Towards the Sustainable Management of Purse Seine Fisheries in Southeast Asia

Mohammad-Faisal Md Saleh, Wahidah Mohd Arshaad, Raja Bidin Raja Hassan, Katoh Masaya, Abdul Razak Latun, Nurul Nadwa Abdul Fatah, and *Khairiah Jaafar*

The Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 (SEAFDEC, 2011) adopted during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" in 2011, includes Resolution No. 10 on the need to "*Strengthen knowledge/science-based development and management of fisheries through enhancing the national capacity in the collection and sharing of fisheries data and information*," and Resolution No. 22 to "*Establish and strengthen regional and sub-regional coordination on fisheries management and efforts to combat IUU fishing including the development of regional/sub-regional Monitoring, Control and Surveillance (MCS) networks*." These Resolutions have also been directed towards the development of management strategies for sustainable fisheries, more particularly, purse seine fisheries which is one of the most practiced fisheries in the Southeast Asian region. In responding to such Resolutions, the Malaysia-based SEAFDEC Marine Fisheries Resources Development and Management Department (SEAFDEC/MFRDMD) implemented the project "Comparative Studies on the Management of Purse Seine Fisheries in the Southeast Asian Region" from 2013 to 2019, in cooperation with the SEAFDEC Secretariat and SEAFDEC Training Department. With funding support from the Japanese Trust Fund, the Project involved eight participating ASEAN Member States (AMSs), namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam; and was aimed at coming up with: 1) an analysis of the historical data on catch and effort of purse seine fisheries among the AMSs; 2) evaluation of the purse seine fisheries management systems among the AMSs; and 3) a review of the genetic structure of commercially-important small pelagic fishes targeted by purse seine.

In the Southeast Asian region, purse seine fisheries (**Figure 1**) existed since the nineteenth century (Morgan & Staples, 2006; Raja Bidin & Abdul Razak, 2016). Purse seine is usually operated with the use of fish aggregating devices, luring lights, and other devices to exploit the small pelagic fishes. The several types of purse seine include fish purse seine, anchovy purse seine, Thai purse seine, luring purse seine, and tuna purse seine. Nowadays, modern purse seine vessels are equipped with radar, depth sounder, sonar transceiver, and satellite navigational instruments (SEAFDEC, 2017). The statistical report in 2016 indicated that purse seine fisheries contributed 30.5 % to the total marine capture fisheries production of Southeast Asia, reflecting the significance of purse seine fisheries as the most productive gear in the region after trawl.

Through the years however, the expansion of purse seine fishery in the region was unregulated (Morgan & Staples, 2006) resulting in the overexploitation of small pelagic fish resources. The catch of small fishes gradually decreased from 3.7 million t in 2010 (Abu Talib, *et al*., 2013) to 3.5 million t (SEAFDEC, 2017). Management of the purse seine fisheries had been neglected because of inadequate information on stocks and biological characteristics of the small pelagic fish resources. It has therefore become necessary to develop management strategies for the sustainable purse seine fisheries in the region, and address the relevant Resolutions that call for the sustainable management of the region's fisheries.

Considering its mandate, SEAFDEC/MFRDMD was therefore tasked to review the purse seine fisheries management systems and other fisheries management measures in other parts of the world to determine the management systems and measures that would be applicable for the Southeast Asian region. Meanwhile, it was also deemed necessary that genetic studies of the small pelagic fishes be carried out to verify the extent of the connectivity of commercially-important pelagic fish species targeted by purse seine fisheries, and provide scientific

Figure 1. Purse seine fisheries in the Southeast Asian region

background for concerted management actions of the AMSs for shared stocks of small pelagic fish species.

Investigation of the Purse Seine Fisheries in Southeast Asia

Stock assessment

At the outset, stock assessment was carried out using simple and holistic methods which can be either a fishery-independent or fishery-dependent data survey, especially in situations where the data are limited, as in the case of most AMSs. All these methods of data collection have been widely used to assess the pelagic fishery resources in the Southeast Asian region since 1970s. The fishery-dependent data combined with data from fishery-independent surveys would provide a more accurate picture of the stock status. Thus, attempts were made to determine the stock status of small pelagic fishes in the region using a standard method applicable to all AMSs to generate harmonized results.

The respective 20-year data on purse seine fisheries provided by the participating AMSs, were analyzed and harmonized during the Core Expert Meetings and Regional Workshops organized by SEAFDEC/MFRDMD between 2014 and 2018. In order to calculate the catch per unit effort (CPUE), fishing effort by number of trips was chosen as the unit of effort since the data on hauls or days per trip of most AMSs were lacking. The data on number of trips was more stable compared to the fishing effort by number of purse seine vessels. The calculated CPUE was used in the Production Model analyses to illustrate the stock status of small pelagic fishery resources particularly for the AMSs with adequate catch and effort data. The Fox Model was used because its r^2 values are more precise than the Schaefer Model. For Feedback Control (Rule 2-2), the analysis was done at country and sub-region levels. For countries with scarce data, the allowable biological catch (ABC) value was estimated at the country level.

Genetic study

Sardines are among the groups of small pelagic fish species that are highly targeted by purse seine fisheries in the Southeast Asian region. Among the sardines species, the spotted sardinella (*Amblygaster sirm*) (**Figure 2**) was selected for genetic studies as these are easily distinguishable from among the various species, and thus misidentification

Figure 2. Spotted sardinella (*Amblygaster sirm*)

Figure 3. Sampling sites for genetic study of the spotted sardinella, *Amblygaster sirm*

could be avoided during the sampling. Sardines are widely distributed in the Southeast Asian waters but information on the various species remains limited. To determine its genetic stock structure, the spotted sardinella was subjected to mitochondrial DNA (mtDNA) analysis to ascertain whether this species exist both in the South China Sea (SCS) and Andaman Sea (ANS) or the population is panmictic which is characterized by random mating within a breeding population. During 2014-2018, samples of *A. sirm* were collected from the SCS sub-region (six sampling sites), Gulf of Thailand sub-region (one sampling site), ANS sub-region (two sampling sites), and from Java Sea (one sampling site) (**Figure 3**).

Dominant small pelagic fishes

Further analysis of the compiled data from the AMSs, indicated that there are other dominant small pelagic fish species that have also been targeted by purse seine fisheries in the Southeast Asian region in 1996-2016. Aside from sardines, the other species include among others, anchovies, Indo-Pacific mackerel, round scad, neritic tunas, Indian mackerel, selar scad, and hardtail scad (**Figure 4**). On the other hand, the fish species that could not be identified were grouped as other pelagic fishes. Mixed fish are small-size fish that are

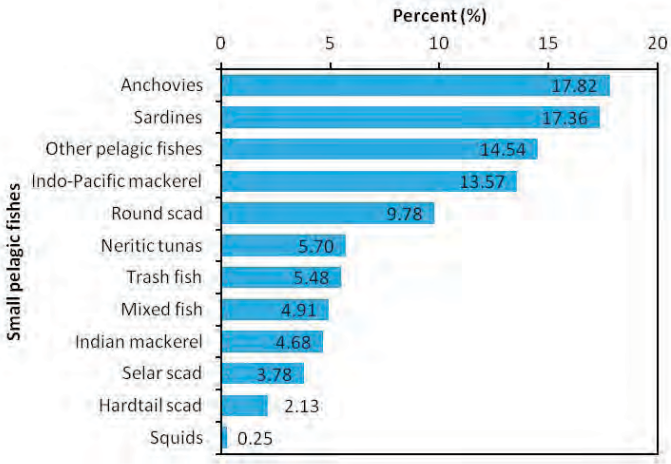

Figure 4. Dominant small pelagic fish species caught by purse seine in the Southeast Asian region during 1996-2016

fresh but has lower price, thus, it is processed into value-added products such as fish crackers, fish balls, and others. Trash fish are small-size fish that are no longer fresh because of the long duration of trip in the sea, thus, it is used as feeds for animals, aquaculture as well as agriculture fertilizer.

Purse seine fisheries management

The purse seine fisheries management systems among the participating AMSs were compiled and the methods in assessing their respective fishery resources, as well as the existing fisheries laws and regulations related to purse seine fisheries in respective countries were analyzed (**Table 1**). Currently, licensing of purse seine vessels is compulsory in all AMSs, which is renewable either annually or biennially. The licensing scheme encompasses various aspects such as regulations on vessel tonnage, engine power, mesh size, seine net length, among others.

Table 1. Synthesis of the stock assessment methods and purse seine fisheries management measures adopted by the AMSs

Country	Stock assessment methods	Management measures
Brunei Darussalam	Catch and effort data collection from 2001 to 2013	• Licensing scheme • Monthly catch logbooks • Fishing zonations • Minimum seine mesh size • No take zones • Marine protected areas (MPAs)
Cambodia	Catch and effort data collection on mackerels (Rastrelliger spp.) from 1992 to 2006	• Licensing scheme • Fishing logbooks • Annual closed season for *Rastrelliger* spp. • MPAs
Indonesia	Acoustic survey in Fisheries Management Area 711 in the SCS in 2016	• National Fishery Policy • Fishery Management Plan (FMP) • Licensing scheme • Fishing zonations • Fishing license moratorium • Minimum seine mesh size • Control light density • Closed seasons • Closed areas • MPAs • Marine Managed Areas (MMAs)
Malaysia	Acoustic surveys in West Coast of Peninsular Malaysia in 2013, East Coast of Peninsular Malaysia in 2013-2014, and Sarawak and Sabah in 2015	• Licensing scheme • Fishing zonations • Control on size and power of fishing vessels • Minimum seine mesh size • Monitoring, Control and Surveillance Program • Resettlement of surplus fishers to other sectors • No take zones • Identify nursery grounds in areas within 5 nm from the shoreline • MPAs • Marine Park • Fisheries Prohibited Area (FPA) • *Refugia* site
Myanmar	Simultaneous hydro-acoustic and trawl sampling (swept area method) using the research vessel Dr. Fridtjof Nansen in 1979, 1980, 2013, 2015, and 2018	• Licensing scheme • Fishing zonations • Moratorium on fishing licenses • Annual closed season • Closed fishing areas • MPAs • Identify nursery grounds as reserved fishing areas • FPA including 3 nm around the islands
Philippines	National Stock Assessment Program (NSAP) in 2015	• FMP • Licensing scheme • Fishing logbooks • Minimum seine mesh size • Fisheries Observers' Program • Closed season for sardines • Annual catch ban of some pelagic fish species • Annual closed fishing season for round scad • MPAs
Thailand	Fox Surplus Production Model for pelagic fishes and anchovies for all fishing gears in Thai waters in 2017 and 2018	• National Policy for Marine Fisheries Management 2015-2019 • FMP • Licensing scheme • Control on size and power of fishing vessels • Allowable fishing days • Minimum seine mesh size • Monitoring, Control and Surveillance Program • Resettlement of surplus fishers to other sectors • Moratorium on fishing license • Annual closed fishing season • Closed fishing areas • MPAs
Viet Nam	Acoustic survey of small pelagic fishes in 2012-2013 and comprehensive survey in Viet Nam Sea from 2011 to 2015	• Licensing scheme • Fishing logbooks • Minimum seine mesh size • Monitoring, Control and Surveillance Program • Catch Monitoring Program • MPAs

Stock assessment analysis: Production (Fox) Model

Initially, the total allowable catch (TAC) was considered as one of the management measures to be adopted during the stock assessment. However, it was found that TAC was not applicable as the compiled data was inadequate to comply with the requirements of the TAC system. Moreover, the TAC system is not suitable for the multi-species situation of purse

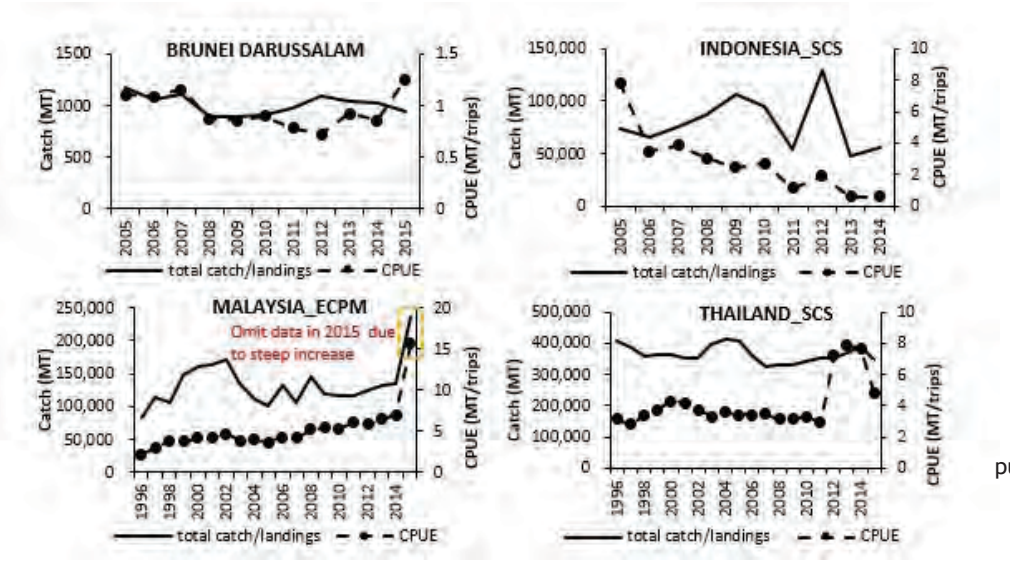

Figure 5. Trend of CPUE by trip of purse seine fishery for the countries in the South China Sea sub-region in 1996-2006

Table 2. Estimated MSY and target fMSY by Fox model for the countries in the South China Sea (SCS) and Andaman Sea (ANS) sub-regions

Country	Sub-region	Year	Current catch (MT)	Current effort, trips	r^2	MSY		Target fMSY	Deficit/ surplus	%
						MSY (MT)	fMSY	0.8 fMSY		
Brunei Darussalam	SCS	2005-2015	949	758	0.7061	1,045	1,319	1,055	96	9.2
Indonesia	SCS	2005-2014	56,128	89,562	0.8641	95,147	35,971	28,777	39,019	41.0
Malaysia	SCS (ECPM)	1996-2014	134,979	19,210	0.5828	131,679	35,211	28,169	-3,300	-2.5
Thailand	SCS	1996-2015	347,960	71,754	0.8876	382,926	89,286	71,429	34,966	9.1
	ANS	1996-2015	134,203	59,138	0.8744	165,008	75,188	60,150	30,805	18.7

seine fisheries in the region. Thus, the Production (Fox) Model and Feedback Control (Rule 2-2) was used instead.

Apparently, in the SCS sub-region, Brunei Darussalam had the most stable trend of CPUE during 2005-2015. Malaysia and Thailand also showed stable trend of CPUE in 1996-2015 but drastically changed at latter years.

Indonesia on the other hand, had a decreasing CPUE over the years (2005-2014) despite of having high catch from purse seine fleets (**Figure 5**). The current fishing effort (F, by trip) in Indonesia in the SCS sub-region had already extremely exceeded the estimated target fMSY level, thus, it is assumed that the pelagic fish stock in that area was long overfished and would collapse in the future if the trend of excessive fishing effort continues. For Brunei Darussalam, the estimated MSY and target fMSY level showed that its pelagic fishery resources are at sustainable level (**Table 2**). Meanwhile, the Malaysian (East Coast of Peninsular Malaysia or ECPM) pelagic resource is currently fully-exploited since the estimated MSY level was already reached in 2014. The current effort for Thailand, in the SCS and ANS, had already reached the estimated fMSY level in 2015. Based on the estimated MSY and fMSY values, it is recommended that the fishing effort in Indonesia should be decreased and the current fishing effort in Malaysia and Thailand should not be increased for the sustainability of pelagic fisheries.

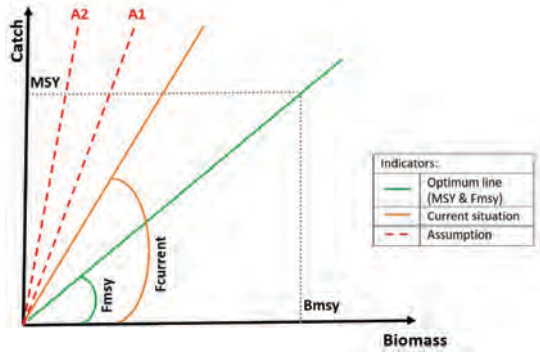

Figure 6. Biomass and catch for purse seine fishery in Indonesia in the South China Sea

(Source: SEAFDEC/MFRDMD, 2019)

In **Figure 6**, the current situation of the stocks for purse seine fisheries in Indonesia is represented by orange line. This indicates that if the effort by trip increases, the orange line will reach A1. Further increasing of the effort, the line would coincide with A2, and eventually approaches the Y axis. The biomass would become very low considering that the biomass reduces as effort increases. However, the situations would be different when the effort decreases. The MSY (green line) and BMSY (black broken line) values are at the optimum level. In general, when the effort is decreased, the orange line will approach or even go lower than the green line. During this time, the biomass value could recover and increase since the effort is reduced.

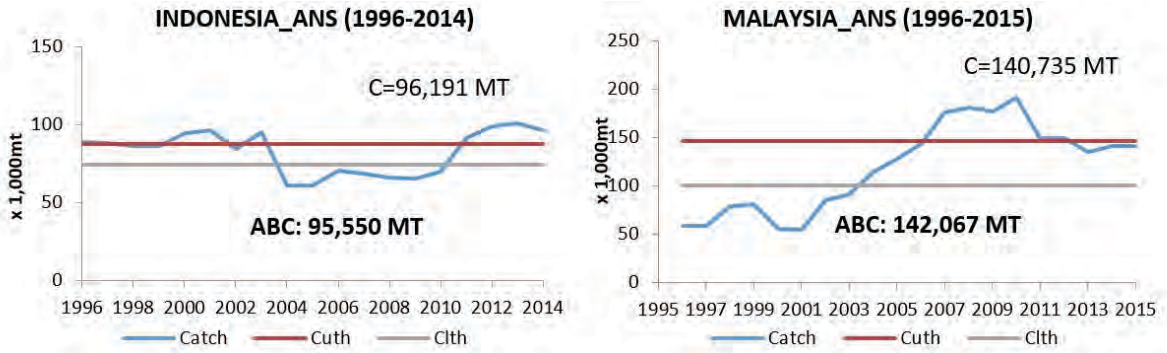

Figure 7. Feedback control analysis (Rule 2-2) for purse seine fisheries in Indonesia (ANS) and Malaysia (ANS) (ABC: allowable biological catch; C: current landing; Cuth: catch upper threshold; Clth: catch lower threshold)

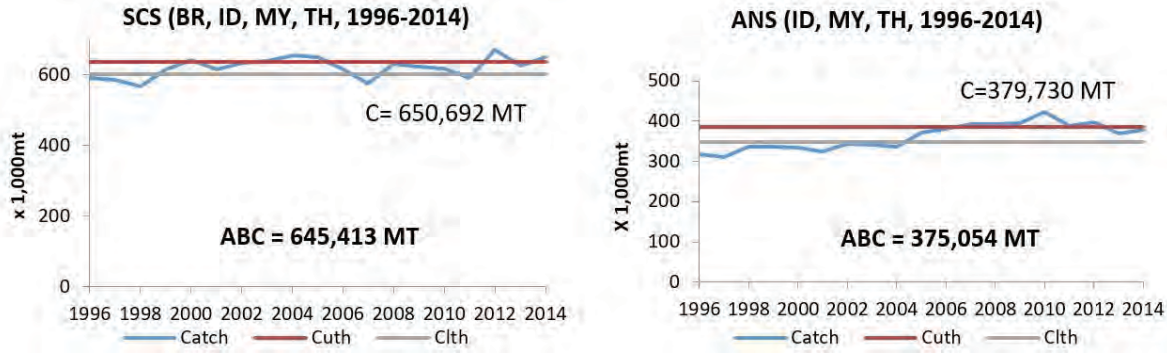

Figure 8. Feedback control analysis (Rule 2-2) for purse seine fishery in SCS and ANS sub-regions (ABC: allowable biological catch; C: current landing; Cuth: catch upper threshold; Clth: catch lower threshold)

Stock assessment analysis: Feedback Control

The Feedback Control (Rule 2-2) analysis was done at country and sub-region levels. The allowable biological catch (ABC) value at country level was estimated only for Indonesia in the ANS and Malaysia also in the ANS which have scarce data. Since each country had different systems for collecting statistical data and information, the analysis at country level was considered to be more appropriate. The result of the analysis showed that the pelagic stock in Indonesia (ANS) and Malaysia (ANS) were sustainably exploited (**Figure 7**). Although the analysis at sub-region level showed that the current catch in 2014 had already reached the estimated ABC for SCS (Brunei Darussalam, Indonesia, Malaysia, Thailand) and ANS (Indonesia, Malaysia, Thailand) sub-regions, it is assumed that the pelagic resources in SCS and ANS are still sustainable (**Figure 8**).

In reality however, the accuracy of the analyses at sub-region level is uncertain because not all AMSs were included and the data were highly dispersed and imprecise. Also, it should be noted that the ABC analyses at country and sub-region levels may not represent the status of pelagic fisheries in the region in 2019 since the available catch data was until 2014 or 2015 only, thus, the present status might be different from the results of the ABC analyses. Consequently, the comprehensive evidence that would assist stakeholders in developing the fisheries management plan at sub-region level, could not be provided.

Therefore, for sustainable purse seine fisheries, it is recommended that the Surplus Production Model should be used to determine the optimum level of effort (fMSY), especially when the catch and effort data are sufficient and reliable. However, if the data is not sufficient, Feedback Control (Rule 2-2) which determines the ABC could be used

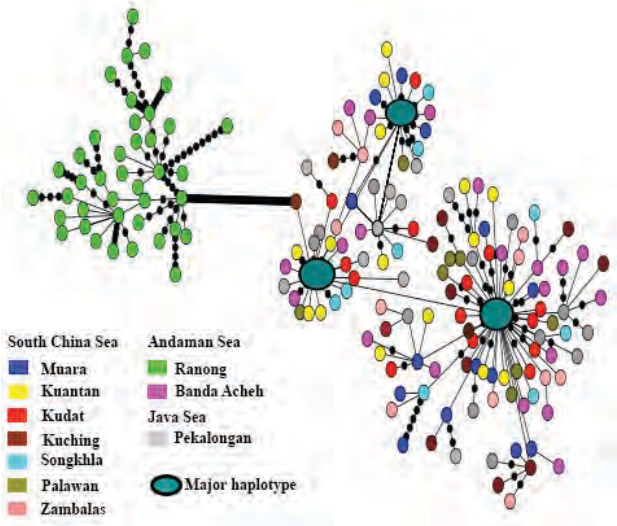

Figure 9. Minimum spanning network inferred from mtDNA Cytochrome b gene

instead of TAC system because of the multispecies nature of fisheries in the region.

Genetic stock structure

During 2014-2018, a total of 498 samples of *A. sirm* were obtained from the SCS sub-region, Gulf of Thailand sub-region, ANS sub-region, and Java Sea. Based on the genetic analysis, both DNA markers, Cytochrome b (**Figure 9**) and Cytochrome c Oxidase Sub-unit I (COI) (**Figure 10**), revealed two highly genetic divergent stocks. One stock is in the northern ANS (*i.e.*, Ranong) while the rest of the populations could be found in the SCS (*i.e.*, Muara, Kuantan, Kuching, Kudat, Palawan, Zambales, and Songkhla), southern ANS

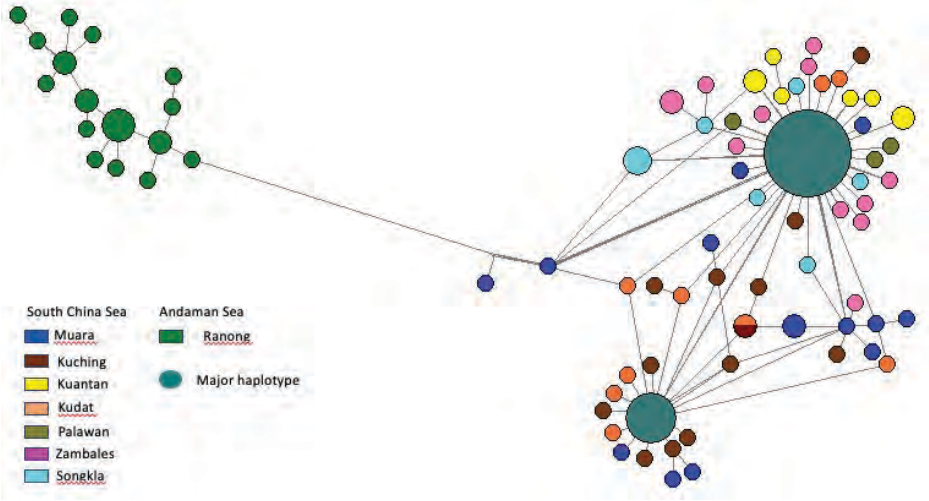

Figure 10. Minimum spanning network inferred from mtDNA COI gene

Box 1. Issues and recommendations for sustainable purse seine fisheries management in the Southeast Asian region

Issues	Recommendations
Data collection	• Improve data collection especially on catch and effort - collecting timely and accurate data - adopting the standard format of data reporting prescribed by the Project to enable sound statistical analysis - adopting harmonized stock assessment methods (Production (Fox) model analysis, Feedback control analysis, among others) - complying with the standard procedures of data sharing as agreed among AMSs
Input controls (fishing capacity)	• Assess and control fishing capacity - regulating fishing capacity through fishing licenses and catch quotas • Enhance the licensing scheme of purse seine vessels - controlling the number of purse seine vessels - limiting the size of purse seine vessels - restricting the number of fishing days
Output controls (catch)	• Enforce catch quota system - applying total allowable catch (TAC), but there are difficulties in implementing successful catch quota system - applying individual quota (IQ) which indicates a quota allocated to an individual fisher • Improve handling of bycatch (non-target species) - promoting the recommendations of the Bycatch Management Information System which include the safe release technique of sea turtles, sharks, and rays
Technical controls	• Restrict the design of fishing gear and accessories - limiting the length and depth of seine net - enlarging mesh size - reducing the intensity of fish luring lights - registering and controlling the number of fish aggregating devices • Regulate the fishing grounds and seasons - establishing a zoning system including closed area for specific species - implementing closed season for concerned species
Management measures	• Review the legal frameworks periodically - developing fisheries management plan • Support the monitoring, control and surveillance (MCS) activities - upgrading the MCS capability among national enforcement agencies - strengthening the MCS network among the AMSs within the same sub-region • Develop the capacity of human resources - conducting regular capacity building activities - promoting co-management among fisheries stakeholders (government, non-government organizations, private sector, fishing community, among others)

(Banda Aceh), and Java Sea (Pekalongan). Since *A. sirm* could not be found in the Strait of Malacca (Carpenter & Niem, 1999), it is suggested that each stock should be managed independently. Further study is recommended to confirm the genetic stock structure of the spotted sardinella being a cryptic species in Ranong.

Recommendations

Based on the foregoing analyses of the stock assessment, the issues had been identified and recommendations provided (**Box 1**) for possible adoption by the AMSs for effective management of purse seine fisheries in the Southeast Asian region, as appropriate.

Way Forward

SEAFDEC/MFRDMD would continue its collaboration with the AMSs and relevant organizations for the new project on shared stocks "Fisheries Management Strategies for Pelagic Fish Resources in the Southeast Asian Region" under the JTF 6 Phase II. In this new project, in-depth fisheries analyses would be pursued. The focus of the Project would be on regional stock and risk assessment, as well as on the current status of targeted pelagic fish species in the South China Sea and Andaman Sea. Genetic study to clarify genetic structures as well as otolith analysis to determine life-history of selected neritic tuna species would also be conducted.

Acknowledgement

Special gratitude goes to the SEAFDEC Council Director for Malaysia cum Director General of Department of Fisheries Malaysia, *Hon. Dato' Haji Munir Haji Mohd Nawi*, for his kind support to this Project. The support of the Japanese Trust Fund is highly appreciated as well as the cooperation of the fisheries agencies of the participating countries, namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam. Special thanks also go to the resource persons, namely: *Prof. Matsuishi Takashi Fritz* (Hokkaido University, Japan), *Dr. Rumeaida Mat Piah* (UMT, Malaysia), *Prof. Siti Azizah Mohd Nor* (UMT, Malaysia), and *Dr. Noor Adelyna Mohammed Akib* (USM, Malaysia), to the former Chiefs of SEAFDEC/MFRDMD, *Ms. Hjh. Mahyam Mohd Isa* and *Mr. Ahmad Adnan Nuruddin*, as well as former Deputy Chiefs, *Dr. Kenji Taki* and *Dr. Osamu Abe* for their encouragement and guidance, and to the officers and Project team members from SEAFDEC/MFRDMD for their hard work to ensure the successful completion of this Project.

References

Abu Talib, A., Faisal, M., Raja Bidin, R. H., Tamimi, M., & Katoh, M. (2013). Regional synthesis report on tagging of small pelagic fish in the South China Sea and the Andaman Sea, 2007-2012. In, Abu Talib, A., Katoh, M., Razak, A., & Raja Bidin, R. (Eds.) Tagging Program for Economically Important Small Pelagic Species in the South China Sea and the Andaman Sea. Regional Project Terminal Report JTF II (SEAFDEC/MFRDMD/SP/23). SEAFDEC/MFRDMD, Kuala Terengganu:, Malaysia.

Carpenter, K. & Niem, V. (eds.). (1999). FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae). Food and Agriculture Organization of the United Nations. Rome, Italy. Retrieved from *http://www.fao.org/3/x2401e/x2401e00.htm*

Morgan, G., & Staples, D. (2006). The history of industrial marine fisheries in Southeast Asia. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand. Retrieved from *http://www.fao.org/3/a-ag122e.pdf*

Raja Bidin, R. H., & Abdul Razak, L. (2016). Purse Seine Fisheries in Southeast Asian Countries: A Regional Synthesis. Fish for the People 14:1. Retrieved from *http://repository.seafdec.org/handle/20.500.12066/980*

SEAFDEC. (2011). Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020. Southeast Asian Fisheries Development Center, Bangkok, Thailand. Retrieved from *http://repository.seafdec.org/handle/20.500.12066/382*

SEAFDEC. (2017). Southeast Asian State of Fisheries and Aquaculture 2017. Southeast Asian Fisheries Development Center. Bangkok, Thailand. Retrieved from *http://repository.seafdec.org/handle/20.500.12066/1092*

SEAFDEC/MFRDMD. (2019). Report on Consultation Meeting with the Regional Resource Person, Dr. Matsuishi Takashi Fritz. Kuala Lumpur, Malaysia.

About the Authors

Mr. Mohammad-Faisal Md Saleh is Research Officer at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. He was the Project Coordinator from March 2017 until 2019.

Ms. Wahidah Mohd Arshaad is Research Officer at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. She is the Leader of the Genetic Component of the Project.

Mr. Raja-Bidin Raja Hassan is currently the Chief of SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. He was the former Project Coordinator from 2013 until February 2017.

Mr. Katoh Masaya is the Deputy Chief and Project Fund Manager of SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. He was also actively involved in the Project.

Mr. Abdul-Razak Latun is Special Department Coordinator at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia.

Ms. Nurul-Nadwa Abdul Fatah and **Ms. Khairiah Jaafar** are Contract Officers designated for for thre Project at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia.