institutional frameworks established or strengthened towards the establishment of area-specific trawl fisheries bycatch management plans - formulation of the fisheries management plans was facilitated while the existing mechanism of trawl fisheries management was strengthened through the application of stakeholders participatory approach under the formulation of consultative groups in local, provincial/region and national level, *e.g.* Samar Sea Fisheries Management Plan of the Philippines
- Resource management and fishing operations enhanced - led to the adoption of more selective fishing gear and practices for implementation of the zoning of fishing areas, through the studies on trawl net selectivity, *i.e.* mesh size (40 mm) and mesh shape (square mesh), where the results were applied or recommended for the local and national area management plans
- Studies on the critical fishing ground included ichthyoplankton and fish larvae conducted - and the results were applied or recommended to local and national area management plans
- Trawl fisheries socioeconomic studies including economic analysis of the impacts of 'bycatch' reduction on trawl economics carried out - supported or strengthened the management frameworks
- Ecosystem Approach for Fisheries Management (EAFM) promoted in collaboration with the relevant organizations and partners, *i.e.* FAO, APFIC, CTI-CFF, NOAA, GEF, NORAD, Swedish Government, CTSP, USAID, and national fisheries agencies of the participating countries
- Public-private partnership of trawl fisheries stakeholders initiated and strengthened to understand the co-management approach and the need for collaboration in formulating the bycatch management plans for trawl fisheries

To keep momentum on the bycatch management projects going, SEAFDEC is currently implementing "Responsible Fishing Technology and Practices" from 2020 to 2024, with support from the Japanese Government through the Japanese Trust Fund at SEAFDEC. A series of activities, *e.g.* consultation meetings, expert meetings, research and development, and capacity building programs are being implemented based on the current situation to assess the environmental impacts of fishing gear and practices on the fishery resources of the Southeast Asia region and address the national interests and concerns in mitigating the impacts of fishing gear on the marine ecosystem.

Way Forward

Measures, such as closing the most sensitive areas for certain fishing and modifying fishing gear to be more habitat-friendly, could enhance the sustainability of fisheries as the impacts of fishing activities on the environment could be mitigated. The use of selective fishing gear is also among the measures, as only the desired species and sizes are targeted but this would also entail improvements of the conservation measures. Protection of the larger or older adult and mature fishes is necessary for the sustainability of the species that are currently being utilized for human consumption. Modifications of fishing gear and operations are also necessary to reduce the bycatch of marine mammals.

In SEAFDEC (2020), the areas where SEAFDEC and AMSs could cooperate in exploring the development of new techniques and methods had been summarized, for example in fisheries research, capacity building, and education, especially on the impacts and mitigation of the impacts of fishing on the fishery resources. The topics for research and capacity building could include:

- Technologies and management to reduce bycatch and discards, including selectivity of fishing gears
- Impacts of gears, *e.g.* trawl net, seine net, and dredge, on the sea bottom
- Light and its interaction with fish behavior
- Impacts of fishing operations on ETP species including marine mammals
- Environment-friendly fishing gear materials, *e.g.* natural and biodegradable materials
- Alternative environment-friendly fishing gear other than bottom trawl
- Management concept of fishing gear selectivity has been conducted since the 1950s, thus, the need to reconsider and apply the Balance Harvesting concept
- Mitigating the impacts of fishing on the environment should reconsider the management approach
- Impacts of fishing on the habitats and critical fishing grounds, *e.g.* seagrass beds, coral reefs, nursery grounds, and so on by assessing the habitat complexity and perturbing sea beds (benthic) communities
- Effects of fishing operation on water quality, *e.g.* resuspension of sediments caused by towed bottom fishing gear, *e.g.* trawl, seine, dredge

From the Project "Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management (REBYC)" which was implemented during 2002–2008 and the Project "Strategies for Trawl Fisheries Bycatch Management (REBYC-II CTI)" during 2011–2016, it was suggested that gear modification could provide the solutions to reduce the negative impacts of fishing on the environment. Therefore, the approaches established through those projects could be applied with appropriate management concepts but should be supported by appropriate legal and incentive frameworks in introducing them to all stakeholders as well as in the decision processes.

4.1.2 Innovations for Responsible Fishing Operations

4.1.2.1 Energy Efficiency and Fuel-saving Options for Fishing Vessels

Improving the propulsion system

All movements of a fishing vessel in the water create resistance force. The vessel is subjected to dynamic force and resistance of its surroundings to maintain its moving speed. In propulsion systems, the thrust force produced must be equal to the resistance force to move forward. To minimize drag, it is necessary to improve the vessel's propulsion system. In general, direct-drive shafting at a zero-degree propeller shaft angle is the most efficient since the propeller thrust is going forward through the water current that goes straight ahead. The efficiency of the shaft angle between 0° and 6° creates small losses, from 6° to 12° gives medium losses, and shaft angles greater than 12° produce variable loading into the propeller blades (**Figure 86**). Minimizing the shaft angle could result in reduced thrust variation on the propeller (cavitation) and significantly increase the life span of the propeller. The reduced propeller shaft angle also minimizes power loss in the transmission system because the upper blade is receding from the onrushing water as it rotates up, while the lower blade is moving forward into the slipstream as it rotates down which results in uneven blade loading that can cause vibration and/or cavitation.

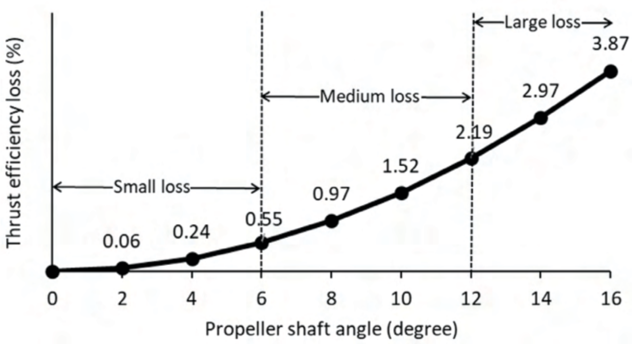


Figure 86. Thrust efficiency loss (%) in relation to propeller shaft angle (degree)

Vessel design, size of the propeller, propeller clearance, and the water flow's path to the propeller blade should be taken into consideration when constructing and/or renovating fishing vessels to improve the performance and energy use of the vessels. If the hull shape of the vessel is obtuse, it will increase the water resistance of the hull to the flow. In case the propeller clearance is small, a propeller with a small diameter should be used, although it might not be able to absorb all the thrust efficiently, resulting in an inappropriate force that facilitates the vessel to move forward in both speed and thrust especially for trawlers and purse seiners. Installing a new propeller shaft aligned to attain improved propulsion efficiency and efficient utilization of fishing vessel fuel, would result in reduced total fuel consumption after vessel renovations. To provide high-efficiency thrust, the flow platform should be improved to ensure that the propeller axis is aligned with the flow pattern of the ship hull for a smooth and efficient flow of water supply to the propeller.

In practice, it is difficult to install such a propeller, but it is most important to have propeller clearance to the hull structure and keel (aperture size) adequate for the propeller size requirements and there must be enough space for the engine and gearbox inside the engine room. The angle of the propeller shaft should be as small as possible compared to the keel (**Figure 87**). Thus, the design of the engine base and the transmission system should be adjusted to match the angle to support the driving force and reduce vibration.

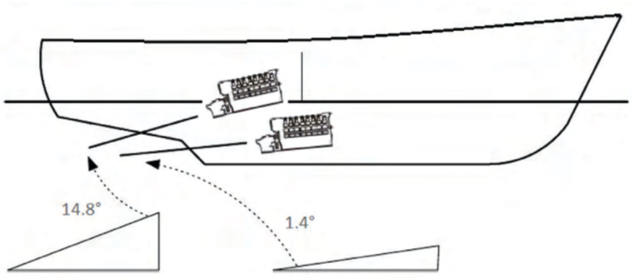


Figure 87. Adjusting the propeller shaft alignment

Most fishing vessel owners and skippers have misunderstood the importance of propeller clearance to avoid the enclosed distance between the propeller and the hull structure. Consequently, many fishing vessels have been set with the angle of the propeller shaft made steeper to avoid such close ranges, missing the hydrodynamics performance and the direction of the force.

To enhance the understanding and awareness of the fishing vessel owners on the aforementioned concepts, SEAFDEC/TD embarked on a six-year Japanese Trust Fund-funded Project "Optimizing Energy Use and Improving Safety at Sea in Fishing Activities" in 2013, which included the "R&D on the implementation of fishing operations with optimizing energy use." Specifically aimed at improving fishing vessel design appropriate for local fisheries in the Southeast Asian region, the R&D activity focused on the SEAFDEC/TD innovation which includes not only in upgrading the purse seine fishing vessels but also the improvement of the propulsion system and of the length of waterline, which has then pilot-tested in Pattani Province in southern Thailand, in collaboration with the Department of

Box 10. Case study on improving the propulsion system of purse seiner in Thailand

Renovation of the engine bed and transmission gears: The engine foundation (engine bed) has been adjusted to a lesser angle so that the propulsion engine and reduction gear are placed at the same angle of the vessel as it moves straight forward and mounted close to the keel of the vessel. As a result, the propeller shaft angle has been changed from 14.8° to 1.4°.


Engine installation in the engine room

Refinement of the stern tube: After the previous propeller shaft exit had been firmly sealed *(left)*, the new propeller shaft angle *(middle)* is installed, and a new exit is drilled at the sternpost for the stern tube installation *(right)*.



Reinstallation of propeller blade: The angle of the propeller blade should be adjusted to higher degrees to optimize the thrust/propulsion efficiency of the fishing vessel during traveling/fishing operations.

Box 10. Case study on improving the propulsion system of purse seiner in Thailand *(Cont'd)*

Evaluation

Engine speed (rpm)	Vessel speed (kt)	
	Pretest	Posttest
1,850	8.0-8.5	11.0-12.0
1,500	5.0-6.0	8.0-9.0
1,200	4.0-5.0	7.0-8.0
1,000	3.0-4.0	6.5-7.0

Cost

Item	Amount (USD)
Materials (engine bed and mounting materials)	2,320
Labor	1,000
Docking and services	1,680
Total	**5,000**

Benefits

- Increased vessel speed
- Efficient fuel consumption and reduced greenhouse gas emission by 36 %
- Reduced vibration and noise at the stern
- Smaller waves or turbulence (vortex) at the stern which means that there is less resistance

Fisheries of Thailand, the Fisheries Association of Pattani Province, and the owner-operator of the pilot purse seine fishing vessel (Thanasansakorn et al., 2019).

Fishing vessel owners in southern Thailand have already applied the innovation on improved fishery machinery for purse seine fishing vessels aimed at enhancing working practices and optimizing the energy utilization of their fishing vessels' operations, e.g in this case where it has become necessary to make the vessel more thrust efficient, as well as improve the length of the waterline to increase the vessel speed capacity and reduce vessel operation cost (**Box 10**). After addressing the issues and concerns with respect to such improved technology based on the results of the pilot study, the results would be used as inputs for the compilation of a regional reference for optimizing energy use and ensuring safety at sea of fishing vessels in the Southeast Asian region.

Improving the length of the waterline

Fishing vessels operate at a certain speed for particular fishing gear. As the vessel speed accelerates, the wave resistance also increases, leading to efficiency loss and high fuel consumption. Reducing fuel consumption allows greater savings for the cost of fishing operations. In general, a vessel cruising at low speed consumes lesser fuel than at high speed, but such a relationship is non-linear. It is therefore important to consider the optimum speed, also called the "operating speed" or "service speed," which is used to set up the speed range of vessels in operation. Such operating speed is an important factor that should be considered in improving and/or renovating the vessel design to increase the vessel speed capacity and reduce vessel operation costs (*e.g.* fuel cost, working days at sea, etc.).

To achieve the optimum speed, the vessel should have an appropriate L/B ratio, where L or LwL is the length of the vessel at waterline from bow to stern when it sits on the water surface, and B is the beam or width of the vessel measured between the most outboard points of the vessel (**Figure 88**). The larger L/B ratio indicates slimmer hull shape and less wave-making resistance, resulting in a more efficient high-speed performance of the vessel, optimized its energy used, and increased its load-carrying capacity. In the pilot project in Pattani Province in southern Thailand, the pelagic purse seiner was improved by increasing the vessel length from 13 m to 18 m (**Box 11**).

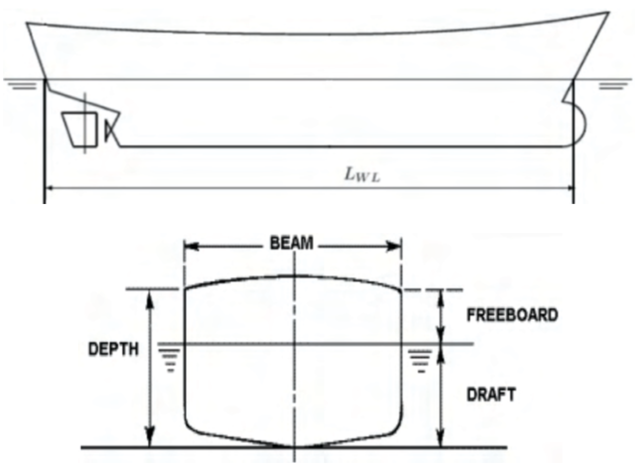


Figure 88. Vessel length at the waterline *(top)* and beam or width of the vessel *(above)*

Way Forward

Pilot testing of the improved technology would be continued to address the issues and concerns encountered during the refinement and verification trials on optimizing energy use in fishing operations and find the best options that could lead to further improvement of the innovations, which also

Box 11. Case study on improving the length of waterline of purse seiner in Thailand

Renovation: Cutting of the hull structure (A); making two sections of hull structure (B); and increasing the hull structure (C) to reach 5 meters in length (m).

A. 
B. 
C. 

Evaluation

	Before renovation	After renovation
Propulsion engine capacity	375 hp	375 hp
Breadth	4.4 m	4.4 m
L_{wl}	13 m	18 m
L/B ratio	2.95	4.09
Maximum speed (nm/h)	8.601	9.944
Fuel consumption (l/h)	27.348 l/h	27.348 l/h
Fuel consumption (l/nm)	3.179 l/nmi	2.750 l/nmi
Greenhouse gas emission per hour	72.198 kg of CO_2	
Fuel consumed/equivalent to produce carbon emission/100 miles	317.963 liters equivalent to 839.422 kg of CO_2 emission	275.020 liters equivalent to 726.052 kg of CO_2 emission
Fuel saved/h or reduced carbon emission/h	4.269 l/h or equivalent to 11.270 kg of CO_2/h emission	

Cost

Item	Amount (USD)
Materials	2,350
Labor	6,300
Docking and services	3,350
Total	**12,000**

Benefits

- Bigger space is available for handling the catch onboard, more comfortable living space is created for fish workers onboard, and better ship stability
- Efficient fuel consumption
- Fresh catch arrives the markets faster and thus, commands good price

include not only improving and/or renovating the operations of the physical structure of the vessels but also on the possible reduction of manpower onboard and on proper handling of catch onboard. Specifically, this would require among others, standardizing the rate of fuel consumption per kilogram of catch, comparing the quality of fish catch and post-harvest losses per fishing trip, determining the average rate of greenhouse gases emitted by the vessels per kilogram of fish caught, and identifying the factors that lead to improved working conditions and safety at sea of fishers on board. After refining and verifying the improved technology at the pilot sites in Thailand and other selected AMSs, this would be promoted to the rest of the Southeast Asian countries to contribute to the enhancement of sustainable fisheries development in the region. The output of this R&D could form part of the compiled standard operation procedures for optimizing energy use in fishing vessels, especially in terms of the efficient operation of tools and systems, reduction of post-harvest losses, reduction of manpower onboard fishing vessels, and minimizing the impact of fishing activities on the environment, thus, promoting responsible fishing operations in the region. The results could also be used as a basis for the compilation of a regional reference for optimizing energy use and ensuring safety at sea of fishing vessels in the Southeast Asian region.

4.1.2.2 *Development and Accomplishment of Fishing Site Identification System*

A traditional method practiced by fisherfolk to determine productive fishing areas is generally based on experience and information sharing, notwithstanding the evidence that spatial structure and distribution of the pelagic fish species are not arbitrary. This is considering that these species are particularly vulnerable and adapt rapidly to changing environmental factors and global changes, resulting in diverse distributions and assemblages. This situation complicates the process of identifying abundant fishing grounds by the fisherfolk and makes the conventional practice of predicting the assemblage of fish inefficient. It is with this backdrop that a new system was established for sustainable fish catch and meeting the rising demand for food and enhancing the revenues of fishers.

Generally, the presence of small pelagic fish species could be predicted because their distributions are greatly affected by the physical and biological processes taking place in the sea surface environment. The two most important indicators of the physical and biological processes in marine ecosystems, the sea surface temperature (SST) and chlorophyll-*a* (chl-*a*) are intrinsically related. While chl-*a* is a critical oceanographic parameter that plays a significant role in determining the ocean's productivity, SST is an indicator for the physical environment, which regulates the physiology of organisms and phytoplankton growth.

Satellite remote sensing devices can detect these physical and biological parameters in real-time and have primarily supplanted those traditional practices of fishers, as these are more effective and efficient methods than field sampling. Remote sensing data also offer information on SST variations that affect the existence of phytoplankton, the principal food source for fish, contributing to the formation of fish concentration zones.

Fishing Site Identification System

Known as the fishing site identification system (FSI), the system (**Figure 89**) consists of four main components, namely: image receiving and processing, modeling of potential fishing areas, database, and information dissemination system (IDS).

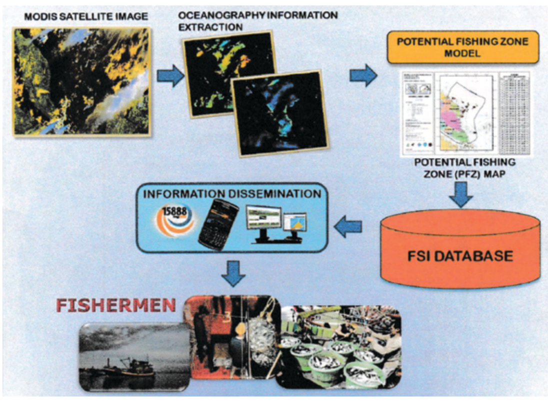


Figure 89. Components of FSI
(Muhammad-Fuad et al., 2012)

Image Receiving and Processing

The Moderate Resolution Imaging Spectro-radiometer (MODIS) data will be acquired daily. After processing the data, maps of SST and chl-*a* would be generated. Both products are then evaluated to determine the fishing location through the thermal front (**Figure 90**).

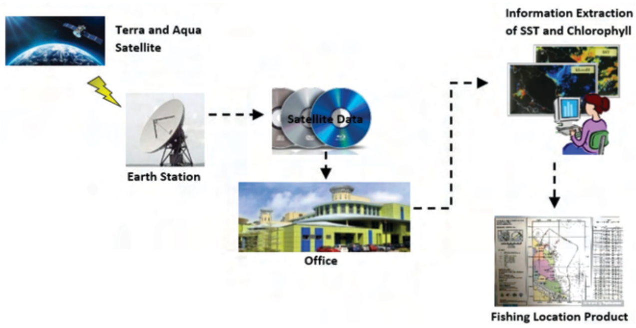


Figure 90. Satellite data analysis and information gathering
(DPPSPM, 2014)

Modeling of potential fishing areas

Chlorophyll-*a* is a well-known indicator of phytoplankton abundance, which correlates with the presence of fish, and SST provides a view of the ocean's surface and contouring it reveals oceanic fronts, currents, eddies, and upwelling (**Figure 91**). These two criteria were examined to generate the possible fishing locations, then stored in the FSI Database by employing geographic coordinates (longitude and latitude).

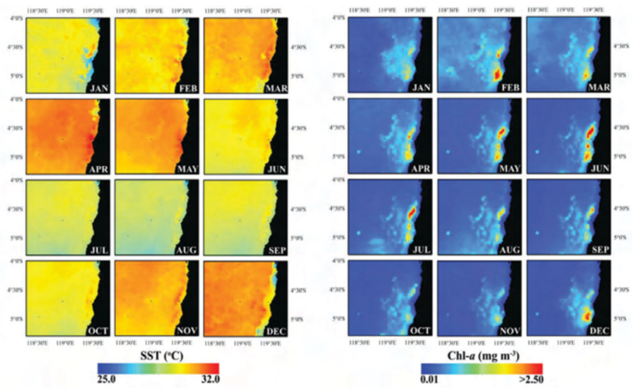


Figure 91. Examples of MODIS monthly climatological composite SST (˚C) and chl-*a* (mg/m^3)
Source: *Suhartono et al., 2015*

Database

Database development is a critical prerequisite for providing access to information concerning potential fishing areas. It is, therefore, crucial to have complete, accurate, and real-time information for the successful transmission of information on possible fishing locations to the local fisherfolks associations and fishers (**Figure 92**).

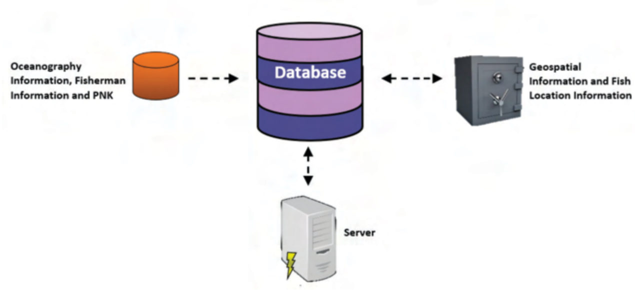


Figure 92. Database

(DPPSPM, 2014)

Information dissemination system

The information dissemination system (IDS) offers fisherfolks information on prospective fishing grounds based on the availability of cloud-free satellite imagery (**Figure 93**). For example, in Malaysia, the fish geolocation can be generated as early as 5:00 PM on any given day and is valid for three days. The precision is within a three-kilometer radius of the specified coordinate.

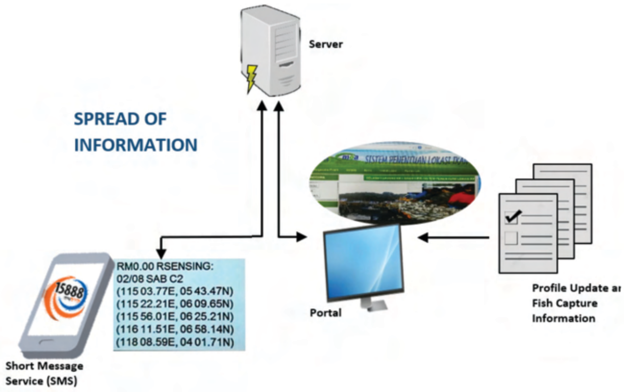


Figure 93. Information dissemination system

(DPPSPM, 2014)

Pilot Studies

The FSI has been pilot-tested in Malaysia starting in 2010 and later in Indonesia. Based on the initial results, several issues and concerns had been encountered during the pilot-testing, especially in the Malaysian setting. Such concerns would be addressed before expanding the pilot testing of the FSI in other Southeast Asian countries.

Malaysia

The recent increase in fuel prices has had a substantial effect on the fishing industry of Malaysia, considering that fuel costs can account for up to 50 % of the overall cost of operating a commercial fishing fleet. In addressing such concern, the development of the fishing site identification (FSI) system was initiated by a Malaysian project team in January 2007 and was completed in December 2010. The system was initially introduced in late 2010 on the east coast of Peninsular Malaysia and was later on expanded to include the west coast, *i.e.* in Sabah, and Sarawak, in early 2011.

The FSI system could be utilized by the trawler, drift net, and hook and line operators. To promote the usage of the system, the project team conducted a nationwide registration and encouraged the fishers to register with their local fisherfolk associations and provide the required information on the owner and vessel registration, capture zone, licensing status, and a cell phone number, to be able to use the FSI.

The initial findings from monitoring and analysis of trawler vessels indicated that their catch has increased by more than 30 % since 2011 upon adopting the FSI system. Based on the fishers' responses to the questionnaires distributed throughout the promotion program, 92.9% of fishers were delighted with the development of the FSI system as it has improved their daily incomes. Additionally, results of the questionnaire survey also showed that trawler operators and fisherfolk from Peninsular Malaysia had indicated a confidence level greater than 90 % on the accuracy of the FSI system. This has been demonstrated from the analysis of trawler landings on Peninsular Malaysia's east and west coasts, which revealed a rising trend of fish landings in 2014. Furthermore, the assessment of the operating costs revealed a decrease of more than 30 %.

Indonesia

A study utilizing satellite-derived SST and chl-*a* data combined with GIS to identify possible fishing areas for Rastrellinger kanagurta was conducted in the archipelagic seas of Spermonde in the Makassar Strait of Indonesia's central region. Satellite data incorporated into the GIS and combined with other databases can provide a more complex and valuable information system that can be used to rapidly and precisely assess possible abundant fishing areas.

The archipelagic waters of Spermonde provide an important fishing area for fisherfolks on the west coast of South Sulawesi. SST and chl-*a* data collected from MODIS measurements were used as the primary satellite data set in the analysis. The relationship between SST and chl-*a* concentrations in the archipelagic waters of Spermonde was calculated, and it was determined that there was a positive correlation between SST and chl-*a*, implying that an increase in SST results in an increase in chl-*a* concentration (Suhartono *et al.*, 2015).

The forecasted model was constructed using satellite-derived SST and chl-*a* as environmental datasets and then integrated with the GIS approach to map the presence of R. kanagurta throughout the Spermonde archipelagic waters (**Figure 94**).

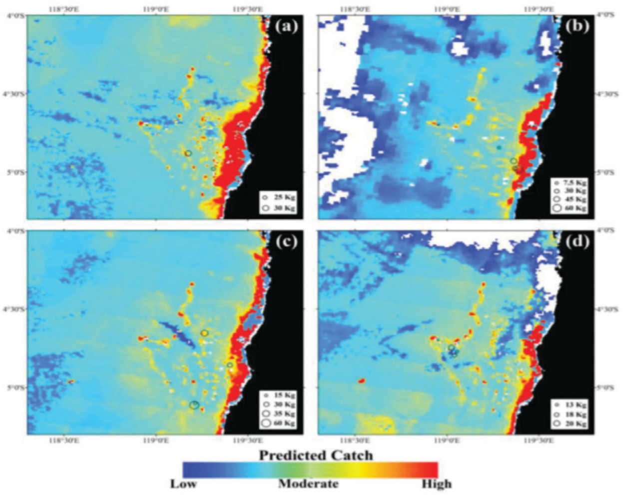


Figure 94. Examples of potential fishing maps: all prediction maps showed the possible fishing grounds which occurred along the coasts

Source: Suhartono et al.*, 2015*

Issues and Challenges

Several concerns and obstacles had been associated with the implementation of this project that includes the following:

a) The tropics have a high cloud cover rate which is greater than 50 % that prevents the daily generation of the potential fishing zone (PFZ) using the MODIS data
b) The use of low-resolution satellite imagery is not ideal for developing this project, despite the fact that it can solve the issue of cloud covering
c) Apart from a lack of technological skills, fisherfolks take a long time to adapt to the latest technology
d) There are challenges encountered in acquiring extensive information on catch, locations, and expenditures from fishers, owing to their low sensitivity to data gathering and storage
e) Need to enhance the initiatives that focus on the involvement of the FSI system by local fisherfolks associations to distribute PFZ to trawl operators

4.1.2.3 Technology on Preservation Onboard Fishing Vessels

SEAFDEC/TD has been developing a design and also initiating the construction of an onboard refrigeration system to be used for fishing vessels by adopting a hybrid technology that can make use of multi-mode operation sources, *e.g.* from the propulsion engine or diesel generator or electricity from the shoreline. In addition, the design also utilizes various types of preservation tools onboard that are more suitable for the fishing gear and target species, such as the refrigeration seawater (RSW) and air blast freezing system. The possibility of using both RSW and air blast freezing systems in unison is also being explored as means of prolonging the freshness of the catch at their premium quality onboard, taking into account the optimum utilization of energy.

Refrigeration seawater (RSW)

Refrigeration seawater (RSW) is a system used onboard fishing vessels to preserve the freshness of the catch. The advantage of using the RSW system is its cost-saving capacity and its ability to preserve the catch at premium quality until it is unloaded ashore or for further processing. Its cooling efficiency is improved, cooling down the catch close to the freezing point much faster than using ordinary ice or limited ice, thus, ensuring the freshness and fresh quality of the catch while being transported onboard. It should be noted that the approximate electricity consumption per ton of ice (box) produced for the icemaker and refrigeration plant for temperate and tropical areas, is approximately 60 kWh/t (Myers, 1981). This does not include requirements for handling, crushing, or storage.

Airblast freezing system

The use of airflow to improve heat transfer from the product being cooled through the refrigeration system is probably the most common method used in commercial fishing vessels. However, the natural convection of the air alone would not give a good heat transfer efficiently, therefore, forced convection using fans has been introduced. To enable the product to reach the freezing point within a reasonable time, the airflow rate should be fairly high (2-6 m/s). Also, to obtain uniform cooling rates throughout the freezer, the airflow should flow over each fish in every fish container.

Power take-off (PTO)

The power take-off is any of several methods used for taking power from a power source, such as the main engine, and transmitting it to an application such as a water pump, hydraulic pump, and/or compressor for the refrigeration system. Usually, the refrigeration system whether in an industrial establishment or on a fishing vessel uses an energy source which is either from the electric motor or engine, to keep the compressor of the refrigeration system going. It is designed to be capable of using more than one type of energy source which consists of the 1) main engine and the 2) electric motor.

Split shaft power take-offs

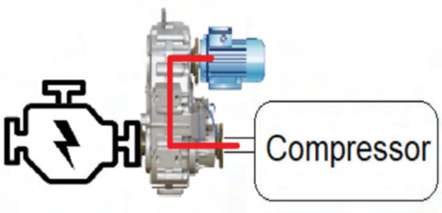
In a fishing vessel, the propulsion engine or diesel generator has greater capacity in delivering a relatively steady amount of torque at both high and low running speeds. Consequently, the propulsion engine or diesel generator can drive the compressor of the refrigeration system by providing enough power take-off, which is a mechanism to bring power from its operating speed that properly matches with the requirements of the refrigeration unit that utilizes the power source. Split shaft power take-offs have many advantages, making it an excellent option to capitalize on the full potential of the fishing vessels. The split shaft power take-offs are equipment like a gearbox or power take-off application that allows single or multiple pumps to be driven from a single prime mover. This multiple/split type power take-off is a combination of different propulsion technologies. In the hybrid transmission system, an electric motor performs the function in place of the engine, such as exerting force to the transmission shaft.

The split shaft power take-offs are advantageous to use because of their properties that include:

- Multiple outputs
- Various styles and sizes
- Standard PTO is driven by a pulley for versatility
- A shiftable compressor can drive both the electric motor and main engine
- Fuel is utilized efficiently and the cost is beneficially optimized
- Waste from fish preservation onboard is reduced

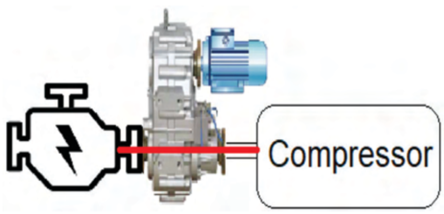
The refrigeration system could use either the electric motor or the engine, as the energy source to keep its compressor going. The functions of such energy sources are summarized below:

1) Hybrid refrigeration system driven by an electric motor



In general, the compressor of the refrigeration system is driven by an electric motor, the size of which depends on the cooling capacity or cooling efficiency of the compressor. This means that a lot of electricity is needed from the diesel generator. Since the electricity demand is defined as fuel consumption, even when a fishing vessel moored at the fishing port/jetty, it will still be able to operate the refrigeration system through the electric motor. This is because fishing vessels must continue to run either through its diesel generator ordinarily or by utilizing the shoreline power source when the main engine stops. But whenever the fishing vessel leaves the pier/port and the main engine is in use, the refrigeration system can change the mode of operation to engine mode so that the compressor would continue to function.

2) Hybrid refrigeration system driven by the propulsion engine



The merit of the refrigeration system is driven by the propulsion engine. Whenever the fishing vessel leaves from the fishing port to the fishing ground for a certain fishing period, it will take time to operate the engine. Therefore, using the engine drive mode will result in energy utilization without using the electricity sourced from the diesel generator.

4.1.2.4 Reduction of Carbon Emissions

Catch per unit of fishing effort and greenhouse gas emission of a purse seine fishing vessel is among the most important factors that determine the impacts of the increasing contribution of Southeast Asian fisheries to global seafood production. Purse seine fishing is one of the activities that significantly contribute to the region's seafood production but requires considerations in terms of the energy use (man and machine), and in mitigating the negative impacts of fishing activities and vessel operations on the environment.

A privately-owned purse seine fishing vessel in southern Thailand, the "Nor Lapprasert 8" has been commissioned by SEAFDEC/TD through a collaborative arrangement since 6 July 2018 for a pilot project on labor reduction onboard fishing vessels during the fishing operations, as well as enhancement of the working practices and living conditions onboard the vessels following proper hygiene and adopting the low-impact and fuel efficient (LIFE) fishing concepts to catch fish, and preserving the freshness of the catch at sea for the benefit of the consumers. The initial activity using this pilot purse seine fishing vessel was launched through a joint fishing operation between the local fishers and SEAFDEC staff from 8 to 12 February 2019 and continued thereafter. During the trial period, the pilot project has shown improved efficiency of the fishing gears (net plan), fishery machinery, and fish handling tools. After more than three years of research on fuel saving/ energy efficiency using this pilot vessel by adopting the appropriate technology on improving energy efficiency, SEAFDEC has contributed to the improvement of fishing practices and working conditions onboard fishing vessels, and reduction of the manpower onboard purse seine fishing vessels. The summary of such efforts made by SEAFDEC/ TD is shown in **Table 64**.

After implementing the project, the new carbon emission record is shown in **Table 65**, while the changes and improvements compared before and after the implementation of the project using the pilot purse seine fishing vessel, are shown in **Table 66.**

Table 64. Summary of the data on the operation of the pilot purse seine fishing vessel (from 2019 to date)

Total fishing operation (no. of days)	Total fishing voyage (no. of trips)	Total fish catch (kg)	Total fuel consumption (l)	Total engine operation (h)
219	20	260,500	54,035	4,919
Ave fuel consumption per hour (l)	Ave fuel consumption per voyage or trip (l)	Ave no. of fishing days per voyage (day)	Ave catch per fishing voyage (kg)	Catch per 1.0-liter fuel consumption (kg)
10.98	2,701.75	11	13,583	4.82
Ave fuel consumption (l/day)	Ave selling price of catch (THB/kg)	CPUE (kg/day)	CO_2 emission per day (kg CO_2)	CO_2 emission per 1.0 kg of catch (kg CO_2)
246.73	30	1,189.49	651.36	0.5475

Table 65. New carbon emission recorded about the pilot purse seine fishing vessel

Ice consumption/trip reduced by	Compared to emission kg CO_2	New total emission/trip kg CO_2	New emission per 1.0 kg of catch (kg CO_2)
150 box = 36 tons	972	6160	0.453

Table 66. Improvements made before and after the implementation of the project using the pilot purse seine fishing vessel (2019-2021)

Aspects to be improved	Before project implementation	After project implementation
Manpower onboard (MO)	more than 30 fishers	17 fishers
Average hauling time	About 1.5 h	30 min
Living space (LS)	72 m^2 (2 levels: 3m x 6m each) shared by 29 fishers (skipper uses different area), each fisher occupies 2.50 m^2 of workspace	72 m^2 (2 levels: 3m x 6m each) shared by 17 fishers (skipper uses different area), each fisher occupies 4.23 m^2 of workspace
Total catch (TC) recorded on logbook	260,500 kg	
Ave catch per voyage	13,583 kg	
Total gross income (at THB 30/kg)	USD 260,500	
Fishing trip (FT): Thailand regulations indicate that fishing vessel more than 30 GT is permitted to go fishing for not over 240 days/year		219 days (11 days/trip)
GHG emission	0.5475 KgCO_2 to catch 1.0 kg of fish	0.4530 KgCO_2/kg of fish (to catch 1.0 kg)

greenhouse gas emission (GHG Emission) refers to the carbon emission or the release of carbon dioxide gas from burned fossil fuel into the atmosphere. Included in Table 66 are some facts about greenhouse gas emissions from the fisheries sector considered as one of the sources of carbon emission that fuels climate change.

Fuel Consumption (FC): the rate at which an engine uses fuel, expressed in units such as voyage per liter, liters per working hour, or liters per kilogram of the catch. The pilot purse seine fishing vessel makes use of Cummins Engine brand model K-500. Since the first fishing operation until now and referring to the data record for fuel consumption, the average fuel consumption, working-hours of engine operation, and the CO_2 emitted had been recorded in detail as shown below:

For the sake of showing an example, consider 1.0 liter of diesel that weighs 835 g. Diesel consists of 86.2 % carbon or 720 grams of carbon per liter of diesel. To burn this carbon to CO_2, 1920 g of oxygen is needed. The sum is then 720 + 1920 = 2640 g of CO_2/liter of diesel. It should be noted that in the U.S.A., the electricity generated by the electric power industry results in the emission of carbon dioxide (CO_2) which is equal to about 0.99 pounds of CO_2 emitted per kWh.

As shown in **Table 66**, 0.5475 KgCO_2 is emitted to the atmosphere while catching 1.0 kg of fish before the project implementation. After the project implementation, 0.4530 KgCO_2 is emitted per kilogram of fish caught.

GHG emission (before project implementation)
= 0.5475 KgCO_2 to catch 1.0 kg of fish
GHG emission (after project implementation)
= 0.4530 KgCO_2/kg of fish

Moreover, the fuel consumption of propulsion engine is 246.73 liters/day, then correspondingly the gas emitted from fuel consumption is: 246.73 × 2.64 $kgCO_2$ = 651.36 $kgCO_2$/liter.

Catch Per Unit Effort (CPUE): also called the catch rate, is frequently the single most useful index for long-term monitoring of a fishery. Declines in CPUE imply that the fish population cannot support the level of harvesting. Increases in CPUE could mean that a fish stock is recovering, and more fishing effort can be applied. CPUE can therefore be used as an index of stock abundance, where some relationship is assumed between that index and the stock size. The simple calculation of CPUE is the total catch divided by the total amount of effort used to harvest the catch.

$$\text{CPUE} = \frac{\text{Total catch (kg)}}{\text{Total amount of effort used to harvest the catch}}$$

$$\text{CPUE of pilot purse seine fishing vessel} = \frac{260{,}500 \text{ kg}}{219 \text{ days}}$$

CPUE = 1,189.49 kg/day
= 4.82 kg of catch/liter of fuel consumption
Or equivalent to = 1 kg of catch/0.2074 liter of fuel consumption

4.1.2.5 Reducing Labor in Purse Seine Fishing Operations

Due to the kinds of equipment being used for fishing and set up onboard many fishing vessels, *e.g.* purse seiners and trawlers, a large number of workers is required in fishing vessels, especially in the case of Thailand. For example, purse seiners require as many as 30 - 40 fishers onboard while trawlers require up to 22 fishers onboard. In the case of purse seiners in Thailand, heavy demand for labor comes from the enormous weight of the catch, while the nets are largely pulled aboard by hand. In view therefore of such a scenario, the Department of Fisheries (DOF) of Thailand had approached SEAFDEC/TD and with the collaboration of the Pattani Fishery Association in southern Thailand, to design a more labor-efficient purse seiner. In 2018–2019, experts from SEAFDEC/TD worked with the vessel owner on the project that aimed to design and reconfigure a 91-GT purse seiner (Nor Larpprasert 8) based in Pattani Province and used as the pilot fishing vessel for this project.

The design and reconfiguration of the fishing vessel included the installation of a multi-purpose crane, hydraulic system, power block, and central cooling with refrigeration system, on the purse seiner. The crane and power systems facilitate the hauling of nets that was done before by fishers, and the refrigeration system prolongs the preservation of the catch, thereby increasing its value in the market. The costs of the reconfiguration had been shared, with SEAFDEC paying for the equipment and the vessel owner paying for the installation as well as the acquisition of new nets. The installation of the new equipment in 2018 took two months because of the extensive optional renovations, although SEAFDEC estimated that installation of similar equipment installation on other fishing vessels would take less than one month to complete. SEAFDEC also reported that the technology and equipment are promptly available in Thailand and spread the information to all major stakeholders and important fishing ports of Thailand to also undertake the appropriate vessel improvement.

Cost-Benefit Analysis (before and after reconfiguration)

Before the equipment installation, the vessel required around 30 fishers for each seven-to-ten-day fishing trip, yielding a catch that was worth about USD 15,833, based on the vessel owner's price estimates and cross-checked with SEAFDEC experts. Such manning level also meant that the fishers' living space of 72 m^2 (4 levels of 3m x 6m space) was shared among 29 fishers (the skipper sleeps in a different area), and implied that each fisher occupied an average of 2.5 m^2 of space onboard, before the reconfiguration.

Since the installation of the new equipment in early 2019, the purse seiner has seen an approximate reduction of 37 percent in terms of labor required. The power block, crane, and hydraulic systems enable net hauling to be done more efficiently by fewer fishers. In this case, the fishers needed onboard have gone down from 27 to 17, while the average time for hauling the fishing nets is less than an hour and 30 minutes, down from more than two hours before the reconfiguration. With more adjustments, SEAFDEC forecasts that eventually, the manning will come down to 14 or 15 men, about half of the original fishing crew. The total costs of labor per year will be reduced as well, from USD 137,237 per year to USD 108,100 in the second year after reconfiguration, even with an increase of monthly wages for fishers to USD 400 per month, which is at par with past policy proposals made by Thai vessel owners and workers' organizations. The costs of workers' permit will also be reduced along with the overall cost of the workforce by 45 percent (*i.e.* to approximately USD 2,633) in two years. Even accounting for the increases in base pay of the fishers, supervisors, and skippers, the savings from the total labor cost are significant at approximately 21 percent.

The central cooling and refrigeration systems have proven to reduce the quantity of low-quality fish, especially the fish caught on the first few days at sea which loses its value as the quality deteriorates from 34 percent down to around 10 percent. This means that with the current renovations, 90 percent of the catch can be sold at full market price (up from 70–80 percent of the quantity before the installation), increasing revenues by roughly 10 percent from USD 15,833 to USD 17,416 on average per trip.

The work area onboard for fishers has also seen significant change. After the boat reconfiguration, the 72-m^2 living area is now shared by only 17 fishers (excluding the skipper), hence each fisher now has 4.23 m^2 of workspace versus the 2.48 m^2 before. This means that the fishers no longer work in such a crowded space, which has been notoriously dangerous in the fishing industry, this means safer work conditions.

Fuel costs are largely unchanged after the reconfiguration. The vessel owner however noted that any increases in fuel usage due to the installation of the crane are offset by the reduction in the number of fishers onboard. SEAFDEC is planning to change the configuration of the refrigeration system starting in late-2019 as the engineering team believes that such changes could lead to reduced energy costs. With regards to engines used in the fishing industry, certain more efficient fuel-injection engines have been in use elsewhere, but these are not available in Thailand and are three times more costly than the traditional engines. As a result, most vessel owners in Thailand have reportedly shown little interest in the lower-carbon types of engines. Meanwhile, the owner of the pilot fishing vessel and SEAFDEC had estimated that the resale value of the vessel after the reconfiguration is about USD 330,000 an increase of about two-thirds of its USD 200,000–230,000 value before the changes.

Improvements in their working conditions had led to reduced turnover rate of fishers from 30 percent to effectively zero in the months after the reconfiguration. This demonstrates that the installation of basic power-hauling equipment on purse seiners can help alleviate labor shortages and improve the conditions of those working and living onboard the vessels. The total cost of the comprehensive reconfiguration carried out on the pilot fishing vessel (excluding the cost of acquiring new nets) is USD 58,330. This includes the central cooling system, refrigeration system, other installations, and the core reconfiguration: crane, power block, and hydraulic system. The investment cost for the vessel's reconfiguration is relatively high as far as the owners of even the smallest commercial fishing companies that own one or two fishing vessels. However, SEAFDEC is of the view that the investment costs could be reduced if only the core equipment are changed, *i.e.* crane, power block, and hydraulic system. The central cooling system, the refrigeration system, and the purchase of new purse seine nets are not necessary for the core reconfiguration, as vessel owners can make such additional improvements over time. Assuming that a ten percent increase in revenue per trip due to the enhanced cooling and refrigeration systems, from an average of USD 15,833 per trip to USD 17,416 per trip, at 30 trips per year, the increase in annual revenue during the second year after the reconfiguration is estimated at USD 47,500. Adding the savings from the labor cost of USD 29,138 per year, the total amount could easily cover the investment cost for the reconfiguration and installations in less than one year. The summary of the cost of the vessel reconfiguration and benefits gained is shown in **Table 67**.

Table 67. Summary of reconfiguration cost and benefits

Comprehensive Reconfiguration Cost (excluding new nets)	USD 58,333
Estimated increase in revenue per year after reconfiguration	USD 47,500
Savings from labor cost per year after reconfiguration	USD 29,000
Return on investment (estimated period)	Less than 1 year

Way Forward

Currently, SEAFDEC/TD is undertaking this activity under the Japanese Trust Fund Project "Responsible Fishing Technologies and Practices" that includes 1) marine engineering technologies (*i.e.* fuel efficiency, greenhouse gas reduction, and safety of fishing operation at sea) at the national and regional level; and 2) the development of fish handling techniques onboard fishing vessels. The R&D on the development of appropriate technologies to reduce carbon emissions to the environment at a low level in response to the issues of global crisis by climate change and reduce labor onboard by applying appropriate hauling devices to contribute to improving the national economies and fishers' well-being onboard fishing vessels, would be enhanced and continued. The results of such activities would be shared by SEAFDEC/TD with the AMSs through the production of information and training materials/models that would be introduced through the training courses of SEAFDEC/TD on the improvement of appropriate fishing vessel technology in terms of marine engineering, and also through the SEAFDEC website. Capacity-building programs through online workshops and demonstrations, as well as hands-on practical sessions, could also be organized.

4.1.3 Abandoned, Lost or Otherwise Discarded Fishing Gear

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a collective term for the various causes of loss of fishing gear as identified by Macfadyen, *et al.* (2009). The term "abandoned fishing gear" means fishing gear over which the operator or owner, although has the control, is unable to retrieve and deliberately leave the gear at sea due to force majeure or other unforeseen reasons. Meanwhile, "lost fishing gear" refers to fishing gear over which the owner or operator has accidentally lost control and can no longer be located and/or retrieved by the owner or operator. The term "discarded fishing gear" refers to fishing gear that is released at sea without any attempt by the owner or operator for further retrieval or recovery. Unless un-retrievable, fishing gear is deliberately abandoned by fishers at sea and becomes ALDFG because of bad weather, or injury of fishers, or mechanical failure of the fishing vessel, and finally the gear could no longer be retrieved. Fishers engaged in IUU fishing may also abandon their gears when at risk of being inspected or arrested, and in order to escape quickly, have to dispose of any evidence.

Gear is often lost due to snagging on obstructions in or on the water, the interaction between gears snagging on each other, and when it is impossible to retrieve even after all efforts are made. Discarded gear is usually a gear that had been damaged beyond repair and the vessel has nowhere to dispose of it properly and thus, is intentionally left at sea. Subsequently, ghost fishing is a related issue and easily occurs when ALDFG continues to efficiently catch and kill aquatic animals. There are various factors that affect the ability, efficiency, and duration of ALDFG to ghost fish. Aquatic animals could be caught in derelict nets and traps, while other gear types could attract scavenging aquatic animals and are subsequently caught, and thus, causing redundant loop and long-term ghost fishing due to their self-baiting mechanism.

The FAO-UNEP had undertaken few attempts since 2009 to quantify the approximate scale of the source of marine litter that includes ALDFG which contributes approximately 10 percent (640,000 mt) of global marine litter by volume (Macfadyen *et al*., 2009), with land-based sources being the majority cause of marine debris in coastal areas. The Global Ghost Gear Initiative (GGGI) reported in 2018 that The Ocean Cleanup28 found ALFDG constituting 46 % of surface debris and 70 % of macro plastics. The large scale of fishing operations across the Asia-Pacific region generates ALDFG, but this is so far un-quantified because ALDFG is usually hidden under the water and is seldom seen as a threat until some marine mammals (*e.g.*, dugong, dolphin) or sea turtles wash up on a beach entangled in fishing gear or has died due to ingestion of plastic or fishing gear. Consistent data on ALDFG in Asia-Pacific fisheries operation is limited. Currently, the data is aggregated to marine litter information with no existing standardized and updated figures on ALDFG in fisheries. In 2021, a global marine pollution assessment conducted by the Alfred Wegener Institute for Polar and Marine Research estimated that fisheries-related wastes constituted a total of about 13.8 percent (**Figure 95**) of the total marine litter types (AWI Litterbase, 2021).

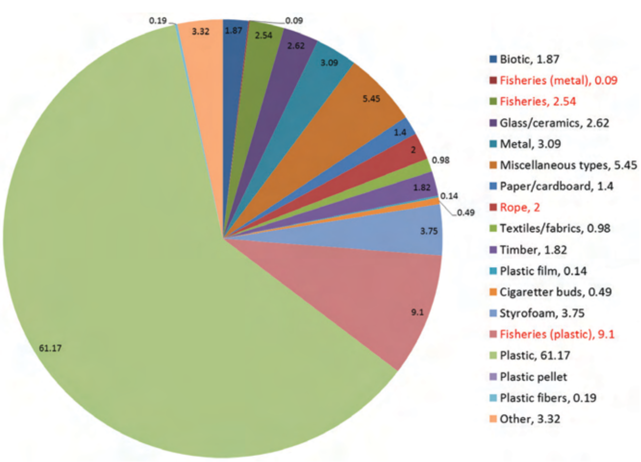


Figure 95. Global distribution of marine litter types in 2021 (%)

Source: *adapted from AWI Litterbase (2021)*

Among the marine debris pollutions, ALDFG is a problem that is an increasing concern in the Southeast Asian region as it leads widely to health-threatening of the ocean diversity, fisheries industries, and fisheries communities. ALDFG is a source of marine plastics and has a category on its own as the fishing industry in the Southeast Asian region had been largely dependent on such gear (Lyons *et al*., 2019). It is difficult to exactly estimate the number of fishing activity that makes different contributions to the total marine litter based on locality, but it is clear that the majority of fishing takes place not only in marine environments but also in freshwater environments, and thus the latter, which also host major capture fisheries in some countries, could have facilitated some contributions to the litter.

Apparently, ALDFG contributes huge impacts on navigational hazards and associated safety issues, yet the ability of ALDFG to ghost fish has detrimental impacts on the fish stocks, with no means of generating economic benefits and with potential impacts on the vulnerable or threatened species and the benthic and intertidal environments. The extent and impacts of the problem are thought to have increased significantly over the last 50 years with the increasing levels of fishing capacity and activity in the world's oceans. The impact of fishing gear on the environment has been intensified by the utilization of non-biodegradable materials for fishing gear, primarily plastics, which are generally more persistent in the environment than materials sourced from nature. Therefore, without proper measures and management to address ALDFG, the amount of fishing gear remaining in the marine environment will continue to accumulate.

Fishing Gear Marking: A tool to cope with ALDFG issues

Globally, gillnets and trap fisheries have the most impacts as the highest risk of ghost fishing compared with other gear types such as fish aggregating devices (FADs), hooks and lines, bottom trawls, mid-water trawls, and seine nets that are found to have lesser impacts than the two fishing gears previously mentioned. This is likely to have the same tendency in the Southeast Asian region since gillnets and traps are widely used by fishers along the coastal areas. To mitigate the opportunity and risk of ghost fishing and ALDFG, properly marked gear can help identify the ownership and location of the gear and ascertain its legality. This has been an integral requirement of the Code of Conduct for Responsible Fisheries, which intends to create a disincentive for intentional abandonment or discarding of gear, increase the visibility of passive gear, which could reduce gear conflicts and damage by passing vessels, and reduce accidental gear loss. Remedial methods to mitigate ghost fishing include, for example, programs to detect and remove ALDFG, and the use of less durable and biodegradable materials for fishing gear to reduce their capability and duration in ghost fishing.

In 2016, FAO published the "Abandoned, lost and discarded gillnets and trammel nets: Methods to estimate ghost fishing mortality, and the status of regional monitoring and management," in order to focus on the issue of ALDFG contributing to marine litter. However, the marking of fishing gear as one of the measures to minimize ALDFG is still not universally applied. It has been recognized that properly marking fishing gear with gear tracking technology and an associated reporting system can reduce ALDFG and its impacts, including ghost fishing. Gear marking and tracking is an important tool for recovery of lost gear and to facilitate management measures for such actions as inappropriate disposal, as well as provide incentives for the proper management of fishing gear, including its disposal and recycling.

In 2018, FAO hosted the Technical Consultation for the Marking of Fishing Gear in Rome, Italy, which led to the publication of "The Voluntary Guidelines for the Marking of Fishing Gear" in 2019. FAO is now working at the global level with various partners to address ALDFG and microplastics. Consistent application of an approved gear marking system may also assist the application of measures to identify and prevent IUU fishing, which in turn should reduce gear abandonment and disposal at sea.

ASEAN Resolutions on Marine Debris

In November 2017, the ASEAN Conference on Reducing Marine Debris held in Thailand recommended an integrated land-to-sea policy approach by developing and implementing the Regional Action Plan for Combating Marine Debris in the Southeast Asian Region. Subsequently, the 34th ASEAN Summit in June 2019 adopted both the Bangkok Declaration on Combating Marine Debris in the ASEAN Region and the ASEAN Framework of Action on Marine Debris. These efforts demonstrate the commitment of the ASEAN to advance the concrete action on environmental protection.

As a follow-up, the ASEAN Regional Action Plan for Combating Marine Debris was developed from October 2019 to July 2020 through extensive consultations with relevant experts and stakeholders. Led by Thailand and with support from the World Bank, this Regional Action Plan proposes the phased implementation of a systematic and integrated response to guide regional actions in addressing the issue of marine plastic pollution in the ASEAN over the next five years (2021–2025). The Regional Action Plan for Combating Marine Debris will play an important role in helping the ASEAN to tackle plastic wastes and protect the vital marine environments that sustain the region for generations to come.

Regional and International Cooperation to Combat ALDFG in Southeast Asia

International recognition of marine litter is demonstrated by large numbers of international organizations and agreements that now focus specifically on ALDFG, in addition to numerous national and local-level initiatives that are being implemented around the world and in the Southeast Asian region. Recently, research on marine plastics, especially identification of their types and distribution, have been increasingly carried out and the results had been published by many environmental concerned authorities in the Southeast Asian region, but there are no published results of research studies on the ecological and environmental impacts of marine plastics. Moreover, there is a very limited number of published research studies on ALDFG in the Southeast Asian region.

In addressing the ALDFG issues, the concerned SEAFDEC Technical Departments, *i.e.* SEAFDEC Training Department (SEAFDEC/TD), Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD), and Inland Fishery Resources Development and Management Department (SEAFDEC/IFRDMD) embarked on some initiatives to acquire the necessary baseline information on some major types of fishing gear used in the region. Specifically, SEAFDEC/TD conducted a survey on gillnets, traps, and pots which are possibly the major types of ALDFG in the coastal areas. Results of the surveys and research works have identified the quantities and types of fishing gear that contribute to the ALDFG. Such initiatives would be beneficial to and the lessons learned and methodology on how to collect the primary information of the ALDFG would encourage the SEAFDEC Member Countries to commence research studies in their respective countries. The following are the initiatives carried out by the concerned SEAFDEC Technical Departments in cooperation with collaborating partners (**Box 12**).

National Initiatives/Activities on ALDFG and Marking of Fishing Gear

Recognizing the adverse impacts of ALDFG on the marine resources and environment, the Southeast Asian countries have attempted to address the issues on ALDFG at their respective national levels. Although it is not mandatory to adopt the Marking of Fishing Gear to primarily mitigate the quantity of the ALDFG discharged into the oceans, some Southeast Asian countries (**Box 13**) have already commenced some research works to demonstrate the rationale for Marking of Fishing Gear such as gillnets and pots in close collaboration with international agencies, *e.g.*, FAO or GGGI, by carrying out trials on various types of markings. Additionally, however, the application of the Marking of Fishing Gear is compulsory for some specific fishing gear and fishing grounds in some regions, such as

Box 12. Initiatives of concerned SEAFDEC Departments in addressing issues on ALDFG
SEAFDEC/TD • In 2020, SEAFDEC/TD has embarked on a 5-year project "Responsible Fishing Technology and Practices," supported by the Japanese Trust Fund 6 Phase II. Considering that ALDFG is one of the emerging concerns and issues identified by SEAFDEC Member Countries at an Inception Meeting organized in late 2020, a series of ALDFG surveys had been conducted intensively in the Gulf of Thailand and the Andaman Sea through interviews using specific-designed questionnaire focusing on gillnets and traps (pots) fishing gears. Results of the surveys will be analyzed and shared with the SEAFDEC Member Countries to develop and apply the methodology to assess the quantity and measures to prevent the occurrence of ALDFG and its impacts in the region. While it is recognized that Fishing Gear Marking is one of the tools to mitigate the ALDFG, SEAFDEC/TD will simultaneously conduct a study on the suitable marking of fishing gear to be applied at the national and regional levels. • SEAFDEC/TD collaborated with the Food and Agriculture Organization (FAO) for the conduct of the 'Survey to Estimate Levels of Abandoned, Lost or Otherwise Discarded Fishing Gear in Thailand: Gillnets and Trap Fisheries in 2021,' using a preliminary questionnaire designed by FAO to collect information on ALDFG, *e.g.*, gillnets and traps fisheries through face-to-face interview with fishers in Thailand. Results of this survey will be used as part of the ALDFG assessment at the global level and will be possibly applied for monitoring and reporting of ALDFG at national and regional levels. Moreover, in an upcoming collaborative activity between SEAFDEC/TD and the Bay of Bengal Large Marine Ecosystem (BOBLME) Phase II, SEAFDEC/TD will conduct a study on fishing gear marking in the Andaman Sea during 2022–2023. • SEAFDEC/TD carried out the Preliminary Investigation to Estimate the Abandoned, Lost and Discarded Traps (Pots) and Gillnets along the Coasts of Thailand, under the Project Responsible Fishing Technology and Practice, supported by the Japanese Trust Fund (JTF 6 Phase II) of the Government of Japan in 2020–2024
SEAFDEC/TD- MFRDMD-IFRDMD Collaboration • SEAFDEC/TD, SEAFDEC/MFRDMD, and SEAFDEC/IFRDMD had collaboratively initiated the Project "Regional Collaborative Research and Capacity Building for Monitoring and Reducing Marine Debris from Fisheries in Southeast Asia," through the ASEAN Cooperation Project (Japan-ASEAN Integrated Fund or JAIF) during 2021–2023
SEAFDEC/TD-BOBLME Phase II Collaboration • SEAFDEC/TD-BOBLME Phase II (Bay of Bengal Large Marine Ecosystem) launched the 3-year Project "Sustainable Management of Fisheries, Marine Living Resources and their Habitats in the Bay of Bengal Region for the Benefit of Coastal States and Communities: Support to SEAFDEC Member Countries" with support from FAO/GEF

Box 13. Initiatives of some Southeast Asian countries to address the issues on ALDFG
Malaysia: data collection and monitoring of ALDFG in artificial reefs by SCUBA diving undertaken by the Department of Fisheries (DOF) Malaysia, and implementation of the Marking of Fishing Gear targeting tuna long liners undertaken by DOF Malaysia in Penang, Malaysia
Philippines: implementation of the Marking of Fishing Gear for gillnets and pots undertaken by the Department of Agriculture - Bureau of Fisheries and Aquatic Resources (DA-BFAR) in collaboration with the FAO/IMO in Visayan Sea, Philippines
Thailand: experiment on Marking of Fishing Gear undertaken by the Department of Fisheries (DOF Thailand) on some commercial fishing gear, *e.g.* trawlers, purse seines and falling nets and entangling nets, of which the application of the marking of fishing gear is compulsory for some permitted fishing gear (*e.g.* gillnets, tuna purse seines operated in association with fish aggregating devices (FADs)) operated in the Indian Ocean to comply with the requirements of the Southern Indian Ocean Fisheries Agreement (SIOFA)
Myanmar: research survey on ALDFG undertaken by the Department of Fisheries of Myanmar in collaboration with the Fauna and Flora International (FFI) and Marine Ocean Project (MOP) in Myeik Archipelago in 2018, where gillnets were found as the most common type of gear used by small-scale fishers and now performing as ALDFG, although Marking of Fishing Gear is not yet implemented
Indonesia: implementation of a field project that focused on the practical application of marking of fishing gear (in general) undertaken by Ministry of Marine Affairs and Fisheries (MMAF) in collaboration with Global Ghost Gear Initiative (GGGI)

those required by the regulations of the Southern Indian Ocean Fisheries Agreement (SIOFA).

Way forward

In addressing the issues on ALDFG and promotion of the Marking of Fishing Gear concept at the national and regional levels, some AMSs are progressively exerting their efforts in exploring the means and methods by implementing pilot projects and eventually coming up with some scopes, lessons learned, and valuable recommendations which could productively pave the way for future development of regional actions. Studies and trials on the Marking of Fishing Gear have been made recently by some AMSs (*e.g.*, Indonesia (Dixon *et al*., 2018), Thailand (Chumchuen & Krueajun, 2021), and the results and recommendations are briefly summarized as follows:

- Marking of fishing gear can make use of great varieties of materials, namely: metal, plastic, bamboo, coconut shell, and others as they are affordable and available locally. An advance innovation, "FibreCode" tags similar to a barcode, provides user-level identification upon scanning through a mobile device, and could also be applied as an option which will then be assessed using a multi-criteria analysis to determine the preferred method
- Further studies and development efforts should be carried out to improve the suitable materials used for gear marking, the appropriate installation methods, and the effective cost for fishing gear marking, and

to explore the possibility of embedding the fibers into appropriate non-plastic materials to ensure eco-friendliness and readability of information in the fibers using an electronic device

- Gear marking study must be implemented in the context of broader measures for managing fishing gear and wider fisheries management measures as gear marking alone is unlikely to address the issues related to ALDFG and ghost fishing which are apparent in small scale-scale fisheries and probably in other similar fisheries particularly practiced in developing countries
- o Awareness building on the benefits of gear marking can lead to fishers' voluntary application provided they are incentivized, for rigid legislative control and enforcement may not be appropriate for small-scale fisheries
- The government's support is anticipated by most fishers for the application of fishing gear marking practice, especially the cost of producing the markers
- Developing a system of reporting lost gear is necessary to help retrieve lost gear and to enable data collection and increase the chances of lost gear retrieval, although incentives and benefits should also be incorporated with the reporting system
- Strengthening fishers' education and awareness building, capacity building, in general, should be promoted together with spatial management of fishing effort and circular economy approach to managing of the end-of-life gear

Lessons learned from the aforesaid initiatives should be analyzed and considered in developing the appropriate guidelines or standard operating procedures (SOPs) for the marking of fishing gear in the Southeast Asian region. Nevertheless, in the development of the guidelines or SOPs, the concerns of small-scale fishers should be taken into consideration since most of the gear involved in the ALDFG issues are being operated by small-scale fisheries in the region.

4.2 Challenges and Future Direction

A wide range of commercial fishing technologies has been utilized by the fishing industry of the AMSs with a view to maximizing fish catch (including those of other aquatic animals) to meet the increasing demand for food. Nonetheless, excessive fishing including the practice of adopting irresponsible technologies and practices have led to the deterioration of fishery resources, *e.g.* increased catch of juveniles and low-value fish by non-selective gears such as trawls, use of fish aggregating devices/techniques (*e.g.* luring light) in purse seine operations without appropriate regulation and management, use of bottom tow gears such as dredges that impact on the environment especially the benthic communities and habitats, losing or discarding gears that continue to fish and create negative impacts on marine organisms and the ecosystems. Understanding the impacts as well as the development of appropriate technologies and practices are therefore necessary to mitigate such possible impacts from fishing operations. Also, the adoption of novel technologies is also crucial for fishing operations to be undertaken in a responsible manner toward the sustainability of the resources, minimizing the impacts of fishing on the environment, and reducing greenhouse gas (GHG) emission and the impacts of fishing on the climate in the future. Thus, the AMSs and relevant institutions and organizations should consider the following aspects in their efforts toward enhancing the promotion of responsible fishing practices toward sustainable utilization of fishery resources:

Understanding the impacts of fishing gears on resources/ habitats

- The AMSs, relevant organizations, and institutions to consider undertaking research studies on the impacts of fishing gears on the fishery resources (*e.g.* target species, associated and dependent species, marine mammals) and the habitats; and on the development of appropriate mitigations of the impacts. Research studies should also be undertaken to establish the technical measures for reducing the unintentional mortality of non-target marine resources including the endangered, threatened, and protected (ETP) aquatic species. Catching of such species should be avoided while their escape and release at certain fishing depths should be facilitated as well as discarding the individual resources in live conditions. Moreover, the technical measures to reduce the impacts of fishing on the seabed and sensitive habitats should also be studied, including the development of spatial and temporal management, improvement of fishing gears and methods to reduce their destruction on the seabed, and replacement of intrusive fishing gears with more habitat-friendly gears.

- The AMSs, relevant organizations, and institutions to regularly monitor the development and modification of fishing gears and techniques by fishers, undertake necessary research studies on the efficiency and impacts of such gears and techniques on fishery resources and the habitats, and come up with the regulatory measures as appropriate and necessary.

- The AMSs, relevant organizations, and institutions to strengthen the Regional Network for the Reduction of the Impacts of Fishing on Coastal and Marine Environments in Southeast Asia (IFCOME Network) and facilitate the sharing and dissemination of information on programs and initiatives related to the reduction of the impacts of fishing and monitor the developments to be used as the basis for improving the design of fishing gears and promotion of responsible fishing practices.

Developing responsible fishing technologies and practices

- The AMSs, relevant organizations, and institutions to continue the development of responsible fishing technologies and practices, *e.g.* selective fishing gears or fishing operations that minimize generation of by-catch and non-target species; energy efficiency technologies and systems that contribute to saving fuel in fishing operations; and adoption of the Low Impact and Fuel Efficient (LIFE) fishing technologies to mitigate the impacts of fishing gears on the resources and habitats.

- The AMSs, relevant organizations, and institutions to initiate research studies on fuel consumption and GHG emission in various types of fishing gears and operations. Technologies and innovations that aim to reduce energy consumption and GHG emission should be also be investigated and promoted not only to minimize the impacts of fisheries on climate change but also on the operational costs of fishing activities.

- The AMSs, relevant organizations, and institutions to continue developing and applying on-board fish handling technologies appropriate for the various fishing operations of the AMSs, including those for small fishing vessels, with the objective of improving the quality and freshness of the catch and enhancing their utilization for human consumption.

- The AMSs, relevant organizations, and institutions to continue the development and promotion of technologies that aim to reduce the number of fishing crew onboard fishing vessels, *e.g.* purse seiners, considering that the availability of fishing crew is a very important factor for fishing activities. Moreover, the adoption of such technologies would lead to better working conditions, safety at sea, and improved occupational health of the fishing crew in compliance with the relevant international requirements.

Addressing the issues on abandoned, lost or otherwise discarded fishing gears (ALDFG)

- The AMSs, relevant organizations, and institutions should consider the existing regional instruments, *i.e.* the Strategic Plan of Action for ASEAN Cooperation on Fisheries (SPA-Fisheries), the ASEAN Framework of Action on Marine Debris, and the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030, as reference for their collaborative efforts in addressing the issues on ALDFG which is one of the sources of marine debris in the Southeast Asian region.

- The AMSs, relevant organizations, and institutions to continue exploring the sources, impacts, and the extent of impacts of ALDFG on aquatic species and their habitats, and also sustain investigation of the appropriate mitigation measures, particularly through fishing gear marking in cooperation with fishers, private sector, and other relevant sectors in accordance with the FAO Voluntary Guidelines on the Marking of Fishing Gear, and other measures to prevent and mitigate the impacts of the ALDFG.

5. Utilization of Fishery Resources

5.1 Status, Issues, and Concerns

5.1.1 Utilization of Fishery Resources

Fishery and aquaculture production is varied based on species, processing, and product forms, and result in the production of food or non-food uses. As of 2018, about 88 % of the 179 million mt of total global fish production was utilized for direct human consumption, while 12 % was used for non-food purposes (FAO, 2020d). Fish utilization and processing methods differ significantly across continents, regions, countries, and even within countries. In Asia, a large amount of fish production is sold live or fresh to consumers, unlike in Europe and North America where fish production is mainly sold in frozen and preserved forms. Fish commercialized in the live form are typically more appreciated in East Asian and Southeast Asian countries (**Box 14**).

Non-food utilization of fishery resources

Fishery resources are primarily utilized to provide food for humans. A portion of these; however, are used as raw materials in the production of fishmeal and fish oil, in the ornamental fish market, in the baitfish industry, as well as materials in the manufacture of pharmaceutical products, pet food, and for direct feeding of cultured aquatic and terrestrial animals (FAO, 2020d). In 2018, approximately 12 % of total global fish production, or approximately 22 million mt, was used for these purposes.

Box 14. Utilization of fishery resources of the ASEAN Member States *(Cont'd)*
Brunei Darussalam: The aquaculture production had a positive increase from 983.5 million mt in 2015 to 3,501.3 million mt in 2020. The raw materials of processed fish and fishery products are from marine capture and aquaculture, and a portion are sent directly to local markets, while seafood required for exportation will go through preparation, processing, and packaging in facilities. Processers will convert whole fish or shellfish to various other products such as fish fillet or steaks, or other items like frozen products, breaded fish portions, and canned or smoked products (Estrebillo & Hiramoto, 2021).
Cambodia: Most of the inland fishery production are sold through wet markets in small villages and towns, and since the use of ice to keep the fish fresh is limited, most of the produce are sold live, or are preserved in fermented or turned into dried forms. Cambodia has a known history of traditional processing of freshwater fish into fish paste, fermented fish, dry salted fish, smoked fish, fish sauce, and dried fish, which are intended for both domestic and international markets. Cirrhinus fish species is particularly important in the production of processed fish products for the domestic market. Most marine fish commodities are dried, such as shrimp, crab, squid, octopus, cuttlefish, and lobster (FAO, 2011a).
Indonesia: Fishery production from capture fisheries and aquaculture had increased gradually during 2011–2015. About 85 % of the fishery production goes to the local market, while the remaining is exported to Asian markets. Production from small-scale fisheries is typically distributed to local markets for direct consumption or for processing. Medium to large-scale fishery production is generally processed into canned foods such as sardines or used as raw materials for processing of boiled fish, fish bait, or fortification products for export (Ariansyach, 2017). Approximately 55 % of fish are consumed fresh while the rest is consumed frozen, smoked, or canned. The traditional drying, salting, smoking, and canning are ways of post-harvest processing. However, due to the limitation of ice supply as well as refrigerated storage and transport facilities, the remaining amount are usually processed, and consumed as dried, salted, smoked, or fermented fish. Less than 2.0 % of the total catch are processed for canned products, with pelagic species being utilized most. They are usually utilized for the production of oil from sardines and skipjack. Some fish, shrimp, and tuna are frozen and exported, while a small percentage are made into fish oil, fishmeal products, and silage (FAO, 2011b). Additionally, fillet processing and canning industries often produce leftover products in the form of fish bones and skin. Even in some fish production centers which produce surimi and fillets, fish skin is left over as residual waste from the processing. The leftover materials are further processed into high-value products such as gelatin. The fillet industry produces bone and fish skin wastes of up to 3–4 mt per day, and the tuna and skipjack canning industry produces 5,803 mt of bones, 2,106 mt of skin and 9,641 mt of head. From the bones, 721.9 mt of gelatin (yield 12.4 %) can be obtained, and from the skin (9.6 % yield) 202.2 mt of gelatin can be obtained, for a total of 924.1 mt of gelatin from both types of wastes from fish processing. Apart from that, 2,277.1 mt of calcium (39.24 % yield) can be obtained from tuna bones, along with around 1392.7 mt of meat (24 % yield) containing 306.4 mt of protein (22 % tuna meat protein content).
Lao PDR: Capture fisheries and aquaculture in Lao PDR are based on water resource ecosystems, consisting mainly of rivers, streams, hydropower, irrigation reservoirs, diversion weirs, small water bodies, flood plains, and wet-season rice fields. Most of the fishes caught and cultured are consumed by fishers and fish farmers, while the development of fisheries is mainly to attain food security. A variety of fishes such as catfish (*Clarias macrocephalus*) and featherback (*Notopterus notopterus*) are mostly processed into sausage, patty, cracker, dried fish, and fermented fish. Popular processed fish products include deep-fried breaded fish patty as well as spicy fish sausage (FAO, 2006).
Malaysia: Local production of food fish in Malaysia was around 1.87 mt in 2019, with 1.19 mt coming from inshore capture fisheries and 0.26 mt from deep sea capture fisheries. An estimated 75 % of fish is used for food purposes, with the remaining 25 % being used for fertilizer, animal feed, and industrial purposes. A huge percentage of fish caught from the marine capture sector are sold in fresh and chilled forms. Mangrove crab, mollusks, and freshwater fishes caught in inland areas are typically sold in live form. Although the market for live fish is small, most fish farmers tend to market their products in live form to restaurants to acquire higher prices. Anchovies are sold in dried form, where they are usually cooked in brine and dried on land before being marketed. Traditional fish processing done by family operations in fishing villages produces preserved food, such as shrimp paste, pickled shrimp, salted fish, dried cuttlefish, fish sauce, fermented fish, fish crackers, fish balls, and fish cake. However, in recent years, commercial operations have steadily increased, resulting in many small family businesses being phased out. Moreover, fish balls and surimi are also being made industrially now. Additionally, shrimp and tuna meant for export are preserved by freezing in processing plants. Most of the trash fish caught are converted into fishmeal for incorporation into animal feeds (FAO, 2009a).
Myanmar: The extensive inland waters and coastlines possess abundant and unique freshwater species and marine resources, making Myanmar one of the most self-sufficient countries for fish and fishery products. Approximately 80 % of fish, mostly fresh and chilled, are for direct consumption and roughly 10 % of catch are processed into fishmeal. Among the freshwater fish species, rohu fish, a non-oily white fish, is the most popular fish. Other than being sold for local consumption, it is also the top exported fishery product. It is consumed locally and included in various menus, such as fried, minced, fish ball, fish stick, fish cracker, and fish curry. Some examples of rohu fish utilization include fish muruku and fish cracker. Fish muruku is a ready-to-eat fried, crispy snack added with a tinge of spice, while fish cracker is typically made by mixing fish meat with tapioca flour, salt, sugar, and monosodium glutamate, then formed into cylindrical shape, steamed, cooled, chilled, sliced, sun dried then deep-fried. Furthermore, rohu fish is exported as whole, gutted, back gutted, minced, cut, and formed into stick and finger (FAO, 2010b).
Philippines: Reports as of 2014 indicated that fish is typically consumed as fresh, fermented, dried, smoked, or canned (FAO, 2014). Approximately 70 % of the total catch are consumed fresh, while the remaining 30 % are processed into cured, canned, frozen products, or are discarded. Majority of the cured fish and fishery products are sold and consumed locally, with only a small quantity being exported. The majority of frozen fishery products are for export while canned products, especially tuna, are consumed locally in small quantities. Most of the processing plants manufacture traditional products, for example dried and smoked fish for domestic and foreign markets. Also, there have been improvements in handling methods for good quality fresh fish caught for exportation through the use of insulated containers and proper icing. There is also an increasing demand for modern freezing equipment in processing plants such as contact plate freezers for processing shrimps, as well as air blast and brine freezers for tuna. The primary exported frozen products include tuna loins, cephalopods, and shrimps. Moreover, fillets, comminuted, surimi-based products and ready-to-eat fish products have also gained popularity, with products like fish balls, fish sausage, squid balls, and fish nuggets being sold in local supermarkets. Additionally, some processors also convert the by-products of deboned milkfish into value-added products such as fish rolls and dumplings to reduce wastage. Traditional products like salted, dried, smoked, and fermented fish are usually manufactured when there is a steady supply of raw materials. Typically, they are processed by small-scale family businesses which may result in inconsistent quality and limited shelf life of the finished products.

Box 14. Utilization of fishery resources of the ASEAN Member States *(Cont'd)*
Singapore: Being a small country state with limited space for fish farming, the country is dependent heavily on importation of fresh seafood. Nevertheless, the food fish farming industry is thriving with 123 fish farms which accounts for 9 % of annual live and chilled food fish consumed locally. This local food fish production comes from coastal farming in floating net cages along the northern coast of Singapore. For sea-based farms, there are 110 sea-based farms in coastal and southern waters, in which the majority are sited in the Straits of Johor with two deep sea farms in the Southern Waters (WAS, 2020). These farms culture various fish species including milkfish, mullet, snappers, groupers, tilapia, threadfin, and sea bass which are then supplied to live fish markets and supermarkets. Local production of seafood in Singapore was 4,567 mt in 2020 (DOS, 2021).
Thailand: About 81 % of the total fish production in 2006 was directed for human consumption, while the remaining 19 % was used for animal feed (FAO, 2009b). As for marine fish, 22 % were trash fish and used for non-food purposes, mostly for the fishmeal industry. The remaining 78 % were used for human consumption, and 24 % of it were consumed as fresh fish, while the remaining were channeled for processing, such as chilling, freezing, canning, smoked, dried, salted, or converted into shrimp paste or fish sauce. In particular, the fish processing industry has grown exponentially over the years, especially freezing and canning, to increase export. Cultured fish are sold either live or dead. Fish that are intended to be sold alive are typically transported by trucks and kept in water-filled metal boxes.
Viet Nam: Viet Nam has a vast system of rivers, canals, natural reservoirs, artificial reservoirs, and ponds. Tra fish, grass carp, carp, and tilapia are some of the traditional aquaculture species found in the north of Viet Nam. Tra fish is one of the main exported freshwater aquaculture species processed into fish ball, sausages, smoked fish, and fillets for domestic consumption and export.

Reduction into fishmeal and fish oil

Fishmeal and fish oil are key components of compound animal feed because they contain high levels of protein, essential amino and fatty acids, and other nutrients required for growth, development, and reproduction. Thailand and Viet Nam are among the world's major fishmeal producers, as well as the dominant players in Southeast Asia, accounting for roughly 90 percent of the region's total output over the last 15 years as shown in **Figure 96** (Indexmundi.com, 2021). In 2020, these two countries produced 460,000 mt and 340,000 mt of fishmeal, respectively. These are far in excess of the 108,000 mt output of Malaysia, Indonesia, and the Philippines combined. The output of Thailand was close to 500,000 mt from 2006 to 2014, before falling to less than 400,000 mt in 2015. Leadbitter (2019) attributed this decline to the current push to eliminate the use of illegal, unregulated, and unreported (IUU) fishes for raw materials in the supply chain, as well as a drop in domestic demand due to major shrimp disease outbreaks. In contrast, while the upward production trajectory of Viet Nam fishmeal has slowed in recent years, the annual outputs remain above 400,000 mt with no signs of decline. The majority of Thai and Vietnamese fishmeal is utilized domestically, with the remainder exported to China, Japan, India, Taiwan, Bangladesh, and other AMSs.

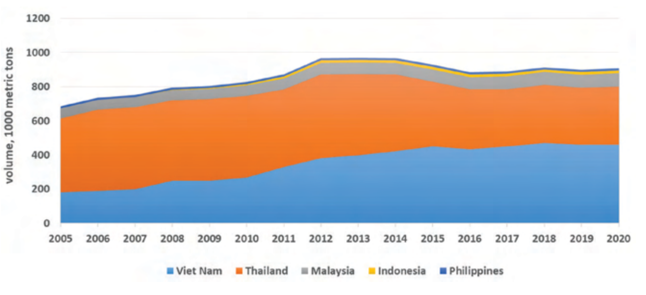


Figure 96. Fishmeal production of Southeast Asia from 2005 to 2020 by quantity (mt)

In terms of raw materials, fishmeal from Southeast Asia differed from that produced in South America and Europe. The fishmeal from these regions are typically composed of a single or few species, often of low-value fish specifically targeted for reduction fisheries, while fishmeal produced in Southeast Asia has been primarily made from trash fish or feed fish composed of multiple species. However, beginning in the late 1990s, fish trimmings from the seafood processing industry had been used in fishmeal production. According to recent data, up to 75 % of total production came from fish trimmings, primarily tuna, small pelagics, and *Pangasius* sp.

Ornamental fish trade

Fishkeeping is a popular hobby enjoyed by millions of people all over the world. This fascination with ornamental fish has created and sustained a multibillion-dollar industry involving the import and export of over 2,500 freshwater and marine fish species in over 125 countries (Dey, 2016). Southeast Asia has been the world's leading supplier of both freshwater and marine ornamental fish since 1989 (**Figure 97**). The AMSs exports totaled 128.4 million USD in 2018, accounting for more than 39 % of the total global value (United Nations Statistics Division, 2021).

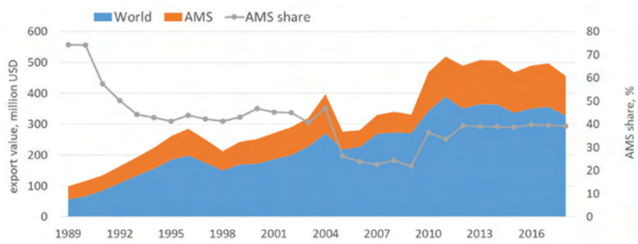


Figure 97. Export value (USD million) of ornamental fish in the world and the ASEAN Member States from 1989 to 2018

Singapore remains one of the world's top exporters and Asia's main trading hub for ornamental fish. It held the top spot for many years, albeit with a gradually decreasing trend. Singapore had a market share of 58.0 percent in 1989, but it fell to 32.0 percent in 1995, 25.0 percent in 2000, 15.0 percent in 2013, and 11.5 percent in 2018. Nonetheless, this value remains enormous, given that at least 70 countries share the export market in 2018, compared to less than 20 in 1989.

Other AMSs that made significant contributions include Indonesia (9.8 %), Thailand (6.9 %), Malaysia (5.5 %), Myanmar (3.8 %), and the Philippines (1.7 %), with the exports in 2018 totaling USD 32.2 million, USD 22.5 million, USD 18.0 million, USD 12.4 million, and USD 5.6 million, respectively. While the UN database did not include the 2018 export data for Brunei Darussalam, Cambodia, Lao PDR, and Viet Nam, these AMSs have been reported to have also engaged in the breeding, production, and trade of ornamental fishes, particularly freshwater species (Mutia *et al*., 2017). In 2003, the export of Viet Nam was valued at USD 42.3 million, making it one of the highest in the region for that year. Its exports in 2017 totaled USD 3.2 million.

Singapore was also the top importer in Southeast Asia and the world in 2018, with imports valued at USD 13.0 million, followed by Malaysia (USD 4.9 million), Thailand (USD 2.6 million), Indonesia (USD 1.8 million), Brunei Darussalam (USD 0.5 million), and Myanmar (USD 0.1 million). While also producing the majority of its traded fish, Singapore imports more than 30 % of its supply from other countries, primarily from its neighboring AMSs (Evers *et al*., 2019; Yue, 2019; Monticini, 2010).

Freshwater species accounted for more than 90 % of the total volume traded globally, 90 % of which was bred and raised in farms and hatcheries, and the remainder wild-caught (Evers *et al*., 2019). Freshwater ornamental fish farming is a well-established industry in Southeast Asia, with various species raised in earthen ponds, concrete/fiberglass tanks, or vertically stacked glass tanks (Ng, 2016; Yue, 2019). Singapore, as the trade capital, leads in ornamental fish research, breeding, husbandry, packaging, and transportation, although the other AMSs such as Indonesia, Thailand, and Malaysia have made significant strides as well (Mutia *et al*., 2007; Ng, 2016; Yue, 2019). Meanwhile, the Philippines produced freshwater ornamental fishes through captive breeding as well, but trading is restricted to the domestic market (Muyot *et al*., 2019).

Marine species accounted for only a small portion of the ornamental fish trade, with 98 percent coming from the wild fishery (Dey, 2016). The Philippines and Indonesia are two of the few countries that supply marine ornamentals to major markets like the United States, Europe, China, and Canada (Livengood & Chapman, 2007; Muyot *et al*., 2019; Biondo & Burki, 2020). However, the trading of marine ornamentals is still a contentious issue, because breeding technology for many species is either underdeveloped or non-existent so that harvesting from the wild is frequently the norm (Muyot *et al*., 2019; Akmal *et al*., 2020). This practice, however, is deemed unsustainable and puts a strain on the natural environment's ecological balance, considering that fish collectors often employ destructive harvesting techniques such as the use of sodium cyanide (Livengood & Chapman, 2007; Mutia *et al*., 2007). While cyanide fishing and other destructive methods have been prohibited in the Philippines and Indonesia, nearly 15 % of marine ornamentals exhibiting evidence of cyanide poisoning continue to enter the EU markets (Vaz *et al*., 2017), indicating the need for more stringent measures to completely eradicate such illegal activities.

Other uses of the fishery resources

Bait fishing, whether for recreation or livelihood, is popular all over the world, especially in Southeast Asia. This activity frequently involves the use of low-value fish as bait. Aquaculture of carnivorous marine fish such as sea bass and grouper as well mangrove crab is also widely practiced in the region, and while formulated feeds are now commercially available for these species, "wet feeds" such as trash fish (fish food) or mollusks continue to play important role in the feeding regimen (Aquino, 2018; Chankakada *et al*., 2020).

Moreover, bioactive organic compounds from crustacean shells, phycocolloids (*e.g.* agar, carrageenan, and alginates) from seaweeds, gelatin and collagen from fish skins, and pigments (*i.e.* carotenoids) from microalgae, and a variety of other marine organisms have all been used in biotechnological, pharmaceutical, and industrial applications (Pangestuti & Kim, 2015; Younes & Rinaudo, 2015, Serive & Bach, 2018). Fish silage and hydrolysates derived from byproducts of fish processing (*e.g.* viscera) are also finding applications in the food and feed industries as well as in agriculture (He *et al*., 2013; Mamauag & Ragaza, 2017).

Maximizing the utilization of fishery resources

Fishery resources are mostly utilized for food purposes, with 88 % of total fish production being used for direct human consumption (FAO, 2020b). Fish not used for direct human consumption are reduced to fishmeal and oil to be used as feed, for raising carnivorous aquatic species such as salmon, shrimp, sea bass, sea bream, and others.

For fish destined for human consumption, fresh fish is the most important product, followed by frozen, canned, and cured fish. Fish represents a valuable source of proteins and nutrients in the diet of many countries. With over one-third of world fish production currently being traded internationally, quality and safety assurance has become a major issue. In addition, post-harvest handling, processing, and transportation of fish require particular care to ensure proper quality and safety. The physical loss of the value of fish is caused by many reasons such as poor handling and preservation or discarding of bycatch. Economic losses happen when spoilage of wet fish leads to the decrease in value or when there is a need to reprocess cured fish resulting in a raised cost of the finished product. Additionally, inadequate handling and processing methods can also lead to reduced nutrients and nutritional losses. Hence, the conversion of large quantities of fish catches into animal feeds can be considered as a "loss" to human food security.

In the Southeast Asian region, the volume of low-value fish catch depends on the fishing season, fishing grounds, and fishers' efforts in sorting out the catch. Low-value fishes are grouped into those of deteriorating quality unsuitable for human consumption, which is used to produce feeds, and low-value small-sized fish, which are acceptable for human consumption. The quality of fish tends to deteriorate due to poor methods and unavailability of facilities to preserve fish onboard fishing vessels as well as the long period spent at sea.

Thus, it is of utmost importance that fish catches are utilized responsibly and post-harvest losses are minimized to attain food security for the Southeast Asian region. SEAFDEC/MFRD has conducted post-harvest projects on small pelagic marine and freshwater species in the region to maximize utilization by collaborating with the National Centre for Quality Control and Product Development (NCQC) of Indonesia to examine the utilization of small pelagic fish species, and with the Fisheries Administration (FiA) of Cambodia for the utilization of freshwater fish catch.

SEAFDEC/MFRD has conducted several activities that include the utilization of underutilized marine and freshwater fish species for the development of surimi and value-added fish products to produce fish jelly products such as fish balls and cakes, which are popular traditional products in the Southeast Asian region. The development of the surimi industry has offered markets to what was considered before as low-value fishes. Fish species such as threadfin bream, lizard fish, big-eye snapper, croaker, and goatfish or red mullet are often regarded as being of low economic value due to poor consumer preference and poor quality, but their usage in the surimi industry had indicated their importance in producing value-added products for human consumption such as fish sausage, fish burger, fish tofu, fish floss, fish siew mai, and many others.

A project on the utilization of low-value freshwater fish species was carried out in Cambodia in collaboration with FiA. Three fish species that are considered low-value and underutilized, namely: featherback fish (*Notopterus* spp.), snakehead fish (*Channa* spp.), and soldier river barbs (*Cyclocheilichthys enplos*), are used in the study. The results had allowed the development of a new range of value-added fish products from these underutilized freshwater fishes and helped to promote the conversion of underutilized freshwater fishes for human consumption while also improving the socioeconomic conditions of people dependent on freshwater fisheries. Featherback and snakehead fishes are used to produce fish bak kwa, fish cracker, fish siew mai, and fish tofu, while soldier river barbs are utilized to produce snacks such as fish muruku and fish satay.

These technological approaches have allowed the maximum utilization of fishery products, ranging from low-value small demersal and pelagic fish species to underutilized freshwater species, and the technology would be transferred to the AMSs. These value-adding technologies have also helped to minimize wastage and losses, thus contributing to food security and the economy of the AMSs.

5.1.2 Management of Food Losses and Wastes

Food loss is defined as any food that is lost in the supply chain between the producer and the market that leads to a decrease in the quantity or quality of the food. Food waste is defined as a safe and nutritious food that is discarded, whether by choice or due to spoilage as a result of negligence. As the global population is projected to grow to 9.7 billion by 2050, there are concerns that food production will be unable to keep up with rising demand. By minimizing food losses and wastage, improvements to food security could be achieved as this would ensure that more food is available instead of being lost or wasted throughout the supply chain. The impact of food loss and waste vary widely among the AMSs, so as the management strategies employed to reduce food losses and wastage (**Box 15**).

Box 15. Management strategies employed by some AMSs to reduce food loss and waste
Indonesia: The country has measured or estimated the quantities of food loss and waste across the fishery supply chain using the methodology of Food Loss on Production and Harvest Phase, Handling Phase, Storage Phase, Processing and Packaging Phase, Distribution and Marketing Phase, and Food Loss on Fishery Products during Household Consumption. Areas where food loss and waste occur are spread throughout the supply chain. During production, fish may be damaged due to inadequate cooling processes or facilities while on board or death due to weather changes, water upwelling, and water pollution. During postharvest, fish loss may occur due to damage during handling after unloading and storage, by pests or predators, or spoiling of fish that were not sold as they were stored for too long. For processing, less-skilled workers may cause higher wastage of fish parts when carrying out separation of flesh from the bones and skin, and limited waste utilization technology *e.g.* utilization of shrimp shell waste into chitin/chitosan, the process of utilizing fish canning industry waste (fish oil) is also a restricting factor. For distribution, excess supply of fish and shortage of buyers led to unsold products being wasted, and products may also be damaged due to delays in distribution/transportation, poor packaging, improper handling, and inadequate facilities and infrastructure. Retailer product quality standards may also make it difficult for fish farmers to supply products to the market. Food waste occurs at the consumption stage due to products with non-standard packaging that are wasted, and food thrown away in households and food providers such as restaurants and catering services. Currently, interventions to minimize food loss and waste along the food supply chain are being implemented. In the processing supply chain segment, there are measures such as by-product utilization training, post-harvest facilities assistance, development of cold storage and integrated cold storage, regulation on Increasing Value Added of Fishery Products as well as implementation of Miniplant Zero Waste Development Program. For reducing food loss and waste during distribution, Indonesia has initiated support programs for the Provision of a Cold Chain System, which includes construction of a portable frozen warehouse for fish storage, procurement of refrigerated cars/trucks for the distribution of frozen and fresh fish and procurement of ice making machines (blocks or flakes) as a cooling medium for the sale or marketing of fish to consumers or buyers, in order to maintain the quality of fish. Additionally, the Guidance for Handling in the Distribution of Fishery Products has been published to support local fishery industry. In the area of consumption, measures for reducing food loss and waste in Indonesia include educating consumers to avoid over-buying, for example purchasing large quantities of foodstuffs that are not required to be used immediately, and giving consumers a better understanding of the difference between "best before" and "best by" dates. In addition, consumers can implement better storage practices and stock management at home, and better evaluate portion size to be appropriate. Improved food preparation techniques that will maximize utilization of food and prevent deterioration of food quality should also be adopted. Finally, utilization of leftovers in recipes rather than throwing them away should also be done.
Malaysia: Generally, the fish supply chain consists of the following main phases, namely: harvest/production, sorting, chilling/freezing, packaging, storage, transportation, and market/consumer (domestic/export). The critical stages of the supply chain segment where food loss and waste occur most are at the harvesting and market/consumer phases. To minimize food loss and waste in the fishery supply chain, Malaysia has implemented interventions and measures, which include those for the production supply chain phase, where measures such as encouraging the use of efficient technologies, improving fishing vessel storage facilities, implementing traceability systems, and building capacity by developing expertise and conducting training, are being carried out. The implementation of Good Manufacturing Practice (GMP), monitoring programs such as the Hygiene on Board (HOB) program, and developing the Malaysian Standard of Hygiene on Board (MSHOB) to enhance the willingness of local vessels in practicing proper fish handling procedures, also serves to reduce food loss. For processing, the use of efficient technologies, implementation of traceability systems, certification programs such as GMP and HACCP as well as capacity building of fish workers, contribute to reducing food loss. During distribution, the use of better packaging and temperature-controlled storage of products in properly equipped transportation also decreases the amount of fish lost during this stage. Finally, awareness program and campaign conducted on consumers helped to reduce food waste at the consumption stage.
Philippines: Food waste and loss occur across the different stages of the supply chain. During the production stage such as fish capture or harvesting of farmed fish, inappropriate postharvest handling may result in food loss. Onboard fishing vessels, undersized or non-valuable fish are discarded. During processing, non-compliance to cold chain and inappropriate processing and preservation conditions also contribute to food loss. Inappropriate transport and distribution facilities during distribution as well as inappropriate handling and preparation techniques by consumers also lead to food loss and waste of fish and fishery products. Under the Comprehensive National Fisheries Industry Development Plan launched in 2016, the country aims to reduce fisheries postharvest losses from 25 % to 15 % (Department of Agriculture, 2016). This would be achieved by the setting up of Community Fish Landing Centers (CFLCs) in strategic coastal communities which could provide postharvest facilities and give more fishers access to ice-making facilities to reduce food loss due to inappropriate storage temperatures. Other facilities such as fish stalls, air blast freezers, ice plants and cold storage facilities, refrigerated vans, solar driers/smokehouses, and warehouses would also be provided. Furthermore, the utilization of fishery by-products to produce new products has also been gaining popularity. Some examples of such products include dietary supplements that include calcium from the backbones, fins, and offal of several fish species as well as shrimp flavor concentrate from shrimp heads that are dried and processed, and are used as base for the commercially available shrimp flavors sold either as cubes, bouillons, or powdered additives.
Singapore: A study by the Singapore Environment Council published in 2019 estimated that 25,000 mt of fish and seafood are lost per year in Singapore. This figure accounts for both local production of food and imported food landings. The study's methodology consisted of interviews with key stakeholders in the food supply chain in Singapore, including farmers, importers, distributors, retailers, waste management experts, academicians, and non-profit organizations, as well as literature review of past studies focusing on food loss and waste conducted globally and in Singapore. Food loss and waste occur throughout the food supply chain. During the primary production of fishes, food loss and waste can be caused by several factors including disease, poor water quality, and poor post-harvest handling. For midstream processes such as processing, packaging, and distribution, incorrect freezing process can lead to a loss of quality during frozen storage. Frozen products can suffer from "freezer burn" and are more susceptible to damage by rough handling. Losses in fish also occur during processing, such as canning or smoking, where trimming spillage are thrown away. Food loss during retail and consumption can be caused by oversupply of fish and seafood resulting in food loss if they are left unsold. Inadequate consumer knowledge of proper storage and management of food purchases could also result in food spoilage and wastage. To minimize food loss and waste in the fishery supply chain, Singapore has implemented numerous measures. For production, climate resilient and sustainable aquaculture technologies have been developed which will minimize food loss. For example, real-time water quality monitoring systems had been incorporated into coastal fish farms that serves to alert the farmers during poor water quality conditions (*e.g.* when there is low dissolved oxygen). Floating closed containment systems, whereby fishes are reared in a controlled environment to protect them from adverse conditions have been developed as well. For processing, the National Environment Agency (NEA) of Singapore launched the Food Resource Valorisation Awards in 2021 (NEA, 2021), which aims ...

Box 15. Management strategies employed by some AMSs to reduce food loss and waste *(Cont'd)*
... to recognize the efforts of companies that adopt food waste valorization solutions as well as raise awareness of the concept. Through this award, Singapore seeks to encourage more organizations to adopt and develop similar food waste valorization solutions by recognizing companies that engage in the conversion of food waste, such as homogenous by-products, rejects, and mixed food waste into products that contribute to a sustainable economy. One example of waste valorization in Singapore's fishery supply chain is the use of grey mullet offcuts (head, bones, and trimmings left after processing into fillets) to make soup (Tan & Liu, 2020). In the area of distribution, Singapore minimizes food loss and waste by requiring food establishments to employ appropriate cold chain requirements to ensure food safety, as part of the licensing requirements. To assist the industry, the new Singapore Standards for Cold Chain Management of Chilled and Frozen Food to Assure Food Safety and Quality was published in October 2021 with the intention to strengthen cold chain ecosystem by setting out the General Requirement and Code of Practice for management of chilled and frozen food including seafood. The guide on Good Handling Practices and Cold Chain Guide for Chilled Seafood was also developed by the Singapore Food Agency (SFA) which includes guidelines on temperature control, processing and packaging, transportation, and display for sale to ensure the quality and safety of chilled fish and seafood to minimize losses. An example of this implementation is the e-commerce retailer Redmart which delivers fresh produce to consumers by utilizing normal delivery trucks, but the trucks are lined with reusable insulation and industry-grade ice plates that can be refrozen after each use to maintain the optimum temperature (Neo, 2019). This maintains the cold chain process during delivery and reduces potential food loss when delivered to consumers. For consumption stage, the Food Waste Reduction outreach program in 2015 of NEA aimed at encouraging the adoption of smart food purchase, storage, and preparation habits, helps consumers save money while reducing food wastage at source (NEA, 2020). Educational materials have been publicized on print and social media platforms, and Food Waste Minimisation Guidebooks were published in 2017 for food retail establishments, supermarkets, and food manufacturing establishments to reduce food waste across the supply chain.
Thailand: Majority of fish catch of the country is intended for human consumption, and the remainder is mainly utilized to produce feeds and fertilizer. Higher quality fish are used for human consumption while lower quality fish are used to produce feeds, and fish of the lowest quality are used for fertilizer. Since all parts of fish are utilized to produce either food or non-food products, there is rarely food loss and waste in the fishery supply chain. Nonetheless, the key stage that generates the most food loss is postharvest after production and before processing due to ignorance of low temperature control during handling. To minimize food loss and waste in the fishery supply chain, the country has invested in automation process and use of traceability systems during production stage. For processing, traceability systems are also being implemented. For distribution, better logistics and transportation, packaging, and usage of information technology to monitor temperature during distribution, are meant to reduce food loss. For consumption, educated retailers and consumers, and higher consumer awareness have helped to reduce food waste.
Viet Nam: Under Resolution 48/2009/ NQ-CP, the government set the target of reducing the rate of aquaculture postharvest losses from 20 % to 10 % in 2020 (APEC, 2018). This target would be achieved through building aquaculture ponds equipped with advanced equipment to limit risks caused by environmental impacts such as weather and epidemics, and improvement of freezing preservation technology (Ministry of Agriculture and Rural Development, 2009). In addition, the government has also enacted a policy to provide financial incentives for businesses, farmer cooperatives, and farmers for investment in agricultural facilities such as freezers to reduce postharvest losses.

5.1.3 Food Safety from Marine Biotoxins

Potential hazards in aquaculture can be broadly classified into biological hazards and chemical hazards. Common biological hazards are bacterial pathogens (*e.g. Salmonella* spp., *Shigella* spp., *Vibro* spp., listeria monocytogenes, and pathogenic strains of *Escherichia coli*), parasites (*e.g.* trematodiasis, cestodiasis, and nematodiasis), and viruses (*e.g.* Norovirus, Hepatitis A virus). The primary chemical hazards for aquaculture products include veterinary drug residues, agri-chemicals (*e.g.* pesticides, herbicides, fungicides, disinfectants), heavy metals, persistent environmental contaminants (*e.g.* organochlorine compounds like PCBs and dioxins), and naturally occurring biotoxins (*e.g.* marine biotoxins, scombrotoxins). These hazards are usually associated with the farming system and management, aquaculture habitats and practices, the species being farmed or caught, environmental conditions of the farming sites, and cultural habits of food preparation and consumption. Control measures have been established to address the potential risk from marine biotoxins and scombrotoxins in the context of intensifying climate change, growing population, and wide-spreading environmental pollution.

Over the recent decades, increasing eutrophication, warmer seas, ocean acidification, and food web modifications resulting from overfishing and other factors, have led to increased prevalence of harmful algal blooms (HABs) globally. These algal species can be broadly classified into microalgae (unicellular organisms) and macroalgae (multicellular, also called seaweeds), and together they produce more than half of the oxygen in the earth's atmosphere. The occurrence of algal blooms denotes an increase in the abundance of a single (or more) algal species in each area and the growth reaches bloom proportions when a series of environmental factors occur in synchrony—temperature, salinity, light, turbulence, availability of micro- or macronutrients, availability of trace elements, and in the case of microalgae, interactions with populations of marine bacteria, viruses, and algal grazers. Moreover, a growing interest in increasing aquaculture and mariculture facilities to meet the increasing demand for food has brought with it significant food safety concerns related to phycotoxins caused by the proliferation of HAB species, as consumption of seafood and fish is the primary route for exposure to phycotoxins (algal toxins) in humans. HAB phycotoxins may bioaccumulate in fish and shellfish that can induce toxic syndromes in humans who consume them, with symptoms ranging from skin, eye, or ear irritations to more severe reactions such as liver and kidney damage and gastrointestinal, cardiovascular, respiratory, and neurological conditions.

Another worrying trend is the expansion of several HAB-forming species which have enlarged their geographic ranges over time. A well-known example is that of the causative species of paralytic shellfish poisoning (PSP) *Alexandrium tamarense* and *A. catenella*., which have caused blooms mainly in the temperate coastal regions of Europe, Japan, and North America in the 1970s. In the last 20 years, these species have made their way into the Southern Hemisphere, forming toxic blooms off the coasts of Australia, New Zealand, Papua New Guinea, and South Africa as well as reaching off the coasts of Brunei Darussalam, India, Thailand, and Philippines. Moreover, microplastics have also been implicated as potential carriers of HAB species in the marine environment. With climate change expected to affect the distribution of microplastics in the oceans, how this phenomenon translates into changes in the geographic expansion of HAB species remains to be investigated as it is already a worrying trend.

At present, no routine diagnostic tests are available for HAB-associated poisoning in humans, and clinical diagnosis is based largely on symptoms presented and dietary history. There are also no known antidotes for many of these toxins, making symptom management the only care available to those suffering from the painful toxic effects. In view of this, monitoring seafood for toxicity is essential to manage the risks together with adequate regulations to ensure that the design and implementation of appropriate monitoring and mitigation measures would be able to control HABs and prevent negative health effects and economic losses worldwide. Hence, the monitoring of seafood for marine biotoxins is urgently necessary by adopting surveillance programs to check the levels of toxic phytoplankton. Such a concern reflects the growing urgency of preventing and mitigating HABs occurrences, which is essential to manage possible risks.

Initiatives for Monitoring Marine Biotoxins and Scombrotoxins

In order to better manage the public health risks associated with the consumption of contaminated seafood products in the Southeast Asian region, SEAFDEC/MFRD had launched multiple initiatives to help AMSs to detect, monitor, and share information on marine biotoxins detection. The training sessions organized by SEAFDEC/MFRD (since 2004–2019) had covered a wide range of topics, like the detection of heavy metals, pesticide residues, drug residues, and marine biotoxins and scombrotoxins in aquaculture products. The most recent training activities, that had been customized based on the feedback and requests by the AMSs (2009–2019) focused on marine biotoxins, covering Diarrhetic Shellfish Poisoning (DSP) toxins, Paralytic Shellfish Poisoning (PSP) toxins, Tetradotoxin (TTX), Amnesic Shellfish Poisoning (ASP) toxin (domoic acid), Azaspiracid (AZA) toxin, Brevetoxins (BTX) which causes Neurotoxic Shellfish Poisoning (NSP), as well as algae identification techniques. The overall objectives of these training activities are to equip the AMSs with essential knowledge and laboratory capabilities on aquaculture safety, with which the AMSs would be able to establish monitoring programs to assess the occurrence of the hazards in their countries. As many AMSs are also major exporters of fishery products to the global market, it is therefore essential to enhance the countries' marine biotoxins detection capabilities to facilitate a stable agri-trade and the economic growth of the countries.

Besides the programs mentioned above, the ASEAN community has also established the ASEAN Food Reference Laboratory (AFRL) for Marine Biotoxins and Scombrotoxins under the purview of the ASEAN Food Testing Laboratory Committee (AFTLC), which is under the Prepared Foodstuff Product Working Group (PFPWG) overseen by the Economic Community sector of the ASEAN. The AFRL for Marine Biotoxins and Scombrotoxins is the 10th AFRL established in 2019 and is currently being hosted by the National Centre for Food Science (NCFS) of the Singapore Food Agency (SFA) under the Foodborne and Natural Toxins team, and with a multi-disciplinary team of scientists and advanced analytical facilities. To date, it has established testing capabilities of over 35 marine biotoxins as well as scombrotoxin and is accredited under ISO/IEC 17025, the testing methodologies are benchmarked with the world's leading reference laboratories (*e.g.* EU reference laboratories for marine biotoxins) and through the participation in proficiency tests (PTs) organized by internationally recognized PT providers. Currently, this AFRL is conducting a survey to solicit interest by the AMSs on proficiency and training activities to commence in 2022 in this specialized food safety area.

5.2 Challenges and Future Direction

Fishery resources have been harvested and utilized for human consumption as well as for non-food purposes. Although the proportion of utilization of fish (and other aquatic species) for human consumption has increased over the years, which could be a result of the technologies developed for reducing food losses and wastes, as well as for preservation and processing of fish catch, it is still necessary for the countries in the region to continue developing and improving their fishery products to meet the changing market demand. One of the important issues on the utilization of fishery resources is to ensure the safety and quality of fishery products by enhancing the capacity of countries to comply with quality assurance systems, such as the HACCP, GMP, among others, in processing establishments as appropriate, availability of accredited laboratories to detect contaminants in food products, *e.g.* chemicals, antibiotics, as well as biotoxins that are subjected to trade regulations, and the application of cold chain management throughout the fishery supply chain from catching/harvesting until reaching the consumers.

Box 16. Status updates by the AMSs on the monitoring system and occurrence of marine toxins and scombrotoxin
Indonesia: Indonesia has established a biotoxins monitoring program under the purview of the Fish Quarantine and Inspection Agency to control water quality and monitor toxins in shellfish. For the last 3 years, there has been no detection of marine biotoxins that exceed the national limits. A national reference laboratory with the ability to detect ASP, PSP, NSP, AZA, ciguatoxins and scombrotoxins has been established and obtained accreditation for the laboratory management system under ISO/IEC 17025, to ensure that the country's marine products bound for export comply with the international food safety standards (*e.g.* Codex MRLs).
Malaysia: There had been cases of PSP toxins and tetrodotoxin intoxication cases reported from 1976 to 2013 in Malaysia, but no cases of poisoning due to ASP, DSP, and NSP caused by domoic acid, AZA, and BTX. Malaysia has the testing capabilities for marine biotoxins such as ASP, PSP(Saxitoxins), AZA, BTX, TTX and Scombrotoxins. The Department of Fisheries Malaysia (DOFM) is responsible for conducting marine biotoxins for shellfish monitoring under the National Sanitation Shellfish Program. In recent years about 40 % pufferfish were tested positive for TTX, but no contravene cases so far. There has been no scrombotoxins poisoning cases reported under the SPS Marine Program and Hygiene on Board Program which is also under DOFM.
Myanmar: There is no marine biotoxin monitoring program in Myanmar. Instead, a survey on ASP, DSP and PSP in mussels, clams and oysters was conducted from 2009 to 2017 and no positive detection was reported. A monitoring program to assess the histamine level of fish under the Scombridae & non-Scombridae family had been established, covering specifically the species of hilsa, platu, plalan, bata, Spanish mackerel, tuna, sardine, anchovy, and lotia according to EU requirements. Sampling and testing were conducted two times per year by the EU approved processing plants. There has been no outbreak of poisoning due to marine biotoxins and scrombotoxins reported by Myanmar.
Singapore: With over 90 % of current food being imported from overseas, regulating for food safety at import is crucial. The Singapore Food Agency (SFA) is responsible for food safety and it has in place a multiprong approach to ensure the safety of marine food products. Singapore adopts a science-based risk management approach for higher risk fish and seafood. For example, veterinary health certificates are required for live oysters and they may only be imported from countries, which meet SFA's requirements for a shellfish sanitation program. To support this science-based risk management approach, adoption of international standards such as Codex is crucial. It is also important to have necessary food legislation to provide regulatory levers should there be any food safety risks. These include mandatory licensing of traders and requiring each consignment to be issued an import permit by SFA. Moreover, SFA has put in place a science and risk based regulatory program to ensure the safety of seafood and products. Imported seafood such as oysters and fish are subject to a wide range of biological and chemical testing which includes hazards such as marine biotoxins (*e.g.* ASP, DSP, PSP and TTX), pathogenic bacteria (*e.g.* Group B streptococcus (GBS)), virus (*e.g.* norovirus), as well as heavy metals. Imported aquaculture products allowed for sale in the market are those that are found to fulfill SFA's food safety requirements. Shellfish such as mussels and oysters from coastal farms are also regularly sampled and tested for the full range of marine biotoxins. Besides the regulatory program for import control, SFA also established Market Monitoring Program with a customer centric approach, to monitor and test seafood products such as mussels, clams, scallops, and fish from retailers (*e.g.* supermarkets and wet markets) for marine biotoxins and scombrotoxin. To date, two samples were found to have failed the test, one for marine biotoxins and one sample for scombrotoxin, while there have been no marine biotoxins poisoning cases reported since 2001.
Thailand: The Department of Fisheries has established Bivalve Mollusc Sanitation Program to monitor ASP, PSP, DSP, AZA, yessotoxins (YTX) and pectenotoxins (PTX) in marine products. The program includes quality control for bivalve products to meet the requirements of business partner countries. As for the surveillance program on scombrotoxin, the country has implemented GMP and HACCP in processing plants with control measures on safety and quality, where histamine levels in raw materials (*e.g.* Scombridae genus) and final products (*e.g.* fish sauce) are strictly monitored to ensure that international standards are complied with. Moreover, marine biotoxins and scombrotoxin in fish and fishery products have not been reported as a food safety issue.

Efforts of the AMSs to improve the utilization of fishery resources should therefore be continued and intensified to be able to contribute towards achieving several SDGs, particularly SDG 12: Sustainable Consumption and Production. Thus, the following aspects should be considered by the AMSs, and relevant institutions and organizations, in improving the utilization of fishery resources:

- The AMSs in collaboration with the private sector and consultation with stakeholders should consider investing in the promotion of the technologies and in setting up of facilities and infrastructure that aim to minimize pre- and post-harvest losses and wastes across the entire fishery supply chain, starting from the production of fish, through the processing, packaging, and distribution, as well as during the sale and consumption to ensure that more food fish is available instead of being lost or wasted. Regional assessment should also be conducted on the efficient utilization of fishery resources and in reducing post-harvest losses, while the implementation of the Regional Guidelines on Cold Chain Management for Seafood should also be promoted.
- With support from relevant organizations, the AMSs should continue strengthening the capacity of their respective national laboratories to be able to analyze contaminants in fish and fishery products, including marine biotoxins and scrombrotoxin with a view to ensuring the safety of fishery products for human consumption as well as enhancing the competitiveness of the products in the international markets.

6. Fishery Management

The coastal waters of the Southeast Asian region are among the most productive in the world (Sugiyama, 2004; Pomeroy, 2013) with more than 250 million people in the region relying on fish for at least 20 percent of their average per capita intake of animal protein (Pomeroy *et al*., 2020). Fishing has also been providing employment, livelihoods, and generates direct and indirect economic benefits for coastal communities in the South China Sea (Teh *et al*., 2017). Fishing is carried out within a country's own territorial sea or exclusive economic zone (EEZ) (Wongrak *et al*., 2021) and also in the high seas.

Improvement of fisheries management in the Southeast Asian region will involve promoting regional dialogues on fisheries management and improvement of governance. It will also involve developing and supporting regional alliances and networks and national fishery associations in the areas of policy and regulation development and capacity building. There are several strategies to consider in terms of how to address the priority issues and threats for marine capture fisheries in the Southeast Asian region (Pomeroy *et al*., 2016), *i.e.* a) Strengthening transboundary fisheries management; b) Engagement with the private fisheries sector; c) Ecosystem approach to fisheries management; d) Addressing maritime security issues; and e) Addressing globalization of trade and market access.

The ASEAN and SEAFDEC have been paving the way for enhancing better governance of the region's fisheries within the context of an ecosystems approach through the Code of Conduct for Responsible Fisheries (CCRF) and the regionalized CCRF (SEAFDEC, 2003). The ASEAN and SEAFDEC have also been responding to the other international instruments such as the International Plan of Action (IPOAs) on the management of fishing capacity, conservation and management of sharks, reducing the incidental catch of seabirds, and illegal, unreported, and unregulated (IUU) fishing, all of which are aimed at enhancing governance in fisheries management (Mahyam *et al*., 2011).

6.1 Status, Issues, and Concerns

6.1.1 Management of Fishing Capacity and Combating IUU Fishing

Illegal, unreported and unregulated (IUU) fishing and fishing overcapacity have been contemplated as the utmost root of overfishing for most of the coastal fisheries in the region and worldwide (Pomeroy, 2012; Stobutzki *et al*., 2006; Song *et al*., 2020), could even lead to the collapse of a fishery. IUU fishing can take place in all areas of capture fisheries and is considered a major factor that undermines the sustainability of fisheries. It occurs in both small-scale and industrial fisheries, in marine and inland waters, as well as in zones of national jurisdictions and in the high seas. The notions for combating IUU fishing initially come from the marine environment, which has been facing serious challenges from massive, organized fishing activities, specifically industrial fishing companies that disobey standard fishing practices to the extent of destroying the fishery resources that also lead to overexploitation. This implies that IUU fishing can contribute to the overfishing of fish stocks and could even result in the possible collapse of a fishery.

The origin of the terms illegal, unreported, and unregulated had been initially introduced in March 2021 and documented in the "International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing" adopted by the 24th Session of the FAO Committee on Fisheries (COFI). **Illegal fishing** is defined as fishing without permission and conducted in the territorial waters of a particular country/state or fishing that offend state laws, and fishing activities in the high seas against laws and agreements of two or more countries based on the agreements with Regional Fisheries Management Organizations (RFMOs). **Unreported fishing** refers to fishing activities that are not reporting or are misreporting the yield and offend national and regional rules and guidelines; while **unregulated fishing** means that fishing fleets have no flags or nationality in water bodies of countries not members of RFMOs and fishing activities in water bodies that have no existing management actions (MRAG, 2008). For these definitions of IUU, each action is aimed to protect marine fisheries where the areas and fish distribution involved several countries and there is awareness of multi-nations collaboration necessary to deal with the IUU fishing that has destroyed the fishery resources.

It was estimated that about 26 tonnes of the world's yearly fish landings are considered as IUU harvest, equal to a fifth of wild-harvested fish, and account for a net yearly cost of around USD 10 to USD 23 billion (Agnew *et al*., 2009; Sumaila *et al*., 2006). Thus, IUU fishing poses a direct threat to food security and socioeconomic stability in many parts of the world, and in turn, could result in lost economic and social opportunities, both short-term and long-term. Developing countries that depend on fisheries for food security and export income are most at risk from IUU fishing. Therefore, combating IUU fishing is of paramount importance to protect the huge amounts of resources harvested illegally that had disadvantaged the small-scale and subsistence fisheries.

The Department of Fisheries Malaysia also estimated that the country loses up to USD 1.44 billion to illegal fishing every year (The ASEAN Post, 2020). Recently, the vigorous inter-agencies enforcement activities of the Malaysian Maritime Enforcement Agency, Marine Police, and the Royal Malaysian Police in Malaysian fisheries waters through special operations which began in May 2019 to curb IUU fishing activities, have successfully reduced the total loss due to IUU fishing activities from RM6 billion in 2017 to RM4.25 billion in 2020 (Yazeereen, 2021).

In 2010, the European Commission (EC) has enacted tough legislation against IUU fishing to make sure that IUU fisheries products do not end up on the EU market. Countries that disregard IUU fishing are first put on notice and issued a yellow card. If the country shows improvement in its anti-IUU fishing efforts, the observation period for at least six months will continue until the yellow card is eventually rescinded. Countries that do not show satisfactory progress after the monitoring period are identified or categorized as uncooperative and issued red cards. Marine products from these countries are banned from entering the EU and classified under the final state which is the blacklist, and their fisheries products caught by all fishing vessels operating under that country's flag are prohibited by the EU, while EU fisheries companies are also banned from cooperating with those countries (The ASEAN Post, 2020).

The Philippines was issued yellow card in June 2014 but managed to have it rescinded in April the following year. Cambodia received a yellow card in November 2012 and was downgraded further to the EC's blacklist in March 2014, and all fisheries products caught by fishing vessels registered in Cambodia have since been banned from the EU (The ASEAN Post, 2020). In April 2015, the EU announced that Thailand was in breach of the IUU fishing regulation by carrying out inappropriate fishing activities (Wongrak *et al*., 2021) and was issued yellow card which was lifted in January 2019, in recognition of the substantive progress made by Thailand in tackling the concerns on IUU fishing (Banks, 2019). Viet Nam received a yellow card in October 2017, and has been anxious to get it rescinded through communication, laws, and technical measures, following recommendations from the EC delegation (The ASEAN Post, 2020).

SEAFDEC has been promoting several measures and initiatives to combat IUU fishing activities in the region considering that IUU fishing has been recognized as a deterrent to the sustainable development of fisheries in the Southeast Asian region and many forms of IUU fishing occur in the region (Mazalina *et al*., 2015). Meanwhile, the AMSs have also made tremendous efforts in implementing several initiatives (**Figure 98**) as well as strengthening cooperation on transboundary issues through bilateral dialogues where the platform for harmonization has been provided by SEAFDEC (Jaya *et al*., 2019). SEAFDEC also has been requested by the AMSs since 2011 to come up with guidelines to prevent the entry of fish and fishery products from IUU fishing activities into the supply chain of the inter-and intra-regional as well as international fishery trade system. To this end, SEAFDEC/MFRDMD

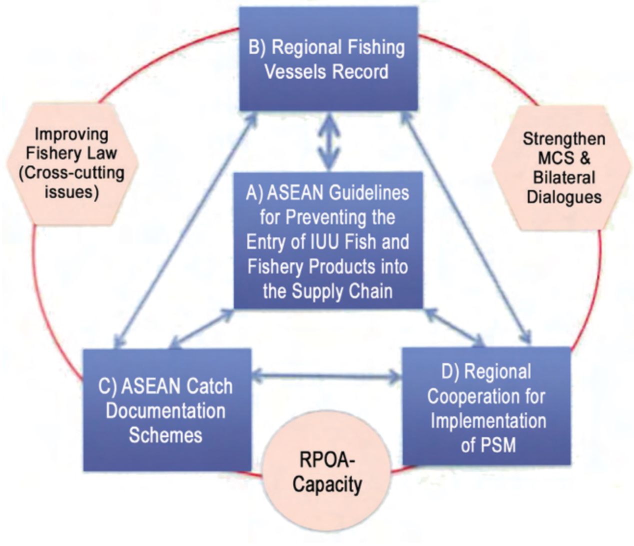


Figure 98. Initiatives of SEAFDEC and the AMSs towards combating IUU fishing in the Southeast Asian region

*(**Source:** Jaya* et al., *2019)*

in collaboration with SEAFDEC/Secretariat had developed the 'ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain' (ASEAN Guidelines) through a participatory and consultative process involving fishery experts from the AMSs to enhance the credibility of the region's fish and fishery products. The ASEAN Guidelines was finalized in September 2014 and subsequently endorsed by the 37th Senior Officials Meeting of the ASEAN Ministers on Agriculture and Forestry (SOM-AMAF) in August 2015 and finally by the 37th Meeting of the ASEAN Ministers for Agriculture and Forestry (AMAF) in September 2015. The ASEAN Guidelines were published by SEAFDEC/MFRDMD in 2015 (Mazalina *et al*.,2015).

- *The ASEAN Guidelines for Preventing the Entry of IUU Fish and Fishery Products into the Supply Chain*

SEAFDEC as a technical arm of ASEAN always works together with all AMSs under the ASEAN-SEAFDEC Strategic Partnership Mechanism in developing several management tools, guidelines, and measures with the objective of enhancing the cooperation among the AMSs to combat IUU fishing in the region, *e.g.* the ASEAN Guidelines for Preventing the Entry of IUU Fish and Fishery Products into the Supply Chain (ASEAN Guidelines), eACDS, and RFVR.

The ASEAN Guidelines serves as guiding principles for Southeast Asian countries to combat IUU fisheries by controlling and monitoring the trade of fish and fisheries products. The ASEAN Guidelines comprises three main parts *i.e.* Part 1: Introduction; Part 2: Forms of IUU Fishing Activities Occurring in the Southeast Asian Region; and Part 3: Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain. Part 3, which is the most important part of the ASEAN Guidelines, is aimed at preventing the entry of fish and fishery products from IUU fishing activities into the supply chain based on the root cause of IUU fishing activities that occur in the region (Mazalina *et al*., 2015). SEAFDEC/MFRDMD has worked with AMSs in the promotion and dissemination of the ASEAN Guidelines since 2016, after which the AMSs had been encouraged since 2019, to consider continuing the evaluation of the implementation of the ASEAN Guidelines on their own every year, and to keep track of the activities to combat IUU fishing in their respective countries.

The ASEAN Guidelines is being promoted for implementation in the AMSs. As the ASEAN Guidelines is voluntary, its implementation is based on the capacity of each AMSs, while the status of implementation is subject to the self-evaluation by each AMSs. During the 2017 Regional Technical Consultation, the status of implementation of the ASEAN Guidelines in all AMS was discussed considering the results of the country visits organized by SEAFDEC/MFRDMD in 2018 (Abdul-Razak *et al*., 2019a), and those of the 2019 JTF6-IUU Project Terminal Meeting (Abdul-Razak *et al*., 2019b). The self-evaluation scoring rates given by the AMSs in 2017, 2018, and 2019, are shown in **Figure 99**.

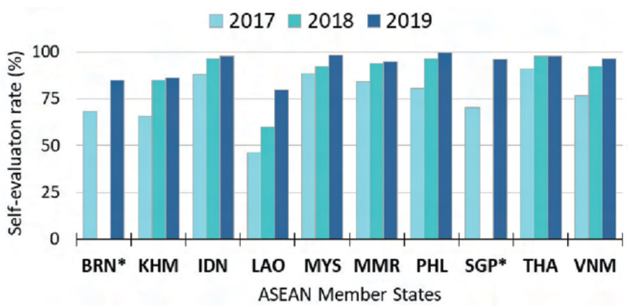


Figure 99. Self-evaluation rate (%) of the ASEAN Member States on the implementation of the ASEAN Guidelines during 2017-2019 (*MFRDMD was not able to conduct country visit in 2018 due to technical and budgetary constraints)

Source: *Abdul-Razak* et al., *2019c*

The data indicated that the average percentage of implementation of the ASEAN Guidelines by the AMSs in 2017 was 75.92 % which increased by 17.28 % to 93.20 % in 2019. All AMSs have implemented more than 80.00 % of the recommended actions in the ASEAN Guidelines in 2019 indicating that all AMSs were committed to combat IUU fishing in the region. Although all AMSs also recognize the importance of combating IUU fishing through trading measures and are seriously tackling the issue of IUU fishing, the implementation of the ASEAN Guidelines differs from country to country. This is based on the circumstances surrounding their respective fishery and trading industries in the country and the capabilities of agencies responsible for the management of the fishery including handling of fish and fishery products traded in the country. All AMSs are encouraged to continue conducting the self-evaluation on the implementation of the ASEAN Guidelines on their national initiatives, to keep track of the activities to combat IUU fishing in their countries (Abdul-Razak *et al*., 2019c).

6.1.1.1 Management of Fishing Capacity

The growing numbers of fishing fleets throughout the region coupled with rapid increases in harvesting capacity has not been matched with the development of national capacities and regional/sub-regional cooperation to manage the fishing effort. Limited management, or regulation and control, of the active fishing capacity, has allowed fisheries to operate in an "open-access regime" leading to the continuous increment in the number of vessels and people engaged in fisheries. Therefore, there is a need to improve and implement licensing schemes and other capacity management measures that effectively limit entry into the fisheries, replacing the present inadequately designed systems (SEAFDEC, 2017c).

The issue of managing fishing capacity has been raised during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020, held in Bangkok, Thailand on 13–17 June 2011, under Sub-Theme 1.2: Management of Fishing Capacity. Recognizing the importance of management of fishing capacity, SEAFDEC in collaboration with the ASEAN has developed the Regional Plan of Action for Management of Fishing Capacity (RPOA-Capacity) through dialogues with the ASEAN-SEAFDEC Member Countries such as through regional technical consultations and expert meetings. The RPOA-Capacity was supported by the SEAFDEC Member Countries during the 47th Meeting of the SEAFDEC Council in 2014. Subsequently, it was endorsed during the 24th Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi) in June 2016 and adopted by the 38th Meeting of the ASEAN Ministers on Agriculture and Forestry (AMAF) in October 2016 in Singapore (SEAFDEC, 2017c).

The overall objective of the RPOA-Capacity is to serve as a guide for the management of fishing capacity in an ASEAN perspective and also to support the AMSs in the development and implementation of their respective NPOA-Capacity (SEAFDEC, 2006a). The RPOA-Capacity is also meant to support the need to enhance regional cooperation on fisheries management and/or management of fishing capacity in sub-regional areas such as the Andaman Sea, Gulf of Thailand, South China Sea, and Sulu-Sulawesi Seas. Strengthened regional and sub-regional cooperation on the management and control of fishing capacity would provide an effective platform for the AMSs to support their efforts to combat IUU fishing (SEAFDEC, 2017c). The RPOA-Capacity comprises five parts, namely: 1) Assessment of Fishing Capacity; 2) Preparation and Implementation of National Plans; 3) International Consideration; 4) Required Urgent Measures for Regional Fisheries Management, and 5) Mechanisms to Promote of the Implementation.

SEAFDEC/MFRDMD then conducted the "Regional Technical Consultation on Regional Plan of Action for the Management of Fishing Capacity (RPOA Capacity)" on 8 December 2020 (Annie-Nunis *et al.*, 2021), with the objectives of: i) updating the information regarding the implementation status of fishing capacity (RPOA-Capacity) in the AMSs, and ii) finding the way forward for the implementation of NPOA and RPOA-Capacity in the AMSs. The status of the development and implementation of the NPOA-Capacity by the respective AMSs appears in **Box 17**.

Apart from the updated information regarding the implementation status of fishing capacity (RPOA-Capacity) in the AMSs, the participants of the 2020 Regional Technical Consultation also discussed the issues/challenges and strategies in improving RPOA-Capacity implementation in their respective countries (**Table 68**).

Box 17. Status of the development and implementation of the NPOA-Capacity of the ASEAN Member States
Brunei Darussalam - Even though Brunei Darussalam has not yet developed NPOA fishing capacity, its policy on Sustainable Fisheries Management under the Brunei Fisheries Limits Chapter 130, and Fisheries Order 2009, a legislative infrastructure is provided for the management of fisheries activities and fishing areas, as well as marine reserves and parks. The country has adopted an overarching policy on sustainable fisheries industry development. This underlying policy has been translated into operational and field-level management programs to ensure that: i) the resources is protected from over-fishing and destructive fishing activities; ii) the breeding grounds (coral reefs and mangroves) are protected and conserved, and that recruitment and recovery are promoted, and iii) responsible fishing and environment-friendly technologies developed are promoted.
Cambodia - The country's NPOA of fishing capacity and fishing operation was adopted by the Government but it is still in its national language. The contents of Cambodia's NPOA management of fishing capacity include: i) strict registration of all fishing vessels through cooperation with the local governors; and ii) licensing only the authorized fishing vessels; iii) management of marine fishing resources; iv) concrete policy on marine protected areas (MPA); v) management of fishing grounds by zoning fishing areas; vi) fishing gears permitted to operate, and more fishing activities following the Law.
Indonesia - Management of fishing capacity in Indonesia is reflected in the legal frameworks that had been issued and include among others: a) Regulation of the Minister of Marine Affairs and Fisheries number 18/PERMEN-KP/2014 on Fishery Management Areas of the Republic of Indonesia; b) Regulation of the Minister of Marine Affairs and Fisheries number 9/PERMEN-KP/2020 on Inland Fishery Management Areas of the Republic of Indonesia; c) Regulation of the Minister of Marine Affairs and Fisheries number 59/PERMEN-KP/2020 on Fishing Channel and Allocation of Fishing Gear in the Fishery Management Areas of the Republic of Indonesia; d) Decision of the Minister of Marine Affairs and Fisheries number 50/KEPMEN-KP/2017 on the Potency Estimation, Total Allowable Catch, and Level of Utilization of the Fish Resources in the Fishery Management Areas of the Republic of Indonesia; and e) Regulation of the Minister of Marine Affairs and Fisheries number 29/PERMEN-KP/2016 on Guidance for the Planning of Inland Fishery Management. The marine and inland fisheries management in Indonesia is being taken to the next level by transforming from a centralized to decentralized approach as a follow up of the above-mentioned regulations and as regulated in the Regulation of the Minister of Marine Affairs and Fisheries number 33/PERMEN-KP/2019 on Organization and Work Procedure of the Fishery Management Body in the Fishery Management Areas of the Republic of Indonesia. The anticipated constraints/challenges to implementing aforesaid Regulation are the discrepancies among the Fishery Management Bodies in terms of quality and quantity of the human resources as well as interbody/interagency coordination.
Malaysia - Malaysia has published the National Plan of Action for the Management of Fishing Capacity in Malaysia (NPOA Fishing Capacity) in 2008 and NPOA Fishing Capacity Plan 2 in 2015. Now, Malaysia is currently developing the NPOA Fishing Capacity Plan 3. Under the NPOA fishing Capacity 2, Malaysia has underlined 3 strategies to implement and manage fishing capacity, such as: i) Review and implement effective conservation and management measures; ii) Strengthen capacity and capability for monitoring and surveillance program; and iii) Promote public awareness and education program. Malaysia has successfully: i) enforced the use of 38 mm cod-end mesh size for trawl net in all fishing zones; ii) conducted Resources Assessment surveys; iii) gradually restructured the operation area for trawlers; iv) introduced a conservation zone (one nautical mile buffer zone from the coastline) for fishing operation in the West Coast of Peninsular Malaysia (encompassing Kedah, Perak, and Selangor); v) maintained all records of fishing vessels and fishing gears/appliances electronically (Sistem ELesen) and developed the Malaysian Fishing Vessel Record (MFVR) managed by DOFM; vi) undertaken several initiatives to promote an EAFM mechanism as a tool of fisheries management; and vii) conducted public awareness programs on sustainable fisheries, including managing fishing capacity, conserving, and restoring fisheries resources and habitat. Constraints/Challenges to implementing the NPOA Fishing Capacity include: i) limited funds for implementation; ii) fishers have limited knowledge and skills to operate different fishing gears other than the current fishing gear used.
Myanmar - Myanmar has not yet developed the NPOA-Capacity management plan, as the country needs international and regional expertise to support the development of the NPOA-Capacity management plan. Myanmar also needs capacity building for the usage of specific gear for specific stock and determination of fishing capacity methodologies. Despite this, Myanmar has implemented several fisheries management measures such as Marine Protective Area (MPA) 2020, Closed Season Closed Area (CSCA) since 2013, Trawl fishing gear mesh size (1.5 inches for shrimp, 2.0 inches for fish), Installation of Turtle Exclusive Device (TED) at trawl gears 2020; banned the building of new vessels relevant to fishing activities; enhanced the management of licenses for marine capture fisheries; suspended the issuance of fishing rights of foreign fishing vessels since 1st April 2014; and established the policy on usage of VMS system. The development of NPOA-capacity has been considered and would be based on RPOA-Capacity including fisheries co-management.
Philippines – The Philippines has not yet developed the NPOA-Capacity, but Reference Points and Harvest Control Rules are being processed and finalized in all Fisheries Management Areas (FMA) covering the entire Philippine waters. Constraints or challenges to developing its NPOA-Capacity include: capacity building needed in all levels of government and stakeholders; and alternative livelihoods for the fishers as fishing capacity are expected to be reduced.
Singapore - Singapore has a small capture fisheries sector, but its legislation ensures that only the Singapore Food Agency (SFA)-licensed fishing vessels can fish in Singapore waters. Foreign fishing vessels are not permitted to fish in Singapore waters.

Box 17. Status of the development and implementation of the NPOA-Capacity of the ASEAN Member States *(Cont'd)*
Thailand - Thailand has utilized its Fisheries Management Plan (FMP) to manage fishing capacity instead of the NPOA-Capacity. Currently, the FMP is the national fisheries management plan and policy approved by the country's cabinet. Regarding the country's capacity control measures as specified in Objective 1 of the FMP, the fishing effort for all species both in the Gulf of Thailand and the Andaman Sea is controlled at the level that can produce MSY. The target is to maintain fishing effort below the Fmsy. There are eight measures under this objective, which include among others: controlling the number of fishing days for each vessel, and implementation of a vessel buyback scheme. Unfortunately, the country's artisanal fishing vessels are not required to obtain fishing licenses and the fishing effort for the artisanal vessels is unlikely to be controlled.
Viet Nam – Viet Nam has issued the Fisheries Law 2017 with many guiding documents which has been in effect from 2019 to manage the fisheries towards sustainable development, and promote its National Action Plan against IUU fishing. Currently, Viet Nam is developing various instruments that include: draft of its Fisheries Development Strategy to 2030 and a vision of 2045; and Projects to establish seafood processing and value enhancement. Viet Nam also has signed the Agreement on National Measures of Port Fishes (PSMA) and Agreement for the conservation and management of amphibian and migratory fish stocks (Agreement for the conservation and management of fish stocks and highly migratory fish stocks, UNFSA), and the national action plan has been issued to implement the above agreements. The sea area of Viet Nam is divided into 3 fishing zones (*i.e.* coastal areas, open areas, high seas) while the operating area of fishing vessels in the maximum length is being enhanced. Fishing licenses are managed by quotas, *i.e.* the central government manages the quotas for fishing vessels with length 15 m or more, while the provinces manage the quotas for fishing vessels with lengths less than 15 m. Fishing vessels with a maximum length of 15 m or more also are obliged to install the cruise monitoring equipment.

Table 68. Issues/constraints and actions/strategies in the implementation of the RPOA-Capacity

Plan of action	Issues/Constraints	Actions/Strategies
Section I: Assessment of Fishing Capacity		
1.1 Diagnosis and identification of fisheries and fishing capacity	• High cost to carry out resource surveys in deep-sea waters • Inadequate capacity of human resources on taxonomy of uncommon fish species, stock assessment, data analysis, among others • Multispecies marine resources • Inadequate updated data on fishery resources • Intrusion of commercial fishing vessels in coastal waters • Complicated procedures on fishing vessels registration • Insufficient information on total number of commercial and small-scale fishing vessels • Insufficient information on the status of the fish stock • Inaccessible and/or inaccurate catch data/ log sheet • Carrier vessels operating in territorial waters and EEZs were not covered by VMM/VMS program • Lack of countrywide electronic catch documentation and traceability system • Lack of validation of catch unloaded from fishing vessels • Limited information on the number of deployed fish aggregating devices (FADs)	• Development and implementation of NPOA-Capacity should be pursued, and annual budget from 2020 to 2024 to be allocated • Procurement of a new research vessel to facilitate fishery resource surveys • Utilization of M.V. SEAFDEC 2 to conduct fisheries surveys • Conduct of national/regional training workshops on fish taxonomy, stock assessment, data analysis, and others • Establishment of new fisheries management system for the development of various fisheries management plans (*e.g.* species-area specific rather than gear-based management) • Conduct of regular fishery resource monitoring and surveys • Adoption of the eACDS and land-based catch data application • Strengthening of law enforcement • Implementation of vessel monitoring measure (VMM) • Assistance to local governments in filing cases and enforcement of local ordinances • Enforcement of closed fishing seasons and areas in coastal waters • Coordination with relevant agencies • Inventory of commercial and small-scale fishing vessels • Establishment of Fisheries Management Areas (FMAs) including the adoption of Reference Points and Harvest Control Rules (HCR) • Consolidation of information on the status of fish stock in FMAs • Safekeeping of logbooks to be analyzed by appropriate authorities • Requiring all commercial fishing vessels to comply with VMM and electronic catch reporting system (ERS) • Designation of Fisheries Observers for commercial vessels • Development of a simplified logbook for artisanal fishing vessels • Limitation of number of fishing days for highly efficient fishing gear (*e.g.* trawl, purse seine, and others) • Development of alternative/diversified livelihood for fishers • Establishment of marine conservation zones
Section II: Preparation and Implementation of National Plan of Action for the Management of Fishing Capacity		
2.1 Development of national plans and policies	• Limited capacity building activities • Limited funds for policy implementation • Limited knowledge of fishers to operate modern fishing gear • Limited expertise to develop plans and policies • Inadequate financial resources • Inappropriate policies and regulations	• Implementation of the NPOA-Capacity • Continued engagement and consultation with fishers • Seeking technical and financial support from regional and international organizations (*e.g.* SEAFDEC, FAO for the development of NPOA-Capacity plan • Development of policies towards sustainable fisheries development
2.2 Subsidies and economic incentives	• Large amount of budget and long period of implementing buy back schemes • Inadequate educational level of fishers • Low income of fishers	• Participation in the WTO negotiation of fisheries subsidies • Allocation of annual budget for the buyback scheme • Conduct of training and awareness raising activities to support fishers • Development of policies to support fishers in sustainable exploitation fishery resources, preserving products, and stabilizing selling prices of aquatic products

Table 68. Issues/constraints and actions/strategies in the implementation of the RPOA-Capacity *(Cont'd)*

Plan of action	Issues/Constraints	Actions/Strategies
2.3 Regional Considerations and Cooperation	• Limited resources • Insufficient collaboration among the AMSs	• Cooperation among the AMSs to combat IUU fishing in the region • Updating the RFVR Database • Exchange of information and experience in fisheries management
Section III: International Considerations and Fishing in High Seas or RFMO Competent Areas		
	• Inability to access fishing in the high seas • Closed WCPFC high seas areas should be for fishing • Lack of expertise in tuna fishing in the IOTC competent area • Insufficient information on fishing grounds and resources • Lack of information on regulations	• Cooperation among the AMSs and relevant agencies to protect the competent areas • Adherence to the IOTC Resolution • Self-imposed fishing access to reduce the catch of juvenile tunas (BET) • Analysis of historical fishing effort data • Data collection from logbooks, onboard observers, ERS, etc. • Exchange of updated information on fisheries and aquatic resources, regulations, and others
Section IV: Required Urgent Measures for Regional Fisheries Management		
	• Limited resources • Insufficient measures to manage transboundary species • Lack of timely and accurate information	• Sharing of experiences and lessons learned on fisheries management among the AMSs • Participation in the discussion at the sub-regional/regional level regarding the management of transboundary species • Humanist handling of cases at sea
Section V: Mechanisms to Promote Implementation		
	• Limited of resources • Lack of technical support for the information-sharing program, training program, and experts' consultation program on the fishing capacity to support the NPOA-capacity • Lack of systematic data collection and analysis • Prioritizing national interests and commitments	• Enforcement of fishery laws in the respective EEZs and high seas • Engagement with stakeholders through consultation programs • Conduct of training and capacity building activities to improve fishing capacity management • Provision of technical support for systematic data collection and analysis • Ensure the interests of the countries in the region • Development of a mechanism for sharing of information and experience among countries for regional compliance

In addition, during the 2020 Regional Technical Consultation, most AMS requested SEAFDEC to provide technical assistance for the preparation of NPOA-Capacity and capacity building especially fisheries management and fisheries survey. Specifically, Brunei Darussalam requested technical assistance from SEAFDEC and Malaysia for the development of their NPOA-Capacity, while Cambodia requires capacity building and training, particularly on fisheries management. In its response, Malaysia indicated that there has been certain inadequacies of the number of younger experts, particularly in fishery taxonomy and stock assessment, to conduct resource surveys. Thus, the collaboration with SEAFDEC on the aforementioned concerns was requested. Malaysia also requested for capacity building through training on taxonomy, especially for deep-sea resources; stock assessment; and determination of fishing capacity methodologies. Meanwhile, Myanmar also sought technical assistance for its plan to conduct the deep-sea survey and expressed the desire to collaborate with regional and international organizations. The Philippines has already completed zero drafts for its NPOA-Capacity but requested technical assistance from SEAFDEC for the finalization of the said document, and also sought technical assistance from SEAFDEC for its acoustic survey. Thailand specifically sought technical assistance from FAO on the application of FMP to manage fishing capacity.

6.1.1.2 Fishing Vessels Registration and Fishing Licensing

Recognizing the severity of degradation of the fishery resources in the Southeast Asian region brought about by uncontrolled practice of IUU fishing, the AMSs have been promoting sustainable fisheries management at the national level in accordance with a provision in the Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Fisheries Management, viz: "*States should review the issues of excess fishing capacity at the national level and recommend where appropriate, measures to improve registration of fishing vessels, introduction of rights-based fisheries and reduction in the number of fishing boats and level of fishing effort using government incentives*" (SEAFDEC, 2003). Updates on fishing vessels registration and licensing undertaken by the AMSs at national levels as of 2021, are shown in **Box 18**.

Box 18. Status of implementation of vessels registration and licensing undertaken by the AMSs
Brunei Darussalam - All fishing vessels with in-board engines in Brunei Darussalam are registered with the Maritime and Port Authority of Brunei Darussalam. Fishing licensing in Brunei Darussalam is under Section 13 of the country's Fisheries Order 2009, which provides that all fishing gears must be licensed to be able to carry out fishing activities. Fishing license is separated into three types, namely: license for individual fishing, small-scale fishing license, and commercial fishing license. Licenses for individual fishing and small-scale fishing are authorized by the country's Department of Fisheries (DOF) while commercial fishing license is authorized by its Ministry of Industry and Primary Resources. Fishing license could be renewed annually and fishing vessel should be inspected for issuance of certificate of "sea-worthiness" by the Maritime and Port Authority of Brunei Darussalam before the application for renewal of fishing gear license is filed for approval by the Department of Fisheries.
Cambodia - Registration of all vessels in Cambodia is carried out by the Ministry of Public Works and Transport (MPWT), under which the Merchant Marine Department and the Provincial Department of Public Works and Transport are responsible for fishing vessel registrations. New fishing vessels are required to be registered, after which the vessel's owner will receive the vessel's card. The official number or vessel registration number is indicated in the vessel's card consisting of two alphabets and four-digit number that refers to management areas/coastal provincial areas. However, the MPWT does not have the capacity sufficient enough to register the large number of relatively small fishing vessels in Cambodia. As a result, only a small number of vessels are registered (or licensed). Moreover, issuance of fishing license in Cambodia is under the responsibility of the country's Fisheries Administration (FiA) and Provincial Department of Agriculture Forestry and Fisheries (PDAFF). Fishing vessels with engine power bigger than 90 HP are issued fishing license by the FiA, while fishing vessels with engine power smaller than 90 HP, receive their fishing licenses from PDAFF. The fishing licenses issued are valid for one year. Fishing vessel owners who want to do fishing should apply for fishing licenses to the responsible authorities as mentioned above. There are two types of fishing licenses, namely: fishing gear license and fishing boat license. One of the challenges encountered is related to the current regulations where fishing vessels are required to have prior registration with the MPWT.
Indonesia - Fishing vessels registration in Indonesia is being implemented by two ministries: the Ministry of Transportation and the Ministry of Marine Affairs and Fisheries. The requirements for registration include: 1) certificate of measurement of vessel in tonnage, 2) vessel registration, 3) nationality certificate, 4) fishing vessel registration such as fishing vessel book, fishing vessel marking, and 5) license (fishing vessel license). The authorities issuing the fishing license are the district/municipal government, provincial government and central government for fishing business license, fishing license and fish carrier license to persons and companies that operate fishing vessels. The licenses for vessels below 5 GT and between 5 and 10 GT are issued by the district; for 11 to 30 GT vessels by the province; and vessels over 30 GT by the central government. However, the country is confronted with several problems on fishing licensing, the most common of which include double flagging where a fishing vessel could have license from Indonesian authorities as well as license from the country of origin. In an effort to mitigate the problem, foreign vessels are required to have complete certificates from responsible agencies in its country of origin, while ex-IUU fishing boats are no longer issued fishing licenses.
Malaysia - The country's Fisheries Licensing Policy is one of the main policy documents used in governing fisheries management in Malaysia, as it also supports the enforcement of the Fisheries Act 1985 and its regulations. The Fisheries Licensing Policy of Malaysia are used to: 1) manage the fishery resources sustainably by controlling the number of fishing vessels, fishing gears as well as fishing effort; 2) facilitate monitoring of fishing activities within Malaysian waters; 3) assist in promoting the enforcement activities, especially in identifying encroachments of local and foreign fishing vessels; 4) combat IUU fishing; and 5) minimize conflicts between traditional and commercial fishers. Issues confronting the country's vessel registration and licensing systems include the limited capacity in carrying out periodic monitoring activities by ground staff. This has constrained the fishers to use technology in license management, especially during the license renewal.
Myanmar - As a government policy, Myanmar has two (2) types of vessel registration, i.e for inshore and offshore vessels. National offshore fishing vessels, carrier vessels and foreign fishing vessels have to register with the Department of Marine Administration (DMA) and all types of inshore fishing vessels have to register with the Township Administrative Department. The Department of Fisheries (DOF) issues the licenses for those inshore and offshore fishing vessels. Inshore fishing vessel license is issued by the township fishery officer, while offshore/inshore fishing and carrier vessel licenses are issued by the head of state/region offices and the Director General of DOF based on the license application.
Philippines - Prior to vessel construction or importation, the Philippines requires a *Construction Clearance or Importation Clearance*, whichever is applicable. This is prescribed under Section 33 of implementing rules of Republic Act 8550, as amended. A fishing vessel is cannot be registered without Clearance from the Bureau of Fisheries and Aquatic Resources (BFAR). Philippine authorities conduct background check on fishing vessels to be imported prior to issuance of *Importation Clearance*. This includes checking whether the vessel is or is not recorded in the existing IUU list of various RFMOs. Only fishing vessel registered in the Philippines can be issued with a fishing license, provided all other regulatory requirements are complied with and license fees are fully paid. Issuance of a fishing license is covered under Fisheries Administrative Order (FAO) No. 198-1, series of 2018. Registration of fishing vessels falls under the jurisdiction of the following entities: Municipal fishing vessels (3.0 gross tons and above) must be registered with the Local Government Units, while commercial fishing vessels (> 3.0 gross tons) must be registered with the Maritime Industry Authority (MARINA), which is under the Department of Transportation and Communication (DOTC). In accordance with Section 13 of FAO 198-1, series of 2018, commercial fishing vessels must also be: 1) installed with an accredited vessel monitoring system; and 2) deployed with an authorized fisheries observer onboard.
Singapore - The fishing license of Singapore has a validity of one year, renewable and issued by Singapore Food Agency (SFA). Licensing is separated into: 1) inshore and offshore fishing vessels, and 2) inboard and outboard fish carriers.
Thailand - Vessel registration is carried out by the country's Marine Department, while fishing license is issued by the Department of Fisheries (DOF). The fishing license issued is for two years from 1 April of year 1 to 31 March of year 2, by DOF (district fishery officer) in 23 coastal provinces. The problems on fishing license include the fact that some fishers continue to use high efficiency fishing gears without licenses or use other licenses instead, while most fishers renew their fishing licenses later than the expiry date. In order to address these problems, inspections by the fishery patrol units had been enhanced while reminders to concerned fishers on renewal of their fishing licenses are issued one month prior to the license expiry, while dissemination of information about license renewals has been intensified.

Box 18. Status of implementation of vessels registration and licensing undertaken by the AMSs (Cont'd)
Viet Nam - The country's Fisheries Law 2017 requires that all vessels with lengths that range from and greater than six (6) m must be registered at its fishing vessel management agency. Foreign fishing vessels, Vietnamese fishing vessels operating outside of Viet Nam Sea should register at the Central level, while all fishing vessels should register at the province levels. Vessels with length less than 6 m are listed at the commune for management purposes. In terms of fishing license, vessels with lengths that range from and greater than 6 m are required to have fishing license to do fishing, and are given fishing license if the quota of fishing license allocation is available. The fishing license quota is defined every five years, however, the quota for foreign fishing vessels exploiting the fishery resources in Vietnamese waters is defined every year. At the national level, the Ministry of Agriculture and Rural Development defines the total quota of fishing licenses in the country's offshore waters that are allocated to the coastal provinces. The Provincial People Committee of the coastal provinces defines the total quota of fishing licenses in the inshore and coastal waters. This system however, has some issues that include lack of sufficient available data for defining and allocating the fishing license quota upon specific waters, among others. In order to address the existing issues, the fisheries management authority has implemented outreach programs to improve the understanding and awareness of local fishers, and enhanced stock assessments and fisheries research to provide insights into the wealth of fish stocks and social-economic performance of the country's fishing industry.

International and regional initiatives on fishing vessels database as information to support combating IUU fishing

- FAO Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels

The Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels (Global Record) developed by FAO is a global initiative that primarily involves state authorities and regional fisheries management organizations (RFMOs) in compiling an online comprehensive and updated repository of vessels involved in fishing operations. The Global Record is aimed at providing useful and powerful tool to deter and eliminate illegal, unregulated, and unreported (IUU) fishing activities, within the framework of legal instruments available including the Port State Measures Agreement (PSMA), making it more difficult for vessels to operate outside the law.

An essential element of the Global Record is the assignment of a Unique Vessel Identifier (UVI) to each vessel worldwide, which remains constant throughout the vessel's lifetime regardless of change of name, ownership or flag.

The information in the Global Record requires only 5 key data elements, such as: 1) Unique Vessel Identifier (UVI), 2) Current flag, 3) Vessel name, 4) Length overall (LOA), and Either Gross Tonnage (GR) or Gross Registered Tonnage (GRT). On the other hand, the RFVR Database has 28 KDEs as shown in **Table 69**.

- Regional Fishing Vessels Record Database

The Regional Fishing Vessels Record (RFVR) Database for vessels 24 meters in length and over was developed by SEAFDEC/TD in collaboration with the AMSs under the ASEAN-SEAFDEC Strategic Partnership (ASSP) mechanism. The RFVR Database includes basic information required for the Database to serve as effective tool to support fishing vessel inspection in an effort to reduce Illegal, Unreported and Unregulated (IUU) fishing vessels through enhanced transparency, traceability, and support inspection in relation to the promotion of port State measures (PSM) activities. It is expected that the RFVR Database could work as a practical tool for concerned authorities such as the local inspectors, port state inspectors, high rank fisheries officers, and technical fisheries officers of the AMSs in checking and taking corrective actions against inappropriate behavior of their respective countries' fishing vessels, thereby supporting the elimination of IUU fishing in the Southeast Asian region. For example, the AMSs would be able to take appropriate actions against "stateless vessels, IUU fishing vessels, or vessels engaged in poaching" by sharing information and identifying problematic vessels through the RFVR Database.

The information in the RFVR Database includes 28 key data elements (KDEs) that comprise the basic information requirements that could be shared by the AMSs with the RFVR Database, as shown in **Table 69**. The number of fishing vessels 24 meters in length and over of the AMSs in the RFVR Database, grouped into fishing vessels, carrier vessels, processing vessels, and support vessels, is shown in **Table 70**.

Table 69. Information from the AMSs on fishing vessels 24 meters in length and over to be shared with the RFVR Database

1. Name of vessel	2. International Radio Call sign
3. Vessel Registration Number	4. Engine Brand
5. Owner Name	6. Serial number of engine
7. Type of fishing method/gear	8. Hull material
9. Fishing License number	10. Date of registration
11. Expiration date of fishing licenses	12. Area (country) of fishing operation
13. Port of registry	14. Nationality of vessel (flag)
15. Gross tonnage (GRT/GT)	16. Previous name (if any)
17. Length (L)	18. Previous flag (if any)
19. Breadth (B)	20. Name of captain/master
21. Depth (D)	22. Nationality of captain/master
23. Engine Power	24. Number of crew (maximum/ minimum)
25, Shipyard/Ship Builder	26. Nationality of crew
27. Date of launching/Year of built	28. IMO Number (If available)

Table 70. Total number of fishing vessels in the RFVR Database (24 meters in length and over)

Country	Fishing vessels	Carrier vessels	Processing vessels	Support vessels	Total
Brunei Darussalam	10	-	1	-	**11**
Cambodia	6	-	-	-	**6**
Indonesia	1,988	222	-	-	**2,210**
Lao PDR	-	-	-	-	**-**
Malaysia	144	-	-	-	**144**
Myanmar	1,130	186	-	-	**1,316**
Philippines	67	93	-	7	**167**
Singapore	-	1	-	-	**1**
Thailand	339	19	-	-	**358**
Viet Nam	2,144	492	-	-	**2,636**

Remarks: *Information in the Database of the Regional Fishing Vessels Record had been updated in 2021 (except those from Indonesia and Philippines that were updated in 2020)*

- Vessels Watchlist

Participating countries to the Regional Plan of Action to Promote Responsible Fishing Practices including Combating IUU Fishing in the Region (RPOA-IUU) are doing their parts in controlling IUU fishing, upon recognizing that IUU fishing undermines the objectives of the RPOA-IUU, which is to enhance and strengthen the overall level of fisheries management in the region and to optimize the benefit of adopting responsible fishing practices. The countries have also become concerned that some fishing vessels that operate in the region do not comply with the obligations imposed by flag States.

The RPOA-IUU Secretariat shares the information among the RPOA-IUU participating countries about IUU vessels' movements and sightings. Their information indicates that there are several IUU fishing vessels suspected of unloading catch, re-supplying and/or re-fueling in the region. This has called for the establishment by the RPOA-IUU of a watch list of IUU fishing vessels to assist the countries in focusing their efforts to take action, where appropriate and when possible, in accordance with their national laws and consistent with the IPOA-IUU and other relevant international fisheries instruments, against vessels flagged to RPOA-IUU participating countries or flagged to a third party (non-RPOA countries) that are operating in the region and may be engaged in IUU fishing activities.

Vessels will be considered for inclusion in the Provisional IUU Watch List when there is evidence for believing that a fishing vessel has engaged in, or supported, IUU fishing activities. While transmitting the information to the RPOA-IUU Secretariat, the nominating RPOA participating country should provide a copy of such information to the relevant flag State.

Way Forward

To coordinate and facilitate sharing of information from the RFVR Database with the FAO Global Record in the future, series of discussions with authorities concerned from the AMSs had been convened. The mechanisms of sharing the information could be under the following proposed aspects, namely: A) bulk data upload, and B) connection to Application Programming Interfaces (APIs). The bulk data upload through CSV files is the only ready-to-use and currently available data exchange mechanism of the actual Global Record Information System. The CSV files, therefore, could provide an initial, short-term and satisfactory temporary solution to the issues on submission of data into the FAO Global Record. In essence, a CSV file is a simple file format which allows data to be saved in a table-structured format and could be opened using any spreadsheet program such as Microsoft Excel or OpenOffice Calc. The data upload through CSV/Excel files is based on simple spreadsheets called templates with selected sets of data fields as column/table headings. As a rule, States are the official sources and owners of the data, while the responsibility of keeping the data complete and up-to-date lies with the FAO Global Record. In this regard, regional fisheries bodies such as SEAFDEC would only act as data channels. Nevertheless, such arrangement may entail prior consent and final authorization of the relevant States to allow SEAFDEC to submit the States' respective data into the FAO Global Record.

The automated data exchange mechanism based on the Application Programming Interfaces (APIs) has been proposed to serve as platform in streamlining data transfer from national and relevant regional systems into the FAO Global Record, but this is still being finalized. The APIs would provide a programmatic interface through which data provider systems could automatically submit their data into the FAO Global Record. This method of communication between software systems is widespread and durable, technology-independent and makes use of the common internet for interoperability. Setting up such a channel requires little software development effort and offers multiple benefits, which include *inter alia*, close to real time data updates, resource savings and improved consistency and reliability of data by reducing the possibility of human errors, decreasing delays and streamlining data transfer processes. As a result, the APIs will help to have a leaner system because of the regular updates, thus, "mass-update" bias of large and massive data information update is avoided. Since APIs, are "contracts" between systems, the API and the system architecture should be perfectly tuned up prior to the start of sharing any documentation and testing, thus, exchanging of information through the APIs would serve as a mid-term solution. When the system is ready, SEAFDEC would do its part in testing and fine-tuning the APIs.

6.1.1.3 Catch Documentation Schemes

Traceability system is one of the important emerging market requirements being put into force in response to the pressing needs expressed by the markets to ensure that fish and fishery products in the supply chain are not derived from IUU fishing activities. It is also being used to facilitate the tracking of the flow of products through the production processes or the supply chain to ensure that these are safe for human consumption. Since its enforcement by several markets in the mid-2000s, traceability has become a popular concept in industrial logistics, regardless of the production regimes and types of products. In the Codex Alimentarius Commission, traceability is defined as "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution." Therefore, traceability facilitates the compilation of knowledge and information regarding the identity, history and source of a product or of the materials contained within a product, and also provides information regarding the destination of a product, or any ingredient contained within it, making traceability system an information management tool.

In the fisheries sector, information on traceability is used in relation to: a) food safety to ensure that products and materials from which they are made, come from origins that meet food safety conditions; b) application of tariffs and quota tariffs, making sure that appropriate rates of duty are applied; and c) warrantying that the fish is derived from sustainable sources, including those from fishing operations and vessels which follow the conservation rules.

The UN Fisheries Resolution on Sustainable Fisheries of 9 December 2013 expressed the concerns over the continued threat to marine habitats and ecosystems, such as from illegal, unregulated and unreported (IUU) fishing, and also acknowledges the negative impacts that such activities have on food security and State economies, particularly in developing regions. The Resolution therefore called upon States to, inter alia, initiate within FAO the elaboration of guidelines and other relevant criteria relating to catch documentation schemes. In response to this request, as expressed in paragraph 68 of the Resolution, the Thirty-first Committee on Fisheries (COFI 31) in Rome, 9–13 June 2014, proposed that FAO undertake the elaboration of guidelines and other relevant criteria related to catch documentation schemes. Thus, the Voluntary Guidelines for Catch Documentation Schemes (VGCDS) were developed by FAO in 2017, which included the Catch Documentation Schemes (CDSs) for wild capture fish caught for commercial purposes in marine or inland areas, whether processed or not. Moreover, such Guidelines had also been elaborated to recognize that all available means are in accordance with relevant international laws and other international instruments, such as, the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU) which should be used to prevent, deter and eliminate illegal, unreported, and unregulated (IUU) fishing. As part of the Guidelines, the CDSs build on the primary responsibility of the flag States to prevent, deter and eliminate IUU fishing, and also constitute a valuable supplement to port State and other measures. These Guidelines are therefore aimed at providing assistance to States, regional fisheries management organizations, regional economic integration organizations, and other intergovernmental organizations, in their efforts towards developing and implementing new CDS, or harmonizing or reviewing their existing CDSs.

A Catch Documentation Scheme (CDS) for the certification of legal provenance is referred to as the Catch Certification Scheme (CCS) with the central document referred to as a Catch Certificate (CC) - as opposed to a Catch Document or a Catch Form. Logbooks and landing records are also catch documentation schemes. Moreover, a CDS should be designed to address the concerns on IUU fishing, especially from the point of view of Monitoring, Control and Surveillance (MCS) or from a trade documentation perspective, and is an important tool in combating IUU fishing. However, since a CDS it is not equivalent per se to a traceability system, it has therefore become necessary to develop a Catch Documentation and Traceability System (CDT) not only to trace the fish and fishery products in the value chain but also to certify their origin and quality with respect to food safety and sustainability.

- Catch Documentation and Traceability Systems in Southeast Asia

The fisheries sector in Southeast Asia is critically important considering its significant contribution to the people's social, economic, and livelihoods. Several ASEAN Member States (AMSs) have been the top ten seafood producing countries exporting to the world seafood market during the past decades and even now. However, challenges in addressing the international fish-trade related issues, particularly the IUU fishing issues, have significantly impacted on the ASEAN seafood export until the present.

At the beginning, Catch Documentation and Traceability System (CDT) was considered as a relatively new concept for fisheries managers and seafood companies, not only in Southeast Asia but also globally. Nonetheless, in the Southeast Asian region, efforts had been made by SEAFDEC in collaboration with the AMSs to establish and promote a CDT under the Japanese Trust Fund (JTF)-funded Project "Combating IUU Fishing in the Southeast Asian Region through Application of Catch Certification for Trading of Fish and Fishery Products" implemented by SEAFDEC/MFRDMD since 2013. The Project came up with the "ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain" which supported as one of its activities, the promotion and implementation of the "ASEAN Catch Documentation Scheme" in the Southeast Asian region.

In 2015, the AMSs requested SEAFDEC to develop the ASEAN Catch Documentation Scheme (ACDS) to enhance the traceability of fish and fishery products in the Southeast Asian region. SEAFDEC therefore, through technical consultations with its Member Countries, drafted the ACDS concept during 2015–2017, and the concept was endorsed by the ASEAN during the 25th Meeting of the ASWGFi in 2017, and subsequently adopted by the SOM-AMAF Meeting, also in 2017. The ACDS concept constituted one of the most significant regional initiatives pursued by SEAFDEC with the collaboration of the AMSs for improving the traceability of marine capture fisheries to ensure that the entry of fish and fishery products from IUU fishing activities into the supply chain is prevented; and this led to the development of national CDTs by the respective AMSs for their fish and fishery products bound for the export market based on the ACDS concept.

- Development of the Electronic ASEAN Catch Documentation Scheme

As of 2018, it was found that most AMSs remain fully or largely reliant on the use of paper-based CDTs, particularly at the point of catch and at landing, and subsequently at the processing plants and distribution of processed products. Except for some countries like Indonesia, Singapore, Thailand, and Viet Nam, many countries continue to use paper-based collection of data across all stages in the fish supply chain, *e.g.* at sea during capture, at port upon landing, in processing plants. In order to address such concern, initiatives had been launched to establish the electronic format of the CDT or eCDT, like for example the electronic ASEAN Catch Documentation Scheme or eACDS.

The eACDS was developed by SEAFDEC/TD to support the implementation of the ACDS concept, taking into consideration the instruction of the SEAFDEC Council of Directors that the ACDS should not create unnecessary burdens, costs or lengthy processes for the supply chain, especially to the importers and exporters. Thus, SEAFDEC/TD developed the eACDS applications, and in June 2017, the eACDS was pilot tested in Brunei Darussalam and a series of consultations and on-site trainings on the use of eACDS ensued with involvement of relevant stakeholders in collaboration with the DOF of Brunei Darussalam to apply, test and improve the applications of the eACDS, especially making the application more user-friendly. This led to the development of the web-based and mobile applications of the improved eACDS, for offline reporting of the catch at sea. During the succeeding years, the eACDS has also been pilot tested in Viet Nam, Myanmar, and Malaysia.

SEAFDEC/TD developed the 1st Version of the electronic system of the ACDS (eACDS-VER.1) in collaboration with Brunei Darussalam as the pilot country in 2017–2018. The prototype eACDS covers the management of the Catch Declaration (CD), Movement Document (MD), and issuance of Catch Certification (CC). However, catch reporting at sea became a fundamental problem when mobile devices operated offshore do not have internet signal. As a result, there was no monitoring system on how raw-fish materials were used in the processing plants and no vessel tracking functions. For these reasons, SEAFDEC/TD has improved the eACDS applications in collaboration with the Directorate of Fisheries (D-Fish) of Viet Nam from 2019 until the 3rd Quarter of 2020. Based on the lessons learned from the existing paper-type Viet Nam Catch Certification for the EU Market, SEAFDEC developed the 2nd Version of the eACDS (eACDS-VER.2) in close collaboration with the Sub D-Fish in Binh Thuan Province, Viet Nam.

The eACDS-VER.2 application is meant to replace the eACDS-VER.1 as a new prototype application for promotion in the AMSs. The new eACDS system includes mobile apps in both online and offline modes for catch reporting at sea, which is part of the Catch Declaration process. Also added in the 2nd Version are other critical functions on traceability called the Statement of Catch (SC) for monitoring the use of raw-fish materials in the processing plants. The system also includes information on transshipment at sea and many new features in the applications, such as vessel tracking on the eACDS Mobile app., timeline activities recording, summary report, a dashboard for the manager, among others. As the eACDS-VER.2 include traceability of fish in the whole value chain, new features had been added, such as:

1. Request port-out/port-in by vessel owner/fishing master via an online webpage
2. Bilingual for both eACDS web-based and eACDS mobile application (English-local language)
3. eACDS-catch report application can provide the date, start, and end position
4. eACDS-catch report application for transshipment at sea

5. Dashboard to summarize report for the manager
6. Mapping the status of a vessel (online and offline)
7. Information and timeline of fishing vessel activities
8. Vessel tracking system on eACDS
9. New application on mobile for purchasing: eACDS-Market Application

Currently, the eACDS consists of two applications: (I) *web-based application* which is designed for: (a) port-out permission and issuance of initial Catch Declaration (CD) to fishing masters, (b) port-in permission including catch weight and species verification and issuance of the CD to fishing masters, (c) issuance of Movement Document (MD), (d) issuance of Statement of Catch (SC), and (e) requirement of Catch Certification (CC) and issuance of CC; and (II) *mobile application* designed for catch reporting at sea and purchasing fish. The eACDS requires several inputs of basic data and information called "Key Data Elements" (KDEs) including information on: 1) Point of Catch, 2) Buyers/Receivers and Sellers (Broker/Wholesaler), 3) Processors, 4) Exporters and International Shippers, 5) Importers, and 6) End Consumers.

The promotion and implementation of eACDS in participating AMSs, namely: Brunei Darussalam, Viet Nam, Myanmar and Malaysia were carried out in response to their requests during the SEAFDEC high level meetings. The progress of such implementation is summarized as follows:

Brunei Darussalam
The selection of Brunei Darussalam in 2016 as the first country to pilot test the eACDS had an advantage because Brunei Darussalam has only one fishing port, the Muala Fishing Port which is near the offices of the Department of Fisheries, besides, not many fishing vessels are in operation. The sea areas and fishing grounds are also clearly divided into zones so that vessels can be easily controlled and monitored. There are only 3-4 processing companies in the country that purchase their raw materials from their own vessels. A challenge of Brunei Darussalam is to encourage stakeholders to use the eACDS application to issue Catch Certification, and use it for their export of fish and fisheries products even if their export may not be in large quantities. After pilot testing the eACDS in Brunei Darussalam in June 2017, series of consultations and on-site trainings on the use of eACDS application for all relevant stakeholders were conducted in collaboration with the Department of Fisheries (DOF) of Brunei Darussalam.

Viet Nam
In responding to the request made by Viet Nam during the 40th Meeting of SEAFDEC Program Committee in November 2017, the eACDS was introduced to relevant stakeholders in Binh Thuan Province, as the first pilot site in Viet Nam. Four sites in Viet Nam have been considered to pilot test the eACDS, namely: Phan Thiet Fishing Port, Lagi Fishing Port, Phu Hai Fishing Port, and Phan Ri Cua Fishing Port. Participated by 50 fishing vessels, the pilot test carried out several activities including discussions on development and verification of the eACDS application, training on the use of the eACDS application through trials on the use of eACDS application conducted in Binh Thuan Province as the pilot site, in collaboration with the Sub D-Fish.

Myanmar
The Council Director for Myanmar reiterated during the 50th Meeting of the SEAFDEC Council in March 2018 that he looked forward to cooperating with SEAFDEC in strengthening regional cooperation to combat IUU fishing by supporting the implementation of the eACDS at the national level. To follow up on such proposition, the eACDS system was introduced to relevant stakeholders and the Department of Fisheries (DOF) of Myanmar through a discussion on the initial planning and cooperation with DOF of Myanmar for the eACDS implementation. The DOF proposed Yangon as its pilot site with the participation of three private jetties, namely: Aung Phyo Myat Jetty, Ei Phyo Yanada Jetty, and Nrwe Pinle Jetty, and involvement of about 100 fishing vessels. Training was conducted on the collection of KDEs, verification of the application to develop the eACDS database, and use of the version of eACDS application,

Malaysia
In 2019, the eACDS system was introduced for all relevant stakeholders and the Department of Fisheries Malaysia, as requested by Malaysia during the 41st Meeting of SEAFDEC Program Committee in November 2018. Two pilot sites in Kelantan and Kuantan were selected as proposed by DOF Malaysia. Initial discussion on planning and cooperation with DOF Malaysia agreed that a baseline survey would be conducted, and training would be organized for the analysis of the data as well as for the collection and verification of KDEs for the eACDS database development, and also on the use of the eACDS application.

- Development of Other Regional Initiatives on Catch Documentation and Traceability

Other initiatives on eCDTs have also been promoted in the Southeast Asian region, including the development of a transparent and financially sustainable electronic Catch Documentation and Traceability (eCDT) system by the USAID Oceans Project (a five-year collaborative project between SEAFDEC and USAID (2015–2020)). This was carried out through the establishment of a wide range of partnerships in both the public and private sector, including productive partnerships with government ministries, global seafood companies, processors, suppliers, sector associations, non-governmental organizations (NGOs), and academic institutions. The development of such eCDTs had added to the regional momentum for action on seafood traceability where the industry (suppliers, processors, buyers) had been encouraged to invest in eCDT systems to improve the efficiency of their operations and regulatory compliance.

More specifically, the USAID Oceans Project supported the development of national eCDTs and complementary private sector technologies in Indonesia and the Philippines. In Indonesia, this comprised supporting the development of the Government of Indonesia's national systems (e-logbook and Stellina) and three private sector technologies, such as the following:

- The **Pointrek** two-way communication Vessel Monitoring System (VMS) which was developed for large and medium-scale capture fisheries, is a web-based application at sea that can connect with Inmarsat's satellite networks to monitor the movement of vessels, including data such as: speed, heading, distance, weather information and two-way communications. Pointrek VMS provides real-time VMS and electronic catch data via a mobile tablet, installed onboard fishing vessels. The system offers person-to-person communication from ship to shore by offering onboard Wi-Fi to connected mobile devices via text message, email, and the conventional SMS technology.
- **Trafiz** was developed as a mobile catch documentation application for small-scale fish suppliers and buyers that provide first data entry point for seafood products originating from small-scale fishers. Trafiz enables data collection at the landing site, allowing users to enter and submit catch data via a mobile device and cellular connectivity. Trafiz also includes value-added user functions that support loan and payment management and other tools that add user value. Trafiz therefore, supports catch reporting, as well as business functionalities that help small-scale fishers manage their business.
- **TraceTales** was developed to enable the processing companies to capture data throughout the processing stage. With the system, processors can quickly and easily compile the information that are essential to comply with the various national and international traceability requirements, thereby ensuring the company's access to valuable export markets, as well as bring paper-based record keeping online for improved business and resource management.

In the Philippines, the USAID Oceans Project supported the Bureau of Fisheries and Aquatic Resources national eCDT system and one private sector to develop a technology known as the "Futuristic Aviation and Maritime Enterprises, INC. (**FAME**)" for small-scale vessel trackers and monitors that also serves as communication devices, enabling small-scale fishers to participate in the eCDT system and establishing increased communication and safety at sea. FAME makes use of radio frequency to send and receive information, and its gateways receive the information from transponders and sends to the cloud. Telemetry data can be sent up to 50 km offshore and can be extended farther via mesh technology between the transponders. Even if a vessel/device is out of range, but within range of another vessel equipped with a FAME transponder, the data can still be sent to a gateway. Personal communication, together with telemetry data can also be sent through the FAME transponders. FAME also provides a dashboard through a web and mobile browser-based application, allowing users to see the details of each transponder and other related data in near real-time, anywhere. The dashboard allows users to draw geofencing areas for remote areas or areas to prioritize, as well as generate custom reports with integrated graphs. FAME users can receive notifications (alerts) both to fishers at-sea and users on-shore. Fishers can use their mobile phones with USB On-The-Go (OTG) or Bluetooth to send and receive messages without mobile phone tower connectivity. Their platform is fully customizable and has been modified to incorporate the required Key Data Elements (KDEs).

- Issues and Concerns

Adoption of the eCDTs is a relatively new concept in fisheries in the Southeast Asian region, and lessons on their implementation are to be learned. During the 2019 Workshop on the Technical Guidance on the Design and Implementation of Electronic Catch Documentation and Traceability Systems in Southeast Asia, gaps were identified by the AMSs during their adoption of the eCDTs, as shown in **Box 19**.

Way Forward

Among the major benefits of traceability include the prevention of damages to human health due to food safety concerns, in terms of illness or death, as the distribution of the contaminated products is avoided. Furthermore, if the source of the problem and the precise batches of contaminated products could not be identified, then the food business operator concerned will be obliged to withdraw and destroy all batches which could have been potentially affected. Promotion of traceability which provides the tool to address the aforesaid issues, should therefore be enhanced.

Moreover, traceability can improve stock control and reduce out-of-date product losses, lower inventory levels, quicken the identification of process and supplier difficulties, and raise the effectiveness of logistics and distribution operations. In the longer term, better food safety management resulting from improved traceability, provides greater guarantee in terms of sustained market access and buyer confidence. Improved customer confidence also helps with branding and improved brand equity. In this regard, traceability should be promoted as

Box 19. Identified gaps in the implementation of Electronic Catch Documentation and Traceability systems by the ASEAN Member States
Brunei Darussalam • Large volume of capture fisheries production is contributed by small-scale fishers (70 %) • Limited human resources and assets for MCS activities • Selectivity of jobs by local youth
Cambodia • Limited market access due to inability to keep up with production and marketing systems of neighboring countries • Insufficient cross-border collaboration among key players • Inadequate cross-border trade regulations and means of implementing the regulations • Limited incentives for the private sector to enter into development of commercial post-harvest facilities • Insufficiency of appropriate financial resources • Absence of port-in port-out system to meet the ASEAN Catch Documentation Scheme (ACDS) requirements • Fisheries Administration being challenged by traders selling fish at sea without transmission of catch records to authorities • High numbers of small-scale fishers
Indonesia • Absence of integrating data from downstream and upstream in a single national data system, to support decision making for fisheries management • Identification of responsible unit to monitor compliance • Accountability towards verification and validation processes
Lao PDR • Absence of any catch documentation or traceability system • Recording of information includes only the amount of sale at landing sites • Fishing ports consist mainly of small local landing sites along the Mekong River, reservoirs and lakes • Fisheries sector is characterized by 95 % small-scale fishing activities • Inadequacy of necessary resources • Inadequate capacity building programs for staff
Malaysia • Only 6 states implement Catch Certificate – Penang, Perak, Selangor, Johor, Pahang, and Sabah • Need for additional resources (manpower, financial) necessary for monitoring, auditing, and verification • Need for training of new officers and conduct of refresher courses for existing officers • Key Data Elements are collected more than once through different forms managed by different agencies with very limited scope for data sharing, resulting in lack of proper consolidation and organization of these KDEs under one eCDTS platform • Current approach to CDT is very compartmentalized within government and should be streamlined • eCDT, let alone CDT, across fisheries in Malaysia is not yet officially mandated or streamlined under any policy
Myanmar • Fisheries sector is characterized by predominantly vessel type(s) for offshore fisheries (trawlers) • Catch documentation and traceability system is largely paper-based • Low interest of policy makers and decision makers in the fisheries sector • Insufficient technical capacity and financial resources • Inadequate post-harvest facilities
Philippines • Lack of appreciation of CDT as a mechanism for sustainable fisheries development • Need to harmonize CDT systems of trading partners in the development of IT system for CDT in the Philippines • Catch documentation is mainly paper-based and primarily for business dealing purposes • Non-uniform methodology for data capture, storage, and sharing; differences in terminology used by different players along the chain; and differences in the types of data captured and transmitted by different players along the chain • Restrictive policies and unsupportive governance • Subscription or adherence to several standards dictated by international markets and other international and non-regulatory standards which have their own lists of certification requirements • Compliance with regulations and certification requirements are considered labor and resource intensive • Inactions on the part of the government agencies tasked with regulating food systems hamper the maturation of technologies and standards necessary for achieving whole-chain traceability • Lack of buy-in and commitment to implement an electronic CDT system by both small- and large-scale sector stakeholders • Limited awareness of the CDT system brought about by the diversity of nature and technology (*e.g.*, computers, smartphones) and multiplicity of fishing gear and target species of the small-scale fisheries sector • Limited capacity to pay for increased CDT, particularly in the case of small-scale fishers • Inadequacy of needed skills and human capacity • Absence of trust among companies to participate in the implementation of CDT system which they believed could result to data breach
Singapore • Limited domestic fishing grounds • Extensive species and sources of seafood imports • No commercial fishing
Thailand • Ability and willingness to adopt technology that is not compulsory, depend on the personalities and progressiveness of boat captains and owners • Fisheries regulations of Thailand including VMS requirements have been changing frequently in recent years causing mistrust in the government ...

Box 19. Identified gaps in the implementation of Electronic Catch Documentation and Traceability systems by the ASEAN Member States *(Cont'd)*

Thailand ***(Cont'd)***

- Insufficient technical capacity and interest of fishers on the technology (as suggested by the following findings during the pilot testing of the Hi-Chat application and e-logbook technology), *e.g.* the use of e-logbook technology, for some older captains who are resistant to change and end up designating the filling of the e-logbook to a crewmember, although most boat captains use the Hi-Chat application, so that the problem is more on users' interest rather than technical capability
- Companies are wary of authorities getting data for the eCDT, implying the need for bridging over through incentives, demonstrating the benefits, and so on
- Need improvements in terms of the number of KDEs collected by the e-logbook system, as additional data points are necessary for the system to be compatible with the CDT system in use by the Department of Fisheries of Thailand, and with other international standards—including USAID Oceans' recommended point of production KDEs
- Needs value proposition analysis based on the evaluation of efficiencies and benefits
- Unclear cost-sharing structure

Viet Nam

- Fisheries sector is characterized by small-scale fishing (71 % small vessels)
- Low awareness of fishers on IT
- Limited application of IT for the CDT
- Country's catch documentation system is mainly paper-based up to the point of the processors
- Low awareness of the need for CDT on the part of fishers and limited application of IT for CDT

a marketing tool, by providing customers with unique information about the products they are buying and their origin. This also implies the need for the AMSs to consider the development and improvement of their traceability systems that could complement those of the importing countries not only in commercial/large-scale fisheries but also by exploring appropriate approaches for the small-scale fisheries in coastal and inland waters through the use of new technologies that support traceability processes and systems. This would enhance the intra- and inter- regional trading of fish and fishery products.

During the 2019 Workshop on the Technical Guidance on the Design and Implementation of Electronic Catch Documentation and Traceability Systems in Southeast Asia, gaps were identified by the AMSs (Box 19), which could be summarized into: inadequate capacity building not only of the human resources but also institutional, especially in IT as the traceability systems require sufficient knowledge in IT to be able to use the applications; limited mainstreaming of the concepts of eCDTs in national policies, laws, and regulations; laws and regulations do not generally address the concerns on the need to promote traceability of fish and fishery products at national level; weak cooperation and collaboration among agencies concerned with traceability as well as with the private sector, among others. Efforts should therefore be exerted to plug these gaps in order that the benefits of traceability with respect to the sustainable management of the fishery resources could be realized.

More specifically at the regional level, AMSs should harmonize the catch documentation scheme importer's requirements (paper-based and electronic), including IT Catch. Furthermore, the AMSs should move toward ensuring compatibility and linking of data in the future for the traceability processes and systems. This would necessitate the development of new projects or additional activities for the existing relevant projects being implemented in the Southeast Asian region.

6.1.1.4 Port State Measure (PSM) Implementation

As a legally binding international instrument to prevent, deter, and eliminate IUU fishing by preventing foreign vessels engaged in IUU fishing from using ports and landing their catches, the 2009 FAO Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA) was approved by the FAO Conference on Fisheries at its 36th Session, 22 November 2009 and open for signature from 22 November 2009 until 21 November 2010, by all States and regional economic integration organizations. During that period, 23 States and the European Union (EU) signed such PSMA, which was then subsequently entered into force on 5 June 2016. As of 8 March 2021, there were 69 Parties to the PSMA, including the European Union as one Party representing its 27 Member States. Nine new Parties have deposited their instruments of accession to the PSMA since the Second Meeting of the Parties held in Santiago, Chile on 3–6 June 2019.

From a global perspective, the proportion of coastal States where the PSMA is in force is 56 % and the proportion of the total States where the PSMA is in force is 48 %. Coastal and landlocked States represent 81 % and 19 % of the total States, respectively. From the regional perspective, the proportion of PSMA enforcement in the coastal States is lowest in the Near East (29 %) and Southwest Pacific (38 %); medium in Latin America and the Caribbean (52 %), Asia (58 %), and Africa (58 %); and highest in Europe (73 %) and North America (100 %). Meanwhile, the proportion of PSMA enforcement in the total States is lowest in the Near East (24 %), Southwest Pacific (38 %), and Africa (39 %); medium in Asia (46 %) and Latin America and the Caribbean (48 %); and highest in Europe (69 %) and North America (100 %).

Currently, six (6) ASEAN Member States (AMSs) are Parties to the PSMA, namely Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam. The AMSs recognize that the implementation of PSM requires inter-agency collaboration as well as regional and international cooperation. Considering therefore its role as the technical arm of the ASEAN, SEAFDEC collaborated with FAO and other relevant organizations as well as with its Member Countries for jointly organizing a number of regional capacity development programs and activities related to PSM since 2015. Specifically, such collaboration has provided the regional forum where the SEAFDEC Member Countries could discuss the key issues for information exchange at regional and international levels as well as identify the needs of the AMSs for capacity building to effectively implement their respective port State measures (PSM) programs.

Since then, the AMSs have been making progress in implementing their PSM programs, and their efforts had been strengthened when the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 (RES&POA-2030) was adopted in 2020 by the ASEAN-SEAFDEC Member Countries after this had been endorsed through the ASEAN and SEAFDEC mechanisms. The RES&POA-2030 encompasses various key plans of action that include the task of SEAFDEC to support the AMSs in improving the capacity of relevant national authorities to effectively implement the requirements of port State measures and flag State responsibilities.

The progress of the AMSs in implementing their respective PSM measures and flag State responsibilities were reported during the "Teleworkshop on Development and Improvement of Regional Fishing Vessels Record (RFVR) for Combating IUU fishing in Southeast Asia," which was organized by SEAFDEC/TD in September 2021. During the Teleworkshop, updates related to the activities of the AMSs in combating IUU fishing as well as on port control and PSM implementation were reported, the summary of which is shown in **Box 20**.

Legal aspect

On the legal aspect, implementation of the PSMA assumes that States would make some legal adjustments to warrant conformity and strong linkages between national frameworks and the PSMA contents. This could include the development of national legislations necessary for the effective implementation of the PSM based on their respective national fisheries laws and regulations (Onoora, 2008). To date, six AMSs are Parties to the FAO/PSMA, while some countries are undergoing the necessary domestic processes to access/ratify/accept the PSMA in the future. Legally, the duties of Parties to the PSMA should conform and have strong linkage between the national laws, regulations and practices, and the provisions of PSMA, such as: 1) review and collect the national legislations and procedures in relation with the implementation of the PSM, as well as flag, coastal and market State responsibilities and duties; 2) designate legal power to Denial the Use of port AFTER ENTRY in national legislations; 3) ensure that there are specific provisions in the national legislation to support in implementation of PSMA especially for providing legal authority for officials and inspector; and 4) amend relevant penalties in national legislation for violating the provisions of port State measures.

Nevertheless, the possible legal framework for PSMA implementation by non-Party to the PSMA could include: 1) implementation of PSM although without any legal obligation to comply with the provisions of the PSMA; 2) provision of essential information about the PSMA focusing on the role, responsibilities and obligations of the port States; 3) awareness raising among nationals about the benefits of implementing the PSMA; 4) promotion of the ways to strengthen coordination and collaboration among various agencies concerned at national, regional and global levels; 5) review of stakeholders' perspectives on port State measures and good governance issues; 6) participation in related national and regional action plans and recommendations in general, legal and policy, institutional and capacity development and operations terms; and 7) review and redrafting of specific laws or regulations dealing with the application of port State measures.

Box 20. Status of implementation of port control and PSM activities by the AMSs

Cambodia
- Party to the PSMA as of the end of 2019
- Establishment and/or revision of several legal documents and national action plans such as the marine fisheries policy, the NPOA-IUU and national plan of control and inspection for marine fisheries (NPCI-MF)
- Development of fisheries management plans for freshwater and marine fisheries to control and monitor the fisheries activities
- Development of the national strategy and action plan for PSMA implementation that includes the procedures of selecting the designated ports in the coastal areas

Indonesia
- Party to the PSMA, and strengthened the implementation of the PSM
- Establishment of four (4) designated ports for PSM inspection
- Institution of reforms in the national policy and law for marine and fisheries sector including administrative sanction and investigation of Indonesian fishing vessels operating in the high seas and other States' jurisdiction

Box 20. Status of implementation of port control and PSM activities by the AMSs *(Cont'd)*
Malaysia • Establishment of the Standard Operation Procedure (SOP) to handle foreign fishing vessels suspected to be engaged with IUU fishing • Amendment of Fisheries Act 1985 that includes newly amended law on imposing penalties to offenders to be six-time heavier than that of the previous provisions, and creation of special task force to address illegal fishing activities by foreign vessels (Cabinet Order 24th April 2019)
Myanmar • Enforcement of regulation to disallow foreign fishing vessels from landing in Myanmar ports without prior permission or license. • Establishment of regulation for all carrier vessels to report transshipment data to the Department of Fisheries of Myanmar • Recording of landed data by the Department of Fisheries starting 2012, from the nine (9) landing sites in Yangon • Conduct of the Workshop on Formulation of a National Strategy and Action Plan for Compliance with the Port State Measure Agreement in Myanmar (23-27 October 2017) with technical assistance from FAO • Continued implementation of PSMA that includes information sharing of IUU fishing vessels with neighboring countries and regional fisheries management organizations • Application to become part of participating countries of the RPOA-IUU which the RPOA –IUU Secretariat agreed to start in 2021 • Full cooperation and participation in the efforts of the ASEAN Working Group on Fisheries and SEAFDEC on the implementation activities to combat IUU fishing and promote sustainable fisheries development • Signing of the Memorandum of Understanding (MOU) with Thailand to improve fisheries cooperation especially with respect to PSMA implementation, sharing of information on regulations for export/import of marine fisheries products not obtained from IUU fishing activities, and aquaculture development
Philippines • Accession to the PSMA on 26 April 2018 after the Philippine Senate gave its concurrence on 5 March 2018. • Adoption of Fisheries Administrative Order on PSMA or the implementing rules of the PSMA by the National Fisheries and Aquatic Resources Management Council (NFARMC) on 27 September 2021 • Establishment of an inter-agency Memorandum of Agreement (MOA) on a One-Stop Action Center (OSAC) for the effective implementation of the PSMA • Amendment and updating the fisheries law through the enactment of Republic Act No. 10654 that includes updates relevant to increased deterrent fines and penalties for offenders, port State measures, observer's program coverage, vessel monitoring system requirements, catch documentation scheme, among others • Development and adoption of the National Plan of Action to prevent, deter and eliminate illegal, unreported and unregulated fishing through the issuance of Executive Order No. 154 in 2013
Singapore • Approval by the Minister of Sustainability and the Environment of the policy on PSM but pending legislative amendments but is targeted for completion in 2022 • Establishment of the requirements for vessel information/document in line with Annex A of the FAO Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, which are provided in advance to vessels requesting entry to Singapore port • Making the country's gazetted laws accessible to the public to allow efficient information exchange, and allowing where necessary, the engagement of relevant stakeholders in the implementation of the regulations and procedures • Establishment of Standard Operating Procedures (SOPs) in line with the port State measures (*e.g.* IUU fishing vessels seeking entry into port and IUUF vessels in Singapore)
Thailand • Designation of 25 ports for PSM (19 international ports and 6 neighboring ports) • Accession to the PSMA on 10 May 2016 • Implementation of significant enforcement activities • Development of the requirements prior to port entry • Implementation of activities relevant to PSM (*e.g.* Traceability System, MCS, Processing Statement Validation) • Issuance of Decree laws and regulations to support PSM implementation • Development of NPOA-IUU in support of PSM implementation • Development of the "Processing Statement and PSM Linked System" (PPS) • Updating of the inspection manual based on information indicated in the National Plan of Control and Inspection (NPCI)

Viet Nam
• Publication of the list of designated fishing ports for offshore fishing vessels entering designated ports (vessels of 15 m in length and over)
• Issuance of the list of designated fishing ports for foreign flagged fishing vessels to port in/enter
• Establishment of the procedures for controlling port in/port out in accordance with the PSMA
• Strengthening of mechanisms for exchange, dialogue and international cooperation on combating IUU fishing though:
  o Development a national action plan on the implementation of the PSMA and UNFSA
  o Conduct of high-level delegations' dialogue with the European Commission (EC) for exchange on techniques and implementation of the results and recommendations
  o Signing of a hotline to exchange information on combating IUU fishing with other countries
  o Signing of a Memorandum of Understanding to combat IUU fishing with a number of countries, *e.g.* Australia
  o Active participation in regional initiatives and multilateral forums to exchange information and experiences on combating IUU fishing

Regional Capacity Building on PSM Implementation and Way Forward

To support the implementation of PSM in Southeast Asia, many international organizations such as FAO, RFMO, NOAA, SEAFDEC and so on, had organized capacity building programs on PSM implementation for the AMSs at regional and national level. On the part of SEAFDEC, its Japanese Thrust Fund supported project also organized capacity building activities for the AMSs through regional training courses and workshops. For example, the Regional Training on Port State Measures Implementation in Southeast Asia organized in February 2018 in Bangkok, Thailand in collaboration with FAO and NOAA focused on the: 1) preparation of national legal aspects, policies and institutional implementation of PSM, 2) PSMA inspection of vessels, and 3) lessons learned on PSM implementation in Thailand. The training had created a better understanding of the implementation of Port State Measures in the AMSs, enhanced the knowledge of the stakeholders on Port State Measures and relevant activities as tool to combat IUU Fishing, the situation and preparation on PSM implementation in the region, the way to practical improvement of Port State Measures, and the regional cooperation necessary to support the implementation of PSM in the region.

In July 2019 and October 2021, the Regional Training on Port State Measures (PSM) implementation for Inspectors in Southeast Asia" was organized in collaboration with partners such as the Department of Fisheries (DOF) Thailand, Australian Fisheries Management Authority (AFMA), FAO, NOAA, and the United States Agency for International Development (USAID), which focused on updating the current situation on inspection activities for port control and PSM in the AMSs through sharing of information on implementation on PSM inspection with partners. The training also provided the participants an opportunity to observe PSM inspection at port activities for tuna carrier vessels. This led to their better understanding of the implementation of PSM, and enhanced knowledge, skills and experience in inspection to support PSM and port control implementation.

Moreover, the Teleworkshop on Development and Improvement of Regional Tools for Combating IUU Fishing in Southeast Asia organized by SEAFDEC in August 2020 in cooperation with the AMSs, came up with the updated status, actions and needs for PSM implementation in Southeast Asia (except for Lao PDR that has no fishing port) (**Table 71**). Specifically, the priority needs to implement PSM in the AMSs could include: 1) capacity building to support the implementation of PSM, and 2) sharing and exchange of information in support of the PSM implementation.

6.1.1.5 MCS Systems and Regional Cooperation for Combating IUU Fishing

Monitoring, Control and Surveillance (MCS) is an important mechanism for effective fisheries management. As described by FAO (1981), the definition of M, C and S comprises: **Monitoring -** the continuous requirement for the measurement of fishing effort characteristics and resource yields; **Control -** the regulatory conditions under which the exploitation of the resource may be conducted; and **Surveillance -** the degree and types of observations required to maintain compliance with the regulatory controls imposed on fishing activities. Several key international fisheries-related instruments highlight the need for effective implementation of MCS activities to combat IUU fishing, such as the 1982 UN Convention on the Law of the Sea; the 1993 FAO Compliance Agreement; the 1995 UN Fish Stocks Agreement; the 1995 FAO Code of Conduct, and the International Plans of Action elaborated under the Code of Conduct; and the 2009 FAO Agreement on Port State Measures, as well as regional policy frameworks of the RFMOs, and also as to serve as means of enhancing efforts for the conservation and management of the fishery resources.

For countries in the Southeast Asian region, various government agencies such as fisheries, natural resources and environment, navy, marine police, coast guard, and customs among others, are involved in the implementation of their respective national laws in preventing illegal fishing activities under their national jurisdictions. Nonetheless, interagency cooperation is important to attain successful and effective implementation of national MCS operations. Countries in the region have therefore established their respective national inter-agency integration and cooperation units. Such as for example, the following:

- Cambodia: National Committee for Maritime Security (NCMS
- Indonesia: Special Task Force 115
- Malaysia: JBOM Committee (maritime task force Malaysia)
- Myanmar: One Stop Service
- Thailand: Thai–Maritime Enforcement Coordination Committee (Thai-MECC)
- Viet Nam: Working Group 689

The implementation of MCS is necessary not only at the national level, but also at the regional and international levels. The establishment of a regional MCS network in Southeast Asia is important to strengthen the capabilities of the countries for combating IUU fishing and destructive fishing activities that impact on the sustainability of the region's fishery resources (Yleaña and Velasco, 2012).

Table 71. Recommendations and actions/needs of AMSs for PSM implementation (as of Teleworkshop 2020)

Recommendations	Actions/needs	Concerned AMSs
1) Encourage AMS to identify designated ports for foreign fishing vessels and not allowing foreign fishing vessels to unload fish and fishery products in non-designated ports	• Sharing of information among AMSs with regard to PSM	Brunei Darussalam
2) Come up with the list of designated ports that include information on the name of the port, address of the location, contact person, and corresponding designation as well as official website in English	• List of designated ports are clarified and shared among AMSs	Brunei Darussalam, Cambodia
3) Provide, as a minimum standard, the information requested or relevant document to be provided by any AMS to vessels before granting them entry to its port	• Closely work with AMSs with assistance from SEAFDEC or FAO to prepare the minimum standards	Brunei Darussalam, Cambodia
4) Exchange of information on country's laws and regulations to be shared among the AMSs, and consider that any AMS should not allow its fishing vessels excluding carriers to unload catch at other country's ports	• Sharing of the most updated information on laws and regulation	
5) Encourage AMS to require foreign fishing vessels and carriers to submit pre-arrival information (such as approval to land their catch, the origin of catch or certificate of catch) so that the port State can decide whether to authorize or deny entry of such vessel into their ports, while decision to deny shall be communicated with the flag State	• Implementation of PSM	Brunei Darussalam
6) Provide awareness building to relevant stakeholders (*e.g.* fishing boat owners, importers, port authorities, etc.) at national level to enhance their understanding of the country's laws and regulations, and other procedures on inspections	• Provide capacity building for fisheries officers and inspectors on implementation of PSM	Brunei Darussalam
7) Adopt the Standard Operating Procedures (SOPs) on the risk assessment and inspection of vessels	• Using SOP on the risk assessment and inspection of vessels • Expertise to support the risk assessment	Brunei Darussalam, Myanmar
8) Consider the minimum requirements for inspection of vessels as agreed among all AMSs		Brunei Darussalam, Cambodia, Myanmar, Singapore, and Thailand
9) Support the inspection of vessels, which requires the historical data/information of the vessels	• AMS should be able to share the historical data/information of their own vessels upon the request	Brunei Darussalam, Cambodia
10) Transmit the results of each inspection to the flag State of the inspected vessels	• Sharing of relevant information to support inspection activities	Brunei Darussalam, Cambodia, and Myanmar
11) Facilitate the implementation of this Regional Cooperation, and where possible, each AMS establishes a national communication mechanism that allows for the direct electronic exchange of information; with due regard to appropriate confidentiality requirements	• Mechanism to exchange relevant information among AMSs	Brunei Darussalam, Cambodia, Myanmar, and Thailand
12) Request FAO, RFMOs, ASEAN, SEAFDEC, and relevant agencies for training of trainers for port inspections including legal and operational aspects with emphasis on the practical hands-on components	• Request FAO, RFMOs, ASEAN, SEAFDEC and relevant agencies for training of trainers on port inspection including the legal and operational aspects with emphasis on the practical aspects	Brunei Darussalam
13) Develop a network/team among AMSs on the training of trainers for port inspections (Note: Consider utilizing the existing training module developed by RPOA-IUU in collaboration with the other agencies on port inspections to support the TOT programs)	• Participation in meetings and consider the use of existing training module developed by RPOA-IUU in collaboration with the other agencies on port inspections to support the TOT program • Training for trainers on port inspections	Brunei Darussalam, Myanmar, and Thailand

In support to the efforts of the AMSs, several common concerns were identified through the series of bilateral and sub-regional dialogues facilitated by SEAFDEC, aimed at ensuring the sustainable management of fisheries and combat illegal and destructive fishing activities in the Southeast Asian region. These concerns include among others, the adoption of an efficient MCS system for effective control of fishing capacity and combat IUU fishing, destructive fishing, and encroachment by larger fishing vessels in coastal waters (Wanchana *et al*., 2016). Through sub-regional fora facilitated by SEAFDEC, the establishment in several sub-regions of sub-regional MCS mechanism was discussed among the concerned countries, namely:

- Gulf of Thailand: among Cambodia, Malaysia, Thailand, and Viet Nam
- Northern Andaman Sea: between Myanmar and Thailand
- Southern Andaman Sea: among Indonesia, Malaysia, and Thailand

The countries made strong efforts for the networking and improvement of their relationships and communication, although engagement in non-legally binding transboundary and sub-regional cooperation was preferred. In establishing the MCS networks for sub-regional fisheries management coordination, the key for such a cooperation to be successful is the active involvement of relevant authorities in the cooperation, nationally and regionally (Jaya *et al*., 2019), taking into account the following considerations: common understanding among designated national agencies; enhanced cooperation among neighboring countries; clarification of national priorities; and agreement by the countries concerned of the scope of cooperation. The potential collaboration and coordination of the Networking came in the forms of joint control of transshipments at sea, application of various tools to monitor the fishing activities including tractability system, *e.g.* eACDS, VMS, CCTV, AIS, ERS; and information sharing through sub-regional database on fishing gear and vessel marking systems, catch and landing, analysis of information for fishing effort and stock status, and so on.

As for areas beyond the EEZs and the high seas, the effective implementation and coordination of MCS are essential to strengthen transboundary fisheries management, control fishing efforts, and surveillance across countries for sustainable utilization of the fishery resources. One of the very important platforms for combating IUU fishing is the regional fisheries management organizations (RFMOs) as the international organizations regulating regional fishing activities in the high seas. There are approximately 17 RFMOs covering various geographical areas worldwide, some of which overlap. Of these, only three RFMOs are located near the Southeast Asian region, *i.e.* Commission for the Conservation of Southern Bluefin Tuna (CCSBT), Indian Ocean Tuna Commission (IOTC), and Western and Central Pacific Fisheries Commission (WCPFC). Among the AMSs, only Indonesia is a member of CCSBT; Indonesia, Malaysia, Philippines, and Thailand are members of IOTC; and only the Philippines is a member of WCPFC.

Moreover, cooperation in the implementation of MCS has also been strengthened through the International Monitoring, Control and Surveillance (IMCS) Network, which was established in 2001 and which provides the global platform for exchanging information and collaborative activities among the networks of States, RFMOs and regional organizations, NGOs, private sector, and for improving the efficiency and effectiveness of fisheries-related MCS activities. The IMCS hosts the biennial conference on Global Fisheries Enforcement Training Workshop (GFETW).

Another important regional platform for combating IUU fishing is the Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated Fishing in the Region (RPOA-IUU) which was endorsed by the ASEAN Ministers responsible for fisheries in May 2007, and embraces eleven (11) countries, namely: Australia, Brunei Darussalam, Cambodia, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand, Timor-Leste, and Viet Nam. The RPOA-IUU is aimed at enhancing and strengthening the overall level of fisheries management in the region in order to sustain the fishery resources and the marine environment, and to optimize the benefit of adopting responsible fishing practices. Through sub-regional approach, the responsibility of the RPOA-IUU is divided into three sub-regional areas, namely: a) southern and eastern South China Sea and Sulu-Sulawesi Seas, b) the Gulf of Thailand, and c) the Arafura-Timor Seas. The RPOA-IUU Coordination Committee holds meetings annually for sharing of information and reporting the progress of the implementation of MCS activities as well as sharing data on IUU Vessels List.

Under the ASEAN mechanism, an ASEAN IUU Task Force was also initiated in 2019 to support effective exchange of information for better communication between the law enforcement authorities and governmental competent authorities responsible for combating IUU fishing (ASEAN, 2020), and during the 27th ASWGFi Meeting in June 2019, the AMSs agreed to change the ASEAN IUU Task Force into the ASEAN Network for Combating IUU Fishing (AN-IUU). Subsequently, the concept of the AN-IUU was endorsed by the 42nd Meeting of the ASEAN Ministers on Agriculture and Forestry (AMAF) in October 2020. The AN-IUU would serve as a cooperation framework for information sharing and capacity-building among the AMSs on MCS and dissemination of best practices, especially on maritime domain surveillance and investigation activities, and experiences of the Network among the AMSs.

Moreover, the ASEAN SOM-AMAF endorsed in 2020 the Roadmap on Combating IUU Fishing in the ASEAN Region (2021-2025). Similar with the efforts of the ASEAN in combating IUU fishing, the Asia-Pacific Economic Cooperation (APEC) also endorsed the APEC Roadmap on Combating IUU Fishing at its third Senior Officials' Meeting in 2019. The APEC Roadmap is aimed at addressing the issues on IUU fishing in the Asia and Pacific region through various capacity building programs and strengthening of institutional capacities and compliance with domestic and international conservation and management measures that address IUU fishing within the APEC member countries, through technical assistance and enhancement of monitoring, control and surveillance, and traceability systems.

Way forward

In the AMSs, the respective national authorities have enhanced the promotion of the MCS system for effective fisheries management and conservation of the fishery resources. Moreover, sub-regional and regional cooperation on MCS have also been strengthened with the aim of improving the governance of trans-boundary fishing and fighting against IUU fishing. Regional cooperation for combating IUU fishing has therefore been enhanced in the Southeast Asian region, through regional and sub-region platforms, *e.g.* APFIC, ASEAN, SEAFDEC, RPOA-IUU, AN-IUU, RFMOs, that provide for effective exchange of information across the countries.

Nonetheless, it is also necessary to provide human capacity building programs as these are essential elements for the AMSs to enhance their knowledge, especially improvement in the areas of policy and legislation, fisheries statistics and data collection, as well as in stock and risk assessments of the fishery resources to provide the scientific-based recommendations for the policy decision makers. Meanwhile, the promotion of MCS, PSM and risk analysis for combating IUU fishing would continue to support the AMSs, especially for the adoption of the technologies on MCS.

Coincidentally, the COVID-19 crisis has shown the need for the countries to accept new technologies to support the implementation of MCS and improve the effectiveness of fisheries management for the sustainability of the fishery resources in the fisheries sector. Reporting of catch from remote areas would benefit from such technologies as these would reduce the risks of spreading the virus, for example replacing the observers' program onboard by cameras. Moreover, and the effectiveness of fisheries management could also be enhanced more effectively through monitoring, control and surveillance (MCS), limiting the fishing effort, and increasing research activities.

6.1.1.6 Combating IUU Fishing in Inland Fisheries

Although the definition of IUU fishing in inland waters has not been established specifically and potentially, the definitions used for IUU fishing in marine fisheries could be referred to with appropriate and adequate adjustments in accordance with the characteristics of inland fisheries. IUU fishing practices, particularly in inland water fisheries, could therefore include: unfriendly fishing methods such as the use of toxic chemical substances, explosive materials, and prohibited gears and ways such as electro-fishing, and many other irresponsible practices (Ma *et al*., 2018); fishing without license or quota for certain species; catching undersized fish or fish that are otherwise protected by regulations; and fishing in closed areas or during closed seasons, among others.

A big portion of inland fisheries in Southeast Asia is dominated by the Mekong River Basin bordered by Myanmar, Viet Nam, Thailand, Lao PDR, and Cambodia; and also includes the Indonesian inland waters that comprise the Sundaland, Wallace, and Sahul Land. The Mekong River is considered as the largest inland fisheries producer on earth and provides a significant contribution to the economic growth of around one-half of Southeast Asian countries, namely: Myanmar, Viet Nam, Thailand, Lao PDR, and Cambodia (Hecht *et al*., 2019). Meanwhile, in the lower part of the Mekong Basin (LMB), people rely heavily on fish which is important for their protein intake, making up 47–80 %, which is considered the highest inland fish protein consumption in the world (Hortle, 2007). This massive figure of inland fisheries in this region suggests that combating IUU fishing is essential and urgent for the sustainability of inland fisheries. In addition, in 2014, Indonesian inland capture fisheries produced 446,509 mt or equivalent to 2.17 % of the national total fish production or 6.96 % of total capture fisheries (SEAFDEC, 2014). Even with a tiny portion of inland waters compared to its marine areas, the inland fisheries of Indonesia have contributed substantially to the country's total fish production.

Recent management measures on sustainable fisheries, such as the imposition of closed season or prohibition of the use of certain fishing gears have also focused more on the marine fisheries sub-sector than in the inland fisheries. This has led to national fisheries policies and interventions skewed toward the marine fisheries sub-sector. Similarly, at the global level, attention on the depletion of fishery resources and on IUU fishing is focused predominately on marine fish stocks despite the importance of freshwater fishes around the world to local communities. As a result, inland fisheries are often underappreciated and undervalued in resource planning and decision-making.

IUU Fishing in Inland Waters

The most common illegal practices that destroy wild inland fishes include electro-fishing, and the use of toxic substances and explosive materials. Electric fishing or electro-fishing can kill not only the targeted fishes in terms of size and species but also other aquatic biotas from all stages of their aquatic life. Mature fishes that contribute to the release recruitment of young fish will die and non-hatched eggs are of no exception. Larval stages of fishes are easily killed by such unselective fishing practice. While the use of toxic substances and explosive materials could significantly demolish the fishery resources including the aquatic biotas, and such practices also contribute to habitats destruction. Toxic chemical materials used for fishing pollute the water and reduce the water quality, kill the aquatic plants that are important as nursery grounds, and demolish the fish habitats, ultimately destroying fisheries. Regulations on the use of destructive fishing gears are commonly imposed in the Southeast Asian countries but surveillance remains a big challenge because of the nature of the region's fisheries, which are open access and people are fishing for subsistence.

A substantial challenge in the sustainable development of inland capture fisheries is on the collection and reporting of reliable data on wild-caught fish. There are limited port landing sites for inland capture fisheries and most of the harvested fish is consumed in households without entering the market chain. Therefore, data on inland fish catch are scattered and not well documented by government authorities. Fish catch and effort data are necessary as these are used to determine the total stock of fish in targeted water bodies. Without sufficient reliable data on catch and unit effort, authorities and scientists would not be able to determine the total allowable catch of particular fisheries, which could lead to possible overexploitation. The numbers of fishers and fishing gears are also not well recorded and remain unreported because the majority of inland capture fisheries involve small-scale and subsistence fisheries, while the numbers of on-ground fishery officers are minimal.

Issues and Concerns

In marine fisheries, port landings are crucial facilities as these are used for recording, licensing and monitoring the fishing activities. Data collected from the ports could also contribute to determining the fish stock and total allowable catch, and the development of appropriate policies to protect the fish population and sustain economic development. Expanding port landing sites in inland water bodies equipped with officers and facilities would be important to establish and facilitate capture data documentation. Inland fisheries ports can be designed based on the localities and should be capable of undertaking multi-purpose tasks of not only recording fish catch but also facilitating fishers' ability to sell fish and obtaining fair prices of their catch. While determining the fishing capacity is much easier in marine fisheries, this could also be easily determined in inland fisheries if the fish stocks are well assessed and the catch effort is well documented. Determining fish stocks in inland fisheries so far is mostly based on poor fish catch data which could lead to misrepresentation of the real status of inland fisheries and literally, translate to destruction of the fish population.

Logbook of fish catches and the involvement of observers in industrial marine fishing activities have been known to improve the reliability of the catch data in marine capture fisheries. The same method could also be implemented in inland fisheries by working closely with fishers, especially the permanent fishers who catch fish on a daily basis. The inland fishers themselves can serve as the observers and logbooks could be provided by local fisheries authorities. Trust needs to be established between the fishers and officers, and the governments could consider providing subsidies for fishers who are able to document their fish harvests and catch efforts continuously.

Licensing and registration of marine fishing vessels and fishing gears are not relevant to inland fisheries because inland fisheries are dominated by subsistence and artisanal fishers, and mostly involve the impoverished people with limited capital. However, co-management, local wisdom, and the EAFM concept could be implemented in inland fisheries to monitor the fishing activities. The governments or authorities can work closely with the local people to socialize good fishing practices, instill the importance of sustainable fisheries, and teach fishers how to harvest fish wisely to allow adequate recruitment. Some local wisdom already exist in Indonesia, such as protecting the lubuk or the deepest area in the river during the dry season to allow fish to settle and save them during low water levels and prevent their overexploitation (Dian *et al.*, 2016). Promotion of such local wisdom could be strengthened and allowed to be adapted in other areas to protect the fishery resources.

Way forward

There are some key messages that can be implemented to protect inland fisheries and to combat illegal activities that can destroy biotas and habitats. Local communities' engagement would be useful to create trust between the fisheries authorities and local people. As inland fisheries continue to be open access and dispersed, the involvement of local people in data documentation and monitoring of illegal activities is the key. Also, to improve catch data documentation, expanding the numbers of small fish landing ports, either operated by the local community or the government, would be crucial for documenting the catch from fishing activities in inland waters. A good data on catch and effort should be targeted as these are crucial for determining the status of the stocks of commercially important inland water fish species.

6.1.1.7 Application of Innovative Technologies for Combating IUU Fishing

The application of innovations and technologies has been progressing, especially in support of the functions of MCS, for effective fisheries and habitat management, and combating IUU fishing in many countries. The technologies and tools for effective MCS system have been available and have been used (*e.g.* automatic identification system, vessel monitoring system, electronic catch reporting system or e-logbooks, CCTV, drone, satellite imagery, etc.) for monitoring and controlling of fishing activities in land, on ports, and at sea. The technologies have also been improved making them user-friendly, such as mobile applications, offline and what has now evolved into the artificial intelligence and machine learning.

As for the regional initiatives, SEAFDEC has been supporting and promoting the technologies, tools and measures for the AMSs to apply in combating IUU fishing, *e.g.* RFVR, eACDS (from web-based to mobile application) with support from the Japanese Trust Fund and the SEAFDEC-Sweden Project (2013–2019). SEAFDEC also collaborated with the USAID during 2015–2019 for the implementation of the Project 'Oceans and Fisheries Partnership' also known as the Oceans Project aimed at among others, developing and promoting the electronic catch documentation and traceability systems and initiatives in the region (*e.g.* FAME, PointTrek, TRAFIZ, TraceTales). Such initiative also demonstrated the advancement of technologies and tools that check and connect the marine capture fisheries data throughout the supply chain in the demonstration sites of the AMSs.

SEAFDEC embarked on a questionnaire survey in 2020, to assess the application of innovative technologies for combating IUU fishing. Summarized below are the responses from the AMSs to the questionnaire taking into account the current technologies used in the respective AMSs.

Indonesia and the Global Fishing Watch have shared vessel monitoring system (VMS) data for all Indonesian flagged fishing vessels in a publicly available data platform since 2017. Indonesia's VMS data includes nearly 5,000 medium-sized commercial fishing vessels that are not required to carry AIS, and are therefore not reliably trackable by any other means. In order to improve marine and fisheries resources surveillance to combat IUU fishing, the Indonesian Directorate General (DG) for Surveillance has developed an online application system to monitor VMS transmitters, called SALMON. This application allows the owner of fishing vessels to monitor their vessels' movements, and integrates the functional features such as transmitter activation, monitoring fishing vessels' movement, and e-SKAT (transmitter activation letter) services. This application can be downloaded through Google Play Store. The DG for Surveillance also conducts air surveillance to improve vessel monitoring especially in the areas that are vulnerable to IUU fishing. PoinTrek, a two-way communication Vessel Monitoring System (VMS) and real-time fish catch reporting system, was also introduced in Indonesia through the SEAFDEC-USAID Oceans Project.

In the Philippines, a VMS system developed by Futuristic Aviation and Maritime Enterprises, Inc. (FAME) of the Philippines, is now being installed in large fishing vessels (30 GT and above). Through the Oceans Project, a small-scale vessel tracker and monitoring system has been developed that also serves as communication device, enabling small-scale fishers to participate in electronic Catch Documentation Traceability (eCDT) and establish enhanced communication and safety at-sea. This system has been piloted in the learning site in General Santos City, Philippines in 2018.

Malaysia has imposed the installation of a Mobile Transceiver Unit (MTU) for Malaysian fishing vessels operating in Zone C, C2, and C3. While, all Malaysian fishing vessels operating in zone B, are required to install an Automatic Identification System (AIS) transponder. Moreover, the Malaysian fishing vessels operating at the high seas are required to install CCTV.

Myanmar has implemented Vessel Monitoring System (VMS) since 2019, eACDS (pilot project), and E-licensing for combating IUU fishing. While all Singapore fishing vessels are equipped with AIS transponders for the tracking of vessel movements.

For Thailand, the Department of Fisheries (DOF) of Thailand has developed control and monitoring systems for all operating fishing vessels. Such systems include:

1. Vessel Monitoring System (VMS): a satellite-based monitoring system for licensed commercial fishing vessels ($\geq$ 30 GT) that broadcasts signals at the port and during fishing operations at sea. Together with the VMS, Support Vessel Data and analytical data from AI, support the technical knowledge for the adoption of the VMS technology using computer programs
2. Fishing Info: a port-in and port-out control system, where inspection of fishing vessels is initiated, the information is linked with the Thai Fishing Vessel Database of the Marine Department of Thailand and other relevant authorities
3. Electronic Reporting System/Electronic monitoring (ERS/EM): a surveillance system for Thai fishing vessels operating overseas and transshipment vessels to facilitate submission of reports, *e.g.*, fishing logbook, permitted transshipment status, and showing up real-time photos of suspicious-looking vessels' activities at the Fisheries Monitoring Center (FMC)
4. Machine Learning System: an ongoing development project where the VMS data analysis accessed by AI is automated to build an analytical model of warning system when fishing activities are suspected to be breaking the laws

Way forward

Novel technologies are important for the authorities to support the implementation of MCS and improve the effectiveness of fisheries management for the sustainability of the fishery resources. Such technologies (*e.g.* VMS, AIS) would help support the countries' efforts toward monitoring and surveillance of fishing activities, traceability of fish catch throughout the supply chain, as well as regional/sub-regional networks for sharing and exchange of information. The concerns raised with respect to the applicability of the technologies should be considered, such as making these user-friendly and enhancing their capability of providing real time data. It has also become necessary that the availability of offline records, internet, improved capacity of data storage, and data security, should be ensured at lower costs. The fast evolution of such technologies in the fisheries sector over the past years, *e.g.* machine learning and use of robot, sensors or Artificial Intelligence (AI), had been happening. Although these had already been introduced and tested in MCS and for combating IUU fishing in the region, some of the new technologies are still beyond the limit of human knowledge to be able to efficiently use them, and it is in these aspects that SEAFDEC and the AMSs have been monitoring the changes and developments.

For example, the human observers' onboard program might still be useful, while adjustments are being made with regard to the use of onboard digital cameras and recorders which still requires humans to review the footage of the information collected in the form of video clips. Nevertheless, with huge amount of data, the AI could be useful in compiling and analyzing the data. Such technology is therefore useful for improving effective fisheries management.

Many countries had been affected by the COVID-19 crisis in 2020–2021. Nevertheless, the countries continued to develop and implement their respective national measures, especially those that concern the health of laborers or crew onboard fishing vessels. As a result, the relevant national agencies had also adjusted the modes of work of fishers but also making sure that IUU fishing activities are prevented from occurring during this critical time. The use of the aforementioned novel technologies and innovations should therefore be promoted as these could be useful tools for remote monitoring and control of fishing activities at sea, and thus, support the governments' efforts in maintaining the fish stocks and in combating IUU fishing in their respective waters amidst the present crisis.

6.1.2 Management Concepts and Approaches

6.1.2.1 Ecosystem Approach to Fisheries Management (EAFm) and Ecosystem Approach to Aquaculture (EAA)

Ecological approach in fisheries (EAF) is a strategy that aims for the promotion of sustainable development, and the application of an ecosystem approach balances the fulfillment of the three objectives of the Convention on Biological Diversity (CBD): conservation, sustainable use, and fair and equitable sharing of the benefits arising from the utilization of genetic resources (Staples & Funge-Smith, 2009). The EAF was therefore devised as a tool to support the implementation of the FAO Code of Conduct for Responsible Fisheries (CCRF) with respect to the sustainable exploitation of fishery resources worldwide.

Ecosystem Approach to Fisheries Management

Ecosystem Approach to Fisheries Management or EAFM is one of the approaches currently being used in fisheries management (Jaya & Zulbainarni, 2015; Kusnandar & Mulyani, 2015). Applicable not only for the sustainable management of marine and coastal fisheries but also for inland fisheries and aquaculture, the EAFM approach is aimed at achieving an integrated, comprehensive, and sustainable fisheries management while balancing the socioeconomic aspects, knowledge, information, and the uncertainties about abiotic-biotic components and human interactions in the ecosystem.

Thus, EAFM has been used as an approach to improve fisheries management that has already existed but might had been conventionally applied by focusing on the target aquatic species (commodities or economic components) without looking at the interactions and relationships among the various aspects of the ecosystem. Several things had led to this paradigm change and could include increased understanding of the strong interaction among the fishery resources, and interaction of the fishery resources with the environment; of the ecosystem services for human life that need to be maintained and cared for to be sustainable; as well as of the ecosystem functions for humans and the environment—awareness of the many factors of uncertainties about the functions and dynamics of the ecosystems.

The application of the EAFM has already been globally accepted and endorsed in many international fora and countries. The approach, which represents a move away from the usual fisheries management systems that focused only on the sustainable harvest of target species, anchors toward systems and decision-making processes that balance environmental well-being with human and social well-being, within improved governance frameworks. The EAFM helps to manage fisheries more holistically; reduce user group conflicts; help unlock financial resources; enhance cooperative work with other stakeholders, and better resolve fisheries issues and challenges. The EAFM is not only applicable for marine and coastal fisheries management, but its concept and principles could also be used and applied to inland fisheries management, *i.e.* the Ecosystem Approach to Inland Fisheries or EAFm, as well as to aquaculture or the Ecosystem Approach to Aquaculture (EAA). Together with EAFm and EAA, EAFM is a strategy for the integration of the fisheries and aquaculture activities within the wider ecosystem in order that the promotion of sustainable development, equity, and resilience of interlinked social-ecological systems, is in place.

- Applying the EAFM in the Southeast Asian countries

In the Southeast Asian region, EAFM has been acknowledged as an applicable concept and approach which can be applied in the different scales of fisheries management, whether in marine, coastal, and inland environments, as well as in aquaculture. For being holistic, the EAFM framework is doable and the concept has already been adopted by a number of the Southeast Asian countries through various pilot projects that introduce and promote its application.

In the Philippines for example, EAFM is mainstreamed in the plans and programs of its Bureau of Fisheries and Aquatic Resources (BFAR), especially the concept of formulating the EAFM Plans in the 12 fisheries management areas (FMAs) that cover the entire waters of the Philippines in accordance with Fisheries Administrative Order 263. Among the successful cases of EAFM implementation in the Philippines, include the EAFM projects in Balayan Bay in Batangas Province and Samar Sea in Eastern Visayas between the Provinces of Leyte and Samar, and also the EAFM incorporated in the Fishing Closed Season Regulations enforced in Zamboanga, Palawan, Davao Gulf, and in the Visayan Sea (bounded by the islands Masbate to the north, Panay to the west, Leyte to the east, and Cebu and Negros to the south).

In Indonesia, the management measures implemented have resulted in positive aspects such as the high pressure in combating IUU fishing practices, sustainability of the resources, and welfare of the fishers. While the marine fishery management plans of the country's 11 Fishery Management Areas are being updated, the management plans for inland fisheries have been developed for verification prior to their implementation.

In Thailand, its Department of Fisheries (DOF) has been promoting the transfer of knowledge on fishery resources management using an ecological approach, to the fishing communities. The sustained efforts of DOF to provide budgetary support to the country's EAFM activities have led to the development of more than 20 fisheries management sites not only in coastal but also in inland fishing communities that adopt the EAFM approach.

In general, many projects that apply the EAFM concept and principles had been implemented in the Southeast Asian countries. These include:

- Cambodia:
  - Lower Mekong Basin Wetland Management and Conservation Project
  - EAFM learning in Trapeang Ropov fishing areas
  - Flooded forest rehabilitation in Siem Reap Province
- Malaysia
  - Establishment of EAFM in Lawas, Sarawak, Malaysia (marine & coastal)
- Indonesia:
  - Coral Reef Rehabilitation and Management Program-Coral Triangle Initiative (COREMAP-CTI) Project
  - Sustainable development of ecosystem resources in the Indonesian Seas Large Marine Ecosystem (ISLME) by FAO (GEF 5)
  - The Indonesian GEF Coastal Fisheries Initiative (CFI) in Eastern Indonesia
- Lao PDR:
  - Fisheries management in Nam Kadun, Bolikhamsai Province
- Myanmar:
  - Ecosystem Approach to Fisheries Management Area in Aung Kan Thar Village, Mon State
- Philippines:
  - Balayan Bay EAFM in Batangas Province
  - Samar Sea EAFM in Eastern Visayas
  - Fishing Close Season Regulations, *e.g.* Zamboanga, Palawan, Davao Gulf, Visayan Sea
- Thailand:
  - Aquatic bank project at Nong Tod Yia, Yasothon Province
  - Community-based Ecosystem Approach to Fisheries Management at Baan Aoa Kung and Baan Koh Ma Praw, Phuket Province
  - Community-based Ecosystem Approach to Fisheries Management at Baan Hin Lard, Baan Khow Pilaiy and Baan Kokhai, Phang-nga Province
  - Community-based Ecosystem Approach to Fisheries Management at Baan Hin Row, Baan Aou Thong Lang and Baan Pak Khong, Krabi Province
  - Community-based Ecosystem Approach to Fisheries Management at Baan Pak Don Sak and Baan Koh Raad, Don Sak, Surat Thani Province
  - Community-based Ecosystem Approach to Fisheries Management at Pak Nam La Mea, La Mea, Chumphon Province
  - Ecosystem Approach to Inland Fisheries Management at Ubol Ratana Dam, Khon Kaen Province
  - Fisheries communities based on Ecosystem Approach to Fisheries Management in Sawee, Chumphon Province
  - Fisheries communities based on Ecosystem Approach to Fisheries Management at Bang Ma Prow and Baan Pak Na, Langsuan, Chumphon Province
  - Happy with fisheries at Saroy Sub-district, Wang Chin District, Phrae Province
  - Pilot Learning Site for Ecosystem Approach to Fisheries management at Baan Nai Nang, Krabi Province

Through the application of EAFM, fisheries management systems adopted in the region that used to focus only on the sustainable harvest of target species have gradually moved towards systems and decision-making processes that balance environmental well-being with human and social well-being, within improved governance frameworks. The EAFM approach has therefore helped in the more holistic management of fisheries, and as a result user group conflicts had been considerably reduced; financial resources unlocked; cooperation of concerned stakeholders enhanced, and fisheries issues and challenges resolved and addressed.

The integrated fisheries management schemes using the EAFM approach that are being promoted in the region have also manifested in the roles that government plays in encouraging the communities to participate in addressing environmental issues and concerns for the sustainability and preservation of the ecosystem and the environment which is their source of life. Therefore, fisheries management should not be separated from these three inseparable dimensions: the fishery resources and their ecosystems, utilization of the fishery resources for socioeconomic interests of communities, and the fisheries policies governing the community initiatives.

- SEAFDEC initiatives in promoting the EAFM

From 2014 to date, SEAFDEC has been playing a significant role in transferring the knowledge gained from a training course on EAFM in 2014, *e.g.* by simplifying the E-EAFM training materials developed by many organizations and initiatives, such as FAO, US National Oceanic and Atmospheric Administration (NOAA), SEAFDEC-Sweden Project, Bay of Bengal Large Marine Ecosystem (BOBLME), Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF), IMA International, GEF, Norwegian Agency for Development Cooperation (Norad), Coral Triangle Support Project (CTSP), USAID, and so on, in order to make these materials suitable for the region. Such materials had been introduced to the region through the training courses on Essential EAFM (E-EAFM), Training of Trainers on EAFM (TOT-EAFM), and training on EAFM for Leaders, Executives and Decision Makers (LEAD EAFM). With a total of about 150 participants in the regional training courses conducted by SEAFDEC/TD and more than 444 participants in the national training sessions organized by the respective Southeast Asian countries under the supervision of the SEAFDEC/TD Team during 2014–2021, a total of about 594 persons from SEAFDEC Member Countries had been trained on the application of the EAFM concept and principles by SEAFDEC/TD.

Moreover, through the Japanese Trust Fund Project "Human Resource Development" and the Small-scale Fisheries Project of SEAFDEC/TD, support has been extended to some AMSs for enhancing the capacity of their respective national key officers in the implementation of the EAFM concept at the learning sites, *e.g.* in Myanmar, Cambodia, Lao PDR, and Thailand. This activity is meant to strengthen the knowledge and capacities of the core EAFM team in each country on the concepts related to sustainable fisheries, and ensure that the teams apply the knowledge and skills gained from the EAFM training sessions in real situations. In June 2021, SEAFDEC/TD carried out an online survey on the impacts of the EAFM training and the usefulness of the EAFM implementation in the learning sites. Results of the survey were reported by representatives from the AMSs during the one-day meeting in July 2021, where the EAFM-Training respondents indicated that the knowledge that they gained from the EAFM training courses include the concept and key principles of EAFM, and the development of fisheries management plan that they considered important and useful, especially for the fisheries and extension officers. The respondents also mentioned that they fully apply the EAFM concept and principles in their actual work. Moreover, they also recognized the significance of promoting the EAFM concept to all levels of relevant stakeholders in fisheries.

From the implementation of sustainable fisheries management at the EAFM learning sites, many lessons could be obtained and learned. Firstly, such activities have demonstrated that in managing the fisheries holistically, many of the key EAFM principles could be adopted. Since the implementation of EAFM involves the challenge of identifying an appropriate scale for the fisheries management units, working with different groups of stakeholders and increasing stakeholders' participation, coordination, and cooperation, especially the women and those who are socially and economically disadvantaged, is crucial. Nonetheless, for effective stakeholders' engagement, the EAFM activities should also involve those who are not in the fisheries sector along with the community members who are most affected by the changing trend of fishery resources. Secondly, considering that the EAFM concept needs to address multiple objectives some of which are aimed at restoring fisheries habitats and resources while others could be aimed at promoting sustainable livelihoods, skills training on the production of value-added fisheries products and through other non-fisheries livelihood options should form part of the project activities. Moreover, having multiple objectives, the EAFM should be promoted to also take into account the need to understand the conflicts in fishing communities, their origins, and the challenges while the different stakeholders' groups with different interests are brought together to collaboratively alleviate those conflicts. Finally, the application of EAFM has led to building the understanding and enhanced awareness of habitat values and sustainable use of resources, adopting and revising rules and regulations to become more effective and responsive to international standards, and enforcing fisheries rules and regulations fairly and impartially, which have proven to be critical in the promotion of good governance.

Ecosystem Approach to Aquaculture

As for aquaculture, the production of which can be categorized as the output of extensive, semi-intensive, and intensive culture systems, this sub-sector has become the fastest-growing food activity globally and has expanded sevenfold during the past decade, contributing substantially to the region's food security, employment generation, and foreign exchange earnings. In 2018, approximately 46 % of all fish eaten globally came from aquaculture (FAO, 2020b). The rapid growth of the aquaculture sector worldwide and the interaction of aquaculture activities with other economic sectors and natural resource users require a responsible and integrated approach to aquaculture development.

A similar approach – the ecosystem approach to aquaculture (EAA) is "a strategy for the integration of the activities within the wider ecosystem in order that sustainable development, equity, and resilience of interlinked social-ecological systems are promoted in the aquaculture sub-sector" (Soto *et al*., 2008; FAO 2010c). The three principles in the EAA ensuring that aquaculture as a strategy contributes positively to sustainable development (FAO, 2010c) are shown in **Box 21**:

Way Forward

Although the EAFM is well recognized in the Southeast Asian region, however, based on the review of the challenges and suggestions from the SEAFDEC Member Countries on the achievements of the EAFM in the region, there are some issues that need to be taken into action to ensure that the EAFM is fully used and implemented. These include the promotion of the EAFM concept which should be continued together with the strengthening of collaboration and coordination among the regional EAFM networks. Capacity building for all relevant stakeholders should also be sustained to enhance the understanding of more numbers of fisheries officers and communities of the concept and principles of EAFM. The consistency of the EAFM activities carried out in the communities should be strengthened, and the EAFM communities to be expanded and integrated with other related fields (*e.g.* ecologically-based tourism, local fish market village, community learning center). Additionally, full efforts should be put in place in the work process to maintain the achievement of EAFM in each country. The suggestion of Indonesia for SEAFDEC/TD to strengthen the EAFM implementation in Southeast Asia should be considered, and that it is also important for the Southeast Asian countries to develop the legal basis to support the promotion of EAFM implementation in the whole Southeast Asian region.

There is still needed to build the capacities and skills of relevant stakeholders on the application of the EAFM concepts, principles, steps in management planning, and EAFM implementation. In certain AMSs, such as Thailand and Indonesia, EAFM is being integrated into formal educational programs at universities and colleges. EAFM is also being formally adopted by the fisheries departments of several AMSs and is used as the framework for managing their respective national fisheries. The E-EAFM course itself is a living program that continues to be shared and modified to suit the capacity-building needs of learners. Meanwhile, the national, regional, and international EAFM networks and/or technical working groups are being established in partnership and collaboration with national fisheries and other regional and international organizations. For example, SEAFDEC is collaborating with FAO for the GEF Project on Promoting the Blue Economy and Strengthening Fisheries Governance of the Gulf of Thailand through the Ecosystem Approach to Fisheries" (GoTFish Project), and with FAO and BOBLME for the project on Sustainable Management of Fisheries, Marine Living Resources and their Habitats in the Bay of Bengal Region for the Benefit of Coastal States and Communities: Support to SEAFDEC Member Countries aimed at promoting EAFM knowledge and implementation in the AMSs.

6.1.2.2 Community-based and Co-management

The primary purpose of fisheries management is to establish an appropriate system of management rules based on defined objectives, as well as a mix of management

Box 21. Principles in the EAA to ensure that aquaculture contributes positively to sustainable development (FAO, 2010c)
Principle 1*: Aquaculture development and management should consider the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.* Developing aquaculture in the context of ecosystem functions and services is a challenge that involve defining ecosystem boundaries (at least operationally), estimating some assimilative and production carrying capacities, and adapting farming practices accordingly. The mix of ecosystem services will depend on wider management practices, and the trade-off among different services must be acknowledged. This is especially important in the case of ecosystem functions that are unique, essential, or threatened to ensure their preservation.
Principle 2*: Aquaculture should improve human well-being and equity for all relevant stakeholders.* This principle seeks to ensure that aquaculture provides equitable opportunities for development and equitable sharing of its benefits. This includes ensuring that it does not result in any undue detriment for any groups within society, especially the most vulnerable. Both food security and safety are to be promoted as key components of well-being.
Principle 3*: Aquaculture should be developed in the context of other sectors, policies, and goals.* This principle recognizes the interactions between aquaculture and the larger system, in particular, the influence of the surrounding natural and social environments on aquaculture practices and results. This principle also acknowledges the opportunity of coupling aquaculture activities with other production sectors to promote materials and energy recycling and better use of resources in general.

means to implement the regulations, which are put in place by a system of monitoring, control, and surveillance (Wilson *et al*., 2003). Throughout the past decade in the Southeast Asian countries, several management measures have been introduced and applied for the management of small-scale inland and coastal fisheries. Such measures include co-management, community-based fisheries management, integrated management, and government-based management, among others (Muthmainnah *et al*., 2019). However, choosing the appropriate management measures would be up to the situation of the specific localities.

A system of community-based management, which protects the rights of access by fishing communities, including indigenous peoples, is likely to be the best pro-poor arrangement in many indigenous fishing communities. This could mean restriction of access to the resources to a well-identified group, which helps community property rights reduce the risks of overfishing, thus preventing the fishers from falling into the downward spiral case of poverty and resource overexploitation associated with open access regimes. At the same time, the fact that these property rights are granted to groups rather than individuals ensures a certain level of equity within the community by allowing all members (including the poorest) to access the fishing grounds and therefore could rely on fishing to sustain their livelihoods. As a matter of fact, the concept of community property rights is central to the indigenous peoples and implies the recognition and enforcement of preferential access rights of (indigenous) fishing communities (FAO, 2009c).

As for co-management, which is another approach, the focus is to uphold property rights or rights to access and limit other users from the resource. Co-management addresses the issue of ownership of resources and mechanisms to allocate use rights through rules and regulations. However, to date, literature in many countries had limited documentation on informal or customary use-rights appropriation – in terms of their construction, logic, and historical transformation. It is therefore necessary to look into the social circumstances of the management actors because as their circumstances change, so does the community's organizational structure (Agbayani, 2007).

In order to enhance the promotion of community-based management and co-management in the Southeast Asian countries, the Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region 2030 adopted by the ASEAN and SEAFDEC Member Countries specified as a priority action the need to "*Enhance and promote the participation of local communities, fisheries associations and other stakeholders in fisheries management and co-management. In addition, communities should take part in fisheries and stock assessments by providing data, local ecological knowledge, and status of the stocks*."

Several AMSs have adopted community-based and co-management approaches by applying them in combination with other approaches, such as the Ecosystem Approach (EA), Integrated Coastal Management (ICM), and Rights-based Management, and adapted in their respective countries for more effective and efficient results. **Box 22** shows the definitions of community-based management and co-management, as well as other approaches aiming to enhance the participation of local communities in fisheries management.

Promotion of co-management and community-based management at the national level

Some AMSs have recognized the important potential roles of community-based management and co-management systems in contemporary fisheries management. Although community-based management systems have been the most long-enduring fisheries management system in the region, each country is taking different approaches toward the promotion of these systems (**Box 23**).

Box 22. Definitions of fisheries management concepts
Community-based management (CBM) is a central element of co-management and focuses on the community. The government plays a minor role or external player or adviser while community is the major player in the management *(Robert, 1995)*.
Co-management (CM) is a partnership/participative arrangement between local resource users, government, other stakeholders and external agents, sharing the responsibility and authority for fishery management. Co-management focuses on an agreement among partners/users to share power and right to manage. Fisheries co-management can be classified according to the power sharing of the government and fishers. Moreover, co-management is not only for fisheries management but is also a mechanism for fishers and community participation in addressing the problems and needs in terms of community, economic, and social development *(Robert, 1995)*.
Community-based co-management includes the characteristics of CBM and CM, and focuses on the need for people and the community to be involved in resources management, economic development, social empowerment coupled with sharing power and responsibility among the community, external organizations, and relevant institutions *(Robert, 1995)*.
Rights-based fisheries promote the right of fishers to fish or utilize the fisheries resources provided they are licensed or permitted by the competent government authorities that give the licensed fishers' access and use rights to the fishing grounds. Such rights are accompanied by obligations to comply with the rules and regulations of the right-based regime *(SEAFDEC, 2006b)*.

Box 23. Adoption of co-management and community-based management in the AMSs	
Cambodia	Cambodia prescribed in 2006 the Law on Fisheries where rights on traditional use of fishery resources for local users are ensured. Subsequently in 2007, the Sub-decree on Community Fisheries Management was enforced, prescribing further details on rights, roles, and responsibilities of community fisheries in fishery management. According to such legislations, local communities in Cambodia all over the country have been actively participating in fisheries management of their respective areas through the Community Fisheries (CFi) with the involvement of government officers and other agencies.
Indonesia	Indonesia has successful cases of community-based and co-management approaches in Buru Island in Maluku Province in collaboration with the government, NGO, and the fishing communities. Products from small-scale fishers in the Island could access the international market creating positive impacts on the welfare of the coastal communities. With such successful cases, the Government of Indonesia is in the process of expanding the coverage of the CBM and CM into other areas of the country.
Myanmar	Community-based fisheries co-management is a strategic priority of the Department of Fisheries (DOF) of Myanmar with coastal communities being engaged in fisheries management. The DOF of Myanmar has adapted and implemented legal and regulatory frameworks for co-management, inshore fishing capacity management, and combatting IUU fishing at the Union level. Moreover, human and technical capacity for co-management at the Union, State/Region, and district levels had also been developed. Co-management institutions at community level are in place and support to MCS is assured based on limiting the access and application of territorial users' rights. As a result, community livelihoods had improved based on sustainable resource use, and increased value adding of the catch and landings.
Thailand	In Thailand, some management functions are delegated to local fishing community organizations as prescribed by the Royal Ordinance on Fisheries, B.E. 2558 (2015) and its amendment. The Inland Fisheries Research and Development Division has continuously implemented projects on CBM of which the local fishers and stakeholders had been coordinately playing important roles. Policy proposals and guidelines for artisanal fisheries enhancement had been developed, where the guidelines are aimed toward increasing the understanding of fishers on fishery management schemes, exchanging opinions on the pros and cons of such schemes, and mitigating the problems caused by the management schemes. Several coastal fishing communities of the country have already applied the guidelines with successful results and proved that these schemes could be self-reliant.
Viet Nam	The concept of co-management has long been promoted in Viet Nam since 1990s until the present. The Government of Viet Nam has recently promulgated the revised Fisheries Law in 2017, including an Article of co-management regulations. To this end, the Prime Minister of Viet Nam also issued Decree No. 26/2019/ND-CP dated 8 March 2019 detailing a number of articles and measures to implement the Fisheries Law. Specific Section of the Decree provides guidance in addressing the issues related to co-management in fishery resources protection.

Promotion of co-management and community-based management at the regional level

At the regional level, several organizations including SEAFDEC have undertaken activities to support the AMSs to apply management concepts that promote delegation of some management authorities to the communities and local organizations. SEAFDEC/TD started the promotion of co-management, community-based management, and rights-based fisheries in 1999 by introducing such concepts at a pilot project site in Bang Saphan Bay, Prachuap Khiri Khan Province in Thailand. Shortly after and during the ASEAN-SEAFDEC Conference in 2001, the Resolution and Plan of Action were adopted where one of its Plan of Action specifies the need to "*Establish and implement comprehensive policies for innovative fisheries management, such as the decentralization of selected fisheries management functions to the local level, the progressive introduction of rights-based fisheries management through licensing and community fishing rights, the improvement of vessel registration systems and the development of supporting legal and institutional frameworks*."

With such regional policy framework at the backdrop, enhanced community participation in fisheries management has been promoted in the Southeast Asian region. Through the SEAFDEC Project "Towards Decentralized Management of Sustainable Fisheries," which was implemented shortly after the adoption of the Resolution and Plan of Action, the "Regional Guidelines for Co-management Using Group user Rights for Small-scale Fisheries in Southeast Asia," was developed. This Regional Guidelines elaborates the delegation of fisheries management authorities on coastal fisheries to local fisheries organizations including the need for them to encourage small-scale fishers to take part in management actions under the government policies and guidelines. Subsequent to the development of this Guidelines, programs and projects had been formulated and implemented with a view to enhancing the capacity of officers of the AMSs on the concept, through training for trainers (TOT) and promoting their implementation through pilot projects at selected sites in the AMSs. The list of projects implemented by SEAFDEC to promote co-management and community-based management in the AMSs appears in **Box 24**.

Considering that prior to the promotion of the CM and CBM approaches, it is important to know exactly the situation and condition of the management areas as well as the participation capability of the community people and government, especially the local officers, SEAFDEC/TD, therefore, promotes the CM and CBM concepts at the national level through the conduct of Training of

Box 24. SEAFDEC projects in promoting co-management and community-based management in the AMSs
2002-2005: Toward Decentralized Management for Sustainable Fisheries in the ASEAN Region (SEC)
2005-2009: Capacity Improvement of Fisheries Community for Fisheries Management and Alleviation of Poverty (TD)
2006-2010: Strengthening Small-scale Fisheries Management through the Promotion of Rights-based and Co-management Concept (TD)
2008-2012: Promotion of Rights-based Fisheries and Co-management towards Institutional Building and Participatory Mechanism for Coastal Fisheries Management (TD)
2015-2018: Enhancing Coastal Community Resilience for Sustainable Livelihood and Coastal Resources Management (MFRDMD)
2014-2019: Facilitating fisheries activity information gathering through introduction of community-based resources management/co- management (sub-project under the project on "Enhancing the Compilation and Utilization of Fishery Statistics and Information for Sustainable Development and Management of Fisheries in Southeast Asian Region") (TD
2017-2019: Human Resource Development for Sustainable Fisheries (TD)

Box 25. Some of the recent pilot activities on co-management and community-based management carried out by SEAFDEC/TD
• **Nam Oon Reservoir, Sakon Nakhon, Thailand** Management actions were carried out using CM and CBM approaches to address the problems of illegal fishing and the decline of fishery resources in the reservoir. While the establishment of conservation zones was completed, awareness building and declaration of the community rules had been promoted. As a result, the fishers and local officers noted that illegal fishing had been reduced which could be due to two key factors, *i.e.* enhanced understanding of the local people on resources conservation, and participation of fishers in the decision making regarding the management actions to be undertaken.
• **Nam Xouang Reservoir in Vientiane Prefecture and Vientiane Province and Nampakan River in Mai Nampakan Village, Khammouane Province, Lao PDR** The CM and CBM approaches had been applied for improving the abundance of fishery resources as well as the livelihoods of fishers. After the establishment of the Fisheries Management Committees (FMCs), fishers had been empowered to be able to monitor and undertake surveillance of the fishing activities in their respective areas by themselves. Their livelihoods had been improved through the practice of fish processing and fish culture. As a result, illegal fishing had been reduced and the products from the women's groups had been selling well that led to improvements in the fishers' household incomes.
• **Chong Khneas Community Fisheries in Tonle Sap Lake of Siem Reap Province, and Crab bank in Angkaol Village of Kep Province, Cambodia** In promoting the CBM and CM concepts, SEAFDEC/TD provided the technical support for the development of the conservation zone management plan (fisheries management, rehabilitation, and livelihood) in Chong Khneas Community Fisheries (CFi). The Chong Khneas CFi also collaborated with the officers of the Government of Cambodia to improve the internal rules, and promote awareness building, especially on the MCS system. In another site at Angkaol Village, crab bank is being promoted. Regulations for operating crab banks were developed and enforced through the participation of the Angkaol CFi. In operating the crab banks, fishers voluntarily give the gravid blue swimming crabs to the CFi for spawning and proper releasing of the eggs. The CFi had learned lessons from such approach and become aware of the importance of conserving the resources especially those of the blue swimming crabs.

Trainers (TOT) and Mobile On-site Training (MOT), and follow-up activities on CM and CBM. The recent activities implemented by SEAFDEC/TD on CM and CBM during 2014–2019, are summarized in **Box 25**.

After the implementation of the aforesaid SEAFDEC Project during 2014–2019, the key achievements and improvements attained by concerned communities from the application of the community-based and co-management approaches are summarized in **Box 26**.

Way Forward

The experience of SEAFDEC in the implementation of CM and CBM in the pilot sites in some AMSs indicated that such approaches could be used and adapted by the other countries in Southeast Asia. However, there are various factors of successes and failures that could be present which differ from area to area, such as the cooperation and technical inputs from governments and/or other agencies, access to microfinance services, cooperative mechanism whether functional or not, types of ownership of common properties, conflict-resolution among the various resource users, and poverty in the communities. Moreover, the establishment of fishers' groups or community organizations is a very important factor that determines the success of the implementation of fisheries management activities in their own areas, as well as the support extended by the government and/or other agencies to such groups or organizations. It has also been observed that communities, where leaders of groups are strong, are able to bring about more effective fishery management.

It is therefore important to consider learning lessons from the factors that led to successes and failures for better fishery resources management in the future. Furthermore, the COVID-19 pandemic has impacted the promotion of sustainable fisheries management in the region. It would be crucial therefore for fisheries managers to think about the adaptation measures for the promotion of the fisheries management action plans, which should be in line with mitigating the impacts of the COVID-19 situation on the sustainability of fisheries in the Southeast Asian region.

Box 26. Key achievements and improvements attained from the application of the community-based and co-management approaches
• **Development of management and conservation plan** The development of fisheries management and conservation plan or the rules and regulations is being carried out effectively through participatory approach among the stakeholders concerned, leading to the recognition of the community management plan by the government officers and the community. Moreover, the technical support provided by the SEAFDEC/TD Project and the local government offices had increased the confidence of the fishers in developing and implementing the fisheries management plan by themselves.
• **Improvement of stocks** Demarcation of the conservation area and enforcement of closed season including MCS is being effectively undertaken through the collaborative efforts between the fishers and government officers, especially in the pilot sites in Lao PDR and Thailand. As a result, the fishers could catch more fish after the project implementation. As for Cambodia, the promotion of crab bank in the pilot site had increased the awareness of local fishers on resources conservation especially the blue swimming crab, which is economically important for the country.
• **Reduction of conflicts in communities** The cooperation among fishers within communities for the establishment FMCs, formulation of the community rules and regulations, and the collaborative work to address the problems together, had facilitated the reduction of conflicts among the stakeholders in the communities. These had also led to reduced practice of illegal fishing by the community fishers.
• **Enhancement of the roles of women in fisheries-related activities** Specifically in Lao PDR, the skills of women in fish processing and marketing have been improved. The women's groups have been able to develop their products and find more marketing channels. As a result, the women could generate additional incomes for their households instead of depending only on the fishing activities of their respective husbands. In the pilot sites in Thailand and Lao PDR, the women also play the important role of providing advice during negotiations when problems occur.

6.1.3 Habitat Protection and Fishery Resources Enhancement

Fishery resources play significant roles in the social and economic aspects of the world. They provide not only a primary source of protein to people but also contribute to their livelihoods especially in coastal and rural areas in the Southeast Asian region. Several countries in the Southeast Asian region are among the top fisheries producers in the world. In 2017, the marine fisheries production in the region was recorded at around 17.33 million mt generating USD 25,292 million (SEAFDEC, 2020a). This was due to the coastal ecosystem in the region being very productive, having high biodiversity of marine fish species, and providing multiple ecosystems and suitable for habitats to fisheries resources.

It is recognized that optimum utilization and a healthy ecosystem is prerequisite for sustainable fisheries production. However, during the past several decades, the growth of regional and national human populations, as well as the development of aquaculture and fishery-related industries, have made great demands on fishery products. Unfortunately, these had increased the demands and the corresponding technology has resulted in the overexploitation of some economically important pelagic and demersal species. The continued dwindling of fishery resources compels most fishers to increase the use of modernized and more effective but destructive fishing methods which adversely impacted the ecosystem, particularly stocks and habitats.

Therefore, strategic fisheries management in the Southeast Asian region is urgent and should be directed towards reducing human pressure on fishery resources, the ecosystem as well as their habitat. Accordingly, the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 include provisions encouraging the AMSs to "Promote resource enhancement approaches with appropriate monitoring and evaluation programs, *e.g.* deployment of appropriate resource enhancement structures, restocking of commercially-important aquatic species, and restoration of degraded habitats, taking into consideration possible socio-ecological impacts" (Plan of Action No. 35) and "*Promote the adoption of different management approaches to sustainably manage major critical coastal habitats,* e.g. *mangroves, coral reefs, and seagrasses; and develop and disseminate information and guidance on the use of appropriate tools and interventions*" (Plan of Action No. 37).

Programs for Habitats Protection and Fishery Resources Enhancement

The programs that have been implemented to alleviate the declining resources or ecosystem degradation include 1) artificial reefs & habitats rehabilitation, 2) catch area management, and 3) restocking & releasing (**Boxes 27 and 28**). It should be noted that these programs should not be carried out as a stand-alone measure but should be integrated with other management measures to ensure the sustainability of the fishery resources.

Issues and Challenges

In the past decades, the deployment of ARs and establishment of MPAs, closed season, and *refugia* area were conducted to protect habitat and enhance fisheries resources. However, there is a concern that some are being implemented too quickly, with the intention of meeting political rather than conservation and enhancement targets.

It is developed without proper research, planning, or governance mechanisms. This issue is compounded further by insufficient government funds for both management and enforcement (Savage *et al*., 2020).

In general, catch area management can be used as a management tool for the fishery with high fishing pressure. However, the common problem of catch area management at the national level is not enough protection afforded for highly migratory species, which often require large and continuous catch management areas. It could be occurred by collaborating at the regional level. Additionally, the key success of catch area management is enforcement with requires a significant number of human resources, and associated financing funds which are still lacking in the region.

Resource enhancement through releasing eggs, larvae, and juvenile is a popular method in Southeast Asian countries. However, the capability to produce and release juveniles from aquaculture facilities is limited as well as lack of seed production techniques and facilities.

Box 27. Programs for habitats protection and fishery resources enhancement implemented by the ASEAN Member States
Artificial reefs & habitat rehabilitation (A&H): There is a positive correlation between habitat ecology and abundance of resources. In this regard, artificial reefs (ARs) and habitat rehabilitation programs have been implemented throughout Southeast Asia. It has been proven to be an effective program to enhance fishery resources in the areas with low productivity and prevent encroachment of illegal fishing gear in the prohibited areas like coastal areas or the degraded habitats such as coral reefs, seagrasses, and mangroves.
Catch area management (CAM): This program could be the solution to consider marine areas in which specific management measures are applied to improve the productivity of habitats to sustain resource recruitment. Commonly, it relates to fishing prohibition schemes such as marine protected areas (permanently regulate fishing activities either by restricting access or regulating activities in an area), closed season area (some fishing gears, mostly commercial scale, are restricted to a certain time of year) and fisheries *refugia* (prohibiting catch during the critical stage of the life cycle of target species), and others.
Restocking and releasing (RR): This program usually refers to enhancement of fishery resources by releasing early life stages of aquatic animals to the wild. The key success depends on knowing enough about the ecology of the species, their nursery habitats, and the survival of released life in the wild. All the AMSs have their own releasing program. However, the capacity to produce and release life from aquaculture facilities or cages placed in the sea is limited.
Others: Programs of reducing degraded habitat and overfishing includes restrictions on fishing gear, fishing effort, zoning and licensing, EAFM and community based management, and fishery regulations, etc.

Box 28. Programs for habitats protection and fishery resources adopted by the AMSs
Brunei Darussalam • A&H: Since 1985, the Department of Fisheries of Brunei Darussalam had developed and set up various types of ARs (*e.g.* used tires, redundant oil jackets, and concrete and stainless steel prefabricated pyramidal structures). Moreover, AR sites were also established for eco-tourism activities (FRA-SEAFDEC, 2010) • CAM: Six MPAs (20 % of the total fisheries management area) were established where fishing activities are restricted • RR: A total of 500,000 hatchery-reared postlarvae and juveniles of *Macrobrachium rosenbergii* were released into the Temburong River for stock enhancement • Others: In 2021, trawl fishing was banned in waters of Brunei Darussalam. Also, catching, landing, and importing of sharks and rays have been banned
Cambodia • A&H: More than 350 conservation areas had been rehabilitated through mangrove reforestation resulting in enhanced fish stocks and increased fish production through community participation. Moreover, a total of 165 units of ARs concrete modules and base, and logs of trees were deployed in 2017 in the Tonle Sap Great Lake at depths of less than 10 m. Also, two ship containers were deployed in 2017 in Koh Rong Saloem, Preah Sihanouk. • CAM: Since September 2019, the mackerel *refugia* was established at Peam Krasob, Koh Kong Province, and aimed at 1) raising public awareness of the proclamation on creation of management area to community fisheries, local authorities and fishermen, 2) installing mooring buoys at the boundary of *refugia* sites, and 3) enforcing closed fishing season of mackerel. • RR: In 2021, the blue swimming crab bank program was initiated in the *refugia* site in Koh Po, Kep Province with the goal of releasing at least 30 kg of blue swimming crab each year
Indonesia • A&H: Three types of AR models had been promoted, namely: cube shape model, dome model, and pyramid model. The materials used include used tires, out-of-commission steel structures, and old or confiscated pedicab units • CAM: The country is in the process of establishing *refugia* sites in West Kalimantan for banana shrimp in mangrove areas and in Bangka Belitung for squid (Uroteuthis chinensis) in coral reefs and seagrass beds • Others: Stock enhancement activities include determining the bio-limnological characteristics of release sites, developing of fisheries co-management approach, and making use of local knowledge for the management of the sites
Malaysia • A&H: Research and development of artificial reefs (ARs) program in Malaysia was started in year 1975 by using discarded tires, PVC pipe, ceramic, concrete culvert and confiscated fishing vessels. Findings from previous studies had led to the development of complex and durable structures of ARs in the coastal areas, that are made from reinforced concrete, steel, and decommissioned oil rig platforms. Approximately more than 215 new large size ARs site were established from 2006-2020 by the Department of Fisheries Malaysia (DoFM) within five nautical miles radius from the coastline. Besides deploying new AR structures yearly, scheduled monitoring programs have also been conducted to determine the effectiveness of AR structures in increasing the surrounding fish biomass and biodiversity ...

Box 28. Programs for habitats protection and fishery resources adopted by the AMSs
Malaysia *(Cont'd)* • CAM: The catching of anchovy in Kedah waters was prohibited in September 2020. Meanwhile, special *refugia* for shrimp in Sarawak and lobster in Johor had been established following the concept of *refugia* similar to that in Sarawak known as the "tagal system" for the seasonal conservation of the freshwater fish, Malaysian red mahseer (Tor tombroides) • Others: Exit Policy for trawlers in Zone B and Zone C was established and partly implemented in the east coast of Peninsular Malaysia in 2021. Also, the catch size of short mackerel and Indian mackerel using purse seine in Zone C in Perak State was controlled in 2020
Myanmar • A&H: Although AR deployment and coral planting have not yet been established in the country, the Department of Fisheries of Myanmar recognized that ARs play important role in marine aquatic resources enhancement and intends to establish the country's AR program but technology on the development of ARs and financial support for such development would be required • CAM: the country is in the process of identifying the spawning area which will be managed by a closed season approach where all fishing activities are prohibited for three months (15 February to 15 May) each year • Others: Inland fisheries management in Myanmar is divided into two categories, *i.e.* leasable fisheries and open fisheries. In leasable fisheries, fishing rights are granted to lease-holders under a lease agreement subject to stipulations relating to the area, species, fishing implements, period, and fishing methods used. The lease-holders are responsible for carrying out stock enhancement and conservation of fisheries habitats. Moreover, selective harvesting of stocks is also being promoted while means of protecting the inland fishery resources from illegal fishing activities are also being developed
Philippines • Others: The National Program on the Fisheries Enhancement of Inland Waters was launched covering 36 minor lakes and 320 small reservoirs to increase the country's fisheries production from inland fisheries, rehabilitate and/or restore the physical conditions of the country's minor lakes and reservoirs, enhance fisheries, and repopulate indigenous aquatic species in support of biodiversity conservation, poverty alleviation, and food sufficiency
Singapore • A&H: The main objective of ARs is to provide coral larvae with elevated and stable settlement surfaces which could reduce smothering by sediment or scouring by rubble • CAM: The Sisters' Islands Marine Park is a 40-ha marine park established for habitat conservation, research, education & outreach, and other recreational uses (except recreational fishing, as all of the marine park is a no-take zone)
Thailand • A&H: Since 2019, the Department of Fisheries was providing support to the fishing communities to increase the fish habitat through the construction of fishing enhancing devices (FEDs) using natural materials such as coconut leaves • CAM: The establishment of *refugia* sites for short mackerel in Trat Province and blue swimming crab in Surat Thani Province is being considered. The habitats in Trat Province include coral reefs, mangroves, and seagrass beds where purse seine and trawl operations are proposed to be regulated and prohibited during the closed seasons; while the habitats in Surat Thani Province include mangroves and seagrass beds where fishing operations are proposed to be prohibited • RR: Providing support to the coastal fishing communities to implement aquatic animal bank, particularly crab bank and cuttlefish bank. Also, breeding and releasing of other economically important species such as spotted Babylon, banana shrimp, tiger prawn, blue swimming crab, mangrove crab, and sea cucumber are carried out • Others: Thailand has measures of restricting the number and size of fishing vessels and fishing efforts to control fishing capacity. The marine resources in the Gulf of Thailand and the Andaman Sea are categorized into three separate species groups: (1) demersal, (2) pelagic, and (3) anchovies. The precautionary approach is used as the guiding principle, and maximum sustainable yield (MSY) of the three combined resource categories is used as a reference point in setting the total allowable catch (TAC) limits in this exercise. The number of fishing days per vessel per year is stipulated by issuing licenses based on the TAC size and total allowable effort (TAE) (Department of Fisheries Ministry of Agriculture and Cooperatives, Thailand, 2015)
Viet Nam • A&H: The ARs used are reef balls, cylinder reefs, and cube reefs installed in several places such as in Ninh Thun (2011), Quang Nam (2014), Nahe An (2015), Phu Quoc (2018), Nha Trang (2019), Ca Mau (2020) and Thai Binh (2020). Also, Nha Trang University had installed ARs (200 cylinder reefs and 100 cube reefs) in Ninh Thuan Province to protect, recover, and develop fisheries resources • CAM: Monitoring of the country's MPAs is done once a year and the results were used as a basis in formulating policies and regulations on the protection and development of aquatic resources. Engagement of the stakeholders during the process of establishing the conservation zones helped in pooling the knowledge and experience of local stakeholders, *e.g.* officers, fishers, scientists, and government authorities (Hung, 2021) • RR: "Marine Animal Bank" is currently schemed to promote stock enhancement

Since the 1970s, the Southeast Asian countries have had long historical in place their respective national legislations, policies, and program regarding habitats protection and fisheries resources enhancement to promote conservation and management of the marine resources. It is necessary to evaluate the effectiveness of those implementations. This is a basic requirement of policymakers. However, only a few are conducting due to limitations on the knowledge and skills, and lack of published materials such guidelines. Publishing of evaluation guidelines as well as capacity-building evaluation methods and techniques are among the challenges in the region.

Recommendations and Way Forward

Multispecies stock assessment should be considered rather than the single-species stock assessment for sustainable fisheries management. To ensure the success of habitats protection and fisheries resources enhancement, it is vital that a plan of action highlighting the key activities in a strategic plan and the sequencing of these activities in the proper time frame be put in place. The national or regional plan should also indicate the responsible agencies for initiating action or assigning tasks to be accomplished to meet the objectives within the stipulated duration of time.

To restore fishery resources, several management tools including the installation of ARs have been applied. However, the disadvantages of the ARs are the lack of collaboration between the government and fishers, in which the fishers are only involved in the identification of fishing ground and following the regulations. Therefore, the absence of fisher co-management could not effectively promote resources management because the fishers have always the tendency to disobey due to lack of ownership. Hence, seeking modern tools to enhance the fishery resources by incorporating the resource users to be resource managers is required. For example, fish enhancing devices (FED) or known as floating ARs, are currently being explored in the Philippines and other countries in the western Pacific including Thailand (Cabral *et al*., 2014; Manajit *et al*., 2019).

Sharing indigenous and scientific knowledge (particularly impact assessment of degraded natural habitats and fisheries resources due to human activities) among the stakeholders targeting on raising awareness on the importance of habitats and fisheries resources to humans should be conducted regularly. Research on habitat and fisheries resources enhancement should be continuously carried out, and the results could significantly support the policy formulation as well as increase fishers' acceptance when the management plans are implemented. The future activities of the ongoing project "Sustainable Utilization of Marine Fisheries Resources and Resource Enhancement in Southeast Asia" implemented by SEAFDEC/TD from 2020 to 2024 include fish larvae identification and determining of spawning-nursing grounds and season using larvae survey results, artificial reef design and construction, and evaluating methods of enhancing fisheries program in terms of environment and fisher economy.

6.1.4 Application of Fishery Information Systems for Fisheries Management

Geo-information technology refers to an integration of knowledge and technologies involving Geographic Information System (GIS), Remote Sensing (RS), and Global Navigation Satellite System (GNSS), which could be applied in a wide range of work (GISTDA, 2015). GIS is commonly used for visual display, quantification, and analyses of spatial data. Ecological data, including fisheries data, generally contain a spatial component and are well suited for analysis through GIS. Moreover, RS is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance. RS could therefore be used to classify objects on earth, including those on the surface as well as in the atmosphere and oceans, based on propagated signals. (Eder & Neely, 2013).

These technologies, such as the GIS and RS applications, could be used in various stages of monitoring, conservation, management, sustainable development, and environmental protection, and so on. Results of analysis using the GIS technology could be applied to any decision-making plans quickly and accurately (GISTDA, 2015). GIS and RS technologies are potential tools for fisheries management especially when it comes to decision-making processes, as they could give clear visualization of the data and information in place and time. Over the past decades, there were a lot of instances where GIS and RS had been used in fisheries science and found to have the capability to support the management of fisheries and aquaculture in various aspects.

Application of GIS and RS

The recent activities of SEAFDEC that aim to support and encourage the Southeast Asian countries to utilize the GIS and RS technologies for the sustainable utilization of the fishery resources in the region, SEAFDEC/TD initiated in 2020 the five-year project "Sustainable Utilization of Fisheries Resources and Resources Enhancement in Southeast Asia" which includes the activity to use Fisheries GIS or FGIS and RS to improve fisheries management. At the onset, the "Regional Consultation Workshop on the Utilization of FGIS and RS to Improve Fisheries Management in Southeast Asia" was organized in 2020 to update the SEAFDEC Member Countries on the use of GIS and RS in research and studies on fisheries and environmental science. Information on the status of utilization of these technologies in the studies or research activities in the SEAFDEC Member Countries, compiled during the Regional Consultation Workshop, are summarized in **Box 29** (SEAFDEC/TD, 2020).

Issues and Challenges

Although raised in the 1990s, the major challenges for GIS and RS applications (**Box 30**) have not yet been fully addressed (Nishida, 1994) because of the fragmented nature of the fisheries, especially in the Southeast Asian region.

Available resources

The current available resources that could be used to support the application of GIS and RS in fisheries and aquaculture management are shown in **Box 31**. Accessibility to such resources is also indicated for easy reference.

Box 29. Application of GIS and RS technologies in fisheries of the ASEAN Member States

Brunei Darussalam

- The study "Analysis of Species Assemblages and Fishing Gear Clusters in the Coastal Waters Brunei Darussalam," conducted in 2006 is already completed. This study, which had 3-phase assessment, was principally intended to elaborate a new fisheries strategy --- defining the optimal fishing effort configuration (number of licenses by type of fishing gear) and related policy/ management options (*e.g.* trawl ban, managed fisheries) for improved management of the country's fisheries.
- The study "Fish Aggregating Devices (FADs) Site Identification," which was completed in 2017, was meant to (i) improve the production of high value fish species, particularly neritic tuna, and enable fishers to target the export markets, and (ii) increase the fishing time and reduce searching time, which generally leads to reduction in fuel consumption. Using the data compiled through the use of GIS and RS technologies, fishers were able to deploy FADs in the purse seiners' common fishing areas of the country, which are mostly within zone 2, 3 and 4.
- The study on "Site Identification and Design for Artificial Reefs (AR)," which is still ongoing, aims to: 1) Produce connectivity and dispersal model output; 2) Assess the viability of sites of choice as potential AR deployment stations; and 3) Consolidate findings to highlight potential AR sites for baseline investigations. The scope of the study covers: 1) Primary Data Collection and Surveys (water sampling and ADCP); and 2) Model Setup to simulate the recruitment of coral larvae at each potential site based on its dispersal pattern and prevailing currents and makes use of GIS and RS technologies. The study intends to come up with model simulation of the potential AR deployment sites.

Indonesia

- The research "Identification Potential Fishing Ground (PFG) in Indonesian Waters based on RS Data and Geostatistical Model," is still ongoing, requires analyzing the information on sea surface temperature (SST) and primary productivity, to come up with the geostatistical model that would indicate the areas which could be potential fishing grounds

Malaysia

- The research study "Fish Site Identification (FSI)," as a collaborative work between DOFM, Malaysia Space Agency (MySA), Fisheries Development Authority of Malaysia (LKIM), and National Fishermen's Association of Malaysia (NEKMAT). The first phase on "FSI on pelagic fish" was conducted from 2007 until 2010, while the application of the findings by fishers started in 2011 with 40,000 fishers involved. After using the FSI results, the concerned fishers were able to increase their catch by 30 % and prove that the accuracy of the FSI was 80 %, and as a result the fishers could reduce their total operation cost by about 30 %. The subsequent study on FSI for tuna is ongoing and is in the various stages of verification at sea.
- The research study "Carrying capacity studies for fisheries cage culture system in Johor, Kelantan, Terengganu, Selangor, Penang," which was carried out by FRI in Kg. Acheh, Perak, and in Batu Maung, Penang (DOFM). While the case studies had been completed, the results established the value of the current carrying capacity of the areas of concern. Risk assessment was done, and the forward actions formulated had been considered and are in the various stages of implementation, specifically in some cases where relocation of fish cage systems to other areas had to be undertaken.
- The research study "Blood cockle stock assessment and spatial distribution for natural/induced spawning programme in Penang, Johor, Melaka and Kedah," which was carried out by FRI Kg. Acheh, Perak and FRI Batu Maung, Penang (DOFM). The research attempted to locate the natural spawning grounds of blood cockle. On the completion of the study, the current stock and spatial distribution were established, while further actions were formulated and their implementation is currently ongoing.
- The research study aimed at identifying "The Location of Gold Fish Farms in Johor and Koh Fish Farms in Perak," which is under the responsibility of the Fisheries Biosecurity Division of DOFM, which is still ongoing. Ornamental fish is an important export-oriented commodity and ornamental fish culture has been considered as one of the fastest-growing sub-sectors of Malaysia's agriculture sector. The country has been using GIS and RS for mapping the locations of the ornamental fish farms and in determining the corresponding management systems adopted by the farms.

Singapore

- The research study "Coastal and marine habitat mapping for the Straits of Malacca using SPOT and LANDSAT data" which was undertaken by CRISP/ NUS and was completed in 2013.
- The research study on "Monitoring water quality in Singapore reservoirs with hyperspectral remote sensing technologies" which was carried out by CRISP/ NUS. And was completed in 2019.
- Research study "Spatiotemporal variations of extreme sea levels around the South China Sea: assessing the influence of tropical cyclones monsoons and major climate modes" which was conducted by EOS/NTU and was also completed in 2019.

Thailand

- The two ongoing research projects of the DOF of Thailand: 1) Fisheries Monitoring System: Vessel Monitoring System (VMS), and 2) Fisheries Map, are meant to help the fisheries officers in monitoring and managing the fishing activities in the waters of Thailand
- Flooding compensation assessment for affected aquaculture farmers using Geo-Informatic Technology: Case study of Supanburi Province
- Geographic information system application for artificial reef potential site assessment: Case study of Chumphon Province
- Surface model and Geographic Information System (GIS) application to site selection for sea ranching of black tiger shrimp (*Penaeus monodon*) in Songkhla Lake
- Application of Geographic Information System to Aquaculture Database in Phuket Province
- Approach for assessing the sustainability of marine shrimp area using spatial analysis technique
- Application of Geo-Informatics to study shrimp farm area change in Nakhon Si Thammarat Province
- Integrated coastal management of the northern part of the inner Gulf of Thailand
- Site suitability assessment for artificial marine habitat deployment in the coastal seas of Chon Buri Province with spatial analysis

Box 29. Application of GIS and RS technologies in fisheries of the ASEAN Member States *(Cont'd)*

Viet Nam

- The study on "Researching the application of remote sensing and GIS supporting the management, surveillance and warning of diseases in aquaculture" which was carried out by Vietnam Institute of Fisheries Economics and Planning (VIFEP), started in 2017 and finished at the end of 2020. The study was meant to research and apply RS and GIS technology in monitoring, management, and warning of any environmental and diseases problems in aquaculture in coastal areas of Viet Nam and to develop WebGIS for management, monitoring, and warning of diseases in aquaculture areas. Pilot case studies were undertaken in Khanh Hoa Province and Ben Tre Province for the lobster, shrimp, and clam culture areas.
- The ongoing research project "Satellite monitoring of Vietnamese Marine Domain and Resources Project (Movimar)" which is a responsibility of the Fisheries Information Center, Directorate of Fisheries. This project availed of imported techniques and equipment from Collecte Localisation Satellites (CLS) in France that are now being used to undertake the activities related to monitoring and tracking fishing vessels. The tracking device is now installed in about 3,000 fishing vessels.
- The research project "Building geographic information system (WebGIS) to support the management of aquaculture in coastal zones in Nghe An Province" which was conducted by VIFEP. Although the research was already completed, the system is still operating online. The project supported the management of shrimp and clam culture areas of five (5) coastal districts in Nghe An Province.
- The research study "Planning tidal flats for aquaculture in Quynh Luu District using remote sensing (satellite data and flycam data)" by VIFEP which was already completed, and the results of the study are being used to support the detailed planning of tidal flats of Quynh Luu Districts-Nghe An Province. The plan is mainly aimed for sustainable aquaculture management.

Box 30. Major challenges for GIS and RS applications in fisheries of the Southeast Asian region

Data

- Standardization of data collection structures with adjustment for discrepancies in space or time
- Conversion of analog data to digital data
- Consolidation of data gathered and databases
- Automation of data collection systems
- Establishment of simple database linked to GIS platform
- Consideration of 3D or 4D database for GIS
- Development of easy methods to access oceanographic and satellite information
- Development of easy methods to process matrix (raster) information

Presentation

- Application of enhanced visualization to fisheries GIS
- Effective and easy ways to present 3D and 4D parameters of fisheries and oceanographic information such as catch, CPUE, temperature, and salinity

Stock assessment, prediction, and spatial numeral analyses

- Development of linkages between GIS and stock assessment
- Applying GIS methods, models, simulation, and geo-statistics in a fluid, dynamic 3D environments
- Development of space-oriented prediction methods for fishing and oceanographic conditions

Fisheries management using GIS

- Space-oriented fisheries management
- Ecosystem-based fisheries management
- Essential fish habitats and marine reserves
- Fishing effort monitoring systems using global positioning system (GPS) and vessel monitoring system (VMS)
- Fisheries impact assessment (development of space-based stock assessment)
- Spatial allocation of the results of stock assessments such as MSY and TAC
- Monitoring and modeling of quota arrangements

Software

- Development of user-friendly and high-performance fisheries GIS software that can handle simple parameters and also satellite information, and perform simple mapping as well as complex integrated spatial numerical analyses

Human interaction

- Establishment of the international fisheries GIS association for networking to exchange ideas and information
- Collaborative and interactive GIS activities in fisheries resource research by fisheries scientists, oceanographers, fishers, and fisheries managers for effective, meaningful, and realistic achievements
- Fostering a trustful relationship between researchers, fishers, and politicians

Way Forward

Under the project "Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand" implemented by SEAFDEC from 2016 to 2022 with support from the UNEP/GEF, also known as the Fisheries *Refugia* Project, a combined national and regional Google Earth-based Geographical Information Systems (GIS) on fisheries and marine biodiversity would be developed featuring information on locations and management status of coastal habitats, fisheries *refugia*, MPAs, and critical habitats for threatened and endangered species. These national GIS databases will be used in the preparation of annual syntheses of new and additional data relating to the science and management of fish life-cycle and critical habitat linkages. Details of this Google Earth-based GIS information in the Fisheries *Refugia* Project appear on the project website https://fisheries-refugia.org/.

Box 31. Available resources that support the application of GIS and RS in fisheries and aquaculture management
GIS Resources • Esri Open Data Hub (https://hub.arcgis.com/search) • FAO Global Gateway to Geographic Information Systems (GIS (http://www.fao.org/fishery/collection/gisfish/en) • Natural Earth Data (http://www.naturalearthdata.com/downloads/) • NASA Earth Observations (https://neo.sci.gsfc.nasa.gov/) • NOAA OneStop: A NOAA Data Search Platform (https://data.noaa.gov/onestop/) • OpenStreetMap (https://gisgeography.com/openstreetmap-download-osm-data/) • Socioeconomic Data and Applications Center (SEDAC) (https://sedac.ciesin.columbia.edu/) • UNEP Environmental Data Explorer (http://geodata.grid.unep.ch/index.php) • FAO Map Catalog (https://data.apps.fao.org/map/catalog/srv/eng/catalog.search#/home)
RS Resources • FAO Global Gateway to Geographic Information Systems (GIS), Remote Sensing and Mapping for Aquaculture and Inland Fisheries (http://www.fao.org/fishery/gisfish/index.jsp) • JAXA's Global ALOS 3D World (https://www.eorc.jaxa.jp/ALOS/en/aw3d30/) • LP DAAC MODIS land products (https://lpdaac.usgs.gov/data/) • NASA Earthdata Search (https://search.earthdata.nasa.gov/) • NASA Earth Observations (https://neo.sci.gsfc.nasa.gov/) • NASA MODIS Land (https://modis-land.gsfc.nasa.gov/) • NASA OceanColor (https://oceancolor.gsfc.nasa.gov/) • NOAA Comprehensive Large Array-data Stewardship System (https://www.avl.class.noaa.gov/saa/products/welcome) • NOAA OneStop (https://data.noaa.gov/onestop/) • Sentinel Open Access Hub (https://scihub.copernicus.eu/dhus/#/home - • USGS Earth Explorer (https://earthexplorer.usgs.gov/) • VITO Vision (https://www.vito-eodata.be/PDF/portal/Application.html#Home)

Another Project "Strengthening the Effective Management of Inland Fisheries and Aquaculture in AMSs with GIS and RS Technology" implemented by SEAFDEC also applies GIS and RS technologies in fisheries and aquaculture. This Project makes use of the catch data collected from selected fishing grounds of the participating countries as target sites, which are then analyzed together with the environmental information obtained from satellite data images of such target sites. The final output from the data analysis could include levels of impacts of the environmental factors and changes in the inland fishery resources that could be used for the effective improvement of inland capture fisheries management.

From the aforementioned projects and studies, it could be deduced that several Southeast Asian countries have applied the GIS and RS technologies in their endeavors in fisheries and aquaculture management, *e.g.* in fishing vessels and fleet management; conservation and management of fishery resources and habitats in inland, coastal, and marine waters; improved collection system for catch and landing data from small-scale and commercial fisheries; fishery resources and habitat enhancement, among others (Wanchana & Sayan, 2018). These geo-informatics technologies have the potentials to be used in data and information compilation and analyses, the results of which could help in decision making, especially in formulating management strategies for sustainable utilization of the respective countries' national fishery resources.

6.2 Challenges and Future Direction

Fisheries management is an important factor in ensuring the sustainable utilization of fishery resources. Overcapacity and illegal, unreported and unregulated (IUU) fishing have been identified as among the major causes for overfishing that lead to the collapse of the fishery resources. With the relevant International Plans of Action (IPOAs), such as the IPOA for Management of Fishing Capacity (IPOA-Capacity) and the IPOA to Prevent, Deter and Eliminate the Illegal, Unreported and Unregulated Fishing (IPOA-IUU) adopted by the Council of FAO under the framework of the Code of Conduct for Responsible Fisheries, such IPOAs have guided the countries in the Southeast Asian region to develop their respective plans for the management of fishing capacity and combating IUU fishing, and for the application of the "tools" that cover various measures for combating IUU fishing activities in different situations and contexts.

More specifically, the need to combat IUU fishing is specified in SDG Target 14.4 viz: "*By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics*." Meanwhile, Target 14.6 indicated that "*By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation*."

With reference to the "ASEAN Guidelines for Preventing the Entry of Fish and Fisheries Products from IUU Fishing Activities into the Supply Chain" and the "Regional Plan of Action for Management of Fishing Capacity," the following aspects should be considered by the AMSs and relevant organizations at the regional and international levels, in improving the management of fishing capacity and enhancing the effectiveness of the measures for combating IUU fishing in the Southeast Asian region:

Developing national policies and legal frameworks for combating IUU fishing

- The AMSs to consider improving their respective legal frameworks in order that the implementation of actions by relevant authorities to combat IUU fishing is facilitated, and that their compliance with the obligations to international laws and regulations of relevant RFMOs is strengthened based on their respective responsibilities as coastal State, port State, and flag State. While most countries have already established their respective NPOA-IUU such as Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam, the other countries had also embedded the principles of the IPOA-IUU in their respective national legislation and fisheries management plans.

- The AMSs to also strengthen their respective national inter-agencies coordination and cooperation for the enforcement of relevant laws and legislations, *e.g.* through the establishment of integrated mechanisms that comprise agencies responsible for fisheries and other relevant agencies having the mandates and legal frameworks for combating IUU fishing, and implementation of MCS, PSM and traceability systems of fish and fishery products.

Enhancing the Management of Fishing Capacity

- The AMSs to continue their respective national efforts in the management of fishing capacity, by determining the appropriate level of fishing efforts to commensurate with the available resources based on the best scientific evidence. However, this also requires improvement of data collection for determining the appropriate reference points, such as maximum sustainable yield, total allowable catch/efforts that are appropriate with large- and small-scale fisheries, considering the variety of fishing gears and multi-species of the catch.

Implementing the flag-State, coastal-State and port-State responsibilities

- Through their respective agencies responsible for fisheries and other relevant agencies, the AMSs should enhance their efforts in improving their national vessel registration and fishing licensing systems, including the development of electronic database systems to facilitate sharing and exchange of information among concerned national agencies as well as with other countries and relevant organizations. As for the development of their respective database systems, the countries could refer to the Regional Fishing Vessels Records (RFVR) for vessels 24 meters in length and over, the RPOA watch list of IUU fishing vessels, the FAO Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels (Global Record), among others.

- Through their respective agencies responsible for fisheries and other relevant agencies, the AMSs should strengthen the implementation of monitoring, control and surveillance (MCS) not only for their national fishing vessels but also for foreign fishing vessels engaged in fishing operations in their respective waters.

- The AMSs to apply appropriate catch documentation and traceability systems of fish and fishery products (including from small-scale fisheries) from the point where the catch is harvested until reaching consumers, including the use of an electronic system to facilitate the sharing and exchange of information among the concerned national agencies and the points of issuance of documents. Adoption of the ASEAN Catch Documentation Scheme for Marine Capture Fisheries (ACDS) should be considered as this would enhance the competitiveness of their fish and fishery products in the importing markets that require all products accessing their markets to be not coming from IUU fishing activities.

- Through their respective agencies responsible for fisheries and other relevant agencies, the AMSs should enhance their capacities in implementing the port State measures (PSM) in order that landing of fish and fishery products from IUU fishing or related activities from foreign vessels in designated ports of the respective AMSs, is prevented.

Strengthening international cooperation

- With technical support from SEAFDEC, the AMSs should consider strengthening international cooperation for combating IUU fishing through bilateral and multilateral arrangements; cooperation to comply with State responsibilities under the frameworks of the relevant RFMOs in their respective areas (as a party or non-contracting party); and the regional cooperation under the frameworks of the Regional Plan of Action to Promote Responsible Fishing Practices including Combating IUU Fishing in the Region (RPOA-IUU), the ASEAN Network for Combating IUU Fishing (AN-IUU), regional and sub-regional MCS network.

- For relevant international and regional organizations, to consider providing regional frameworks to support the AMSs in the implementation of the necessary actions, as well as strengthening of networks for sharing of information to combat IUU fishing, *e.g.* lists of registered vessels and IUU vessels, respective countries' relevant laws and legislations, incidents regarding the encounter with vessels suspected of having been engaged in IUU fishing activities.

Adopting innovative technologies for combating IUU fishing

- With support from relevant international and regional organizations, the AMSs to initiate the application of appropriate innovative technologies for combating IUU fishing, *e.g.* observers' programs onboard fishing vessels or use of CCTV onboard fishing vessels, vessel monitoring systems (VMS), Automatic Identification System (AIS), Artificial Intelligence (AI) to identify IUU fishing patterns, and so on. Such technologies could reduce the manpower required to deal with the collection, analysis, and interpretation of a huge amount of data relevant to combating IUU fishing.

Another important aspect that should be considered for the management of fisheries is the fact that although the majority of fishery production are derived from large-scale fisheries but the majority of the workforce in the fishing industry of the region are small-scale and artisanal fishers conducting fishing activities in wide areas of coastal and inland waters. Taking into consideration such a situation, a centralized management scheme may not be effective, especially for the management of small-scale fisheries. Other management approaches that had been introduced during the past decades could be adopted with a view to enhancing the participation of local communities and institutions in the relevant work of responsible government authorities. Moreover, appropriate habitat protection and resources enhancement programs as well as the adoption of technologies such as the GIS and RS to support fisheries management should also be examined. Therefore, in order to improve the effectiveness of fisheries management (and aquaculture) at various scales, consideration should be given to the following:

Promoting management concepts appropriate to the region

- The AMSs to consider adopting management approaches that are appropriate for different localities and specificities of the region, *e.g.* community-based fisheries management (CBFM), co-management (CM), ecosystem approach to fisheries management (EAFM), and ecosystem approach to aquaculture (EAA). Government interventions could include the development of appropriate legal frameworks that allow the delegation of selected management authorities to local communities and local institutions, provide appropriate support to local communities, *e.g.* in the identification of issues/challenges, development of management plans, data collection, and monitoring programs, as well as relevant capacity building activities as appropriate.

- For relevant organizations and institutions to support the AMSs in providing better understanding to stakeholders on the innovative fisheries management concepts/approaches, *e.g.* the CBFM, CM, EAFM, EAA; and promoting the implementation of such management concepts/approaches in selected pilot sites of the AMSs, as well as sharing of experiences among the AMSs to enhance wider implementation of the approaches in other countries/areas.

Enhancing habitat protection and fishery resources

- The AMSs to sustain the promotion of habitat protection and fishery resources enhancement programs, *i.e.* Artificial Reefs and Habitat Rehabilitation; Catch Area Management, including marine protected areas, closed season area (and fisheries *refugia*); Restocking and Releasing using seed stock from hatcheries; and Others such as restrictions on fishing gear, fishing effort, zoning and licensing, among others. Inter-agencies coordination in this regard is necessary especially for spatial management schemes, such as fisheries *refugia* while sub-regional or regional cooperation is also necessary for the management of transboundary species.

Applying GIS and RS for fisheries management

- The AMSs to consider enhancing the application of Geographic Information System (GIS) and Remote Sensing (RS) technologies for fisheries and aquaculture management, *e.g.* in fishing vessels and fleet management; conservation and management of fishery resources and habitats in inland, coastal, and marine waters; improved collection system for catch and landing data from small-scale and commercial fisheries; fishery resources and habitat enhancement. The results from such endeavors could help policymakers in decision-making, especially in formulating management strategies for sustainable utilization of the respective countries' national fishery resources.

7. Aquaculture Development

7.1 Status, Issues, and Concerns

7.1.1 Socioeconomic Importance of Aquaculture for Food Security and Poverty Alleviation

Southeast Asia is home to 661.5 million people or about 8.5 % of the world's total population in 2020, with an average GDP per capita of USD 5,017 (World Bank, 2021). Although not fully recognized as a major contributor to GDP, the productivity of aquaculture and its ancillary industries add to the growth of the GDP of the Southeast Asian countries. Noteworthy to mention is the role of aquaculture as leverage in managing and improving the balance of trade through seafood trade for food and industrial needs of importing countries. In countries like Indonesia, Myanmar, the Philippines, Thailand, and Viet Nam, the aquaculture sub-sector contributes to the means for reducing trade deficit at lower opportunity costs. High levels of local fish production also create food sufficiency for domestic consumption and offer a good reduction in fish importations.

The availability of locally produced food fish to feed the growing populations of Southeast Asian countries would mean lower costs due to reduced transport costs. More so, when aquaculture products in various forms are exported, especially the high values such as shrimps and those processed in higcostsh value forms, contribute significantly to the export incomes of the Southeast Asian economies, notably in Thailand, Indonesia, Philippines, and Myanmar. However, the contribution to foreign currency earnings statistics related to export income from aquaculture products is not generally available and this affects the estimation of the contribution to foreign currency earnings through exports of aquaculture products. Nonetheless, in view of the contribution of aquaculture to Southeast Asian countries' GDP through earnings from the exportation of aquaculture products, the importance of aquaculture to the national economies in terms of poverty alleviation and nutritional benefits needs a thorough evaluation.

The world's population by 2050 is projected to grow to about 10 billion, and consequently, food demand would also increase. The aquaculture industry has grown globally, and its generally high levels of productivity continue to successfully fill in the shortage of fish supply from capture fisheries. FAO (2016) reported that fisheries and aquaculture provide income and support livelihoods for many people around the world, and it has been estimated that many developing countries in Asia would contribute over 80 % of total aquaculture production to the world's food system. Most Southeast Asian countries are the major net exporters of food fish for consumption around the globe. Many of these exports are mainly finfishes and shrimps, as well as other aquatic resources for non-food and industrial uses such as seaweeds. The aquaculture sub-sector provides luxury to gourmet seafood diners and health-conscious consumers of metropolitan centers of the world. Production and exports of seafood come from a variety of aquaculture production systems, including those practiced by industrial and small-scale producers. The industrial production scale dominates the brackishwater shrimp and freshwater tilapia aquaculture. Medium and small-scale producers are often the source of high-value farmed finfishes such as groupers in the live food fish trade. In contrast to industrial aquaculture in developed countries which has gained significant private investments, aquaculture systems in Southeast Asia are predominantly small-scale and family-owned, managed, and operated as small-scale endeavors (European Environment Agency, 2016). The contribution of small-scale aquaculture (SSA) to economies is evident and significant in most developing countries, while a range of benefits could also be obtained by households not directly involved in fish culture but through indirect linkages. Households can benefit from an increased supply of fish and fish-based products in local markets, as well as from reduced prices of fish. Furthermore, increased opportunities for employment are not only generated along the fish farming value chain, but also through the direct employment on farms, and associated services such as the production of aquafeeds, seeds, and fertilizer (Karim *et al*., 2020).

Role of aquaculture in national economies of Southeast Asian countries

In spite of the role of many SSA producers in seafood production for local consumption and export trade, poverty and food insecurity in fishing and aquaculture communities persist right in these food production areas in Southeast Asia. One deep-seated reason is that poverty is rooted in the insecurity of jobs and income sources in the aquaculture sub-sector. Hunger and food insecurity remain a challenge and are most devastating and formidable for the world's poor and disadvantaged (Blanchard *et al*., 2017; Tacon & Metian, 2018). How do we feed the world nutritiously and equitably while sustaining the natural capacity of resources to provide food and other equally essential services?

While the development of aquaculture is mainly driven by an increase in demand, production, and associated income, the growth of this sub-sector is constrained and disproportionately influenced by several socioeconomic factors, including access to financial capital and land-use policies. For example, water bodies in some Southeast Asian countries such as Myanmar, remain unexplored for SSA even if aquaculture in these water bodies would likely show potential benefits (Karim *et al*., 2020). Nevertheless, a significant potential contribution of SSA to local and regional markets in providing increased income and health nutrition could be expected (Belton *et al*., 2015).

A study of aquaculture industries in Central Visayas in the Philippines revealed the socio-cultural and economic aspects of aquaculture right in coastal fishing communities (Rica, 2015). Most (79 %) of the aquaculture production systems are conducted in freshwater ponds producing Nile tilapia, *Oreochromis niloticus*, and in brackishwater ponds that grow milkfish, *Chanos chanos*. These ponds are being operated by private individuals who often informally hire individuals or families living near the aquaculture sites as caretakers and helpers on a non-permanent and on-call basis. Ironically, aquaculture operations are labor-intensive as caring for live aquatic animals requires the full-time engagement of caretakers. Food security is compromised as observed by the periodicity of consumption in these communities. The regularity of consumption, not necessarily of fish but of most food items in general, is normally low but with periodic high only during harvest time (50 %) which usually happens every 3 - 4 months, as oftentimes wages and commissions are delayed until harvest. Nonetheless, the staple rice is generally secured as it is being provided by the aquaculture enterprise owners as part of the compensation for the caretakers of the fishponds. In comparison, capture fishers do not have this assured supply of staple rice. Overall, aquaculture enterprises developed in capture fishing communities have provided some level of food security to fish farm workers. More so, the increasing demand for ancillary services required in aquaculture farms and fish marketing enterprises has created more jobs, although similarly insecure, for households in the vicinities of aquaculture farms. Aquaculture, therefore, although to a limited extent, helps to provide access to staple food for its workers and spares its workers from poverty. However, the security of jobs and food sources needs improvement.

Potential aquaculture stakeholders need access to affordable low-risk aquaculture technologies, markets, control, and access over common property resources and rights to participate in aquaculture development planning. Aquaculture has brought employment that contributes to poverty reduction in developing countries such as the Philippines, Cambodia, and Viet Nam (Irz *et al*., 2007; Nguyen *et al*., 2016; Sheriff *et al*., 2008). In some rural areas in Cambodia for example, poverty is linked to food insecurity. The fisheries sector of Cambodia has undergone a major reform that prioritizes poverty alleviation and food security. According to the study of van Brakel & Ross (2011), the majority (65 %) of the rural households are either landless or land poor, owning one hectare or less of land, and usually net buyers of food. Food consumption amounts to 70 % of the total household expenses. Capture fisheries contribute mainly to food security, nutrition, and income generation. Through pond-based and rice-fish aquaculture, the development of its aquaculture subsector has received increasing attention because of its potentially important role in providing food security and rural income generation. Aquaculture in cages and pens are the major fish farming systems in inland areas in the country. However, this culture system is highly dependent on feeds using fish from the wild. Concerns have therefore been raised over the impacts of the mounting demand for fish food on the availability of fish protein sources to consumers, as well as its detrimental effect on the environment. Thus, concerns about wild seed supply, availability of fish feed, and the integrity of water quality should be addressed.

In Viet Nam, Nguyen *et al*. (2019) found that the growth of aquaculture productivity enables poverty reduction that seems to have a more significant effect on the not-so-poor than the ultra-poor sectors of the economy. Further, it also revealed that the higher the value of fish species, the more likely is the impact of aquaculture productivity marked on poverty reduction. Shrimps and lobsters are high-value species exported such that several aquafarmers are engaged in various farming activities of such commodities. Thus, aquaculture production improves farmers' scarce resources while at the same time, stimulating the overall economic growth. Similarly, van Houng and Cuong (2012) highlighted that the increasing availability of seeds, appropriate control of inputs, and access to loans for capital investments enhance aquaculture's contribution to the poor farmers' income and food security. Subsequently, it can be an effective solution to alleviating hunger and poverty since freshwater aquaculture plays a crucial role in stabilizing concerns on fish food supply in fish capture scarcity.

Indonesia is one of the major global aquaculture producers for both domestic and international markets. Aquaculture and capture fisheries are essential contributors to the Indonesian economy providing food security, income generation in rural areas, and significant export earnings. Aquaculture is a growing sub-sector with potentials for expansion and is deemed as an essential contributing factor to the four national pillars of development in terms of economic growth, creation of job opportunities, reduction of poverty, and environmental recovery and mitigation (Rimmer *et al*., 2013). While Indonesia emphasizes the economic importance of aquaculture production in generating income from rural communities and exporting commodities to bring in foreign earnings to the country, it also thrusts on the expansion of markets and improved trading advancement that links economic transformation and the marketing of diversified products. It is the gateway to international markets that can strengthen and capacitate human skills in trading and exporting aquaculture products.

Thailand is likewise one of the world's sources of seafood from capture fisheries and aquaculture. Shrimps (*Penaeus vannamei* and *P. monodon*) and freshwater prawns (*Macrobrachium rosenbergii*) are major exports produced in large-scale and medium-scale farms that provide benefits to corporate investors and a multitude of workers and traders. The study by Sheriff *et al*. (2008) meanwhile showed that grouper culture provides an opportunity for poor households to engage in fish culture and generates substantial financial benefits. However, the role and contribution of aquaculture in economic growth are being challenged by the need for financial capital and access to credits, as capital investments are required in the development of aquaculture, and these concerns have also been felt by SSA operators. With limited capital to finance aquaculture operations, especially industrial-scale enterprises, exposure to risk and uncertainties are a major concern among stakeholders.

In the Philippines, Irz *et al*. (2007) found strong evidence that aquaculture contributed to the alleviation of poverty in rural areas. In-depth analysis of the sharing of benefits among low-income fish farm workers and the better-off investors in fish farming operations showed that the former received a relatively large share of the revenue from aquaculture than the better-off people whose financial investments in aquaculture production systems are highly exposed to risks. Aquaculture enterprises, big or small, have primarily employed unskilled workers, often with insecure terms of engagement. However, the study was conducted several years ago, and it is unknown whether the benefits for the poor are sustained.

Singapore reported the prevalence of family-based ownership of most aquaculture farms (Shen *et al*., 2021). A relatively small farm that can produce 600 mt of fish per year is unwilling to invest in new technologies, fearing that recouping their investments might not be possible once the technology fails. Thus, private investments and agri-tech venture capital, especially in aquaculture operations, are poorly developed as they are unfamiliar with the industry. There are constraints in migrating or transferring from the low-technology to high-technology production systems, although the future of the aquaculture industry of Singapore is leaning towards the need to invest in high technology, bio-secure, space-efficient, and dynamic aquaculture operations. Singapore is a small county, but it is positioned to serve as a research and education hub for R&D on tropical aquaculture that should focus on reproduction, genetic improvement, and hatchery technologies generating a genetically improved seed for local and overseas production.

The aquaculture feasibility study of Brunei Darussalam conducted by the ASEAN-Japan Centre in 2021 categorized that the aquaculture industry has a high potential for contributing to the country's economy and has therefore been engaged as a leading alternative industry for the country's economy. With the objective of increasing fisheries output, the Government of Brunei Darussalam is promoting export-driven aquaculture activities towards foreign investors. Although the country has limited natural water resources available within and surrounding its territory, it propels further expansion and investment for aquaculture through a vital industry that overall contributes to the fisheries sector.

Brunei Darussalam is engaged in various aquaculture farming systems. Pond culture is the most basic form of aquafarming used by farmers. Since this type of system does not require complex technology, capital costs are generally lowered. Such system is commonly used for the production of freshwater fish and prawns. On the other hand, marine fish farming in floating cages is common in coastal and inshore areas but is usually operated by commercial and foreign investors due to its high requirements for capital and operation costs. Recirculating aquaculture system (RAS) farming is commonly adopted in both the marine and freshwater fish in either concrete or fiberglass tanks. While RAS is environment-friendly, it needs more capital input due to the costs of its filtering systems. Highlighting the country's aquaculture industry potential for further expansion and contribution to economic development, foreign investments usually venture into large-scale and commercial companies because of a faster and higher rate of return on investment. While investment in small-scale enterprises still exists in the industry, it is minimal. Nonetheless, benefits are still evident from these small players because they stimulate the local economy, foster long-term economic sustainability for these businesses, and contribute to the industry's value chain system, opening more opportunities as the industry further develops.

In Lao PDR, aquaculture also plays a crucial role in sustaining food consumption. It is an alternative source of fish as well as other aquatic organisms especially when fish are inaccessible (Dalasaen & Amnath, 2016). Fish is preferred and considered the primary source of animal protein for most people in Lao PDR. A study reported that fish farmers in Lao PDR become involved in pond fish culture due to its relatively low entry cost, particularly, in constructing ponds. Likewise, fingerlings of tilapia and carp are again accessible from nearby countries (Garaway, 2005). Nevertheless, there have been no recent studies citing that aquaculture has significantly reduced the nation's poverty.

The country report of Malaysia revealed that aquaculture is a strong driver of the nation's economic growth. It is projected that the aquaculture sub-sector would address the continuous demand for fish consumption and reduction of fish supply due to overfishing with the growing population of the country. Further, Yusoff (2015) reported that the Malaysian government initiates a program to develop locations for the culture of various high-value aquatic species. The program is meant to strategize the Malaysian Government's goals towards food security, job opportunities generation, and increased income earnings.

Enhanced role of aquaculture during the COVID-19 pandemic

Discussions about the role of aquaculture in poverty alleviation and food security will not be complete and updated without looking into the impacts of the COVID-19 pandemic, which has caused significant shocks affecting the coastal social-ecological systems in different parts of the world (Manlosa *et al*. 2021). Its widespread impacts have unraveled vulnerabilities in many aspects of society, including food systems. Specifically, fishing and aquaculture operations and the trade of high-value tropical seafood harvested are constrained by limited shipment and more stringent international transport measures. Thus, the likelihood of reduced export earnings and compromised trade balance has been a major concern (Bennett *et al*., 2020; Zhang *et al*., 2021)

Nonetheless, the fisherfolks and small-scale aquaculture operators who are important players in the food fish production systems had already been living in a difficult situation even before the pandemic. The untoward impacts of the health pandemic, such as increased health risks especially for the already marginalized fishing households in remote and poverty-stricken fishing communities due to further lack of food, malnutrition, and constrained access to health facilities, had enhanced the impacts. Lost jobs for women in the processing sector, market disruptions, lower demand, and access to high-end markets, especially for highly perishable fish and products, are among the severe situations that affected the global food system (Bennett *et al*. 2020).

Nevertheless, some studies had established some trends that showed the resilience and innovativeness of the stakeholders in the aquaculture and fisheries sector to be able to perform its role in securing fish supply in the midst of the impacts of the COVID-19 pandemic (Bene, 2020). There is a probable lower disease infection rate as operators and workers in fish farms are fairly stationary than in capture fisheries which are characterized by the migratory nature of fishing activities (Bennett *et al*., 2020). In many communities of fish farmers, there is a resurgence of food fish, and aquatic resource sharing during the crisis. This has occurred in areas around the tilapia growing systems in lakes in rural Laguna in the Philippines (Magcale-Macandong *et al*., 2021). In smaller distant fishing communities, the revival of local food networks through direct selling of fish within the immediate community, either at low prices, barter, or give-away, is more profound to address hunger and avoid sickness aside from those symptoms associated with the pandemic (Bollido, 2020). In more urban and metropolitan areas, there is a shift in demand for seafood raw materials or pre-cooked seafood from restaurants to residences inclined to home cooking. During the crisis, some opportunities, therefore, arise, *i.e.* 1) enhanced collective action among fish farmers, fishers, and traders and local government; 2) application of the already existing ecosystems approach to fisheries management during the pandemic period; 3) for the enterprising fishers, networking, online selling, and deliveries offer improved income and employment opportunities; and 4) emergence of small-scale local processing and value-adding of fishery products. Small-scale aquaculture livelihoods are among the opportunities being promoted to complement a short value chain and localized distribution system. Last but not least, opportunities for sea ranching and stock enhancement in intertidal flats to increase economically important fish stocks and harvest. Such strategies are feasible as community quarantine measures include stay-at-home advisories that harmonize with close monitoring and protection of released stocks and monitoring of spill-overs and catch in nearshore waters. Therefore, during this COVID-19 pandemic, the role of aquaculture is manifested and magnified in its continuous performance in the local food systems. Although there were disruptions in the geographic functionality of the food fish distribution, both involving wild and aquacultured fish that are distributed through a complex and far-reaching trading system (Manlosa *et al*., 2021), the presence of aquaculture systems spread around various locations compensated for making fish available in many fish consumption areas in most Southeast Asian countries.

Two-pronged role of aquaculture for securing food and livelihoods

1. Aquaculture for direct food fish production

The increasing demand for food fish to feed the growing global population in the midst of the declining productivity of some capture fisheries gave impetus for the development and investments in aquaculture technologies. As Southeast Asia recovers from the COVID-19 pandemic, governments and industries must transform their food production systems to make them more modern, climate-proof, and inclusive (ADB, 2021). Looking back, the production of fish juveniles in hatcheries is a major breakthrough that enabled grow-out culture systems to contribute to food fish production to augment the catch from capture fisheries intended for direct human consumption. The breeding and rearing of freshwater, brackishwater, and marine species continue to address the growing demand for fish or animal protein in general. Hence, more than half of the fish eaten around the globe had been produced from aquaculture. When producing food fish through aquaculture, control of the supply of fish in the market gives the fish farmer the ability to create surplus stock or reduce their production to reap optimal profits.

Indonesia produces about 15.6 mt of aquacultured commodities annually, with about 28 % of its aquatic animal culture integrated with rice farming, in the so-called fish-rice farming system. Viet Nam yields 3.6 million mt of aquaculture products annually, mainly comprising catfish and giant tiger prawn. The Philippines ranked next with 2.3 million mt of produce from aquaculture dominated by milkfish and shrimps. These aquaculture production levels have been highly dependent on seed production and fish farming technologies. Likewise, the success of fish production is also dependent on the advances in feed development, improved fish nutrition, and fish health management, comprising the overall progress in fish culture techniques. These fish production levels in marine aquaculture systems are mainly conducted in large water bodies along the marine coastlines especially in archipelagic countries like Indonesia and the Philippines. Likewise, Viet Nam has a long coastline which is equally beneficial for offshore fish culture operations.

Meanwhile, Cambodia, Thailand, and Viet Nam benefit from the use of the huge Tonle Sap Lake and the Mekong River system for freshwater fish production. These water bodies likewise support aquaculture operations in ponds, tanks, reservoirs, and other forms of water impounding systems. The aquaculture production of Thailand has significantly increased during the last few decades and significantly contributed to the country's socioeconomic development. Estimates of total aquaculture production in Thailand have gradually grown from around 0.6 to 0.9 million mt over the last twenty years. Farmed shrimp is the main animal aquatic product that accounts for about 40 % of the country's total aquaculture production and is closely followed by fish (38 %) and mollusks (22 %). To be assured of a sustainable fish food supply through aquaculture, investors should be innovative and find practical solutions that rely on diverse technology inputs and smart market-based management approaches.

2. *Aquaculture for fisheries conservation, rehabilitation, and improved productivity*

Arising from aquaculture's fundamental role to produce fish for direct consumption, often through intensification of culture systems, there are implications that aquaculture contributes to the endangerment of aquatic biodiversity and the pollution of the environment. On the contrary, there still exists the less well-recognized role of aquaculture in the conservation and recovery of threatened and endangered species. This other role of aquaculture aside from the direct production of food fish for direct human consumption is in the aspects of the restoration of threatened and endangered species populations, and wild stock population enhancement. The aquaculture sub-sector is in an advantageous position to minimize the extinction of the wild relatives of farmed species. In support of this role of aquaculture in the conservation and rehabilitation of threatened aquatic stocks, genetic markers, and genetic stock identification have been used to help differentiate species and stocks of wild and farmed species. Some aquatic species that are threatened in the wild are also farmed to ensure that farmed species are the ones being traded for food and other uses, instead of those from the wild.

Policy and governance support towards sustainable aquaculture

The aquaculture sub-sector around the globe is one of the several food production systems where policy and governance support towards sustainable management and operations is well instituted. The sub-sector is guided by the FAO Code of Conduct for Responsible Fisheries (CCRF) where Article IX is focused on Aquaculture. Thus, both voluntary and legally binding international mechanisms, guidelines, and codes of practice have been developed to ensure adherence to the principles of sustainable aquaculture. Given such a regulatory and governance framework, the role of aquaculture in food production, economic development, and food security is a work in progress. Industrial-scale aquaculture continues to gain the interest of investors and in some cases an item of interest among foreign corporate investors. On the other hand, small-scale aquaculture is being used as a strategy to improve food fish supply in rural communities to address hunger and lack of income opportunities. Small-scale aquaculture is a crucial intervention for food security and nutrition in developing countries because this enables the low capital and labor-rich households to counter poverty and hunger through engagement in the self-sustaining food production system. The contribution of SSA to food security and nutrition should be taken into account in the formulation and implementation of policies, both local and international, while the integration of SSA producers will enable their participation in productive and profitable market enterprises.

Policies and legal framework towards the overall development of the aquaculture sub-sector with a focus on its role in poverty alleviation and food security are imperative to enable the sub-sector to meet the challenges of the new normal. The Asian Development Bank (ADB) recently added that governments in Southeast Asia should enact policies that integrate technology, infrastructure investments, innovation, and regulatory reforms to ensure food security (*e.g.* affordable crop insurance) and continued economic development. Increasing access to credit and microfinance programs with low-interest rates, flexible loan repayments, and options for restructuring loans for aquaculture operators. Digitization of fisheries businesses, both downstream and upstream has been recommended in Indonesia and some other Southeast Asian countries (Indonesian Traditional Fisherfolk Union DPP KNTI, Jakarta, April 17, 2020). Digitization will eventually expand the market access of fishery products to national or international markets, even in the midst of health pandemics.

In view of the significant contribution of mariculture operations in large-scale fish production, Ruff *et al*. (2020) studied the extent of certain socioeconomic, governance, and biophysical factors that can explain country-level patterns of mariculture production. Results showed that socioeconomic conditions are a significant contributor to whether a country would engage in mariculture and the magnitude of its operations. The socioeconomic parameters, including governance factors, explained up to 33 % more of the variation in mariculture production compared to models including only biophysical parameters. Therefore, improving seafood farming infrastructure, creating local demand for seafood, and facilitating knowledge transfer from land-based and freshwater aquaculture could help countries develop stronger mariculture industries.

In Thailand, policy instruments are recommended to address the problems reportedly encountered by its aquaculture sub-sector that faces a range of production, market, and financial risks extending beyond the private space of farms to include public spaces and shared resources. The Government of Thailand has attempted to manage these shared risks using the lens of territorialization and institutionalized risk management through spatially explicit forms of collaboration among and between farmers and non-state actors in the shrimp and tilapia production sectors in the country (Sampantamit *et al*., 2010). Its findings demonstrate how these policy instruments address risks through dissimilar but overlapping territories that are selectively biased toward facilitating the individual management of production risks while enabling both the individual and collective management of market and financial risks.

7.1.2 Fish Health Management

Aquaculture is the fastest-growing food-producing sector in the world. In 2018, inland aquaculture accounted for 62.5 percent of the world's farmed food fish production. A 527 percent rise in global aquaculture production was observed from 1990 to 2018. However, this production growth is being threatened by fish diseases resulting in losses of more than USD 6 billion per year (FAO, 2020). In this regard, fish health management is one way of abating the problem, which begins with disease prevention and control rather than treatment. One component of fish health management is the emergency preparedness and response system (EPRS) for managing aquatic disease outbreaks. EPRS comprises contingency planning arrangements that can minimize the impacts of severe aquatic animal disease outbreaks through containment or eradication in case of disease occurrence. In 2016, the EPRS was harmonized among the AMSs with the initiative of SEAFDEC/AQD in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA), Food and Agriculture Organization of the United Nations (FAO), ASEAN Network of Aquatic Animal Health Centres (ANAAHC), and Department of Fisheries, Thailand (DOF Thailand).

Disease surveillance and monitoring program

In different countries, disease surveillance or monitoring is one of the activities being conducted to determine the presence of diseases in their territory or to demonstrate disease-free status. Except for Cambodia and Lao PDR, most AMSs have a monitoring or surveillance program. Diseases included in the monitoring and surveillance program are usually those listed in the OIE database and other significant and emerging aquatic animal diseases. However, some AMSs have different priorities with respect to disease surveillance and monitoring. Like for example in Malaysia, surveillance is conducted on diseases that cause high economic losses for the country. In Brunei Darussalam, an active surveillance program is carried out in the shrimp industry and a passive surveillance program for the rest of the country's fish industry.

Quarterly, the AMSs submit the aquatic animal disease reports to the OIE and NACA through the OIE Regional Office in Tokyo, Japan and NACA headquarters in Bangkok, Thailand. In addition, the AMSs provide disease information on the OIE-listed aquatic animal diseases to the OIE World Animal Health Information System (WAHIS) every six months. Information in the WAHIS can be accessed and verified by the public.

Information on emerging diseases provided by the OIE, FAO, and NACA are communicated by competent authorities to the stakeholders to raise their awareness. Furthermore, precautionary measures are recommended such as movement restrictions, health certification, and quarantine to control the introduction or spread of the emerging transboundary diseases.

Fish health diagnostic laboratories

An important aspect of aquatic animal disease prevention and control is the existence of a laboratory with skilled personnel who conduct diagnostic services at different levels (**Box 32**). The fish health diagnostic laboratories of the respective AMSs (**Box 33**) are managed by personnel who continuously undergo training to update and enhance their skills in carrying out disease diagnoses.

Box 32. Disease diagnosis levels (Bondad *et al.*, 2001)	
Level I	Diagnosis is done through gross clinical observation: observation of the cultured animals and the environment
Level II	The laboratory is capable of traditional diagnostic techniques like bacteriology, mycology, parasitology, and histopathology
Level III	The laboratory is capable of advanced diagnostic techniques like virology, electron microscopy, molecular biology, and immunology

Box 33. Fish health diagnostic laboratories in the AMSs	
Brunei Darussalam	The Aquatic Animal Health Services Centre (AAHSC) of the country's DOF is responsible for providing diagnostic services to the growing aquaculture industry in the country, making use of the OIE standards in performing diagnostic tests on aquatic animals
Cambodia	The Marine Aquaculture Research and Development Center (MARDeC) is the laboratory for aquatic animal health diagnosis in the country, which can perform Levels I and II disease diagnosis, but not for all aquatic species and diseases
Indonesia	A total of 140 aquatic animal disease laboratories including 15 fish health and environment laboratories operate under the Directorate General of Aquaculture (DGA), 47 laboratories under the Fish Quarantine Inspection Agency (FQIA), three under the Research, Development and Extension Agency (RDEA), and 75 laboratories managed by the local government, while the private sectors in the provinces usually have fish health officers and in-house Level I and II laboratories, and those under the DGA are national reference laboratories capable of Level III diagnosis that is being operated by the local government and mostly Level I laboratories that focus on water quality monitoring
Malaysia	The four service laboratories under the Fisheries Biosecurity Division of the country's DOF and one National Fish Health Research Division laboratory are managed by the Fisheries Research Institute and can perform Levels II and III diagnoses
Myanmar	DOF of Myanmar is capable of Levels I and II disease diagnosis, while the country's Aquatic Animal Health and Disease Control Section (AAHDCS) is capable of Level III diagnosis
Philippines	The National Fisheries Laboratory Division (NFLD) under the Bureau of Fisheries and Aquatic Resources has a central fish health laboratory and 16 counterpart fisheries laboratories in the regions with different levels of diagnostic capabilities on the detection of diseases, and there are two more fish health diagnostics laboratories, one at SEAFDEC/AQD and the other under the Negros Prawn Producers Marketing Cooperative Incorporated, that are capable of Level III disease diagnosis
Thailand	DOF Thailand has two national reference laboratories for aquatic animal health operating under its Aquatic Animal Health Research and Development Division (AAHRDD) for freshwater aquatic animal disease diagnosis and the Songkhla Aquatic Animal Health Research Center (SAAHRC) for brackishwater aquatic animal disease diagnosis, and there are 19 regional laboratories under the DOF located in different areas of the country
Viet Nam	There are 41 aquatic disease diagnostic laboratories in the country that include eight aquatic animal disease testing laboratories under the Regional Animal Health Offices (RAHO) and the National Centre for Veterinary Diagnosis (NCVD), 27 laboratories under the provincial Sub-Department of Animal Health (Sub-DAH), and six ISO/EIC 17025 accredited laboratory under the National Agro-Forestry and Fisheries Quality Assurance Department (NAFIQAD), while there are also privately-operated laboratories at the Research Institute for Aquaculture and in a fisheries university, and some private laboratories that are also accredited to provide diagnostic services for aquatic diseases

To improve laboratory competency, some laboratories in Brunei Darussalam, Indonesia, Philippines, and Thailand participated in the proficiency testing program for aquatic animal diseases organized by the Australian Centre for International Agricultural Research (ACIAR) and NACA, the Asia-Pacific Laboratory Proficiency Testing Program by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Government; and the Australian National Quality Assurance Program (ANQAP) and Arizona University. Indonesia also availed of the twinning program with the OIE Reference Laboratory.

Early Response System

Fish farmers and extension officers in the respective AMSs are knowledgeable in recognizing disease emergencies based on their experience and shared information among farmers. Fish farmers are trained to recognize signs of OIE-, nationally-, locally- listed aquatic animal diseases, emerging diseases, or unexplained mortality at Level I diagnosis. Some farmers also attend local and international seminars and other meetings on aquaculture practices and fish health management. Compliance with the requirements for certification, registration, or accreditation of aquaculture farms also improves farmers' knowledge of aquatic animal diseases. In addition, information, education, and communication (IEC) materials such as posters, disease cards, leaflets, manuals, and other publications are distributed to frontline individuals at the pond from time to time.

In Brunei Darussalam, when a disease is detected, the farm is declared as an infected zone, and a disease action plan is enacted. Containment, mitigation, and eradication of the disease are immediately implemented. Routine monitoring of the farm is conducted until the area is declared safe and free from the disease.

Indonesia, Malaysia, and Singapore have task forces that respond to aquatic disease emergencies. The task force investigates the cause of mortality, provides guidance on the implementation of standard operating procedures for a massive fish kill, and assists in key decisions regarding fish disease treatment procedures. DOF Malaysia also conducts risk analysis to identify high-priority aquatic disease threats that might be introduced to the country. The Import Risk Analysis (IRA) covers a list of diseases, biodiversity, or genetic threat to national aquatic resources, which are included in the application for the importation process. All registered farms in Malaysia are obliged to notify the DOF in case of occurrence or suspicion of a listed fish disease or the occurrence of mass mortality. The country developed a Fish Disease Notification Form that is distributed to registered farms.

In Indonesia, farmers and farmer associations are encouraged to report disease occurrence to the nearest fish health office immediately and to submit samples to the nearest fish health laboratory. Farmers can directly report fish mortality to the competent authority through a short text message or an online application, and indirectly, through an extension service or the nearest laboratory of the national fish diseases information system.

In Singapore, the Aquatic Animal Contingency Plans are activated when the notifiable aquatic disease is detected in a farm or other aquatic animal holding facilities. The key aspects of the contingency plans include quarantine and movement restrictions of affected animals, vaccination (for specific pathogens *e.g.*, RSIV), compliance to proper biosecurity measures, on-site investigation and sampling of susceptible fish species from the affected farm and adjacent farms, culling of affected and in-contact fish, disinfection and cleaning of the premises and all in-contact equipment and tanks, and re-inspection of the premises to ensure compliance with disinfection and biosecurity protocols.

Standard operating procedure

In Brunei Darussalam, when imported fish are detected positive for diseases, the competent authority of the exporting country is notified to investigate traceability. The disease action plan is immediately implemented to prevent disease spread in the country. Once a report on fish disease or mortality is received in farms, the Mobile Technical Unit (MTU) of DOF is immediately sent to the site to investigate. The infected pond is immediately quarantined, and the information gathered with the samples collected will be sent to AAHSC for confirmation. In case of a confirmed disease incidence, the disease action plan is implemented.

In Cambodia, the officers of the Fisheries Administration Cantonment of each province contact and report any disease occurrences to the aquatic animal health officers at the national level (Fisheries Administration). The suspected or diseased aquatic animal samples are collected and sent for further diagnosis.

In Indonesia, the fish farmer reports suspected disease occurrence to the extension officer and laboratory personnel at the district level, either personally or through an internet-based system or application. Through the latter mechanism, farmers can directly report to CA through SMS gateway, phone, and website. The system has positive results but needs improvement.

In Viet Nam, in case of disease occurrence in the farm, the farm owner must notify the CAs at communal or district levels, then the information will be transferred to the provincial level (Sub-DAH), and the DAH (headquarters and regional office). After receipt, the information is verified, and once the case of disease occurrence was verified, the provincial Sub-DAH conducts a field investigation to assess the situation and take samples for pathogen identification. When the causative agent is identified, an updated report is submitted to the DAH and RAHO. The DAH supervises the implementation of the provincial Sub-DAH and guides and supports in case of new or dangerous disease outbreaks. The Sub-DAH reports aquatic disease situations to the MARD and international organizations, co-operates, and requests their help in emergency disease occurrence. The collaborating agencies include D-FISH, the national extension system, Research Institutes and Universities, and farmers' associations.

The other AMSs like Myanmar, Malaysia, Philippines, Singapore, and Thailand, report the result of their respective Monitoring and Surveillance Program as an SOP for the early detection of disease occurrence or outbreaks.

Awareness building and training programs

The competent authorities annually allocate budget for training programs for their own staff and farmers. The training program aims to update new regulations, enhance knowledge and skills in recognizing clinical signs of incoming diseases, and the prevention and control protocols for specific aquatic animal diseases.

DOF Brunei Darussalam annually conducts training courses and on-the-ground awareness building for farmers and fisheries staff from the MTU and AAHSC on recognizing signs of the listed diseases, emerging diseases, or unexplained mortality. Pamphlets and posters on diseases related to the farmer's cultured commodities are distributed to help recognize any signs of diseases in their farms. To build national expertise on aquatic animal diseases, concerned staff are required to attend training courses on laboratory diagnostics every year.

Cambodia has established and enforced laws on reporting aquatic diseases. This action is supported by an equally aggressive campaign to raise awareness of the aquatic animal disease and health management. Competent officers, farmers, and even the public undergo several training and attend workshops at the central and provincial levels as part of the information dissemination and awareness programs. Additionally, the aquatic animal disease and health management officers produce manuals on fish health and disease management. Meanwhile, aquatic animal farmers are encouraged to adopt good aquaculture practices (GAqP).

Indonesia recognizes that public awareness of fish disease outbreaks is fundamental, particularly among farmers and stakeholders. They must understand how to prevent outbreaks, treat them, and eradicate diseases so that they can independently minimize mortalities, economic losses, and spread of disease to other ponds or farms. Public awareness is improved through national seminars and workshops, public counseling, and the distribution of brochures and leaflets in central aquaculture production in the Indonesian region.

In the Philippines, fisheries health officers are required to undergo training conducted by the NFLD on fish health management before assuming their designations. The NFLD staff act as resource persons in in-house training sessions as well as in workshops, fora, and formal training courses conducted by the regional offices and other government and non-government organizations. Training programs for staff development and capacity building are included in annual plans. Training courses on fish health management are also being offered by SEAFDEC/AQD. Fish health experts in the Philippines are often invited to join and collaborate for regional projects of the FAO, NACA, OIE, EU-TRTA, and other organizations on aquatic animal health.

For Thailand, the DOF regularly updates its websites where staff, farmers, industry stakeholders, and others get information on the disease status and events within or out of the country. AAHRDD and SAAHRC update publications and produce new ones annually. In case of severe disease occurrence, DOF experts and officers invite farmers to convene and discuss the measures to be undertaken.

In Viet Nam, training programs are being conducted focusing on topics that enhance the aquatic animal disease management capacity of veterinary officials from the central, regional, and provincial levels. These activities strengthen the capacity of the local aquatic animal health staff on legislation, disease surveillance and reporting, and response to disease outbreaks. Knowledge of veterinary epidemiology (*i.e.*, data analysis and disease warning), disease diagnosis, pathology, and biosecurity are strengthened during post-graduate education, in both local and international information-sharing networks.

Issues and Concerns

Cambodia has some issues on transboundary diseases for finfishes (*Gyrodactylus* sp., *Dactylogyrus* sp., *Argulus* sp., *Trichodina* sp., *Streptococcus* sp., *Aeromonas* sp.) and crustaceans (*Macrobrachium rosenbergii* infected by nodavirus/extra small virus (MrNV/XSV) and white spot syndrome virus (WSSV). Poor environmental conditions such as poor water quality in fishponds are regarded as one of the causes of persistent parasitic and bacterial disease problems and the emergence of new diseases.

In Myanmar, imported seeds including fish fry and shrimp larvae, are often of low quality and disease infected. The success of hatchery and farm operations is threatened due to poor management and the lack of technical know-how and technology that leads to disease occurrence. This situation has prompted the increase in the use of antibiotics and other chemicals which eventually increased environmental risks and highlighted the lack of adequate biosecurity control.

Although vaccines are already available in the market, vaccines for use in tropical food fish are limited and rarely used by small farms. Singapore is pushing for the use of autogenous vaccines, which are customized and herd-specific products. Although their efficacy is not assessed experimentally, the shorter development timeframe for such products is vital for the management of emerging diseases in food finfishes. There is still a need to develop regulations for the manufacture of autogenous vaccines and their use in tropical food finfish.

Several legislations that prohibit the use of antimicrobials have been issued by the responsible agencies in all AMSs. However, surveys still revealed the non-specific use of antimicrobials and other pharmaceuticals. The surveys imply that regulations and legislations are not properly implemented. The indiscriminate use of antimicrobials may lead to resistant strains of pathogens, thus resulting in the difficulty of treating diseases and the deterioration of the environment.

Although EPRS is already available in some AMS, its effectiveness still needs improvement through simulation exercises. There is also a need for the intensive training of individuals involved, including reiterating their roles and responsibilities.

Financial concerns seem to hamper the success of fish health management from disease diagnosis to EPRS. Brunei Darussalam mentioned that financial support is required to strengthen its EPRS. Cambodia fails to submit reports due to financial constraints, insufficient personnel, and training to improve the technical know-how in diagnostic capability and capacity.

Another issue that could hamper the success of fish health management is the insufficient awareness of the aquaculture industry players in matters related to aquatic animal health. There is a need to raise awareness among farmers of the importance of biosecurity measures, prevention of the spread of disease, local and import quality assurance (*e.g.* screening of stock, purchasing from accredited sources, and implementation of GAqP). Farmers are also not aware that not adopting GAqP which correlates to food safety and that the presence of food hazards in aquaculture products, could result in rejection in the international market and the banning of future export of products from the relevant country.

Way forward

The diverse educational backgrounds of farmers and their perception of the different aspects of aquatic animal health could be one of the challenges in fish health management. This concern could be addressed through regular conduct of activities on capacity building, information dissemination, and regular field consultation with local health officers. IEC materials are an efficient mode of awareness building since it can be illustrated, translated to local languages, and can be taken home by farmers for future reference.

Problems with transboundary and emerging diseases necessitate the formulation of new trade requirements within the region. Laboratory diagnostic capabilities and disease surveillance and monitoring programs should therefore be boosted. The existing networks reporting to WAHIS and Quarterly Aquatic Animal Disease (QAAD), and the transparent and prompt trans-national notification of new disease situations should be strengthened. The OIE and WAHIS system and QAAD reports to NACA are excellent platforms for the transparent reporting of country disease status. These systems will facilitate the timely notification of significant pathogen detections and the implementation of mitigation measures within the region.

Incorporation of water quality and other environmental issues in training courses, IEC materials, and laboratory services would help mitigate the effect of aquatic diseases. Aquatic animal health practitioners, as well as farmers, should understand the effect of environmental conditions on the general health of aquatic animals.

The capabilities of laboratory personnel in disease diagnosis can be enhanced through the twinning program of OIE. Personnel in satellite laboratories should also be trained for Level III diagnosis and equipment should be also upgraded in these laboratories.

7.1.3 Overcoming Fishmeal Dependence in Aquaculture

Fishmeal has traditionally been used as a primary source of protein in aquaculture feeds because of its high digestibility and well-balanced amino acid profile. Although global consumption has declined since its peak in 1996 (6.3 million mt per year), current rates are roughly three times of those 57 years ago and have been on a gradual uptrend since 2012 as shown in **Figure 100** (Indexmundi.com, 2021). The fishmeal consumption of the AMSs similarly peaked in 1999 at 1.9 million mt per year, before it gradually declined in subsequent years. In 2020, the AMSs collectively utilized 966, 000 mt of fishmeal accounting for more than 20 % of the global consumption rate.

The leading sources of high-quality fishmeal (Peruvian, Chilean, Danish) produced from small pelagic fishes like anchovies, scads, mackerels, herrings, and menhadens are the Latin American and the Nordic region. In Southeast Asia, Thailand and Viet Nam are the largest producers and exporters of fishmeal made from multispecies bycatch and trimmings (*e.g.* tuna) from the fish processing industry (Leadbitter, 2019).

However, the aquaculture feed industry's overdependence on fishmeal has both economic and ecological implications. Fishmeal is becoming more expensive as the rapid growth of the aquaculture feed industry pushes prices up. In Southeast Asia, trash fish or low-value fish bycatch are used as raw materials for fishmeal production as well as for human consumption, intensifying the demand for this resource strains the wild fisheries.

The adoption of alternative feed ingredients, especially protein sources, in aquaculture feeds is recognized as a viable option to reduce fishmeal overdependence and consequently to make fish farming more sustainable. Fishmeal substitutes and the status of their utilization in the region had been the focus of a consultative gathering of representatives from the AMSs in Myanmar in 2014 (Catacutan *et al.*, 2015). Besides utilizing alternative feed ingredients in feed development, feed management strategies should be taken into consideration as it can also affect the profitability of aquaculture operations.

Use of Aquaculture Feeds

Several commercially important species are cultured in the region and their feeding habits, dietary protein

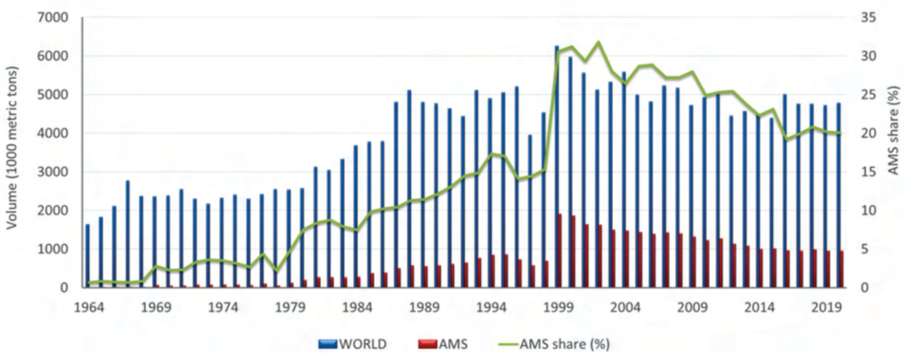


Figure 100. Fishmeal consumption of world and the AMSs from 1964 to 2020

requirements, and farming systems determine how much fishmeal is used in their diets. Herbivorous (*e.g.* milkfish, carps, and barbs) and omnivorous (*e.g. Pangasius* and tilapia) fishes require relatively lower dietary proteins (25–40 percent), therefore, the levels of fishmeal in formulated diets for these animals tend to be similarly low. On the other hand, carnivorous species (*e.g.* catfish, snakehead, sea bass, grouper, crabs, and shrimps) require high levels of dietary protein in their diets. These fishes are fed either raw low-value fish or aquaculture feeds which correspond to the nutrient requirement of the cultured fish species. Furthermore, low-value freshwater species are cultured in extensive or semi-intensive farming systems, relying mainly on natural food with occasional supplementation of plant-based feedstuffs such as rice bran. Species with higher commercial value, such as milkfish, tilapia, *Pangasius*, sea bass, and shrimps, are fed aquaculture feeds which are either manufactured domestically or imported from neighboring countries. Mangrove crabs and groupers are more often fed exclusively on fish bycatch.

Table 72. Aquaculture feed utilization of the ASEAN Member States

Country	Aquaculture feed utilization
Brunei Darussalam	With primary cultured species that include blue shrimp as well as groupers, Asian seabass, giant tiger prawn, pompano, snappers, jacks, tilapia, and milkfish (FAO, 2021) in intensive and semi-intensive types of culture in ponds, coastal and offshore cages, and recirculating aquaculture systems; most fish farmers require formulated feed inputs which are mainly imported
Cambodia	Freshwater aquaculture accounts for 90 percent of the total aquaculture production with *Pangasius* sp., snakehead, silver barb, cyprinids, gourami, and tilapia being the most cultivated species along with carps and catfishes as well as marine fishes such as Asian seabass and grouper (Somony, 2017; FAO, 2021); utilization of aquaculture feeds is limited due to high feed cost so farmers use farm wastes and by-products as well as "trash fish" either as sole feed or in combination with rice bran as a source of nutrition for the cultured fish (Joffre, 2019; Chankakada *et al.*, 2020)
Indonesia	Aquaculture production being dominated by Nile tilapia, milkfish, torpedo-shaped catfish, white leg shrimp, common carp, *Pangasius* sp., giant gourami, and giant river prawn (FAO, 2021) grown in ponds, paddy fields, and cages; demand for aquaculture feeds is large and continuously growing but the feed manufacturing industry relies significantly on imported materials such as fishmeal, soybean meal, corn meal, and blood meal driving up the cost of commercial feeds (Laining & Kristanto, 2015; Sarifin, 2017)
Lao PDR	Aquaculture is mainly centered on freshwater species such as tilapia, carps, barbs, catla, and rohu (FAO, 2021); requires commercial feeds for pond- and cage-cultured fish particularly tilapia while in other farming systems, supplemental feeding is done using local materials such as plant-based materials (rice bran, vegetables, corn, rice, cassava) and insects (Tammajedy, 2017)
Malaysia	With at least 40 cultured species that include whiteleg shrimp, tilapia, torpedo-head catfish, *Pangasius* sp., Asian sea bass, and giant tiger prawn that are being produced in significant volumes (FAO, 2021) in ponds, used mining pools, tanks, and cages; these commodities are fed locally-produced as well as imported formulated feeds (Yusoff, 2015; Manaf, 2017), but in hatchery operations, shrimp and fish broodstock are traditionally given raw, unprocessed maturation diets such as squid, polychaetes, fish, and bivalves
Myanmar	Aquaculture is dominated by rohu, silver barb, common carp, tilapia, and giant tiger prawn and at least 15 other species including catfishes, giant freshwater prawn, and marine fishes cultivated (FAO, 2021) in ponds and cages; fish farmers typically combine rice bran, peanut oil cake, sesame cake, cottonseed cake, rapeseed cake, soybean meal, mustard oil cake, and wheat bran to make daily feeds for most freshwater species, while tilapia, *Pangasius*, tiger shrimp, and sea bass are fed formulated feeds, and softshell mangrove crab and grouper are still heavily reliant on fish bycatch (Kyaw, 2015; Moe, 2017)
Philippines	The major cultured finfish and crustacean species such as milkfish, shrimp, tilapia, and mangrove crab with catfish, carp, siganid, grouper, freshwater prawn, and *Pangasius* sp. being produced in smaller volumes (Philippine Statistics Authority, 2020), are fed formulated feeds that are already commercially available for these species and are heavily used in cage culture and semi-intensive and intensive farming in ponds; some farmers rely on natural food while fish bycatch is still used in feeding mangrove crabs and grouper
Singapore	The majority of aquaculture production is from coastal farms with milkfish, mullet, Asian sea bass, grouper, snapper, and pompano as the favored species while land-based farms produce catfish, tilapia, snakehead, gourami, marble goby, and carps (Ong & Ong, 2015; FAO, 2021), which fed either "trash fish", commercial and farm-made formulated feeds, processed (confectionery) and by-products (plant waste, fish trimmings, poultry by-products); recent developments are now aimed at transforming fish farming into a more high-tech system (*e.g.* vertical aquaculture farm) to improve fish production (Shen *et al.*, 2020)
Thailand	The utilization rate of aquaculture feeds is high, with feeds for fish species comprising around 90 percent of the total aquaculture production costs (Krongpong, 2017) of cultured finfish and crustacean species that include whiteleg shrimp, giant tiger prawn, tilapia as well as catfish, carp, and giant freshwater prawn (Sampantamit *et al.*, 2020), which are fed four types of commercially accessible diets, *i.e.* for eight farmed species complete feed, concentrated feed, premixes, and supplemental, all of which are regulated by DOF Thailand
Viet Nam	The utilization rate of locally-produced aquaculture feeds is high given the intensive farming of the most economically important species, *Pangasius* sp. as well as black tiger shrimp, whiteleg shrimp, Asian sea bass, snakehead, carps, tilapia, and at least five more species in ponds, floating cages and rice-fish farming systems (Tuan, 2015; FAO, 2021), which are fed locally-produced feeds for all life stages of fish, particularly *Pangasius* sp., which are available commercially (Hasan *et al.*, 2019)

Table 73. Estimated feed demand (thousand mt) in 2017 and 2019 in selected ASEAN Member States

	2017			2019			Increase rate (%)
	Fish feeds*	Shrimp feeds	Total	Fish Feeds	Shrimp Feeds	Total	
Viet Nam	2,700	450	**3, 150**	4,560	1, 000	**5, 560**	76.51
Indonesia	1, 263	330	**1, 5963**	1, 460	352	**1, 812**	13.81
Thailand	495	450	**945**	613	478	**1, 091**	15.43
Philippines				275	100	**375**	
Malaysia	96	85	**181**	130	105	**235**	29.83

Source: *Merican, 2018; Merican, 2020*
**Includes feeds for freshwater and marine fishes*

The intensity of aquaculture feed utilization in the respective AMSs varies according to the level of aquaculture operations and the farming systems being practiced (**Table 72**). Some AMSs depend heavily on aquaculture feeds, particularly those engaged in intensive farming systems, while some have minimal usage.

The estimated feed utilization for species (*i.e.* Chinese carp, tilapia, catfish, shrimp, freshwater crustacean, milkfish, other marine and freshwater fish) typically grown in Southeast Asia increased dramatically from 2000 to 2017 posting an annual percentage rate (APR) of 8 percent per year (Tacon, 2020). From 2017 through 2025, this is expected to increase at a rate of 4.5 percent each year on average. Gains in feed utilization vary significantly among the AMSs (**Table 73**), with Viet Nam posting the largest rise between 2017 and 2019 (Merican, 2018; Merican, 2020). Overall, the feed consumption of the region's cultured commodities increased significantly, owing to the rapid rise of fed aquaculture.

Research and Development on Alternative Feed Ingredients

The Ministry of Maritime Affairs and Fisheries of Indonesia, in partnership with the FAO, launched the Aquafeed Self-sufficiency Movement from 2017 to 2019 to create an aquaculture feed supply chain that is independent of external inputs (FAO, 2020). The use of locally accessible ingredients had therefore been encouraged by the initiative to reduce production costs. Palm kernel meal (PKM), a byproduct of the country's massive palm oil industry, was investigated as a cost-effective aquaculture feed ingredient. This product can replace up to 20 percent of fishmeal in feeds. Other local ingredients utilized in farm-made feeds include copra meal, rice bran, duckweed, turi wheat (*Sesbania grandilflora*) leaf meal, detoxified *Jatropha curcas* kernel meal, and aquatic weed *Ceratophyllum* sp. Shrimp head meal and local fishmeal made from fish processing wastes had been particularly considered important as animal protein sources. Imported soybean meal is also widely used.

Malaysia has conducted extensive research into using fishmeal substitutes in aquaculture feeds (Manaf & Omar, 2015; Manaf, 2017). Agricultural resources and byproducts, as well as wastes from agro-industrial processing sectors like bone meal, blood meal, and chicken byproduct meal, are used as alternative protein sources in commercial and farm-made feeds. Plant protein sources (*e.g.* soybean, canola, wheat gluten, and pea) have been utilized successfully in omnivore fish diets, whereas poultry byproduct meal and shrimp head meal have been studied in carnivorous species diets. Single-cell proteins from microbial fermentation, food processing wastes, insect meal, bioethanol industry byproducts, and microalgae have also been investigated.

For several years, researchers in the Philippines have been studying alternative protein sources, including a wide range of locally available materials with the potential to replace fishmeal (Cruz *et al*., 2015, Mamauag, 2016; Aya, 2017). These include a variety of leaf and seed meals (*ipil ipil*, sweet potato, papaya, feed pea, and cowpea), aquatic weeds (water hyacinth, crinkle grass), food agricultural wastes (mango peels, citrus pulp, and peels), food processing byproducts (meat and bone meal, poultry byproduct and okara), processed raw materials (spray-dried hemoglobin meal, protein-enhanced copra meal and distiller's dried grains with solubles (DDGS)), microalgae (*Arthrospira platensis* and *Chlorella vulgaris*), and other unconventional feedstuffs (snail and earthworm). These ingredients had been tested in diets for marine and freshwater finfish and shrimp, giant freshwater prawn, and abalone.

In Singapore, studies on the use of food processing wastes such as okara (soybean curd residues) and fish trimmings revealed that feed made from these sources could complement commercial feeds for cost-effective snapper culture (Yihang & Ong, 2015). Recently, a commercial enterprise is pursuing large-scale production of the black soldier fly larvae meal as a source of protein for aquaculture feed and pet meals (The Fish Site, 2020). Because of its beneficial nutritional composition, insect meal is considered a good fishmeal alternative.

Research on the utilization of alternative ingredients in aquaculture feed in Thailand focused on replacing fishmeal with plant and animal protein sources in the diets of major cultured species (Kosutarak, 2015; Krongpong, 2017). These ingredients include soybean meal, sesame meal, palm kernel meal, peanut meal, coconut meal, poultry meal, pig meal, meat and bone meal, feather meal, silkworm meal, snail meal, and fish and shrimp hydrolysates. Although locally available, these are also utilized by other sectors (*e.g.* livestock, pet food, fertilizer, and biofuel) or consumed directly as human food. Thus, aquaculture feed manufacturers remain reliant on imported ingredients. The country is also a key fishmeal producer in the region and globally, although the issue related to illegal, unreported, and unregulated (IUU) fishing had a severe influence on the country's aquaculture feed sector (Leadbitter, 2019), highlighting the need for alternative feed ingredients.

In Viet Nam, locally grown and imported soybeans are widely used in commercial feeds (Tuan, 2015). According to studies, soybean meal may replace up to 80 percent of fishmeal in catfish diets, 30 percent in snakehead and knife fish diets, and 50 percent in pompano diets. Other imported plant protein sources include canola meal, corn gluten, peanut meal, cottonseed meal, and sunflower seed meal.

Aside from using alternative feed ingredients, the cultivation of low-trophic level species that require low protein levels in their diets is also promoted, as non-animal protein sources are efficiently utilized by these species. Likewise, feed management strategies have been studied to reduce feed costs and address pressing water quality issues from culture production. Skip feeding has been suggested as an economically and environment-friendly practice in the cage culture of Nile tilapia in the Philippines (Cuvin-Aralar *et al*., 2012). In addition, a biofloc-based aquaculture system has been demonstrated as a sustainable approach in the production of various farmed species such as giant freshwater prawn, Pacific whiteleg shrimp, and catfish (Cuvin-Aralar, unpublished data; Ekasari *et al*., 2019).

Fishmeal Substitution in Diets of Aquaculture Species

SEAFDEC/AQD research efforts in recent years have concentrated on finding alternative protein sources in milkfish, grouper, tiger shrimp, tilapia, giant freshwater prawn, and abalone diets to reduce feed costs. However, few studies have been done on the inclusion of plant-derived feed additives in aquaculture feeds for these species.

Supplementation of soybean meal and soy protein concentrate at 40 percent in a low fishmeal milkfish diet gave excellent performance against commercial feeds (Coloso, unpublished data). Meat and bone meal, when supplemented at 30 percent in the milkfish diet, promoted good growth and survival, and also showed no histological alterations in milkfish tissues (Catacutan *et al*., 2015). A previous milkfish feeding experiment verified the beneficial use of DDGS in milkfish diet formulation (Mamauag *et al*., 2017). Feed efficiency and growth in fingerlings of other species, such as grouper (*Epinephelus fuscoguttatus*) increased when fed a diet containing 10 to 15 percent hydrolysate from milkfish offal (Mamauag & Ragaza, 2016). In addition, fermented copra meal (PECM®, protein-enhanced copra meal) can entirely replace soybean meal in the diets of grouper juveniles (Mamauag *et al*., 2019). Furthermore, spray-dried hemoglobin meal can be utilized in pompano diets (Mamauag *et al*., 2021).

Tank- and lake-based cage feeding studies showed the potential of replacing fishmeal with cowpea meal in giant freshwater prawn feeds at 30 to 45 percent inclusion level (Aya *et al*., 2015). Also, beneficial utilization of agricultural wastes and byproducts have been tested in diets for freshwater fish such as Nile tilapia (Aya *et al*., unpublished data). About 30 to 45 percent of okara meal could replace fishmeal in the diet, as well as supplementation of one percent each of citrus peel and citrus pulp as feed additives promoted better growth performance of tilapia fingerlings. Meanwhile, tilapia fry production increased when broodstock diets were supplemented with 50 percent ensiled mango peel. Moreover, the inclusion of up to 75 percent processed meal from invasive knife fish (*Chitala ornata*), an introduced species in the Philippines, in the diet of Nile tilapia juveniles resulted in higher growth performance (Abarra *et al*., 2017).

Diet development studies in land-based tanks for the tropical abalone, *Haliotis asinina*, revealed that with a good binder, the marine sources of protein in formulations could be reduced with a significant increase in shell length and weight gain, potentially shortening the culture period (Bautista-Teruel *et al*., 2016). Evaluation of enriched *Ulva pertusa* also showed that this seaweed species could partially replace fish and soybean components of formulated feeds for juvenile abalone (Santizo-Taan *et al*., 2019), while raw and fermented meals derived from *Chaetomorpha linum* can be included in the diet of black tiger shrimp at six percent and 12 percent inclusion levels, respectively (Biñas, unpublished data).

Polychaete production research has also begun at SEAFDEC/AQD (Alava *et al*., 2017; Mandario, 2020), in acknowledgment of their ability to improve crustacean maturation and their potential as an alternative protein source in aquaculture feeds.

Issues and Challenges

Several issues and challenges have been recognized regarding the use of alternative sources as fishmeal replacements in the diets of various aquaculture species. Information on anti-nutrient factors, nutrient composition, pesticide residues, and quality are key considerations in utilizing plant-based feed ingredients. While several local sources had been identified and tested, production volume remains insufficient to support commercial-scale feed manufacturing. There is also limited information on the digestibility, amino acid composition, and appropriate dietary inclusion levels of many plant-based fishmeal substitutes. In addition, appropriate processing techniques to increase the nutritional composition of alternative ingredients that can be locally sourced needs further studies. Standards on the quality and safety of alternative feed ingredients specifically for use in aquaculture feeds have yet to be developed. Stakeholders interested in alternative protein sources have limited access to the results of feed development studies or the low adoption of these feed formulations by the commercial feed companies.

Way forward

Continued development of alternative feeds for economically important fish species in the region is necessary. Other raw materials that hold enormous potential in aquaculture feed formulation should be explored and evaluated under realistic farm conditions. These include biofloc meal, insect meal, aquatic weeds, and other agriculture and fisheries wastes and byproducts which could keep production costs down. Suitable equipment is also needed to process a huge amounts of these unconventional raw materials as feed ingredients. In this aspect, the collaboration between local government agencies, the academe, and research institutions is encouraged to develop low-cost equipment to process these materials into utilizable feed ingredients.

In 2018, SEAFDEC/AQD initiated the development of a database on alternative feed ingredients (http://afid.seafdec.org.ph). This initiative is a crucial step to collate and exchange information among the AMSs on the emerging alternative feed ingredients with promising use in aquaculture feeds. At present, the database covers information from at least 70 published papers. This will be constantly updated for there are many new and novel protein sources that are successfully applied to replace fishmeal in aquaculture feeds. In fact, a lot of alternative plant-based protein sources are continuously produced with the help of biotechnology. Research efforts should also address the application of emerging protein and lipid sources in aquaculture feeds and their effects not only on the biological performance but also on the fish health and quality of farmed species. Also, appropriate processing treatments to enrich the nutritional value of locally available indigenous protein sources should be applied and their suitability, viability, and profitability tested in diets of farmed species to promote cost-effective feeds for fish culture. Therefore, cooperation and collaboration among the AMSs, specifically the research and development institutions, private sector, and the academe both at the national and local levels, in several areas of research in fish nutrition and feed development should be strengthened, especially now that biotechnology is employed in producing cost-effective feeds. It is also of paramount importance that the promotion of alternative feed ingredients and sound feeding management practices be integrated or addressed in synergy in future feeds and feeding studies, the results of which should be disseminated to small-scale fish farmers engaged in fish culture. Other policies recommended for the AMSs on overcoming the dependence on fishmeal by development and use of alternative dietary ingredients in aquaculture feed are shown in **Box 34**.

Box 34. Recommended policies on the use of alternative dietary ingredients in aquaculture feeds

- Develop national standards on alternative feed ingredients, including the protocols for detecting contaminants in alternative feed ingredients and aquaculture feeds
- Increase regional and local awareness of the importance of reducing aquaculture's reliance on fishmeal and "trash fish" as major protein sources for aquaculture species
- Create a network involving food (fish and fruit) processors and aquaculture feed millers at the national and local levels to determine the volume of wastes and byproducts generated from the primary food processing industries and their potential use in aquaculture feed production
- Strengthen collaboration among the government sector (particularly the policymakers), research and development institutions, and the private sector (feed industry and farmers) on initiatives related to identification, development, promotion, and mass production of alternative protein sources
- Implement programs on the proper processing techniques of alternative feed ingredients to maximize their use in aquaculture feed formulations that small-scale fish farmers can adopt
- Compile and disseminate information on available alternative plant products through training programs as well as traditional and online information-sharing platforms
- Conduct field trials involving farmers, extension workers, and feed millers to demonstrate the effectiveness of using alternative ingredients in formulated feeds

7.1.4 Production and Dissemination of Good Quality Seedstocks

Aquaculture continues to lead aquatic food production globally (FAOa, 2019) with over 90 percent (102.9 million mt) of global aquaculture production is supplied by Asia in 2017. Southeast Asia plays a significant role in food security, with freshwater fish accounting for 30 percent of the aquaculture production. The region continues to move towards intensified farming of high-value aquaculture species (*e.g.* shrimp, mangrove crab, seabass, grouper, pompano, among others), which was previously dominated by low-trophic herbivorous fish (*e.g.*, milkfish, tilapia, siganid, carp).

With the diminishing production of capture fisheries over the years, the focus has shifted to the aquaculture industry in order to respond to the increasing demand for fish, thus, requiring increased area and intensified production. However, propelling this strategy has resulted in increased production cost from feed inputs, deterioration of the environment (land and water), an outbreak of viral and bacterial diseases, and reduced quality of seedstocks. Extensive research and development on replacing fish meal and oil to attain sustainability, disease diagnostics and therapeutics, development of intensive yet sustainable aquaculture systems, and adoption of a plausible genetic program should be accomplished and straightforwardly applied to the aquaculture industry.

Seed Production

- ***Marine Fish***

Seed production technologies have been established for a range of economically valuable species of marine finfish in the region through research and development. Among those species with life cycles that have been successfully closed in captivity and can be mass-produced in hatcheries include milkfish (*Chanos chanos*), groupers (*Epinephelus* spp.), Asian sea bass (*Lates calcarifer*), snapper (*Lutjanus* spp.), mullet (*Mugil* spp.), rabbitfish (*Siganus* spp.), and carangids such as pompano and trevally. While milkfish farming today is primarily based on hatchery-bred fry, farming of other marine species in the region relies partially or entirely on wild-captured seeds. However, the production of a sufficient volume of marine seeds is constrained by a number of issues surrounding captive breeding and larval rearing. Captive breeding of marine fish requires high investment and operational costs, which is beyond the means of most small-scale farmers.

In Indonesia, the government has established a centralized captive breeding facility for milkfish to supply eggs for subsequent larval rearing in small backyard hatcheries. The system proved to be successful in ensuring a sufficient supply of milkfish fry, which also allowed the country to mass produce groupers and other marine fish. The high investment cost of breeding most marine fish is partly due to their late sexual maturity, which requires a long period of broodstock conditioning. For instance, milkfish, groupers, and the Asian sea bass attain sexual maturity at the age of 3–5 years. Some studies were undertaken at SEAFDEC/AQD to advance the onset of puberty in marine fish to breed with younger and even smaller broodstock. Reproductive hormones, such as gonadotropin hormone-releasing hormone (GnRH) and follicle-stimulating hormone (FSH), administered through injection or feeding effectively advance the gonadal development in juvenile grouper (Palma *et al*., 2019a, 2019b; Nocillado *et al*., unpublished).

Moreover, the low larval survival of marine fish remains a bottleneck in its mass seed production. Most marine fish larvae, such as groupers, have small mouths, thus the choice of initial live feed is limited. The SS-type rotifer (*Brachionus rotundiformis*) is widely provided as an initial live feed for marine fish larvae although the survival rate has been relatively low and inconsistent. Several species of minute rotifer belonging to the genera *Proales*, *Colurella*, and *Lecane* have been isolated and evaluated for their potential as an initial live feed. *Proales similis* improve the survival of grouper larvae when provided in combination with *B. rotundiformis* in the first 10 days of rearing. Development of mass production techniques for *P. similis* and its application to other species of marine fish larvae is ongoing at SEAFDEC/AQD. For copepods, despite its excellent nutritional value and established suitability as live feed for marine fish larvae, use in aquaculture remains uncommon because of limitations in the production system. To improve nutritional value, especially the fatty acid profile of live prey, short-term enrichment methods have also been developed and applied for marine fish. These enrichment preparations have also been utilized for thyroid hormone manipulation to hasten metamorphosis in marine fish larvae, a critical period in which larvae are highly sensitive to environmental disturbance. At SEAFDEC/AQD, iodide supplementation has shown to accelerate metamorphosis in rabbitfish larvae (Cabanilla-Legaspi *et al*., 2021a).

Viral disease outbreaks remain a major problem in marine fish farming, particularly viral nervous necrosis (VNN) which significantly impacts larval survival. Methods to vaccinate marine fish larvae against nervous necrosis virus (NNV) have been developed through immersion or feeding of live feed bioencapsulated with the vaccine. At SEAFDEC/AQD, a vaccination regimen for marine fish breeders was established to prevent vertical transmission of NNV thereby allowing the production of NNV-free seeds from infected breeders (Pakingking *et al*., 2018).

Molecular markers have been developed for several marine fish in the region, including milkfish, sea bass, and groupers which can be applied in breeding programs. Yet, in contrast to the success in freshwater finfish, particularly tilapia, breeding programs in marine fish is difficult due to the challenges in captive breeding as mentioned above and thus not commonly applied in the industry. Most marine fish hatcheries in the region continue to utilize wild-caught breeders.

In the Philippines, one of the most economically viable marine species kawakawa (*Euthynnus affinis*) is being observed as a possible commodity for aquaculture. The full-cycle farming technology from Ehime Prefecture in Japan would be adopted. The Philippines has the optimum conditions for rearing kawakawa as it requires a warmer temperature (around 20–28 °C) to achieve rapid growth. Currently, SEAFDEC/AQD is conducting studies to determine the reproductive biology, feeding habits, and migration patterns of kawakawa. Subsequently, the techniques for broodstock management would be established (Cabanilla-Legaspi *et al*., 2021b).

- ***Crustaceans***

Mangrove crab

Mangrove crab belongs to the genus *Scylla*, which comprises four species, namely: *S. serrata*, *S. tranquebarica*, *S. olivacea*, and *S. paramamosain*. The first three are commonly found in the Philippines, while *S. paramamosain* is common in Viet Nam, Indonesia, and Thailand. The rising global demand for mangrove crabs and ecological threat to its natural population paved the way towards the development of a culture technology in Southeast Asia.

In Malaysia, *S. olivacea* is the most abundant mangrove crab species, while the presence of *S. paramamosain* is relatively low, while *S. serrata* is not recorded (Naim *et al*., 2019). Although *S. paramamosain* is scarce, it is favored for culture as it can reach the market size after only three months of culture. Hence, the breeding and larviculture technology of *S. paramamosian* was developed in Terengganu, Malaysia. Results showed that 80 to 90 percent of the broodstock spawned while the survival rate from larva to crablet was 5 to 10 percent. It should also be highlighted that biosecurity measures should be properly observed to prevent mortality caused by fungal, bacterial, and protozoal infections (Khoa & Harrison, 2019). In order to develop inter-species breeding among mangrove crabs, the study of Fazhan *et al*. (2017) of the Institute of Tropical Aquaculture, Universiti Malaysia Terengganu, showed that mating among all three *Scylla* species (*S. olivacea*, *S. tranquebarica*, and *S. paramamosain*) is feasible in captivity. *S. tranquebarica* and *S. olivacea* showed the highest versatility in selecting other species as mating partners. However, *S. paramamosain* preferred their own species to mate and choose other species only when other choices are unavailable. This information is important in developing a protocol for the breeding and seed production of mangrove crab hybrids. Consequently, it also serves as baseline data for future studies on the spawning and hatching of hybrid larvae.

In the Philippines, *S. serrata* is preferred for culture because it is fast growing. At SEAFDEC/AQD, existing hatchery protocols for *S. serrata* are continuously refined to improve the production of the seedstock. As a result, crablet production doubled from 1 percent in 2017 to 2 percent in 2019. In addition, the average survival from zoea 1 to crab instar continued to improve such that a 10 percent survival rate has been achieved. A total of 7.3 million newly-hatched larvae had been produced in the hatchery, which generated 656,200 pieces of crablets and 581,040 pieces of which were sold to local stakeholders. The increase in survival was attributed to reduced frequency of antibiotic application, increased feeding frequency starting the megalopa stage, and frequent water exchange (SEAFDEC/AQD, 2019). Additionally, the SEAFDEC/AQD formulated *Tetraselmis* paste showed promising results in producing rotifers compared to live and commercially available paste thus, a good alternative to live algae in the hatchery rearing of *S. serrata* seedstock (SEAFDEC/AQD, 2019). For quality assessment, exposure of newly-hatched *S. serrata* larvae to 40 mg/L formalin for 3 hours, also known as a formalin stress test, appeared to be a reliable and practical method for selecting good quality larvae for culture (Quinitio *et al*., 2017). It has also been observed that *S. serrata* juveniles developed morphological deformities upon exposure to antibiotics during the larval stage. As such, antibiotic use in larviculture should be eliminated, and search for potential alternatives could be pursued (Pates *et al*., 2016).

In Thailand, *S. olivacea* is considered high-value crustacean species due to its tasty meat and ovary. Consequently, its dwindling natural population has been observed due to overexploitation. To ensure the production of gametes and larvae in captivity, Khornchatri *et al*. (2019) studied the endocrine controls involved in reproduction which is the first step in successfully breeding *S. olivacea*.

Although the successes in mangrove crab hatchery operations had been reported in some countries, the production of its larvae remained low as most hatcheries face inconsistent survival rates from zoea to crablet stages. This problem is often attributed to the difference in the quality of newly-hatched larvae due to the multiplicity of broodstock sources, mass mortality caused by "molt death syndrome" during the transition from zoea 5 to megalopa stage, lack of suitable larval diets, fungal and bacterial infections due to non-compliance with biosecurity measures, and lack of species-specific culture protocol.

Penaeid shrimp

The global production of farmed shrimp is consistently growing at a rate of 6 percent annually, with a global trade estimated at USD 28 billion per year (FAO, 2020a). Among the crustacean species, the white leg shrimp (*Penaeus vannamei*) occupied the world's top aquaculture production by volume in 2020. Meanwhile, shrimp aquaculture in the region is dominated by *P. vannamei* and *P. monodon*.

In 2017, SEAFDEC/AQD initiated the revival of the giant tiger shrimp (*P. monodon*) industry under the banner program called "*Oplan Balik Sugo*" (Operation Black Tiger Shrimp Revival). The program aims to bring back the once-booming tiger shrimp industry in the Philippines through the production of high-quality post larvae (PL) in the hatchery. This initiative can be achieved through an effective breeding program using specific pathogen-free (SPF) broodstock and disease-resistant PL. Hence, the biosecure hatchery complex was built at SEAFDEC/AQD to support the breeding program of *P. monodon*. In 2019, hatchery-produced PL of *P. monodon* was stocked in SEAFDEC/AQD's Dumangas Brackishwater Station (DBS) ponds for grow-out culture, yielding harvests of about 2.8 mt with 93 percent survival after 113 days in the 5,000 m^2 pond and 4.4 mt with 89.7 percent survival after 120 days in an 8,000 m^2 pond in October and November, respectively.

During the Regional Meeting on Agricultural Biotechnologies in Sustainable Food Systems and Nutrition in Asia-Pacific of the Food and Agriculture Organization of the United Nations (FAO) in 2017, the Chulalongkorn University of Thailand presented its work on RNA-sequencing analysis to identify differentially expressed genes in response to infectious diseases and candidate markers associated with disease resistance in *P. vannamei*. The aim of the efforts was to assist selective breeding of disease resistance shrimp lines and develop a platform to evaluate the health status of shrimp based on gene expression profiling. Furthermore, data on shrimp hatchery surveys in Thailand showed that controlling temperature with larger tanks and probiotic supplementation improved the survival rate of shrimp postlarvae (Nooseng, 2019). The potential of inactivated vaccines (Amar *et al*., 2020) and RNAi (Amar *et al*., unpublished) in improving the growth and survival of *P. monodon* has also been shown in experiments conducted at SEAFDEC/AQD.

Flathead lobster

Lobsters are known as high-value seafood and its demands inspired the development of aquaculture techniques for the species, particularly the flathead lobster (*Thenus orientalis*). There are very few attempts to conduct full-cycle aquaculture for lobsters in Southeast Asia, and due to the interest of entrepreneurs, sourcing seeds from the wild is being widely practiced in Indonesia, Philippines, and Viet Nam (Radhakrishnan, 2015). SEAFDEC/AQD is currently conducting R&D activities to develop breeding and farming techniques for this lobster species as the availability of healthy and quality seeds is still a major constraint. This project conducted in Iloilo, Philippines by SEAFDEC/AQD aims to promote the local lobster production industry that is not fully dependent on capture fisheries (Ursua *et al*., 2021).

Freshwater species

Freshwater aquaculture in Southeast Asia has long been dominated by tilapias (*Oreochromis* spp.), carps (Cyprinidae), and catfishes (*Clarias* spp.). The successful culture of these fish species is mainly associated with the early establishment of the aquaculture system. Early genetic improvement initiatives using either or both conventional and advanced genetic techniques have progressed the production of high-quality seedstocks from these species (Eknath *et al*., 1993). Hence, genetically improved broodstocks are well developed and available in different parts of the region.

The success of the catfish industry in Indonesia can be attributed to the effective national breeding program, which resulted in several superior strains of catfish. The initiative was driven by the decreasing reproductive performance of cultured catfish in the country, which was mainly linked to poor broodstock management and improper farming methods. At present, the outputs of this genetic improvement program are widely used in the country (Gustiano *et al*., 2021).

Similarly, the development of tilapia strains of desirable traits (*e.g.*, fast growth and saline tolerance) resulted in various strains of this species in the Philippines. The impact of these tilapia technologies on the availability of good quality seedstocks and advancement of freshwater aquaculture, overall, is not just within the bounds of the region but stretches wide to other parts of Asia and America (Worldfish, 2015). However, challenges such as the decreasing tilapia seed production brought about by the increasing water temperature and the reported mismatch between the species of maternal origin and present-day offspring of the genetically improved strains threaten the potential of these technologies.

To increase the spawning rate and seed production of tilapia in a pond-based hatchery system during summer months, the aquashade technology (*i.e.* partial, complete shading, or roofing of ponds using nets) for tilapia broodstock is applied to reduce the water temperature by as much as 3 °C. As per the issue of the genetic purity and integrity of improved tilapia strains, several technical and non-technical interventions can be applied, such as but are not limited to: a re-evaluation of the improved strains and development of effective broodstock management. Re-evaluation of the effectiveness and genetic gains from these strains should be emphasized (Ordonez *et al*., 2017) and regularized as part of the entire genetic improvement program. Likewise, a more effective center to farm-level broodstock management protocol should be developed as it is critical in the continuity of genetic gains, which ensure the quality of seeds from these improved strains (Hulata *et al*., 1986; Macaranas *et al*., 1995).

Furthermore, giant freshwater prawn (*Macrobrachium rosenbergii*) is expected to play a significant role in regional aquaculture production due to the recent development in neo-female broodstock technology wherein functional females can produce all-male progenies. This can be achieved using either microsurgical ablation of the androgenic gland or silencing of the sexual-differentiation gene. Currently, Thailand is taking the lead in improving this species by applying modern genetic techniques (*i.e.*, gene silencing technology). In contrast, SEAFDEC/AQD is exploring the potential of the earlier technology, ablation-derived neo-female broodstock, to improve the quality of seedstocks in the Philippines.

In general, technologies developed for the farming of freshwater species have played significant roles in sustaining the availability of good quality seedstock in the region. Apart from the need to further explore the nutritional aspects of freshwater species, mitigating the effect of stressful conditions, and developing or adopting efficient breeding programs, regularly evaluating the effectiveness of genetically improved strains, and implementing stricter and more effective schemes in broodstock management are relevant interventions to ensure the availability and sustainability of quality seedstocks.

- ***Mollusks***

Mollusks contribute about 21.3 percent (17.5 million mt valued at USD 34.6 billion) of the world aquaculture production (FAO, 2020b), while Asia accounts for about 92 percent of mollusks production in the world (FAO, 2020a). Major countries in Southeast Asia actively farming mollusks are Cambodia, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam. The major mollusk species groups of commercial significance in the region are abalone (*Haliotis* spp.), green mussel (*Perna viridis*), oysters (*Crassostrea iredalei* and *Crassostrea* spp.), and blood cockle (*Anadara granosa*). While the farming of these species persisted for decades, the method of obtaining seeds is largely dependent on the wild. Meanwhile, efforts have been made on the hatchery and seed production in some of these species aimed at providing a sustainable supply of quality seeds to farmers.

Abalone

Abalone is a high-value seafood commodity in the region and is one of the most highly-priced delicacies with a significant value despite its relatively small production quantity. The bulk of production is contributed by Malaysia, Philippines, and Thailand (FAO, 2020b; Cook, 2014). In the Philippines, the species *Haliotis ovina*, *H. glabra*, *H. varia*, and *H. asinina* are commonly found, the latter being the most abundant. SEAFDEC/AQD has been into large-scale seed production of the donkey's ear abalone (*H. asinina*), and the research focused on increasing juvenile yield through feeding the appropriate diatom strain, supplementation with microparticulate diet, and application of anesthetics. Similarly, the effect of seaweed quality and enrichment (Santizo-Taan *et al*., 2020) on broodstock, larval, and juvenile performance has also been evaluated. The five percent improvement in seed production is attributed to the increase in diatom feeding. Out of about 3.80 million trochophore larvae produced, 47 percent (about 1.80 million larvae) developed into the veliger stage. A total of 61,137 early juveniles with 3–8 mm shell length had also been produced in the hatchery (SEAFDEC/AQD, 2019). Despite the established culture techniques for abalone, its aquaculture remains stagnant. One of the reasons could be the lack of information on good sources of quality abalone broodstock and seedstock. Hence, Romana-Eguia *et al*. (2019) conducted a study aimed at generating a preliminary database on possible sources of genetically diverse *H. asinina* stock. In the study, samples from one hatchery-bred and nine wild-sourced founder stocks and their F_1 offspring were analyzed for genetic variability using microsatellite markers. The information generated from this study will be used to identify local stocks most suitable for breeding and farming. Furthermore, Indonesia is exploring the potential of probiotics supplementation to enhance the growth and survival rates of juvenile abalone (Amin *et al*., 2020).

Green mussel

Mussels had been one of the major mollusk groups extensively cultured in Southeast Asia with Indonesia, Philippines, and Thailand contributing significantly to the global aquaculture production (FAO, 2020a). Although the thriving culture of this species relies on the collection of seeds from the wild, there are initiatives to establish the seed production technology for this species in response to the observed decline in production trend brought about by the diminishing natural spatfall. In the Philippines, initial studies had been conducted on the establishment of a mussel hatchery, where conditions are optimized to attain: high fertilization success and survival to the D-hinged stage (Piñosa *et al*., 2020); high growth and survival from D-hinged to pediveligers (Apines-Amar *et al*., 2020); and high survival and settlement rates and bigger spats (Mero *et al*., 2019). The result of preferential feeding trials showed that mussels fed on *Isochrysis galbana*, *Chaetoceros calcitrans*, and *Tetraselmis tetrahele* (Maquirang *et al*., 2020) with a combination of *I. galbana* and *C. calcitrans*, supported better growth and higher survival (Apines-Amar *et al*., 2020). In Myanmar, an experimental larval rearing of *P. viridis* was also initiated. The study demonstrated that penicillin and streptomycin resulted in a higher growth and survival rate of *P. viridis* (Nwe, 2020).

Oysters

Farming of tropical oysters *C. iredalei* and other *Crassostrea* spp. have been practiced in the region for decades. Almost all oyster aquaculture in Southeast Asia relies heavily on wild spats, unlike the oyster aquaculture in temperate and subtropical countries that increasingly access hatchery-produced spat. In recent years, however, the Southeast Asian countries have progressed towards artificial propagation of oyster seed in hatcheries as a consequence of the diminishing, unsustainable, and unreliable spatfall from the natural environment. Experimental and commercial oyster hatchery operations were reported in Malaysia (Tan *et al*., 2014), Philippines (Madrones-Ladja *et al*., in press), Thailand (Day *et al*., 2000), and Viet Nam (O'Connor *et al*., 2012). The potential of hatcheries to provide supplementary sources of oyster spat to sustain small-scale farmers and businesses is still on its burgeoning stage in the region. More so in Viet Nam, where the oyster industry has developed and thrived as a result of the development of oyster seed supply. Genetic techniques to improve seed quality, such as triploid induction, are also being explored (O'Connor *et al*., 2012). Furthermore, recent developments to move forward the hatchery seed production of oysters is the continued investigation on the genetic improvement program for this mollusk species group, particularly in Viet Nam (Vu *et al*., 2020). On the other hand, Malaysia evaluated the aquaculture potential of inter- and intra-specific crosses between *C. belcheri* and *C. iredalei* (Wan Nawang *et al*., 2019).

Way Forward

The rapid growth of aquaculture production in the region requires a sufficient supply of seedstocks, especially marine seeds, given the expansion or shift towards mariculture. Sustainable seed production can be achieved through genetics-based breeding programs to ensure the selection and maintenance of genetically variable breeders through successive generations capable of producing seedstocks that are healthy, fast-growing, and resilient to diseases and environmental stresses. Breeding programs are strongly practiced among freshwater species, particularly tilapia, which allowed the development of various strains with superior growth performance. For marine crustaceans, particularly penaeid shrimps, significant threats from viral diseases have forced similar breeding programs to ensure the availability of disease-free spawners and seeds. Such breeding programs are uncommon in the marine fish industry given major issues that persist in captive breeding. Research and development activities are underway to circumvent the reproductive difficulties surrounding marine fishes although technologies take considerable time to be established. The consolidated progress of genetics, fish health management, intensified culture system, and cost-efficient feed program can lead the way in creating a more sustainable aquaculture production in the succeeding decades. Non-technical intervention from the government is needed to address the gap. The centralized breeding facility for marine fish to supply backyard hatcheries proved efficient in enabling mass seed production. Enabling policies and incentives should be promoted to encourage more operators to venture into the production of seedstocks.

7.1.5 Production of Safe and Quality Aquaculture Products

As the human population continues to grow, coming with it is the greater demand for food. Aquaculture is the fastest-growing food source, and the industry tries to catch up with demands through rapid intensification. However, this intensification has resulted in the occurrence of diseases and degradation of the environment. Farmers have resorted to using antibiotics as therapeutants to prevent and treat diseases. Chemicals and products that have claimed to improve water and soil quality or strengthen the immune system of shrimp and fish had been introduced into the market. Also, fish farmers have been using different kinds of feed (live and manufactured), which could be contaminated with harmful chemicals and zoonotic organisms. Moreover, the indiscriminate use of antibiotics could result in antimicrobial-resistant strains of bacteria. These antimicrobial-resistant genes can be transferred horizontally from aquatic to terrestrial to human and vice versa, affecting the organisms and the environment. Some countries are stricter to the point that detection of drug residues in imported aquaculture products means rejection. Consequently, the production of safe and quality aquaculture products is a challenge to fish farmers, and the current trend is towards responsible aquaculture through ecosystem approaches for the production of safe and quality aquaculture products.

Safe and quality aquaculture products

Recognizing the threat that antimicrobial resistance (AMR) brings, the Food and Agriculture Organization of the United Nations (FAO) implemented a project on the prudent and responsible use of antimicrobials in fisheries and aquaculture in 2017. The project was aimed at developing and enhancing the knowledge, skills, and capacity of the participating Competent Authorities (CAs) on fisheries and aquaculture; and assisting the CAs to develop and implement policies and national action plans (NAPs) on the prudent and responsible use of antimicrobials.

Recognizing the importance of detection protocols for different food hazards, the SEAFDEC/MFRD and the SEAFDEC/AQD with funding from the Government of Japan, developed standardized methods of their detection. Laboratory manuals on the detection of antibiotic and pesticide residues were published including oxolinic acid and oxytetracycline/tetracycline/chlortetracycline by high power liquid chromatography (HPLC)-fluorescence method in 2004; 29 pesticides residue using gas chromatography in 2004; and chloramphenicol and nitrofurans using liquid chromatography-tandem mass spectrometry (LC-MS/MS) method in 2005. SEAFDEC/MFRD also produced three Technical Compilations, namely: 1) Heavy Metals, Pesticide Residues, Histamine and Drug Residues in Fish and Fish Products in Southeast Asia 2004-2008; 2) Biotoxins Monitoring in ASEAN Region 2009-2012; and 3) Traceability Systems for Aquaculture Product in the ASEAN Region 2010-2015. Moreover, two regional guidelines were developed by SEAFDEC/MFRD, namely: 1) Traceability System for Aquaculture Products in the Asian Region and 2) Cold Chain Management of Fish and Fishery Products in the ASEAN Region. Aside from manuals on antibiotic and pesticide residue detection, SEAFDEC/AQD also published a manual on antimicrobial sensitivity tests including bacterial isolation and identification techniques in 2004. SEAFDEC/AQD acquired an atomic absorption spectrophotometer for the detection of heavy metals and metallic elements. Detection of different foodborne pathogens using polymerase chain reaction (PCR)-based methods were also reported such as *Escherichia coli* (2008), *Salmonella* spp. (2008), *Shigella* spp. (2010), *Staphylococcus aureus* (2010), and *V. Cholerae*

(2010). Detection protocols or kits for other food hazards, such as histamine, have also been made available.

To assist the exporting countries in designing and implementing food safety guidelines and protocols that comply with the European Union (EU) requirements, the EU organized the Regional Workshop on Safety of Aquaculture Products in 2018. Attended by the representatives from the AMSs and lecturers from Europe, the Workshop included lectures, hands-on training, case studies, and discussions geared toward bringing participants in a position where they could identify the gaps and non-compliances in their national systems, thus, contributing to improved and reinforced sanitary and phytosanitary frameworks necessary in the respective AMSs.

In order to obtain updates on the current aquaculture practices in the region, SEAFDEC/AQD organized the International Workshop on the Promotion of Sustainable Aquaculture, Aquatic Animal Health, and Resource Enhancement in Southeast Asia (SARSEA) in 2019. With funding from the Government of Japan, the Workshop was attended by representatives from the AMSs reporting on the status of their respective practices on sustainable aquaculture, aquatic animal health, and resource enhancement, including pressing issues, gaps, possible strategies, and recommendations. The country paper presentations were followed by a workshop that identified problems and issues in realizing sustainable aquaculture. Some of the issues focused on food safety, traceability of aquaculture products, non-compliance to good aquaculture practices (GAqP), ecolabelling, and environmental degradation.

To address the environmental and food safety issues arising from aquaculture practices, several research and verification studies related to the production of safe and quality aquaculture products that maintain the integrity of the environment have been carried out by SEAFDEC/AQD. Studies on responsible aquaculture through ecosystem approach are on mangroves to purify farm effluents, greenwater culture system, integrated multi-trophic aquaculture (IMTA), and biofloc technology (BFT). Other studies are on the implementation of biosecurity measures. Lectures on GAqP, food safety, and biosecurity measures have been incorporated into the training courses offered by SEAFDEC/AQD.

Good Aquaculture Practices

GAqP is a series of considerations, procedures, and protocols designed to foster efficient and responsible aquaculture production and expansion, to help ensure final product quality and safety, as well as environmental, economic, and social sustainability. GAqP implies the

Table 74. Steps in aquaculture production relevant to GAqP and Food Safety that farmers generally practice

Steps	Practices
Site selection	Sites that are near residential areas (presence of human wastes, chemicals), near other farms, both agricultural (presence of runoffs, pesticides, fertilizers, manures) and aquaculture (due to contaminated water; disease transmission), near industrial establishments (presence of heavy metal contamination, PCBs), and near forest reserves are avoided, while water sources are checked to make sure that these are free from contaminants or food hazards
Pond design and construction	Ponds are designed to have separate water inlets and outlets, and are provided with a reservoir to stock water before use in ponds; and settling ponds to receive pond effluents before draining water to the sea; while some shrimp farms incorporate shrimp toilets in their ponds
Pond preparation	Pond preparation involves a series of activities that provide a contaminant-free environment to the organism to be cultured, making it safe for human consumption, and some of these activities include: • *Sludge removal*. Sludge is removed as this could contain toxic substances, high organic load, and microorganisms that contaminate the cultured organisms • *Plowing or tilling*. Plowing or tilling helps in the breakdown/oxidation of organic residues and other toxic substances that the cultured organisms may assimilate • *Liming*. Liming is carried out to kill any biological food hazards
Seed stock	Seed stocks are obtained from areas not contaminated with any food hazards
Water management	Water coming in and out of the culture pond is filtered and treated
Feeding	Feeds and feed ingredients are free from unsafe levels of biological, chemical, and physical contaminants and/or other adulterated substances, while all ingredients used must be free from prohibited substances
Grow out culture or production technique	The use of drugs is avoided, and in cases where drugs are used, the recommended withdrawal period is observed to avoid detection of drug residues in the aquaculture products, while the culture environment adapted to the species raised is maintained at all phases of production, and specifically: • Stock and environmental conditions are routinely monitored for early detection of aquatic animal health problems • Management practices implemented are those that reduce the likelihood of disease transmission within and between aquaculture facilities and natural aquatic fauna, and reduce stress on animals for the purpose of optimizing health
Harvest and post-harvest	Make sure that fish are free of antibiotics and other residues before these are harvested, while the harvested products are immediately washed and iced to avoid accelerating the spoilage process

production of safe aquaculture products for human consumption that also addresses environmental, economic, and social sustainability for on-farm processes, resulting in safe and quality food and non-food agricultural products. Steps in aquaculture production are important factors in delivering safe aquaculture products to the consumers and environmental sustainability. Some of these factors relevant to producing a safe and quality aquaculture product generally practiced by farmers in Southeast Asia are presented in **Table 74**.

Furthermore, in order to yield safe and quality aquaculture production, efforts toward the development of novel technologies, the introduction of innovations, and the establishment of systems continue. For example, aquaculture mimicry or aquamimicry is a concept where natural estuarine conditions are simulated in culture ponds. This is facilitated by establishing zooplankton blooms, mainly copepods, and beneficial bacterial populations to improve and maintain water quality. The plankton serves as supplemental feed to the cultured organisms. Aquamimicry has been used for shrimp farming in Brunei Darussalam, Indonesia, Malaysia, Singapore, and Thailand.

Aquaponics combines traditional aquaculture (fish, prawns) with hydroponics (cultivating plants in water) in a symbiotic environment. Effluents from aquaculture are filtered out by the plants as vital nutrients, after which the cleansed water is re-circulated back to the ponds. Aquaponics is practiced by most Southeast Asian countries such as Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Biofloc technology or BFT uses aggregates microbial communities of bacteria, algae, or protozoa, and living or dead particulate organic matters, and involves the manipulation of carbon to nitrogen (C:N) ratio to convert toxic nitrogenous wastes into useful microbial protein that serves as food to fish while water quality is improved. A carbon source is usually added to the culture water, such as cassava, rice bran, and molasses. BFT helps improve water quality under a zero-water exchange system, thus preventing the introduction of diseases to fish farms from incoming water. Although the use of the BFT is quite expensive considering that it requires a high-density polyethylene (HPDE) liner to line the pond bottom and rigid aeration at all times, it is being adopted to culture fish and shrimp in Brunei Darussalam, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam.

The greenwater culture system is a technique that cultures an aquatic organism in water abundant in phytoplankton, *e.g.*, chlorella, turning the water green. Greenwater culture provides highly nutritious culture water that serves as feed for the fish and shrimp stock. In shrimp culture, greenwater is usually produced from growing tilapia, where reservoirs are stocked with high saline tilapia or other finfish such as siganids. After > 14 days, the water from the reservoir with finfish can be used to culture shrimp. Greenwater is practiced in Malaysia, the Philippines, and Viet Nam.

Integrated multi-trophic aquaculture or IMTA is the farming in the proximity of species from different trophic levels and with complementary ecosystem functions in a way that allows one species' uneaten feed and wastes, nutrients, and by-products to be recaptured and converted into fertilizer, feed, and energy for the other cultured commodities. The by-products including wastes of one aquatic species, serve as inputs (fertilizers or food) for another. In the IMTA, the cultivation of fed species is combined, such as finfish or shrimp, with extractive species, such as shellfish and seaweeds. IMTA is not new in the Philippines and is now gaining popularity in Indonesia, Malaysia, and Viet Nam. In Thailand, IMTA is combined with the Recirculating Aquaculture System (RAS).

RAS is another approach for removing major toxic pollutants from the culture water without causing environmental concerns. Pond effluent passes through a series of filtration systems to remove solid wastes, ammonia, microbes, and oxygenated before flowing back to the culture ponds. In Brunei Darussalam, its hatchery for giant freshwater prawns and mangrove crabs makes use of the RAS technology. Sea bass, hybrid groupers, red snapper, and saltwater tilapia had also been cultured following the RAS starting in January 2021, as well as in its grow-out farms for giant freshwater prawns. Meanwhile, a white leg shrimp farm in Cambodia which started operating in 2019, uses a super-intensive indoor RAS. In the same year, a RAS farm for the cultivation of *Pangasius* opened in Indonesia and in early 2016, a RAS farm for catfish cultivation started operation. Usually, RAS is being adopted in Indonesia to revive the dwindling eel industry. RAS has been practiced in Malaysian finfish hatcheries, while in Singapore, RAS is used in both hatcheries and farms. In the Philippines and Viet Nam, RAS is being used to culture tilapia in hatcheries and farms. The use of RAS in culturing mangrove crab became popular in the Philippines in recent years, and Thailand uses the RAS system to farm shrimp.

Hazard analysis critical control point (HACCP) is a system for managing and documenting processes to assure food safety. A HACCP system is designed to identify the significant hazards associated with the products or operations and establish procedures to monitor the products and operations to ensure that hazards are controlled. Previously, HACCP is the responsibility of food processors and not of producers of raw food materials. At present, HACCP principles have been used to assess different risks in aquaculture in Cambodia, Lao PDR, the Philippines, Thailand, and Viet Nam.

Importing countries have set standards with regards to the safety of exported aquaculture products, checking for antibiotic residues and the presence of other contaminants or food hazards. They are also particular with the method and the environment of the products that were produced, and whether the farmers practice responsible aquaculture to ensure environmental sustainability. To address these issues and ensure that farms adhere to these standards, exported aquaculture products need to obtain certification from recognized certification bodies. Several aquaculture certification services assist farmers in Southeast Asia to demonstrate responsibility and adherence to best practices. Some of these include the Aquaculture Stewardship Council (ASC) which is supported by the World Wildlife Fund (WWF) issues certification for aquaculture products that target the American and European markets; Best Aquaculture Practices (BAP) which is developed by the Global Aquaculture Alliance (GAA) and is used by the American markets; and GlobalGAP that is used for products targeting the European markets. Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam are some of the clients of such aquaculture certification bodies.

Issues, Challenges, and Constraints

Food safety of aquaculture products starts at the farm level. However, aquaculturists, especially small-scale farmers, have low awareness and understanding of food hazards and their effect on humans and the environment. In spite of the extensive effort of both the government and local and regional institutions to educate the aquaculture sector on food safety, food hazards, good aquaculture practices, HACCP, certification, antimicrobial resistance, among others, the majority of the stakeholders remain adamant, non-compliant to GAqP, still uses antibiotics, and rejects government advises. This leads to the production of aquaculture products that are unsafe for human consumption and the possible degradation of the environment. Adoption of GAqP by the aquaculture sector would require a great effort on the part of the governments.

Way Forward

Responsible aquaculture through ecosystem approaches for producing safe and quality aquaculture products is one direction to produce safe and quality aquaculture products. Practicing the principles of HACCP should be promoted and recommended to the aquaculture sector. Information, education, and communication strategies and techniques to create food safety awareness among the stakeholders should be improved so that even those who could not go to school would understand the importance of delivering safe aquaculture products. Government should assist, especially the small-scale farmers in the implementation of GAqP, not only in terms of technology but also financially.

7.1.6 Impacts of Intensification of Aquaculture on the Environment

For several decades, aquaculture has emerged as a significant contributor and the fastest-growing food sector in the world (FAO, 2020) bringing economic benefits to rural and coastal communities while playing an increasingly vital role in global food security (Beveridge *et al*., 2013; Bene *et al*., 2016). The benefits of aquaculture include simple access to high-quality food, a source of income, and revenue for developing countries (Martinez-Porchas & Martinez-Cordova, 2012; Salin & Ataguba, 2018). The aquaculture sector has continued to dominate in developing countries, particularly in Asia (de Silva & Davy, 2010); and contributed to an average of 90 percent of the total volume of aquaculture production globally (Hall *et al*., 2011), wherein 16 percent came from Southeast Asia in 2019 (**Figure 101**). In Southeast Asia, aquaculture rapidly expanded in response to market demand, both domestic and international (Hishamunda *et al*., 2009). The highest producing country from Southeast Asia is Indonesia followed by Viet Nam, accounting for an average of 62.10 percent and 17.41 percent, respectively, of the total volume of the region's production in 2019 (**Figure 102**).

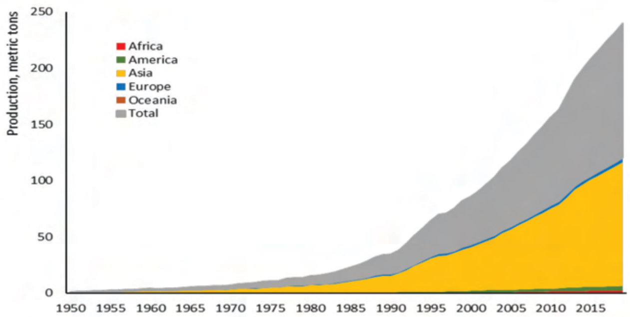


Figure 101. Total volume of aquaculture production from 1950 to 2019

*(**Source:** FAO Database)*

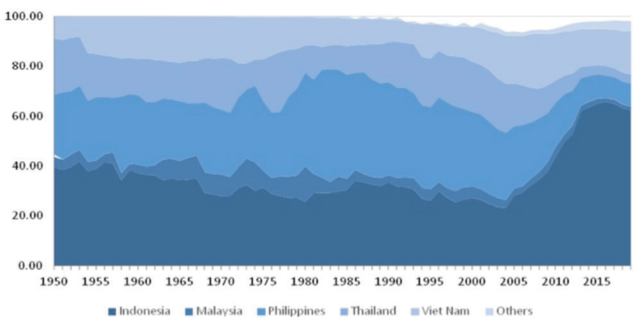


Figure 102. Percent contribution of Indonesia, Philippines, Malaysia, Thailand, Viet Nam, and other Southeast Asian countries (Brunei Darussalam, Cambodia, Lao PDR, Myanmar, Singapore, and Timor-Leste) to the total volume of aquaculture production in Southeast Asia from 1950 to 2019

*(**Source:** FAO Database)*

The relevance of aquaculture in the region goes beyond its significant contribution to global aquaculture production since the people of the Southeast Asian countries consume fish as the primary source of animal protein and an essential part of their diet (Hishamunda *et al*., 2009). For instance, in 2016, Indonesia recorded 43.88 kg/capita/year (KKP & JICA, 2017), Malaysia with 59 kg/capita/year (FAO,2021a), and Thailand with 27.2 kg/capita/year (FAO, 2021b), while the Philippines reported 36.8 kg/capita/year of fish consumption in 2015 (BFAR, 2019). Moreover, the rise of aquaculture is timely and relevant to the increasing demand for fish and fishery products and the dwindling supply of wild fishery stock due to overexploitation (Little *et al*., 2016). As a result, the aquaculture sector is expected to grow continuously in the future (Bostick, 2008).

Adverse impacts of aquaculture intensification

Aquaculture expansion is inevitable and likely to increase rapidly for the next 40 years due to the growing demand for fish as the human population is expected to continuously rise (Hall *et al*., 2011; Godfray *et al*., 2010). Increased aquaculture production comes with increasing environmental impacts (Hall *et al*., 2011). Even though ecosystems have a remarkable ability for recovery, poor aquaculture management has resulted in irreparable damage (Martinez-Porchas & Martinez-Cordova, 2012). The environmental impacts of aquaculture vary with species, system, management, production methods, intensity, location, and environmental carrying capacity to absorb impacts (Little *et al*., 2016).

- *Destruction of habitats*

Mangrove systems in Southeast Asia are the world's most biodiverse and have contributed a wide array of commodities and services critical to the coastal community lifestyles, such as protection from typhoons and storm surges, erosion control, sediment trapping, nutrient recycling, and wildlife habitat, and nurseries (Primavera, 2006; Macintosh, 2011; Garcia *et al*., 2014). However, aquaculture development, such as the construction of shrimp ponds, has negatively impacted coastal ecosystems due to a significant decrease in the acreage of mangroves (De Silva, 2012; Garcia *et al*., 2014). The conversion of mangrove forests means destroying the natural habitat that supports microscopic to huge terrestrial and aquatic wildlife as well as damaging the breeding and nursery grounds of many commercial aquatic faunas (Bagarinao & Primavera, 2005).

Between 1980 and 2005, Asia lost over 54 percent of the total world mangrove areas, with aquaculture accounting for 12 percent of that loss (Giri *et al*., 2008). In the Southeast Asian region, Indonesia with approximately 28 percent of the world's mangrove forest lost about 3.11 percent between 2000 and 2012 (Hamilton & Casey, 2014). About 17 percent of the mangrove area in Malaysia was lost from 1965 to 1985 (Barbier & Cox, 2004). Philippines, holding at least 50 percent of mangrove species (around 65 species) of the world (Garcia *et al*., 2014), lost an estimated 279,000 h or 50 percent of mangrove area from 1951 to 1988 mainly due to pond construction (Primavera, 2000). In Thailand, the construction of shrimp farms diminished the mangrove cover from 312,700 ha to 168,683 ha between 1975 to 1993.

- *Loss of biodiversity*

The aquaculture sector has been over-dependent on the wild population for fish meal and fish oil production (de Silva, 2012). Fishmeal and fish oil are important feed ingredients in aquaculture, and its global use has significantly increased despite several developments done in the feed industry to lower feed conversion ratios (Huntington & Hasan, 2009). Large quantities of fish collected for the production of fish meal and fish oil have contributed to excessive fishing pressure on some fish populations, with potentially detrimental implications (Leadbitter, 2019). With this, there is scientific agreement that fish populations are rapidly depleting worldwide (Jenkins *et al*., 2009), and some argue to instead use it directly for human consumption (de Silva, 2012).

Diana (2009) listed the effects of aquaculture on biodiversity (**Box 35**). In addition, the introduction of alien fish species is considered as one of the biggest threats to finfish biodiversity, with direct and indirect impacts that can have immediate or long-term effects (De Silva *et al*., 2009). Predation and diseases are the potential direct effects of alien fish introduction, resulting in decreases in native species, endangering species, and eventually leading native species to extinction. In addition, indirect consequences classified into two categories could include ecological impacts (*e.g.* habitat damage, competition with native species) and genetic change (*e.g.* hybridization, introgression), all of which could lead to displacement or extinction of native species (De Silva *et al*., 2009).

Box 35. Effects of aquaculture on biodiversity

- Escapement of aquatic crops and their potential hazard as invasive species
- The relationships among effluents, eutrophication of water bodies, and changes in the fauna of receiving waters
- Conversion of sensitive land areas such as mangroves and wetlands, as well as water use
- Other resource use, such as fish meal and its concomitant overexploitation of fish stocks
- Disease or parasite transfer from captive to wild stocks
- Genetic alteration of existing stocks from escaped hatchery products
- Predator mortality caused by, for example, killing birds near aquaculture facilities
- Antibiotic and hormone use, which may influence aquatic species near aquaculture facilities

Aquatic pollution

- *Excess feeds*

Fish nutrition and feeding are critical to aquaculture sustainability, wherein, as fish farming becomes intensive, it also becomes less dependent on natural food and more reliant on prepared feeds. However, aquafeeds are a significant source of pollutants in the aquaculture production system (Millamena *et al*., 2002). The composition of feeds and feed conversion affect both the physical and chemical nature of waste materials and the amounts produced (Alava, 2002). Aquaculture wastes from feeds can be categorized as solid wastes and dissolved wastes. Solid wastes are primarily derived from excess feeds and fecal matter that remain suspended in the water culture system or settle and be deposited as organic matter at the seabed and pond bottom soil, resulting in sediment chemistry and biology changes (Dauda *et al*., 2019). Excess dissolved nutrients in water like phosphorus can lead to eutrophication of water bodies (Patrick, 2017). Both these wastes are present in the water of the culture system and, if they exist at elevated levels, may negatively affect the water quality and harm the fish and other inhabitants. The routine method used in dealing with this problem is the continuous replacement of the unsuitable water through water exchange using clean water (Chatla *et al*., 2020). Discharge of this untreated poor-quality water to the environment could contaminate the nearby culture systems and the natural aquatic environment, resulting in acute toxic effects and long-run environmental risks (Dauda *et al*., 2019).

- *Chemicals*

For the past years, chemicals were used as therapeutants, disinfectants, algicides and pesticides, plankton growth inducers (fertilizers and minerals), feed additives, and water and soil treatment compounds (Rico *et al*., 2012; Primavera 2006). The unnecessary release of these chemicals to the natural aquatic environment could cause significant impact and environmental toxicity at elevated levels.

- *Antibiotics*

Antibiotics were widely used and successful in treating aquatic animal diseases. However, indiscriminate use of antibiotics, specifically in intensive farming, results in residues of antibiotics in cultured products and bacterial resistance. Bacterial resistance has been observed in widely used natural antibiotics, namely: erythromycin, oxytetracycline, tetracycline, and chloramphenicol. Modes of application, such as oral administration using feeds containing antibiotics, bath treatment, and pond sprinkle, affect the aquatic environment. In Malaysia, low to moderate tetracyclines and sulfonamides, and quinolones with a level higher than the two were already widely distributed in Malaysian farms (Chen *et al*., 2020). In the Philippines, aquaculture intensification has led to the use of various chemical products such as oxytetracycline, oxolinic acid, chloramphenicol, and furazolidone, which have been incorporated in artificial feeds of shrimps as treatments against luminous vibriosis (Cruz-Lacierda *et al*., 2000). However, it has been suggested that the use of antimicrobials must be avoided since this could lead to the development of drug-resistant strains of bacteria that may affect future therapy of shrimp diseases (Tendencia & de la Pena, 2002).

Alleviating the negative impacts of aquaculture

Aquaculture development will not be sustainable unless there is a significant improvement in the local, national, and regional planning and management considering the environmental, social, economic, health, and animal welfare concerns (Salin & Ataguba, 2018). Besides, aquaculture should also operate in line with other primary food-producing sectors such as agriculture and animal husbandry within ecological limits to reduce environmental degradation (Edwards, 2015). Although aquaculture can alleviate unemployment and poverty, the environmental repercussions must not be sacrificed on the platform of poverty reduction (Salin & Ataguba, 2018). Therefore, a balance must be attained between increasing productivity while reducing environmental consequences. A holistic approach involving stakeholders should be adopted for aquaculture to reach its goal of food security and poverty alleviation without causing harmful effects on the environment (Primavera, 2006). With proper monitoring and management, the impacts of aquaculture on the ecosystem and biodiversity could be kept to a minimum (Salin & Ataguba, 2018). Over the past decade, national development laws, policies, strategies, and plans, including best management practices and manuals on farming techniques, are being made in addressing the negative impacts of aquaculture (Hishamunda *et al*., 2012).

- *Habitat rehabilitation*

Several efforts on restoration and rehabilitation of mangrove areas have been successfully initiated in various parts of Southeast Asia including Indonesia (Kusmana, 2017), Malaysia (Hashim *et al*., 2010), Philippines (Primavera & Esteban, 2008), Thailand (Kongkaew *et al*., 2019), and Viet Nam (Hai *et al*., 2020) that reversed the widespread environmental problems associated with mangrove destruction and degradation (Macintosh *et al*., 2002). In Indonesia, different planting designs (*e.g.*, square, zigzag, and cluster) and techniques (*e.g.* "banjar harian," bamboo pole, *guludan*, water break, enormous polybag, ditch muddy, huge mole, and cluster) had been used to rehabilitate damaged mangrove ecosystems utilizing *Rhizophora* spp. (Kusmana, 2017). A coastal structure has been used in Malaysia in conjunction with a mangrove restoration project in coastal forests that are prone to erosion, resulting in 30 %

mangrove sapling survival after eight months of monitoring (Hashim *et al*., 2010). In the Philippines, several successful mangrove rehabilitation activities had been carried out by the national government. Its implementation was done at the grassroots level in excellent coordination with local government units, non-governmental organizations, and local communities through people's organizations with regular monitoring and field visits (Primavera and Esteban, 2008). With the help of NGOs, government cooperation, and the stabilization and strengthening of sustainable management, Thailand's community-based mangrove management has also been particularly successful (Kongkeaw *et al*., 2019). Rehabilitation success in Viet Nam was attributed to several reasons, including careful species selection, explicit monitoring and reporting standards, and the implementation of a co-management model that gives incentives for local populations to profit from the management of restored mangroves (Hai *et al*., 2020). Furthermore, mangrove-friendly aquaculture technologies had been adopted in mangrove conservation and restoration sites by small-scale, family-based operators by rearing aquatic organisms in an enclosed area without allowing mangrove trees to be cut. Examples of these aquaculture technologies include silvofisheries in Indonesia, aquasilviculture in the Philippines, and mangrove-shrimp ponds in Viet Nam (Primavera, 2006).

- *Stock enhancement*

Several stock enhancement activities have already been done in Southeast Asia, which include the successful stocking of common carp and several gouramis in Indonesia (Kartamihardja, 2016), Nile tilapia and Indian major carp in Lao PDR (Garaway *et al*., 2006), tiger shrimp, giant clam, abalone, and mangrove crab in the Philippines (Altamirano *et al*., 2016; Lebata-Ramos *et al*., 2016; Salayo *et al*., 2020), and various freshwater species in Viet Nam (Dzung, 2016).

Stock enhancement requires clear and well-defined objectives and well-formulated stocking strategies that consider the risk, benefits, environment, and fish stocked. Harvest yields and the social, economic, and cultural benefits are all essential factors to consider when evaluating stocking success. Furthermore, fisheries management measures, such as fisheries policies, rules, and guidelines for dealing with property and access rights, must be implemented to assist stock enhancement (Ingram & de Silva, 2015). Lebata-Ramos *et al*. (2016) suggested that any stock enhancement action should be preceded by a baseline evaluation of the population of the target species for release (**Box 36**).

Box 36. Baseline assessment of the population of target species for release before stock enhancement activity

- Assessment of the habitat for the presence of food and shelter for the stocks to be released
- Consider possible predators that may prey on the released stocks
- Animals for release should be tagged to differentiate them from their wild conspecifics
- In areas where poaching is prevalent, secured areas such as marine protected areas, sanctuaries, and the like are the recommended sites for release to provide stocks with some form of protection
- Proper information dissemination should be employed before releasing for all stakeholders to be aware of the proposed activity, which may, in one way or the other, affect their livelihood

- *Integrated multi-trophic aquaculture*

Over the years, environment-friendly and integrated aquaculture had been considered as one of the mitigation approaches to address aquaculture waste, especially excess uneaten feeds and nutrients in the culture system. Currently, the integrated multi-trophic aquaculture (IMTA) is an economically and environmentally sustainable aquaculture practice that involves a combination of fed-species and extractive species to be effective and efficient (Edwards, 2015; Jumah, 2020; Park *et al*., 2018).

Several studies have already been conducted on the IMTA system which is aimed at reducing waste in the culture system and obtaining additional income from the extractive species. One of these is the combination of milkfish (*Chanos chanos*), sandfish (*Holothuria scabra*), and seaweeds (*Kappaphycus* sp.) in a pen culture, which was carried out in Guimaras, Philippines. Since sea cucumber was found to have an excellent performance in reducing the fecal matter of the cultured fed species, a combination of finfish, sea cucumber, and macroalgae is highly recommended (Jumah, 2020). In addition, IMTA in the open waters of Cebu, Philippines made use of the donkey's ear abalone (*Haliotis asinina*) as fed species and seaweeds (*Gracilaria heteroclada* and *Eucheuma denticulatum*) as inorganic extractive species resulting in the successful growth of the two-month-old hatchery-bred donkey's ear abalone. The abalone reached 53.8 × 28.2 mm (L × W) and body weight of 37.8 g after 12 months. The red seaweeds, *G. heteroclada*, and *E. denticulatum* functioned as a natural filter of ammonia and nitrate but not nitrite and phosphate (Largo *et al*., 2016).

- *Feeding management*

As suggested by Dauda *et al*. (2019), the immediate solution in managing the environmental impacts of aquaculture is proper feeding management that can reduce wastes resulting from the fish feed. Boyd (2003) also suggested some practices for proper feeding management that include the use of high quality, water-soluble feeds that contain only the required amount of nitrogen and phosphorus and application of feeds conservatively to avoid overfeeding and ensure that much of the feed is consumed as possible. Aquafeeds should be environment-friendly by considering new knowledge on nutrient requirement and digestibility and improving the techniques of producing more water-stable feeds and broader use of alternative protein sources (Millamena *et al*., 2002).

SEAFDEC/AQD has been strengthening its research and development activities to identify and employ cost-effective feed ingredients as alternatives for fish meal, the major dietary protein source for aquafeed production. Alternative protein sources are considered to reduce environmental impact and lower costs in aquaculture, especially if these ingredients are locally available. Several nutritional studies involving fish protein substitutes (plant, terrestrial animals, and fish by-products) in fish diets have been conducted, with results indicating that some feed ingredients could be used commercially without affecting fish growth or revenue from the farmed fish. Also, the use of distiller's dried grains with soluble (DDGS), hydrolyzed milkfish offal, mungbean produced positive results in laboratory experiments (Mamauag, 2016). Furthermore, research on the utilization of low-cost feed is being undertaken to reduce reliance on the fish meal for aquafeeds (SEAFDEC/AQD, 2020).

- *Zoning and site selection*

A coherent legal and regulatory framework for aquaculture zoning and site selection in bodies of water as well as the granting of tenure rights and aquaculture permits should be established (Aguilar-Manjarrez *et al*., 2017). As an initial step towards local-scale aquaculture licensing, a carrying capacity assessment is required to define and quantify potential aquaculture zones (Ross *et al*., 2013). With this, legislation can help promote, regulate, and develop aquaculture in a controlled manner.

In addition, various combinations of technological advancements, improvements in the existing technologies and management techniques, and better site selection to satisfy the ecosystem's carrying capacity may be the solution to environmentally sustainable aquaculture. Carrying capacity, or "the potential maximum production a species or population can maintain in relation to available food resources" (Davies & McLeod, 2003), is a vital idea for ecosystem-based management (Ross *et al*., 2013).

Progress in R&D is already being achieved in reducing the adverse environmental impacts of intensive aquaculture effluents. However, codes of conduct, best management practices (BMPs), good aquaculture practices (GAqP), and the ecosystem approach to aquaculture (EAA) should be implemented extensively to better integrate aquaculture into inland watersheds and coastal zones with a more productive utilization of land and water (Primavera, 2006; Philippine National Standard, 2014; Edwards, 2015).

Way Forward

The rapid rise of aquaculture is considered a significant contribution to world fish supply and a solution to the declining productivity of marine fish stocks due to overfishing and helps to ensure food security. However, the intensification of aquaculture has produced several environmental concerns, including loss of biodiversity, destruction of habitats, and aquatic pollution, among others. Improving and re-designing aquaculture is necessary to minimize its negative impacts and make it more environment-friendly and sustainable.

SEAFDEC/AQD is gearing towards improving fish production that will contribute to the livelihood of the stakeholders through developed aquaculture systems that are sustainable, economically viable, environment-friendly, and socially equitable. Responsible aquaculture entails the development of environment-friendly technologies and monitoring its impacts on biodiversity and water quality. As a result, various research and verification projects are continuously being done to generate high-quality seed stock, specifically shrimp postlarvae, using enhanced biosecurity measures and environment-friendly schemes. In partnership with the National Fisheries Research and Development Institute (NFRDI) of the Philippine the Bureau of Fisheries and Aquatic Resources (BFAR), cost-effective feed formulation is also being done in various aquaculture locations in the Philippines. Currently, SEAFDEC/AQD is continuously refining protocols in nutrition, seed production, grow-out, and health management (SEAFDEC/AQD, 2020).

In addition, other organizations such as the WorldFish Centre also target to strengthen livelihoods and enhance food and nutrition security by improving fisheries and aquaculture through developed technological innovations, supported institutions and policies, and delivering transformational impacts. The challenge of building sustainable aquaculture and resilient small-scale fisheries and enhanced contribution of fish to nutrition can only be addressed by partnering with the communities, research innovators, entrepreneurs, and investors who play essential roles in co-creating demand-driven research (WorldFish, 2020). On the other hand, the Network of Aquaculture Centres in Asia-Pacific (NACA) continues to publish a wide range of publications, including technical papers and manuals, policy briefs and guidelines, certification standards, codes of practice, and other voluntary aquaculture instruments to guide better management practices to improve crop outcomes and on-farm resource utilization efficiency leading to enhanced profitability of farmers and environmental performance.

Reducing the negative environmental implications of intensive aquaculture effluents is already progressing in R&D. The results of scientific studies should be adequately and broadly shared with fish farmers and local communities.

Furthermore, research organizations must work in close collaboration with policymakers and government agencies to better understand and apply environment-friendly technologies and attain sustainable and responsible aquaculture.

7.1.7 Genetics in Aquaculture

In 2018, global aquaculture production (82.1 million mt) was almost at par with capture fisheries production (96.4 million mt) with the increased farmed fish production dominated by contributions from Southeast Asian countries (FAO, 2020). Aquaculture production statistics in 2018 showed that Indonesia, Philippines, Thailand, and Viet Nam are among the top aquaculture-producing countries in the region. This notwithstanding, the annual growth rate of aquaculture production, in general, has been decreasing for the past 10 years, which could be attributed to global challenges in fish farming and inbreeding such as the lack of quality seedstock, adverse impacts of climate change, environmental degradation, fish diseases, high cost of inputs (*e.g.*, feeds), and others. Some of these problems could be due partly to aquaculture intensification, which could be avoided or minimized. Aquaculture in the Southeast Asian region has not been spared from such issues; hence, research and innovations, be these environmental and genetic interventions that could help resolve these challenges, are important.

Genetic tools for improved fish production

Environmental or non-genetic methods, *e.g.*, culture systems improvement, husbandry techniques, and others, that can improve subtropical and tropical aquaculture yield, have been well studied in Southeast Asia. In contrast, research and programs on genetic and genomic interventions in aquaculture have been relatively slow, especially since these approaches, particularly genomics, require scientific and highly technical laboratory and bioinformatics skills. This situation occurs because information on linkage maps, reference genomes, and single nucleotide polymorphism (SNP) arrays in tropical aquaculture species is still lacking. In addition, such programs (*e.g.*, genome-wide association studies or GWAS) have high investment costs since genomic selection requires genotyping large numbers of samples (Khatkar, 2017).

Research advancements in aquaculture genetics, which applies theories of heredity and variation of inherited characters or traits in farmed fish, and aquaculture genomics, which is a branch of molecular biology that deals with the structure, function, and mapping of complete sets of genes (also known as genomes) in aquatic organisms, have become of interest in recent years. Genetics and genomics are both biological disciplines that allow an understanding of how production and performance traits are passed on through generations in a particular aquatic species and how their genes influence the expression of phenotypic traits and physiological functions. As a means or tool in stock improvement, genetics has been used more often in plant breeding (*e.g.* variety development) since plants can be easily bred and manipulated genetically. On the other hand, aquatic animals have more complex genetic, reproductive, and physiological mechanisms. Nevertheless, several genetic improvement programs on commonly farmed fish and crustaceans have been implemented in Southeast Asia in three decades, starting with applying traditional selective breeding schemes mostly on low-value species that have short generation intervals such as tilapias. In the last five years, advanced schemes supported by genetic markers or genomic information have been conducted. Starting with genetic profiling of aquaculture stocks using DNA markers (*e.g.*, mitochondrial DNA markers, simple sequence repeat markers or microsatellite markers, single nucleotide polymorphism markers, and others), the results can later be used as a reference to fast-track genetic improvement via marker-aided broodstock management and selective breeding. **Table 75** summarizes the various species and the conventional genetic programs (some complimented with DNA marker tools for tagging and genetic traceability) used by public research and development agencies and some privately-operated fish production industries in quality strain development.

Genomics studies, on the other hand, have likewise been pursued and later on applied to determine the genes linked to important production traits, such as growth, reproductive efficiency, disease resistance, stress tolerance (especially heat stress due to climate change and sex determination), among others. Genomic data such as RNA sequencing (RNA-seq) to profile transcriptomes provide a valuable resource to evaluate gene function and genetic variants within genes. It is particularly useful in identifying genes involved in immune response and an organism's reaction to environmental factors like water temperature (as reviewed in Yañez *et al*., 2020). Most of these genetics and genomics research, aside from earlier studies on tilapia genetic improvement, which mainly utilized international funds, is supported by grants from both international and local sources. Some research is also done as collaborative initiatives among Southeast Asian countries with the primary intent of sustainably managing aquatic genetic resources in conservation and aquaculture. Examples are the genetic management and conservation of the tropical Anguillid eels, Carangid species, commercially farmed seaweeds, mangrove crabs, and others. **Table 76** lists the different genetic stock diversity studies and aquaculture genomics work on stocks bred and developed in Southeast Asia. Although costly, the ultimate goal of having a genetic marker or genome-wide molecular marker research is to generate reference data for marker-assisted selection, genome-wide association studies, genomic selection, and, if permitted, gene editing and other more advanced genetic improvement technologies.

Table 75. List of species and the traditional selective breeding programs used to produce improved strains in Southeast Asia (SEASOFIA 2017 list, updated)

Genetic Improvement Program/ Method	Technology and Product (Strain) Produced	Country Where It Was Developed* and/or Available
TILAPIAS		
Nile tilapia		
Genetically improved (GIFT) farmed tilapia program/ combined family and within-family selection for improved growth	GIFT Technology/ GIFT Malaysia (20+ generations)	Malaysia, Philippines*
Genome Supreme Tilapia (GST)/ rotational mating scheme, combined selection for improved growth yield and robustness, marker-assisted selection (using SSR markers)	GST Technology/ Genomar Supreme Tilapia (GIFT derived stock; 29+ generations)	Philippines*
GET-Excel Program/ Outcrossing two fast-growing strains (FAST and GIFT) for improved growth	GET Excel Technology/ GETExcel and i-EXCEL or improved GET Excel stocks	Philippines*
Genetically Male Tilapia Project/ Sex reversal and chromosome manipulation methods (androgenesis/gynogenesis)	YY Supermale	Philippines *
Streptococcus agalactiae*-resistant Nile tilapia*/ family selection (Suebsong *et al*., 2019)	Disease resistant Nile tilapia (F_1 using a commercial stock)	Thailand*
Manit Farm and Akvaforsk Genetics project (2009)/family selection Source: http://www.manitfarm.com	Super black Nile tilapia Disease resistant, fast-growing Nile tilapia (with microchip ID for backtracing)	Thailand*
Brackishwater Enhanced Selected Tilapia (BEST) Program/ Hybridization and outcrossing, size-specific selection	BEST Technology/ Salt tolerant BEST Tilapia strain, improved BEST or iBEST	Philippines*
Cold Tolerant Tilapia/ hybridization	Cold tolerant tilapia	Philippines*
Freshwater Aquaculture Center Selected Tilapia (FAST) Program/ Rotational mating, hybridization	FAST Tilapia	Philippines*
Molobicus or SaltUno project/ hybridization to produce salt-tolerant tilapia	SaltUno strain	Philippines*
Red tilapia		
Streptococcus agalactiae*-resistant Red tilapia*/family selection (Sukhavana *et al*., 2019)	Disease resistant red tilapia (F_1 using a commercial stock)	Thailand*
Manit Farm and Akvaforsk Genetics project (2009)/family selection Source: http://www.manitfarm.com	Super red tilapia Disease resistant fast-growing red tilapia (with microchip ID for backtracing)	Thailand*
Interspecific hybridization conventional breeding of red tilapia for propagation	Red tilapia strains (Philippines, Taiwan, and Thailand strains)	Philippines*, Taiwan*, Thailand*, Malaysia, Indonesia
CARP		
Common carp (*Cyprinus carpio*)/ genomic selection, combined selection (four generations family selection) (Su *et al*., 2018)	Freshwater Fisheries Research Center's Xinlong strain and the synthetic carp strain (from Jian carp x Huanghe carp and later with Heilongjiang carp)	Freshwater Fisheries Research Center, China*
Julien's golden price carp (*Probarbus jullieni*) Molecular biology and genetic engineering techniques	Cryopreserved sperm for planned breeding	Malaysia*
CATFISH		
Clariid catfishes		
African catfish crossbreds/ interpopulation crossbreeding (Sunarma *et al*., 2016)	EN (Egypt female x Netherlands male) African catfish crossbreed	Indonesia*
Interspecific hybridization (*C. macrocephalus* x *C. gariepinus*; *C. batrachus* x *C. gariepinus*)	Clariid catfish hybrids	Philippines, Thailand
Mass selection (*Clarias macrocephalus*) for fast growth, disease resistance (against *A. hydrophila*)	Except for improved strain developed in Pitsanulok FTRC, Dept of Fisheries, Thailand, no improved strain was identified; however, 4th and 2nd generation *C. macrocephalus* used in growth improvement (Jarimopas *et al*., 1990; Komainprairin *et al*., 2004) and strain used in *A. hydrophila* disease resistance (Na-nakorn *et al*., 1994) were produced.	Thailand (not disseminated but used only for research purposes; Na-nakorn and Brummett, 2009)
Pangasiid catfishes		
Siamese catfish (*Pangasianodon hypophthalmus*) breeding/ family selection	growth improvement in the second generation selected Siamese catfish (Tahapari *et al*., 2018)	Indonesia*

Table 75. List of species and the traditional selective breeding programs used to produce improved strains in Southeast Asia (SEASOFIA 2017 list, updated) *(Cont'd)*

Genetic Improvement Program/ Method	Technology and Product (Strain) Produced	Country Where It Was Developed* and/or Available
GIANT FRESHWATER PRAWN (GFP)		
Mass selection on five GFP strains (Barito, Musi, Asahan, Ciasem, and GI Macro) (Khasani *et al*., 2018)	Heritability and selection response after four generations	Indonesia*
Multi-trait selective breeding program/ optimal genetic contribution selection, incomplete diallel crossing using founder stocks from Bengal, Myanmar, Thailand, and selected population (Nantaihu strain) (Sui *et al*.,2019)	Heritability (harvest body weight)	China*
Giant freshwater prawn breeding program for improved growth (10 years or 10 generations) at the National Breeding Centre for Southern FW Aquaculture (NABRECSOFA)/ 3 x 3 diallel cross, selection done per generation (Vu and Nguyen, 2018)	Selected line (using base populations from Mekong and Dong Nai rivers)	Vietnam* (Research Institute for Aquaculture or RIA 2)
MARINE SHRIMPS		
***Fast-growing* Penaeus monodon**/ via triploidy induction using cold shock (Pongtippatee *et al* 2018)	Triploid black tiger shrimp	Thailand*
Selective breeding in Penaeid shrimps/(*e.g.*, family and mass selection) for fast growth and/or disease resistance (some programs are marker-assisted); hybridization	High health shrimp stock (SPF/SPR) (*P. monodon*, *L. stylirostris*, *L. vannamei*); markers related to disease resistance Thai strain SPF *P. monodon* is both fast-growing and WSSV disease resistant Thai strain *L. vannamei* resistant to both WSSV and Vibrio	Brunei Darussalam*, Thailand* (Withyachumnarnkul *et al*. and Songsangjinda in FAO, 2016), Indonesia
MARINE FISHES		
Grouper		
Domestication, broodstock management, individual selection, Interspecific hybridization	Purebreds (2nd generation *C. altivelis*, 3rd generation *P. leopardus*), fast-growing and/or disease-resistant hybrids (*E. fuscogutattus* x *E. lanceolatus*, *E. fuscoguttatus* x *E. polyphekadion*)	Gondol Research and Development Institute for Mariculture (GRDIM), government and private hatcheries in Indonesia* (Sugama *et al*.,2016)
Milkfish (*Chanos chanos*)		
Broodstock Management (possibly marker-assisted)	Domesticated Philippine stocks	Indonesia, Philippines
Asian sea Bass (*Lates calcarifer*)		
Selective breeding for disease resistance	High health *L. calcarifer* stock	Malaysia*
Mass selection to measure growth and fillet trait heritability (Pattarapanyawong *et al*., 2021)	Genetic parameters for growth and fillet trait	Thailand*
Pompano (*Trachinotus blochii*)		
Mass selection ***Broodstock development*** and management	Ongoing mass selection and broodstock development	Philippines
SHELLFISHES		
Abalone (*Haliotis* spp.)		
Interspecific hybridization	Better (hybrid) stocks that are fast-growing and have good carcass quality	Philippines*, Thailand*
Oyster		
Triploidy induction	Triploid oysters produced	Malaysia*, Philippines*
Green Mussel (*Perna viridis*)		
Asian green mussel domestication and broodstock management	Local broodstock	Philippines
SEAWEEDS (Eucheuma, Gracilaria, and others)		
Genetic manipulation Conventional selection for disease resistance Tissue culture Marker-assisted selection Polyploidy	Disease resistant seaweeds Seaweeds with improved carrageenan quality	Malaysia*, Philippines*

Table 75. List of species and the traditional selective breeding programs used to produce improved strains in Southeast Asia (SEASOFIA 2017 list, updated) *(Cont'd)*

Genetic Improvement Program/ Method	Technology and Product (Strain) Produced	Country Where It Was Developed* and/or Available
MANGROVE CRABS		
Selective breeding (mass selection)	Fast-growing mangrove crabs with improved reproductive ability	Philippines*
SANDFISH/SEA CUCUMBER (*Holothuria scabra*)		
Broodstock development, mass selection	Ongoing	Philippines

**Note that the list is not exhaustive*

Table 76. Examples of genetic stock diversity and genomics studies* in selected aquaculture species found/ developed in Southeast Asia

SPECIES/strain	Genetic diversity	Genomics
NILE TILAPIA		
Genomar Supreme Tilapia		58K SNP array, High-density linkage map (Joshi *et al.*,2018)
Different farmed tilapia strains	Maternal mismatches in farmed tilapias in the Philippines based on COI gene (Ordoñez *et al.*, 2017)	
Molobicus hybrid tilapia strain		Species composition in the Molobicus hybrid tilapia using ten diagnostic SNP markers (Bartie *et al.*, 2020)
Different tilapia species *O. mossambicus*, *O. niloticus* and *O. urolepis*	DNA barcoding of tilapia from Papua and Indonesia (cytochrome oxidase I marker) (Dailami *et al.*, 2021)	
Nile and **RED TILAPIA** strains	Microsatellite and mitochondrial DNA marker-based assessment of farmed Nile and red tilapia strains in the Philippines (Romana-Eguia *et al.*,2004)	Genome-wide association study and genomic prediction of *Streptococcus* resistance in red tilapia using low-density marker panels (Sukhavachana *et al.*, 2021; Sukhavachana *et al.*,2020)
CARP		
Mud carp (*Cirrhinus molitorella*)	Genetic diversity and population structure (microsatellite markers) of mud carp from Mekong, Red, and Pearl rivers (Nguyen and Sunnucks, 2012)	
CATFISH		
Pangasiid catfishes	Genetic diversity (mtDNA-RFLP) and population history of *Pangasionodon hypothalamus* and Pangasius bocourti in the Cambodian Mekong River (So *et al.*, 2006)	
Clariid catfishes	Microsatellite genetic variation in farmed African catfish populations in Indonesia (Imron *et al.*, 2011)	
TROPICAL ANGUILLID EELS		
	Genetic diversity and population structure of *Anguilla bicolor Pacifica* in Southeast Asia using DNA control region (Marini *et al.*, 2021)	
SNAKEHEAD		
Snakehead (*Channa striata*)	Genetic diversity (cyt b and D-loop) and structure of snakehead in the Lower Mekong Basin (cross country comparison) (Duong *et al.*, 2019)	
GIANT FRESHWATER PRAWN (GFP)		
Macrobrachium rosenbergii	Microsatellite loci characterization in the Malaysian giant river prawn (Bhassu *et al.*, 2008)	
	Genetic diversity of hatchery stocks of GFP in Thailand (Charoentawee *et al.*, 2007)	

Table 76. Examples of genetic stock diversity and genomics studies* in selected aquaculture species found/ developed in Southeast Asia (Cont'd)

SPECIES/strain	Genetic diversity	Genomics
MARINE FISH		
Milkfish (*Chanos chanos*)	Genetic diversity of Indonesia milkfish using AFLP (Adiputra *et al*., 2012),	
	Microsatellite marker diversity assessment of Philippine milkfish stocks (Romana-Eguia *et al*., 2018 and Santos *et al*., 2015)	Developing ómics-enabled resources, tools, and technologies to enhance milkfish aquaculture production (Ravago-Gotanco *et al*., ongoing)
Grouper		
Grouper *Epinephelus suillus*	Genetic variability and population structure of stocks from Makassar Strait and Bone Bay, South Sulawesi, Indonesia (RAPD DNA) (Parenrengi and Tenriulo, 2008)	
Orange spotted grouper (*Epinephelus coiodes*)	Genetic population structure using allozyme electrophoresis in Brunei and Sabah (Sulaiman *et al*., 2008)	
Red snapper (*Lutjanus malabaricus*)	Genetic population structure using allozyme electrophoresis in Brunei Darussalam and Sabah (Sulaiman *et al*., 2008)	
Sea bass (*Lates calcarifer*)	Genetic variation in *Lates calcarifer* from Wallacea Region estimated using RAPD markers (Irmawati *et al*., 2021)	Multi-trait genomic prediction of harvest and fillet traits in Asian sea bass (Sukhavachana *et al*., 2021)
	Genetic relatedness and differentiation of hatchery populations of Asian sea bass broodstock in Thailand inferred from microsatellite genetic markers (Senanan *et al*., 2015)	
MARINE SHRIMP		
Tiger shrimp (*Penaeus monodon*)	Cryptic diversity of giant tiger shrimp *Penaeus monodon* in Indonesia (COI mtDNA) (Yudhistra and Arisuryanti, 2019)	Chromosome level whole-genome assembly of *P. monodon* to facilitate the identification of growth-associated genes (Uengwetwanit *et al*., 2021)
CRABS		
Blue swimming crab (*Portunus pelagicus*)	Genetic diversity (COI marker) of blue swimming crab (*Portunus pelagicus*) from several waters in Indonesia (Fujaya *et al*.,2019)	
Mangrove crab (*Scylla* spp.)	RAPD-based genetic diversity in mud crabs in Eastern Thailand (Klinbunga *et al*., 2000)	Genetic differentiation and local adaptation signatures for a highly dispersive *Scylla olivacea* in the Sulu Sea using RADSeq (Mendiola and Ravago-Gotanco, 2021)
	COI gene sequence genetic diversity of *Scylla tranquebarica* in Sabah, Malaysia (Sharif *et al*., 2016)	
	Genetic diversity in orange mud crab *Scylla olivacea* in the Philippines (Paran *et al*., 2021)	
	Genetic identification of four mangrove mud crab species using multiple molecular markers (Mandal *et al*., 2021)	
SEAWEEDS		
Kappaphycus spp.	Genetic diversity analysis of cultivated *Kappaphycus* in Indonesia using COI gene (Ratnawati *et al*., 2020)	

**Note that the list is not exhaustive*

Way Forward

Through the years, most of the research outputs from SEAFDEC/AQD regarding genetics and genomics in aquaculture have been geared towards assessing the genetic diversity of key species mostly found in the Philippines (and adjacent countries), to include the Nile tilapia, red tilapia, giant freshwater prawn, mangrove crab, abalone, shrimps and more recently, the Philippine milkfish and the tropical Anguillid eels (Cuvin-Aralar *et al*., 2019, Romana-Eguia *et al*., 2019, Romana-Eguia *et al*., 2018, Romana-Eguia *et al*., 2004). The main objective of such studies is to know the species and/or genetic stock structure and diversity either for conservation, stock management, or selective breeding. At SEAFDEC/AQD, research initiatives on genetics and selective breeding, in particular, began in the mid-1980s, with funds from the International Development Development Centre of Canada (IDRC) under a regional network, then referred to as the International Network on Genetics in Aquaculture (INGA). SEAFDEC/AQD embarked on a farmer-friendly tilapia mass selection scheme while the other Southeast Asian countries under INGA, conducted family selection and/or combined family and within family selection methods to improve farmed Nile tilapias and Asian carps. No region-wide genetic improvement project has been conducted since thence. Genetics, especially genomics, has been applied extensively in several aquaculture research areas, *e.g.* from nutrition to fish health management and ecological (*e.g.* climate change) studies. Current applications cover nutrigenomics, immunogenetics, molecular marker-based disease diagnosis, and researches that require an understanding of aquatic organisms' resiliency towards environmental stressors through 'omics (transcriptomics, etc.) principles. Recently, interest in gene editing as applied in tropical aquaculture species such as tilapia has been noted. Since such studies require advanced technical/laboratory skills and equipment, major research funds are needed to support infrastructure and capacity building. In the Philippines, several aquaculture genetics/genomics projects have been undertaken with support from the Philippine Department of Science and Technology (DOST) apart from the Department of Agriculture's Biotechnology Program. Several of the DOST projects which started a decade ago were initiated with SEAFDEC/AQD as one of the cooperating agencies, together with major academic institutions such as the University of the Philippines and several private universities. The milkfish genetic diversity studies were part of this program (Romana-Eguia *et al*., 2019). However, currently, the DOST has prioritized the provision of funding support to the academic institutions which have continued these genetics/genomics-based researches, *e.g.* on mud crab, milkfish, oysters, and seaweeds.

Therefore, SEAFDEC need to reinforce linkages and collaborate or form research networks among its Member Countries as well as come up with comprehensive genetics/genomics programs towards the improvement of priority species in aquaculture, targeting important traits such as fast growth, disease resistance, and climate resilience.

7.1.8 Traceability of Aquaculture Products

The Codex Alimentarius Commission (2004) defines traceability or product tracing as 'the ability to follow the movement of a food through specified stage(s) of production, processing, and distribution." Traceability has become an important tool to deal with issues that are associated with food safety and quality assurance to prevent risk and gain consumers' support. Traceability has now become a common feature for the international trade of fish and fishery products. The strengthened ties between countries across the globe have encouraged and facilitated bilateral trade. In trade, records of traceability are used as proof of compliance to food safety, biosecurity, and regulatory requirements. These records also ensure that quality and other contractual requirements are fulfilled. In situations such as a food recall, a robust traceability system will allow efficient tracking of affected products through the supply chain.

The AMSs also export a significant volume of aquaculture fish and fishery products annually to regional and global markets. As traceability becomes a trade requirement for eligibility to export aquaculture products to major markets such as Japan, the European Union (EU), and the United States of America (USA), establishing reliable traceability systems is important for the sustainable development of the aquaculture industry in the Southeast Asian region. To tap into demand for aquaculture fish, several large-scale aquaculture companies in the region can comply with the stringent export requirements. Governments and organizations have also been developing different systems on seafood traceability such as TraceFish of the EU and TraceShrimp of Thailand.

Other than the strict regulatory requirements, stress from the general public has led to businesses implementing traceability systems for aquaculture products. A new generation of educated consumers with a higher level of awareness has driven increasing market demand for food safety, security, and sustainability for aquaculture products. Consumers are also becoming more cautious of the food they eat—whether the food is from a safe and sustainable source, and whether production, transportation, and storage conditions can ensure food safety and quality.

Traceability is a component of a food safety management system and it helps to ensure the safety and quality of aquatic organisms in the aquaculture supply chain and verify that they are farmed in accordance with national or international management requirements or to meet national security and public safety objectives. Traceability should provide the linking of vital information across each stakeholder to ensure that the products can be traced effectively. By implementing a traceability system that includes keeping proper records throughout the supply chain of aquaculture products, transparency of product information is guaranteed for all stakeholders. This allows a greater sense of security to consumers who are at the receiving end of the supply chain. Reliable information and comprehensive documentation also allow timely information sharing as well as prompt and effective intervention by relevant competent authorities should problems arise. In times of massive aquaculture, product recalls, traceability system implemented allows timely identification of batch affected or stakeholder involved along the supply chain. Thus, traceability enables prompt verification of records, and through the effective identification of the root causes of food recall incidents, the impact could be minimized.

Regional Guidelines on Traceability Systems for Aquaculture Products in ASEAN region

In 2017, the Regional Guidelines on Traceability System for Aquaculture Products in the ASEAN Region was developed in consultation with the AMSs, namely: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam. The Guidelines recommend that the countries should establish/promote and maintain records, both individually and regionally through an integrated approach, that are sufficient to identify the immediate previous sources and immediate subsequent recipients of the aquaculture products (**Box 37**). The documented information should be archived and kept for at least two years.

National and Regional Initiatives

The implementation of traceability of aquaculture products differs among the AMSs. Some countries are major exporters, like Thailand (shrimps) and Viet Nam (catfish and shrimp), and they have begun the implementation of traceability systems for aquaculture products. Although traceability implementation is mandatory or voluntary depending on governmental or private sector initiatives or obligations, traceability has now become a common feature in the international trade of fish and fishery products, hence, there is an urgent need for all countries to implement traceability systems in their respective aquaculture industry. Also, some countries already have their traceability systems in place and have established a certain degree of the legal framework as well as computerized or electronic traceability systems to track the aquaculture products from farm to fork. This allows them to export their aquaculture products to countries like those in the EU and USA. The status of implementation of traceability systems of aquaculture products in the AMSs is listed in **Box 38**.

Issues and Challenges

Among the difficulties faced by the region are the differing traceability systems for aquaculture products among the AMSs. Some countries already have in place a robust traceability system that permits them to export aquaculture products to European Union (EU) or the United States (US) and have established a certain degree of the legal framework as well as advanced computerized traceability systems to track their aquaculture products from farm to fork. However, some AMSs are still in the process of

Box 37. Regional Guidelines on Traceability System for Aquaculture Products in ASEAN region
Feed producer: Member States should establish and maintain effective record-keeping practices as early as from the fish feed used. Regardless of the source of aquaculture products, be it locally reared in fish farms or imported from foreign sources, feed mill-related information should be identifiable upon tracing. The feeds product traded should be identified as the TU.
Distributor: the Member States should adopt an integrated approach to the development, maintenance, and updates of record-keeping pertaining to the distributions and movement of aquaculture products-related activities. Distributors are known to be responsible for the distribution of bulk sales or bulk auctions, particularly with feeds involved as the TU from feed miller down the supply chain.
Hatchery: Member States should recognize the importance of hatcheries, where it involves the receiving of the seeds of aquaculture product and subsequent grow out into fish seedlings or fish fry as a new TU. This could range from a few thousand to several hundred thousand fishes being passed down the supply chain.
Chemical supplier: the Member States should establish and maintain information and records associated with materials used that are from external sources to the main domain of the supply chain. The identified TU could be the supply of the various chemical substances or supplements at the receiving end, *i.e.* the different stakeholders such as fish farms and fish processing plants.
Farm: Aquaculture products within the region could be raised from fingerlings or seeds bred at the hatchery or through imports from the hatchery for better quality control. Member States should establish legal frameworks, laws, and regulations to ensure farms or hatcheries comply with regional guidelines or global standards in farming activities. Locally reared aquaculture products with commercially acceptable or marketable size are the common TU identified.
Middlemen: the Member States should be aware of a number of tiers of “middlemen” –within the aquaculture supply chain. Reared aquaculture products with commercially acceptable or marketable sizes from the fishermen or farms are the common TU identified.
Processor: the Member States should establish/promote and maintain legal framework and regulations for the processors to follow as the processing of aquaculture products are performed differently in the ASEAN region, either through processing plants and establishments or direct processing at the fish farms. Processed aquaculture products are the common TU identified.
Retailer: Retailers should be recognized as the suppliers to the public or consumers, not to other stakeholders upstream of the supply chain. Member States should establish laws and regulations for retailers to follow, particularly inaccurate record-keeping, since they are likely to break down the TU received, package, label, or modify the nature of the aquaculture products before marketing the products. The immediate TU could be in the form of processed aquaculture products or packaged aquaculture products with appropriate labeling.
Exporter: Exporters trade and sell processed or unprocessed aquaculture products as TU to other businesses where they do not alter the nature of the TU. New TU could be created if other stakeholders are at the receiving end where the TU could be broken down, processed, and modified. Member States should enforce and ensure accurate documentation and communication of information throughout the production chain given that the exporter is either positioned at the end of the chain or the beginning of another chain with their TU exported.

Box 38. Status of traceability systems for aquaculture products in the Southeast Asians region
Brunei Darussalam: Three private companies are engaged in traceability systems in shrimp farming. Each shrimp farmer maintains their records of the date of stocking, feeding, and harvest. The country is also the sole supplier of blue shrimp fry which are cultured in different private companies and harvested and sold to local shrimp buyers for the domestic market or to big processing companies that also operate shrimp hatcheries in the country.
Cambodia: Aquaculture production mainly supplies the local demands. With increasing aquaculture demand and production, the Fisheries Administration (FiA) had introduced the Aquaculture Technical Guideline including the list of banned chemical components for aquaculture activities to improve its effort in adopting good aquaculture practices (GAqP), and to ensure the safety and quality of the country's aquaculture products. Training on GAqP is provided to fish farmers and model farms had been selected for GAqP recognition. Although the implementation of GAqP is tedious and involves high costs, some fish farmers understand that the safety of farmed fish is a priority and is preferred by local customers.
Indonesia: In order to meet market demands related to traceability, the Ministry of Marine Affairs and Fisheries (KKP) is currently developing a National Fish Traceability and Logistics System (STELINA) to ensure the traceability of fish, supply chains, and fishery products electronically by integrating information systems including fishing, cultivation, distribution, processing, and marketing. STELINA is expected to be a link of information from upstream (production) to downstream (processing and market). Testing of the STELINA application prototype has been carried out in several locations, namely in Bitung in 2019, and at 2 (two) UPIs in DKI Jakarta and Bali in 2020. The test was carried out to get a picture of the implementation and testing of the real readiness of STELINA implementation in the field. In general, the trial results recommended the need to formulate the STELINA regulatory regulations and develop applications in accordance with the fisheries business processes in Indonesia. For the aquaculture sector, a pilot project is being implemented with the integration of the Indonesia Good Aquaculture Practices (IndoGAP) into the STELINA application in Banyuwangi Regency, East Java.
Lao PDR: The traceability system for aquaculture in Lao PDR has yet to be implemented, but the focus of such implementation is on import, export, and transit of commodities, as well as inspection at the country's International Checkpoint before the commodities, could enter Lao PDR.
Malaysia: Traceability systems include Traceability Form BP-DJ01 for farmed shrimps in ponds, Certificate of Origin (COO), Health Certificate, and coordination between the MAQIS Department and the Royal Malaysian Customs. Apart from the issuance of health and origin certificates, the Department of Fisheries Malaysia is also responsible for issuing the Declaration of Import and Export of Shrimp to the United States (Form DS 2031) which is a mandatory condition for shrimp to enter the United States. The use of this traceability form has been successfully implemented to curb the export of transshipped frozen shrimps from other countries through Malaysia to the United States market. Export control through the declaration of traceability forms has also helped to restructure the local shrimp farming industry from the jeopardized disruption of trade of the Malaysian major shrimp importing countries.
Myanmar: Under the supervision of the Aquaculture Division of DOF Thailand, the Aquatic Animal Health and Disease Control Laboratory apply the PCR technique for testing live aquatic animals and products for export and import. For fish, tests are performed to detect the koi herpes virus, red sea bream iridovirus, viral nervous necrosis, spring viraemlatia of carp, tilapia lake virus. For crustaceans (shrimp, crab, etc.), the tests are done to detect white spot syndrome virus), taura syndrome virus, yellow head virus, infectious hypodermal and hematopoietic necrosis virus, hepatopancreatic parvo-like virus, infectious myonecrosis virus, early mortality syndrome, *Macrobranchium rosenbergii* nodavirus/extra small virus) following the OIE guideline.
Philippines: Traceability of aquaculture fishery products is being supervised by BFAR which implements programs and activities that enhance and strengthen the said products' traceability systems. BFAR Administrative Circular Order No. 251 of 2014 on traceability system for fish and fishery products requires documentation of traceability for wild-caught, farmed fish, and other aquatic products, in the aquaculture supply chain which is divided into three main groups, namely: 1) pre-production (hatchery/nursery, feedmill/aquatic veterinary products); 2) production (grow-out farm), and 3) post-harvest (auction market, transport, processing establishment, cold storage, shipment). Each of these stages of the supply chain requires a documentation system for traceability.
Singapore The Singapore Food Agency (SFA) is the national authority for aquaculture development including licensing all marine food fish farms and land-based farms. The SS670: 2021 Specification for Good Aquaculture Practice was published in 2021 to provide guidance to local agricultural farms on a holistic approach of farm management in the areas of food safety, produce quality, environmental management, workers and animal health, safety, and welfare as well as traceability of aquaculture products. In response to changes in consumers' preferences, some local farms are value-adding their aquaculture products. Harvested fish are sent to SFA-licensed fish establishments or processors for further processing into fillets before being sold to retailers such as supermarkets. For the processing of RTE fish slices, the SFA-licensed fish processors are required to implement Safety Management System (FSMS) equivalent, *e.g.* HACCP, ISO which includes traceability systems.
Thailand: An electronic traceability system has been in development for effective tracking of fish and fishery products in the entire supply chain from the origin of harvesting to the end processed products. It is achieved by means of identification and recordkeeping through the certification divisions/traceability system of DOF Thailand, namely: 1) Fisheries Map, 2) GAP Standard Certification, 3) Fishery Product Health Certification, 4) Animal Health Certification, 5) Thai Flagged Catch Certification (TFCC), 6) Movement Document (MD), 7) Purchasing Document of Aquatic Animal (E-APD), and 8) Fisheries Single Window.
Viet Nam: Farmed aquatic animals are managed by three agencies. The stage from stocking to harvest is managed by the Directorate of Fisheries (DoF) under the Ministry of Agriculture and Rural Development, the stage from harvest to processing is managed by National Agro-Forestry-Fisheries Quality Control Department, and lastly, the stage from goods on sale in the market to consumers are managed by Ministry of Industry and Trade. However, there is difficulty in tracing the origin of a product being on sale in the market back to the processing factory, farm, unit/individuals supplying inputs for production, as this requires linkage among several agencies. Moreover, the National Standard on Good Aquaculture Practices in Viet Nam (VietGAP) is a comprehensive solution for controlling the quality of input materials, maintaining the good health of aquatic animals, and ensuring a better life for laborers and farmers, while also ensuring the integrity of the environment and easy traceability to complete profile system. VietGAP is a single aquaculture module that complies with existing legislation and allows the application of VietGAP standards to different species, as well as applying it on the growing stage to postharvest stage. VietGAP documentation includes 5 parts, namely: General requirements on legal documents; Food safety; Animal health and welfare; Environmental integrity; and Socioeconomic aspects.

implementing traceability systems and enhancing their capabilities of building up a legal framework for traceability implementation and introducing traceability systems to the industries through government support such as regulatory enforcement, education, and training. Despite the progress made, the aquaculture industry, particularly its small-scale stakeholders are still facing some concerns and difficulties. With these challenges faced, there are some framework and technological recommendations that could aid in improving the traceability implementation. Some examples of challenges and recommendations are shown in **Box 39**.

7.2 Challenges and Future Direction

Aquaculture production from many countries in Southeast Asia has been increasing during the past decades. Specifically, in 2019, the contribution of aquaculture to the region's fisheries production was reported to be more than one-half of the region's total fisheries production. The productivity of the aquaculture sub-sector had been derived from the culture of various commodity groups, *e.g.* finfishes, shrimps, crustaceans, mollusks, seaweeds, at various scales and levels of intensification. Although aquaculture has provided the necessary inputs that augment the region's total fisheries production as the contribution from capture fisheries has decreased after encountering various issues and challenges due to the decline in fishery resources, aquaculture has also been confronted with various challenges, particularly from the emerging disease outbreaks, high cost feeds and continued dependence on fish-based ingredients for aquaculture feeds, limited technologies that are environment-friendly and adoptable by aquafarmers at various levels and scales, as well as the requirements for good quality and safety of aquaculture products, and traceability to comply with requirements of importing countries. It is, therefore, necessary for the AMSs to continue addressing such issues and challenges in order that the aquaculture sub-sector could continue to grow and contribute to food security, income generation, and socioeconomic development in the future. Efforts to ensure the sustainable development of aquaculture would also make substantial contributions towards achieving several SDGs, particularly SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 12: Responsible Consumption and Production; and SDG 14: life below water. Therefore, to ensure the sustainable contribution of the aquaculture sub-sector to the economic development of the Southeast Asian region, the following considerations should be taken into account by the AMSs and relevant institutions and organizations:

Box 39. Issues/challenges and recommendations on traceability system in Southeast Asia
Lack of resources Issue/challenge: In the region, the aquaculture supply chain is dominated by individual small-scale stakeholders (*i.e.* hatcheries, feed mills, farmers, middlemen). The small size and limited income of these small-scale stakeholders mean that incorporating record keeping (the main component of traceability system) will entail higher operating processes and more manpower, which requires funds that small-scale stakeholders lack. Recommendation: Local competent authorities may encourage paper documentation by providing templates of records in local language for each stage of the aquaculture supply chain (*i.e.* hatcheries, feed mill, farmers, middlemen, buying stations/ collection centers, processing plants, and retailers). Stakeholders could also jointly purchase simple equipment or technology to assist them in data keeping such as barcode printers and readers which could help to reduce the overall cost of a traceability system for individual stakeholders.
Lack of awareness Issue/challenge: Limited knowledge of the benefits and advantages of having a traceability system in aquaculture operations. Some operators may also be averse to changes and in implementing new processes and traceability systems for their business operations. Recommendation: Transfer of knowledge and technology to various stakeholders via relevant competent authorities, such as through a series of workshops, roadshows, and training courses, should be enhanced. The approach should strategically cover each province and the message should be to reiterate the fundamentals of traceability and its importance to their business endeavors. Information, education campaign through flyers and other forms of reading materials written in the local language is also an effective tool.
The complexity of the supply chain Issue/challenge: The presence of diverse stakeholders throughout the supply chain, as well as the processing and free trading, could result in the mixing of raw materials and end products. The absence of cooperatives to manage these stakeholders will form a complex supply chain framework which makes it more difficult to implement a traceability system. Recommendation: Government should consider registering and licensing middlemen. Training and dialogue sessions may be arranged to educate middlemen on proper record keeping and handling of aquaculture products.
Legal framework Issue/challenge: The necessary legal framework to enforce traceability in the aquaculture industry is limited. Without the legal framework, various stakeholders will lack the motivation and incentive to implement a traceability system in their operations. Additionally, the lack of technical guidance and assistance could prevent the successful implementation of a traceability system. Unestablished documents and record details of aquaculture products also make it more difficult for small-scale stakeholders to adopt the traceability system. Recommendation: Local governments could develop a legal framework complete with guidelines and models to aid the adoption of traceability by the various stakeholders. Under this legal framework, each of the stakeholders must be properly registered and licensed in order to partake in the trade within the aquaculture supply chain. To support the enforcement of the new legal framework, it is important for the government to build up its capabilities (*e.g.* establish a department to be in charge of ensuring proper implementation, as well as conducting audits for traceability systems).

Integrating aquaculture in rural development in Southeast Asia

- The AMSs should promote the integration of small-scale aquaculture in their respective efforts to attain poverty alleviation and food security. A self-sustaining food production system like aquaculture would enable the low capital and labor-rich households in rural areas to counter the issues of nutrition and hunger. The contribution of small-scale aquaculture to food security should be considered in the formulation and implementation of policies in both local and international scenarios. Integration of small-scale aquaculture producers into working groups would enhance their participation in productive and profitable market enterprises.

Implementing best fish health management practices

- The AMSs should address the effective implementation of fish health management practices. Although this has been challenging due to the varying educational backgrounds of fish farmers and differences in their perceptions, it can be addressed through a series of consistent capacity building, information dissemination, and regular field consultation and monitoring. Information, education, and communication materials are efficient modes of awareness building as the contents could be illustrated, translated into local languages, and can be taken home by farmers for future reference.

Providing assistance in the development of alternative feeds for economically important fish species

- The AMSs should close the value chain of producing raw materials that hold enormous potential as aquaculture feed ingredients. Mass-producing these materials under realistic farm conditions would help achieve cost-efficient prices for alternative aquafeeds. This will create an advantage for the farmers as it keeps the costs of feeds reasonable and the supply of alternative feeds readily available. Guidelines or training should be developed to help fish farmers to produce aquaculture feed ingredients so that there are sufficient raw materials for alternative fish feeds; while information on alternative protein sources should be compiled to give commercial feed companies access to the results of feed development studies so affordable feeds could be produced at a bigger production scale.

Investigating scientific and policy interventions to support quality seed production

- The AMSs should continue and improve their research and development activities on reproductive challenges surrounding various species. The consolidation of progress in research being conducted on genetics, fish health management, intensive culture system, and cost-efficient feed program can pave the way for creating a more sustainable aquaculture production in the succeeding decades. Non-technical intervention, *e.g.* policies and incentives from the government is necessary to bridge the gap in the continuous supply of seedstocks in Southeast Asian countries.

Addressing food safety issues at the farm level

- The AMSs should enhance the awareness and understanding of stakeholders on food hazards and their effect on humans and the environment to small-scale farmers. Good aquaculture practices (GAqP) guidelines had been institutionalized in the AMSs. Promoting good practices at the farm level still needs intensive information dissemination, in order that the production of aquaculture products that are unsafe for human consumption could be avoided and the possible degradation of the environment prevented.

Regulating the impacts of intensification of aquaculture on the environment

- R&D on reducing the negative impacts of the intensification of aquaculture on the environment has already been in progress, but the AMSs could continue to seek policy and planning support from government agencies and concerned private sector for the dissemination of information for the better understanding of stakeholders on the significance of environment-friendly culture practices across the aquaculture industry.

Establishing comprehensive genetics and genomics programs

- The AMSs should explore linkages and collaborate or form research networks and come up with comprehensive genetics and genomics programs towards the improvement of the stock structures of priority species in aquaculture, targeting important traits such as fast growth, and robustness.

8. Fisheries-related Issues

8.1 Climate Change and Natural Disasters

Southeast Asia is one of the world's most vulnerable regions to climate change being in the tropics and embracing many countries that are in the so-called typhoon belt, and its people are the most at risk since a substantial portion of the populace and their economic activities are concentrated along the low-lying coastal areas. Climate change refers to changes inf climate incidences over extended periods typically ranging from decades to millions of years (IPCC, 2014). The Intergovernmental Panel on Climate Change (IPPC) reported that tchanges in many extremee weathers and climate events have been observed since 1950 (IPCC, 2014) and some of these changes have adverse impacts and are considered as disasters since they create widespread damages and serious disruptions in the normal functioning of communities or societies (IPCC, 2012). IPCC revealed evidence of observed changes in extreme cases, such as heatwaves, heavy precipitation, droughts, and tropical cyclones (IPCC, 2021b). The analysis of a multi-year time series of dissolved organic carbon exported from the tropical peatlands in the Sunda Shelf (Singapore) found that seasonal acidification is driven by 0.10 pH units and 20–30 % of such substance might be relatively refractory and exported to the open Indian Ocean (Zhou *et al*., 2021). IPCC and scientists also found that for each degree of additional global warming, the most extreme precipitation events currently recorded are anticipated to nearly double in frequency (IPCC, 2021a; Myhre *et al*., 2019). In addition, IPCC during its press conference for the 'Climate Change 2021: the Physical Science Basis' suggested that during this changing climate period, countries should not only look back at the historical data of extreme events, as new types and/or intensification of extreme events could happen more in magnitude, frequency, or timing, especially in regions that had never been encountered such events before but should also prepare for the occurrence of such events (IPCC, 2021b).

This section provides an overview of the current knowledge of climate change and its effects on fish, fisheries, and aquaculture, as well as on livelihoods, paying particular attention to Southeast Asia if and where the information is available. The following sections include reviews of the adaptation options, regional platforms and policies, national efforts to mitigate the impacts of climate change, climate-related activities undertaken by SEAFDEC, and the ASEAN Member States (AMSs).

Impacts of climate change on fish and fisheries

With extensive research studies and reviews on the impacts of climate change on fish and fisheries, major concerns still prevail, which could include: (1) changes in migratory routes of fishery resources; (2) alterations of fish reproduction and stress responses; (3) Increased risks of speciation, low survival, and immobility; and (4) habitat disruptions.

- *Changes in migratory routes of fishery resources*

Ocean warming leads to changes in species distribution and promotes multi-scale temporal and spatial changes in fish stocks (Cheung *et al*., 2013; 2016). Fish move towards colder waters resulting in increasing yields in high latitudes but decreasing catch in the tropics (Kibria *et al*., 2017). This could have adverse effects on the food security of tropical countries, especially on their small-scale fisheries sectors which are dependent on these resources.

- *Alterations of fish reproduction and stress responses*

Changes in salinity or water acidification affect the fish physiological functions especially reducing the sperm quality while changes in temperature are also directly involved in the quality of the released gametes and embryos development (Servili *et al*., 2020), especially in marine bivalves, *e.g.* oysters and mussels (Ishimatsu & Kurihara, 2011). Results of the study on heat stress in mangrove crab (*Scylla serrata*) across different sites of varying climate profiles in the Philippines, indicated population-specific differences in heat-stress responses (Shrestha *et al*., 2021).

- *Increased risks of speciation, low survival, and immobility*

Increasing sea temperatures and changes in seawater chemical composition also affect the marine species and the ecosystems, and the recovery of benthic and fish populations can vary greatly. Depending on the major species and impacts, fish populations could take 10 to 50 years or more to recover, albeit recovery would be dependent on improved fisheries management (Obura, 2017). The recent study of 150 million years of fish evolution revealed that commonly eaten fish species, *e.g.* anchovies and sardines are less likely to adapt and evolve in much warmer waters, increasing their risk of becoming extinct (Avaria-Llautureo *et al*., 2021).

- *Habitat disruptions*

Coastal ecosystems have been impacted negatively by sea level rise and extreme events, such as typhoons and storm surges, especially the coastal habitats that serve as hatcheries and nursery grounds for juvenile fish (Kibria *et al*., 2017). The study on the spatial and temporal relationship of ocean biophysical parameters with habitat utilization of the Indian mackerel (*Rastrelliger kanagurta*) in the Exclusive Economic Zone (EEZ) of Peninsular Malaysia found that although an increase in temperature of 1.8 °C resulted in high potential catch areas for the Indian mackerel in the said EEZ, elevated temperatures of 2.6 °C and 3.3 °C would decrease the potential catch areas for such species (Kamaruzzaman *et al*., 2021). With the increasing sea level, it was estimated that about 20 - 90 % of global coastal wetlands will be lost by 2100 (IPCC, 2019). Sea level rise also results in a saltwater intrusion in estuaries, driving and relocating marine species to upstream areas (IPCC, 2019). Marine heatwaves and ocean acidification have caused coral bleaching that triggers loss of calcifying species and biodiversity as well as limits habitat suitability (IPCC, 2019). In addition, oxygen minimum zones in the tropical Pacific and Indian Oceans have been progressively expanding because of a reduction in ventilation and oxygen solubility in warmer water, resulting in more stratified oceans. These increasing zones could limit the areas for fish habitats of the tropical pelagic species (Stramma *et al*., 2012).

In the inland water habitats, climate change causes fluctuations in water temperature, dissolved oxygen, streamflow, and circulation (Cisneros *et al*., 2014) which are important growth-related factors for freshwater fishes. Devkota & Kathayat (2020) reported that increased temperature along with hypoxia is expected to have significant impacts on the sex determination of the tropical fish (zebrafish, *Danio rerio*). Scientists also estimated that a 3.2 °C increase in global mean temperature would jeopardize more than half of the habitats for one-third of world freshwater fish species (Barbarossa *et al*., 2021). They also found that increases in maximum water temperature are more hazardous to freshwater fishes than changes in minimum water temperature or high and low flow conditions (Barbarossa *et al*., 2021). Floods and droughts brought about by extreme weathers could result in an excess amount of freshwater and water availability or the less of it, while typhoons would increase the risk of rain-generated floods which could eliminate fish habitats and farm facilities, *e.g.* in the case of Viet Nam (Johnson & Hung, 2020). Extreme drought episodes could also reduce the proportion of land surface, lessening the aquatic ecological habitats and decreasing the density and biomass of freshwater fish species, as in the case of Borneo, Indonesia (Wilkinson *et al*., 2019). Sea level rise is projected to extend the areas of salinization of groundwater and estuaries, resulting in decreased availability of freshwater and suitable ecosystems in the inland areas of the Mekong Delta (Toan, 2014). The impacts of climate change and natural disasters could negatively affect the various stakeholders in inland fisheries, considering that most of the production from inland waters is small-scale, especially the numerous subsistence fishers whose productions are consumed locally, a situation which is common in several developing countries of the Southeast Asian region (Funge-Smith & Bennett, 2019; Harrod *et al*., 2018).

Impacts of climate change on aquaculture

The impacts of climate change on aquaculture could be direct and indirect. The direct impacts could include physical and physiological distresses of the fish stocked in confined systems, while indirect impacts could include disruptions in primary and secondary productivity, input supplies, and fish prices among others (Maulu *et al*., 2021). While climate conditions would differ in each season, fluctuations in temperature and intensity of solar radiation and precipitation affect the water quality in outdoor fishponds or fish cages. These changes in turn, directly impact the sustainability of aquaculture production in both negative and positive ways, although the negative effects often outweigh (Maulu *et al*., 2021).

In the studies carried out by SEAFDEC/AQD on the gonadal development and spawning of rabbitfish, it was observed that the gonadal development and spawning of the fish were affected when exposed to a temperature of 33 °C as the females with oocytes were atretic while the spawned eggs did not hatch. Another research on the embryonic development of important marine fishes, *i.e.* milkfish, rabbitfish, and the Asian sea bass found that embryonic development was aborted when incubated at 33 °C temperature. Moreover, increased temperature also affects the survival of mud crab (*Scylla serrata*) which was significantly lower when exposed to 33 °C temperature than at 31 °C and ambient temperature (AQD, 2013).

The study on the effect of acidification on shrimp post-larvae (*Litopenaeus vannamei*) revealed that the survival, growth, feed index, biochemical constituents, and hemocyte populations decreased significantly inCO_2drivenn acidified seawater while the level of antioxidants and metabolic enzymes increased significantly under oxidative and metabolic stresses. This indicated that more acidic seawater can produce harmful effects on the biology and physiology of economically important shrimps (Muralisankar *et al*., 2021). Results of the study on marine shrimp exposed to acidic seawater at 1,000 ppm CO_2 for 30 weeks indicated that survival was only 55 % compared with 90 % in the control. Acidic seawater coupled with higher temperature did not only delay the gonad maturation of sea urchin but also significantly suppressed maturation (Ishimatsu & Kurihara, 2011). From the study on the effects of low pH on survival, growth, size distribution, and carapace quality of the freshwater prawn (*Macrobrachium resenbergii*) postlarvae, negative effects were observed at pH 4‒5 resulting in failure of the prawn to metamorphose (Kawamura *et al*., 2015). The low pH also reduced the tactile sense of the prawn postlarvae (Kawamura *et al*., 2018).

Furthermore, climate change also impacts the socioeconomic well-being of the stakeholders, *e.g.* freshwater shortage and farm location conflicts could create competition among the water and resource users. Water shortage and conflicts among water users could lead to the relocation of farms or even to the termination of fish farm operations. Meanwhile, the farming practices should also be adaptive to the changing climate, *e.g.* culture of fish species that are tolerant to high water temperature. In addition, a fish disease which is the major problem in aquaculture could be aggravated both in frequency and impact due to climate change (Marcos-López *et al*., 2010), and could even destroy the whole production before the stocks are harvested and return of investment is realized.

Impacts of climate change and natural disasters on livelihoods

Climate change is a major threat not only to the sustainability of the ecosystems and aquatic organisms but also to the sustainable livelihoods of people, particularly those engaged in the utilization of natural resources and aquaculture activities. Failure or changes in specific species or functions within a system will have knock-on effects on other species and functions, resulting in falling effects. This will result in decreases in adult fish stocks and production, as well as negative consequences for the fishing industry.

Because of the magnitude and extent of its impact on fisheries and aquaculture production, the threats brought about by climate change had become a regional concern. Such threats could lead to reduced diversity in rural livelihoods and increased reliance of stakeholders on non-farm and farm incomes. Moreover, population dislocation from the coastal areas could create insufficiency in terms of the workforce in the sector, while more incidences of droughts and floods could damage aquaculture production and fishing facilities, *e.g.* fishponds, cages, stationary fishing gears, fishing vessels, as well as houses. Considering that fisheries and aquaculture in the region are characterized as small-scale and dependent on natural resources, the impact of climate change on fisheries could adversely affect food nutrition, food security, and livelihoods of the region's populace.

Although the impacts of climate change are oftentimes long-term, the occurrence of sudden natural disasters such as typhoons, floods, or tsunamis could partially damage or even completely destroy fishing communities, fishing boats, and infrastructures such as fishing ports, processing factories, markets, and so on (FAO, 2021). For example, it was estimated that natural disasters in the Philippines had caused 23,000 deaths and affected roughly 125 million people from 2000 to 2016 (Jha *et al*., 2018). One of the most severe disasters that hit the Philippines was the typhoon Haiyan in 2013 where it was recorded that the country's fishing sector accounted for 20 % (about USD 280 million) of the total loss of USD 9.6 billion, represented mainly by destroyed boats and other assets (UNDRR, 2019).

Impacts of fisheries and aquaculture on changes in the climate

Several studies on the contribution of fisheries and aquaculture to climate change have determined that the sector plays a minor role in climate change and thus, a large focus on mitigation would not be necessary. In 2011, it was estimated that of the global food production sectors, about 4.00 % of the greenhouse gas (GHG) emissions was generated by the fisheries sector (compared with the emissions from agriculture and livestock production) but had increased by 28.00 % between 1990 and 2011 (Parker *et al*., 2018). In addition, aquaculture contributed about 0.49 % of human GHG emissions in 2017 (MacLeod *et al*., 2020). Overall, the net GHG contributions from fisheries, aquaculture, and related supply chain features, are relatively small. However, such minimal GHG emissions should not be taken for granted, considering that concerns about fuel prices, long-term energy availability, aquaculture intensity, and climate change have continued to grow, necessitating the importance of putting more emphasis on energy-saving strategies throughout the fisheries and aquaculture supply chain. Governments, civil societies, international organizations, and individuals, in general, have a priority and obligation to address excess GHG emissions and global warming, and other related issues.

Climate change adaptations

Although there is substantive research on the biophysical implications of climate change on aquatic habitats, little is known about how to address these implications in terms of the socioeconomic context of fisheries and aquaculture, as well as on how to implement these adaptations. In fact, the vulnerability of fishers and fishing systems to climate change is defined by their capacity to adapt to climate variations. Thus, as a first step toward establishing climate-adaptive fisheries management techniques, it is critical to understand the wide implications of climate change on biological systems and fisheries.

IPCC highlighted two major adaptation options for managing the risks of climate change relevant to the fisheries sector. These are: 1) development of ecosystem-based options which could include control of overfishing, promotion of fisheries co-management and community-based natural resource management, and enhanced assistance in species migration and dispersal; and 2) enforcement of laws and regulations, *e.g.* fishing quotas (IPCC, 2014). In addition, several gaps in legislation, notably in terms of the extent to which fisheries regulations can help with climate change adaptation should be identified (Hanich *et al*., 2018). Climate adaptation is best served by legislations that support and enforce regulations that help community transitions, especially in small-scale fisheries during these challenging times. These could include outlining the management approaches for emerging fisheries, providing safety and disaster-response strategies, developing an integrated management framework that allows and accounts for effort flexibility and changing pressures, and facilitating management measures that take into account the response of different species on climate variability.

The recent publication of FAO on 'Adaptive Fisheries Management in Response to Climate Change' which is primarily aimed at policymakers, fisheries managers, and practitioners, provides preliminary guidance on effective responses of fisheries management to climate change. This publication adds to the overarching goal of strengthening fisheries resilience, lowering their vulnerability to climate change, and enabling managers to respond quickly to expected changes in marine resource and ecosystem dynamics. One of the recommendations about the publication is on the possible downscaling of climate change projections – to include social and economic scenarios – to match with the scales at which fisheries management occurs with a focus on low-capacity countries. This implies that there is an urgent need to localize the impacts of climate change and identify the local enabling factors that foster and accelerate the uptake of climate-adaptive strategies (Barhri, *et al*., 2021).

Regional platforms to address issues on climate change

Recognizing that climate change affects all economic sectors, the ASEAN Ministers on Agriculture and Forestry (AMAF) in 2009 endorsed the ASEAN Multi-Sectoral Framework on Climate Change (AFCC): Agriculture and Forestry towards Food Security, which covers agriculture, fisheries, livestock, forestry, and other relevant sectors such as environment, health, and energy. Under the AFCC, the ASEAN Ad-hoc Steering Committee on Climate Change and Food Security (AHSCCC-FS) was also set up in 2009 to serve as a platform for Chairs of different sectoral bodies under the different pillars, *i.e.* ASEAN Economic Community and the ASEAN Socio-Cultural Community, and international/dialogue partners, to exchange information, contribute to the development of significant regional guidelines, and discuss initiatives in addressing climate change adaptation and mitigation. AHSCCC-FS aims to develop and implement a comprehensive strategy and roadmap through a mutual learning process on climate change and food security. The TOR and rules of procedures of the AHSCCC-FS had been revised, while its mandate had been extended until 2030.

Another regional platform established in 1996 by the Asia-Pacific Economic Cooperation (APEC) is the so-called Agricultural Technical Cooperation Working Group (ATCWG) which is concerned about the issues of food security, sustainable development, climate change, and deterioration and shortage of natural resources. The tasks of the ATCWG include but are not limited to, networking as a dynamic team among the member economy officials, experts, business community officials as well as experts from the academe. Attention has been paid to the success factors of agriculture in fragile environments to adapt to climate change and mitigate its effects and increase resilience to natural disasters in accordance with international agreements. The specific strategy relevant to cope with impacts of climate change under the ATCWG's Strategic Plan 2021-2025 is to build climate-smart and resilient agricultural systems. The main objective of which is to deal with food security and agricultural risks, production resilience and adversity adjustment, value addition of weather information, and disaster prevention by establishing early warning systems. These would be done through capacity-building activities such as seminars, workshops, and training courses on climate and disaster risk and vulnerability assessment, risk mapping, climate change adaptation, surveillance, and preparedness for mitigating the risks, and disaster risk reduction strategies.

Regional policies on climate change adaptation and mitigation in fisheries

In 2020, the ASEAN-SEAFDEC Member Countries adopted the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region towards 2030 and underscored several actions relevant to climate change (SEAFDEC, 2020). These include:

1) enhance the resilience of fisheries communities in anticipating and adapting to changes in the environments of inland and coastal waters, and those caused by climate change;
2) monitor and assess the perceived impacts of climate change to fisheries and aquaculture; and adjust existing programs to take into consideration the effects of climate change and natural disasters;
3) formulate guidelines to promote the use of practical and simple indicators for inland/floodplain fisheries within the national inland fisheries management framework to facilitate adaptation to the effects of climate change within water bodies;
4) provide government support for R&D on assessing the impact of climate change on aquaculture; and
5) formulate and implement national policies and strategies that will enable the aquaculture sector to adopt measures to mitigate the potential impacts of climate change and environmental stressors by providing support to R&D on climate change, and other environmental-related issues to increase resilience, strengthening the overall capacity of various stakeholder groups and fostering cooperation within the aquaculture sector and with other sectors, and developing standard procedures for disaster risks reduction in aquaculture.

Meanwhile, the Strategic Plan of Action for ASEAN Cooperation on Fisheries 2021−2025 through its action programs, is expected to result in increased resilience of fisheries and aquaculture to climate change, natural disasters, and other shocks. These could be achieved for example, through the development of regional guidelines on indicators for aquaculture and capture fisheries to facilitate ecosystem-based adaptation to the impact of climate change; and identification and promotion of green technologies for adoption, such as low greenhouse gas emission, carbon sequestration from marine waters technology for aquaculture, and the adoption of the integrated multi-trophic aquaculture (IMTA). The ASEAN Sectoral Working Group on Fisheries (ASWGFi) is expected to carry out the operations with the assistance of its technical sub-working groups. In collaboration with the ASEAN Secretariat, a Lead Country may be assigned to steer and commence the implementation of certain activities or priority deliverables. Priority initiatives may be supported by the ASEAN Member States and/or Dialogue Partners, as well as international and regional organizations. The progress of implementation of the activities and priority deliverables would be reported during the ASWGFi and SOM-AMAF annual meetings, with a final review in 2025.

Since changes in the climate could not be avoided, the ASEAN is therefore addressing the impacts of climate change on fisheries and aquaculture not only through the development of policies at the regional level but also by downscaling the applicability of such policies at the local level. With this concern, everyone could take action to reduce their contribution to global warming and the impacts of climate change. At the regional and national levels, research institutions including the public and privately-run, play important roles in the coordination and integration of research to assess, monitor, and develop projections of the perceived impacts of climate change on fisheries and aquaculture, and to move towards a future where relative impacts by the region can be compared on a hemispheric or global scale, as well as in raising recommendations on the mitigation and adaptation measures for such potential impacts. Government extension officials and civil societies could play a key role in promoting climate resilience practices to their people. The private sector and individuals, *e.g.* fishing boat operators/companies, aquaculture farms, could also take part in information sharing and in adapting fishing and farming practices that reduce GHG emissions. In addition, regional and national policies that would encourage the involvement of the private sector and industries to assist fishers/farmers in accelerating the transfer of climate-resilient innovations should be established.

National efforts to address the impacts of climate change

The Southeast Asian countries are Non-Annex I Parties of the United Nations Framework Convention on Climate Change (UNFCCC) and are also Parties of the Kyoto Protocol (UNFCCC, 2018). The Non-Annex I Parties are from developing countries, and the Convention recognizes certain categories of developing countries as being vulnerable to the negative effects of climate change, *e.g.* countries with low-lying coastal areas, and others, such as countries that rely largely on revenue from fossil fuel extraction and trade. The Convention promotes actions such as investment, insurance, and technology transfer that promise to address the needs and concerns of these vulnerable countries. Under the Convention, Parties develop strategies to address climate change and support cooperation in adaptation to the impacts. Under the Kyoto Protocol, Parties set binding targets and standards to reduce emissions of greenhouse gases. **Table 77** summarizes the country-specific national plans and regulations, and the priority concerns and actions relevant to the fisheries sector. In addition, FAO published the 'Addressing Fisheries and Aquaculture in National Adaptation Plans: Supplement to the UNFCCC NAP Technical Guidelines' to provide technical guidance on the integration of fisheries and aquaculture in the formulation of National Adaptation Plans (Brugere & De Young, 2020).

Moreover, each country has developed their respective projects and studies to address climate change issues in their fisheries sector. For example, Malaysia has implemented an annual coral reef monitoring program and established the Coral Bleaching Response Plan as well as identified the resilient areas. The country has also strengthened the fisheries management plan and its implementation corresponding to the migration of fish to preferred habitats. Concerning the severe weather variability that occurs in the country, a public awareness program has been established. Relating to sea level rise which could damage aquaculture infrastructures, the country has issued advisories for affected fish farmers to relocate their aquaculture farms.

In Myanmar, its Department of Fisheries in collaboration with FAO implemented the FishAdapt project supported by the Global Environment Facility (GEF) from 2017 to 2021 to build resilience and strengthen the adaptive capacity of livelihood-dependent communities on fisheries and aquaculture. Several activities had been carried out in the implementation phase including the preparation of three training documents both in English and Myanmar versions, namely: Handbook for Ecosystem Approach to Fisheries Management (EAFM) and Ecosystem Approach to Aquaculture Management (EAAM), as well as the EAFM Toolkit, and the subsequent completion of the National Level EAFM/EAAM and Capacity Plus Training, where the trained persons have been subsequently involved in formulating the community fisheries and aquaculture development plans. The project activities also included vulnerability assessment in respective areas that received different risks/impacts; training on drone and GIS mapping to support the assessment; development of national and regional level Early Warning and Early Actions (EWEAs); and Disaster Risk Management system analysis for fisheries and aquaculture (FishAdapt Project, 2020).

Table 77. Key national climate change regulations/policies of the AMSs and actions relevant to the fisheries sector

Country/National plans/Regulations	Priority concerned and actions relevant to the fisheries sector
Brunei Darussalam 2020 National Climate Change Policy (BNCCP)	Adopted in 2020, BNCCP has 10 key strategies on low-carbon and climate-resilient as a "Whole-of-Nation" approach to reduce Brunei Green House Gas emissions to more than 50 % by 2035 compared to the "Business-as-Usual" scenario. In particular, Strategy 8 has one of the strategic objectives to secure local food production and stocks by adapting to the impact of climate change. The number of fish stocks affected (in units) is regularly monitored (Brunei Climate Change Secretariat, 2020).
Cambodia 2013 Climate Change Strategic Plan (CCCSP) 2014 – 2023	CCCSP which was adopted in 2013, addresses a wide range of climate change adaptation and mitigation measures focusing on building institutional capacity and resilient capacity at the community level, including the fisheries sector (Royal Government of Cambodia, 2013): • Increasing the capacity to identify climate-induced opportunities in agricultural production systems, ecosystems, and natural protected areas to increase productivity such as in fisheries; • Improving the efficiency of the fisheries sector management; • Enhancing community fisheries management; • Ensuring the climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, etc.) including promotion of conservation and management of fisheries and aquaculture in a sustainable way; • Improving human and institutional capacity on new technologies in fisheries that have the adaptive capability to drought, flood, temperature rise, saline intrusion, and destruction from insects and diseases; • Promoting human resource development essential to contribute to adaptation and reduction of impacts on fisheries resources; and • Enhancing the capacity and understanding of climate change in the fisheries sector.
Indonesia 2019 National Action Plan for Climate Change Adaptation 2020 – 2045	Climate Change Adaptation Strategies and Action Framework adopted in 2019, identified four priority sectors for climate change adaptation. One of the priority sectors is marine and coastal, where the strategy is for coastal area protection and maritime safety. There are several delivery strategies, *e.g.* combining the ecosystem-based adaptation and community-based adaptation; application of marine survey technology that is able to detect fish stocks, preventing a potential decline in fishing catches of fishers due to climate change using remotely operated vehicles; increasing the certainty of fishing time and reducing fishers' sailing hazards due to extreme waves by using small fiberglass fishing boats; providing alternative livelihoods for small fishers who cannot go to sea due to extreme waves by strengthening their capacity in cooperative and fishing groups as well as fishers' insurance (weather index insurance); increasing the capacity and information access of small fishers in reading marine climate information (Ministry of National Development Planning, 2019).
Lao PDR 2015 National Strategy on Climate (NSCC) and Intended National Determined Contribution	Adopted in 2015, NSCC's vision and goals identified national adaptation priorities to promote integrated actions on watersheds, reservoir management, water storage for agro-forestry, wildlife management, fisheries, and tree varieties, and the prevention of drought (Phongpachith, 2019).
Malaysia 2009 National Policy on Climate Change	Although the fisheries sector is not mentioned in the policy adopted in 2009, the sector provides food largely for domestic consumption (Ministry of Natural Resources and Environment Malaysia, 2014). Currently, the Climate Change Act is being drafted (Jalil, 2020).
Myanmar 2019 Climate Change Master Plan (MCCMP) 2018 – 2030	Myanmar Climate Change Strategy for the same period as MCCMP adopted in 2019, was developed including the Myanmar Climate Change Alliance (MCCA) website for public access to learning the said two important documents and policy brief. MMCMP identified high-priority activities, indicators, and responsibilities. One of the priorities is climate-resilient productivity and climate-smart responses in the agriculture, fisheries, and livestock sectors. Some activities are identified, for example, development of guidelines (tools, contents) to mainstream climate change into agriculture and fisheries; establishment of an institutional platform to exchange learning and share knowledge on climate-smart agriculture, fisheries and livestock; establishment and strengthening of cooperatives or farmer, fisherfolk, water-user, herder associations to collectively deal with climate change issues; development, integration and legalizing risk-based insurance system to cover the losses and damages on crops, and fisheries due to climate-induced disaster; and building the capacity to develop national and regional monitoring and surveillance plans for the fisheries sector.
Philippines 2008 Climate Change Act	The Act (The Republic of the Philippines, 2008) which was adopted in 2008, provides the policy framework to address the growing threats on community life and its impact on the environment. The national climate change framework strategy has been developed and translated into the National Climate Change Action Plan (NCCAP) 2011 – 2028 (Climate Change Commission, 2011). The immediate outcomes identified include enhanced climate change resilience agriculture and fisheries production and distribution systems, as well as enhanced resilience of agriculture and fishing communities from climate change. The key activities are, for instance, conduct research and disseminate knowledge and technologies on climate change adaptation; integrate and harmonize climate change adaptation and disaster risk reduction in national and local fisheries policies and plans; build the capacity of farming and fishing communities on adaptation and disaster risk reduction; and implement risk transfer and social protection mechanisms for the fishery.

Table 77. Key national climate change regulations/policies of the AMSs and actions relevant to the fisheries sector *(Cont'd)*

Country/National plans/Regulations	Priority concerned and actions relevant to the fisheries sector
Singapore The 2016 Climate Action Plan	Although no specific action for fisheries had been identified, the Plan which was adopted in 2016, stipulates the strategies and targets to meet the pledge to reduce GHG emissions intensity by 36 % by 2030 (compared to 2005). In addition, the 'Climate-resilient Singapore: For a Sustainable Future' explains what climate risks the country faces and proposes a 'Whole-of-Government' strategy to tackle them (Ministry of the Environment and Water Resources, 2011). This includes among others, the implementation of programs to boost productivity, and the conduct of research and development to aid technology adoption by local farms, *e.g.* closed-containment aquaculture systems such as recirculating aquaculture systems to enable fish to be protected from adverse environmental conditions.
Thailand 2015 Climate Change Master Plan 2015 – 2050	Adopted in 2015, the Plan consists of three key strategies: 1) Climate change adaptation, 2) Mitigation and low carbon development, and 3) Enabling environment on climate change management. The fishery sector appears in all these Strategies. For example, Strategy 1, focuses on research and development of long-range forecasting and prediction techniques for climate variation and extreme weather focusing on high-risk areas including fisheries habitats; establishment of climate risk insurance system for agricultural produce, livestock, and fisheries; promotion of ecosystem-based approach to fisheries to include proper training and management for sustainable fish stocks by stock assessment; and improvement and expansion of artisanal fisheries by promoting the participation of local fishing communities in marine and coastal resources conservation. Strategy 2 highlights the promotion of sustainable and eco-friendly farming and fisheries to reduce adverse environmental and ecological effects. Strategy 3 emphasizes the formulation of effective integrated strategies by examining the relationships and correlations between changes in the following factors as a result of climate change: the quality and quantity of output from farming, livestock, and fishery sectors (including changes in the growing and harvesting seasons); the commercial system of domestic and overseas markets, and supply chains.
Viet Nam 2017 Law on Fisheries	The Government and the Ministry of Agriculture and Rural Development (MARD) have issued many important strategies and policies to cope with climate change including the National Target Programme to Respond to Climate Change (2012), the National Climate Change Strategy (2011,) and the National Action Plan on Climate Change (2012) for the period 2012 – 2020. The Law on Fisheries (2017) also guides fishery activities to cope with climate change, and requires fishery activities to adapt to climate change, actively prevent and control natural disasters, ensure safety for people and means of fishery activities; prevent and control aquatic epidemics, and ensure food safety and environmental safety (National Assembly, 2017)

In the Philippines, FAO supported the climate-resilience of tilapia farmers through the project 'Building Capacities for a Climate Resilient Tilapia Farming in the Philippines' in 2015 –2017. Considering that the Philippines is one of the most vulnerable countries to extreme weather events and climate-related disasters, improvement of the capacities of national and local government officials is necessary so that with innovative knowledge and technical services, they would be able to effectively carry out their respective duties and responsibilities. Thus, the project facilitated the collation of evidence-based scientific information from experienced farmers and commodity experts on climate-related risks and mitigation. The project installed automatic weather stations to monitor real-time weather parameters locally and provided simple statistical analyses and early-warning messages through ICT-based applications to farmers. The project was able to provide early warning advisories such as thunderstorms, heavy rains, and extreme temperatures to tilapia farmers via SMS alerts. The project also explored the introduction of innovative crop insurance and other financial arrangements to enhance resilience. These exercises started with tilapia production but are being replicated to other commercially important aquaculture commodities (FAO, 2017).

In Thailand, although there are no direct studies on the impacts of climate change on fishery resources during the past decade, its Department of Fisheries has been monitoring the water quality in fishing grounds to indirectly evaluate the impacts of climate change in some areas. A review study on the impacts of climate and season on water quality and aquatic animals underlined how climate and season influence the water quality including water temperature, dissolved oxygen, and ammonia concentrations. These factors, in turn, affect the growth and survival of fish and increase the risks of aquatic diseases. Pond ecosystem models appear to be promising tools to understand and possibly project how pond aquaculture responds to climate variability and change, and thus, management options useful for maintaining suitable water quality conditions could be explored (Sriyasak *et al*., 2015). The Government of Thailand allocates financial support to disaster victims both fishers and farmers. In addition, the Government always issues notifications to fisheries and coastal communities on the worsening situation of climate change and severe coastal erosion.

Activities of SEAFDEC on reduction of GHGs emissions from fisheries and adaptations to impacts of climate change

Fishing gears such as trawls and dredges require high fuel consumption and thus, their operations greatly impact the environment. Some activities of the project 'Responsible Fishing Technology and Practice' implemented by the SEAFDEC/TD from 2020 to 2024 and funded by the Japanese Trust Fund, had been initiated to address these concerns. The project activities, for example, include the modification and application of fishing gear and practices to mitigate their impacts on the marine ecosystem and optimize the use of energy by the fishing vessels and fishing practices. Such activities are aimed at transferring appropriate and applicable technologies and knowledge to fishers and fisheries officials to optimize energy use in fishing activities.

With the intensification of aquaculture systems in several Southeast Asian countries and the environmental challenges such as those resulting from climate change, both factors – genetic quality and culture management, are equally important. SEAFDEC/AQD, therefore, carried out the project 'Adapting to Climate Change Impacts' from 2016 to 2020 to generate, verify and promote technologies that ensure sustainable production of quality seedstocks for aquaculture and stock enhancement purposes. Many activities had been undertaken, *e.g.* culture of fast-growing species that are disease resistant and can be stocked at high densities; use of recirculating aquaculture systems and integrated multi-trophic aquaculture; implementation of zoning, monitoring, early warning systems; promotion of seaweeds and mollusk farming; and mangrove reforestation for carbon absorption. Furthermore, information on the impacts of climate change has been incorporated in the training courses organized by SEAFDEC/AQD and also in the extension materials that SEAFDEC/AQD has produced.

Way Forward

The characteristics and severity of the impacts of climate change and extreme climate events on the fisheries and aquaculture sector will most likely increase, affecting the most exposed and vulnerable countries and communities that depend on the sector for their livelihoods. It is therefore important that coherent and convergent adaptation and mitigation measures including preparedness for climate disaster response and recovery be mainstreamed in the fisheries and aquaculture sector as a matter of urgency and at an appropriate scale. The region also envisions to focus its plans on monitoring and assessing the perceived impacts of climate change on fisheries and aquaculture, especially through the formulation of guidelines that simplify indicators for inland/floodplain fisheries operations, enhancing the resilience of fisheries communities in anticipating and adapting to changes in the environments, as well as building climate-smart responses in fisheries. The AMSs join the global effort to mitigate the impacts of climate change by establishing ambitious objectives and targets as part of their national policies and plans. These initiatives will aid in the realization of a paradigm shift toward low-emission and promotion of climate-resilient development in all sectors including the fisheries sector.

8.2 Aquatic Pollution

Water is one of the renewable resources crucial for the existence of all beings on earth and is also an essential part of the global ecological system. However, problems on the quality of water have become major concerns in all countries, because of water pollution. As defined, "water pollution is the presence in groundwater of toxic chemicals and biological agents that exceed what is naturally found in the water and may pose a threat to human health and/or the environment. Additionally, water pollution may consist of chemicals introduced into the water bodies as a result of various human activities. Any amount of those chemicals pollute the water, regardless of the harm they may pose to human health and the environment" (Environmental Pollution Center, 2021). Therefore, water pollution or aquatic pollution occurs when the released substances interfere with the beneficial use of the water or with the natural functioning of the ecosystems. Water bodies could become polluted by domestic sewage also known as municipal solid wastes, toxic wastes, sediments, or thermal and petroleum substances. Aquatic pollution could occur not only in marine but also in freshwater environments.

In marine environments, aquatic pollution occurs when substances used or spread by humans, such as industrial, agricultural, and residential waste, particles, noise, excess carbon dioxide, or invasive organisms, enter the ocean and cause harmful effects (Sheppard, 2019). Most of the marine pollution comes from land sources and is washed or blown into the ocean. This pollution damages the environment, the health of all organisms, and economic structures worldwide (National Geographic, 2021). The types of marine pollution can be grouped into marine debris and plastic pollution, ocean acidification, nutrient pollution, toxins, underwater noise, and others. Marine pollution has become an essential issue since at least 8 million tons of plastic end up in our oceans every year (IUCN, 2021), and in 2021, at least 80 million kg of plastics used in the Southeast Asian region will become marine pollution (One Green Planet, 2021).

Similarly in freshwater environments, aquatic pollution happens when toxic substances enter water bodies such as lakes, rivers, and so on, getting dissolved in them or lying suspended or depositing on the bed degrading the quality of the water. These pollutants could seep through and reach the groundwater ending up in our drinking water. The most common pollutants in marine and freshwater environments are municipal solid wastes and industrial discharges.

Municipal solid wastes

Municipal solid wastes (MSW), more commonly known as trash or garbage, consisting of everyday items that humans use every day and then throw away, *e.g.* product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paints, batteries, among others, and come from our homes, schools, hospitals, and businesses. MSW also includes marine debris and microplastics. Industrial discharges are contaminants coming from different types of industry and comprise non-domestic pollutants, *e.g.* metals, metalloids, chemicals, organic and inorganic matters.

In the past decades, water pollution from marine debris and microplastics has become one of the global issues discussed in many international forums. A study on the source of marine debris had exposed that plastic materials are the most common debris making up between 60 % and 80 % (Avio *et al*., 2017) contributing to the main concerns in aquatic pollution because of their durability and ability to resist degradation. **Table 78** shows the projected amount of MSW generated daily by the Southeast Asian countries by 2025 compared to that of 2012.

Researchers first reported finding tiny beads and fragments of plastic, especially polystyrene in the oceans in the early 1970s. The term 'microplastics' which was introduced in the mid-2000s refers to plastic particles that are smaller than 5.0 mm in size (United Nations Environment Programme, 2021). Plastic debris can fragment into smaller pieces of microplastics by abiotic and biotic factors referred to as secondary microplastics while other man-made microplastics that can be found in marine environments are categorized as primary microplastics. Current research studies show that every part of the earth has revealed the presence of plastic events in the water, snow, and ice in the South pole (Isobe *et al*., 2017).

Meanwhile, marine debris is also found in growing quantities in a variety of habitats. Due to its characteristics, *i.e.*, its water buoyancy, colors, sizes, and shapes, some marine debris like natural food sources could result in accidental ingestion by marine organisms which could lead to deaths. Additionally, microplastics can accumulate in marine organisms and end up in humans through the food chain. Although the evidence is yet insufficient to quantify the long-term effect of microplastics in humans, most microplastics often contain additives, such as stabilizers or flame-retardants and other possibly toxic chemical substances that are harmful to humans ingesting them.

An estimated 88 - 95 % of marine debris load in the oceans had been blamed to 10 rivers in Asia and Africa, one of which is the Mekong River which is about 4,300 km long and flows through six countries in Indochina and splits into

Table 78. Amount of municipal solid wastes (MSW) generated daily by Southeast Asian countries in 2012 and 2025

Southeast Asian Countries	2012					2025		
	Urban population[1]	MSW generated daily (kg)[2]		Components of MSW		Urban population[1]	MSW generated daily (kg)[2]	
		Per capita per day	Total (mt)	Types	%		Per capita per day	Total (mt)
Brunei Darussalam	282,415	0.87	247	plastic	91.46	426,000	1.30	554
				misc	5.66			
				lumber	2.88			
Cambodia[3]	n/a	n/a	n/a	plastic	27.00	n/a	n/a	n/a
				others	78.00			
Indonesia[4]	n/a	n/a	85,000	plastic	45.00 – 70.00	n/a	n/a	150,000
Lao PDR	1,916,209	0.70	1,342	n/a	n/a	3,776,000	1.10	4,154
Malaysia	14,629,641	1.52	21,918	n/a	n/a	27,187,000	1.90	51,655
Myanmar	12,847,522	0.44	5,616	n/a	n/a	28,720,000	0.85	21,012
Philippines[5]	n/a	n/a	43,684	plastic	61.90	n/a	n/a	n/a
				others	38.10			
Singapore	4,839,400	1.49	7,205	plastic	55.00	5,104,000	1.80	9,187
				paper	25.00			
				others	20.00			
Thailand	22,453,143	1.76	39,452	plastic	68.00	29,063,000	1.95	56,673
				others	32.00			
Viet Nam	24,001,081	1.46	35,068	plastic	64.50	40,505,000	1.80	72,909
				others	36.00			

[1] *World Bank Report (2012)*
[2] *Hoornweg & Perinaz (2012)*
[3] *Fauna and Flora International (2020)*
[4] *World Bank Group (2018) cited in Sari* et al. *(2020)*
[5] *SEA Circular (2020); Note: Data as of 2014*

several smaller rivers before flowing to the South China Sea (Schmidt *et al*., 2017; Hatta & Nishiwaki, 2018). Nowadays, numerous tonnes of debris is not properly managed, recycled, or disposed of (Jambeck *et al*., 2015). In 2010, five AMSs, namely: Indonesia, Philippines, Viet Nam, Thailand, and Malaysia, were among the largest sources of mismanaged plastic wastes entering the oceans. Such a situation recognizes the urgency to act to contain the problem so that the 34th ASEAN Summit in Bangkok, Thailand in June 2019 adopted the "Bangkok Declaration on Combating Marine Debris in the ASEAN Region," which aims to "promote cooperation for the protection, restoration and sustainable use of the coastal and marine environment, and respond and deal with the risk of pollution and threats to the marine ecosystem and coastal environment, with particular respect to the ecologically sensitive areas."

Status of marine debris and microplastic pollution in Southeast Asia

Marine debris and microplastics in the aquatic environment have been attracting global attention. Several studies have demonstrated that marine organisms are mostly affected by entangling and ingesting marine debris (Galgani *et al*., 2019), and also by taking up microplastics which accumulate in their tissues as toxic pollutants or if at all, because these are very tiny, could enter the circulation and gain access to the liver via the portal vein (Avio *et al*., 2017; Yong *et al*., 2020). The long-term accumulation of microplastics in liver tissues and chronic inflammation could lead to liver diseases and metabolic problems (Yong *et al*., 2020). Thus, the impacts of marine debris and microplastics are of major concern globally but studies on marine debris and microplastics are still insufficient, particularly in the Southeast Asian region. The few studies carried out in the region concluded that pollution from plastic debris was predominantly of the marine debris and microplastics present in every marine ecosystem such as in mangroves, water, sediments, and biota.

In Brunei Darussalam, Qaisrani *et al*. (2020a) reported that plastic materials were found abundantly among the debris on the beaches, comprising plastics, miscellaneous materials, and lumber. Although publications on microplastics are still limited in the country, one study on the contamination in a beach area by Qaisrani *et al*. (2020b) indicated that a beach in Brunei Darussalam had been contaminated by microplastics even if that beach rarely has human activities.

In Cambodia, the data came mainly from Koh Sdach Village which indicated that nearly a third of household wastes (by weight) comprised plastic and plastic materials. Additionally, 52 % of the respondents in a survey expressed that fishing nets are discarded by fishers directly into the ocean. There is no publication on the situation of microplastics in marine ecology in Cambodia.

In the study by Irianto & Dwiyitno (2020), the results showed that the Indonesian waters are a potential ecosystem for microplastics pollution. For example, in Sumba, Indonesia, microplastics were found through the water column (5 m, 50 m, 100 m, 300 m, and near the sea bottom) with 82 % of microplastics found at the thermocline area which is less than 100 m water in depth (Cordova & Hernawan, 2018). MP particles were also found in the gastrointestinal tracts of some fishes, *e.g. Trichiurus* sp. (hairtail) and *Johnius* sp. (croaker) with sizes ranging from 0.12 mm to 5.00 mm (Ismail *et al*., 2019).

In the assessment made by Mobilik *et al*. (2014) on the amount and distribution of marine debris during the different monsoon seasons in the public beaches of Malaysia, the results showed that there were more than 7,000 debris items during the southwest monsoon, around 6,000 during the northeast monsoon, and around 3,000 during intermediate monsoon, and consisting mainly of plastic. The presence of microplastic in the water, sediments, fish, and zooplankton in the marine environment was determined and polypropylene was the most abundant type of microplastic found in the surface water and sediments in Kelantab Bay (Saipolbahri *et al*., 2020). Nine of 11 sampled commercial fish species contained microplastics while at the Terengganu Coast, microplastics were also present in zooplankton including fish larvae, cyclopoid, shrimicroplastics, polychaetes, calanoids, and chaetognaths, ingesting 0.14, 0.13, 0.01, 0.007, 0.005, and 0.003 particles per individual, respectively (Amin *et al*., 2019; Karbalaei *et al*., 2019).

Results of the survey carried out in the waters of Myanmar in 2018 to determine the amount and nature of microplastics, showed that the mean levels of microplastics at the surface layer was from 8,000 to 27,000 microplastics per km^2. Moreover, the most abundant fragments found in Rakhine and Delta area were fibers which were most abundant in the Tanintharyi Coast (Thein, personal communication, 2021).

During the clean-up of Manila Bay, Philippines conducted in 2014, it was revealed that most of the solid wastes collected were plastics and plastic materials. microplastics are ubiquitous and continually accumulate in the Philippine ecosystem, like in the first microplastic study conducted by Argamino and Janairo (2016), the presence of microplastics was recorded in the acid-digested soft tissue of the mussel *Perna viridis*. Newly published studies have also confirmed the contamination of microplastics in the marine environments of the Philippines including in the sediments, waters, and finfish resources (Kalnasa *et al*., 2019; Espiritu *et al*., 2019; Bucol *et al*., 2020; Abiñon *et al*., 2020).

In Singapore, a study in 2018 showed that about one-third of domestic wastes that its populace disposed of comprised packaging wastes. Such solid wastes include not only plastic and paper packaging but also other types of packaging materials, such as metals and glass (Ministry of Environment and Water Resources, 2021).

Thailand could be considered as the highest consumption per capita of plastics in Asia (Corben, 2017). Plastics were the most abundant debris type found in Angsila, Bangsaen, Samaesarn Beach areas (Thusharia *et al*., 2017) followed by other materials such as glass bottles, polystyrene foam, ropes, cans, and others (Department of Coastal and Marine Resources, 2021). In the study on microplastics carried out in Phuket Province by Akkajit *et al*. (2019), who assessed the contamination of microplastics in Kalim, Tri Trang, and Patong Beaches, the results indicated that microplastics varied in abundance from 1 to 35 items m-2 with fiber comprising the majority of microplastics found in the samples. Results of a study on the contamination of microplastics in bivalves, *Danax* sp. and *Paphia* sp. by Tharamon *et al*. (2016) indicated that the most prevalent type of microplastics was the fiber that was found in Chaolao Beach and Kungwiman Beach in Chanthaburi Province, Thailand. A study also confirmed the presence of microplastics in the stomach contents of some economically important fish species (*Panna microdon*, *Dendrophysa russelli*, *Johnius borneensis*, and *Johnius weberi*) caught in the lower Gulf of Thailand and fibers were the major forms of microplastics (Azad *et al*., 2018). An analysis of the sediment cores collected in Thailand indicated that the number of extracted microplastics increased toward the surface so that at the surface sediment, the number of microplastics was 100 pcs/kg (Matsuguma *et al*., 2017).

Viet Nam has always treated with serious concern their plastic wastes situation as it affects the marine environment (Danh & Hoi, 2019). Most of the country's beaches are polluted with debris and plastic wastes. Of the plastic wastes, it was found that almost all kinds are related to fishery activities (culturing, exploiting, trading, etc.) followed by single-use plastics and other domestic wastes (International Union for Conservation of Nature, 2019). Microplastic contamination in surface waters varied with the lowest concentrations recorded in the bays and the highest in the rivers, with fibers dominating the fragments in most environments (Strady *et al*., 2021). When the number of microplastics was investigated in shorelines from Da Nang Beach by Nguyen *et al*. (2021), the results showed that synthetic fiber was the most predominant type of microplastics present.

Harmful impacts of marine debris and microplastics on aquatic organisms and humans

Plastic waste is one type of water pollutions, becoming one of the most serious global issues due to its durability that could persist for years without being degraded or decomposed in the marine ecosystem. The physical effects of plastic debris have been demonstrated in marine organisms, like for example, the incidence of entanglement, suffocation, and disruption of digestion in birds, fishes, mammals, turtles, and the like. While microplastics can enter the systems of marine organisms and humans through ingestion and inhalation, they could cause adverse impacts as these are sources of toxic chemicals such as phenanthrene, mercury, cadmium, and polychlorinated biphenyls (PCBs) that are persistent organic pollutants (POPs).

As a result of the increased utilization of plastic materials, the impact of marine debris on various organisms has been going worst. During the 2013 International Coastal Cleanup, the top ten debris items included cigarette butts, plastic food wrappers, plastics, beverage bottles, plastic bottle caps, straws and stirrers, plastic grocery bags, glass beverage bottles, other plastic bags, paper bags, and beverage cans; and seven of these items are made of plastic (Secretariat of the Convention on Biological Diversity, 2016). Many marine organisms, *e.g.* invertebrates, fishes, turtles, marine mammals, ingest plastic debris in their search for food that generally led to their deaths. Abreo *et al*. (2016a) reported the first evidence in the Philippines of plastic ingestion by the beaked whale *Mesoplodon hotaula* and confirmed the susceptibility of cetaceans to plastic ingestion. Results of the necropsy of a dead adult turtle conducted in Brgy. Lapu-Lapu, Agdao, Davao City, Philippines showed that several plastic materials had caused a blockage in the pyloric end of the stomach leading to its death (Abreo *et al*., 2016b). A dead sperm whale near Kapota Island in Indonesia in 2018 was found to have ingested plastic litter that comprised drinking cups, plastic bags, plastic bottles, slippers, and a bag containing more than a thousand pieces of strings, in all weighing about 6 kg (BBC News, 2018 as cited in Luadnakrob & Arnupapboon, 2021). In Thailand, the number of deaths among marine endangered species in 2016 due to consuming fishing gear and plastic-based wastes was 355 and over 95 % of these are turtles and dolphins (Thaitrakulpanich, 2016). Additionally, marine debris can affect the ecosystems and biodiversity by acting as transport for invasive species or smothering benthic fauna (Todd *et al*., 2010).

Microplastics are widely distributed in marine environments such as in the beach, mangrove areas, seawater, sea bottom, and biota, among others. It can enter the systems of marine organisms through ingestion causing adverse impacts. Yong *et al*. (2020) compiled recent findings related to the potential toxicity and detrimental effects of micro- and nanoplastics (NPs) and established that ingesting microplastics/NPs could result in behavioral abnormalities in fish in terms of feeding, and movements of adults and larvae as well as reproduction in adults, and also the occurrence of changes in blood cells, brain appearance, metabolites, key metabolic enzymes, and oxidative stress-induced enzymes.

Even though the long-term consequences of the accumulation of microplastics in mammals and humans are yet unclear

(Yong *et al*., 2020) but several fishery consumers are concerned that microplastics could be harmful to the consumers as these could be a source of toxic poisoning. Therefore, based on food safety concerns, the contamination of microplastics in fish and fishery products could impede the sustainable development of fisheries as an important economic sector of the Southeast Asian region.

Mitigating debris pollution from the fisheries sector of Southeast Asia

As a marine environment utilizer, the fisheries sector occupies a high proportion of the marine areas, particularly the coastal areas identified as the most polluted areas. This sector could be impacted by the direct dumping of pollutants into the ocean. Therefore, the role of the fisheries sector would form key success in combating aquatic pollution, particularly those of fishers and fisheries communities by cooperating in all efforts to combat marine debris and microplastics pollution.

Some of the programs initiated in the Southeast Asian region that need cooperation from stakeholders in the fisheries sector include the following:

- Studies on abandoned, lost, or otherwise discarded fishing gear (ALDFG)
- Conservative campaign on marine debris by encouraging volunteer fishers to keep all wastes produced in fishing vessels, garbage, or damaged fishing gears to bring to shore and dispose of properly to prevent and mitigate direct dumping of marine debris
- Encouraging aquaculture facilities to bag their garbage and dispose of them properly on land
- Setting up of pilot fishery communities to come up with useful products like building materials from plastic wastes available in the communities
- Building up or improving the capacity of fishery communities to be able to easily manage wastes

Activities of SEAFDEC to address issues on marine debris and microplastics

In an effort toward addressing the issues on marine debris and microplastics in the Southeast Asian region, SEAFDEC collaborated with relevant organizations and agencies to implement several projects by conducting research and providing technical support to AMSs in the capacity building of their human resources to conduct sampling surveys and data analysis. In 2015 for example, SEAFDEC/TD conducted a preliminary assessment of marine debris on the seafloor of Sri Racha in Chon Buri, Thailand (Yasook *et al*., 2015). About 1.9 km2 area was swiped using otter board bottom trawl and collected about 74 kg of marine litter items that composed of fabrics, wood, plastics, metals, glass, ALDFG, and other items (paper, rubber, and coal).

During the Collaborative Research Survey in the Gulf of Thailand using the M.V. SEAFDEC 2 which was conducted in 2018, SEAFDEC/TD collaborated with the Burapha University in Chantaburi Campus, Thailand, to carry out the study on the distribution of marine debris at the seafloor of the Gulf of Thailand, and with Chulalongkorn University, Thailand to carry out the study on microplastics contamination in seawater, seafloor, and fish.

Subsequently, from November to early December 2019, SEAFDEC/TD organized the shipboard training for researchers from various research agencies on marine debris observation utilizing the M.V. SEAFDEC 2 while it was on a survey cruise in the inner part of the Gulf of Thailand. The research technique established during the training would be shared with the other researchers from the AMSs to enhance their knowledge and capacity to study marine debris in the waters of their respective countries.

In 2020, SEAFDEC/TD organized the "Technical Ad Hoc Meeting on Marine Debris in Thailand" in Samut Prakan, Thailand with participants from Japan, Thailand, and SEAFDEC/TD, to establish the 5-year collaborative research between SEAFDEC and Chulalongkorn University, through the Science and Technology Research Partnership for Sustainable Development (SATREPS) Programme of the Government of Japan that promotes international joint research activities. The proposed 5-year collaborative research is aimed at: 1) establishing a center of excellence regarding marine plastic pollution research in Southeast Asia; and 2) supporting, justifying, and updating the action plan issued by the Southeast Asian countries on the management of marine litter.

In 2021, SEAFDEC/TD sought funding from the Japan-ASEAN Integration Fund (JAIF) for the proposed Project "Regional Collaborative Research and Capacity Building for Monitoring and Reduction of Marine Debris from Fisheries in Southeast Asia," which is aimed at enhancing regional collaborative research and capacity building of the fisheries sector in Southeast Asia through the application of scientific knowledge in regional policies for monitoring and reducing marine debris. Moreover, it is expected that the Project would reinforce the contribution of the fisheries sector in addressing the issues on marine debris in Southeast Asia by reducing its negative impacts and encouraging positive actions in cooperation with fishers, the private sector, and other relevant sectors in the AMSs.

Meanwhile, SEAFDEC/IFRDMD which is mandated to promote the sustainable development of inland fisheries takes part in the national pilot study of Indonesia on the presence of microplastic contaminants in freshwater fishes. Results of such pilot study would be used to formulate the appropriate workplan for monitoring and analyzing the presence and risks of microplastic contaminants in freshwater fishes to humans and the environment. Furthermore, the said workplan would also include identifying and reducing or eliminating the sources of microplastics in the freshwater ecosystem. It is also envisioned that the results of this pilot study would provide the methodology and information necessary in establishing the standardized sampling programs and a more comprehensive understanding of microplastics' absorption in freshwater fishes. Ultimately, the results would lead to the identification of the scientific evidence on the microplastic contaminants in the food supply chain and the risks of such pollutants to humans and the environment.

On the other hand, industries are also among the main sources of marine pollution in the region, especially in the form of petroleum or oil spills common in the region. For example, the oil spill accident was caused by a bursting pipeline in Koh Samet, Thailand in 2013. The accident affected the coastal and marine environment in the Gulf of Thailand, and a marine biologist said it would take years before marine life returned to normal in the worst-affected area (The New York Times, 2013). An explosion aboard a power barge off the Philippine Island of Guimaras in 2020 has spilled up to a quarter-million liters of fuel oil, threatening not only the local communities but also the mangrove and seagrass habitats. It was recalled that the mangroves off Guimaras had been affected by the Philippines' biggest ever oil spill in 2006, when an oil tanker sank, spilling half a million liters of fuel and affecting 648 hectares (1,600 acres) of mangrove forests and seagrass areas, which were already recovering that is why cleanup efforts had been enhanced to keep the latest oil spill away from the recovering mangrove swamps. The effect of crude oil on marine life, such as adult fish, may experience reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproduction impairment. Fish eggs and larvae can be especially sensitive to lethal and sublethal impacts. Even when lethal impacts are not observed, oil can make fish and shellfish unsafe for humans to eat (NOAA, 2021).

Recommendations on combating marine debris and microplastics by the fisheries sector

Marine debris pollution could not be separated from that of microplastics, as its impact on the environment is also getting severe due to the increased use of quantities of plastics in many areas of our modern lives, such as for clothing, packaging, storage, and the like. Currently, plastic products are commonly used in the Southeast Asian countries, and the demand for plastic items has even increased. The MSW generated daily by the Southeast Asian region could be estimated at 201,807 mt a day at 0.79 kg per capita per day and is projected to increase to 445,841 mt a day at 1.13 kg per capita per day by 2025 (World Bank, 2012) as shown in Table 78. It has also been predicted that microplastics contamination would be present in all marine ecology including beaches, mangroves, seawater, sea bottom, biota, and many more.

To achieve regional success in reducing aquatic pollution and preventing its adverse impacts on the environment, it is necessary to focus on policy solutions and management of plastic wastes. Various legal instruments and supporting programs have been developed including regional soft-law instruments, namely: the Bangkok Declaration on Marine Debris and the ASEAN Framework for Action on Marine Debris which include the need to mitigate the occurrence of marine debris and microplastics in the Southeast Asian region. These efforts demonstrate ASEAN's commitment to advance concrete action in environmental protection. The ASEAN Framework of Action on Marine Debris could be accessed at https://asean.org/storage/2019/06/3. -ASEAN-Framework-of-Action-on-Marine-Debris-FINAL.pdf.

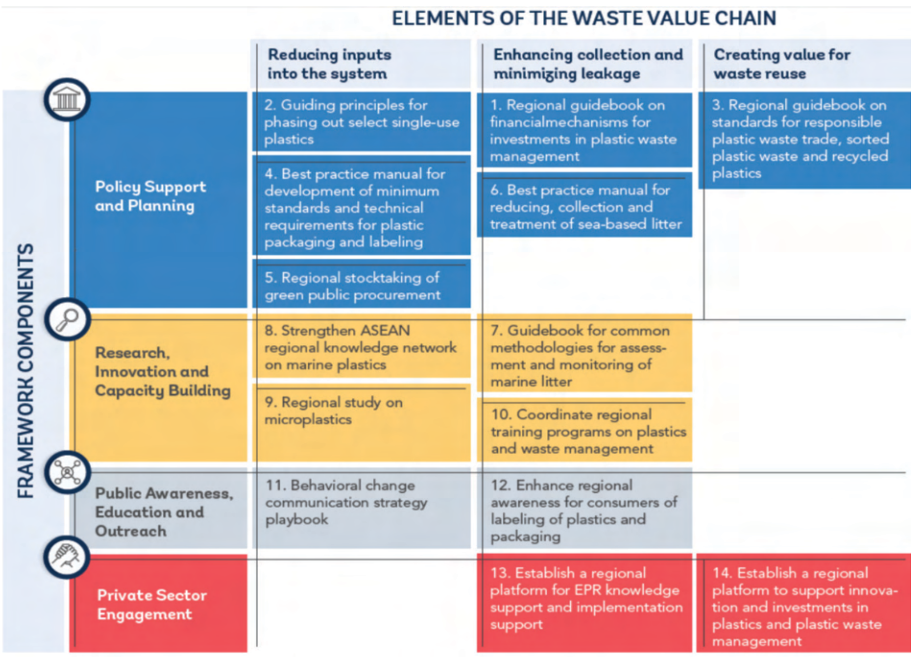


Figure 103. Summary of Plan of Action for Combating Marine Debris in Southeast Asian Region (ASEAN Secretariat, 2021)

As a follow-up, the ASEAN Regional Action Plan for Combating Marine Debris (2021-2025) was developed from October 2019 to July 2020 through extensive consultation with relevant experts and stakeholders. This regional action plan proposes the phased implementation of a systematic and integrated response to guide regional actions in addressing the issue of marine plastic pollution in ASEAN over the next five years (2021-2025). The potential solutions along the value chain to overcome unsustainable plastic consumption, waste management, and marine debris pollution were identified. There are 3 elements of west value chine 4 framework components and 14 regional actions for the Asian Member states (**Figure 103**). The Actions are aimed at addressing plastic issues along the value chain and are categorized according to the four Framework of Action Components (ASEAN Secretariat, 2021).

Furthermore, with the concerns in reducing marine pollution issues, a resolution was adopted by the United Nations under Goal 14 of its "Sustainable Development Goals," specifying in Target 14.1 that: "*By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution*" (UN, 2017). Recently, the "Sustainable Development Goals" became the measurement guide for countries in the region to develop their respective resolutions to address aquatic pollution issues.

Way Forward

In implementing the aforementioned recommendations, the contribution and cooperation of the fisheries sector could form the key success in combating aquatic pollution in the Southeast Asian region. The specific roles of the fisheries sector are therefore summarized below:

- The fisheries sector plays a significant role in improving marine debris and microplastics situation because its activities directly affect the aquatic ecology, and to mitigate the seriousness of the situation, governments should establish national and regional policies and action plans that put more focus on the fisheries sector, *e.g.* strengthen the fishing ports' sewage and garbage management to handle the debris originating from fishing vessels

- Publish guidebooks for the fisheries sector on combating debris and microplastic pollution that provide the guiding principles in reducing and/or eliminating the number of marine debris and microplastics in the marine ecosystem

- Research institutions and the academe to conduct studies on new fishing technologies and practices, and promote the results of such studies to the stakeholders in the fisheries sector, *e.g.* use of biodegradable fishing gear and fishing gear marking would facilitate decomposition and disposal of fishing gears, and ensure that fishing gear are disposed of in a sustainable manner, and subsequently, reduce the impacts and numbers of ALDFG at sea that continue to catch fish and other animals for a long period

- Study and monitor the effect of marine debris and microplastics generated by the fishery sector from damaged fishing vessels and equipment to the reduced potential catch and a potential drop in fishery product demand

- Build up the awareness of fishers through the promotion of fishers' awareness programs or activities integrating activities on combating marine debris and microplastics pollution, promotion of the practices and achievements of the programs to encourage fishers to take actions on their own towards minimizing pollutions in the oceans by controlling the dumping of marine debris and microplastics into the waters

- Establish fishery combatting marine debris and microplastic working group and platform to put each plan into action in cooperation with supporting bodies, and share knowledge and implementation successes and failures with the ASEAN Member States (AMSs), especially taking into consideration the best practices, design principles and experiences in combating marine debris for the benefit of all AMSs

8.3 Impacts of COVID-19 Pandemics on Fisheries and Aquaculture

The coronavirus disease 2019 (COVID-19) was declared a global pandemic by the World Health Organization (WHO) on 11 March 2020 as a rapid response to prevent further infections mainly in people. Since then, COVID-19 has immensely threatened public health, created an economic crisis, and destabilized food security. Since the onslaught of the virus has been worldwide, associated measures had been enforced to decrease the extent of risks and the numbers of infected persons, and mortality rates, such as social distancing, transportation restrictions, and home confinements, travel bans, business closures, among others, consequently affecting global economy resulting in uncertainties not only in the livelihood opportunities but also in the sustainability of supplies at the international and domestic supply chains (UN, 2020).

All aspects of the fisheries supply chain, *e.g.* capture fisheries, aquaculture, transportation, post-harvest processing, and trading of fish and fishery products have been strongly impacted by the measures to contain COVID-19 outbreaks. As the Southeast Asia region has been a major contributor to the world's total fish and fisheries production, therefore, such measures could also result in disruptions to fish production and fish consumption across the value chains in the region (FAO, 2021). While much attention has been focused on the impacts on fisheries and aquaculture related activities at various levels, efforts have also been exerted to cope and maintain functioning at each stage of the fisheries and aquaculture activities which had been disrupted by the measures enforced throughout the coronavirus pandemic restrictions (OECD, 2020).

So, with support from the Japanese Trust Fund, SEAFDEC conducted the study on the "Impacts of COVID-19 Pandemic on the Fisheries Sector of the ASEAN-SEAFDEC Member Countries" to assess the impacts of COVID-19, identify the mitigating measures, and develop policy recommendations on possible actions to be undertaken by the respective countries' fisheries sub-sectors. Through a questionnaire survey, the study focused on the data and information provided by the countries on their COVID-19 situations, especially in relation to their respective fisheries and aquaculture sector. The results of the study, which would be published for dissemination to the region, is summarized below.

Impacts on marine capture fisheries

- *Small-scale fisheries*

As shown in **Figure 104**, the number of people engaged in small-scale fishing activities had increased in Brunei Darussalam, while it slightly decreased in Malaysia and decreased in Myanmar and Thailand. For the number of small-scale fishing vessels in operation, there was a slight increase in Brunei Darussalam and a decrease in Myanmar and Thailand. The duration/period of fishing activity was not affected in Brunei Darussalam and Thailand but decreased in Myanmar. The cost of fishing operation had increased in Brunei Darussalam and Myanmar but there was no change in Malaysia and Thailand. While in Brunei Darussalam, Malaysia, and Thailand, the amount of catch per fishing trip was not affected but this had decreased in Myanmar. The price of catch in wholesale markets/landing centers was stable in Brunei Darussalam and Malaysia but decreased in Thailand. The logistics/access of fishers to markets was

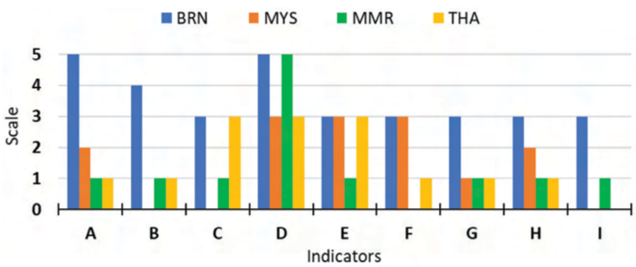


Figure 104. Impacts of COVID-19 on small-scale fisheries of selected ASEAN Member States

(BRN- Brunei Darussalam, MYS-Malaysia, MMR-Myanmar, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Number of people engaged in small-scale fishing activities; B-Number of small-scale fishing vessels in operation; C-Duration/period of fishing activity; D-Cost of fishing operation (fuel, ice, bait, equipment, maintenance, etc.); E-Amount of catch per fishing trip; F-Price of catch in wholesale markets/landing centers; G-Logistics/access of fishers to markets (transportation, buyers, etc.); H-Income of fishers from small-scale fishing activities; I-Liquidity and income of small-scale fishers from other activities)

not affected in Brunei Darussalam but had decreased in Malaysia, Myanmar, and Thailand. Specifically in Brunei Darussalam, the income of fishers from small-scale fishing activities was not affected but it slightly decreased in Malaysia and decreased in Myanmar and Thailand. The liquidity and income of small-scale fishers from other activities were stable in Brunei Darussalam but decreased in Myanmar.

- *Commercial fisheries*

As shown in **Figure 105**, the duration/period of fishing activity was not affected in Brunei Darussalam but decreased in Myanmar. Meanwhile, the cost of fishing operation had increased in Brunei Darussalam and Myanmar but there was no change in Malaysia and Thailand. The amount of catch per fishing trip had not changed in Brunei Darussalam, Malaysia, and Thailand but decreased in Myanmar. Although the price of catch in wholesale markets/landing centers had been stable in Brunei Darussalam and Malaysia, this decreased in Thailand. The transshipment at sea and cold chain systems were not affected in Myanmar and Malaysia, respectively. While access to fish ports was not affected in Malaysia but this decreased in Myanmar. The capacity of cold storage facilities had been stable in Malaysia, and the liquidity and income of fishing operators from fishing had decreased in Myanmar and Thailand.

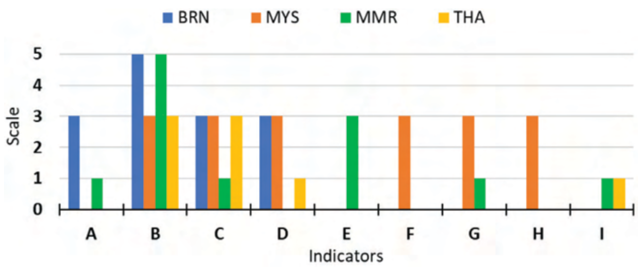


Figure 105. Impacts of COVID-19 on commercial fisheries of selected ASEAN Member States

(BRN- Brunei Darussalam, MYS-Malaysia, MMR-Myanmar, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Duration/period of fishing activity; B-Cost of fishing operation (fuel, ice, bait, equipment, maintenance, etc.); C-Amount of catch per fishing trip; D-Price of catch in wholesale markets/landing centers; E-Transshipment at sea; F-Cold chain system; G-Access to fish ports; H-Capacity of cold storage facilities; I-Liquidity and income of fishing operators from fishing)

- *Inland capture fisheries*

Figure 106 shows that the number of active fishing vessels engaged in inland fisheries operations had decreased in Myanmar but remained stable in Thailand, while the number of people engaged in inland capture fishing activities had decreased in Myanmar but this increased in Thailand. The duration/period of fishing activity had decreased in Myanmar and Thailand. Although the cost of fishing operations was not affected in Malaysia and Thailand, it had increased in Myanmar. There was no change in the amount of catch per fishing trip in Malaysia but there was a decrease in Myanmar. The price of catch in wholesale

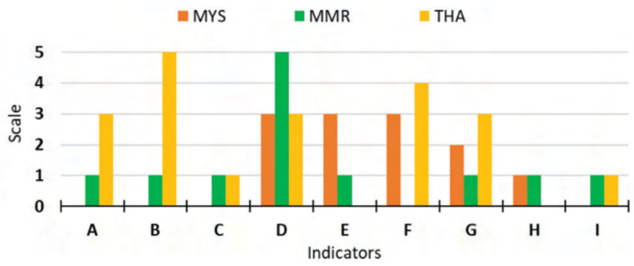


Figure 106. Impacts of COVID-19 on inland capture fisheries of selected ASEAN Member States

(MYS-Malaysia, MMR-Myanmar, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Number of active fishing vessels in operation; B-Number of people engaged in inland capture fishing activities; C-Duration/period of fishing activity; D-Cost of fishing operations (fuel, ice, bait, equipment, maintenance, etc.); E-Amount of catch per fishing trip; F-Price of catch in wholesale markets/landing centers; G-Logistics/access of fishers to markets (transportation, buyers, etc.); H-Income of fishers from inland fishing activities; I-Liquidity and income of fishers from other activities)

markets/landing centers was stable in Malaysia but slightly increased in Thailand. The logistics/access of fishers to markets had slightly decreased in Malaysia and decreased in Myanmar but have not been affected in Thailand. The income of fishers from inland fishing activities had decreased in Malaysia and Myanmar, and the liquidity and income of fishers from other activities had decreased in Myanmar and Thailand.

- *Fisheries Management*

As shown in **Figure 107**, the application of innovative technologies to combat IUU fishing has not affected Brunei Darussalam, Malaysia, and Myanmar but this had increased in Indonesia. The status of implementation of port State measures in Brunei Darussalam, Malaysia, Myanmar, Singapore, and Thailand had been stable, but there was a decrease in Indonesia. The implementation of MCS was not changed in Brunei Darussalam, while the frequency increased in Indonesia, slightly decreased in Malaysia, and decreased in Myanmar and Thailand. The conduct of regular/routine data collection for fish stock assessment and monitoring of shared stocks/transboundary species had

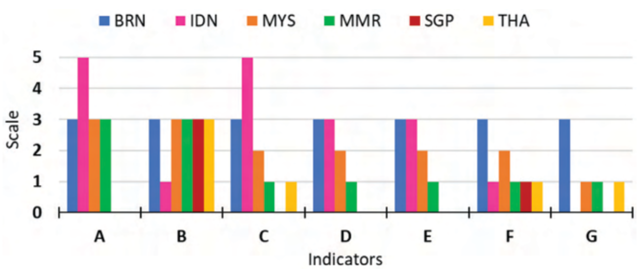


Figure 107. Impacts of COVID-19 on fisheries management of selected ASEAN Member States

(BRN- Brunei Darussalam, IDN-Indonesia, MYS-Malaysia, MMR-Myanmar, SGP-Singapore, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Application of innovative technologies to combat IUU fishing (GIS, remote sensing, etc.); B-Frequency of implementation of port State measures; C-Implementation of MCS; D-Conduct of regular/routine data collection for fish stock assessment; E-Monitoring of shared stocks/transboundary species; F-Conduct of physical meetings/workshops at international/regional/national levels; G-Conduct of research/project activities)

been stable in Brunei Darussalam and Indonesia, slightly decreased in Malaysia, and decreased in Myanmar. The frequency of the conduct of physical meetings/workshops at international/regional/national levels was not affected in Brunei Darussalam, but had slightly decreased in Malaysia and decreased in Indonesia, Myanmar, Singapore, and Thailand. The conduct of research/project activities had been maintained in Brunei Darussalam but had decreased in Malaysia, Myanmar, and Thailand.

- *Fishery resources and aquatic habitats*

For Brunei Darussalam, the COVID-19 pandemic had not created any impacts on its fishery resources and aquatic habitats. In Malaysia, an assessment of its fishery resources and aquatic habitats was conducted in July–September 2020, and the results indicated that in coastal areas, the amount of the fish stocks tend to be higher, and for its inland fishery resources and habitats, no significant impacts were observed as of September 2020, although fish seed restocking activities were carried out in inland waters during 2010–2020. There were no significant impacts observed on coral reefs and seagrass beds which could be due to the short period of assessment and relatively slow changes in the habitats. However, there was an increase in turtle nesting and hatchling due to reduced human activities. Moreover, the water quality at certain sites had improved.

For Myanmar, fishing pressures have become higher in coastal areas and illegal fishing practices had continued in the mangroves and offshore areas. In inland waters, illegal fishing practices such as intensive usage of electric fishing gears had persisted. The illegal fishing practices continued to occur due to the poverty of the dependent communities and travel restrictions. Therefore, the Government provided the fishers with about USD 16.00 support, while DOF Myanmar, in collaboration with the Maritime Police and local communities, is planning to apprehend illegal fishing practices.

For Singapore, the marine habitats remained stable due to the restrictions on the number of passengers on dive boats and decreased access to dive sites. On the beaches, there was an increase in the number of visitors but the negative impacts on beaches were slight or negligible because the crowds were well managed.

Impacts on aquaculture

The number of operational aquaculture farms was stable in Brunei Darussalam and Singapore (**Figure 108**). Although the access of fish farmers to fish farms was not affected in Brunei Darussalam, Indonesia, Malaysia, and Thailand, this had decreased in Singapore. The duration of the cycle of aquaculture from rearing to harvest had not changed in Brunei Darussalam and Singapore but increased in Indonesia, Malaysia, Myanmar, and Thailand. The cost

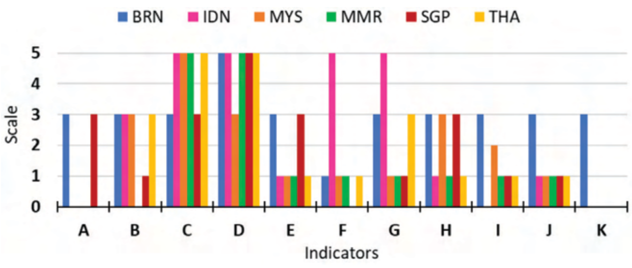


Figure 108. Impacts of COVID-19 on aquaculture of selected ASEAN Member States

(BRN- Brunei Darussalam, IDN-Indonesia, MYS-Malaysia, MMR-Myanmar, SGP-Singapore, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Number of operational aquaculture farms; B-Access of fish farmers to fish farms; C-Duration of the cycle of aquaculture from rearing to harvest; D-Cost of inputs (feeds, chemicals, power, equipment, maintenance, etc.); E-Quantity of production; F-Quantity of seed production; G-Quantity of production of ornamental fishes; H-Farm gate prices of market-size cultured species; I-Logistics/access of fish farmers to domestic/international markets (transportation, buyers, etc.); J-Income of fish farmers from aquaculture activities; K-Liquidity and income of fish farmers from other activities)

of inputs had increased in Brunei Darussalam, Indonesia, Myanmar, Singapore, and Thailand but Malaysia had not been affected. The quantity of production was stable in Brunei Darussalam and Singapore but had decreased in Indonesia, Malaysia, Myanmar, and Thailand. The quantity of seed production had decreased in Brunei Darussalam, Malaysia, Myanmar, and Thailand, but increased in Indonesia. In Brunei Darussalam and Thailand, the quantity of production of ornamental fishes was stable, increased in Indonesia but decreased in Malaysia, Myanmar, and Singapore. The farm gate prices of market-size cultured species were not affected in Brunei Darussalam, Malaysia, and Singapore, but had decreased in Indonesia, Myanmar, and Thailand. The logistics/access of fish farmers to domestic/international markets were not affected in Brunei Darussalam, had slightly decreased in Malaysia and decreased in Myanmar, Singapore, and Thailand. The income of fish farmers from aquaculture activities was stable in Brunei Darussalam but had decreased in Indonesia, Malaysia, Myanmar, Singapore, and Thailand. The liquidity and income of fish farmers from other activities were not affected in Brunei Darussalam.

Impacts on fish processing

As shown in **Figure 109**, the number of operational plants/factories was still the same in Brunei Darussalam and Thailand, but had slightly decreased in Malaysia and decreased in Indonesia and Myanmar. The duration of fish processing operations was not affected in Brunei Darussalam, but had slightly decreased in Malaysia and decreased in Myanmar. The availability of raw materials had decreased in Brunei Darussalam and Myanmar and slightly decreased in Malaysia. The operation cost had decreased in Brunei Darussalam and Malaysia. The processing lines were not affected in Brunei Darussalam and Malaysia but had decreased in Myanmar. The types of processed fish and fishery products had decreased in Brunei Darussalam and Indonesia but remained the same in Malaysia. The quantity of production was stable in Brunei Darussalam but decreased in Indonesia, Malaysia, and Myanmar. The price of processed fish and fishery products was stable in Brunei Darussalam, Indonesia, and Malaysia. The storage capacity of plants/factories had increased in Brunei Darussalam and remained the same in Indonesia. The application of product certification schemes was not affected in Indonesia and Malaysia.

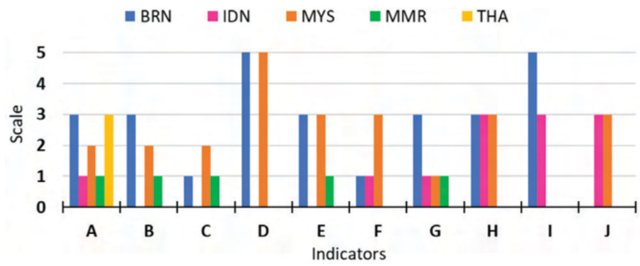


Figure 109. Impacts of COVID-19 on fish processing industry of selected ASEAN Member States

(BRN- Brunei Darussalam, IDN-Indonesia, MYS-Malaysia, MMR-Myanmar, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Number of operational plants/factories; B-Duration of fish processing operations; C-Availability of raw materials; D-Operation cost (equipment, power, etc.); E-Processing lines; F-Types of processed fish and fishery products; G-Quantity of production; H-Price of processed fish and fishery products; I-Storage capacity of plants/factories; J-Application of product certification schemes)

Impacts on trade and marketing

- *Domestic markets*

The number of operational markets had remained the same in Brunei Darussalam, but had slightly decreased in Malaysia and decreased in Indonesia and Thailand (**Figure 110**). The duration of operation of markets was unchanged in Brunei Darussalam but had decreased in Indonesia, Malaysia, and Thailand. The number of fish traders was not affected in Brunei Darussalam but had decreased in Indonesia and slightly increased in Malaysia. The supply of fish and fishery products had been stable in Brunei Darussalam, Indonesia, and Malaysia and slightly increased in Thailand. The demand for fish and fishery products was not affected

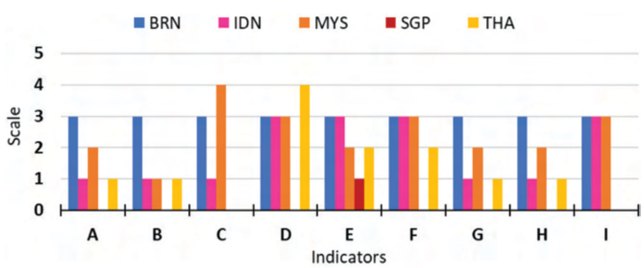


Figure 110. Impacts of COVID-19 on domestic fish trade of selected ASEAN Member States

(BRN- Brunei Darussalam, IDN-Indonesia, MYS-Malaysia, SGP-Singapore, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Number of operational markets; B-Duration of operation of markets; C-Number of fish traders; D-Supply of fish and fishery products; E-Demand for fish and fishery products; F-Selling price of fish and fishery products; G-Logistics/access of traders to markets (transportation, etc.); H-Logistics/access of consumers to markets (transportation, etc.); I-Liquidity and income of fish traders)

in Brunei Darussalam and Indonesia, but had slightly decreased in Malaysia and Thailand, and decreased in Singapore. There was no change in the selling price of fish and fishery products in Brunei Darussalam, Indonesia, and Malaysia, but there was a slight decrease in Thailand. The logistics/access of traders and consumers to markets was not affected in Brunei Darussalam, but had slightly decreased in Malaysia and decreased in Indonesia and Thailand. The liquidity and income of fish traders were not affected in Brunei Darussalam, Indonesia, and Malaysia.

- *International trade*

The logistics/access to international markets had decreased in Brunei Darussalam, Indonesia, Myanmar, and Thailand (**Figure 111**). Although the demand from the international market had increased in Brunei Darussalam and Thailand, it had not affected Indonesia, slightly decreased in Malaysia, and decreased in Myanmar. The types of exported processed fish and fishery products had slightly decreased in Brunei Darussalam and Malaysia, had not changed in Indonesia, and decreased in Thailand. The types of imported processed fish and fishery products had increased in Brunei Darussalam, no change in Indonesia and Thailand, and slightly increased in Malaysia. The traceability of exported/imported fish and fishery products remained stable in Brunei Darussalam and Indonesia, slightly decreased in Malaysia. The application of product certification schemes has not affected Brunei Darussalam and Indonesia but slightly decreased in Malaysia.

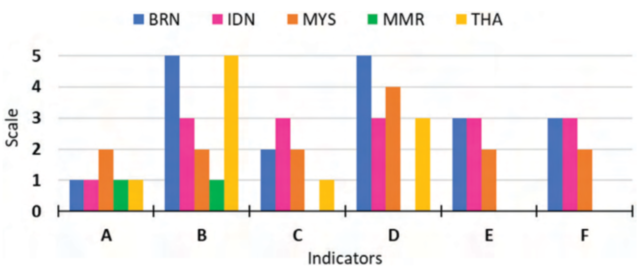


Figure 111. Impacts of COVID-19 on international fish trade of selected ASEAN Member States

(BRN- Brunei Darussalam, IDN-Indonesia, MYS-Malaysia, MMR-Myanmar, THA-Thailand. Scale: 0-Not applicable/no answer; 1-Decreased; 2-Slightly decreased; 3-Stable/no change; 4-Slightly increased; and 5-Increased. Indicators: A-Logistics/access to international markets; B-Demand from the international market; C-Types of exported processed fish and fishery products; D-Types of imported processed fish and fishery products; E-Traceability of exported/imported fish and fishery products; F-Application of product certification schemes)

Gender Roles

In Brunei Darussalam, there were no changes in gender roles before and during the COVID-19 pandemic. For small-scale fisheries, women went on helping their husbands in preparing the things needed for going to the sea as well as performing post-harvest processing; while the men, youth, and elderly continued in managing and operating their fishing boats. However, the elderly had reduced their frequency of engaging in fishing activities during the COVID-19. For commercial fisheries, the men continued to manage and operate fishing vessels and maintain fishing nets.

In Myanmar, there was no change in the roles of women and men in capture fisheries including small-scale fisheries, commercial fisheries, and inland capture fisheries where the role of women in processing and selling fish was retained, while the role of men in fishing continued. For Thailand, the small-scale fishing activities were the same before and during COVID-19, but with more caution during COVID-19. Women sustained processing and selling fish and fishing, while men and youth continued fishing. The elderly still did the housework and looked after the children. For commercial fisheries, women continued to process fish and men continued fishing. For inland capture fishing activities, the fishing activities of men were intensified during the COVID-19.

Mitigation measures and support programs

The national mitigation measures and support programs of the government of the respective countries which were intended for the fisheries and aquaculture sector in response to the COVID-19 pandemic are summarized in **Box 40**.

Way Forward

Although efforts have been exerted to respond to the recovery and sustain the operations in the fisheries and aquaculture sector during the pandemic, the complex impacts of the COVID-19 pandemic on the fisheries and aquaculture sector in Southeast Asia has remained unpredictable and unstable. The accurate support should contribute straight away to the short- and long-term sustainability of this sector. Therefore, thorough cooperation among related stakeholders and organizations is the most important key for the management and implementation of the recovery and support schemes for the fisheries and aquaculture value chains.

8.4 Fisheries Subsidies

With the global decline of fishery resources, numerous international organizations are striving to lobby their global scenarios in conserving the resources and ending any activities that may jeopardize the resources' long-term viability. Subsidies to fisheries have become a major topic of discussion in the World Trade Organization (WTO), considering that a variety of problems have emerged from the financial support extended by governments to the fisheries sector, with the incentives that appear to encourage overfishing rather than to help in achieving sustainable fisheries. It has been estimated that the global fisheries subsidies could be between USD 14 billion and USD 54 billion each year. Subsidies to reduce the cost of fuel for fishing fleets are the most common, accounting for 22 % of the global subsidies (Sumaila *et al*., 2019).

Box 40. Government mitigation measures and support programs for the fisheries and aquaculture sector in response to the COVID-19 pandemic
Brunei Darussalam • Top-up fund for aquaculture operators to bring in raw materials such as fish fry by chartered flight • Assistance for foreign workers on the application of entry permit
Indonesia • Assistance to fishers (*e.g.* provision of groceries and personal protective equipment, portable and mobile cold storage, ice-making machinery, and others) • Employment of thousands of workers who have lost their jobs due to COVID-19 through the Indonesia Coral Reef Garden (ICRG) 2020–2024: One of the National Economic Recovery Programs (PEN) and Mangrove Restoration Program (2020–2024)
Malaysia • Permitting all fishing and aquaculture activities, which were classified as essential services, during the enforcement of Movement Control Order (MCO) to ensure that food security is not compromised and the livelihoods of fishers and fish farmers are sustained • Dissemination of clear Standard Operating Procedures (SOP) and relevant guidelines through the Fisheries State Office, Fisheries District Office as well as social media to avoid miscommunication and ensure timely actions • Establishment of alternative marketing and distribution avenues such as controlled fresh markets in locations accessible to the public to allow fishers and fish farmers to sell their products and ensure that fresh products are accessible to the public at a fair price • Increment of the monthly cost of living allowances for small-scale fishers in marine and inland capture fisheries sub-sectors • Recovery plans to revive the fisheries and aquaculture sector by incorporating the sector in the short-, medium-, and long-term development plans
Myanmar • Allocation of USD 4.0 million for the distribution of fish seeds and fingerlings to fish farmers (July–September 2020) • Allocation of USD 40,514 to support the Safety at Sea Training for fish workers onboard fishing vessels (July–August 2020)
Singapore • Temporary Bridging Loan Programme for business owners to borrow up to about USD 3.7 million as working capital payable for five years (Apr 2020–Sept 2021) • Jobs Support Scheme as wage support for employers to retain local employees (Singapore citizens/permanent residents) during the period of economic uncertainty by co-funding a proportion of the first USD 3,400 gross monthly wages paid to each local employee up to March 2021 (Feb 2020–March 2021) • Foreign Worker Levy Rebate which was a waiver for monthly Foreign Worker Levy Fee by providing the businesses with USD 555 rebate for levies paid for each Work Permit/ Special Pass Holder (Apr–May 2020)
Thailand • Establishment of distribution channels through the Department of Fisheries for direct sale of prawn, white-leg shrimp, and Nile tilapia from fish farmers to consumers in 20 provinces where the selling prices were lower than the market prices • The Department of Fisheries issued the certificate for the operators who follow the measures to prevent COVID-19 contamination in fish and fishery products including aquaculture farms, fishing vessels, fish markets, quays, and central markets to build consumers' confidence in domestic and foreign markets • Establishment of the online market platform "Fisheries Shop" where fishers and fish farmers can sell their products online to avoid risky fresh markets and directly contact customers without dealing with middle persons • Strengthened the collaboration among stakeholders where factories inform fish farmers on the required amount of raw materials so that fish farmers could manage their production capacity and avoid oversupply (December 2020-April 2021)

WTO Negotiation on Fisheries Subsidies

The Doha Ministerial Conference in 2001 propelled the arrangements to clarify and move forward the WTO disciplines on fisheries subsidies, and during the Hong Kong Ministerial Conference in 2005, there was a broad agreement on fortifying those disciplines especially the appropriate and effective Special and Differential Treatment (S&DT) for developing and least-developed members which should be made indispensably part of the fisheries subsidies negotiations. In 2007, the Chair of Negotiating Group on Rules (NGRs) circulated the Draft Consolidated Chair Texts of the Anti-dumping and on Subsidies and Countervailing Measures (AD and SCM) which incorporated the disciplines on fisheries subsidies. Since then, several proposals relating to the Draft Consolidated Chair Texts had been submitted to the Chair. The development of the dialogue has prolonged the negotiations on the prohibition of positive styles of fisheries subsidies to be adopted in addition to the S&DT.

To conclude the negotiations, the Ministerial Conference (MC11) in 2017 decided on a workprograme with the goal of adopting a fisheries subsidy agreement at the next Ministerial Conference, to help in fulfilling the Sustainable Development Goal (SDG) 14.6. Such SDG calls on the UN Members to eliminate subsidies that contribute to overcapacity and overfishing or IUU fishing practices – supposed to be completed by 2020. With these mandates, WTO members have expected to finalize the agreement including the S&DT for developing and least-developed countries and elected Ambassador Santiago Wills of Colombia to serve as chair of the negotiations since November 2019.

The cluster meeting of the Negotiating Group on Rules for Fisheries Subsidies Negotiations was resumed on 25 June 2020, where the draft consolidated text of disciplines was also presented. In September 2020, the WTO members began debating the consolidated draft agreement. The members examined the draft text, especially those that focus on overcapacity and overfishing subsidies, subsidies to distant water fishing, S&DT for developing and least-developed countries, and transparency rules. Focus on specific areas of the text was particularly valuable, according to some members, because it helped generate some recommendations for compromise phrasing as well as better clarity on members' perspectives. Meetings of the cluster on fisheries subsidies were then convened from October to November 2020, before the finalization of the Agreement, which had been scheduled in December 2020.

In early 2021, negotiations using the draft consolidated text that was initially released in June 2020 continued and was still ongoing as of mid-2021, together with revised versions that were released in November and December 2020. In May 2021, the Chair presented a fresh draft text aimed at bringing the members closer to a consensus ahead of the virtual ministerial meeting on 15 July 2021. The significant changes in the revised draft text include tightening of the provisions for overfished stocks, focusing the task of the WTO on subsidies rather than on fisheries management, and eliminating language that could have had unintended consequences to the operation of international fisheries agreements; and transparency and notification obligations linked to the proposed flexibility entitlements, and the future formulation of S&DT as an exemption for subsidies granted by LDCs should be timebound.

During the virtual meeting of ministers and heads of delegations that took place on 15 July 2021, the Members agreed to finish the negotiations before the 12th Ministerial Conference (MC12) scheduled on 30 November to 3 December 2021 and gave the Geneva-based delegates the authority to do so. The Members also confirmed that the current negotiating text could be used as the basis for negotiations on the final agreement.

However, due to the lingering COVID-19 pandemic that forced many States to continue imposing travel restrictions, the General Council of WTO agreed on 26 November 2021 to postpone the MC12 although the new schedule had not yet been set as of the final preparations of this publication in December 2021.

Discussion on WTO Fisheries Subsidies at the Regional Level

The issue of subsidies in fisheries is one of the significant trade-related issues being addressed in the Japanese Trust Fund project "*Assistance of Capacity in the Region to Address International Fish-Trade Related Issues*" under the ASEAN-SEAFDEC Strategic Partnership mechanism. Importantly, the issue of subsidies in fisheries has been considered as a priority to be addressed under the Plan of Action (POA) on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 (SEAFDEC 2020a). The POA includes provisions on the need to "*assess the possible impacts of subsidies of fisheries, particularly on the special requirements and the needs of small-scale fisheries in the region*"; "*strengthen cooperation and mechanisms among AMSs to work towards common positions that could be reflected in international fish trade-related fora* e.g. *WTO...*"; and "*increase participation and involvement of AMSs in international fora and technical committees,* e.g. *WTO...*"

In the Southeast Asian region, the issue of fisheries subsidies was first raised in November 1999 at the SEAFDEC Preparatory Meeting on Issues of International Fish Trade and Environment. As a follow-up, the Regional Technical Consultation (RTC) on Fish Trade in the ASEAN Region was organized in Bangkok, Thailand on 9–11 April 2001. The findings of the RTC were then presented and discussed during the Technical Session of the "Millennium Conference" in Bangkok in June 2001. As a result, the Technical Report, which was produced as a result of the Technical Session, offered many recommendations that could be used as the basis for the formulation of policy considerations on fish trade by the ASEAN-SEAFDEC Member Countries. These recommendations include removing subsidies which are clearly shown to contribute to unsustainable fisheries practices; reviewing, in collaboration with international technical organizations such as FAO, the empirical effects of fishery subsidies on essential social and developmental issues; and developing a regional policy on fisheries subsidies, taking into consideration the regional specific requirements, and producing regional guidelines for fisheries subsidies.

Subsequently, the ASEAN and SEAFDEC organized the RTC on Fisheries Subsidies in 2003 and the Regional Meeting on Fish Trade and Environment in 2004. The meetings agreed that granting of subsidies should be accompanied by careful monitoring of their environmental and socioeconomic consequences and that any proposal opposing the granting of fisheries subsidies not backed up by enough scientific evidence and/or that undermines ongoing national resource management should be rejected. The meetings also emphasized the need for the ASEAN Member States (AMSs) to agree on a common position that the AMSs could use during international negotiations. It was noted, however, that there has been no systematic discussion on subsidies among the fisheries management authorities, and that fisheries management authorities from the AMSs were always underrepresented at the WTO meetings (Torell, 2003).

Consequently, the ASEAN-SEAFDEC Member Countries continue to discuss the regional positions from time to time through the ASEAN-SEAFDEC regional consultations, meetings of SEAFDEC Council, and the ASEAN Sectoral

Working Group on Fisheries (ASWGFi). The regional common positions that had been established so far could be summarized as follows:

- Fisheries subsidies should be recognized as a tool used either as temporary or long-term measures under a broad national development and management framework to ensure the sustainability of fisheries
- Use of fisheries subsidies should be coupled with close monitoring and evaluation of the status of fishery resources as well as the impacts of subsidies on the socioeconomies and the resources, which differ from country to country
- Fisheries subsidies that contribute to sustainable fisheries, as well as people's livelihoods and poverty alleviation, should be permitted
- Some fisheries subsidies whether permitted or removed depending on a number of factors including management regime, the status of the resources, and the length of time that the subsidies are applied
- Fisheries subsidies contributing to over-exploitation of resources or unsustainable fisheries and trade distortion must be removed
- Close coordination between fisheries-related agencies and trade-related agencies in each country should be promoted to reflect the requirements and complexity of the fisheries

During the RTC on International Fisheries-related Issues convened by SEAFDEC in June 2018, it was pointed out that since a large portion of the catch in the region is multi-species, fisheries subsidies should therefore be considered by the types of fishing gear used and not by species. The RTC also recommended that the AMSs should consider the possibility of sending their respective country delegations that comprise their national fisheries officers, to take part in the different clusters of fisheries subsidies negotiations. Meanwhile, the RTC also suggested that SEAFDEC should consider facilitating the identification of a focal point from each AMS as well as the development of the ASEAN common position on fishery subsidies for adoption by the ASEAN Ministers on Agriculture and Forestry (AMAF), which should be reflected at the WTO fora.

In September 2020, SEAFDEC hosted the Webinar on "Fisheries Subsidies: Southeast Asian Region Perspective" to obtain updated information on the status of the negotiations from key relevant partners, *e.g.* SEAFDEC Member Countries, FAO, International Institute for Sustainable Development (IISD), WTO (SEAFDEC, 2021a). Attended by representatives from the ASEAN-SEAFDEC Member Countries, the Webinar identified the need for capacity building on stock assessment because the characteristics of Southeast Asian marine capture fisheries are complex and diversified, including the several species caught and gears used. Various stock assessment approaches have been tried in estimating the status of the stocks of commercially exploited aquatic species. However, there were obstacles encountered in the process due to a lack of time-series data and human resources to develop an acceptable stock assessment model. In this regard, the Webinar also asked SEAFDEC to consider collaborating with FAO and relevant experts for the development of stock assessment capacity building programs to improve knowledge and identify the necessary reference points (*e.g.* overcapacity, overfishing) for a better understanding of the stocks status, as well as the development of an appropriate multi-species stock assessment model to be used by the SEAFDEC Member Countries. The results would be advantageous to the SEAFDEC Member Countries during the WTO negotiations on fisheries subsidies.

Subsequently, SEAFDEC also convened the Webinar on the WTO Fisheries Subsidies Draft Consolidated Text (Negotiating Group on Rules) on 10 and 17 June 2021 to share the views on the WTO Fisheries Subsidies Draft Consolidated Chair Text (WTO-FSCCT) and obtain the views of the ASEAN-SEAFDEC Member Countries on such text (SEAFDEC, 2021b). The experts offered their perspectives on the draft text, focusing on three pillars of disciplines: prohibition of subsidies for IUU fishing, prohibition of subsidies for overfished stocks, and prohibition of subsidies for overcapacity and overfishing. This Webinar expressed the concern on the need to strengthen cooperation to assist the developing countries in identifying IUU fishing and effectiveness of IUU subsidy disciplines, assessment of the level of stock depletion, and the SD&T provisions for developing and least-developed countries.

In summary, the potential impacts of the WTO provisions on the fisheries sector of the region are of high and utmost concern. The region's fisheries and aquaculture are multi-species, multi-gear, and small-scale, but the region's small-scale fisheries sub-sector has been significantly contributing to food security, even considering that the amount of catch is unaccounted or under-represented. Assessment of the utilization of the fishery resources at the species level is necessary under the WTO provisions. It is, therefore, crucial to improving the capacity of the overall sector not only the small-scale fisheries sub-sector, to quantify the reference points and prove that the catch is at a sustainable level. With these concerns, the proposed transition period for two years under the WTO provisions seems to be impractical since the countries require more time, human resources, national legislations among others, to adjust and implement the new obligations.

Way Forward

Fisheries subsidies are among the important trade-related concerns being continuously discussed by the ASEAN-SEAFDEC Member Countries. Several dialogues had been convened to address the issues on fisheries subsidies, focusing on regional issues and requirements. The Member Countries are aware that contributing to unsustainable fishing practices should be avoided. However, more research is necessary to look into the scope and impacts of subsidies. In the continuing international negotiations on fisheries subsidies, capacity building on the stock assessment that suits the regional specificities and harmonized ASEAN position would be beneficial.

9. Socioeconomic Well-being in the Fisheries Sector

9.1 Labor in Fisheries and Fish Workers

Jobs in fisheries are associated with the entire value chain of fish and fishery products, starting from the production of the fish that includes fabrication of fishing gears; boat construction and maintenance; preparation of baits; catching the fish; and acquiring aquaculture seeds and feeds for fish culture as the case may be. At the end of the value chain is the consumption of the fish and fishery products that had undergone the processes of the utilization of raw materials by the fish processing industry, marketing, distribution, until the actual consumption by the public (FAO/ILO, 2013).

Fishing is recognized as among the most dangerous of all professions in the world. Recognizing the need to ensure that fishers have decent conditions of work onboard fishing vessels, the International Labour Organization (ILO) adopted in 2007 its Convention No. 188 or "Work in Fishing Convention" (C188) which is applied to all fishers and all fishing vessels engaged in commercial fishing operations, with the aim of creating decent working conditions for workers in the fisheries sector. C188 stipulates various provisions that include: minimum requirements for work onboard fishing vessels; conditions of service; accommodation and food; medical care, health protection, social security, among others.

As for small-scale fisheries, the "FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication" or SSF Guidelines, which calls for social and economic development to empower the small-scale fishers to assert their human rights, provides the opportunity for the small-scale fishers and fish workers to enhance their socioeconomic well-being. Thus, in the SSF Guidelines, the governments are called upon to ensure that international standards are included in their national legislation, including the right of fishers and fish workers to an adequate standard of living, decent work, and that health, education, and other essential needs are accorded them (FAO, 2014).

In the Southeast Asian region, fishing is considered a difficult job that requires a long period of works with high risk at sea. In several countries, people, therefore, tend to look for easier jobs in other sectors resulting in a shortage of fish workers that necessitated the recruitment of migrant workers to support the fishing industry. The availability of fish workers onboard fishing vessels has therefore become one of the critical issues for several countries in Southeast Asia. Although the direct responsibility in tackling labor-related issues may not be under the agencies responsible for fisheries in most of the Southeast Asian countries, the involvement of the fisheries-related agencies in ensuring good working conditions, safety, and welfare of people engaged in fisheries activities is unavoidable.

Such concern could also be seen in the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030, of which Resolution No. 13 specifies the need to "*Improve the working conditions of people engaged in fisheries activities, and strengthen measures for safety of fishing vessels taking into consideration the specificity of fisheries of the region*"; while the Plan of Action No. 19 also specifies the need to take up priority actions to "*Improve the capability of fishing crew and workers in fishing industry, and conduct educational and skills development program for new crew members and workers entering the industry; while also adopt appropriate technologies to optimize number of crew onboard fishing vessels.*"

Number of fishers and fish farmers and their Conditions in some AMSs

In the Fishery Statistical Bulletin of Southeast Asia published annually by SEAFDEC, some of the AMSs had provided information on their respective numbers of fishers and fish workers, *e.g.* Indonesia, Malaysia, Myanmar, Singapore, Thailand. Although some AMSs that have not submitted their numbers since SEAFDEC had started to include this information in the fishery statistics questionnaire.

Indonesia

The total number of fishers in marine and inland fisheries of Indonesia in 2019 based on the country's Fisher ID Program (KUSUKA) was 2,387,591 fishers; while the number of aquaculture household units (RTP) was estimated to be 1,583,369 households (broken down into seawater aquaculture of 124,700 households; brackishwater of 232,074 households; and freshwater aquaculture of 1,226,595 households).

The Indonesian government has established policies that are directed to the protection of workers onboard fishing vessels in order to address issues such as safety at sea, under-compensation, lengthy work duration, fish handling, and processing onboard. However, the major concerns in the implementation of such policies are towards the monitoring and reporting system on violations of the regulations.

The national laws and regulations regarding safety at sea of Indonesia are intended not only for small-scale fishers but also for all types of fishers to ensure their safety when going to fish. These are, among others, reflected in the following regulations:

- Regulation of the Minister of Marine Affairs and Fisheries Number 42/PERMEN-KP/2016 on Work Agreement for Fishing Vessels Crew
- Regulation of the Minister of Marine Affairs and Fisheries Number 35/PERMEN-KP/2015 on System and Certification on Human Rights for Fishery Business
- Regulation of the Minister of Marine Affairs and Fisheries Number 3/PERMEN-KP/2013 on Harbormaster in Fishing Ports
- Regulation of the Minister of Marine Affairs and Fisheries Number PER.07/MEN/2010 on Seaworthiness of Fishing Vessels

In principle, the applicable laws and regulations are meant to ensure the safety of fishers which include small-scale fishers in terms of seaworthiness before, during, and after their fishing operations. The safety aspect includes administration, facilities, work decency, equipment, capacity, and competence needed for fishing operations.

As for the aquaculture sub-sector, the government of Indonesia also has policies that are aimed at protecting the sustainability of fish farmers in Indonesia through various instruments, *e.g.* Law of the Republic of Indonesia Number 7 of 2016 concerning the protection and empowerment of fishers, fish farmers, and salt farmers. As provided for in its Chapter 1 Article 1, the Law aims to assist fishers, fish farmers facing problems and difficulties in conducting fish farming by empowering them to improve their ability to carry out fisheries or salt business ventures.

Malaysia

The DOF Malaysia collects data on fishers and fish farmers from its licensing and administration records, and constant surveillance. In 2019, the number of fishers recorded was 126,595, while the number of fish farmers in the freshwater system was 15,675 and the number of fish farmers in the brackishwater system was 20,149. However, the data on fish processing is not being collected by the DOF Malaysia.

In the capture fisheries sub-sector, Malaysia recorded approximately 90,000 local fishers and 30,000 foreign fishers. The Malaysian Government has the national policy to gradually reduce the number of foreign fishers in capture fisheries, by encouraging the young locals to venture into the capture fisheries industry. However, the 3D factors (dangerous, dirty, and difficult) in fisheries and the harsh environment in the industry have been the major aspects for the low rate of locals' participation in the fisheries sector in recent years.

As for aquaculture, the sub-sector has been confronted with similar issues related to the hiring of foreign workers in fish farms as with the capture fisheries. Several plans have also been initiated to reduce the number of foreign fish farmers in the aquaculture sub-sector. Although for the past years, the country recorded an increasing number of illegal foreign workers, many of whom have been involved in cases that include not abiding by the numerous numbers of national regulations.

Myanmar

In Myanmar, data on part-time and full-time fishers and workers are being collected monthly to support the country's fisheries statistics but the numbers corresponding to the types of fishing gear have not yet been collected. Information on the current situation on labor in fisheries and fish workers in different fisheries sub-sectors in Myanmar are compiled from the records of the ID Cards issued to fishers and other fish workers. Moreover, all offshore fishing vessels have to comply with the ILO conventions for availability, welfare, and working conditions of labor in fisheries. It should be noted that Myanmar is one of the main countries of origin that provides fish workers to other AMSs, *e.g.* Thailand.

Singapore

In Singapore, there are 746 registered fish farm workers: 38 fishers have been registered for employment/engagement onboard inshore fishing vessels (*i.e.* in 26 "SF" vessels using gill nets or cast nets); and 5 fishers registered for employment/engagement onboard commercial offshore fishing vessels (*i.e.* in 8 "SMF" vessels, 7 vessels using trawl nets and 1 vessel using gill net). There are no reported issues or concerns on labor in fisheries and fish workers in Singapore.

Thailand

In Thailand, the data on workers in the fisheries sector are collected from the aquaculture subsector and the fisheries industries, while the data on fish farmers are collected through the Farmers' Registration based on the Number of Farms. There were 476,042 freshwater aquaculture farms in 2018; 24,608 shrimp aquaculture farms in 2019; 9,608 brackish water aquaculture farms in 2019; and 4,658 marine mollusk aquaculture farms in 2019. As for workers in the fisheries industries, the data are compiled mainly from the Seabook records. In 2019, the records showed 62,425 workers of Thai nationalities and 68,662 foreign workers (mainly from Myanmar, Cambodia, and Lao PDR) holding their respective Seabooks.

Thailand has been faced with problems on labor shortage especially for labor onboard fishing vessels forcing the industry to rely heavily on workers from neighboring countries. The Government of Thailand has been trying to mitigate such concern by acquiring legalized workers from Myanmar, Lao PDR, and Cambodia, and by applying advanced fishing technologies to reduce the manpower required onboard fishing vessels, *e.g.* in purse seiners.

There are a number of national laws and regulations issued by the Government of Thailand with respect to labor in fisheries. These include:

- The Royal Ordinance on Fisheries B.E. 2558 (2015) and its amendments
- The Royal Ordinance Concerning the Management of Foreign Workers' Employment B.E. 2560 (2017) and its amendments
- The Labor Protection in Fisheries Act B.E. 2562 (2019)
- The Immigration Act B.E. 2522 (1979) and its amendments
- The Thai Vessel Act B.E. 2481 (1938) and its amendments

Thailand has ratified the ILO Protocol to the Forced Labour Convention, 1930 (P 29) in June 2018 and the Convention No. 188 on Work in Fishing, 2007 in January 2019, making Thailand the first country in Southeast Asia to adopt these two international standards. Thailand also issued the country's amendments to the Prevention and Suppression of Human Trafficking Act, B.E. 2551 (2008) and the Labor Protection in Fishing Act B.E. 2562 (2019) which have enhanced the capacity of the country in the implementation of the aforementioned international requirements. While some measures are already parts of labor laws of Thailand, such as minimum working age, medical insurance, maximum working hours and rest periods, written work agreement, regular pay (via bank account transfer for fishers), safety equipment for work, and compensation for work-related deaths or injuries, new measures in the Act include annual health check-ups, repatriation from a foreign port to Thailand, and social security-type benefits (ILO, 2019)

Addressing the issues on labor in the fishing industry in Thailand has close linkage with the actions for combating IUU fishing. Under the Port in-Port out control center (PIPO), crew onboard fishing vessels are inspected through the capacity of the multidisciplinary team in charge, before and after fishing operations. The Department of Fisheries has established the Marine Fisheries Protection and Suppression Center to be responsible for coordinating the inspection of vessels at sea together with provincial officers from related agencies. At present, Thailand has already achieved the standard ratio of one labor inspector per 15,000 workers following the ILO Guidelines. So that in 2019, there were 1,889 labor inspectors engaged in the inspection of vessels.

Challenges and way forward

Work in the fishing industry is generally acknowledged as dangerous, dirty, and difficult so that in several countries, the industry currently relies very much on migrant workers. Appropriate legal frameworks to provide authority to relevant agencies should therefore be established and enforced, to ensure that workers enjoy comfortable working conditions and receive protection for safety at sea. At any rate, several countries in the Southeast Asian region, especially those that have large fishing industry, have already made progress in establishing laws and legislations to ensure good working conditions of labor engaged in the fishing industry, especially in capture fisheries at sea.

Issues on labor, however, could not be addressed only by the agencies on fisheries considering that finding solutions to labor issues has a very close association with combating IUU fishing, but also through the engagement of the other relevant ministries, *e.g.* those involved in labor, migrants, social and welfare protection. Moreover, there is also a need to establish systems for the registration of labor, not only for nationals but also the migrant workers. Meanwhile, it is also necessary to integrate labor aspects into the national MCS processes, such as records of labor onboard fishing vessels through the port in–port out control, monitoring programs at sea, and so on.

Considering that a large number of fishing workers in the region are migrants, countries of origin and destination of those migrant workers should work collaboratively to ensure that the workers are legalized and properly recorded in the system so that the engagement of illegal workers and its associated problems including human trafficking could be prevented. Relevant authorities in both countries should help ensure that the workers could access the relevant information, *e.g.* workers' rights, recruitment, contracts, legal standards, and fishers' safety and health. Important information could also be translated and provided in the national languages of the migrant workers and discussed with them in various fora including at the pre-departure orientation.

Due to the high demand for workers in fishing activities at seas, educational and skills development programs should be developed for new crew members and workers entering the industry. Technologies and innovations should also be adopted to reduce the use of fishing crews onboard the vessels. Such improved technologies should also lead to better working conditions, safety at sea, and improved occupational health of the fishing crew that meets the relevant international requirements and standards.

For the small-scale fisheries, adoption of the "FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication" could be mobilized to support the promotion of good working conditions, safety at sea, security of migrant workers. To this end, SEAFDEC produced the Policy Brief "Applying Human Rights-Based and Gender Equality Approaches to Small-Scale Fisheries in Southeast Asia" to serve as a guide for the AMSs to address labor concerns in the fisheries sector, specifically on:

- The right of labor to an adequate standard of living including affordable housing, water, sources of energy, sanitation, education, access to information, and basic health services;
- The right to decent work, including labor rights and social security that are addressed in accordance with the national laws and regulations, and promotion of gender equality and equitable opportunities;
- The right to equal access of men and women to services such as savings, credit, and insurance, including support to market access; and
- The rights of rural/coastal communities, specifically women, indigenous people, migrants, and other vulnerable and marginalized groups, to develop and establish their organizations.

9.2 Microfinance, Credit, and Insurance in Support of Small-scale Fisheries

Small-scale fisheries play an important role in food security, nutrition, poverty eradication, providing nutritious food for local, national, and international markets, and generating income to support local and national economies. Small-scale fishing communities are commonly located in remote areas, earning low incomes, and tend to have limited access to markets as well as to health, education, and other social services (FAO, 2015). Small-scale fishers therefore should be given the opportunity to avail of the financial services in establishments that offer loans, savings, and insurance (general, life, and health), as well as access to credit facilities for their socioeconomic well-being enabling them to establish certain investments, *e.g.* housing, education, other emergencies, and also for fish production. Small-scale fishers also need funds as working capital for their daily fishing operation expenses and related investments for the purchase/replacement of fixed assets, *e.g.* boat, engine, gear, nets, or for upgrading their fishing equipment. In addition, considering that women are involved in the activities related to fisheries production, processing, and marketing, as well as in non-fisheries income-generating activities, as such, they would also need access to financial services and credit facilities. In reality, however, small-scale fishers have limited access to financial institutions because they lack the physical and livelihood assets that could be used for the required collateral.

Small-scale fisheries activities are highly dependent on the ecosystem's health, season, and condition of the water environments as these are mostly operated in open access coastal waters. Fishers could face risks from weather conditions and work-related accidents, while their fishing communities which are mostly located in coastal areas could be confronted with natural disasters, human-related activities, and pollutions. The FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines) is an international instrument that provides the consensus principles and guidance for addressing the concerns in small-scale fisheries. The SSF Guidelines recognize the limitations in financial access and the dearth of investments in the small-scale fisheries sector, as reflected in Article 6.4 which indicates that: "*States should support the development of and access to other services that are appropriate for small-scale fishing communities with regard to, for example, savings, credit, and insurance schemes, with special emphasis on ensuring the access of women to such services*" (FAO, 2015). Moreover, the ASEAN-SEAFDEC Plan of Action (POA) on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 also considers the importance of establishing financial incentives for small-scale fisheries. As indicated in POA No. 17, the need to: "*Raise awareness of the need to develop financial incentives, especially for small-scale stakeholders and cooperatives,* e.g. *micro-credit, with national and regional institutional assistance for the responsible development of fisheries enterprises and developmental activities that optimize economic returns*," should be addressed.

The Experts Workshop on Guidelines for Micro-finance, Credit, and Insurance for Small-scale Fisheries in Asia co-organized by the FAO and the Asia-Pacific Rural and Agricultural Credit Association (APRACA) in May 2019, discussed the ways to improve the access to financial services for small-scale fishers in Asia and developed the guidelines for microfinance, credit services and insurance in support of small-scale fisheries. As a result, two guidelines have been endorsed by the APRACA members in June 2019. These are: 1) Guidelines for microfinance and credit services in support of small-scale fisheries in Asia (Grace & van Anrooy, 2019); and 2) Guidelines for increasing access of small-scale fisheries to insurance services in Asia (Tietze & van Anrooy, 2019).

These guidelines, which have been developed to complement those of the SSF Guidelines, aim to provide the implementation guides for enhancing the access of small-scale fisheries to financial services, microfinance, credit, and insurance, and support the implementation of the FAO Code of Conduct for Responsible Fisheries in terms of promoting and developing measures to facilitate access to insurance coverage in fisheries. Furthermore, the guidelines are also envisioned to contribute towards achieving the Sustainable Development Goals (SDGs) 14: "*Conserve and sustainably use the oceans, seas and marine resources for sustainable development*," specifically target 14. b: "*Provide access for small-scale artisanal fishers to marine resources and markets*." Once access to financial services is provided to small-scale fishers, they would be able to invest in more responsible fishing operations and technologies, reduce overfishing, contribute to fisheries management, and implement climate change adaptation measures (FAO, 2019).

The guidelines had been disseminated among policy and decision-makers and discussed and implemented in some Southeast Asian countries. Widely adopted financial management guidelines for fisheries projects, *i.e.* revolving loan funds and credit programs for fishing communities, are now being updated to facilitate broad application by stakeholders in fisheries and aquatic resource ecosystem management. FAO and its partners have established the "Global Network for Capacity Building to Increase Access of Small-scale Fisheries to Financial Services (CAFI SSF Network)" to facilitate the availability and access to finance and insurance for small-scale fisheries through strengthening the capacity of policymakers, service providers and fisherfolk organizations (FAO, 2020). To increase awareness of the financial service needs of small-scale fishers, a series of webinars on microfinance and credit services had been organized by the CAFI-SSF Network, where SEAFDEC supports and regularly participates in the CAFI-SSF Network activities.

In the region, SEAFDEC/TD carried out an "assessment of the sustainability of currently used fishing technologies and operations in Thailand and operations for innovation and improvements" as part of the FAO project "Financing Innovation for Sustainable Fisheries with the Private Sector." Report of the assessment would be used as a guide on financial investment and financial decision-making process for the fisheries sector, and financial and insurance service providers (SEAFDEC, 2021). Further, SEAFDEC/TD conducted a socioeconomic survey on access to financial services by the fishing communities in the pilot site in Ranong Province, Thailand. The survey results indicated that the fishers have access to credit from the Village Fund established by the Government of Thailand, which provides soft loans with low interest to the local people to improve their livelihoods and occupation. While the fishers could access credit from formal financial institutions (*e.g.* Bank of Agriculture and Agricultural Cooperatives (BAAC)), it has been noted that fishers still rely on the informal financial system being offered by the middle persons acting as loan providers for fishers' immediate financial needs. In fact, the same trend could be observed in the fishing communities throughout the country. In 2020, the Government of Thailand launched the Loan Project to further enhance the liquidity of artisanal and commercial fisheries.

In Indonesia, programs on financial inclusion and microfinance opportunities are enhanced in collaboration with stakeholders, particularly the financial institutions. Recognizing the need to protect the people working in the fisheries sector from occupational risks, including work accidents and equipment damage, the Government established the fishers' insurance program which covers life and business insurances. It guarantees the safety of fishers over the risks that they encounter in fishing, aquaculture, and postharvest activities, *e.g.* fish-salting businesses (Rani, 2016). While the Government supports the premium payment of the insurance for the first year, the fishers will have to pay their premium during the succeeding years, although such an arrangement had constrained the fishers who are not ready to pay such extra expense.

Malaysia has an insurance program for fishers called "Group Insurance Protection Scheme for Fishermen" which was introduced by the Fisheries Development Authority of Malaysia (LKIM). In addition, the program "Self-Employment Social Security Scheme" was launched to provide protection for individuals who are self-employed under the provisions of the Self-Employment Social Security Act 2017 that provides access to insurance protection for fishers. Malaysia has a directive to provide better protection and benefit for fisheries and aquaculture workers.

In the Philippines, the Government recognizes the importance of microfinancing and expedites the promotion of microfinance schemes across the country. In fact, there is a comprehensive financial system encompassing various types of banks, from large universal banks to small rural banks and even non-banks or informal banks, and Microfinance Institutions (MFIs) offering a diversity of products and services, *e.g.* loans, savings, although only a few of such organizations offer micro-insurance services (Vizcarra & Ramji, 2015). The Philippines established the policies and regulatory frameworks for micro-financing through several programs related to the fisheries sector under the Department of Agriculture-Agriculture Credit Policy Council (DA-ACPC), comprising: 1) Working Capital Loan Easy Access (CLEA), 2) Agriculture and Fisheries Machineries and Equipment (AFME), 3) Production Loan Easy Access (PLEA), 4) Expanded SURE Aid Recovery Program (ESURE AID), and 5) Agri-Negosyo Program (ANYO). However, there are challenges encountered in the implementation of the programs, such as the unclear procedures of availing the loan programs, limited numbers of borrowers in some regions due to inadequate proper coordination of the loan project with BFAR, and limited lending channels in some remote areas. The country's Land Bank of the Philippines has initiated a program on Agricultural Competitiveness Enhancement Fund (ACEF), a lending program that aims to provide necessary credit to farmers and fishers, and their cooperatives and associations, and microenterprises and small enterprises to increase their activity and productivity.

Challenges and Way Forward

In the abovementioned cases, the importance of financial services has been recognized as one of the effective tools for supporting small-scale fishers to maintain and enhance their fishing activities in a sustainable manner. In many countries, microfinance programs could support the fishing households in undertaking self-employment and providing small capital to people in the fishing communities for their socioeconomic needs, especially in sustaining their quality of life and food consumption during the off-fishing season. Micro-financing also helps in managing risks and reducing economic and social vulnerability. Therefore, it would be beneficial to small-scale fishers if they could have easy access to financial services for sustaining their livelihoods.

In order to enhance the activities in small-scale fisheries, SEAFDEC continues to engage its Member Countries in the implementation of the SSF Guidelines and provide them technical assistance through the ongoing SEAFDEC/TD project "Small-scale Fisheries Management for Better Livelihood and Fisheries Resources" supported by the Japanese Trust Fund (JTF). As an important part of the activities in small-scale fisheries, financial services should be discussed and concerns addressed in relevant meetings and workshops in order to compile the necessary information that could be shared among the countries for establishing and/or strengthening appropriate financial schemes in their respective countries. At the national level, enhancing communications, cooperation, and partnership among the fisheries sector, particularly small-scale fishers, financial service providers and government agencies concerned would be essential to identify, sort out and overcome any constraints and issues toward increasing "access to financial services" in small-scale fisheries. For better dialogues and understanding, a network on financial services at the national and regional level could be considered like the CAFI-SSF Network at the global level. Furthermore, considering that innovations and new developments are key for the sustainable development of small-scale fisheries that impact the small-scale fishers, appropriate financial service schemes coupled with easy access must be in place and available for small-scale fishers and fishing communities for their sustainable fishing activities and better livelihoods.

9.3 Gender Equity in Fisheries

Socially constructed roles, behaviors, and characteristics are some aspects that a given society considers appropriate for females and males. These roles and characteristics are acquired through socialization processes: people are born female or male but learn to be women or men. Sex is biological, while gender is sociological. Perceptions of gender are contextual and time-specific, therefore, not fixed (even though they may appear as such). In most societies, there are differences and inequalities between women and men in terms of responsibilities assigned, access to and control over resources, as well as decision-making opportunities.

In an attempt to strengthen the perceptions of gender and its role in sustainable fisheries development, gender has been included in relevant ASEAN-SEAFDEC policy directives. Like for example in the ASEAN-SEAFDEC Plan of Action (POA) on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030, POA No. 15 specifies that the AMSs should consider to "*Strengthen the capacity of fisheries communities and the capability of fisheries-related organizations (*e.g. *by empowering such organizations as appropriate) to implement necessary actions towards increased resilience, improved livelihoods, adoption of supplementary livelihoods, and poverty alleviation, in support of achieving sustainable development with gender integration in the process;*" and in the Strategies of SEAFDEC Towards 2030, where Strategy 5 indicates the need towards "*Addressing cross-cutting issues, such as labor, gender, and climate change, were related to international fisheries*." In this regard, SEAFDEC initiated the development of the SEAFDEC Gender Strategy to facilitate gender mainstreaming at all levels of the organization and to serve as an organizational overarching framework to facilitate the efforts of SEAFDEC in integrating gender in its programs, projects, and activities. The main five aspects of the SEAFDEC Gender Strategy are: 1) Mainstreaming Gender at all levels of the organization, 2) Integrating gender in SEAFDEC programs and projects, 3) Incorporating gender perspectives in all events organized by SEAFDEC, 4) Boosting the visibility of SEAFDEC as a gender-responsive and gender-sensitive organization, and 5) Strengthening further the cooperation and collaboration with Member Countries and other organizations on gender aspects.

Recognizing that "gender equality is not only a fundamental human right but is also a necessary foundation for a peaceful, prosperous and sustainable world," the UN Sustainable Development Goals include Gender Equality as its Goal 5 which focuses on the need to "achieve gender equality and empower all women and girls." Specifically, for the fisheries sector, the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines) also provide the guiding principles for gender equity and equality, especially for the small-scale fisheries sub-sector.

Promotion of Gender Equality and Equity in Fisheries

At the onset, SEAFDEC in cooperation with the International Union for Conservation of Nature (IUCN) and Stockholm Environment Institute (SEI) with support from the Embassy of Sweden in Bangkok, Thailand conducted the study on Gender Dimension in Coastal and Fisheries Resources Management in South and Southeast Asia.

From the results of the study, it was found that various national-level mechanisms on gender equity are already in place in the AMSs. Moreover, efforts to support gender equality and address gender issues were also noted across all countries involved in the study. Although sometimes there may be overarching ministries, committees, or commissions responsible for gender that provide the enabling environment for gender mainstreaming, this did not always facilitate translating such gender concerns into policies and projects for fisheries and coastal resources management. The study also recognized that several AMSs have their respective national structures for the promotion of gender equality and women empowerment. These include:

- Brunei Darussalam: International Women's club Brunei Darussalam
- Cambodia: National Council for Women (Women's Empowerment Neary Rattanak IV 2014 -- 2018)
- Indonesia: Indonesian Women's Organization
- Lao PDR: Lao Women's Union
- Malaysia: Gender Equality Act
- Myanmar: Women's Organizations Network of Myanmar
- Philippines: Philippine Commission on Women
- Singapore: Singapore Women's Association
- Thailand: Gender Equality Promotion Committee
- Viet Nam: National Committee for the Advancement of Women (NCFAW); Women's Union

Furthermore, the Practical Guide for Gender Analysis in Small-scale Fisheries and Aquaculture in Southeast Asia (also known as the "Practical Guide") was also developed through the SEAFDEC-Sweden Project, to promote the implementation of the SEAFDEC Gender Strategy in support of the integration of gender perspectives in fisheries and aquaculture in the SEAFDEC Member Countries. Recognizing further that gender analysis is an important tool to understand gender equality in fisheries, SEAFDEC collaborated with relevant partners for the development of tool kits for gender analysis and gender integration in fisheries management projects through the application of rights-based and gender-equitable approaches in the whole value chain of the small-scale fisheries and aquaculture in Southeast Asia. These include: 1) Gender Analysis Tool Kit for Coastal Fisheries Management Practitioner (with support from IUCN and SEI); 2) Gender Research in Fisheries and Aquaculture: A Training Handbook available in various national languages of the AMSs, *e.g.* Bahasa Melayu (Malay language), English, Thai, and Vietnamese (developed through the SEAFDEC-USAID Oceans Project), and Fisheries Management Guidance for Gender-inclusive, Technology-responsive Research (a collaborative effort with the SEAFDEC-USAID Oceans Project).

Issues and Challenges

There is still a lack of collaboration among the gender-related organizations or initiatives and those that are directly responsible for fisheries and coastal resources management. Furthermore, a dedicated budget to fund the sharing of knowledge across agencies is still limited. Nonetheless, another element that validates the idea of an enabling environment is the integration of gender in national constitutions. Since most countries conform to the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) therefore, CEDAW could be used as an entry point to strengthen gender mainstreaming at the national level. Moreover, various instruments on gender analysis are available that could be referred to in gender mainstreaming, *e.g.* the Regional Gender Synthesis and Gender Analysis of the IUCN and SEI. There are five main aspects that should be strengthened for better integration of gender elements in coastal and marine fisheries policies and practices. These are shown in **Box 41**.

Box 41. Main aspects that should be strengthened for better integration of gender elements in coastal and marine fisheries policies and practices*

1. **Capacity development**
2. **Awareness** - There is a need for concrete examples of women's involvement in the value chains to adapt communication strategies to convey their message
3. **Political will** - Supporting and rewarding champions can go a long way to support gender integration from the local to national levels
4. **Budget** - It is important to assess the budgetary requirements and the source of funding – either internal or external
5. **Coordination and collaboration** - Intersectoral coordination from national to provincial levels is a key for further gender integration, and collaboration among NGOs and community-based organizations is also an important element to consider for the uptake of the best practices

* Regional Dialogue on Gender Dimension in Coastal and Fisheries Resources Management in South Asia and Southeast Asia

Way Forward

SEAFDEC has been promoting gender mainstreaming in fisheries through capacity building on gender concepts to fisheries officers and gender analysis for baseline information to create plans for fisheries management. Moreover, SEAFDEC has also taken steps to integrate gender into the fisheries management projects of the AMSs in order to achieve gender equality in the fisheries and improve the livelihoods of women, men, elderly, youth, and marginalized persons in the community. In so doing, recommendations had been raised for promoting and strengthening gender mainstreaming in the Southeast Asian region (**Box 42**).

Box 42. Recommendations for promoting and strengthening gender mainstreaming in the Southeast Asian region for gender equality*

- Community level: facilitate the conduct of awareness-raising sessions for men and women to ensure collective understanding of and learning about the benefits and values of women's tasks in the different spheres of coastal and fisheries resource management
- Project level: facilitate the conduct of training sessions on gender analysis with a focus on the intersectionality of gender and other axes of power
- Promote participatory identification and strategizing to address societal discriminatory norms
- Engage and collaborate with relevant institutions and organizations
- Provide gender awareness materials in simple and easy to understand local languages

* Regional Dialogue on Gender Dimension in Coastal and Fisheries Resources Management in South Asia and Southeast Asia

SEAFDEC has been sustaining the integration of gender analysis in baseline data collection applying gender analysis in four pilot AMSs through the Project "Gender Dimension in the Value Chain of Small-scale Fisheries and Aquaculture in Southeast Asia," which is being supported by FAO. This Project is specifically aimed at improving and strengthening gender dimension in selected small-scale fisheries and aquaculture value chains in Southeast Asia, namely: for marine capture fisheries in the Philippines, mariculture in Thailand, inland aquaculture in Lao PDR, and inland capture fisheries in Myanmar. The Project has initiated the data collection on gender for fisheries management for the gender sensitivity analysis as part of the Project.

In summary, SEAFDEC has already facilitated the conduct of capacity building activities in the AMSs to enhance the awareness and capacity of the human resources at all levels on gender aspects and build the capacity of the SEAFDEC and AMSs' staff involved in programs and projects to enable them to integrate gender aspects in their respective program/project cycle. SEAFDEC will continue to promote gender responsiveness in the AMSs and strengthen the capacity of SEAFDEC and the AMSs on gender integration in fisheries to ensure gender equity and equality in fishing and fish farming communities.

PART III
Outlook on Fisheries and Aquaculture of the Southeast Asian Region

1. Growing Demand for Fish and Fishery Products

In Southeast Asia, fish and fishery products are among the major sources of protein uptake of its people consuming fish at a regional average per capita of 39.4 kg/person/year as of 2017, almost double that of the world's average per capita consumption of 20.3 kg/person/year (FAO, 2020). The role of fisheries in the region has no doubt, formed part of people's livelihood, food and nutritional security, income, as well as of national economic development through domestic and international trade. During the past decade, however, the fisheries sector had been confronted with challenges in sustaining its fish supply to fulfill the heightened demand for fish and fishery products by the increasing population not only within the region but also worldwide. The world population is anticipated to continue to increase from 7.8 billion in 2020 to 8.1 billion by 2030 and 9.6 billion by 2050 (Table 1), but with possible slight decline in birth rate as observed in several countries in 2021 resulting from the COVID-19 pandemic. Although the overall COVID-19 situation had gradually improved in several countries/regions in 2021 with most of the people already developing their immunities through the vaccination programs, among others, such a situation during the coming years remains uncertain, and could still create some impacts on the projected world population and demand for food fish.

During the past 15 years, the overall supply of fish and fishery products from the region continued to show an increasing trend, although at the end of 2019 and 2020 the sector had been largely impacted by the COVID-19 pandemic and ended up generating minimal increases in fish production. In the broader agricultural perspective, OECD-FAO (2021) reported a drop in international agricultural trade during the first few months after the COVID-19 outbreak, but the trade recovered rapidly and continued to grow between 2019 and 2020 but only at the barest minimum average. Results of the study undertaken by SEAFDEC in 2021, noted that the impact of COVID-19 on the sustainability of the fisheries sector was severe at the initial emergence of the disease because of the measures imposed by countries to prevent the spread of disease that resulted in drastic decrease of the market demand and disruption of the supply chain. However, the study also indicated that the sector could still be managed to adapt to the changes, and maintain the supply of fish and fishery products from the aquaculture and capture fisheries sub-sectors. It should therefore be expected that the future supply of fish and fishery products could still be maintained and in fact, could be elevated with continued technological

Table 79 . Projected population, fish production, per capita production, and GDP of the Southeast Asian countries

Countries	Population (million)			Fish production (2019) (thousand t)	Average per capita fish consumption (2017) (kg/ person/yr)[c]	GDP (billion) (2019)[a]
	2020[a]	2030[b]	2050[b]			
Brunei Darussalam	0.4	0.5	0.6	14.7	41.2	13.5
Cambodia	16.7	18.0	22.3	969.1	42.7	27.1
Indonesia	273.5	273.2	309.4	22,614.6	44.7	1,121.3
Lao PDR	7.3	7.9	10.3	183.9	25.3	18.8
Malaysia	32.4	35.3	43.6	1,872.8	57.8	364.4
Myanmar	54.4	61.7	70.8	5,931.8	45.9	66.5
Philippines	109.6	120.2	150.1	4,413.1	26.2	377.1
Singapore	*5.9*	5.8	6.1	7.2	*46.6*	372.1
Thailand	69.8	72.9	71.0	2,488.8	29.5	544.0
Viet Nam	97.3	100.4	109.3	8,270.2	37.7	261.6
Southeast Asia	**667.3**	**696.3**	**793.2**	**46,766.2**	**39.8[d]**	**3,166.4**
World	**7,794.8**	**8,084**	**9,587**	**213,700**	**20.3**	**87,345.3[e]**

Source:
[a] The 2019 Revision of World Population Prospects (UN, 2021)
[b] World Population Prospectus: The 2015 Revision, Key Finding and Advance Tables (UN, 2015)
[c] FAO Yearbook 2018 (FAO, 2020)
[d] Calculated based on per capita fish consumption and population in 2017 (food supply 25,583,882; population 642,278.6 thousand)
[e] International Monetary Fund Database (IMF, 2021)

developments and appropriate management that would ensure the sustainable utilization of the fishery resources.

2. Issues and Challenges towards Sustainable Utilization of Fishery Resources

In order for fish and fishery products to continue fulfilling the projected demand for food fish by the world's increasing population, the FAO Code of Conduct for Responsible Fisheries (CCRF) adopted in 1995 would continue to provide the principal direction towards ensuring the responsible and sustainable development of the fisheries sector. Moreover, another very important global framework that is also relevant to the fisheries sector is the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, universally calling for action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The SDGs are at the center of the 2030 Agenda for Sustainable Development, which provides a shared blueprint for harmony and prosperity of people and the planet, now and in the future. There are several SDGs relevant to the fisheries sector, especially the SDG 14 "Life Below Water" which highlights the importance of fisheries and aquatic resources as it sets the ambition to "conserve and sustainably use the oceans, seas and marine resources." Other relevant SDGs include the SDG 1 "No Poverty, " SDG 2 "Zero Hunger," SDG 12 "Responsible Production and Consumption," among others. The Convention on Biological Diversity (CBD) is another global framework that could be referred to as it is aimed toward the conservation of biological diversity, sustainable use of the components of biological diversity, and fair and equitable sharing of the benefits arising from the utilization of genetic resources. At this stage, Parties to the CBD are negotiating the post-2020 global biodiversity framework to include a new set of global goals and targets for biodiversity. For its sustainable development, the fisheries sector should exert efforts toward achieving such global goals and targets in the future.

Cognizant of the need to comply with the CCRF and undertaking the initiatives toward achieving the SDGs and other relevant global frameworks and targets, the fisheries sector of the Southeast Asian region had been developed and managed within the framework of the "Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030" which was adopted in 2020 by the Ministers and Senior Officials responsible for fisheries of the ASEAN-SEAFDEC Member Countries. Furthermore, the ASEAN Member States (AMSs) had also adopted the "Strategic Plan of Action for ASEAN Cooperation on Fisheries (SPA–Fisheries) 2021−2025" to continue the strategic thrust and action programs from those achieved by the previous Strategic Plan (2016–2020). The SPA–Fisheries aims to ensure a competitive, inclusive, resilient, and sustainable fisheries in the AMSs that contributes to economic growth, poverty alleviation, food security, and nutrition.

In the coming decade, such aforementioned global and regional frameworks would continue to guide the AMSs in ensuring that the development of the fisheries sector (including aquaculture) would be toward sustainability. This implies that the fisheries sector should not only address the need to generate livelihoods, incomes and economic development at the national/regional levels, but also maintain its significant contribution to the world's fish supply and fulfill the increasing demand for fish in the coming years. Nevertheless, a number of emerging and new challenges remains looming in the fisheries horizon that needs to be addressed to ensure the sustainable development of fisheries and aquaculture in the Southeast Asian region.

Promotion of responsible fisheries and aquaculture technologies and practices

After the CCRF was adopted in 1995, SEAFDEC in collaboration with the AMSs and with funding from the Japanese Trust Fund, regionalized the CCRF and developed a series of Regional Guidelines for Responsible Fisheries in Southeast Asia reflecting the regional specificities and characteristics of the region's fisheries, to make sure that the CCRF would be adopted by the countries at the national as well as regional level. Guided by the CCRF and the Regional Guidelines, a new era of fisheries development ensued, which harmonizes development with the aquatic environment and has been promoted to attain sustainability in fisheries. Along the way and as a consequence of pursuing responsible fisheries and aquaculture development, issues and concerns were encountered thus, R&D efforts had to be strengthened in order to address such concerns.

- ***Marine capture fisheries***

The AMSs have been undertaking wide ranging initiatives to improve the effectiveness of fisheries management and ensure sustainable productivity from coastal and marine resources. However, the marine capture fisheries sub-sector continues to be confronted with the pressures from several challenges. SEAFDEC therefore sustains its efforts in addressing such challenges through its R&D endeavors as well as its activities on information dissemination and sharing.

Illegal, unreported and unregulated (IUU) fishing is one of the major contributors to the depletion of the coastal and marine resources. While the "ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain" adopted by the ASEAN Ministers in 2015 provided the overall framework for the AMSs to take actions to combat IUU fishing, other mechanisms had also been established under the ASEAN framework, particularly the ASEAN Network for Combating IUU Fishing (AN-IUU); and the ASEAN Roadmap on Combating Illegal, Unreported and Unregulated Fishing (2020−2025). Initiatives at the national and regional levels as well as collaboration with relevant organizations have been strengthened to support the capacity of the AMSs in fulfilling their responsibilities as coastal State, flag State, and port State, and thereby contribute to the efforts in addressing the issues related to IUU fishing.

Another major challenge faced by the AMSs is the imposition of measures by importing countries to ensure that exported fish and fishery products are derived from sustainable means and sources. This includes compliance with the standards and schemes developed and applied by the private sector, *e.g.* ecolabeling, while several importing countries such as the United States of America and European Union also issued measures preventing the entry of fish and fishery products from IUU fishing into their markets. Future measures from importing countries could be more stringent requiring the exporting countries (including the major exporting AMSs) to comply with. This implies the need to strengthen the implementation of ongoing initiatives for combating IUU fishing, *e.g.* promotion of MCS, application of traceability of fish and fishery products (including those produced by small-scale fisheries), complying with port State measures, carrying out observers onboard programs. Moreover, the application of appropriate equipment and technologies should also be enhanced to reduce the use of excessive human resources in fishing operations, *e.g.* use of modern electronic systems and databases that could be linked and shared with relevant agencies, conduct of risk analysis, use of Artificial Intelligence or AI in analyzing large amount of data to track illegal activities, as the results could contribute to the solutions of some of the possible root causes of illegal and unregulated fishing.

The continued promotion of responsible fishing technologies and practices has remained an important issue for Southeast Asia. While efforts had been made to minimize the impacts of fishing on the fishery resources and their habitats, calls had been made for the reduction of fuel consumption and greenhouse gas (GHG) emission from fishing operations, the development of technologies on fishing gears that reduce the incidental catch of endangered and threatened species, and enhanced compliance with upcoming trade-related measures, *e.g.* the U.S. Marine Mammal Protection Act to be put into practice in January 2023, among others. Moreover, incidences related to abandoned, lost or otherwise discarded fishing gear (ALDFG) should be investigated as it causes mortality not only to fish but other aquatic animals, such as marine turtles and marine mammals. This implies the need to develop and promote some measures such as the adoption of gear marking following the relevant provisions in the FAO Voluntary Guidelines for the Marking of Fishing Gear (VGMFG). Furthermore, the impacts of marine debris and microplastic (from fisheries and non-fisheries sectors) on fish and their habitats, especially the possible contamination in fish that would impact on food safety, has also become an important concern that need to be investigated.

Another significant challenge for the sustainable management of marine capture fisheries in Southeast Asia is the difficulties in obtaining knowledge on the status of the fishery resources and stocks, especially for transboundary species that require regional or sub-regional cooperation to be able to undertake research studies and data collection. While several stock assessment models had been adopted to conduct stock and risk assessments of some neritic tunas and tuna-like species in the region, the future challenge is on how to put the recommendations derived from such stock and risk assessment efforts into practice. Furthermore, there is also a need to develop appropriate target reference points for evaluating the current resource status and the projected capacity level to determine the maximum sustainable yield, allowable biological catch, or allowable effort for marine fisheries. Such information is crucial for the management of fishing capacity to commensurate with the available resources and fish stocks. Moreover, considering the high cost of undertaking conventional stock assessment, the application of innovative and modern technologies could also be explored and applied in monitoring of the fish stocks, *e.g.* genetics study, use of acoustic technologies.

Shortage of fish workers onboard fishing vessels would also continue to be an important challenge for marine capture fisheries of several large fishing nations. While it is necessary to secure workers needed for the industry, there is also a need for vessel operators to comply with relevant international requirements, especially the International Labour Organization (ILO) Convention No. 188 or “Work in Fishing Convention” (C188), the ILO Protocol to the Forced Labour Convention, 1930 (P 29), among others, although most countries in the region have not yet ratified these instruments. Novel technologies to reduce the labor onboard fishing vessels should therefore be promoted, while educational and skills development programs should be initiated for new crew members and workers entering the industry to mitigate the problems related to shortage of fishing crew in the longer term.

- ***Inland capture fisheries***

Inland capture fisheries would continue to be an important sub-sector that contributes to food security and livelihood of people, especially those in the remote rural areas. The sub-sector has been challenged by the multi-users that compete with fisheries on the utilization of water resources. Another important future challenge is on how to enhance data collection on inland fisheries in order that such data could provide justifications on the importance of inland fisheries in the respective countries' national economic development. The application of technologies such as GIS and Remote Sensing should be explored and promoted together with the development of applications using mobile phones as these could also facilitate data collection in remote rural areas. It should be made clear that awareness on the importance of the inland fisheries could be raised with appropriate data collection, analysis, and interpretation.

Another important threat to inland fishery resources that need to be mitigated is the disconnectivity of inland aquatic habitats, due to large infrastructure construction by the other sectors, *e.g.* dams and irrigation weirs that obstruct longitudinal migration of fishes, as well as other construction such as water gates and roads that obstruct movement of fish and larval drift. Such threat could be mitigated through construction of appropriate fish passages, the design of which need to consider the specificity of the localities including the species that are vulnerable to the disconnectivity of their habitats. Inter-agency coordination should then be strengthened to enhance the awareness of concerned stakeholders on the impacts as well as solutions for mitigating the impacts.

Illegal and unregulated fishing practices in inland waters could include the use of unfriendly fishing methods such as fishing with toxic chemical substances, explosive materials, and prohibited gears and ways such as electro-fishing; fishing without license or quota for certain species; catching undersized fish or fish that are otherwise protected by regulations; and fishing in closed areas or during closed seasons, among others. Management measures such as the imposition of closed season or prohibition of the use of certain fishing gears as promoted in the marine fisheries sub-sector could be adapted for inland fisheries. Moreover, the attention on depletion of fishery resources that focused predominately on marine fish stocks should also include the freshwater aquatic species as these are of great importance to rural communities. Through such efforts, inland fisheries could be well appreciated and valued in government resource planning and decision-making.

A substantial challenge in the sustainable development of inland capture fisheries is on the collection and reporting of reliable data on wild-caught freshwater fish. Considering the limited port landing sites for inland capture fisheries and most of the harvested fish is consumed in households without entering the market chain, the data on inland fish catch are scattered and not well documented by government authorities. The recent initiatives on improving the collection of data on inland fisheries should therefore be promoted, and in some instances and where possible, the methods of collecting inland fisheries data could be patterned after those of the marine capture fisheries.

- ***Aquaculture***

In an effort to increase productivity from aquaculture, many Southeast Asian countries have intensified their aquaculture practices and expanded their aquaculture areas. Meanwhile, national policies have provided the enabling business environment to encourage efficiency and technological advancements in the manufacture of aquaculture feeds, R&D on genetics and breeding, disease management, product processing, and marketing and distribution. All these are meant to support the growth of the aquaculture sub-sector to meet the increasing demand for food fish.

Development and promotion of responsible aquaculture technologies and practices in the region should therefore be continued and intensified, especially the technologies that minimize impacts of aquaculture practices on the environment, *e.g.* use of recirculation and recycling systems, moving towards zero-waste in aquaculture production, adoption of the integrated multi-tropic aquaculture (IMTA) system, enhancement of carbon sequestration. The problems on high cost of aquafeeds should be addressed by using feed formulations that small-scale fish farmers can adopt, exploring appropriate alternative plant-based products as feed ingredients, alternative feeding for commercially significant fish species, among others.

In order to support responsible aquaculture practices, the existing policy frameworks could be adopted, *e.g.* the ASEAN Good Aquaculture Practices for Food Fish and ASEAN Shrimp Good Aquaculture Practices certification and accreditation system; the ASEAN Guidelines for the Use of Chemical in Aquaculture and Measures to Eliminate the Use of Harmful Chemical, the Regional Guidelines on Traceability System for Aquaculture Products in the ASEAN Region, among others. The adoption of good aquaculture practices not only helps in ensuring safe aquaculture products for human consumption, but also in making sure that aquaculture productions are in compliance with various requirements, *e.g.* environmentally friendly, social responsibility, food safety, bio-security, traceability, thus, enhancing the competitiveness of aquaculture products in the international fish market.

Aquatic animal disease outbreaks if not properly contained, would continue to be an impediment in the sustainability of the aquaculture sub-sector. While the issue on improved fish health management including disease prevention and control needs to be addressed, the development of early warning system for aquatic animals with well-defined contingency plan should also be considered a priority in order to prevent further spread of aquatic diseases that could cause massive losses to the aquaculture industry. In this regard, there are two important regional guidelines that should be referred to: the Regional Technical Guidelines on Early Warning System for Aquatic Animal Health Emergencies, and the Standard Operating Procedures for Responsible Movement of Live Aquatic Animals for ASEAN. Furthermore, since the use of antimicrobials in aquaculture which is relevant to aquatic diseases, should also be addressed, adoption of relevant regional guidelines, *e.g.* Regional Guidelines on Performing Risk Analysis for Antimicrobial Resistance (AMR), Regional Guidelines for Prudent Use of Antimicrobials in Aquaculture, and the Regional Plan of Action on AMR in Aquaculture, should therefore be promoted.

Promotion of sustainable fisheries management

Due to the nature of fisheries in the region that comprise large number of small-scale fishers, management approaches that enhance the participation of concerned communities, such as community-based management and co-management which has long been adopted by several countries in the region, would continue to be important and should therefore be further promoted. While the development of management plans and rules/regulations on utilization of fishery resources with the enhanced involvement of local communities would contribute to sustainable resources utilization, this would also contribute to addressing the other cross-cutting issues, such as securing sustainable small-scale fisheries (in line with the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication or the VGSSF Guidelines), enhancing gender integration and gender equity in the fisheries sector, and improving livelihoods and socioeconomies of the communities.

The Ecosystem Approach to Fisheries Management or EAFM (as well as the Ecosystem to Aquaculture or EAA) is another approach that should be sustained as agencies responsible for fisheries of the AMSs have already enhanced their knowledge and their capacity in the implementation of the EAFM concept. In Southeast Asia, several sites had been selected to pilot test the application of the EAFM concept with support from relevant international and regional organizations. Therefore, the respective AMSs should continue to expand the adoption of the EAFM nationwide in their countries.

Fishery resources and habitats protection

The concept of fisheries *refugia* has been considered important in the conservation and management of major critical coastal habitats, *e.g.* mangroves, coral reefs and sea grass beds, in accordance with the "Regional Guidelines on the Use of Fisheries *Refugia* for Capture Fisheries Management in Southeast Asia" adopted in 2006. Applying the concept of fisheries *refugia* would complement the existing conservation and management measures, including the integration of fisheries with habitats management. While countries in the region have on-going programs on establishment and operation of fisheries *refugia*, these should be enhanced and expanded to also support the concept of "other effective area-based conservation measures" (OECM) promoted under the CBD framework. This is considering that the concept of OECM is being incorporated in the target of the post-2020 global biodiversity framework which would be finalized at the 15th Meeting of the Conference of the Parties (COP) to the CBD scheduled in October 2021 and April-May 2022 (CBD, 2020).

Promotion of responsible utilization of fish and fishery products

In the future, food security will remain a key concern in Southeast Asia. Hence, feeding more people with less by maximizing the utilization of fishery resources while reducing food losses and wastes would be important areas to look into. As the economies in the AMSs had improved, demands for high quality seafood also grew, leading the countries toward facilitating and encouraging more bilateral trade. This had enhanced the importation of goods between and among countries, even if such goods have to be transported through thousands of miles before reaching the domestic market. Considering that fish and seafood are temperature sensitive and are highly perishable, deterioration occurs due to microbiological metabolism, oxidative reactions and enzymatic activities, processes that could be heightened under poor temperature control. This highlights the need for better food quality preservation during transportation, which also contributes toward ensuring food safety of fishery products. In order to address these concerns, the region would need to implement changes across the fishery supply chain, from processing and packaging to cold chain management.

- ***Processing***

Appropriate processing technologies throughout the post-harvest stage could be utilized to minimize fish losses and wastes, and improve the quality of fish, *e.g.* use of improved and more selective equipment to improve water quality and prevent diseases; use of raised drying racks, ice machines, insulated boxes, refrigerated vehicles, improved fish smoking kilns, mechanical dryers; enhance preservation methods such as smoking, salting, freezing and packaging methods; use of mobile apps to undertake efficient transactions, distributions and marketing; acquire equipment to be used for underutilized species; adopt novel flesh bone separation technology to remove fish meat from by-products such as fish frames.

Technologies on their own will not guarantee that fish losses and wastes would be reduced as frequent maintenance, proper usage and the right knowledge and skills are necessary for such technologies to be adopted effectively. Supportive government policies, enforcement of laws, the media, non-government organizations, and pressures from public to minimize losses and wastes are equally important. The introduction of by-product utilization training, post-harvest facilities assistance, use of efficient technologies, implementation of traceability systems, certification programs such as GMP and HACCP and guidelines would also contribute towards ensuring the quality and safety of chilled fish and seafood, as well as reducing food losses and wastes.

- ***Packaging***

Packaging maintains product safety and quality, offers protection, and facilitates movement of goods and handling. For example, freshwater fish should be packaged in insulated containers such as high-density polyethylene with lids for short distance transportation, while for longer distances the containers should be aerated and cooled by portable devices.

Modifying the packaging process can help extend the shelf life of chilled fish, such as placing in modified atmosphere or making use of vacuum packaging. Chilled and frozen seafood should be stored in other types of packaging materials, such as thermoplastic and other packaging varieties that are thermoformed into the required size before packing, *e.g.* Modified Atmosphere Packaging (MAP). The characteristics of MAP usually require two different films: a relatively rigid lower film that can be thermoformed into a tray, and a flexible film lid which closes the tray and maintains the quality and freshness of the fish under modified atmosphere. Both materials – the upper and lower films – must have high barrier properties but could be reliably combined with one another. Intelligent MAP trays are also fitted with absorbent pads that soak up any liquid from the fish fillet and at the same time release CO_2 that inhibits the development of harmful bacteria and prevents enzymatic spoilage processes. This can often extend the shelf life of the products by several days.

- ***Cold Chain Management***

The Codex Alimentarius Commission (2008) defines Cold Chain as "a term embracing the continuity of successively employed means to maintain the temperatures of foods, as appropriate, from receiving through processing, transport, storage, and retailing." The fisheries industry relies heavily on proper cold chain management practices to ensure quality, safety and commercial viability of its fish and seafood. It is extremely important to ensure that there is no breakage of the cold chain from the production of cultured commodities or wild catch, post-harvest handling, receiving, processing, packaging, transporting to retail markets, to maintaining the high quality and safety of fish and seafood. Cold chain management practices such as the utilization of ice, refrigerated seawater, storage in refrigerated facilities, chilling or freezing, are regulated under the cold chain throughout the supply chain. Additionally, these low temperature conditions must be supported by good and hygienic handling practices to delay the onset of spoilage of the fish and seafood (SEAFDEC, 2019b).

Incorporating training and awareness as an integral part of commercial operations, as well as upgrading the skills and knowledge of concerned technical persons to keep them abreast with the changes in legislation and standards are also important for minimizing fish losses and wastes. Encouraging consumers through various platforms such as campaigns, to accept products that are nutritionally beneficial and meet the food safety standards but may appear visually different from the fresh ones, is also an important way to reduce wastes at the retail market level. It is also crucial to increase the consumers' awareness of food preservation, preparation, and waste avoidance (FAO, 2021).

Enhancement of international fish trade

In order to enhance trade in fish and fishery products, not only for domestic but also for the international markets, the capacity of countries that could not yet comply with the requirements of importing countries should be improved. This is true for the various aspects that had remained to be importantly challenged, *e.g.* analysis of contaminants including chemicals, antibiotics, biotoxins; implementation of quarantine and inspection/sampling procedures, and the Sanitary and Phytosanitary (SPS) measures, strengthening their fish quality and safety management systems in accordance with the global standards, *e.g.* ISO22000: Food Safety Management System.

During the past decades, several trade-related measures have been developed and imposed to ensure that fish and fishery products are produced and harvested (or cultured) in sustainable and responsible manner. These measures include the various requirements from certification schemes for capture fisheries and aquaculture. Adoption of good fishing technologies and good aquaculture practices would therefore enable the fish and fishery products from the region to enter in the international trade. Moreover, considering that several importing countries, *e.g.* the U.S. and EU, had been imposing more stringent requirements to ensure that fish and fishery products from IUU fishing could not enter into the supply chain of their countries, compliance with the requirements for combating IUU fishing therefore remains another challenge for the countries in the region to enable their fish and fishery products to enter the international trade.

Moreover, trade-related measures have also been used to ensure that fishing activities are properly regulated and would not impact on the existence of endangered and threatened aquatic species. Adhering to important international agreements, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) that aims to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species, is also of utmost importance. In the past sessions of CoP–CITES, several commercially-exploited aquatic species, such as certain species of sharks and rays, tunas, seahorses, sea cucumbers, anguillid eels, among others, have already been listed in the Appendices of the CITES. Nevertheless, as listing of species into the CITES Appendices could pose trade difficulties not only for the listed species but also for their look-alikes and their products in various forms, countries in the region should therefore strengthen their collaboration in the collection of relevant data, and sustain the discussions and development of common and coordinated positions on the listings of additional species which could be raised during the up-coming sessions of CoP–CITES. This way, it could be assured that the listings would be undertaken based on the available scientific evidences.

The recent COVID-19 pandemic also brings another challenge for the frozen food exporters, considering that suspension could be enforced by importers for certain period of time for the exporting countries, when their samples are tested positive of the virus. However, such challenge could be only temporary when the pandemic issue is considered threatening. Nevertheless, countries in the region may need to consider establishing systems or certification issuance procedures to ensure that their products are free from any contaminations.

Another regulation that is expected to be put into force by the United States of America is the U.S. Marine Mammal Protection Act or the MMPA, which intends to impose provisions for managing fisheries interactions with marine mammals. Considering that the MMPA would be put into force starting January 2023, it becomes necessary for countries in the region to submit comparative findings in order that products from fisheries where comparability findings is available could be exported to the U.S. It is also necessary for countries in the region to enhance their capacity, especially in data collection on the status of marine mammal species and their bycatch in fishing activities, as well as in their adoption of mitigation technologies to minimize marine mammal bycatch, as this would ensure that products from their fisheries would be able to enter the U.S. market in the future.

The ongoing discussion at the World Trade Organization (WTO) on fisheries subsidies is another important development with a view to discipline subsidies that contribute overcapacity, overfishing, and IUU fishing. Although the final text on fisheries subsidies is still subject to finalization, several challenges could be anticipated once the text is finalized and countries in the region would have to comply with, especially considering that majority of fishers are small-scale catching multispecies and using multigears that result in difficulties in providing catch data by species and in coming up with stock assessment results, as well as difficulties in determining IUU fishing activities especially in overlapping areas. Collaboration among countries in the region to address such challenges is therefore necessary.

Mitigation of the impacts of climate change

An important regional platform that directly supports climate change adaptation, policy making, capacity building, and information exchange among the countries, is the ASEAN Ad-hoc Steering Committee on Climate Change and Food Security. Under such platform, the respective AMSs have engaged in various dialogues to develop effective measures for the fisheries and aquaculture to adapt to climate change impacts and to develop regional guidelines on the use of climate change indicators for fisheries and aquaculture planning. In the coming decade, climate change would remain to be a big challenge not only to the fisheries sector but also to all human activities and the global ecosystems. Therefore, measures and support programs are necessary to mitigate the impacts of climate change to the fisheries sector as well as to enhance the resilience of people that are vulnerable to the impacts, including the development of climate-smart fisheries and aquaculture initiatives.

Putting the policy frameworks and guidelines into practice

While noting that several fisheries-related policy frameworks and guidelines have been developed and adopted at the global and regional levels with a view to guiding the national implementation toward sustainable utilization of fishery resources, several impediments could still be anticipated in putting such policy frameworks into practice in some countries, especially if the existing legal frameworks are insufficient to support the implementation by relevant agencies. It is therefore necessary for the respective countries to review their relevant national legal frameworks to identify the gaps for implementation, and if possible, to amend such frameworks accordingly. In addition, as it is recognized that several issues and required actions involve not only the fisheries but also other relevant sectors, while actions could not be effectively undertaken solely by the agencies responsible to fisheries, it is therefore necessary to establish mechanisms and supporting tools that enable inter-agency coordination in various context and sub-sectors.

Moreover, it is also deemed necessary to strengthen the cooperation between and among countries in the region with relevant international/regional organizations and institutions, especially to facilitate the understanding of the issues and support the countries' capacity building in the implementation of the global and regional policy frameworks, as well as in establishing the tools that support the implementation at the regional and national levels. Involvement of the private sector in the adoption of good practices that comply with provisions of relevant global frameworks and requirements of importing countries is therefore crucial in assuring that fish and fishery products in the region are derived from responsible and sustainable practices. This would also ensure that the fishery resources would be utilized in the manner that would continue to contribute to the well-being of peoples not only those living at present but also the future generations and beyond.

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List of Contributors

Part I. Overview of the Status and Trends of Capture Fisheries and Aquaculture in Southeast Asia	
	Saivason Klinsukhon, Nualanong Tongdee, and Virgilia T. Sulit *(Secretariat)*
Part II. Issues and Challenges in Sustainable Development of Fisheries of the Southeast Asian Region	
Marine Fishery Resources	
• Tuna and Tuna-like Species	Mohammad Faisal Md. Saleh, Wahidah Mohd Arshaad, Annie Nunis Billy, Mazalina Ali, and Mohamad Syahidan Azmi *(MFRDMD)*
• Scads	Mohammad Faisal Md. Saleh, Wahidah Mohd Arshaad, Mazalina Ali, Mohamad Syahidan Azmi, and Raihana Abdul Rahman *(MFRDMD)*
• Mackerels	Mohammad Faisal Md. Saleh, Wahidah Mohd Arshaad, Mohamad Syahidan Azmi *(MFRDMD)*
• Anchovies	Abd Haris Hilmi Ahmad Arshad and Mohammad Faisal Md Saleh *(MFRDMD)* Nur Hidayah Asgnari, Zulifah Rohani, Nadiayatul Atikah Harun, and Nik Syafizah Ghazali *(DOF Malaysia)*
• Sardines	Wahidah Mohd Arshaad and Mohammad Faisal Md. Saleh *(MFRDMD)*
• Marine Shrimps	Abd Haris Hilmi Ahmad Arshad *(MFRDMD)*
• Seaweeds	Joseph P. Faisan, Jr., Hananiah Sollesta-Pitogo, and Leobert de la Peña *(AQD)*
Inland Fishery Resources	
• Contribution of Inland Fisheries to Food Security and Poverty Alleviation	Sevi Sawestri *(IFRDMD)*
• Data Collection on Inland Capture Fisheries	Sevi Sawestri *(IFRDMD)*
• Impact and Mitigation of Impact of Water Barrier Construction on Inland Fisheries	Yoga Candra Ditya, Nana Dahlia, Dwi Atminarso, *(IFRDMD)* Lee Baumgartner *(Charles Sturt University)*
• Increased Production through Culture-based Fisheries and Mitigating Impacts from Aquaculture	Siswanta Kaban, Dina Muthmainah, Dwi Atminarso, and Dian Pamularsih *(IFRDMD)*
• Conflicts on Use of Inland Water Resources	Yoga Candra Ditya, Nana Dahlia, and Dian Pamularsih *(IFRDMD)*
Aquatic Species Under International Concern	
• Sharks and Rays	Wahidah Mohd Arshaad, Hamizah Nadia Alias@Yusof and Abd Haris Hilmi Ahmad Arshad *(MFRDMD)*
• Anguillid Eels	Ni Komang Suryati and Dr. Dina Muthmainnah *(IFRDMD)*
• Sea Cucumbers	Altamirano, J.P. *(AQD)* Zaidnuddin Ilias *(DOF Malaysia)*
• Seahorses	Shelah Mae B. Ursua *(AQD)*
• Corals	Mazalina Ali and Masaya Katoh *(MFRDMD)*
• Inland Species	Ni Komang Suryati, Dina Muthmainnah, and Siswanta Kaban *(IFRDMD)*
Responsible Fishing Practices	
• Reduction of Impacts of Fishing on the Environment	Isara Chanrachkij *(TD)*
• Energy Efficiency and Fuel-saving Options for Fishing Vessels	Suthipong Thanasarnsakorn and Thaweesak Thimkrap *(TD)*
• Development and Accomplishment of Fishing Site Identification System	Annie Nunis Billy, Raja Bidin Raja Hassan, Mohammad Faisal Md Saleh, Osman Muda, Rosdi Mohd Nor, and Raihana Abdul Rahman *(MFRDMD)*
• Technology on Preservation Onboard Fishing Vessels	Suthipong Thanasarnsakorn and Thaweesak Thimkrap *(TD)*
• Reduction of Carbon Emission	Suthipong Thanasarnsakorn and Thaweesak Thimkrap *(TD)*
• Reducing Labor in Purse Seine Fishing Operations	Suthipong Thanasarnsakorn and Thaweesak Thimkrap *(TD)*
• Abandoned, Lost or Otherwise Discarded Fishing Gear	Taweekiet Amornpiyakrit *(TD)*
Utilization of Fishery Resources	
• Utilization of Fishery Resources	Anastasia Eu, Chia Siok (*MFRD)* Joseph B. Biñas *(AQD)*
• Management of Food Losses and Wastes	Anastasia Eu and Chia Siok *(MFRD)*
• Food Safety from Marine Biotoxins	Joachim Chua and Leyau Yu Lee *(Singapore Food Agency, SFA)*
Fishery Management	
• Management of Fishing Capacity and Combating IUU Fishing	Mazalina Ali *(MFRDMD)* Dwi Atminarso, Dian Pamularsih Anggraeni, and Siswanta Kaban *(IFRDMD)*
• Fishing Vessels Registration and Fishing Licensing	Kongpathai Sarapaivanich *(TD)*

• Catch Documentation and Traceability Systems for Capture Fisheries	Kongpathai Sarapaivanich *(TD)*
• Port State Measures (PSM) Implementation	Kongpathai Sarapaivanich *(TD)*
• MCS and Regional Cooperation for Combat IUU Fishing	Pattaratjit Kaewnuratchadasorn (Secretariat) and Mazalina Ali *(MFRDMD)*
• Combating IUU Fishing in Inland Fisheries	Dian Pamularsih Anggraeni, Siswanta Kaban *(IFRDMD)* Dwi Atminarso *(Charles Sturt University (CSU))*
• Application of Innovative Technologies for Combating IUU Fishing	Pattaratjit Kaewnuratchadasorn *(Secretariat)* Mazalina Ali *(MFRDMD)*
• Ecosystem Approach to Fisheries Management (EAFM) and Ecosystem Approach to Aquaculture (EAA)	Panitnard Weerawat *(TD)* Dina Muthmainnah and Siswanta Kaban *(IFRDMD)*
• Community-based and Co-management	Rattana Tiaye *(TD)* Dina Muthmainnah *(IFRDMD)*
• Habitat Protection and Fishery Resources Enhancement	Ahmad Ali *(MFRDMD)* Sukchai Arnupapboon *(TD)*
• Application of Geographic Information System (GIS) and Remote Sensing (RS) for Fisheries Management	Siriporn Pangsorn *(TD)*
Aquaculture Development	
• Socioeconomic Importance of Aquaculture for Food Security and Poverty Alleviation	Nerissa D. Salayo, Raisa Joy G. Castel, and Quenie S. Montinola *(AQD)*
• Fish Health Management	Leobert D. de la Peña, Eleonor A. Tendencia, and Edgar C. Amar *(AQD)*
• Overcoming Fishmeal Dependence in Aquaculture	Joseph Biñas, Frolan Aya, and Roger Edward Mamauag *(AQD)*
• Production and Dissemination of Good Quality Seedstocks	Peter A. Palma, Mary Anne E. Mandario, Ma. Irene C. Cabanilla-Legaspi, Marinelle S. Espino, Marwin B. dela Cruz, and Roger Edward P. Mamauag *(AQD)*
• Production of Safe and Quality Aquaculture Products	Eleonor A. Tendencia, Jeralyn Panizales, and Leobert D. de la Peña *(AQD)*
• Impacts of Intensification of Aquaculture on the Environment	Erish Estante-Superio, Jeralyn Panizales, Hannah Mae Arganioza, and Dan D. Baliao *(AQD)*
• Genetic in Aquaculture	Maria Rowena R. Romana-Eguia *(AQD)*
• Traceability of Aquaculture Products	Anastasia Eu and Chia Siok *(MFRD)*
Fisheries-related Issues	
• Climate Change and Natural Disasters	Sawitree Chamsai and Worawit Wanchana *(Secretariat)*
• Aquatic Pollution	Sukchai Arnupapboon *(TD)*
• Impacts of COVID-19 Pandemic on Fisheries and Aquaculture	Witsarut Choseng and Shiela Villamor Chumchuen *(Secretariat)*
• Fisheries Subsidies	Sawitree Chamsai and Worawit Wanchana *(Secretariat)*
Socioeconomic Well-being in the Fisheries Sector	
• Labor in Fisheries and Fish Workers	Jariya Sornkliang *(TD)* Nualanong Tongdee *(Secrretariat)*
• Microfinance, Credit, and Insurance in Support of Small-scale Fisheries	Thanyalak Suasi *(TD)*
• Gender Equity in Fisheries	Jariya Sornkliang *(TD)* Shiela Villamor Chumchuen *(Secrretariat)*
Part III. Outlook of Fisheries and Aquaculture for the Southeast Asia	
• Growing Demand for Fish and Fishery Products	Sawitree Chamsai and Nualanong Tongdee *(Secretariat)*
• Issues and Challenges Towards Sustainable Utilization of Fishery Resources	Sawitree Chamsai and Nualanong Tongdee *(Secretariat)*

SEAFDEC Addresses

Secretariat

P.O. Box 1046
Kasetsart Post Office
Bangkok 10903
Thailand
Tel: (66-2) 940-6326
Fax: (66-2) 940-6336
E-mail: *secretariat@seafdec.org*
http://www.seafdec.org

Training Department (TD)

P.O. Box 97
Phrasamutchedi
Samut Prakan 10290
Thailand
Tel: (66-2) 425-6100
Fax: (66-2) 425-6110 to 11
E-mail: *td@seafdec.org*
http://www.seafdec.or.th

Marine Fisheries Research Department (MFRD)

52, Jurong Gateway Road,
#14-01, Singapore 608550
Tel: (65) 9046-4787
Fax: (65) 6334-1831
E-mail: *Ong_Yihang@sfa.gov.sg*
http://www.seafdec.org

Aquaculture Department (AQD)

Main Office:
5021 Tigbauan, Iloilo, Philippines
Tel: +63 33 330 7000
Fax: +63 33 330 7002
Manila Office:
Room 100-E, Ground Floor
Philippine Social Science Center (PSSC)
Commonwealth Avenue, Diliman
1101 Quezon City, Philippines
Tel & Fax: +63 2 8927 7825
E-mail: *aqdchief@seafdec.org.ph*
http://www.seafdec.org.ph

Marine Fishery Resources Development and Management Department (MFRDMD)

Taman Perikanan Chendering,
21080 Kuala Terengganu, Malaysia
Tel: (609) 617-5940
Fax: (609) 617-5136
E-mail: *mfrdmd@seafdec.org.my*
http://www.seafdec.org.my

Inland Fishery Resources Development and Management Department (IFRDMD)

Jl. Gub. HA. Bastari No.08
RT.29 RW.27 Kel. Silaberanti
Kec. Seberang Ulu I, Jakabaring, Palembang 30252
Sumatera Selatan, Indonesia
Tel: +627115649600; Fax: +627115649601
E-mail: *ifrdmd@seafdec.id*
http://www.seafdec.id

Southeast Asian Fisheries Development Center (SEAFDEC)
P.O. Box 1046, Kasetsart Post Office, Chatuchak, Bangkok 10903, Thailand
Phone: +66 2940 6326; Fax: +66 2940 6336
E-mail: secretariat@seafdec.org
www.seafdec.org