

Approaches for the Sustainable Development and Management of Fisheries in the Southeast Asian Region

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The Southeast Asian region which is one of the most important areas of the world in terms of economic development, currently embraces ten Member Countries of the Southeast Asian Fisheries Development Center (SEAFDEC), namely: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The region is also significant to the world's food supply since it accounts for more than 30% of the world's total agricultural production, and supplies almost 20% to the world's total fisheries production. This article offers suggestions for enhancing the sustainable development and management of fisheries in the Southeast Asian region.

While fisheries production from many regions of the world appears to be declining, production from Southeast Asia continues to steadily and significantly increase. The Southeast Asian region (**Fig. 1**) envelopes the most important and abundant oceans and seas of the world, such as the Andaman Sea on the west, the Indian Ocean in the south and west, and the South China Sea and western part of Pacific Ocean on the east. It also encompasses the floodplains of the Lower Mekong River Basin which is one of the world's richest areas in terms of freshwater biodiversity. The fishery resources in these waters are by nature tropical and multi-species, and are being exploited by multi-gear fisheries involving large numbers of peoples who are mainly engaged in small-scale or artisanal fishing and small-scale fish farm operations.



Fig. 1. Map of Southeast Asia

The geographical features of the Southeast Asian region create certain sub-areas that share common fishery resources. While the over-all fisheries production of the region appears to be increasing, in some particular sub-areas production could have already declined in view of the severe state of over-exploitation of their fishery resources. As a whole, since fisheries play a very critical role in the economic development and food security of the region, approaches for the innovative and sustainable development and management of the fisheries at the regional level should therefore be urgently established, notwithstanding the disputes in some sub-areas over the use of the resources.

Fisheries Production from Southeast Asia

In 2009, the fisheries production from the Southeast Asian region provided about 20% to the world's total fishery production. More particularly from 2000 to 2009, the region's fisheries production provided significant contributions to the world's total fisheries production (**Table 1**). Among the top fish producing countries of the region, Thailand experienced a decreasing trend of its fisheries production due to the declining marine fisheries resources in the Gulf of Thailand. During the same period, drastic reduction of fisheries production had also been recorded in transboundary fishing areas shared with Thailand, *i.e.* in Indonesia, Malaysia, and in some countries bordering the Andaman Sea.

In the absence of proper catch documentation in the past, catches from these waters which were landed in Thailand could have been erroneously recorded as part of the fisheries production of Thailand. The decreasing catches from such areas could have also greatly affected the statistics on the total fisheries production of Thailand.

Although marine capture fisheries had always been the most important subsector in terms of fishery production, the contribution from this sub-sector had gone down to less than 50% in 2009 from almost 60% in 2005 (**Table 2**). Inland capture fisheries had been playing very important role in providing the main source of protein especially for the poor and rural people. This sub-sector has been contributing more than 8% to the region's total fisheries production. As another important sub-sector for economic development, aquaculture contributed about 33% to the region's total fisheries production in 2005 which increased

Table 1. Total fishery production of the Southeast Asian region* (metric tons)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brunei Darussalam	2,577	1,575	2,152	2,160	3,133	3,103	3,100	3,227	2,747	2,418
Cambodia	298,798	441,200	424,432	390,657	343,492	546,000	661,542	525,100	536,320	515,000
Indonesia	5,120,490	5,409,504	5,515,648	5,915,989	6,005,622	6,646,965	7,183,586	7,510,767	9,054,873	10,064,140
Lao PDR	71,000	81,000	93,000	95,000	95,000	107,800	107,800	91,660	93,500	105,000
Malaysia	1,456,932	1,411,740	1,467,486	1,483,957	1,536,990	1,402,404	1,596,051	1,654,221	1,639,017	1,729,002
Myanmar	1,309,830	1,474,460	1,606,240	1,987,020	2,148,580	2,581,780	2,817,990	2,808,037	3,147,605	3,491,103
Philippines	2,993,292	3,166,528	3,369,524	3,619,282	3,926,173	4,161,869	4,412,158	4,710,952	4,964,703	5,084,674
Singapore	9,984	7,784	7,795	7,109	7,579	7,837	11,675	8,026	5,141	5,687
Thailand	3,713,248	3,648,429	3,797,014	3,914,025	4,137,066	4,132,826	4,051,824	3,675,382	3,204,200	3,137,672
Vietnam	1,961,145	2,009,623	2,647,407	2,859,200	2,944,030	3,397,200	3,656,152	4,315,500	4,559,720	4,782,400
Region's Total	16,937,296	17,621,843	18,930,761	20,274,399	21,147,665	22,987,784	24,501,878	25,302,872	27,207,826	28,917,096
World's Total**	131,000,000	130,700,000	133,000,000	132,200,000	134,300,000	136,400,000	137,100,000	139,800,000	142,300,000	145,100,000
Contribution of the region's to world's total fish production	13.0%	13.5%	14.2%	15.4%	15.8%	16.9%	17.9%	18.1%	19.1%	20.0%

*Sources: Fishery Statistical Bulletin for the South China Sea Area (SEAFDEC, 2000-2010)
Fishery Statistical Bulletin of Southeast Asia (SEAFDEC 2010, 2011)

**Source: FAO Fisheries and Aquaculture Information and Statistics Services

Table 2. Share of the fisheries sub-sectors in the total fisheries production of the Southeast Asian region

Sub-sector	Production (metric tons)		% Contribution to Total Fisheries Production	
	2005	2009	2005	2009
Marine Capture Fisheries	13,587,280	14,140,387	59.1	48.9
Inland Capture Fisheries	1,888,289	2,397,273	8.2	8.3
Aquaculture	7,512,534	12,379,436	32.7	42.8
Total	22,988,103	28,917,096	100.0	100.0

Source: Fishery Statistical Bulletin of Southeast Asia (SEAFDEC, 2011)

to 43% in 2009. However, a large portion of aquaculture production is intended mainly for export with only little portion meant for domestic consumption.

Marine Capture Fisheries Production

The contribution of the region's marine capture fisheries production to the world's total marine capture fishery production was about 18% in 2009. Ranked as the region's largest producer, Indonesia accounted for about 30% of the region's total marine capture fishery production while the Philippines contributed 17%. However, big portions of the production data from most countries had been reported only as either miscellaneous fishes or Osteichthyes or marine fishes *nei* and non-fish groups such as cuttlefish, squids, shrimps, and other crustaceans (SEAFDEC, 2011). This makes classifying the marine capture fisheries production into demersal or pelagic group impossible to reckon with. Nevertheless, Lymer *et al.* (2010) suggested that most of the marine fishery resources in the region could be almost fully exploited or in some cases overexploited taking into account the estimated maximum sustainable yield (MSY)

and production trend (**Table 3**). Considering such scenario, the establishment of appropriate regional strategies that aim for the sustainable development and management of the fishery resources is therefore urgently needed.

Inland Capture Fisheries Production

People living near rivers and other inland water bodies are mainly dependent on freshwater fish and fishery products for food and income. Since large portion of the catch from inland capture fisheries are directly utilized for household consumption, accurate data on the production from inland capture fisheries rarely exist for this region. The current information on inland capture fisheries production (**Table 4**), which is based on available statistics compiled at the national level, indicated that production from 2000 to 2009 has gone through a see-saw fluctuating pattern. After experiencing a sharp decline in 2004, production increased in 2005-2006, down again in 2007, sharply increased in 2008, and finally increased again by about 2.8% in 2009. Generally, inland capture fisheries production of the region had been provided mainly by the countries bordering the

Table 3. Total fish catch and estimated MSY for selected countries in Southeast Asia

Country	Year	Catch (mt)	Estimated MSY (mt)	Fishing Area/Remarks
Vietnam	2004	1,724,200	1,500,000-1,600,000	Gulf of Tonkin (total biomass estimated at 5,075,143 metric tons; demersal biomass - 11,174,261 mt; large pelagic biomass - 1,156,032; small pelagic biomass - 2,744,850 mt)
	2008		582,212	Nearshore zone (50 m depth)
Thailand	2007	1,447,898	2,159,049	Gulf of Thailand
	2007	631,453	912,943	Andaman Sea
Indonesia	2008	4,702,933	5,120,000	National total
			66,100	Fisheries Management Area (FMA) 711: Large pelagic group
			621,500	FMA 711: Small pelagic group
			334,800	FMA 711: Demersal group
			11,900	FMA 711: Penaeid shrimps group
			27,700	FMA 571: Large pelagic group
			147,300	FMA 571: Small pelagic group
			82,400	FMA 571: Demersal group
			11,400	FMA 571: Penaeid shrimps group
			164,800	FMA 572: Large pelagic group
		315,900	FMA 572: Small pelagic group	
		68,900	FMA 572: Demersal group	
		4,800	FMA 572: Penaeid shrimps group	
Malaysia	2008	1,409,929	1,616,988	National potential yield
Philippines	2008	2,559,191	2,500,000	National report
Myanmar	2007	1,679,000	1,050,000	National figure based on marine fishery stock assessment survey conducted by FAO from 1980 to 1983

Adapted from Lymer et al. (2010)

Table 4. Production from inland capture fisheries of the Southeast Asian region (metric tons)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cambodia	245,600	360,000	360,300	308,750	250,00	444,000	559,642	420,000	430,600	390,000
Indonesia	318,334	310,240	304,989	308,693	330,880	297,370	293,921	310,457	497,740	494,630
Lao PDR	...	...	...	...	...	29,800	29,800	28,410	29,200	30,000
Malaysia	3,549	3,446	3,565	3,828	4,119	4,583	4,164	4,283	4,353	4,469
Myanmar	238,210	254,880	289,940	454,320	502,550	631,120	718,000	717,640	814,740	899,430
Philippines	152,351	136,347	131,644	133,292	142,019	143,806	165,081	168,311	179,491	188,444
Thailand	201,500	202,500	198,700	198,400	199,600	198,800	214,000	225,600	228,600	245,500
Vietnam	170,00	243,583	226,958	208,623	...	138,800	152,325	133,600	144,800	144,800
Total	1,159,544	1,510,996	1,516,096	1,615,906	1,179,168	1,888,279	2,136,933	2,008,301	2,329,524	2,397,273

Sources: Fishery Statistical Bulletin for the South China Sea Area (SEAFDEC, 2000-2010)
Fishery Statistical Bulletin of Southeast Asia (SEAFDEC 2010, 2011)

Lower Mekong River Basin (LMRB), namely: Cambodia, Lao PDR, Thailand and Vietnam, as well as by Myanmar and Indonesia.

Aquaculture Production

The aquaculture production from Southeast Asia which accounted for about 17% of the world's total aquaculture production had increased from 3.7 million metric tons in 2000 to 12.4 million metric tons in 2009 (Table 5). Aquaculture therefore has the potentials to fill the gap

between supply and demand for food fish as supply from nature is expected to decline. However, since fish meal still constitutes the essential part of almost all aquaculture feeds, intensifying aquaculture development could lead to increased fishing effort and continued decline of the natural fishery resources.

The major species cultured vary according to the geographical areas and preference of the countries. The main commodity produced by Indonesia is seaweeds comprising about 62% of its total aquaculture production,

Table 5. Total fishery and aquaculture production of Southeast Asia by culture category (metric tons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Fishery Production	16,937,296	17,621,843	18,930,761	20,274,399	21,147,665	22,987,784	24,501,878	25,302,872	27,207,826	28,917,096
Total Aquaculture Production	3,696,068	4,257,005	4,806,000	5,439,809	6,308,557	7,512,534	8,426,187	9,237,586	11,063,934	12,379,436
Mariculture	1,219,702	1,489,952	2,114,640	2,230,322	2,712,679	3,005,014	3,623,260	3,879,786	4,646,146	4,945,239
Brackishwater culture	1,108,821	1,191,961	1,297,620	1,468,748	1,514,054	1,953,258	1,853,761	2,032,269	2,072,026	2,694,336
Freshwater culture	1,367,545	1,575,092	1,393,740	1,740,739	2,081,824	2,554,262	2,949,166	3,325,531	4,345,762	4,739,861

Sources: Fishery Statistical Bulletin for the South China Sea Area (SEAFDEC, 2000-2010)
Fishery Statistical Bulletin of Southeast Asia (SEAFDEC 2010, 2011)

Table 6. Mariculture production from the Southeast Asian region by major species group (metric tons)

Major groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Marine fishes	21971	21,580	29,037	38,504	42,216	70,520	71,099	93,653	245,967	64,279
Marine mollusks	291,122	358,311	495,371	470,724	661,716	672,108	617,095	590,202	588,563	553,401
Aquatic plants	910,635	1,017,136	1,147,212	1,257,452	1,987,178	2,266,406	2,883,247	3,134,993	3,811,616	4,277,095
Others	23,229	388,127	533,988	471,254	201	-	-	-	-	50,464
Total	1,246,957	1,435,154	2,205,608	2,237,934	2,691,311	3,009,034	3,571,441	3,818,848	4,646,146	4,945,239

Sources: Fishery Statistical Bulletin for the South China Sea Area (SEAFDEC, 2000-2010)
Fishery Statistical Bulletin of Southeast Asia (SEAFDEC 2010, 2011)

while Philippines also produced seaweeds (*Eucaema cottonii* and *Eucaema denticulatum*) accounting for about 64% of the country's total aquaculture production in 2009. In the case of Vietnam, the main species cultured is the *basa* catfish which accounted for 41%, while Thailand produced mainly the white leg shrimp accounting for 38%, and for Myanmar, the main species cultured is rohu (*Labeo rohita*) which contributed about 67% to the country's total aquaculture production in 2009. Although seaweeds and aquatic plants are not utilized for direct human consumption, their derivatives constituting about

50% of the production are consumed by humans thus, also contributing to food security. Nonetheless, production of aquatic plants or seaweeds contributed more than 86% to the region's total mariculture production (Table 6) and about 35% of the total aquaculture production of the region.

Outlook of Fish Supply and Demand in Southeast Asia in 2020

The world's consumption of fish is expected to increase dramatically in the next decades, due to the ever increasing

Table 7. Fish production and consumption vis-à-vis population: Southeast Asia

Countries	2009 Population (millions)	2009 Fish Production (mt)	Ave per capita fish consumption (kg/person/year)	Estimated Fish Consumption in 2009 (mt)	Estimated Population in 2020 (millions)	Expected Demand for Fish in 2020 (mt)
Southeast Asia	590.6	26,917,096	38.68	23,062,752	688.0	27,169,335
Brunei Darussalam	0.5	2,418	44.04	22,020	0.5	22,020
Cambodia	14.8	515,000	32.97	487,596	17.0	560,490
Indonesia	240.3	10,064,140	31.43	7,552,629	268.0	8,423,240
Lao PDR	6.3	105,000	24.86	156,618	7.5	186,450
Malaysia	28.3	1,729,002	54.40	1,539,520	32.5	1,768,000
Myanmar	50.0	3,491,103	42.75	2,137,500	68.0	2,907,000
Philippines	92.0	5,084,674	53.49	4,921,080	120.0	6,418,800
Singapore	5.3	5,687	23.44	124,232	6.0	140,640
Thailand	65.0	3,137,672	37.97	2,468,050	70.0	2,657,900
Vietnam	88.1	4,782,400	41.47	3,653,507	98.5	4,084,795
World	6,800.0	145,000,000	18.90	-	8,084.0	152,787,600

Adapted from SEAFDEC (2012) and Pongsri (2010)



gear, marketing, and processing. Women comprising large portion of the workers in fisheries, are mostly employed in the fish processing industry.

While fisheries production shows upward trends during the past decades, over-exploitation of the fishery resources has also been reported with overfishing identified as the primary cause of over-exploitation by commercial and small-scale fisheries. It is therefore necessary to refocus the direction of the region's fisheries considering that their possible reduction or collapse could lead to loss of income and employment as well as to reduced per capita fish consumption of many countries in the region.

population and shift in consumers' preference for healthy food. In the Southeast Asian region (Table 7), the rapid growth of its population would add pressure on the natural resources due to increasing demand for food fish. The estimated fish supply for the region in the next decade could come mainly from aquaculture as production from capture fisheries is expected to decline. Meanwhile, major portion of production from marine capture fisheries will continue to be used mainly for fish meal to sustain aquaculture production. As more people would be consuming more fish for health reasons, increased fish consumption would put more pressure on the supply to meet the increasing demand for fish.

Fisheries production in 2009 seemed insufficient to supply the demand for fish, so that many countries had to import fish and fishery products for their peoples. Although the consumption of Indonesia and Philippines appeared to be lower than their production, these countries produce seaweeds or aquatic plants which are exported and not meant for direct human consumption. In the case of Thailand and Vietnam, most of their products such as the white leg shrimp and *basa* catfish, respectively are also meant for export. Since many countries in the region are aiming to increase their export of fish and fishery products, the aforementioned trend of fish supply and demand is expected to prevail in the next decade.

Impacts of the Changing Fisheries Structures of Southeast Asia

The fisheries sector accounts for about 10% of the gross domestic product (GDP) and contributes greatly to the economy and food security of the Southeast Asian region as trade in fish which represents a significant source of foreign currency earnings in most countries is expected to continue to grow. The sector employs more than 30 million people while another 60 million people are working in associated industries such as boat building, manufacturing of fishing

The Southeast Asian region encompasses the most important and abundant fishery resources in the world, but most of the waters especially the South China Sea have been declared part of the respective EEZs of countries, resulting in disputes among many countries. Brunei Darussalam, Malaysia, Philippines and Vietnam with China and Taiwan, continue to assert their claims over the Spratly Islands, Paracel Islands and Scarborough Shoal in the South China Sea. The overlapping EEZs in the Gulf of Thailand between Thailand and Malaysia; and among Thailand, Cambodia and Vietnam have been claimed by the countries that border such transboundary areas. Meanwhile, intensive fishing operations are conducted in shallow waters of the continental shelf, putting much pressure on the fishery resources and creating to some extent socio-economic impacts on the affected countries that eventually lead to vigorous claims and disputes. Therefore, considering the deteriorating state of the fishery resources in the region, the whole system of fisheries production must be changed from being natural resource-intensive to technology-intensive.

Capture Fisheries

While marine capture fisheries had developed significantly brought about by the introduction of modern technologies and fishing techniques for commercial and small-scale



fisheries, the number of motorized vessels increased while more efficient fishing gears were developed and fishing grounds in the EEZs and offshore areas had been explored. Aside from exploiting the pelagic and demersal fishes some other expensive invertebrates and crustaceans, *i.e.* shrimps, crabs, squid, and other shellfishes, are also being harvested. While the demersal fishery resources have been reported to be fully exploited or even overexploited, some pelagic fish stocks which are harvested by major fishing gear such as trawl, purse seine, and gillnet among others, could have already reached their maximum sustainable yield. In order to sustain the fishery resources, appropriate strategies and measures for fisheries development and management (**Box 1**) should be considered and subsequently adopted.

Box 1. Suggested measures and options for sustainable development and management of marine capture fisheries

Eliminate IUU fishing: Efforts to eliminate IUU fishing in territorial waters should be intensified which would need good recording of the number of fishing boats and fishing licenses. Excessive fishing efforts especially the number and types of trawlers and purse seiners should be limited to the appropriate size of the fish stocks in certain areas of each country, considering that these two main gears have been identified as the main causes of overfishing especially of the demersal and pelagic fishery resources.

Establish fish *refugia* and promote ecosystem approach to fisheries: Where appropriate, establish fish *refugias* or enforce closure of certain areas as management tool to protect the spawning, nursery or feeding grounds of some important economic demersal and pelagic fish species, and eventually enhance the growth and recruitment of the overfished stocks.

Improve fish stocks through aquaculture-based enhancement and sea ranching: Countries should carry out research programs aimed at producing fry or fingerlings of some economically-important pelagic and demersal species for propagation in appropriate areas as part of sea ranching activities. In Japan for example, halibut and flat fish are being cultured for sea ranching where fingerlings are being nursed until strong enough to survive in natural conditions after releasing in nursery grounds. The fingerlings are protected until becoming mature, after which the areas could be opened for harvesting. These measures could be applied for both pelagic and demersal fish species although in the case of highly migrating pelagic fish species, their migratory routes should also be carefully studied before conducting any sea ranching activities. It should also be noted that sea ranching could be more appropriate for demersal or short distance migratory pelagic fish species but not much for the highly-migratory fish species.

The changing structure of the region's marine fisheries had resulted in increasing number of fishing boats, which as of the recent count appeared to be more than five hundred thousand powered boats used not only for commercial but also for small-scale fisheries. While low engine capacity boats which are used by small-scale fisheries account for more than 70% of the total number of fishing boats in the

region, trawls are used to harvest high-value fishes, shrimps and squids that are meant for export, and trash fish which is mainly supplied to the fish meal industry. Purse seines also produce large amount of pelagic fishes especially the neritic and oceanic tunas which are meant for export and also serve as raw materials for the tuna canning industry.

Consequently, the structure of occupation in fisheries which predominantly uses traditional practices and labor force provided mainly by fishing households had also changed. After the introduction of the trawl and purse seine fisheries which are labor intensive, local and outsourced labor from other sectors have been increasingly mobilized to correspond to the expanding industry. As the need for fishing labor force continues to increase, foreign labors had been sourced from many countries in region, *e.g.* Myanmar, Cambodia and Lao PDR are generally the source of labor for Thailand fisheries, while labor force from Bangladesh, Myanmar, and Indonesia are mobilized in Malaysia.

In the Gulf of Thailand, Indo-Pacific mackerel (*Rastrelliger brachysoma*) is the most economically-important pelagic species. Since the annual mackerel catch had fluctuated year by year, the Department of Fisheries (DOF) of Thailand came up with measures to protect the fish spawning grounds by enforcing closed fishing season from 15 February until 15 May every year and declaring about 26,400 km² area in Gulf of Thailand as *refugia* for the mackerel. Such closure regulation was extended to the Andaman Sea for the period from 1 April to 30 June every year. The effective outcome of such measure has been the recovery of the mackerel stock which could now be exploited up to about 100,000 metric tons per year. However, even with this level of exploitation, the size composition of the marketable mackerel had changed where bigger sized fishes are no longer found in markets. As this signals incidence of overfishing, the DOF plans to enforce new closure area in the inner Gulf of Thailand in 2012. Moreover, the DOF also initiated a propagation program of the mackerel in 2011, and the fingerlings were subsequently released in nursery grounds or fisheries *refugia*. Such stock enhancement measures for the Indo-Pacific mackerel developed in Thailand could also be applied to the Indian mackerel (*R. kanagurta*) which is being significantly harvested by Indonesia, Philippines and Malaysia. Furthermore, studies on the biology and stocks of some other small pelagic fishes such as the *Decapturnus* spp. or scads, sardines, and anchovies could also be immediately considered for proper management. Mainly harvested for domestic consumption and regional intra-trade, these small pelagic fishes could therefore contribute to food security in the Southeast Asian region.

The South China Sea area is a highly productive body of water in terms of fisheries and marine living resources,

embracing the world's highest level of biodiversity. Khemakorn (2006) cited that the South China Sea is abundant with various marine aquatic species including 1,027 fish, 91 shrimp and 73 cephalopod species in its northern continental shelf; approximately 205 fish and 96 shrimp species in its continental slope; and more than 520 fish species around the islands and reefs of the southern waters. The fishery resources of the South China area are therefore of great importance for local, national and regional exploitations. While the region's fishery resources have been exploited to their maximum level both in marine and inland capture fisheries, changes in fishing activities have occurred not only in the small-scale subsistence fisheries but also in the market-oriented commercial fisheries. Therefore, for the sustainable utilization of the capture fishery resources, the involvement and participation of the peoples in the communities to manage the resources should be enhanced while the promotion of the Ecosystem Approach to Fisheries should be initiated.

Aquaculture Development

During the last three decades when improved aquaculture technologies had just been introduced, production was negligible and aquaculture was then not considered as sunrise or potential industry. However, at the beginning of the 80s when aquaculture production had remarkably increased, currently accounting for about 43% of the total fisheries production of the region, more focus is now being placed on the sustainable development of aquaculture.

The main water areas used for aquaculture comprise mainly the ponds, small lakes, reservoirs, and tidal/coastal areas, while the main species cultured include various fishes, shrimps, mollusks, and aquatic plants in freshwater, brackishwater and marine environments. In recent years, the major species developed for aquaculture included shrimps mainly the tiger and white leg shrimps, *basa* catfish especially in Vietnam, as well as sweet snails, crabs, abalone, and oysters. At the beginning, almost all aquaculture farms in the region had been operated by households in scattered areas using small-scale extensive production methods and semi-intensive farming. Later, intensive production farms had been in operation while farming methods had been improved to respond to the rigid requirements of the export market. This leads to changes in the structure of aquaculture production, which had been guided by scientific-based planning and proper management policies. As aquaculture continued to achieve high economic efficiency and rapid growth rate, changes in terms of economic pattern also occurred. The aquaculture structure has changed from being small-scale and subsistence which highly depends on natural resources and local labor forces, to being intensified and

large-scale production operations which could supply the increasing demand for food fish not only by domestic consumers but also the export markets. Subsequently, aquaculture continued to enhance job creation and income generation, leading to the reduction of poverty especially in the rural areas. However, many factors should be considered in order to achieve sustainable aquaculture development in the region, *i.e.* careful water surface area planning, infrastructure construction and improvement, and proper selection of seeds for culture and production. The development of aquafeeds that requires balancing the supply of fish meal and fish oil from capture fisheries with plant-based raw materials should be revisited. Nonetheless, sustainable aquaculture development could provide one of the most important solutions in balancing the demand and supply of food fish in the coming years.

Production from inland aquaculture and aquaculture-based fisheries which is expected to increase could boost the contribution of aquaculture to food security in the region, while production from brackishwater aquaculture and mariculture is also expected to gradually increase. Therefore, the need to reduce the utilization of fish meal from capture fisheries through the use of alternative sources of protein for the development of new aquafeeds should be considered for the sustainable development of the whole fisheries sector. Meanwhile, aquaculture-based sea ranching could also be promoted as it plays an important role in enhancing both the demersal and small pelagic fishery resources. Moreover, the creation of intensive zone for high-value fish culture, application of standards for safe and sanitary food production in aquaculture zones, intensified protection of the ecosystem and biodiversity, and readjustment of the fisheries structure, should be put forward for sustainable economic development and food security.

Fish Processing and Post-harvest Technologies

The advancement of fish processing and post-harvest technologies to meet the demand for high-value commodities by the export markets had been a major breakthrough in the fisheries sector. In the past, processing of fish such as salting, drying, fermenting, and fish sauce making, made use of traditional methods which are simple economic activities in many countries of the region.

While most of the fishery products before were mainly sold in local markets and meant for domestic consumption, in the early 80s the demand for frozen fish for export grew quickly leading to the massive construction of infrastructures such as cold storage with corresponding increased freezing capacity, and eventually the number of fisheries enterprises increased rapidly. The main

markets for the region's fish and fishery products had increased including the US, Europe, Japan, and some Asian countries. As the markets are diversified in nature, adaptations to meet the market demands for high export value commodities and the accompanying requirements had been considered. The changing structure of commodities and the expansion of markets require that countries should overcome barriers to trade such as regulations on quality standards of fish and fishery products, and anti-dumping policies of the large markets. While the fast changing structure in food processing focused mainly on quality standards, technologies for value-added products were also established. Therefore, fish processing and post-harvest technologies should be given more emphasis to enhance the initial value of the natural aquatic resources in terms of quality as well as increase the volume of value-added products to serve the high-end market and the consuming public. However, such expansion should take into consideration the fisheries structure of the region. As the potentials from capture fishery resources are expected to gradually diminish, post-harvest losses onboard fishing boats and onshore should be reduced.

Management of Major Fishing Areas of Southeast Asia

For suitable fisheries management arrangements, the vast fishery resources of the Southeast Asian region could be divided into main sub-areas (Ekmaharaj *et al.*, 2009) where two or more countries could be covered in the areas including one for inland fisheries (**Box 2**). Additionally, the establishment of sub-areas for the whole South China Sea could facilitate the sustainable management of fishery resources, considering that the level of harvesting, types of resources and fishing methods and practices in the whole South China Sea are known to be varied requiring different ways and means of managing the existing stocks. Since most of problems occurring in each sub-regional area are quite homogeneous, such as depleted demersal resources, *e.g.* in the Gulf of Thailand due to excess fishing capacity and heavy exploitation by trawlers, while the proposed sub-areas are bordered by two or more countries, dialogues between and among countries with similar culture and fishing practices could be easily conducted with agreements which could be more conveniently reached. Moreover, there is an impending need to curtail the decreasing catch of some small pelagic shared stocks, *i.e.* mackerels, *Decapterus* spp., and scads due to the heavy exploitation of the spawners during the spawning season, and that there is also a need to suppress the declining tuna stocks, *i.e.* yellowfin and bigeye in Sulu Sea, and to combat IUU fishing by the local and foreign vessels operating in the Sulawesi Sea, Southern and Southeastern South China Sea

and Arafura Sea. Since the South China Sea covers many large marine ecosystems (LMEs), proper development and management of the resources could be facilitated and could be done by sub-dividing the area into four sub-areas, namely: Gulf of Thailand, Gulf of Tonkin, Sulu-Sulawesi Seas, and Arafura Sea, where relevant issues could be effectively addressed when the cooperation of the countries bordering the sub-areas is enhanced.

In the LMRB which is the most important sub-area for inland capture fisheries, development and management plans could be collaboratively developed, discussed and agreed upon by respective member and riparian countries, taking into consideration the fact that development and management within the country's territory would follow their respective national plans for inland capture fisheries. Since from the regional point of view, most of the inland fishery resources in the LMRB had been fully exploited, measures to sustain its fishery production should be developed. Moreover, Myanmar is expected to sustain its production from inland capture fisheries because of its policy in leasing natural water bodies, *i.e.* lakes, ponds, and flood plains to the public, where recipients of licenses for lease-fisheries are responsible for the conduct of restocking program in the water bodies involved, and could exploit the resources until the fishing season is over.

A similar scheme is also practiced in Thailand under its Village Fishpond Program, where the Department of Fisheries provides the seeds for restocking in village ponds. This program, which aims to sustain food fish security in the rural areas, promotes the involvement of communities in managing the ponds and harvesting the fish from the ponds. The experiences of Myanmar and Thailand could be adapted to the other Southeast Asian countries by initiating programs that aim to propagate indigenous fish species for restocking in natural inland water bodies to enhance the stocks which might have been heavily harvested and thus, protect the environment and ecosystem. In this case, aquaculture-based and restocking programs could be options for the sustainable development and management of inland capture fisheries.

Lessons learned among the countries in the sub-areas especially the ways and means of developing and managing the fishery resources could be exchanged and disseminated to other sub-areas. However, management of fishery resources in some sub-areas, such as the LMRB could be facilitated in collaboration with the Mekong River Commission (MRC) and management of some shared pelagic stocks in the Andaman Sea could be pursued in collaboration with the Bay of Bengal Large Marine Ecosystem (BOBLME) Project.

Box 2. Proposed sustainable development and management of major fishing grounds of Southeast Asia

Lower Mekong River Basin (LMRB). The Mekong River is one of the world's most important rivers in terms of aquatic biodiversity providing fisheries production of 2.5-3.0 million mt/year to the LMRB. Fish and fishery products from this water system are very important for domestic consumption, livelihood and intra-regional trade of the countries bordering LMRB. Management of the fishery resources in the LMRB is carried out through the Mekong River Commission (MRC) Agreement, signed by the bordering countries, *i.e.* Cambodia, Lao PDR, Thailand and Vietnam while Myanmar and China are considered as dialogue partners. The LMRB is mainly a flood plain area where riverine fisheries using multi-fishing gears are practiced with the high involvement of farmers and rural people. The major threat for the sustainable development of the fishery resources in the LMRB is not mainly from fishing operations but more from the massive construction of dams and reservoirs along the Mekong River. Another critical issue related to the reproduction of fish in the LMRB is the seasonal changes of the monsoon and flooding patterns, and fish migration paths as well as development of proper fish broodstock management during the dry season. These concerns should be addressed for the sustainable development of the LMRB.

Andaman Sea. Part of East Indian Ocean and bordered by the Andaman and Nicobar Islands, the Andaman Sea is situated between those islands and the Malay Peninsula, and is also semi-enclosed. The geographical and bottom features include large continental shelf in the northern part, especially in the coastal area of Myanmar which comprises deep and very deep basin down to 2000 meters in the central part. As one of the important Large Marine Ecosystems (LMEs), some small pelagic fish stocks are shared by the countries bordering the Andaman Sea, *i.e.* the hilsa (*Tenulosa ilisha*) stocks shared by Myanmar and Bangladesh, and the *Rastrelliger* spp. stocks shared by Thailand, Myanmar and Malaysia. The fishery resources in the Andaman Sea had been considered abundant especially in its continental slope, and in the Irrawaddy delta down to depths of 150-300 meters, where large pelagic species such as the yellowfin and bigeye tunas are known to inhabit. The monsoon pattern is a key seasonal change that benefits efforts to conserve the fish stocks in the area because during such season it would be risky to operate any fishing activity. This resulted in reduced exploitation of the fishery resources allowing the fish stocks to recover. In spite of attempts to conduct exploratory fishing operations in the area from time to time, the potentials and status of the economically-important fish stocks are still not fully known. Nevertheless, the coastal and continental shelf stocks have been reported to be almost fully exploited, in which case close monitoring of the fisheries is deemed necessary and proper management measures should be established to ensure the long-term sustainability of the fishery resources in the Andaman Sea.

South China Sea (SCS). One the most important fishing areas in the region, the whole South China Sea is bordered by nine coastal states, namely: Brunei Darussalam, Cambodia, China, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam. It is considered an LME but with specific characteristics in terms of its oceanographic conditions, biology and ecology. The SCS is also a semi-enclosed sea that covers an area of around 3.5 million km² of the Pacific Ocean. The major gulfs and bays include the Gulf of Thailand, Gulf of Tonkin (Vietnam), and the Lingayen Gulf and Manila Bay of the Philippines. The extensive continental shelves, relatively shallow depths, and influx of numerous rivers, make the SCS a highly productive area in terms of fisheries and other marine living resources. In addition, the mangrove forests, sea grass beds, coral reefs and soft-bottom community habitats that abound the SCS are highly productive ecosystems, making the fishery resources of the area of great importance for food security and income generation, not only locally and nationally but also regionally and internationally. As recorded, the South China Sea produces about 10 million mt of fish every year accounting for more than 70% of the region's total fish production and about 7% of the world's total fisheries production. However, the fishery resources in South China Sea could be heavily exploited from the persistent use of destructive fishing gears and practices, especially dynamite fishing, cyanide fishing and the use of very small mesh size nets. Therefore, the possibility of increasing fish production could still be there, despite the difficulties posed during fishing operations in the area due to conflicts among countries bordering the SCS and among fishers.

Gulf of Thailand Sub-area: Once considered one of the most fertile and highly potential fishery areas of the SCS, the Gulf of Thailand (GOT) is bordered by Thailand, Cambodia, Vietnam, Malaysia, and Indonesia, and embraces a topographic feature which includes shallow bottom making it a large basin of less than 80 meters deep. Many rivers bring nutrients to GOT contributing to its diversified fishery resources but making coastal small-scale and offshore commercial fishing operations complicated. The major fisheries focus on various demersal species, shellfishes and many small pelagic species such as the Indo-Pacific mackerel, round scads and Spanish mackerel. At present, the demersal fishery resources in the Gulf are overexploited and depleted due to inadequate effective management measures, more particularly overcapacity fishing practices which put high pressure on the resources. While in 1970s, the catch per unit of effort (CPUE) was more than 350 kg/hour, in 2010 it had gone down to about 20-30 kg/hour. The dwindling demersal fishery resources led to reduced livelihood opportunities which also resulted in conflicts between small-scale and commercial fishers.

Gulf of Tonkin Sub-area: Situated in the waters of Vietnam northwest of the South China Sea, the Gulf of Tonkin possesses a geographic feature which is similar to the Gulf of Thailand, which is shallow and is also a large basin. The fishery resources of the Gulf had been depleted due to the high pressure from intensive fishing operations carried out by fishers from Vietnam and China. Nevertheless, conflicts and opportunities among these two countries' fishers are discussed and agreements reached from time to time during dialogues between Vietnam and China.

Sulu-Sulawesi Seas Sub-area: This huge area comprises many inter-connected seas such as the Sulu and Sulawesi Seas (SSS) which also encompasses the Banda Sea, Molucca Sea, Flores Sea and Celebes Sea areas, as well as the Southern and Southeastern South China Sea. SSS embraces great biodiversity in terms of coastal and offshore resources, and is a very important habitat for tuna species. Its geographic feature includes over 80% deep areas with depths ranging from 200 to 5000 meters, and a number of small islands which are important habitats for sea turtles and are known breeding and spawning grounds of yellowfin and bigeye tunas. The demersal fishery resources are believed to be underexploited because the coastal areas are not suitable for trawling, providing great opportunity for sustainable utilization of such resources. However, this area also experiences high pressure from fishing activities for its small pelagic fishery resources and tuna resources by purse seines and ring nets, and the area has been most strategic for illegal, unreported and unregulated (IUU) fishing in the region especially with the presence of fishing vessels coming from within and outside the region. Purse seine fisheries using payaw as fish aggregating device (FAD), are believed to have resulted in the reduction of the tuna juveniles affecting the tuna stocks. Therefore, there is a need for the countries bordering the area such as Malaysia, Philippines and Indonesia, to enhance their cooperation and come up with joint management approaches for the straddling and highly migratory fish stocks in the SSS.

Arafura Sea Sub-area: The Arafura Sea is connected to the Timor Leste Sea, Papua New Guinea (PNG) Sea and western Australian Sea, and is a significant area for tuna fisheries. The local fishers in the coastal area are still using traditional fishing practices to harvest tunas while many purse seine fishing vessels are operating in the offshore area. Arafura Sea could be another major area for IUU fishing by foreign vessels especially that the tuna resources in this area are still abundant.

Box 3. International, regional instruments and arrangements that play very important roles in dealing with the crisis in fisheries

<p>United Nations Convention on the Law of the Sea. The 1982 UN Convention on the Law of the Sea (UNCLOS) set forth legal frameworks for marine fisheries and environmental protection through the establishment of exclusive economic zones (EEZs). Coastal states exercise sovereign rights for exploiting, conserving and managing the natural resources of their respective EEZs.</p>
<p>Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. The 1995 Agreement is the primary mechanism for international cooperation in conserving and managing the straddling and highly migratory fish stocks.</p>
<p>Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas. The 1993 Agreement has been seen as a significant international instrument for fisheries management in the South China Sea area and for settling various territorial disputes, considering that SCS contains a maritime area considered as high seas.</p>
<p>Code of Conduct for Responsible Fisheries (CCRF). Adopted in 1995, the CCRF has been promoted in the Southeast Asian region through the SEAFDEC project on the Regionalization of the Code of Conduct for Responsible Fisheries. The project was aimed at addressing concerns in the implementation of the CCRF at national level, and clarifying provisions of the CCRF that are critical to the region's fisheries development and management.</p>
<p>FAO International Plans of Action. FAO has promoted the development of International Plans of Action (IPOAs) in order to address specific key issues in the 1995 CCRF as the implementation of the CCRF would be greatly reinforced through the development and promotion of sets of voluntary IPOAs. Thus, IPOAs had been promoted to address specific issues, such as: IPOA for Reducing Incidental Catch of Seabirds; IPOA for the Conservation and Management of Sharks; IPOA for the Management of Fishing Capacity; and IPOA to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA on IUU Fishing).</p>
<p>Regional Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated (IUU) Fishing. With regards to the IPOA on IUU Fishing, the development of the Regional Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (RPOA-IUU Fishing) was initiated by Indonesia and Australia in 2007. The RPOA-IUU Fishing had since then been adopted by the countries in the Southeast Asian region for the sustainable management of their respective fisheries.</p>

Moreover, the South China Sea is also known to embrace areas that encompass non-living natural resources, such as oil and gas resources that made Indonesia one of the world's leading oil exporting countries, and combination of onshore and offshore petroleum resources that provide Brunei Darussalam with the highest per capita gross national production in the region. Nevertheless, the extent of hydrocarbon resource deposits remains unclear, because of the absence of full exploration particularly in the Spratly Islands which comprise the biggest group of islands in the SCS. It is presumed that such situation encouraged many countries in the region to claim territorial rights over the islands in the SCS for possible extraction of the hydrocarbon resources.

Considering that small pelagic fish stocks such as mackerel, scads and highly migratory fish stocks such as tuna and tuna like fishes, are shared by two or more countries bordering the South China Sea, joint development and management schemes for these fish stocks should be established and adopted, especially that these straddling stocks had been reported to have reached their maximum sustainable yield. The tuna stocks of the SCS which are exploited through long line, purse seine, pole-and-line, and live-bait fisheries, are presently not yet overexploited. Nonetheless, many developing countries have expressed interests in tuna fisheries as potential source of foreign currency, and in most cases such fisheries are offshore operations where countries bordering the SCS have to compete with distant water fishing countries for harvesting the stocks. In spite of the lower labor costs of the countries bordering the SCS, increased fuel costs hinder these countries to sustainably harvest the tuna stocks. Meanwhile, it is also almost certain

that extension of fishery jurisdictions resulting from the eventual resolution of the region's boundary issues could restrict fishing operations in the SCS by non-South China Sea states. Under such circumstance, the skipjack tuna resources could be largely available only in the internal waters of Indonesia and the Philippines.

Legal instruments are also key elements for the successful development and management of fisheries. Since the beginning of the 2000s, the crisis experienced by the fisheries sector had become more serious even if the total production trend continued to increase. While the structure of fisheries has changed, the marine capture fisheries subsector is on the verge of collapse, and could eventually create a domino effect for the other fishery sub-sectors to also collapse. Thus, it is imperative that the situation should be carefully handled through multi-disciplinary actions taking into consideration the various instruments and agreements (**Box 3**), and sustain the whole fisheries sector.

Conclusion

The waters of Southeast Asia, which comprises two main LMEs located in the Andaman Sea and South China Sea, possess unique oceanographic, biographic and ecological characteristics and abundant fishery resources with potentials for increased economic growth. These LMEs are also known to encompass large deposits of hydrocarbons fueling continued disputes among countries within and outside the region. The undefined maritime boundary and territorial disputes among the coastal countries of the South China Sea have also seriously undermined the peaceful and optimum utilization of the fishery resources in this area.

Notwithstanding its important role in attaining food security and enhancing the economies of majority of the countries in the region, fisheries should be developed and managed sustainably. While demersal resources of most countries are fully exploited or even overexploited, the integration of rights-based fisheries management with the Ecosystem Approach to Fisheries (EAF) is a promising measure for the sustainable coastal resources management. Together with resource enhancement through restocking of indigenous fish species, sea ranching of endangered species should also be encouraged. The establishment of sub-areas in the LMEs for the sustainable management of both small and large pelagic fish species such as scads and mackerels, and tunas, should be considered. Similarly, the EAF approach could also be applied as means for the management of offshore and high sea fisheries especially in the South China Sea and Andaman Sea. Meanwhile, enhanced cooperation especially in undertaking joint development and management programs such as the establishment of *refugias* in critical fishing grounds of the countries' EEZs as well as in preventing, deterring and eliminating IUU fishing by both domestic and foreign fishing vessels should be promoted. Traditionally, inshore fishing grounds are *open access* areas and as a result, these resources had been overexploited. Unless appropriate property rights are established, it will be extremely difficult to control and rationalize the access to such fishery resources. Empowering the communities along the coastlines to take up the monitoring, control and surveillance of the resources should therefore be enhanced. Management measures for small pelagic and highly migratory pelagic species should be discussed and agreed upon among concerned countries in each sub-area, *i.e.* for mackerel, scads, sardines, hilsa and tunas in the Gulf of Thailand, Gulf of Tonkin, Andaman Sea and Sulu-Sulawesi Seas, while fish *refugias* mainly for small pelagic species should be established in critical fishing grounds. Measures to combat IUU fishing in the Sulu-Sulawesi Seas, Eastern and Southeastern South China Sea and Arafura Sea should be strengthened. Regulations to control the catching of juveniles of the yellowfin and bigeye tunas should be established through collaborative arrangements among concerned countries. For the management of inland capture fisheries, restocking program for the aquaculture-based and village fishponds could be undertaken to supply the food fish required for domestic consumption. While aquaculture development has progressed tremendously during the past decade, the culture of food fish for direct consumption has slowed down which could be due to decreasing production from capture fisheries which serves as raw materials for fish meal and fish oil as ingredients for aquafeeds. Therefore, in order to sustain the aquaculture production of the region, culture of herbivorous fish species should be encouraged and

promoted. As a technical fisheries body, SEAFDEC plays very important role in providing technical inputs and fora in finding ways and means for the sustainable development and management of fisheries in the region. In the absence of a Regional Fisheries Management Body in the region, cooperation among the countries is necessary for the implementation of the management measures and policies, which should be supported by regional bodies, *i.e.* the ASEAN Sectoral Working Group on Fisheries (ASWGF). In summary, since the region's fisheries continue to be on the brink of collapse, precautionary approaches should be considered and adopted for the sustainability of the fisheries sector of Southeast Asia.

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