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PROJECT TERMINAL REPORT

COMPARATIVE STUDIES ON MANAGEMENT OF PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

2019

Edited by:
Mohammad Faisal Md Saleh
Wahidah Mohd Arshaad
Raja Bidin Raja Hassan
Katoh Masaya
Abdul Razak Latun
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MARINE FISHERY RESOURCES DEVELOPMENT AND MANAGEMENT DEPARTMENT

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PREPARATION AND DISTRIBUTION OF THIS DOCUMENT

This terminal report was prepared by Marine Fishery Resources Development and Management Department under Japanese Trust Fund Program (Trust Fund Project VI) for Comparative Studies on Management of Purse Seine Fisheries in the Southeast Asian Region which started in 2013 and ended in 2019. Participating departments and countries involved are SEAFDEC/MFRDMD, SEAFDEC/TD, SEAFDEC Secretariat as well as contributions from SEAFDEC Member Countries including Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam. This terminal report aimed to inform SEAFDEC Member Countries of the status of purse seine fisheries in the Southeast Asia region and to recommend scientific advices on purse seine fisheries management.

The document is distributed to SEAFDEC Member Countries and Departments, partner agencies and other fisheries-related organizations, and to the public to promote the activities and visibility of the Department.

This report would have not been possible without works of numerous organizations, departments of SEAFDEC and its Member Countries in providing valuable information relevant of purse seine fisheries in the region. In particular we would like to acknowledge dedications and contributions by organizations and country respondents:

MFRDMD TECHNICAL TEAM

Mr. Mohammad Faisal Md Saleh (Project Coordinator)
Mr. Raja Bidin Raja Hassan (former Project Coordinator until March 2017)
Dr. Katoh Masaya (April 2010 – March 2015; April 2019 – present)
Dr. Abe Osamu (April 2015 - March 2017)
Dr. Taki Kenji (April 2017 - March 2019)
Ms. Wahidah Mohd Arshaad (Technical Officer for Genetic Study)
Ms. Noorul Azliana Jamaludin (2013 – October 2018)
Mr. Abdul Razak Latun
Mr. Mohd Tamimi Ali Ahmad (2013 – April 2015)
Ms. Annie Nunis Billy
Mr. Osman Muda
Mr. Rosdi Mohd Nor
Ms. Kamariah Ismail
Mr. Adam Luke Pugas
Ms. Nik Zuraini Nawawi @ Omar
Mr. Norfaizal Azli Mat Nor
Ms. Nurul Nadwa Abdul Fatah
Ms. Khairiah Jaafar
Ms. Nur Ayuni Arifin
Mr. Husaini Mohd Rani

RESOURCE PERSONS

1) Professor Matsuishi Takashi Fritz
Faculty of Fisheries Sciences, Hokkaido University, Japan and Global Institution for Collaborative Research and Education (GI-CoRE)
Email: http://bit.ly/2fritz

2) Dr. Rumeaida Mat Piah
Head of Fisheries and Aquaculture Sciences Lecturer, Faculty of Fisheries and Food Sciences, Universiti Malaysia Terengganu, Malaysia
Email: rumeaida@umt.edu.com.my

3) Professor Siti Azizah Mohd Nor
Principal Research Fellow at Institute of Marine Biotechnology (IMB), Universiti Malaysia Terengganu, Malaysia
Email: s.azizah@umt.edu.my

4) Dr. Noor Adelyna Mohammed Akib (USM)
Senior Lecturer at the Centre for Global and Sustainability Studies (CGSS), Universiti Sains Malaysia
Email: adelyna@usm.my

Foreword, SEAFDEC/MFRDMD DEPUTY CHIEF

(April 2010 – March 2015; April 2019 – present)

It was a pleasure to start the activities of the project "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region" by SEAFDEC/MFRDMD (Marine Fishery Resources Development and Management Department) in 2013. It is a great honor to finish the project in 2019. The final outputs of the project were management advices in purse seine fisheries in the region. I hope our advices will help the eight participating member countries namely Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Vietnam to sustain marine resources.

Because purse seine fisheries for small pelagic fishes such as Indian mackerels and scads are very important in the Southeast Asian region, this final report will be a guide for fishery management in the region. The publication presented here would not have been possible without the assistance of various agencies and colleagues from member countries. I particularly wish to acknowledge the funding support provide by Fishery Agency of Japan, as well as the support and cooperation of the participating countries, namely: Department of Fisheries - Brunei Darussalam; Fisheries Administration - Cambodia; Ministry of Marine Affairs and Fisheries - Indonesia; Department of Fisheries - Malaysia; Department of Fisheries - Myanmar; Bureau of Fisheries and Aquatic Resources (BFAR) - the Philippines; Department of Fisheries - Thailand; and Fisheries Administration - Vietnam. I also wish to thank Mr. Raja Bidin Raja Hassan, Chief of SEAFDEC/MFRDMD and the SEAFDEC/MFRDMD staff members who supported this project.

KATOH Masaya, Ph.D.
Deputy Chief and Co-Trust Fund Project Manager
katoh@seafdec.org.my

Foreword, Former SEAFDEC JTF Manager
(April 2017 - March 2019)

Very congratulation on the success of the latest 7-year Purse Seine project under the Japanese Trust Fund VI. Thanks to the persistent efforts of current project leader (Mr. Muhammad Faisal), former project leader (Mr. Raja Bidin, Chief of MFRDMD) and relevant staff of SEAFDEC/MFRDMD, Secretariat, Training Department and Member Countries. Under the great support of resource persons on the stock (e.g. Dr. Matsuishi) and genetic (e.g. Dr. Katoh) analyses, I believe several important findings on the stock and genetic for small pelagic species in the Southeast Asia region have been carried out during the project. We really enjoyed the internal and international discussions on the stock analyses using ABC Rules and Equilibrium Production Model and genetic analysis on *Amblygaster sirm*, which becomes my unforgettable memory. However, there are still a lot of tasks to be solved towards the development of stock management in the SEA region. I look forward to the further development on these fields by MFRDMD and other relevant staff during the next 5-year project under Japanese Trust Fund VI Phase II. Finally, I appreciate the funding support of Japanese Trust Fund on this productive project.

TAKI Kenji
(former Deputy Chief)

Foreword, SEAFDEC/MFRDMD CHIEF

Small pelagic fishes are very important for capture fisheries sector in the Southeast Asian region because it provides cheap protein source for our peoples. These resources are not only link to surface fishery, such as purse seine and gill net, but also the bottom trawlers especially in the coastal areas and continental shelf. Pelagic fish is also considered as migratory species and shared among neighbouring countries in this region so regional cooperation to manage this fishery is inevitable. Nowadays, capture fisheries are facing so many issues, not only due to overexploitation, but also management of the fisheries. The management of purse seine is among the biggest issues in the ASEAN region. Therefore, SEAFDEC/MFRDMD with funding support from the Japanese Trust Fund (JTF) was given the mandate to study and recommend the applicable management options of purse seine fisheries in the Southeast Asian region.

This project corresponds to #10 of Resolution at the ASEAN-SEAFDEC conference in 2011 (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 #22 of Plan of Action (Establish and strengthen regional and sub-regional coordination on fisheries management and efforts to combat Illegal, Unreported and Unregulated (IUU) fishing including the development of regional/sub-regional Monitoring, Control and Surveillance (MCS) networks).

Through SEAFDEC/MFRDMD, the required data related to purse seine fisheries were collected and compiled from each member countries. We are aware that many member countries have different fisheries management system and its quite challenging for us to standardize the requirement data. Some shortcomings on the data submitted by member country were identified. Besides, the genetic study was also done to understand the population structure of *Amblygaster sirm* and to examine the extent of connectivity among the commercially important small pelagic fish targeted by purse seine fisheries in the South China Sea and Andaman Sea.

As the Chief of SEAFDEC/MFRDMD, I had the pleasure to coordinate with eight Asean Member States (AMSs); Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Thailand, The Philippines and Viet Nam. This publication remarks the completion of this project as it brings to end of the seven-year project. It is hoped that this publication will raises awareness to all stakeholders and the public on the importance of sustainable management of the fisheries resources and may serves as stepping stone in managing the purse seine fisheries in the Southeast Asian region.

I would like to express my sincere thanks and appreciation to the Government of Japan for funding this project through Japanese Trust Fund and special thanks to Dr. Masaya Katoh, the Deputy Chief of SEAFDEC/MFRDMD, Mr. Muhammad Faisal Md. Saleh, the Project Coordinator, and the SEAFDEC/MFRDMD staff members for their tireless commitments in this project.

Raja Bidin Raja Hassan
Chief of SEAFDEC/MFRDMD
rbidin@seafdec.org.my

December 2019

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	Allowable Biological Catch
AMS	ASEAN Member State
ANS	Andaman Sea
APS	Anchovy Purse Seine
BMSY	Biomass Maximum Sustainable Yield
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CEM	Core Expect Meeting
COI	*Cytochrome C Oxidase* Subunit I
CPUE	Catch Per Unit of Effort
ECPM	East Coast of Peninsular Malaysia
EEZ	Economic Exclusive Zones
FAD	Fish Aggregating Device
FDD	Fishery Dependent Data
FID	Fishery Independent Data
FMA	Fisheries Management Area
FMP	Fisheries Management Plan
FPS	Fish Purse Seine
GoT	Gulf of Thailand
GRT	Gross Registered Tonnage
GT	Gross Tonnage
HP	Horse Power
IUU	Illegal, Unreported and Unregulated
JTF	Japanese Trust Fund
LL	Light Luring
LM	Length at First Maturity
LOA	Length Overall
MAFF	Ministry of Agriculture, Forestry and Fisheries
MCS	Monitoring, Control and Surveillance
MFMA	Marine Fisheries Management Area
MMA	Marine Managed Areas
MPA	Marine Protected Area
MSN	Minimum Spanning Network
MSY	Maximum Sustainable Yield
MT	Metric tonnes
NM	Nautical mile
PS	Purse Seine
RFMO	Regional Fisheries Management Organisations
SCS	South China Sea
SEA	Southeast Asian
SPS	Sardine/Scad Purse Seine
TAC	Total Allowable Catch
TAE	Total Allowable Effort
TPS	Tuna Purse Seine
TRP	Target Reference Point
UNCLOS	United Nations Convention on the Law of the Sea
VMS	Vessel Monitoring System
WCPM	West Coast of Peninsular Malaysia

EXECUTIVE SUMMARY

In Southeast Asia region, simple purse seining has been used since the nineteenth century, to exploit the pelagic fishes (Raja Bidin & Abdul Razak, 2016; Morgan & Staples, 2006). Nowadays, modern purse seine vessels are equipped with radar, depth sounder, sonar transceiver, and satellite navigational instruments (SEAFDEC, 2017). In 2016, Purse Seine (PS) fishery contributes second largest (30.5%) to the marine capture fisheries (SEAFDEC, 2018) reflecting the significance of purse seiners in the SEA region.

SEAFDEC/MFRDMD initiated the activities of the Japanese Trust Fund (JTF) VI project entitled “Comparative Studies on the Management of Purse Seine Fisheries in the Southeast Asian Region” under Japanese Trust Fund (JTF) in 2013. Initially the project was planned for five years (2013 – 2017) but was extended to 2019 by the JTF Manager. The goal of this project is to propose management strategies for sustainable PS fisheries in the region. MFRDMD had coordinated the project with eight (8) ASEAN Member States (AMSs), namely Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam, with assistance from SEAFDEC/Secretariat and SEAFDEC/TD. The target fish in this project is the small pelagic fish exploited by purse seiners in South China Sea (SCS) and Andaman Sea (ANS).

The four main project activities are; (i) Compilation and comparison of annual Catch Per Unit of Effort (CPUE) where data are available for the past two decades; (ii) Comparing the PS fisheries management systems; (iii) Conducting a genetic on a commercially important small pelagic fish targeted by PS fisheries in SCS and ANS; (iv) Recommendations on management strategies for sustainable PS fisheries in the SEA region. The planned activities covered the most appropriate unit of effort for stock assessment, fisheries management systems in the world including Total Allowable Catch (TAC) to choose the management measures applicable to the PS fisheries in the region, and a genetic study on spotted sardinella, *Amblygaster sirm* for determination of genetic stock structure. These activities are essential since the effective management of shared stock requires measures to be taken in the whole region even covering areas beyond national waters. The activities undertaken throughout the project duration from 2013 to 2019 were four Core Expert Meetings and eight workshops including six internal workshops and two regional workshops.

The methodology for the comparative study on PS fisheries is involving the compilation and analysis of historical catch and effort data. The questionnaires regarding the required biological, catch, effort and related information was designed during the 1st Core Expert Meeting 'The Core Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region' on 26-28 August 2014 and sent to the participating AMSs. Feedbacks to the questionnaires include: (i) Trend of landings/total catch; (ii) Trend of number of vessels and gross tonnage; (iii) Trend of CPUE (landings/number of vessels/year); (iv) Species composition; (v) Growth Parameters; (vi) Length at first maturity, Lm; (vii) Spawning season; (viii) Maximum Sustainable Yield, MSY. Besides feedback from questionnaires, the information on PS fisheries in SEA region was also provided by representatives from AMSs during the core expert meetings and regional workshops, and were updated from 2014 until end of 2018. The catch and effort data were analysed to plot the trends of landing, effort and CPUE, moreover the biological information on small pelagic fish and other information on PS fisheries were compiled.

Among various types of PS, the Fish Purse Seine (FPS) and Anchovy Purse Seine (APS) are actively exploiting pelagic fish in SEA region. However, recently, Cambodia and the Philippines shifted their fishing gear to gillnet and ring net respectively to catch the pelagic fish. As a part of fisheries management, licensing the PS vessels are compulsory in all AMSs. The implementation of licensing scheme encompasses various aspects such as the regulations on tonnage of vessels, engine power, mesh size, length of seine net and others. The license needs to be re-new annually in most AMSs, and biennially in few AMSs. All AMSs have its own Marina Protected Areas (MPAs) in which PS operation is prohibited in order to protect the juvenile fish.

The fish species composition showed that sardines, anchovies, Indo Pacific mackerels, round scads, neritic tunas, Indian mackerels, selar scads and hardtail scads are among dominating small pelagic fish exploited by PS in the SEA region. Few AMSs faced some difficulties in fish identification which resulted the unidentified fish was grouped as other pelagic fish, thus caused imprecise fish species composition. A handful of biological parameters such as growth, mortalities, length at first maturity and spawning season of some commercially important pelagic species were also compiled from numerous studies in AMSs.

In situations where the data are limited, the stock assessment is being carried out using simple holistic method which can be either fishery-independent data survey or fishery-dependent data survey. All these methods of data collection have been widely used to assess the pelagic resources in the SEA region since 1970s. The fishery-dependent data combines with data from fishery independent surveys will provide a more accurate picture of stock status. The existing information on pelagic fisheries resource are: (i) Brunei Darussalam studied the stock assessment on PS fisheries using the catch and effort data from 2001 to 2013; (ii) Cambodia done the stock assessment on mackerels (*Rastrelliger* spp.) using catch and effort data from 1992 to 2006; (iii) Indonesia carried out an acoustic survey in Fisheries Management Area (FMA) 711 (SCS) in 2016; (iv) Malaysia performed acoustic surveys at West Coast pf Peninsular Malaysia (WCPM) in 2013, East Coast of Peninsular Malaysia (ECPM) in 2013-2014, Sarawak and Sabah in 2015; (v) Myanmar had its latest stock assessment in 2015 using the research vessel Dr Fridtjof Nansen; (vi) The Philippines managed to update the small pelagic fish status using the length-frequency analysis and exploitation grades in 2015; (vii) Thailand used the Fox surplus production model in analysing the pelagic fishes and anchovies for all fishing gears in Thai waters in 2017 and 2018; (viii) Viet Nam conducted a comprehensive survey in Vietnamese Sea from 2011 to 2015. Realizing the different method used by AMSs in assessing its fisheries resources, MFRDMD attempted to determine the stock status using a standard method applicable to all AMSs so that the results were standardized and comparable.

Initially, TAC (Total Allowable Catch) was considered as a possible management measure for PS fisheries in the SEA region. However, after a few consultations with the Resource Persons (RPs), it was found that TAC was not applicable as the compiled data was inadequate with the requirements of the TAC system. Moreover, the TAC system is unsuitable in the multispecies situation of PS fisheries in the region. Then, the project adopted other appropriate and suitable managements measures, such as Production Model and Feedback Control. The scientific advices and recommendations on management measures in this project were suggested to certain AMSs based on Production Model and Feedback Control analyses.

Effort by number of trips was chosen as the unit of effort for calculation of CPUE since most AMSs do not have hauls or days per trip data. The number of trips data is more stable compared to the effort using number of PS vessels (unit). Only Brunei Darussalam, Indonesia, Malaysia and Thailand managed to provide sufficient fishing effort by number of trips. MFRDMD calculated the CPUE of pelagic resources from the compiled data. Apparently, in SCS ecosystem, Brunei Darussalam (2005-2015) has the most stable trend of CPUE. Malaysia and Thailand (1996-2015) also showed stable trend of CPUE but drastically changed at latter years, while Indonesia (2005-2014) has decreasing CPUE over years despite of having high catch from PS fleets.

The calculated CPUE was then used in Production Model analyses to illustrate the pelagic status (for AMSs with adequate catch and effort data). The Fox model was chosen because its r^2 values are more precise than the Schaefer model. Results from analyses showed that the current fishing effort (F, by trip) in Indonesia SCS had extremely exceeded the estimated target fMSY level. It is assumed that the pelagic stock in that area was long overfished. It is a concern that due to low productivity, pelagic stock in this area will collapsed in future if the trend of excessive fishing effort continues, thus highly suggested Indonesian fishery authorities to decrease the effort. On the other hand, the estimated MSY and target fMSY level of Brunei Darussalam showed that its pelagic fishery resources are at sustainable level. The current effort for Thailand SCS and ANS in 2015 had reached the estimated fMSY level. Meanwhile Malaysian (ECPM) pelagic resource was currently fully-exploited since the estimated MSY level was reached in 2014. The fishery authorities in Malaysia and Thailand are advised not to increase the current fishing effort, therefore reducing the fishing effort and current catch is the best option for conservation purpose towards sustainable pelagic fisheries.

In addition, the Feedback Control (Rule 2-2) analysis was done at country and ecosystem level. The Allowable Biological Catch (ABC) value estimated at country level was done only for Indonesia (ANS) and Malaysia (ANS) which have scarce data. Since each AMS has different system in regards to statistical data and information collection, analysis at country level is ought to be more appropriate evaluation. The result of the analysis showed that the pelagic stock in Indonesia (ANS) and Malaysia (ANS) were sustainably exploited. On the hand, the analysis at ecosystem level showed that the current catch in 2014 already reached the estimated ABC for both SCS and ANS ecosystem. It can be assumed that the pelagic resources in SCS and ANS is still sustained. However, in reality, the accuracy of the analyses at ecosystem level is questionable due to: i) biasness (the ecosystem analyses were not represented by all AMSs); ii) high dispersion; and iii) uncertainties of data. Thus, this project could not provide comprehensive evidence to assist stakeholders in developing the fisheries management plan at ecosystem level. It is worth to note that all ABC analyses at country and ecosystem levels may not represent the present (2019) status of pelagic fish in the SEA region since the catch data ended in 2014 or 2015. The present status might be different from results of these analyses.

The genetic study of the project was entitled as "Genetic Study of *Amblygaster sirm* Inferred by Mitochondrial DNA (mtDNA) in South China Sea and Andaman Sea". The spotted sardinella, *A. sirm* can be distinguished easily from other species of sardines by the presence of a series of 10 to 20 gold spots (in live or fresh specimens) or black spots (in preserved specimens) along the lateral line, but sometimes the spots are missing. In this study, tissue samples of 35 fishes of *A. sirm* from every site were collected from ten (10) localities in the South China Sea (Muara, Brunei Darussalam; Kuching, Kuantan, Kudat, Malaysia; Songkhla, Thailand; Palawan, Zambales, The Philippines); two (2) sites in Andaman Sea (Ranong, Thailand and Banda Aceh, Indonesia) and one (1) site in Java Sea (Pekalongan, Indonesia). Both DNA markers which were *Cytochrome b* and *Cytochrome c Oxidase* Subunit I (COI) had revealed two highly genetic divergent stocks, which is northern Andaman Sea (Ranong) versus the rest of populations i.e included South China Sea (Muara, Kuantan, Kuching, Kudat, Palawan, Zambales and Songkhla), Java Sea (Pekalongan) and southern Andaman Sea (Banda Aceh). It should be noted that this species could not be found in the Strait of Malacca (Carpenter and Niem, 1999). Thus, it is suggested that these stocks should be independently managed. Further study to identify the possibility of *A. sirm* in Ranong being a cryptic species in this region is highly recommended.

There are few factors that influence the outcomes of this project. Since this project involves the historical catch and effort data on PS fishing gear, therefore comprehensive and reliable data became the main factor in influencing the degree of analysis results. Many catch and effort data sent by representatives of AMSs during regional meetings, workshop and through emails were patchy, insufficient time series and was not in format requested. In some cases, the data submitted was questionable, thus bring the concern of data integrity. In certain cases, no response was given when a request for data verification was sent. Besides that, some issues like change of fishing gears in certain AMSs that occurred in the middle of the project duration also effected the analysis. For instance, Cambodian fishers changed their fishing gear from PS to gill nets in its small pelagic fisheries since 2013 and the Philippines too has focus on the use of ring nets instead of PS. Also, the multispecies situation in pelagic fisheries in SEA region has caused huge species aggregation on catch categories. Multispecies fisheries are subject to widely distributed and homogenously mixed fish stocks which lead to non-selective exploitation. Thus, the implementation of TAC for specific species in SEA region could not be possible.

Based on the issues faced in this project, the recommendations for PS fisheries management in the SEA region are divided into five categories as follows:

1. Recommendations for data and information collection includes (i) all AMSs should improve their data and information collection especially catch and effort; (ii) AMSs should ensure that data collection is well timed and accurate and in accordance to standard

format to enable sound statistical analysis; (iii) AMSs should consider sharing of the catch and effort data in accordance to the agreed procedures.

2. Recommendations for input controls (fishing capacity) includes (i) Enhance the licensing scheme; (ii) Control the number of PS vessels; (iii) Limit the size of PS vessels; (iv) Limit the allowable fishing days.

3. Recommendations for output controls (catch) includes (i) Introduce the catch quota system; (ii) Improve bycatch handling (non-target species).

4. Recommendations for technical controls includes (i) Use larger mesh size; (ii) Limit the length and depth of seine net; (iii) Register and control number of Fishing Aggregating Devices (FADs); (iv) Control the total light intensity of spotlights for luring fish; (v) Encourage establishment of a zoning system (with gear specification); (vi) Identify and establish closed area for specific species; (vii) Encourage AMSs to introduce closed season for specific species.

5. Recommendations for strengthening PS fisheries management includes (i) Review Legal Framework periodically; (ii) Establish Fisheries Management Plan (FMP); (iii) Strengthen the monitoring, control and surveillance (MCS) activities among national enforcement agencies; (iv) Integrate the MCS networking among the AMSs within the same ecosystem; (v) Assessment on PS fishing capacity; (vi) Control of fishing capacity; (vii) Introduce exit plan; (viii) Enhance the capacity building; (ix) Encourage co-management involving coastal fishing community.

In conclusion, for sustainable PS fisheries, AMSs are recommended to use the Production Model to determine the optimum level of effort (fMSY) when they have sufficient and reliable catch and effort data. However, if the data is not sufficient, AMSs may use the Feedback Control (Rule 2-2) which determine the ABC. The TAC system cannot be used in context of the multispecies fisheries in the Southeast Asia region.

BACKGROUND OF THE PROJECT

The global growing fish consumption is the vital call to increase fish and fish products' production to secure the availability of food and nutrition for the growing human population. The number of fishing fleets exploring the vast sea is increasing since 1970s to cater the demand. For the past decades, approximately 53.0% of world fisheries production comes from countries in Asia continent, majorly contributed by Southeast Asian countries that maintained 6.8% annual increment trend, from 16.9 million MT in 2000 to 42.2 million MT in 2014 (SEAFDEC, 2017). The coastal and marine waters of Southeast Asian countries are among the most productive areas in the world. However, the nature of tropical waters consists of highly diverse multi-species fish, thus intrinsically more complex than the composition of fish found in the northern waters. This has resulted in the use of multi-fishing gears and methods. The rapid development of commercial marine fisheries in SEA over the past few decades is due to the work of many production methods and fisheries like trawling, purse seining, shrimp trawling, tuna longlining, drift netting, trolling and other industrial fishing operations (Morgan and Staples, 2006).

Purse seine is the most productive gear in contributing pelagic landings after trawl (SEAFDEC 2018). Introduced into SEA region since 19th century, as alternative to trawls, purse seiners since then become popular commercial fleet to catch the small pelagic fish, for instance, the effect was very significant in Gulf of Thailand (GoT) that seen a dramatic increase in the total pelagic catch from 63,000 MT in 1971 to 480,000 MT in 1977 and then became the dominant fishing gear in other countries like Indonesia and The Philippines (Morgan & Staples, 2006). Many types of purse seines are used, among them are fish purse seine, anchovy purse seine, Thai purse seine, luring purse seine and tuna purse seine. This type of commercial operation is commonly associated with the use of fish aggregating devices, luring lights, and other devices to herd the pelagic fish. Nowadays, the modern purse seine vessels are equipped with radar, depth sounder, sonar transceiver, and satellite navigational instruments (SEAFDEC, 2017). The expansion of purse seining in the region was essentially unregulated (Morgan & Staples, 2006), and it was not long before it caused some concern associated with the small pelagic species resources being overexploited. The challenge now is to exploit the seas in a sustainable manner that preserves the diversity of marine life while providing the people with a source of food long into the future (Butcher, 2004). Thus it is necessary to develop management strategies to bring in the long-term sustainable PS fisheries in SEA region.

The traditional fisheries management techniques are challenging to apply since this region has one of the most diverse marine ecosystems in the world and currently there is no consensus on the most appropriate ways to manage these tropical multispecies and multi-gear fisheries (IFFO the Marine Ingredients Organisation, 2019). Management of purse seine fisheries has not been considerably pursued due to the inadequate information on the stocks of the small pelagic fishes (Raja Bidin & Abdul Razak, 2016). Moreover, the expansion of Economic Exclusive Zones (EEZ) to 200 nautical miles adopted by United Nations Convention on the Law of the Sea (UNCLOS) in 1982, without effective Monitoring, Control and Surveillance (MCS) and fisheries management schemes, has causes the illegal fishing activities in the EEZs of neighbouring countries been unrestrained, thus jeopardizing the transboundary fish resources.

To ensure the sustainability of these pelagic resources, formulation of management strategies of PS fisheries is essential. Considering the likeliness of these pelagic stocks shared by countries bordering with the same ecosystem both in the Andaman Sea and the South China Sea, the management measures will be only effective when it covers the whole region area that is beyond the national waters. At the outset, it is crucial to take a look at the status of purse seine fisheries in eight AMSs, namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Thailand, the Philippines, and Viet Nam. Then, the stock of the pelagic fish in each country was analysed to find the applicable management measures.

This project corresponds to #10 of Resolution at the ASEAN-SEAFDEC conference in 2011 (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 #22 of Plan of Action (Establish and strengthen regional and sub-regional coordination on fisheries management and efforts to combat Illegal, Unreported and Unregulated (IUU) fishing including the development of regional/sub-regional Monitoring, Control and Surveillance (MCS) networks). This project is linked with the preceding JTF II Phase One project “Information Collection for Sustainable Pelagic Fisheries in the South China Sea” (2002-2006) and JTF II Phase Two project “Tagging Program for Economically Important Small Pelagic Species in the South China Sea and the Andaman Sea” (2007-2012). Initially scheduled for five-years, the project was expanded and completed in seven-years duration (2013-2019) considering the significance of the project to the region.

OBJECTIVES OF THE PROJECT

There are five objectives for this project.

Objective 1: To compile and compare annual catch per unit effort (CPUE) data for the last three decades in Malaysia and Thailand where historical catch-effort statistics had been collected by SEAFDEC and to interpret the resources trends in the region.

Objective 2: To assess which unit of effort is most appropriate for Malaysia, Thailand, and other member countries and to examine other indicators for stock assessment.

Objective 3: To compare the existing management systems/measures of purse seine fisheries including Total Allowable Catch (TAC) systems in the world to examine which management system/measure is applicable for management of purse seine fishery in the region.

Objective 4: To compare the genetic structures of commercially important small pelagic species in the region by studying one species of the commercially important sardines.

Objective 5: To propose management strategies for sustainable purse seine fisheries in the Southeast Asian region based on available data.

PROJECT ACTIVITIES

1. Regional and Internal Workshops

MFRDMD have successfully organized eight workshops;

i. 1st Internal Workshop: 18-20 November 2013 (Terengganu, Malaysia).
ii. 2nd Internal Workshop: 25-27 November 2014 (Kelantan, Malaysia).
iii. 3rd Internal Workshop: 6-7 January 2016 (Kelantan, Malaysia).
iv. Regional Workshop: 7-8 March 2017 (Kuala Lumpur, Malaysia).
v. 4th Internal Workshop: 12-14 February 2018 (Terengganu, Malaysia).
vi. Genetic Workshop: 6-9 August 2018 (Langkawi, Malaysia).
vii. 5th Internal Workshop: 12-14 February 2019 (Kelantan, Malaysia).
viii. 6th Internal Workshop: 13-17 October 2019 (Pahang, Malaysia).

The first internal workshop was conducted in Merang, Terengganu, Malaysia in 18 - 20 November 2013 attended by officials from MFRDMD and the local resource person, Dr. Alias bin Man. The workshop was informed on the trends of landings for PS, trends of CPUE of FPS in Thailand, trend of CPUE by standardized GRT for commercial PS in Malaysia, and also on CPUE vs Effort by GRT, CPUE vs Effort by number of unit vessels in Malaysia and Thailand respectively.

The second internal workshop was conducted in Tok Bali, Kelantan, Malaysia from 25 to 27 November 2014 involving officials from MFRDMD. The workshop focused on synthesis of publication of the Current Status of Purse Seine Fisheries in the SEA region. Catch and effort data, trends and status of pelagic stock were among the information extracted from the country reports provided by AMSs.

Next, the third internal workshop was conducted in Tok Bali, Kelantan, Malaysia in 6 -7 January 2016 attended by local resource persons, officials from DOF Malaysia (FRI) and officials from MFRDMD (Figure 1). The workshop aimed to discuss the regional synthesis of general PS fisheries information.

Figure 1. The Third Internal Workshop for 'Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region' in Kelantan, Malaysia, 6 - 7 January 2016.

A regional workshop on 'Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region' was convened in March 2017 attended by six (6) participating AMSs, a regional resource person (Professor Matsuishi Takashi Fritz) from Japan and the representatives from SEAFDEC Secretariat and SEAFDEC/TD (Figure 2). New options for PS fisheries analysis were introduced, namely the Allowable Biological Catch (ABC) and Allowable Biological Effort (ABE), that are more suitable for multispecies situation in SEA region. Feedback control (Rule 2-1 and Rule 2-2) were also considered as applicable method in analysing the PS fisheries.

Figure 2. The Regional Workshop on 'Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region', Kuala Lumpur, Malaysia, 7 - 8 March 2017.

The fourth internal was organized in Dungun, Terengganu, Malaysia in February 2018 to discuss the catch and effort data by using other method/model than Feedback Control method (Rule 2-1 and Rule 2-2) (Figure 3). During the workshop, the Surplus Production Model was introduced and explained by local resource person, Dr. Rumeaida Mat Piah. All participants agreed to use number of trips as the effort unit because of the consistencies of yearly trend and data availability compared to other fishing effort. Subsequently, outputs generated during the workshop became main key in the regional analysis for the project.

Figure 3. The Fourth Internal Workshop on 'Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region', Terengganu, Malaysia 12 - 14 February 2018.

MFRDMD has organized a regional genetic workshop at Langkawi, Malaysia in August 2018 (Figure 4). During this workshop, the genetic experts suggested that there were different species or sub-species of *A. sirm* in SEA due to the different genetic content between samples from two ecosystems which were SCS region (including Banda Acheh) and northern ANS region (Ranong).

Figure 4. The Genetic Analysis Workshop for *Amblygaster sirm* and *Thunnus tonggol* in Southeast Asian Region, Langkawi, Malaysia, 6 - 9 August 2018.

The fifth internal workshop held in Kota Bharu, Kelantan, Malaysia in February 2019 (Figure 5) was intended to enhance the knowledge regarding the fisheries management. The workshop agreed to publish the terminal report of the JTF VI project by the end of year 2019. The workshop also discussed on the direction for the next project, the JTF VI Phase Two.

Figure 5. The Fifth Internal Workshop on ‘Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region’, Kelantan, Malaysia, 12 -14 February 2019.

The final (sixth) internal workshop was held in Kuantan, Pahang, Malaysia in October 2019 (Figure 6) with the focus on preparing the terminal report of the project. The meeting discussed on recommendations for management measures of PS fisheries in SEA region that appropriated with the results of the Feedback Control and Production Model analyses.

Figure 6. The Sixth Internal Workshop on Preparation of Terminal report for JTF VI Project - Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region, Pahang, Malaysia, 13 -17 October 2019.

2. Regional Core Expert Meeting (CEM)

Four regional Core Expert Meetings were successfully convened in Malaysia to discuss the project progress and achievements.

i. 1st CEM: 26-28 August 2014 (Furama Hotel, Kuala Lumpur, Malaysia).
ii. 2nd CEM: 9-11 August 2016 (Furama Hotel, Kuala Lumpur, Malaysia).
iii. 3rd CEM: 12-14 September 2017 (Furama Hotel, Kuala Lumpur, Malaysia).
iv. 4th CEM: 18-19 September 2018 (Melia Hotel, Kuala Lumpur, Malaysia).

The first CEM entitled "The Core Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region" was held in August 2014, in Kuala Lumpur, Malaysia. The meeting was attended by the representatives from Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, The Philippines, Thailand and Viet Nam, the Resource Persons from Japan and Malaysia, the representatives from SEAFDEC/Secretariat, SEAFDEC/TD and DOF Malaysia, as well as the Chief, Deputy Chief and officials from SEAFDEC/MFRDMD (Figure 7).

Figure 7. The 1st CEM on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region', Kuala Lumpur, Malaysia, 26 - 28 August 2014.

Then, MFRDMD had convened "The 2nd CEM on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region" in Kuala Lumpur, Malaysia in August 2016. The meeting was attended by representatives from Cambodia, Indonesia, Malaysia, The Philippines, Thailand, Viet Nam as well as an observer from Lao PDR. The resource persons from Japan and Malaysia, representatives from SEAFDEC/Secretariat, SEAFDEC/TD, DOF Malaysia and the Chief, Deputy Chief and officials from MFRDMD were attended the meeting too (Figure 8). The meeting shared the latest information on the characteristics of catch and effort of small pelagic PS fisheries in each participating AMSs, analysed the comparison between application of TAC, Total Allowable Effort (TAE) and other management options for its data requirement, and understood the population structure of a major species which was *A. sirm*. The publication of the report on the 2nd CEM was issued on 2017 (Appendix II) and the list of participants were attached in the Appendix III.

Figure 8. The 2nd CEM on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region', Kuala Lumpur, Malaysia, 9 - 11 August 2016.

"The 3rd Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in Southeast Asian Region" was organized in September 2017 in Kuala Lumpur, Malaysia (Figure 9). Members of the meeting shared the latest information about landings and CPUEs of PS fisheries in the region, learnt about TAC management and the implementation of TAC in Thailand and Target Reference Point (TRP) in the Philippines. Progress on genetic study for sardine *A. sirm* was also presented. The publication of the report on the 3rd CEM was issued on 2018 (Appendix II).

Figure 9. The 3rd CEM on Comparative Studies for Management of Purse Seine Fisheries in Southeast Asian Region, Kuala Lumpur, Malaysia, 12 - 14 September 2017.

The final CEM meeting entitled "The 4th Core Expert Meeting on Comparative Studies for Management of PS Fisheries in SEA Region" was held in September 2018 in Kuala Lumpur, Malaysia (Figure 10). The participating AMSs shared the updated information on catch and effort data of PS fisheries, provided the clarification for any questionable data, shared the latest/additional output based on the regional synthesis of PS fisheries and discussed the most appropriate management measures for PS fisheries in the region. The meeting also disclosed that the result of the regional analysis can only be assumed as a good scientific trial but not as scientific recommendations due to limitations of data. The importance of accurate and realiable statistical data for future analysis were emphasized. The publication of the report on the 4th CEM was issued on 2019 (Appendix II).

Figure 10. The 4th CEM on Comparative Studies for Management of Purse Seine Fisheries in Southeast Asian Region, Kuala Lumpur, Malaysia, 18 - 19 September 2018.

COMPARATIVE STUDIES ON MANAGEMENT OF PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

Prepared and analysed by:

Mohammad Faisal Md Saleh
Raja Bidin Raja Hassan
Taki Kenji
Matsuishi Takashi Fritz
Nurul Nadwa Abdul Fatah
Khairiah Jaafar

Corresponding author:

Mohammad Faisal Md Saleh
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia
mohd_faisal@seafdec.org.my

ABSTRACT

The 'Comparative Studies on the Management of Purse Seine Fisheries in the Southeast Asian Region' intended to establish suitable management measures exclusively for purse seine fisheries (PS) in the region. The project started with the compilation of purse seine catch-effort statistic from eight AMSs, for two decades from 1996 to 2015. The fish species composition showed that sardines, anchovies, Indo Pacific mackerels, round scads, neritic tunas, Indian mackerels, selar scads and hardtail scads are among dominating small pelagic fish exploited by PS in the SEA region. The effort per trip was chosen as the most suitable unit of effort compare to other effort unit, and catch per unit effort (CPUE) was used to examine the status of pelagic resource. The TAC system was found not suitable due to multispecies situation of PS fisheries in the region and, other management measures i.e Production Model and Feedback Control analyses were decided being more applicable for management of purse seine fisheries in SEA region. The Production Model enables AMSs to determine the optimum level of effort (fMSY) when they have sufficient and reliable catch and effort data. However, if the data are insufficient, AMSs may use the Feedback Control (Rule 2-2) which determine the Allowable Biological Catch (ABC). Based on the findings of this project, the Production Model (Fox) analysis revealed that exploitation of pelagic resources by purse seiners in Brunei Darussalam, Malaysia and Thailand are already at sustainable level, thus increasing the fishing effort is not recommended. However, the pelagic resources in Indonesia (SCS) is not at sustainable level, thus it is highly recommended for them to reduce their fishing effort as much as possible until it reaches one third (1/3) of its current effort. During seven-year project duration, there were some issues arose, for instance, the reliability of the compiled data, i.e. some AMSs were not able to fulfil all the parameters established by MFRDMD. Hence, recommendations on improvement of data and information collection as well on input, output, and technical controls were offered to AMSs for the purpose of sustainable purse seine fisheries.

1. Introduction

The coastal and marine waters of Southeast Asian countries are among the most productive areas in the world (Aprilani Soegiarto, 2010). For the past decades, approximately 53.0% of world fisheries production comes from countries in Asia, majorly contributed by (SEA) countries (SEAFDEC, 2017). Small pelagic fish are more important for food in this region than in any others, accounting for about one-third of the landings, followed by demersal species and tunas (Hongskul, 1999). The catch of small pelagic fish in SEA countries had made up 30% of the total fisheries catch in 2010 (Abu Talib, Mohammad Faisal, Raja Bidin, Mohd Tamimi, & Katoh, 2013). Previous regional projects such as JTF II Phase One project "Information Collection for Sustainable Pelagic Fisheries in the South China Sea" (2002-2006) and JTF II Phase Two project "Tagging Program for Economically Important Small Pelagic Species in the South China Sea and the Andaman Sea" (2007-2012) had contemplated on collecting data regarding the economically important small pelagic species in the SEA waters.

Purse seining, introduced in 19^{th} century, quickly became popular commercial fleet to catch the small pelagic fish, as alternative to trawling in SEA waters (Morgan & Staples, 2006). Many types of purse seines are used, among them are fish purse seine (FPS), anchovy purse seine (APS), Thai purse seine (TPS), luring purse seine (LPS), tuna purse seine, and others. This type of commercial operation is commonly associated with the use of fish aggregating devices (FADs), luring lights, and other devices to herd the pelagics. Nowadays, the modern purse seine vessels are equipped with radar, depth sounder, sonar transceiver, and satellite navigational instruments (SEAFDEC, 2017). The expansion into purse seining in the region was essentially unregulated (Morgan & Staples, 2006), and it was not long before it caused some concern associated with the small pelagic species resources being overexploited in many areas. The catch of small pelagics was gradually decreased; from 3.7 million MT in 2010 (Abu Talib, Mohammad Faisal, Raja Bidin, Mohd Tamimi, & Katoh, 2013) to 3.5 million MT (SEAFDEC, 2017).

Unfortunately, many fisheries in SEA are facing substantial pressures due to human population pressures, overexploitation of marine resources and poor enforcement or lack of fishing regulations targeting stock sustainability (Derrick, Noranarttragoon, Zeller, Teh, & Pauly, 2017). The challenge now is that, in the ecosystems that are already under intense fishing pressure, the fisheries sector needs to be managed in more precautionary manner in order to reduce overfishing (Pauly, et al., 2002) and to preserves the diversity of marine life while providing the people of the region with a source of food long into the future (Butcher, 2004). To ensure the sustainability of marine resources, formulation of a management plan of PS is essential. Considering the likeliness of these pelagic stocks shared by countries bordering with the same ecosystem both in the Andaman Sea and the South China Sea, the management measures will be only effective when it covers the whole region area that is beyond the national waters. Due to the lack of regional PS management in SEA regions, the current project was proposed with aims of construction of management strategies for sustainable PS as well as to provide with scientific background for concerted management actions of AMSs for shared stocks of small pelagic species.

The PS fisheries data sent by AMSs were compiled and arranged by country in several chapters and sub-chapters in this terminal report. The current overview of PS fisheries, PS common fishing areas, and laws and regulations related to PS fisheries was composed into Chapter 3: Overview of Marine Fisheries in the SEA Region. The biological information like catch composition, growth and mortality parameters, length at first maturity and spawning seasons was summarized into Chapter 4: Population Parameters and Biological Information. Next, Chapter 5: The Status of Small Pelagic Fish Stock, has listed the existing and latest assessment of the biomass and MSY of small pelagics resources in each country. The results from catch and effort data analysis was put into Chapter 6: Synthesis for Catch and Effort Information, in which landing trends, trends by trips, inter-annual variations, as well as results from Production Model and Feedback Control analyses were shown. And lastly, Chapter 7: Management Measures for Purse Seine Fisheries has addressed the constraints and issues faced throughout project period, as well as the recommendations to the AMSs in regards to the PS fisheries management.

2. Methodology

The findings from preceding JTF II Phase I and Phase II projects revealed that the latest information on status of the small pelagic fishery is insufficient in most AMSs. Recognizing the importance of sustaining the small pelagic stock in the SEA, SEAFDEC was given a mandate to embark on another project as a continuation of the aforementioned projects.

For the comparative study, the methodology was mainly involved the compilation and data analysis of historical catch and effort data. With PS fishery as the subject, the questionnaires template was designed during 1st CEM. After that, MFRDMD sent the template to the AMSs via email, mail and fax within the agreed timeframe. Besides feedbacks on the questionnaires, the information on PS fisheries in SEA region was also obtained from the materials provided by AMSs representatives during the core meetings and regional workshops, and were kept updated until end of 2018. The catch and effort data were then used to plot the trend of landing, effort, and CPUE in data analysis chapter, while other information on PS fisheries as well as the biological information on small pelagic fish was reported in other chapters.

Initially, TAC (Total Allowable Catch) was considered as a possible management measure for PS fisheries in the SEA region. However, after a few consultations with the RPs, it was found that TAC was not possible due to the compiled data was inadequate with the TAC system's requirements. Moreover, TAC system is unsuitable in the multispecies situation of PS fisheries in the SEA region. Then, this project adopted other option of managements measures, i.e Production Model and Feedback Control as they were found to be more appropriate and suitable. The scientific advices and recommendations on PS management measures were suggested to the certain AMSs based on the results from those two analyses.

2.1. Historical catch-effort statistics compilation

The questionnaires (Appendix I) has a list of questions on essential information related to PS fisheries like catch and effort data, species composition of fish caught using PS, biological information and growth parameters of some small pelagic fish, and the existing pelagic stock assessments information that has been carried out in each AMSs. Initially, the project wished to compile and compare annual the historical catch-effort data for the last three (3) decades. However, after getting feedbacks and information from representatives from AMSs, only the 1996-2015 historical catch-effort data was managed to be compiled.

2.1.1. Select the target species of pelagic fish

The targeted species of the project is the small pelagic fish. Using database from PS's catch by species, a total of thirteen (13) species were chosen including eight (8) most common commercially important pelagic species which are Indo-pacific mackerel, Indian mackerel, round scads, bigeye scads, hardtail scads, sardines, anchovies, and neritic tunas. The rest of catch were grouped into five different categories which are other pelagic species, mixed fish, trash fish, squids and crustacean.

2.1.2. Select the fishing vessel

The pelagic fish is exploited by few commercial vessels such as purse seine, ring nets, gillnets and others. Purse seines was selected as subject for this project since in general, it is the most efficient gear for catching large and small pelagic species that is shoaling, from small sardines to the large tunas. There are many types of PS vessels in the region, however in this project, the PS is grouped into two general categories only, namely Fish Purse Seine (FPS) and Anchovy Purse Seine (APS). Table 1 listed the availability of FPS and APS data from each AMS. However, when interpreting the resources trends in the region, the FPS and APS data was combined, thus represented the whole PS fisheries data for the respective country.

Table 1. Data availability on purse seine type in each AMS.

AMSs	FPS	APS
Brunei Darussalam	Available	Unavailable
Cambodia	Available	Unavailable
Indonesia	Available	Unavailable
Malaysia	Available	Available
Myanmar	Available	Available
The Philippines	Available	Unavailable
Thailand	Available	Available
Viet Nam	Available	Unavailable

2.2. Examine the PS fisheries management measures

Management measures involves specific controls on the fisheries sector, including the technical measures, input and output controls, as well as on the fishers' rights. There are few existing fisheries management measures in the world. In order to reduce the total catch to a biologically and economically sustainable level, authorities frequently introduce TACs. Ideally, TACs should be set at a level that allows the maximum economic yield (MEY) to be achieved in the long term. (World Ocean Review, 2010). At the present, only few countries and Regional Fisheries Management Organisations (RFMOs) have implemented TAC quota i.e. Japan, Norway, Portugal, CCSBT and ICES (Raja Bidin Raja Hassan, 1st CEM). TAC works most efficient and ideal for single species situation, for example, the southern bluefin tuna (*Thunnus maccoyii*) monitored by Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Significant improvements in the biological and economic performance of the southern bluefin tuna fishery has being achieved after implementation of TAC by the members and non-members of CCSBT (Morgan G. R., 1997).

Nevertheless, in some cases, TAC is deemed as impractical, especially those associated with difficulty of enforcement and operational difficulties of setting the quotas, and it ignores the reality of harvesting process in multispecies fisheries. The main problem in the case of multispecies fisheries is that the TACs of different species can be exhausted at different rates. Another problem is the different stock conservation needs. For instance, two species that are caught together from the same fishing site can be in different state, one can be in a very low biomass level whereas another can be in the highest level.

Figure 11 shows the process of determination of TAC by European Union Commission. The formulation of TAC is based on surveys and monitoring programmes and the amount is fixed annually by the Council of Ministers. Every member state in European Union (EU) is responsible to follow the annual TAC allocation, within their respective annual individual fishing quota.

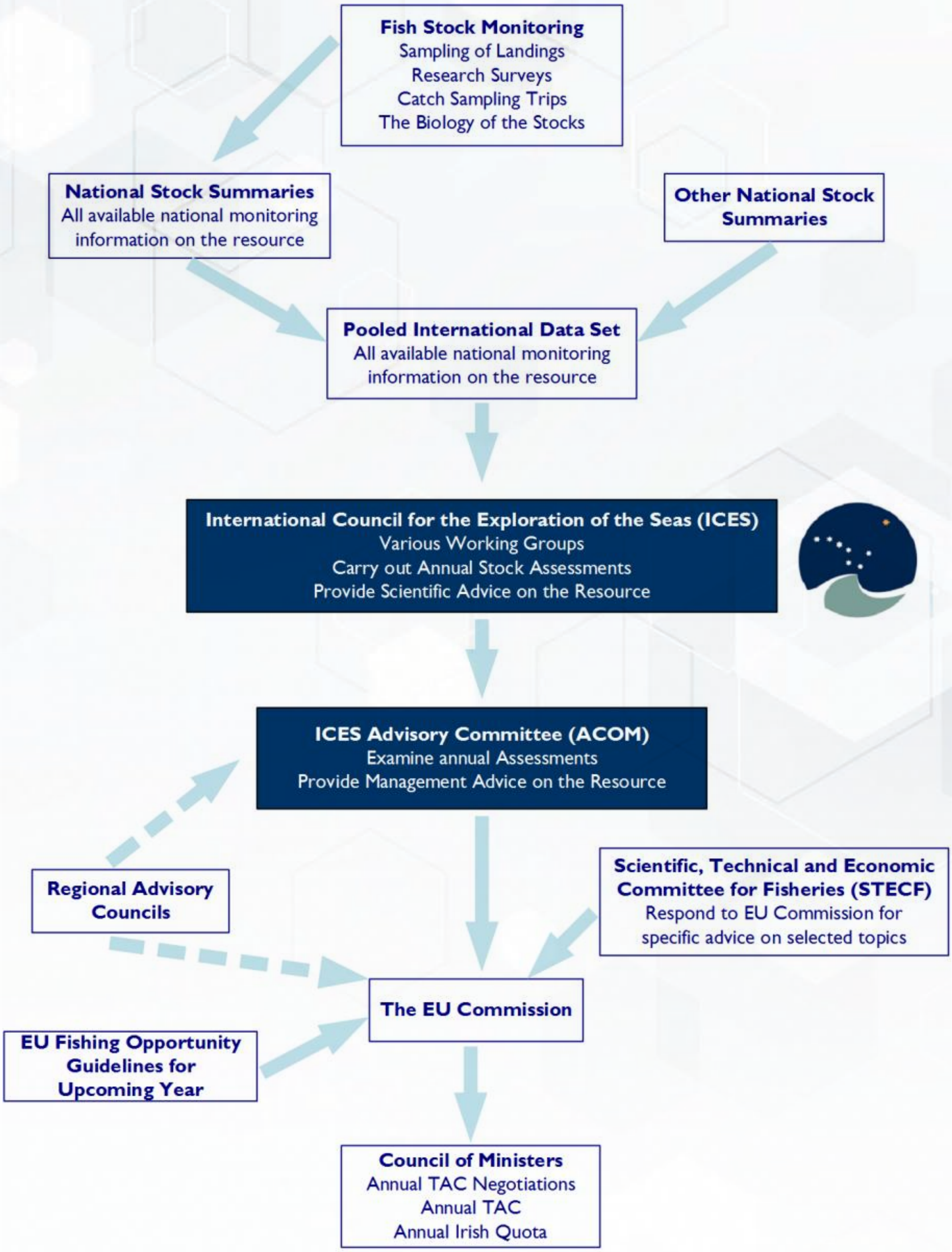


Figure 11. Determination of TAC in European Union Commission.

Source:www.marine.ie/Home/site-area/areas-activity/fisheries-ecosystems/total-allowable-catches-tacs

As one of the objectives of this project, the TAC system was reviewed to determine the applicability and suitability of the system for PS fisheries in the SEA region. After few discussions and meetings involving all concerned parties and resource persons, TAC was found unsuitable to be implemented in the SEA region mainly due to the multispecies catch composition of the PS fisheries. Then, other management measures were suggested like the Allowable Biological Catch (ABC) and Allowable Biological Effort (ABE) strategies. Finally, Production Model and Feedback Control were well-thought as the more appropriate and applicable method to analyse the pelagic stock status in SEA region, using the scientific data compiled during the project duration.

2.3. Examine the Feedback Control and Production Model analyses

2.3.1. Conduct the workshops

Six (6) internal workshops and one (1) regional workshop were successfully organized by MFRDMD throughout the project duration. The workshops usually were done to enhance and enrich knowledge regarding stock assessment, to discuss on data analysis of PS fisheries, and to estimate the pelagic stock status in each AMS and in SCS and ANS ecosystems.

2.3.2. Consult the resource persons (RPs)

MFRDMD have regularly consulted two resource persons for this project. The regional resource person is Professor Matsuishi Takashi Fritz from Faculty of Fisheries Sciences, Hokkaido University, Japan, who has vast knowledge and experiences in research in Fisheries Science, Fisheries Management and Cetology. While, the local resource person, Dr. Rumeaida Mat Piah, from Universiti Malaysia Terengganu (UMT), Malaysia, has expertise in Fish Population Dynamics and Fisheries Management field. Both resource persons contributed great and supportive assistance throughout project duration. They suggested several types of analyses that are more applicable with the compiled data and the multispecies situation.

2.3.3. Screen the data

Data analysis began by screening all the compiled data to verify their reliability and validity. This is a very important step in data analysis as it determines the accuracy of analysis. Unreliable data cannot be use for subsequent analysis. The screening was done through inter-annual variation for landing (MT), number of vessels (unit) and number of trips (trips) data to find out if there is any outliers or unusual data. Then, the screened data was sent through email and fax to the representatives of respective AMSs for data verification.

2.3.4. Estimate the Catch per Unit Effort (CPUE)

In many instances, CPUE is taken as an indirect measure of the abundance of a target species. Theoretically, the smallest unit of effort that best describes the fishery is used as the CPUE index, if it is possible. In this project, number of trips was used as the unit of effort for CPUE due to the data scarce of smaller unit effort like number of hauls and hour per operation. Realistically, it is difficult to track and record number of hauls per operation for each purse seiner as most of the fishers did not record such details. Using the compiled annual catch and effort data, MFRDMD calculated the CPUE (by trip) since many AMSs have sufficient trip data compared to other smaller unit of effort.

2.3.5. Estimate the pelagic stock status

Data analysis continued with the estimation of pelagic stock status using two methods; the Production Models and the Feedback Control (Rule 2-2), as per suggested by resource persons. The results and discussions on those two analyses were elaborated in Chapter 6.

I) Production Model

Production models consider the stock globally; in which they do not take into consideration the structure of the stock by age or size. The production models is aimed to determine the optimum level of effort, that is the effort that produces the maximum yield that can be sustained without affecting the long-term productivity of the stock, the so-called maximum sustainable yield (MSY)

(Sparre & Venema, 1992). According to the Sparre and Venema (1992), the simplest way to deal with the multispecies situation is to apply the production models to the total catch of all species and the total effort by all vessels. The most common production models used in fishery stock assessment are Schaefer model (1954) and the Fox model (1970) (Cadima, 2003). Nevertheless, it cannot be proved that one of those two models is superior to the other. Thus, the most reasonable in each particular case or the one which gives the best fit to the should be chosen (Limburg, 2001). The estimation of the pelagic status was done using Production Model (Schaefer and Fox) based on the following formula. The calculated estimated fMSY becomes one of the Reference Point for this project.

Schaefer model, (1954)	**Fox model, (1970)**
Regression data Y: bx+ a	Regression data Y: bx+ a
MSY: $-(a^2)/4b$ fMSY: -a2/b Opt. CPUE = MSY/fMSY	MSY: (-1/b) exp [a-1] fMSY: -1/b Opt. CPUE = MSY/fMSY

II) Feedback Control

It was agreed to use Feedback Control method too especially for some AMSs which faced data scarcity situation, as the data was insufficient be analysed by PM analysis. The Feedback Control analysis aims to creates the sustainable fishery, and it gives the ABC value that represents the upper limit of allowed catch by a country. In contrast to the PM analysis, Feedback Control simply maintains the fishery at sustainable level, whereby the stock will not be depleted, regardless whether it will lead to the best fishery management or not. The ABC value becomes the Reference Point too in this project. In fisheries, the feedback control exemplifies the actions taken by managers according to the current state of the fisheries, management objectives, and a decision algorithm in a feedback control loop, typically aiming to stabilize annual catches and population abundances at desired levels (Holt & de la Mare, 2009). Rule 2-1 and Rule 2-2 were constructed based on two assumptions, namely: (1) CPUE is proportional to the population; and (2) catch trend will correspond to short term population trend, respectively. These rules are being considered as the most applicable and appropriate for the management of PS fisheries utilizing the available data (Mohammad-Faisal, Wahidah, Raja-Bidin, Noorul-Azliana, & Fatah, 2017; Matsuishi, 2017). The estimation of the pelagic status was done using ABC Rule 2-1 and Rule 2-2 formula as stated below. Eventually, only Feedback Control Rule 2-2 was used since it fit the compiled data.

ABC Rule 2-1

$$ABC = \delta_1 \times CPUE \times \gamma_1$$

Whereby;

δ_1 = 1.0 (High)
1.0 (Middle)
0.8 (Low)

CPUE = current CPUE

$\gamma_1 = 1 + (b / I)$
· b: tangent of the CPUE for recent **3 years**
· I: average of the CPUE for recent **3 years**

ABC Rule 2-2

$$ABC = \delta_2 \times C \times \gamma_2$$

Whereby;

δ_2 = 1.0 (High)
1.0 (Middle)
0.8 (Low)

C = current catch

$\gamma_2 = 1 + \mathbf{0.5} (b / I)$
· b: tangent of the Catch for recent **3 years**
· I: average of the Catch for recent **3 years**

2.4. Scientific advises and recommendations on PS fishery management

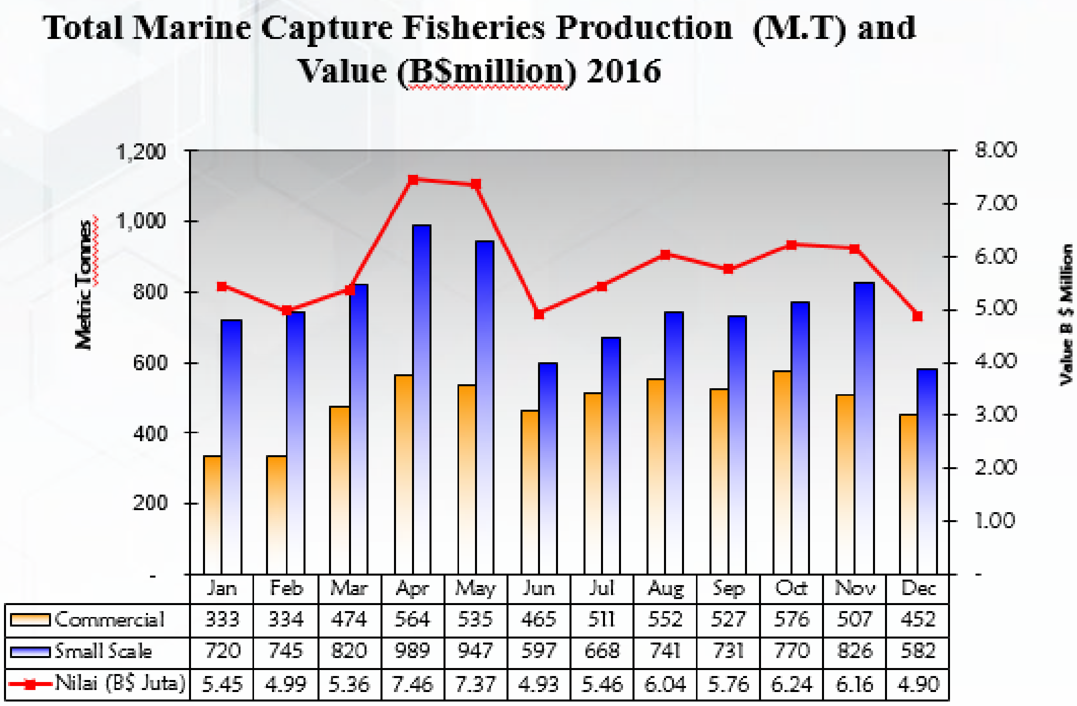
Some scientific advices based on results from two analyses were listed in Chapter 7. Nevertheless, during the 4th CEM, it has been disclosed that the results of the regional analysis can only be assumed as a good scientific trial but not as scientific recommendations due to limitation of data. Many recommendations on PS fisheries management were also listed, including input and output control, technical control and some general management measures.

3. Overview of the Marine Fisheries in SEA Region

3.1. Marine capture fisheries production

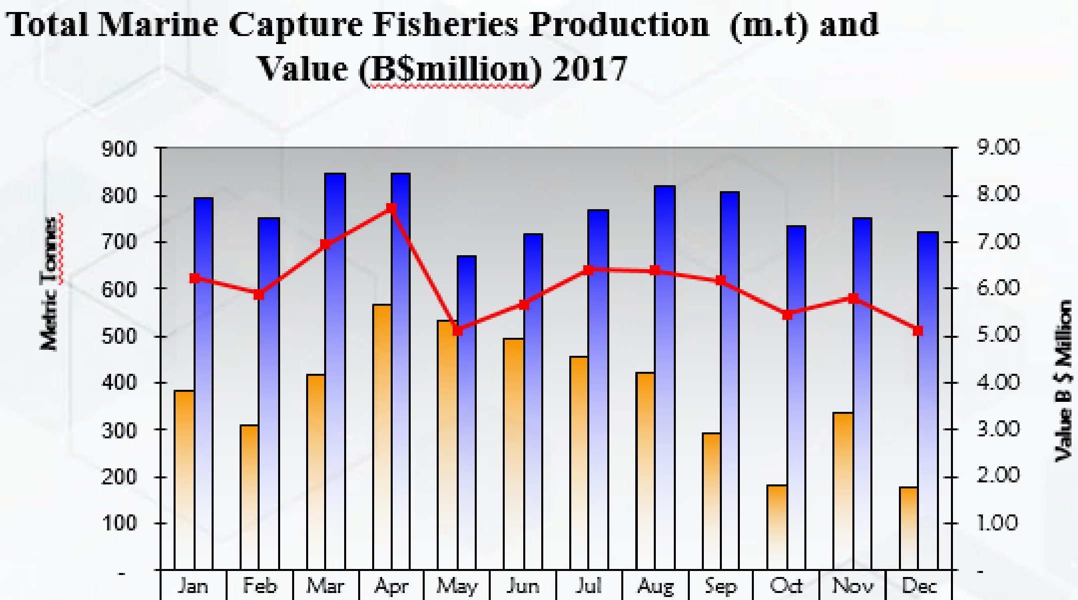
I) Brunei Darussalam

Almost four thousand fishers worked in fishing industry in 2016 (SEAFDEC, 2018). The marine capture fisheries in Brunei Darussalam is contributing by small-scale and large-scale commercial fishing fleets, where the former making 75% to 80% of the total production every year. The total production of marine capture fisheries increased from 10,570 MT in 2000 to 16,069 MT in 2005 with an average contribution of 22% from the small pelagic fishes. However, the value has decreased from 14, 966 MT in 2016 to 13, 796 MT in 2017 (Sheikh Al-Idrus & Marzini, 2019).The overall performance (in terms of production and values) of the major commercial fishing vessels like purse seiners, trawlers and longlines in 2016 and 2017 are shown in Figure 12 and Figure 13.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commercial	333	334	474	564	535	465	511	552	527	576	507	452
Small Scale	720	745	820	989	947	597	668	741	731	770	826	582
Nilai (B$ Juta)	5.45	4.99	5.36	7.46	7.37	4.93	5.46	6.04	5.76	6.24	6.16	4.90

Figure 12. The monthly marine capture fisheries production (MT) and value (B$) in 2016.
Source: *Country Report: Brunei Darussalam: The 4th Expert Meeting on the Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Sheikh Al-Idrus & Marzini, 2019).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commercial	383	312	418	566	533	495	456	423	292	179	335	177
Small Scale	793	753	848	844	668	716	769	819	807	736	750	724
Nilai (B$ Juta)	6.25	5.90	6.95	7.73	5.14	5.67	6.42	6.39	6.18	5.46	5.82	5.13

Figure 13. The monthly marine capture fisheries production (MT) and value (B$) in 2017.
Source: *Country Report: Brunei Darussalam: The 4th Expert Meeting on the Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Sheikh Al-Idrus & Marzini, 2019).

II) Cambodia

With up to six million people involved in fisheries sector, Cambodia's fisheries production is estimated to be worth around USD 200 to 300 million per year (Chea, 2018). The marine fisheries are small and slow to develop sub-sector compared to the inland fisheries. The marine capture fisheries cover around 14-16% of total national fish production every year, just over 120,500 MT (Chea, 2018). The trend shows steadily increasing in marine capture production from 1993 to 2015 (Figure 14). In the fact, the actual catch of marine fisheries is higher than the official statistics suggest. This is because far left from being recorded were the catches from subsistence (family-scale fisheries), the illegal fishing activities, Thai vessels fishing in Cambodian waters and some Cambodian fishing boats selling or transferring their catch to Thai mother-vessels at sea or landing in Thai ports (Puthy & Kristofersson, 2007). Besides that, according to DOF internal reports, the catches from licensed Thai vessels in Cambodian water are estimated to be from 26,500 MT to 37,599 MT (Gillet, 2004).

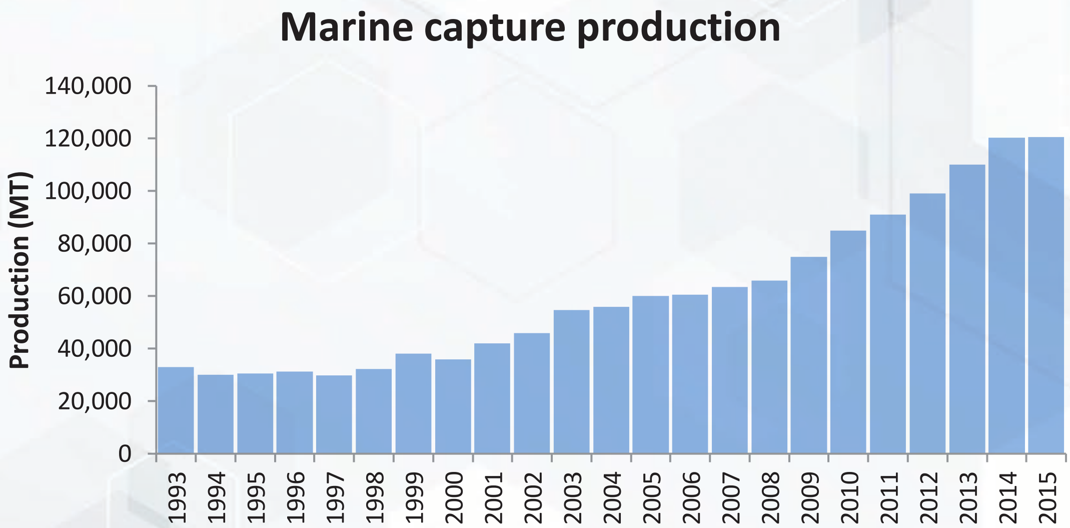


Figure 14. The marine capture production in Cambodia, 1993-2015.
Source: *Purse Seine Fishery in Cambodia* (Chea & Chhuon, 2019).

III) Indonesia

Throughout 2012-2016, Indonesia contributed the highest production to Southeast Asian's total marine capture fishery production. With 2.2 million people were recorded working in the marine capture fisheries, the country managed to catch 6.07 million MT of fish in 2016, valued up to USD 8.3 million (SEAFDEC, 2018). Small pelagic species usually dominated the national annual landing, for instance, in 2014, 30% from 6.0 million MT landing came from small pelagic fish in 2014 (Directorate General of Capture Fisheries, 2015).

The characteristics of shelves in SCS and ANS have also influence the fishing activities, indicated by different main fishing gears operating in the waters. To ensure effective management of fisheries resources, the whole Indonesia maritime waters have been divided into 11 (eleven) Fisheries Management Area (FMAs) (Figure 15) as stipulated in the Minister Regulation No. PER.01/MEN/2009, in which that each area is characterized by different number based on the FAO numerical approach. The fish stock status in Indonesian waters states that the western part had been highly exploited whilst the eastern part had fairly exploited (Suwarso, Imron, Duto, & Asep, 2018).

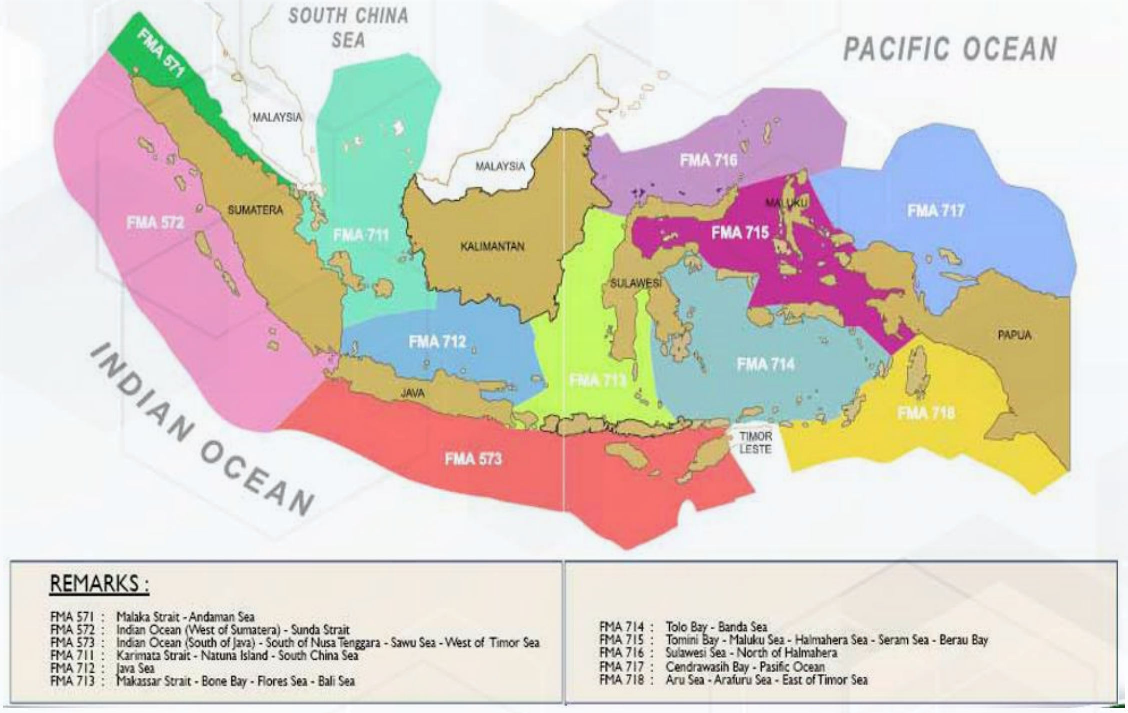


Figure 15. Eleven (11) Fisheries Management Areas (FMA) in Indonesia marine waters.
Source: *FAO Fisheries and Aqualculture Country Profiles, Indonesia* by the Food and Agriculture Organization, 2011b (http://www.fao.org/fishery/facp/IDN/en).

IV) Malaysia

The marine fishery sector is an important sub-sector in Malaysia and plays a significant role in the national economy, with more than 130,000 fishers in marine fishery in 2016 (SEAFDEC, 2018). Malaysia has contributed 1.46 million MT or 8.8% of the Southeast Asia's marine capture fisheries production in 2014 (SEAFDEC, 2017). In 2009, pelagic fish contributed the highest landing to the total marine fish landings in Malaysia at 38.1 % or 530,931 MT (Zulkifli, Richard, & Irman, 2013).

Figure 16. Malaysia and her maritime boundaries.
Source: *Maritime border of Malaysia.jpg* by the Wikimedia Commons contributors, 2019.
(https://commons.wikimedia.org/w/index.php?title=Special:CiteThisPage&page=File%3AMaritime_border_of_Malaysia.jpg&id=324966067).

V) Myanmar

Myanmar marine fisheries are classified into onshore, inshore and offshore fisheries. Onshore fisheries operate in the mud flats and swamps caused by the ebb and flow of the tides. While inshore fisheries operate in the shallow waters within 12 nm of the shore or within sight of shore, and fishing trips last less than one day by artisanal and small-scale fishers using simple fishing gears in small, locally-built vessels, powered or unpowered. Furthermore, offshore fisheries are operating out of sight of land or beyond the 12 nm limit, requires large mechanized vessels with advanced fishing gears and the main species caught are pelagic and demersal (Aung, 1995). Figure 17 shows that the trend for marine capture fisheries production has been steadily increasing from 0.95 million MT in 2000 to 2.7 million MT in 2014, with an average rate of 125 thousand MT annually (SEAFDEC, 2017). In term of value, the country started to report the value from 2008 to the present, and the trend showed increasing value by USD 479 million per year (SEAFDEC, 2017). Myanmar was ranked second place, after Indonesia, for both quantity and value of marine capture fisheries production of SEA in 2016 (SEAFDEC, 2018).

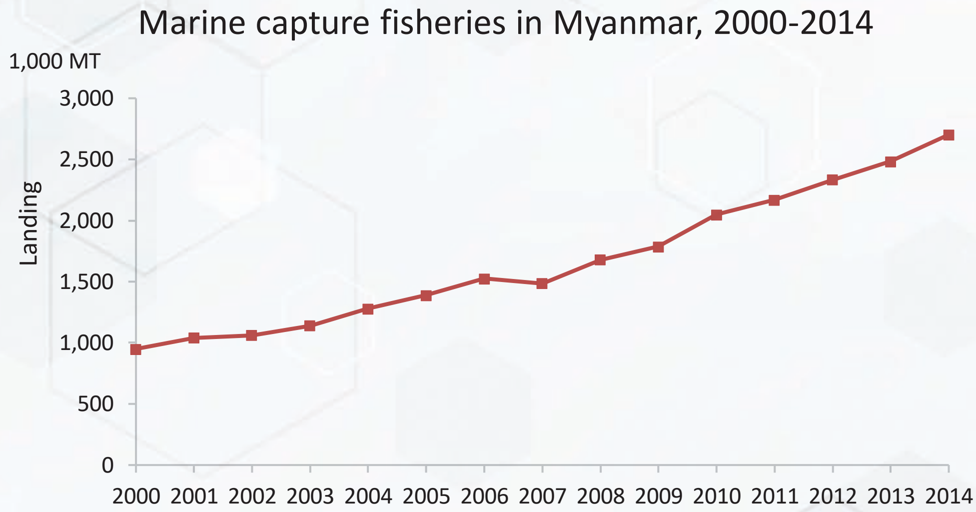


Figure 17. The fishing landing from marine capture fisheries in Myanmar, 2000-2014.
Source: *The Southeast Asian State of Fisheries and Aquaculture 2017* (SEAFDEC, 2017).

VI) The Philippines

In 2011, the Philippines was ranked 11th among top fish producing countries in the world with a total fisheries production of 5 million MT comprising fish, crustaceans, molluscs, and aquatic plants. The marine fisheries production in the country is contributed by municipal fisheries and commercial fisheries. In 2015, 1.22 million MT of fish by municipal fishing (Figure 18) and 1.08 million MT of fish by commercial fishing (Figure 19) was landed, sum up to total of 2.3 million MT of fish. The landing increased 43% in the following year 2016 with marine fisheries production of 2.99 million MT (SEAFDEC, 2018).

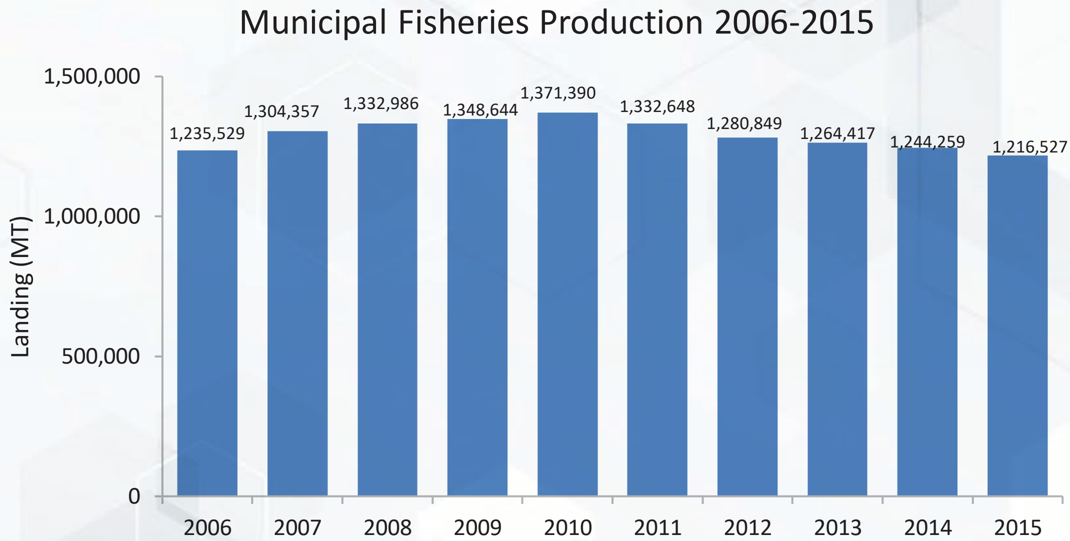


Figure 18. Municipal fisheries production of The Philippines, 2006-2015.
Source: *Country Report: The Philippines: 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Eleserio & Romero, 2019).

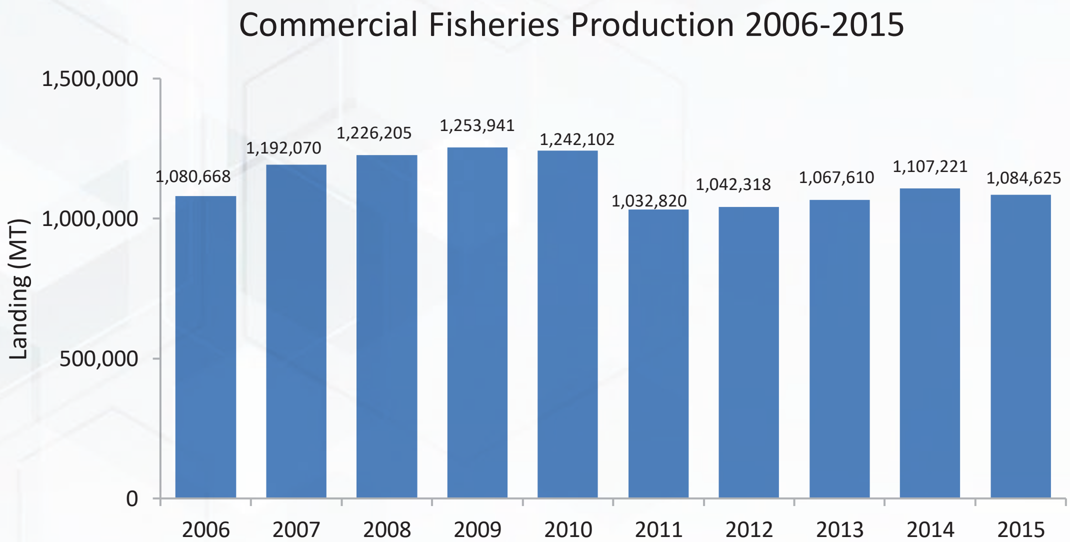


Figure 19. Commercial fisheries production of The Philippines, 2006-2015.
Source: Country Report: The Philippines: 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region (Eleserio & Romero, 2019).

VII) Thailand

Thailand has a massive fishing industry. In 2016, the fishery production of Thai flag was approximately 2.4 million MT with value of USD 4.3 million. Marine capture fisheries sector is important for the economy of Thailand that contributed more than 1.5 million MT in 2018 and involved more than 0.68 million people in the fisheries sector and related industries. Trend of marine capture fisheries production of Thai flag shows increasing amount of landing of marine capture fisheries from 1971 to 2005, and then, the rapid reduction of marine capture production after 2005. The decreasing is considered as a result of that the access of Thai flag in foreign waters has been ceased. For fishing grounds of Thai flag, the production from SCS doubled or tripled the production from ANS (Figure 20). During 2014-2016, the quantity of landing was decreasing and the production value was fluctuating compared to previous years (SEAFDEC, 2018).

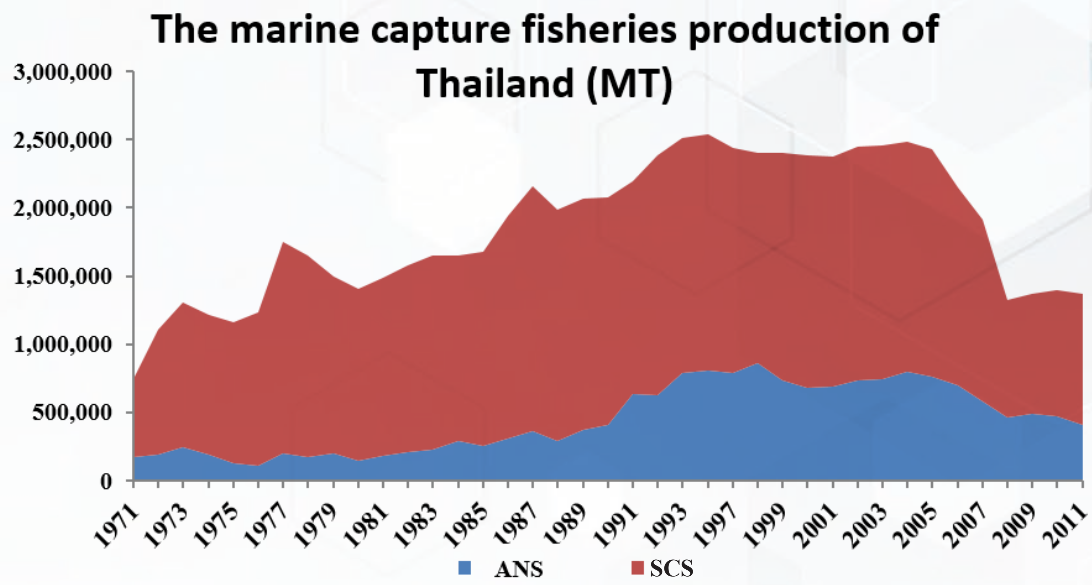


Figure 20. The marine capture fisheries production of Thailand, 1971-2011.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a).

VIII) Viet Nam

The marine water of Viet Nam is divided into four management areas which are Tonkin Gulf, Central, Southeast and Southwest. Marine captured fisheries play an important role in the social and economic development. Since 2015, the production of caught sea fish was reported more than 2 million MT (General Statistic Office, 2017).The total number of fishing vessels have increased rapidly from about 79,996 units in 2007 (Raja Bidin & Abdul Razak, 2016) up to 108,706 units in 2016 (Table 2).

Table 2. The number of fishing boats in Viet Nam, 2008-2016.

Year	Number of fishing boats				
	Tonkin Gulf	Central	Southeast	Southwest	Total
2008	29,582	36,342	23,815	12,492	102,231
2009	34,611	45,186	24,570	15,959	120,326
2010	39,511	47,220	21,490	19,800	128,021
2011	42,659	42,580	26,368	16,756	128,363
2012	40,167	40,713	25,163	17,082	123,125
2013	38,836	38,734	24,065	15,381	117,016
2014	30,860	38,144	21,311	14,771	105,086
2015	32,377	38,339	21,771	14,821	107,308
2016	34,490	37,397	22,140	14,679	108,706

Source: *Country Presentation: The Purse Seine Fisheries in Viet Nam* (Tuyen, 2018)

3.2. Purse seine as the common fishing gear exploiting small pelagic fishes

Small pelagic fish are caught by various type of fishing gears and vessels. The top three main gears in SEA are trawls (44.5%), purse seine (30.5%) and drill/gill net (13.5%) as shown in Figure 21 (SEAFDEC, 2018). Purse seiners have contributed second largest to the marine capture fishery, reflecting the importance of PS fisheries in the SEA region.

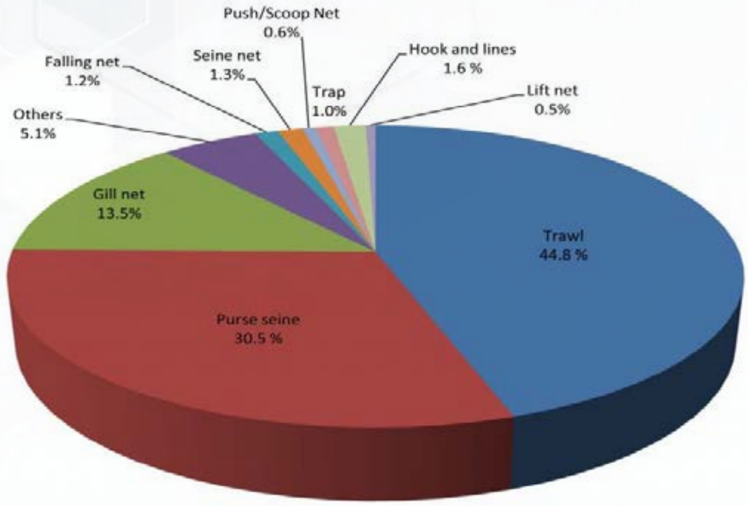


Figure 21. SEA marine capture fishery production by type of fishing gear used in 2016.
Source: Fishery Statistical Bulletin of Southeast Asia 2016 (SEAFDEC, 2018, p. 16).

In SEA region, purse seines had been used since the nineteenth century, to catch pelagic fishes as alternative to trawl. Earlier, the fisheries make use of various surrounding nets that had been modified into simple purse seines, and later, the use of commercial purse seines had been picked up by many countries in the region (Bidin & Razak, 2016). Each country uses different category of PS, either based on length or tonnage of the vessels or type of Fishing Aggregating Devices (FADs). Indonesia, Malaysia, Myanmar and Thailand categorized their purse seiners according to the vessel's Gross Registered Tonnage (GRT).

I) Brunei Darussalam

Purse seine technology was first introduced in Brunei Darussalam in 1985 with seven (7) licenses being issued to the locals. Out of 30 unit registered marine fishing vessels in 2013, twelve (12) was purse seiners (Noorizan & Nur-Aqilah, n.d.). There are two types of PS in Brunei Darussalam which are fish purse seine (FPS) and tuna purse seine (TPS). The FPS use FADs and luring lights as fishing aids to herd the small pelagic. The purse seiners are propelled by a single inboard marine diesel engine with power ranging from 190 to 320 horsepower (HP), and mostly run at a cruising speed of about 10 knots in going to the fishing ground. The commercial purse seiners in Brunei Darussalam operate on a one-day (1) trip basis for some reasons like the limitation on the size of fish storage onboard and the quality of fish landed.

Initially no proper data recording of PS catch was recorded, but starting from 2001, DOF of Brunei Darussalam began providing incentives to the fishers as encouragement for them to record the necessary information, hence as the result, the relevant PS fisheries data has been compiled. Figure 22 shows the fluctuated landings by PS from 2001 to 2017. Table 3 gives the details of PS vessels used in the study of pelagic fisheries in 2003-2005 conducted by SEAFDEC.

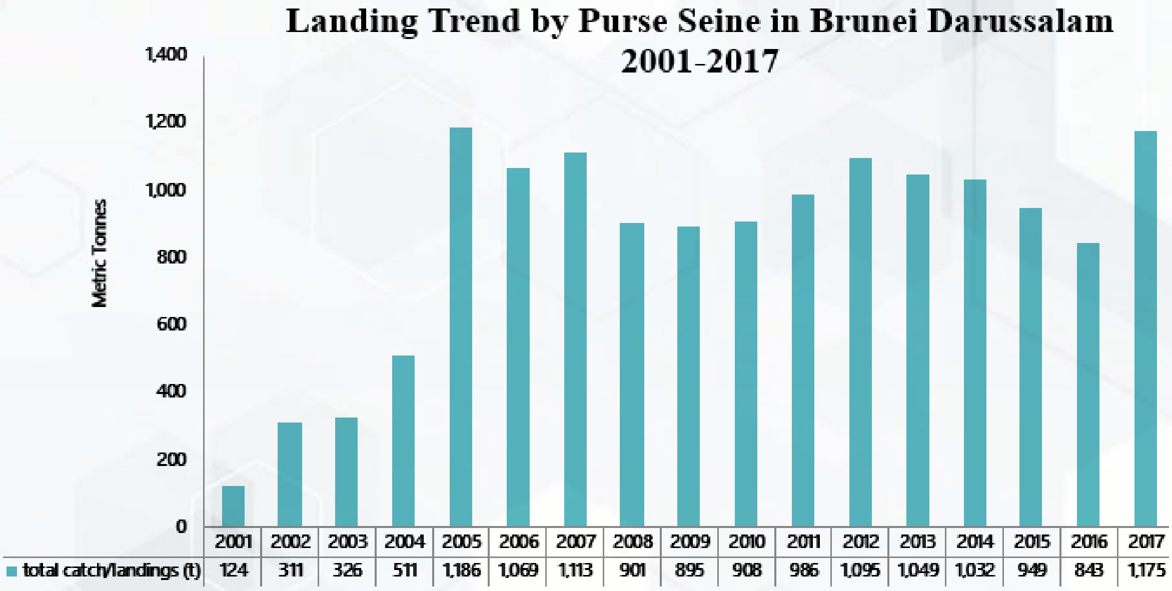


Figure 22. Landing trend of commercial purse seine fisheries in Brunei Darussalam, 2001-2017.
Source: *Country Report: Brunei Darussalam: The 4th Core Expert Meeting on the Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region*. (Sheikh Al-Idrus & Marzini, 2019).

Table 3. Technical details of the purse seine vessels used in the study 'Sustainable Pelagic Fisheries in the SCS, 2003-2005'.

Vessels name	Zone	Engine Type	Engine Power (HP)	Vessel size (GRT)	Length (m)	Mesh size (cm)	Net Length (m)
Azam	3	Inboard	320	70.0	21.43	2.5	600
Radims 2	2	Inboard	190	59.3	21.00	2.5	400
Radims 3	2	Inboard	190	60.0	21.30	2.5	400
Sri Jaya Gadong 3	2	Inboard	250	55.0	18.78	2.5	400

Source: *National Country Report for Brunei Darussalam* (Matzaini H. Juna, Ranimah H A Wahab, & Cinco, 2007).

II) Cambodia

The modern technologies like bottom trawl and PS was introduced in 1950s in Cambodia. Purse seiners are allowed to operate in shallow or deep water to exploit the small pelagic fishes. However, the number of PS vessels was declining from thirteen (13) unit in 1992 to only one (1) unit in 2012 (Table 59 in chapter 6) due to increasing use of pair trawls and gill nets. Figure 23 and Figure 24 shows the examples of PS boats in Sihanoukville province. The PS vessel in Tomnop Rolok is lengthier than PS vessel in Sihanoukville although being in the same province (Table 4). The industrial mackerel fishery operates at offshore using PS or driftnets with boat engines up to 50 HP. The PS operates only during the dry season period of 5 months (20 days per month). The PS boats have crews of about 15 to 30 people (Puthy & Kristofersson, 2007).

Table 4. Type of purse seine vessels in Cambodia waters.

Type of purse seine	Boat	Location
Scad, Sardine, *Rastrelliger* spp., Anchovy	LOA: 20 m	Tomnop Rolok
Anchovy purse seine	HP: 350	Sihanoukville
	LOA: 18 m	
	HP: 190	
Scad, Sardine purse seine	LOA: 17 m	
	HP: 300	

Source: *Country Presentation: Purse Seine Fishery in Cambodia* (Chea, 2018).

Figure 23. Purse seine long-tailed boats in Sihanoukville, Cambodia.
Source: *Country Presentation: Purse Seine Fishery in Cambodia* (Chea, 2018).

Figure 24. Purse seine fishing vessel in Sihanoukville, Cambodia.
Source: *Country Presentation: Purse Seine Fishery in Cambodia* (Chea, 2018).

III) Indonesia

As a country that has very high landings of marine capture for many decades, Indonesian fishers keenly use PS to catch the small pelagic fish. Currently, there are three (3) kinds of PS; small, medium and large as state by Imron and Suwarso (2018), in which medium and large PS fisheries began from Central Java in 1973, and since then expanded to the eastern water. The current number of PS vessels is about 28,000 units, which is 16% of total fishing gears from the Java Sea (Suwarso & Duto, n.d.). The PS vessel is made of wood and wood fibre-plated, GRT between 28 -117 tonnes (average 64 tonnes). The PS net length vary from 450 m to 570 m, net width of about 42 m; one-inch (1) mesh size. The main engine (Nisan) has a horsepower of 180 – 380 HP, equipped with a genset of Mitsubishi type. The number of crews are about 20-25 people, with days at sea range from 11 to 20 days (Suwarso, Imron, Duto, & Asep, 2018).

The purse seiners that operate in SCS are from Palembang, Pemangkat and Pekalongan. The difference between them is the purse seiners from Pekalongan and Palembang usually use combined light and FAD while purse seiners from Pemangkat utilize light without FAD to attract the school of fish prior to fishing. Figure 25 shows the example of design and size of one boat-PS and its nets size at Pekalongan, Central of Java that are used to catch short bodied mackerel and scad.

Meanwhile Figure 27 and Figure 26 show the example of PS boat and design of the PS net in Pemangkat, West Kalimantan. The design of PS fishing gear was emanated from local fishers with the approval of the central government (Suwarso, Imron, Duto, & Asep, 2018).

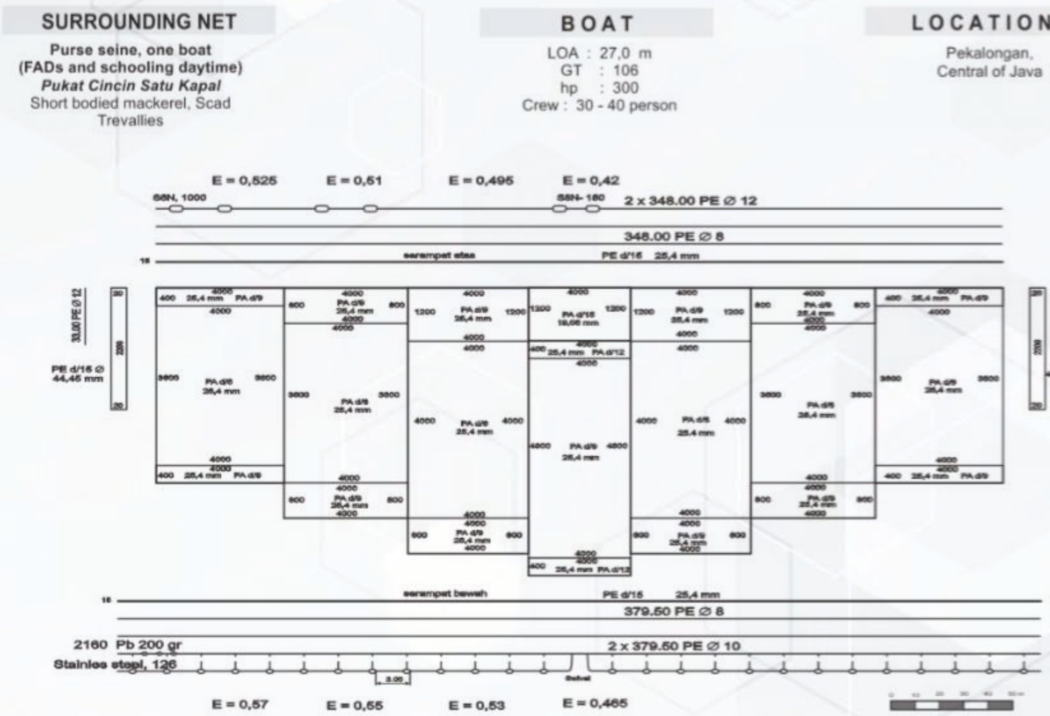


Figure 25. Design of surrounding net and purse seine boat at Pekalongan, Central of Java.
Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto, & Asep, 2018).

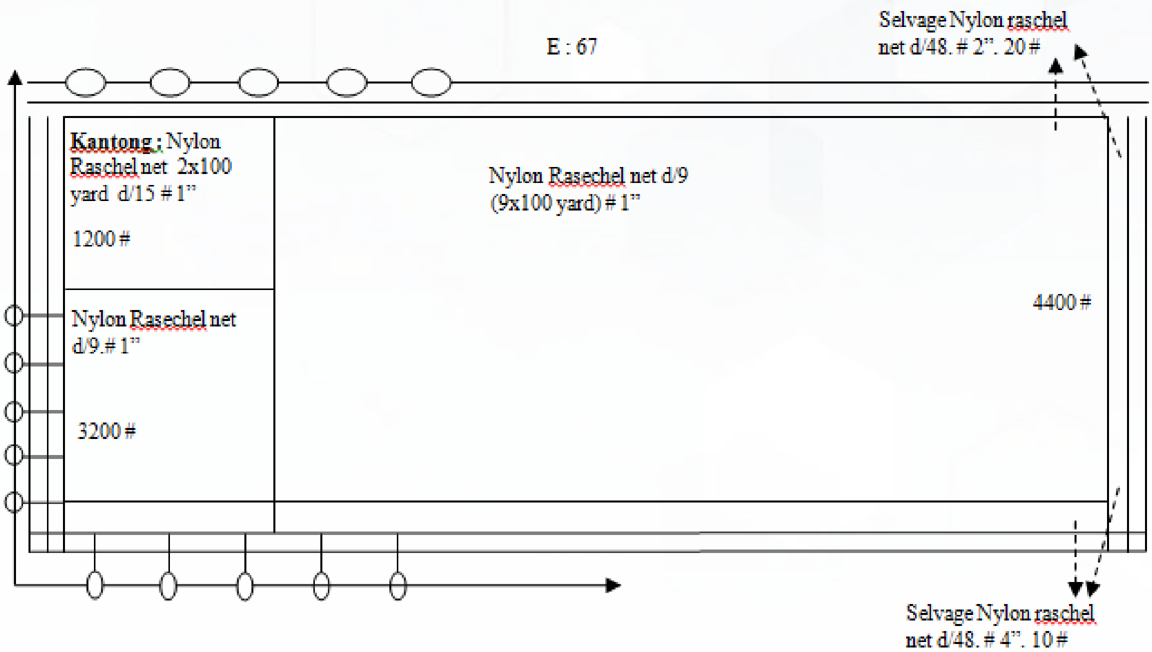


Figure 26. Design of purse seine net in Pemangkat, West Kalimantan, Indonesia.
Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto, & Asep, 2018).

Figure 27. Example of purse seine boat in Pemangkat, West Kalimantan, Indonesia.
Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto, & Asep, 2018).

IV) Malaysia

The two types of PS employed in Malaysian waters are anchovy purse seine (APS) and fish purse seine (FPS). The PS vessel is categorized based on gross tonnages GRT (Sallehudin & Abdul-Wahab, n.d.). Most of PS vessels in Sabah water is in category of 40 to 70 GRT and equipped with fine mesh and coarser mesh (Mohd Zamani, 2018). Although anchovies usually contribute only small percentage to the total marine landings, the APS fishery is very important in WCPM, especially in northern part of Straits of Malacca (Pangkor Island, Perak; Tanjung Dawai, Kedah; Langkawi Island, Kedah). The APS is allowed to operate in area within 1-8 nm, has boiling facilities onboard, and operates with or without spotlight. In WCPM, all APS operates during daytime only. Table 5 shows the differences between APS without spotlight and APS with spotlight in the Malaysian waters.

Table 5. The differences between anchovy purse seine without spotlight and anchovy purse seine with spotlight.

Anchovy PS	**Anchovy PS-Light**
Day operation (0800 – 1700)	Night Operation (1700 – 0800)
Searched for the school of fish	Fishes are attracted by the light
Length net: 915 m	Length net :73 m
Width net: 146 m	Width net: 31 - 36 m
No of crew: 25	No of crew: 7-15

Source: *Country Presentation on Purse Seine Fisheries in the East Coast of Peninsular Malaysia* (Sallehudin, 2018).

The FPS vessel becomes more efficient in catching small pelagic fish with the support of high technology equipments like radar, GPS, sonar, echo-sounder, deck machinery, and can operates with or without FADs. The traditional luring materials are made of coconut leaves and anchored by several concrete sacks, while the FADs like light raft, fish shelter or '*unjam*' are normally set in the areas with a depth exceeding 40 m (DOF, 2015a). The FPS using spotlights as FADs manages to catch more fish per haul and more species of fish, although the small mackerels, *Rastrelliger* spp. is still dominating the catch. Figure 28 shows the design of PS nets that are made of nylon while Figure 29 shows the example of PS vessels in Malaysian waters.

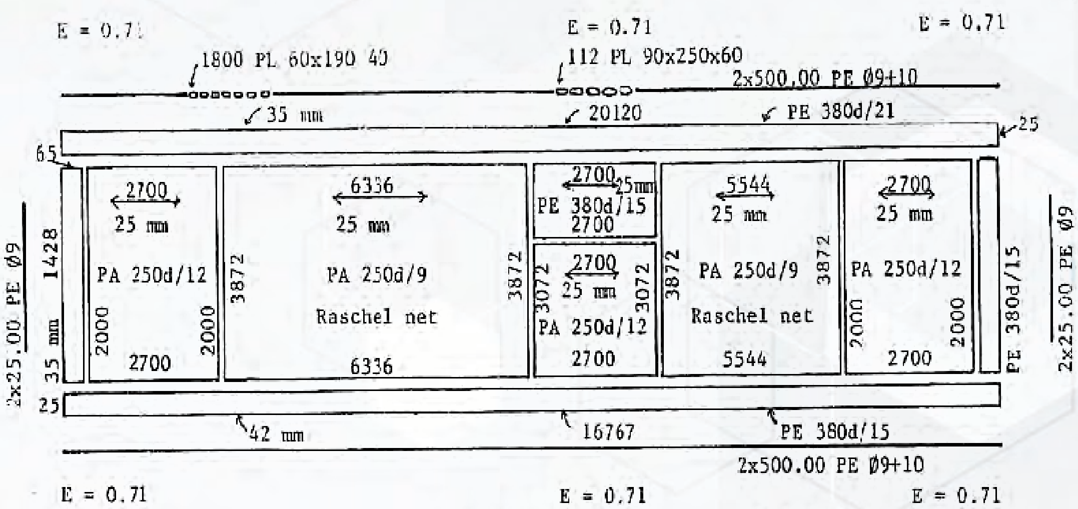


Figure 28. Design of purse seine net in Sarawak, Malaysia.

Source: *Country Report on Purse Seine Fishery in Sarawak* (Jamil, Country Report on Purse Seine Fishery in Sarawak, 2019).

Figure 29. The example of purse seine vessel in Malaysia.

The fishing areas in Malaysia can be divided into four (4) sub-regions, namely the West Coast of Peninsular Malaysia (WCPM), East Coast of Peninsular Malaysia (WCPM), Sarawak and Sabah. Figure 30 summarizes the PS landings in all fishing areas in Malaysia from 2008 to 2013. In ECPM, the trend for FPS, APS and overall PS landings over twenty-year period 1993-2017 were fluctuated, where it reached peak in 2016, then drop drastically in 2017 (Figure 31). Meanwhile, in WCPM, the landing by PS from 1984 to 2015 was recorded according to PS vessel GRT (Figure 32), in which since 2003, PS with GRT more than 40 tonnes landed very high catch of pelagic fish. For 2017, PS had landed 128,544 MT of small pelagic fish, more than 20% from the total marine capture landings in WCPM in that year (Abdul Wahab Abdullah & Sallehudin Jamon, 2018). Sarawak's purse seiners had landed 7,391 MT of fish in 2017, which has been declining since 2014 (Figure 33) (Mr. Jamil Musel, 2018).

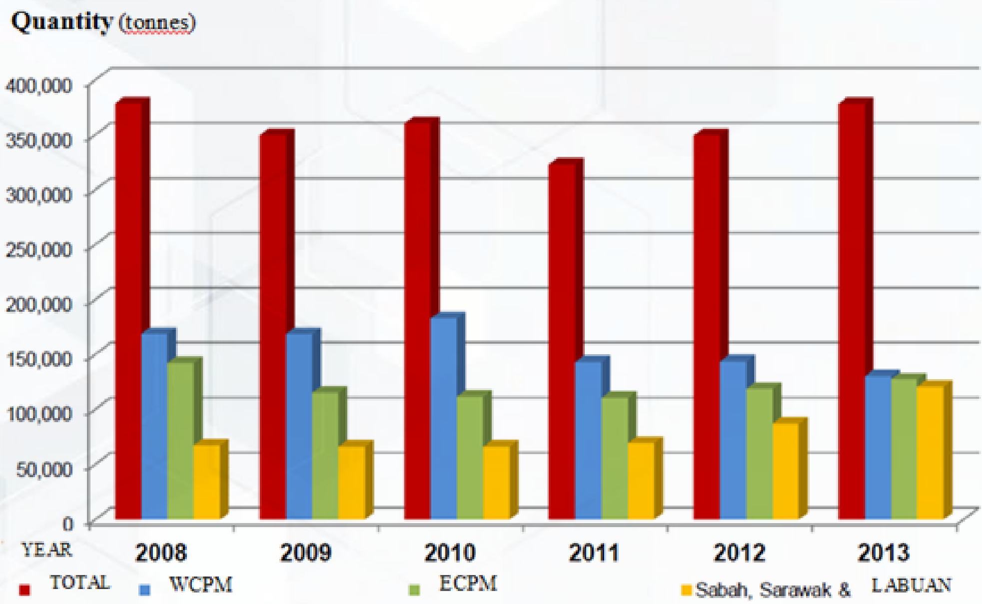


Figure 30. The purse seine landings in different areas in Malaysia, 2008-2013.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a).

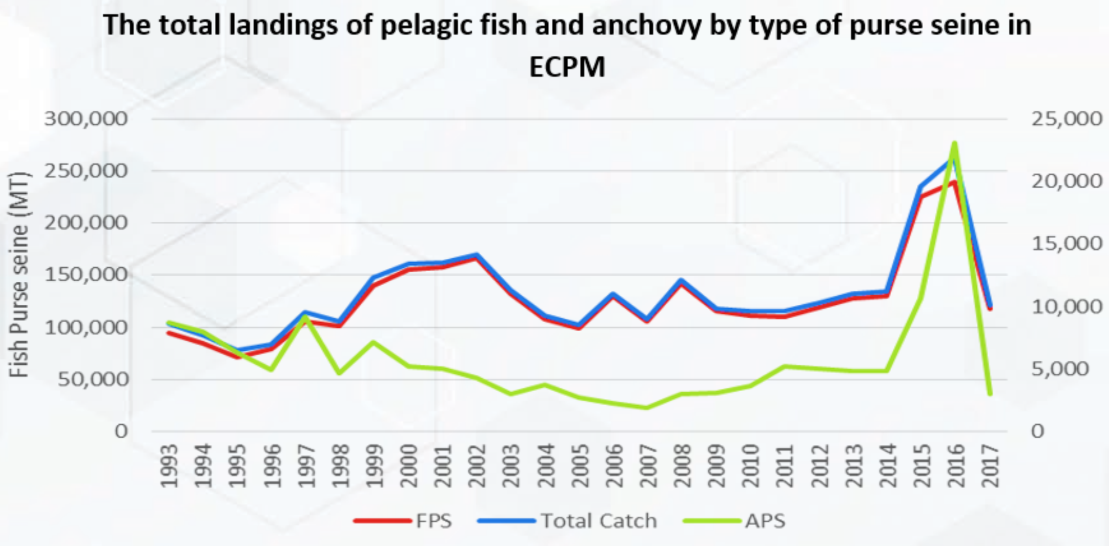


Figure 31. The total catch by purse seine, fish purse seine and anchovy purse seine in ECPM, 1993 -2017.

Source: *Country Report: Malaysia - East Coast of Peninsular Malaysia* (Sallehudin, 2019).

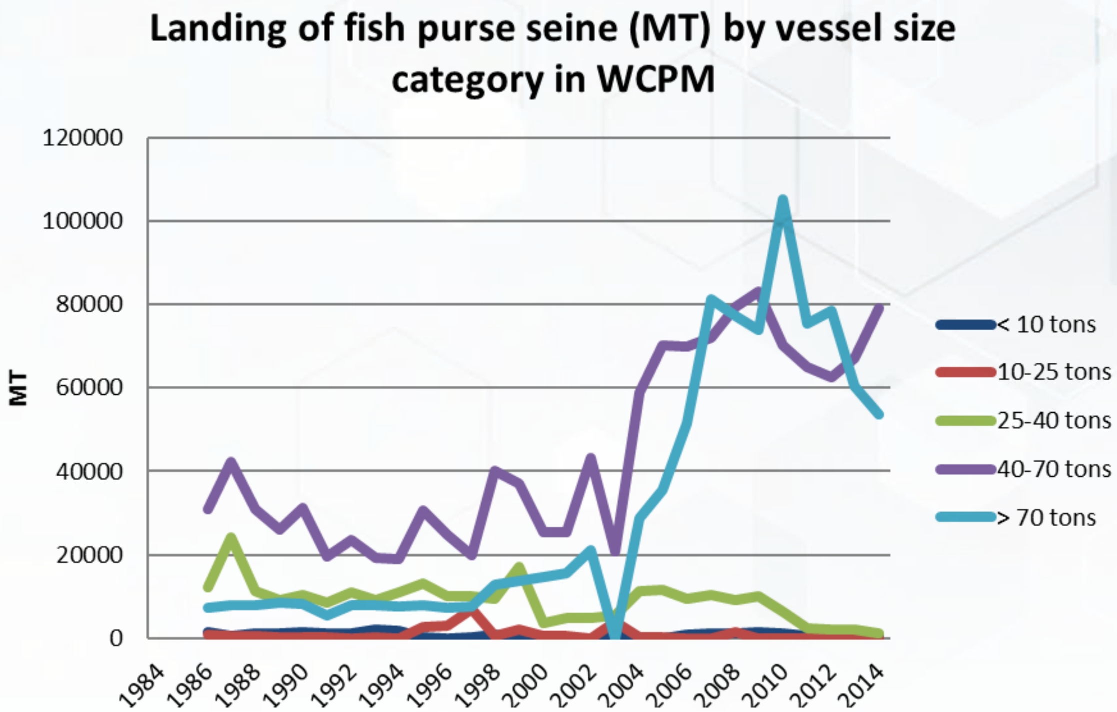


Figure 32. The landing by FPS according to boat GRT group in WCPM, 1984-2015.

Source: *Country Report: Malaysia - West Coast of Peninsular Malaysia* (WCPM) (Abdul-Wahab, Country Report: Malaysia - West Coast of Peninsular Malaysia (WCPM), 2019).

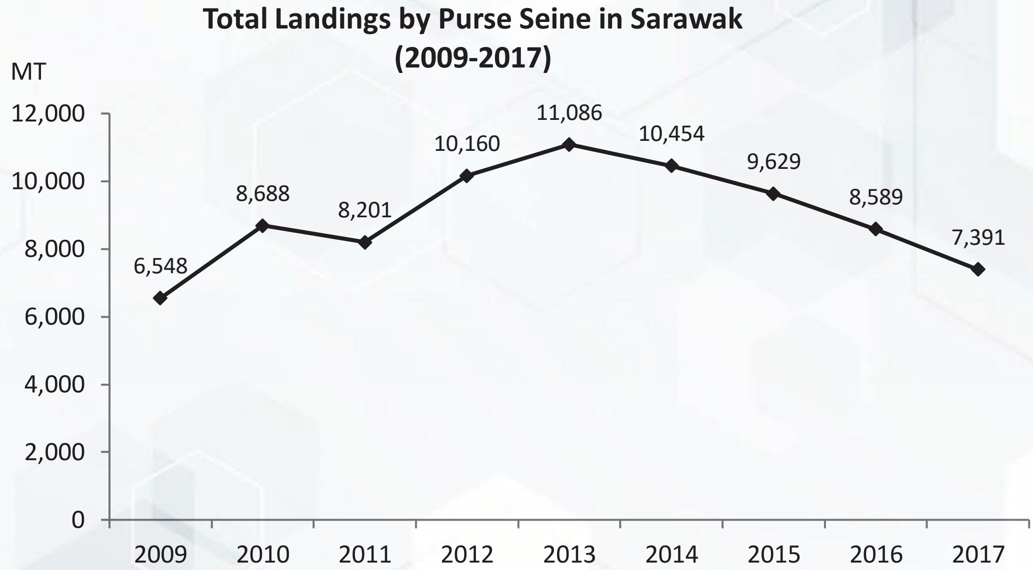


Figure 33. The total landing of fish by purse seiners in Sarawak, 2009 - 2017.
Source: *Country Report on Purse Seine Fishery in Sarawak* (Jamil, Country Report on Purse Seine Fishery in Sarawak, 2019).

V) Myanmar

In southern Rakhine and Tanintharyi regions, PS is the main fishing gear used to exploit the pelagic fishes. There are two main types of PS vessels in Myanmar waters, namely the fish purse seine (FPS) that used to catch pelagic species like hilsa, mackerel and sardines, and the two boats seine (APS) used to catch anchovies in the coastal waters. The number of FPS and APS in Myanmar is summarized in Table 6. The FPS vessel is 50 – 100 GRT, operates in traditional way without the FADs, but uses sonar with help of expertise to search for the school of fish (Figure 34). Hilsa fish is the main harvest of FPS from October to May. Meanwhile, the APS vessels use engine less than 2.5 HP and the length of a boat is less than 30 feet (Figure 35). The APS boat is used to catch the anchovies especially genus Stolephorus, however it also harvests small mackerels *Rastrelliger* spp. and sardines *Sardinella* spp. species (Table 7).

Table 6. The number of purse seine fishing vessels in Myanmar.

Type of Gear	**Year**										
	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
FPS	152	158	161	168	273	278	287	283	284	310	329
APS	375	374	375	377	366	362	360	297	217	350	350

Source: *Country Report: Management of Purse Seine Fisheries in Myanmar* (Shwe & Kyaw, 2019).

Figure 34. Example of fish purse seine vessel in Rakhine, Myanmar.
Source: *Country Report: Management of Purse Seine Fisheries in Myanmar* (Shwe & Kyaw, 2019).

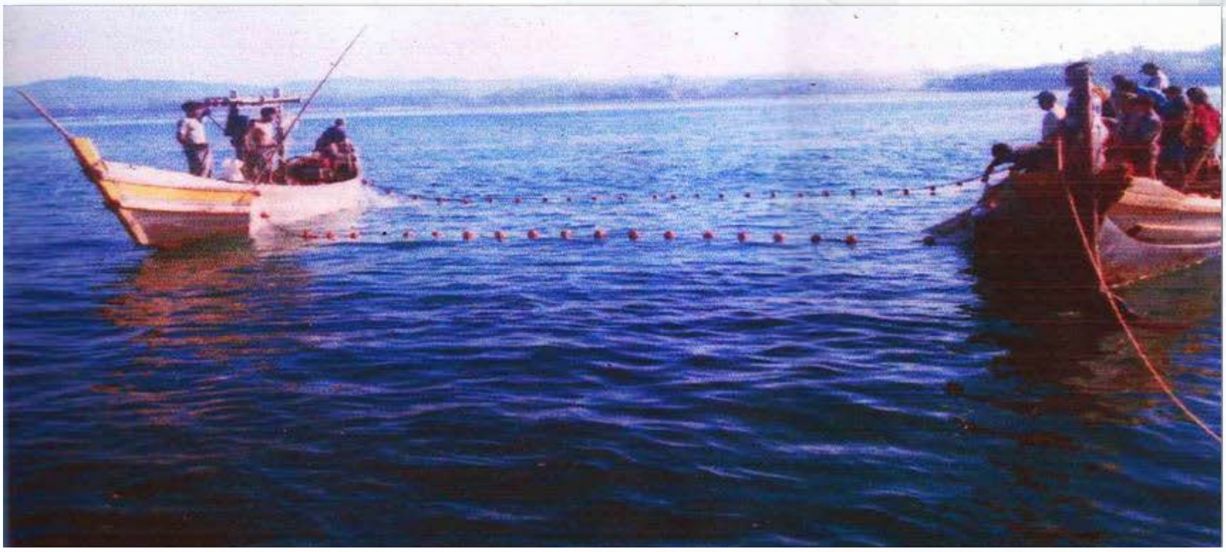


Figure 35. Example of the two boats seine or anchovy purse seine in Rakhine, Myanmar.
Source: *Country Report: Management of Purse Seine Fisheries in Myanmar* (Shwe & Kyaw, 2019).

Table 7. The landings by anchovy purse seine in Myanmar, 2005-2014.

Year	No. of boats	Catch (MT)				Total (MT)
		Anchovy	Sardine	*Rastrelliger* spp.	Others	
2005–2006	368	4,505	1,457	100	1,030	7,092
2006–2007	377	1,978	1,842	30	3,857	7,707
2007–2008	375	5,024	1,028	58	3,022	9,132
2008–2009	374	6,188	2,215	44	2,170	10,617
2009–2010	375	6,973	3,216	20	3,998	14,215
2010–2011	377	7,873	3,926	32	4,301	16,132
2011–2012	366	5,031	1,816	53	5,812	12,712
2012–2013	362	4,205	2,510	79	4,098	10,892
2013–2014	360	2,156	4,773	124	6,899	13,952

Source: *Country Report: Management of Purse Seine Fisheries in Myanmar* (Shwe & Kyaw, 2019).

VI) The Philippines

Ring net is the most used fishing gear in the country, nonetheless majority of commercial fisheries are purse seiners which target the small pelagic fish, particularly round scads, sardines and Indian mackerel. Out of 1.3 million MT of landed marine fish, 60% were caught by PS (Belga, n.d.). There are two types of PS used in country which are the sardine/scads/mackerel purse seine (SPS) and Tuna purse seine (TPS). The minimum mesh size requirement for SPS is 19 mm and tuna purse seine is 3.5 inches (Figure 36). The PS vessels in Philippines are bunt on one side and mechanically hauled by power block or improvised hauling device. The PS highest catch was in 2008, and then the value declined until 2016, and increased again in 2017. Meanwhile, the number of PS boat increased drastically in 2012 and dropped 2015 afterwards (Figure 37).

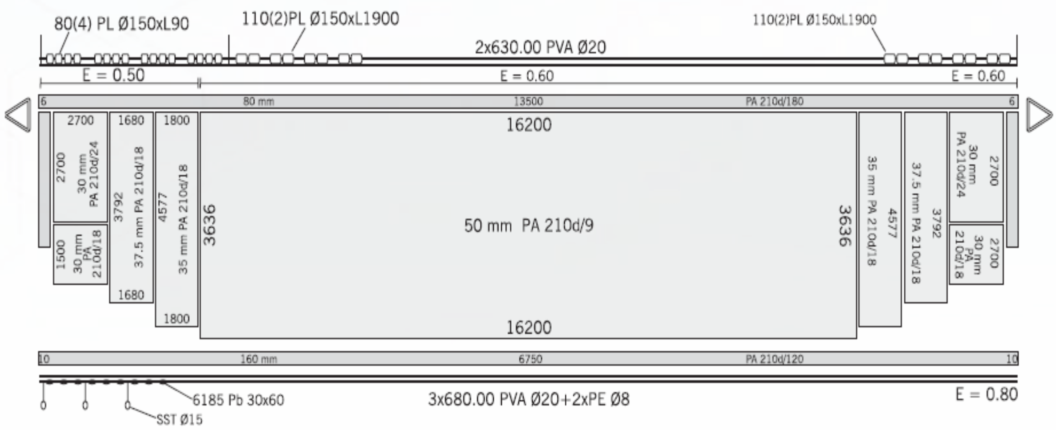


Figure 36. The design of purse seine net in the Philippines.
Source: *Purse Seine Fisheries in the Philippines* (Lamarca, 2016).

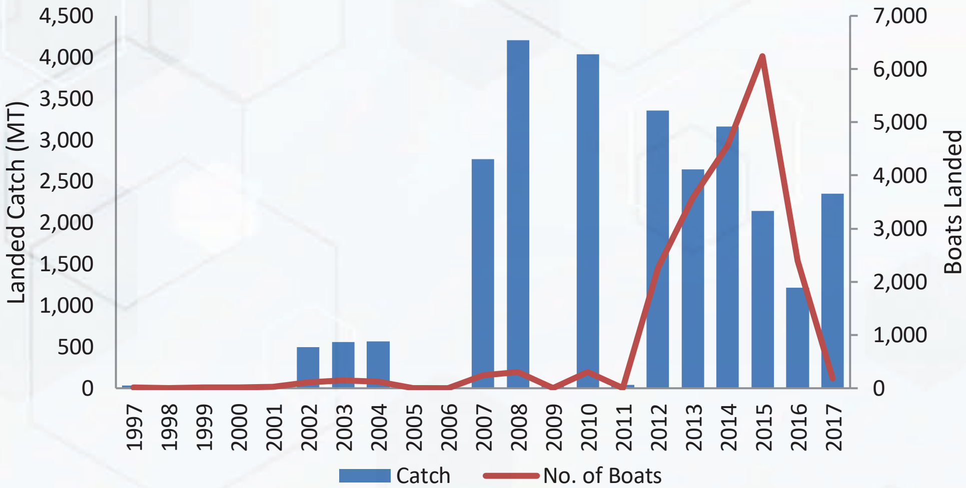


Figure 37. The landings and number of purse seine boats in The Philippines, 1997-2017.
Source: *Country Report: The Philippines: 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Eleserio & Romero, 2019).

VII) Thailand

In general, the PS fisheries contribute about 33% of national catch (Panjarat & Saikliang, Purse Seine Fishery in Thailand, n.d.). In the past, there were five (5) main types of purse seine, namely Chinese purse seine, Thai purse seine (black seine or locally known as *Uan dum*), mackerel purse seine (green seine), bonito purse seine, and anchovy purse seine. Presently, the PS vessels can be categorised into two main types according to the fishing licenses of Thailand, which are Thai purse seine (TPS) and anchovy purse seine (APS). Both TPS and APS are commonly found in the Gulf of Thailand (SCS) and ANS, and Table 8 gives the general details of TPS and APS vessels. The TPS fishing operation techniques can be further divided into three types: free school (FS) operation; light luring (LL) operation; and fish aggregating device (FAD) operation. The APS fishing operation techniques used to be two types: FS and LL operations, where the latter is now prohibited. Nowadays, APS operates only during daytime, using FS operation. TPS usually operates using 25 mm mesh size of the net and sometime can switch to 50 – 100 mm mesh size of the net to target neritic tunas; however, switching between TPS and APS is not allowed.

Table 8. Details of net and vessel of Thai Purse Seine and Anchovy Purse Seine.

	Thai Purse Seine	Anchovy Purse Seine
Net	Polyamide	Polyamide (knotless)
Net colour	Black	Green or brown
Length of net	400 – 1,800 m	250 – 1,100 m
Depth of net	60 – 110 m	15 – 80 m
Mesh size	≥ 25 mm	≥ 6 mm
Vessel size	5 – 200 GT	5- 200 GT
Operation technique	Free school (FS), Light luring (LL) operation, Fish aggregating device (FAD) operation.	FS during daytime only

Source: *Country report on purse seine fisheries in Thailand* (Chumchuen & Noranarttragoon, Country report on purse seine fisheries in Thailand, 2019).

The catch production by TPS was progressive over 40 years. Since 1974, the total catch was steadily over 100,000 MT and continuously increased to reach a peak during 1986–1990 between 524,000 and 568,000 MT. Then, the catch was declined to the range of 342,000 – 450,000 MT. The catch from SCS dominated the landing. The catch from ANS only started to increase from 1982 and had significantly contributed to the national catch of purse seiners for around 30% (Figure 38).

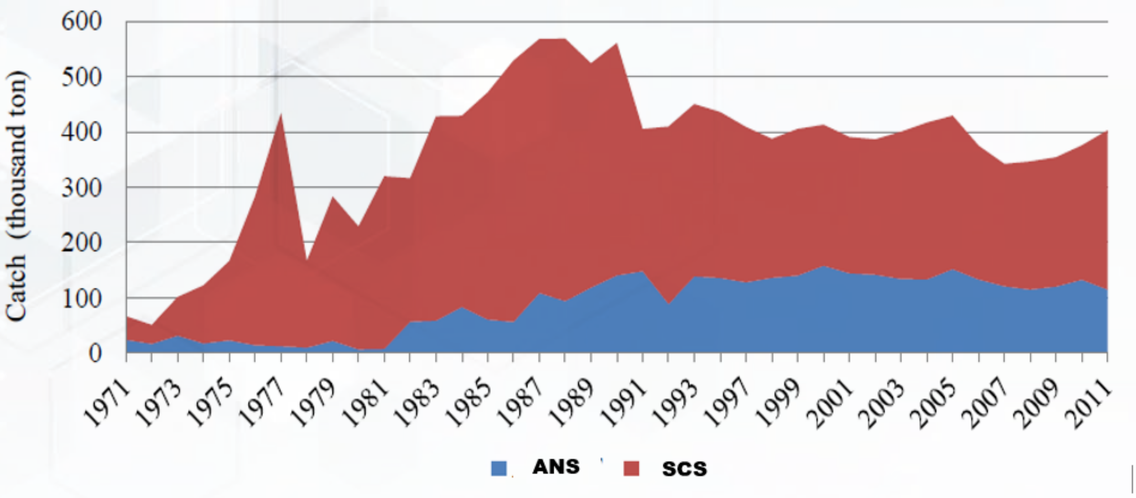


Figure 38. The catch from Thai fish purse seiners in Thailand.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a).

On the other hand, the catch of anchovies from APS only started to increase in 1982. After reaching the peak of more than 150,000 MT in 1993, it fluctuated from 120,000 MT to 150,000 MT in 1994 to 2011. The catch of anchovy from SCS dominated throughout 40-years landings, while the catch from ANS only began to increase in 1991 onwards with the range around 30,000 MT to 60,000 MT (Figure 39). More updated data was shown in Figure 40 that presents the landings from all PS vessels 1996 to 2016. In 2016, it was reported that 35% of national marine capture production was landed by purse seiners.

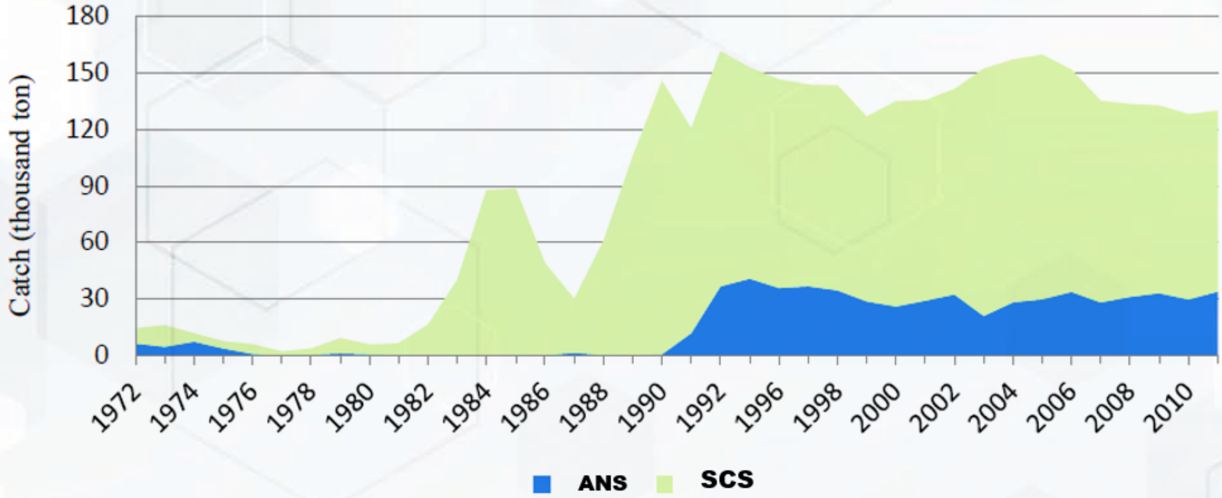


Figure 39. The anchovies catch from anchovy purse seine in Thailand, 1972-2011.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a).

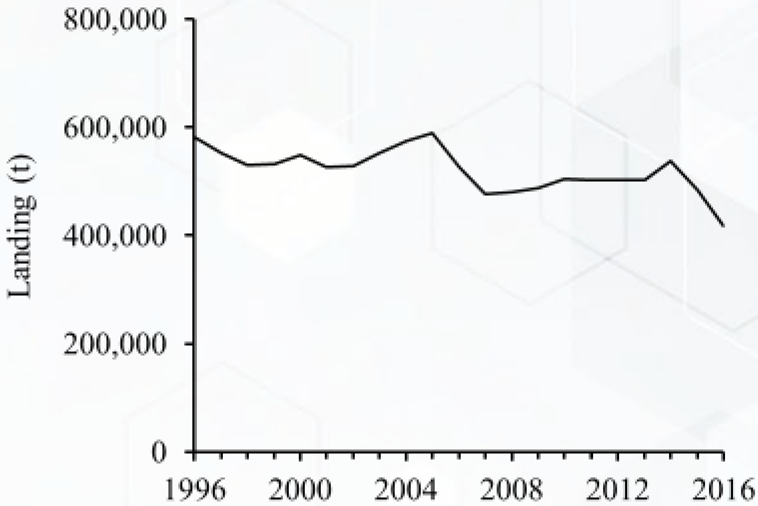


Figure 40. The landings by all types of purse seine in Thai waters, 1996-2016.
Source: *Country report on purse seine fisheries in Thailand* (Chumchuen & Noranarttragoon, Country report on purse seine fisheries in Thailand, 2019).

VIII) Viet Nam

In Viet Nam, two main PS fishing methods are Luring Purse Seine (LPS) and Searching Purse Seine (SPS). The LPS uses light and FAD, and is very popular in many fishery provinces. For this method, the average size of the net is about 250 - 500 m in length and 45 -70 m in depth. Meanwhile, the SPS specializes in catching pelagic fishes which have high movement speed, thus the fleets has modern fishing equipments, mechanical implements and fish finders (Luong, 2009). The SPS net has bigger size; the average size of net is from 500-1200 m in length and 70-120 m in depth. Table 9 shows the different length, depth and mesh size of PS net according to fishing areas in Viet Nam water. LPS is the most popular type of surrounding net, with length of net of 500-900 m, depth of net of 60-140 m and mesh size of 18.0-25.0 mm. Meanwhile, APS has net with length 200-450 m, depth 40-60 m and mesh sizes 6.0-10.0 mm.

Figure 41 shows the annual PS landings according to fishing areas from 2007 to 2014, in which trends show increasing patterns. The PS fisheries are well developed in Central, Southeast and Southeast waters. Figure 42 reveals the increasing number of PS units from 2000 to 2008, and then the numbers were reduced and fluctuated to 2017.

Table 9. Details on net of luring purse seine in different fishing areas in Viet Nam.

Area	**Length (m)**	**Depth (m)**	**Mesh size (mm)**		
			Wing	Body of net	Bunt
Gulf Tonkin	600 - 800	80 – 125	24 – 25	24 – 25	20 – 22
Central waters	650 - 900	80 – 130	20 – 25	20 – 25	20 – 24
Southeast	500 - 800	100 – 140	24 – 25	20 – 25	20 – 24
Southwest	500 - 650	60 – 80	20 – 25	20 – 22	18 – 20

Source: *The Report for the Purse Seine Fishery in the Viet Nam* (Phan, 2016).

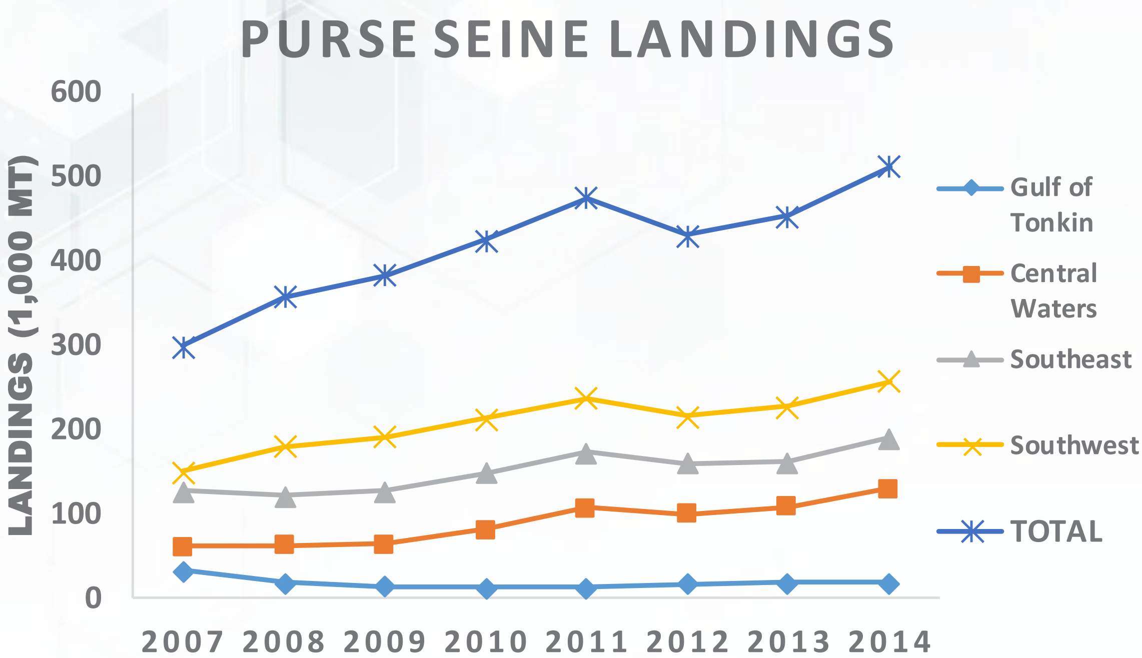


Figure 41. The landings by purse seine according to fishing areas in Viet Nam, 2007-2014.
Source: *The Report for the Purse Seine Fishery in the Viet Nam* (Phan, 2016).

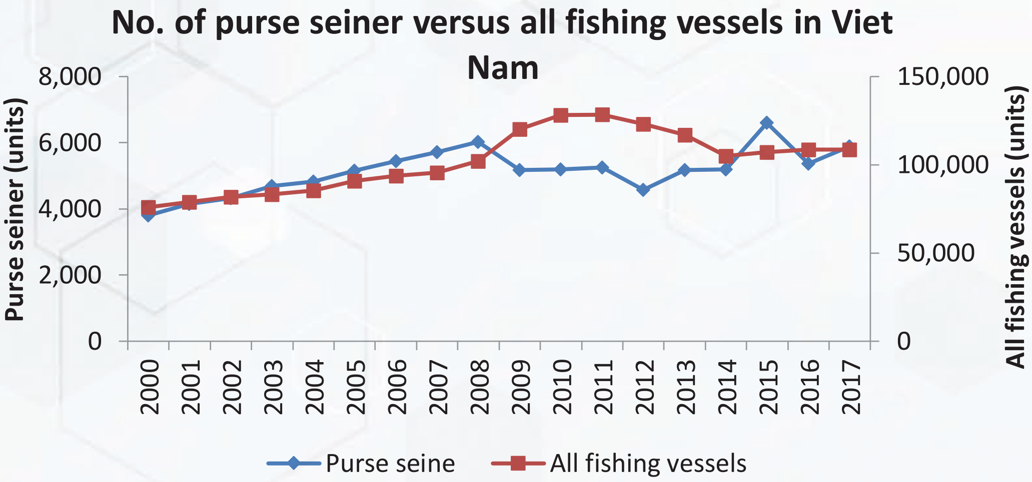


Figure 42. The total number of fishing boats and purse seine in Viet Nam, 2000-2017.
Source: *Country Presentation: The Purse Seine Fisheries in Viet Nam* (Tuyen & Tam, 2019).

3.3. Common fishing areas of purse seine fishing

I) Brunei Darussalam

Brunei Darussalam marine territorial area is around 38,600 km^2 extending to EEZ. The fishing ground are split into four zones defined by distance from the coast as shown in Figure 43 while Figure 44 shows the fishing ground where FADs are deployed by small scale fishermen and commercial PS. Usually zone 2, 3 and 4 are common fishing areas for PS fisheries.

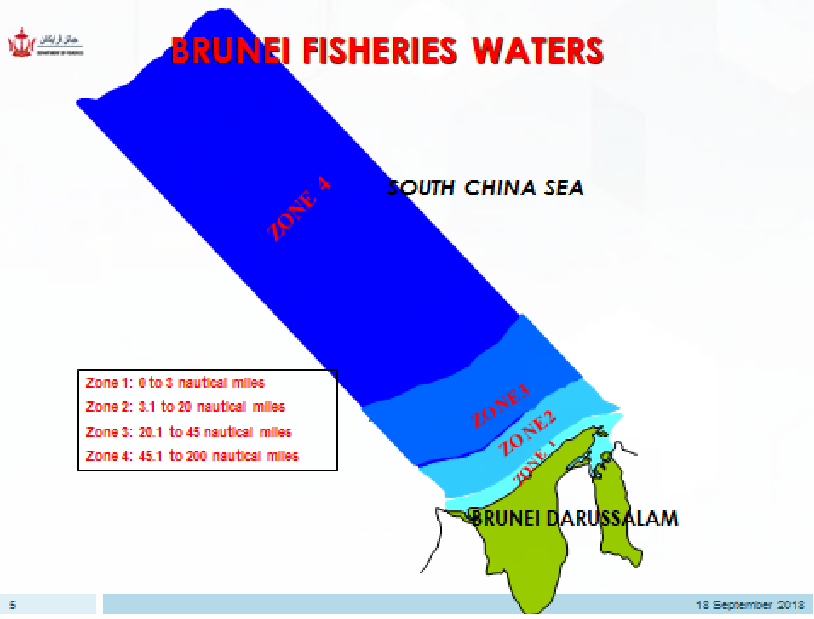


Figure 43. Fishing zonation in Brunei Darussalam.
Source: *Country Report: Brunei Darussalam: The 4th Expert Meeting on the Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Sheikh Al-Idrus & Marzini, 2019).

Figure 44. The fishing area of commercial purse seiners according respective companies registered in Brunei Darussalam where their FADs are being deployed.
Source: *The Purse Seine Fisheries in Brunei Darussalam* (Noorizan & Nur-Aqilah, n.d.).

II) Cambodia

Cambodia has a marine coastline of 435 km and there are four coastal provinces which are Sihanoukville, Kampot, Koh Kang and Kep (Figure 45). The Exclusive Economic Zone (EEZ) covers approximately 55,600 km^2 (Food and Agriculture Organization, 2011a) and is relatively shallow with an average depth of about 50 m, not higher than 80 m (Puthy & Kristofersson, 2007). The official records reveal no disaggregation for PS fisheries from provincial fishing grounds in Cambodia marine water (Food and Agriculture Organization, 2011a).

Figure 45. The map of coastal areas of Cambodia.
Source: *Marine fisheries resource management potential for mackerel fisheries of Cambodia* (Puthy & Kristofersson, 2007).

III) Indonesia

As the world's largest archipelago, Indonesia has a vast fishing area, including the coastal areas to EEZ of FMA 711 which facing SCS and FMA 571 for ANS (Directorate General of Capture Fisheries, 2015). Most of PS vessels operates in deep waters, includes Batam/Tanjung Pinang (Riau Island), Pemangkat (West Kalimantan), Natuna Besar Island, Selor Island, Panjang Island, Subi Island and Sugi Island. At present, Natuna Sea and its adjacent waters is one of the most important fishing grounds for PS fisheries (Figure 46). According to a preliminary study on the dynamic of PS fleets (> 60 GRT), the fishing grounds for PS is located around Jemaja Island, western and southern part of Natuna Island in the SCS. In addition, the mini PS fisheries in the shallow waters at south of West Kalimantan is mainly to catch the mackerels (Suwarso, Imron, Duto, & Asep, 2018). Meanwhile, the islands near Tanjung Balai Asahan in North Sumatera are fishing grounds for Indonesian PS vessels operating in Malacca Straits, ANS (Figure 47).

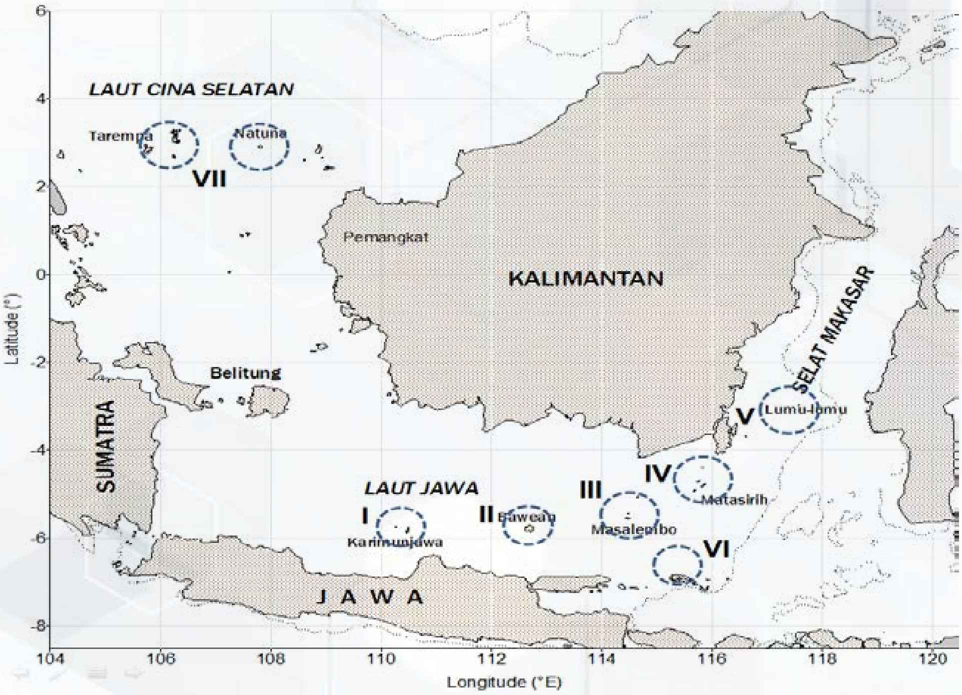


Figure 46. Natuna Sea and its adjacent waters (VII) in SCS, Indonesia.
Source: *Indonesia Country Report* (Suwarso & Duto, n.d.).

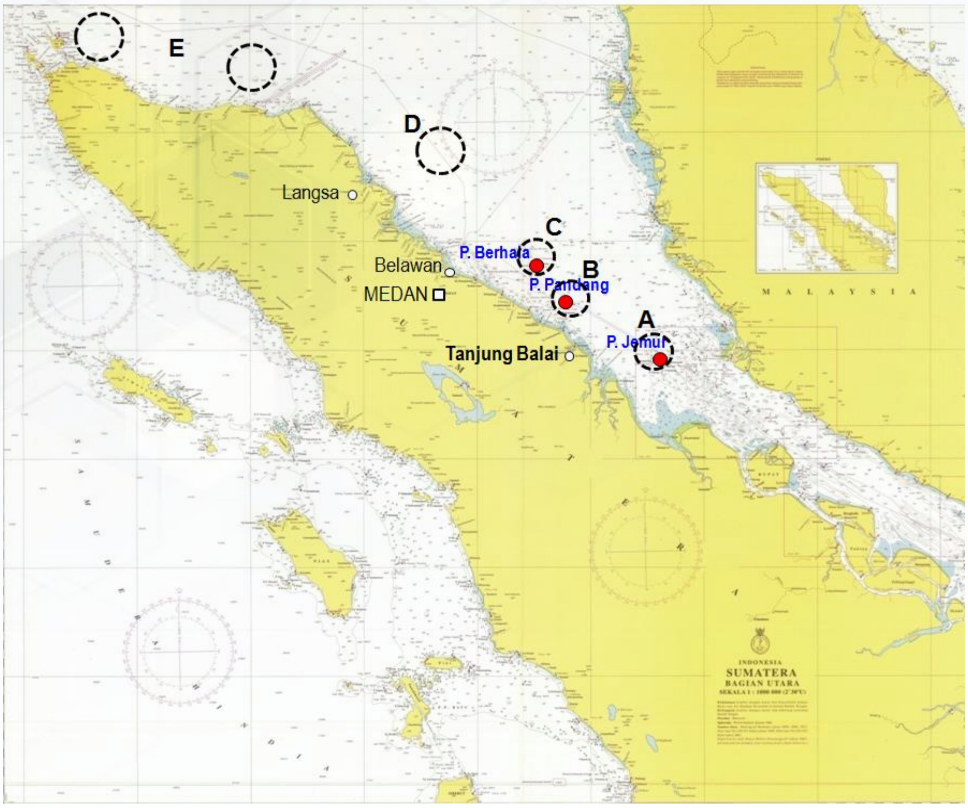


Figure 47. The purse seine fishing areas in Malacca Strait, ANS, Indonesia.
Source: *Indonesia Country Report* (Suwarso & Duto, n.d.).

IV) Malaysia

Malaysia has 4,675 km of total coastline. Figure 48 presents the Malaysian EEZ boundaries. In ECPM, the EEZ areas is about 115,217 km^2 (Department of Fisheries Malaysia, 2015a; Samsudin, 2007). The fishing area in WCPM is limited compared to ECPM. The main fishing sites for FPS in WCPM are shown in Figure 49. In particular, the FADs for PS vessels above 70 GRT to catch small tuna is commonly found at west area of Langkawi Island (Abdul Wahab, 2018). In Sawarak, PS vessels operate in offshore of southern bays and in the north of the state (Jamil, 2018), while in Sabah, PS vessels operate in all fishing zones (Figure 50).

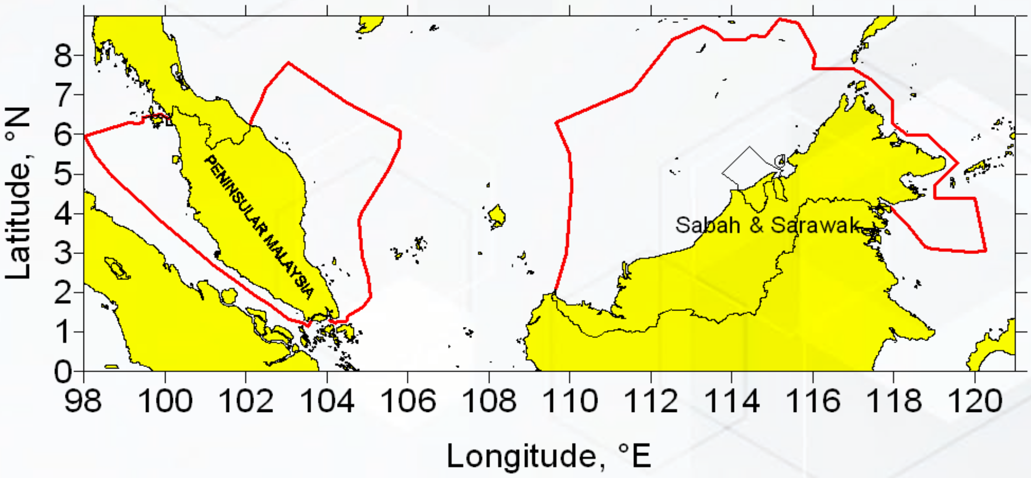


Figure 48. The EEZ water boundaries in Malaysia.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a).

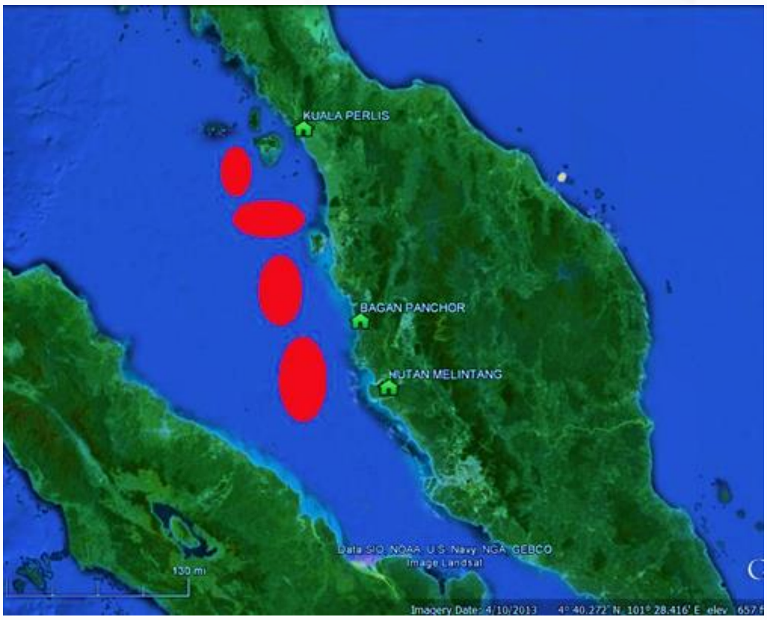


Figure 49. The main Fish Purse Seine fishing ground in WCPM, Malaysia.
Source: *Country Report: Malaysia - West Coast of Peninsular Malaysia* (WCPM) (Abdul-Wahab, Country Report: Malaysia - West Coast of Peninsular Malaysia (WCPM), 2019).

Figure 50. The purse seine vessels in all fishing zones in Sabah, Malaysia.
Source: *Country Presentation on Purse Seine Fisheries in Sabah* (Mohd Zamani, 2018).

Fishing zonation is applied in all Malaysian marine areas. In ECPM, the APS boat operates in Zone A that is reserved solely for the small-scale fishers using traditional fishing gear and owner-operated vessels (Department of Fisheries Malaysia, 2015a). Meanwhile, the FPS operates in zone B, C, C2 and C3 according to vessel GRT specification in respective zone (Figure 51) (Sallehudin, 2019). On the other hand, the continuous heavy fishing pressure over the years in Malacca Straits has led to the revision of the fishing zonation system in WCPM in 2014 (Figure 52) which stated that, from the shore up to 1 nm is the Marine Protected Area (MPA) where any fishing activity is prohibited in this No Take zone. Furthermore, fishing operation in zone C and C2 has been combined due to limited fishing areas in the Malacca Straits, WCPM.

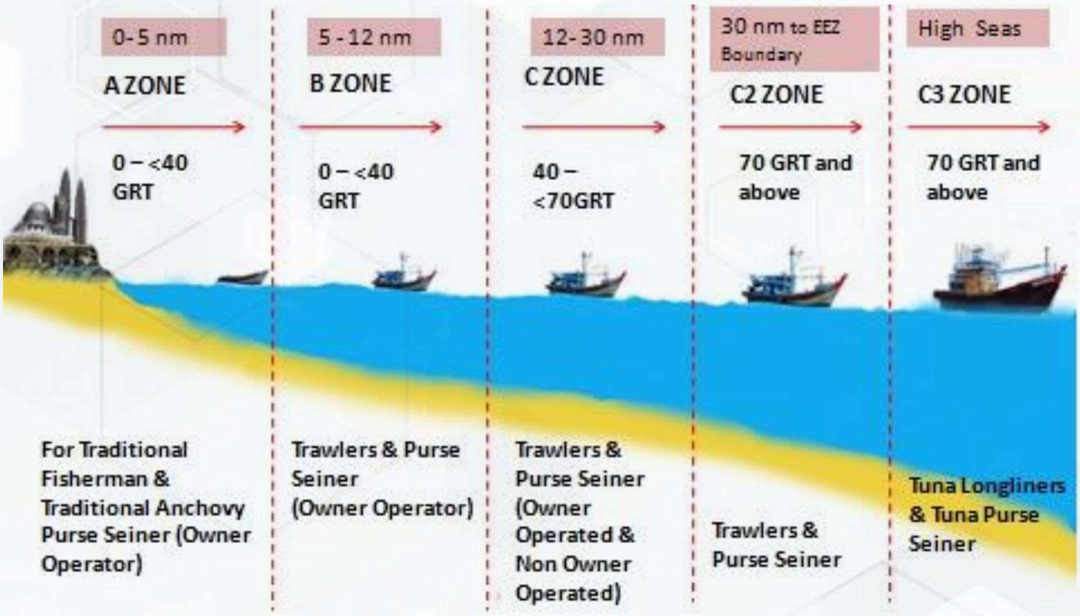


Figure 51. The fishing zonation in the ECPM, Malaysia.
Source: *Country Report: Malaysia - East Coast of Peninsular Malaysia* (Sallehudin, 2019).

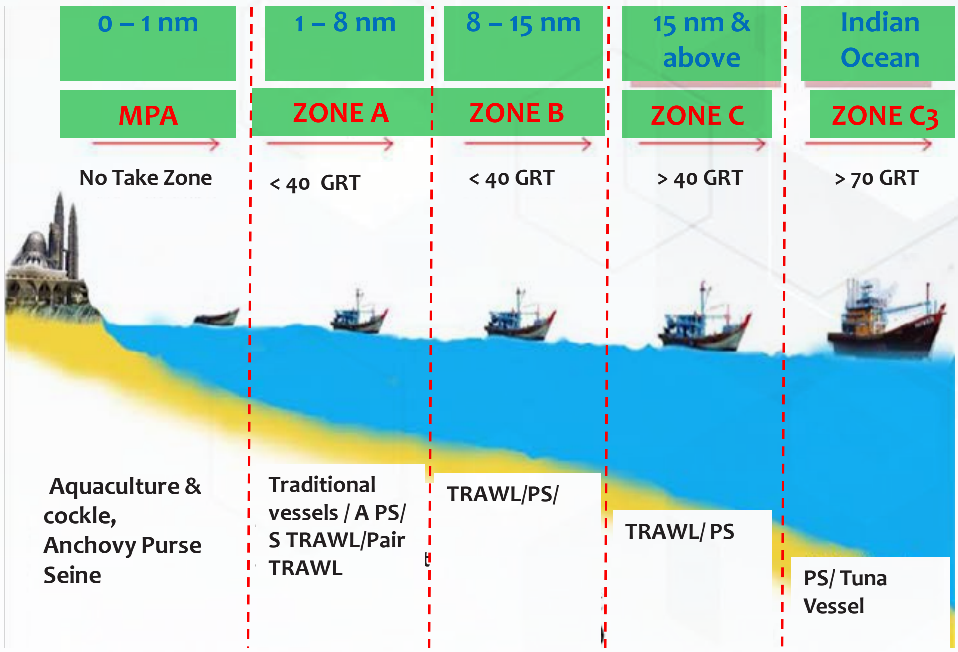


Figure 52. The revised fishing zonation in the WCPM, Malaysia.
Source: *Country Presentation on Purse Seine Fisheries in the West Coast of Peninsular Malaysia* (Abdul Wahab, 2018).

V) Myanmar

Myanmar's marine water cover areas of approximately 230,000 km^2, and is relatively wider in the central and southern parts. The territorial sea of Myanmar comprises of four areas which are Rakhine, Ayeyawady, Mon and Tanintharyi (Figure 53)Figure 53. Four fishing grounds in Myanmar. (Department of Fisheries Malaysia, 2015a; Shwe & Kyaw, 2019). Rakhine area is abundant for anchovies, Ayeyarwady for Hilsa and Tanintharyi for sardinella and mackerels (Kyaw, 2018). The PS vessels are commonly seen in the southern areas of Rakhine and Tanintharyi (Shwe & Kyaw, 2019).

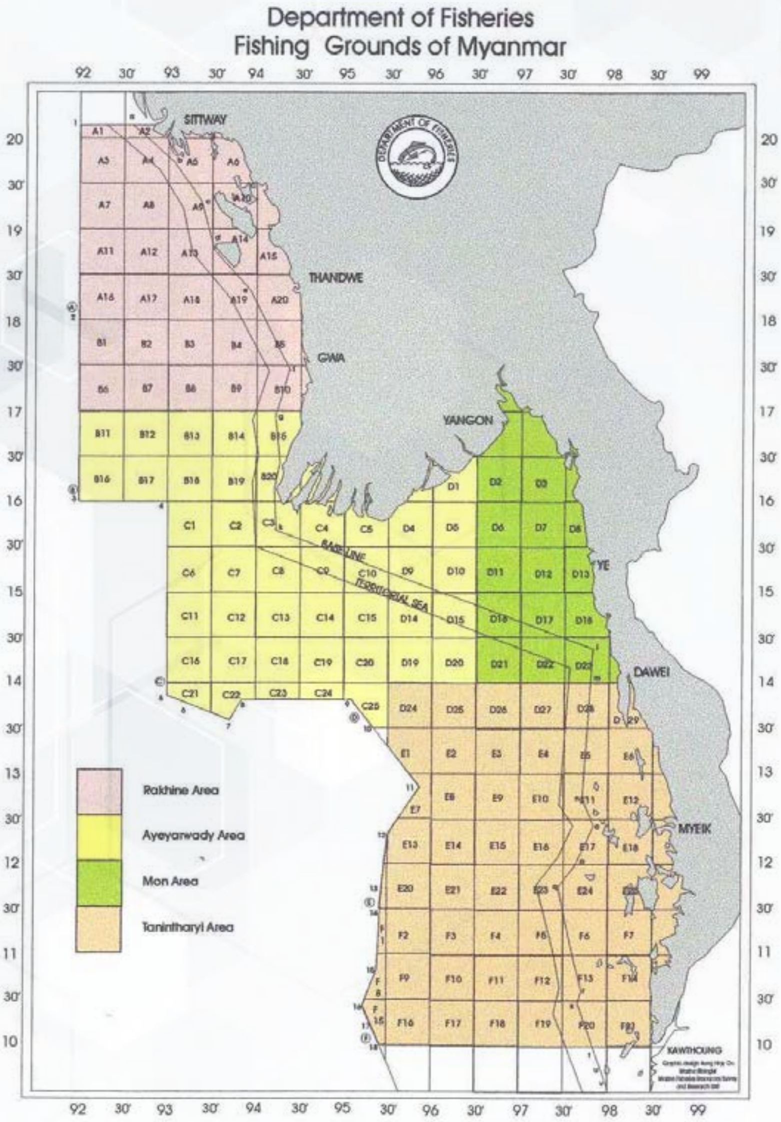


Figure 53. Four fishing grounds in Myanmar.
Source: *Country Report: Management of Purse Seine Fisheries in Myanmar* (Shwe & Kyaw, 2019).

VI) The Philippines

The PS fleets usually operate in commercial waters that is more than 15 km offshore, in FAO area 57 and 71 (respective Indian Ocean and Western Central Pacific Ocean) and in Papua New Guinea water, and then lands their tuna catch in Mindanoa and Navotas (Figure 54). In 2003, the Philippines established four (4) sampling sites for PS and ring nets as the target fishery in the SCS. These sites were Rosario (Cavite), Navotas (NCR), Masinloc (Zambales), and Salomague (Ilocos Sur). Sampling in Masinloc and Salomague was however discontinued as the PS landings since August 2003, indicated the deficiency of the targeted species. Subsequently, Dagupan fish landing was added to cover the major landings of round scads and mackerels using Danish seine in the Lingayen Gulf (Department of Fisheries Malaysia, 2015a).

Figure 54. Major purse seine fishing grounds in The Philippines.
Source: *Country Report: The Philippines: 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Eleserio & Romero, 2019).

VII) Thailand

The main fishing areas for PS fisheries in Thai waters are located in GOT and ANS, with the depth less than 100 m (Tes-a-sen, Kongprom, Boonsuk, & Nooklum, 2012; Chuapun & Ratanaprom, 2005). There are 17 coastal provinces in the GOT with a coastline of approximately 2,700 km and six (6) coastal provinces in the ANS covering 865 km of coastline. The fishing grounds in Thai water are divided into seven (7) zones, in which Zone 1 to Zone 5 are in the GOT, and Zone 6 to Zone 7 are in the ANS (Figure 55) (Panjarat & Boonjohn, 2016).

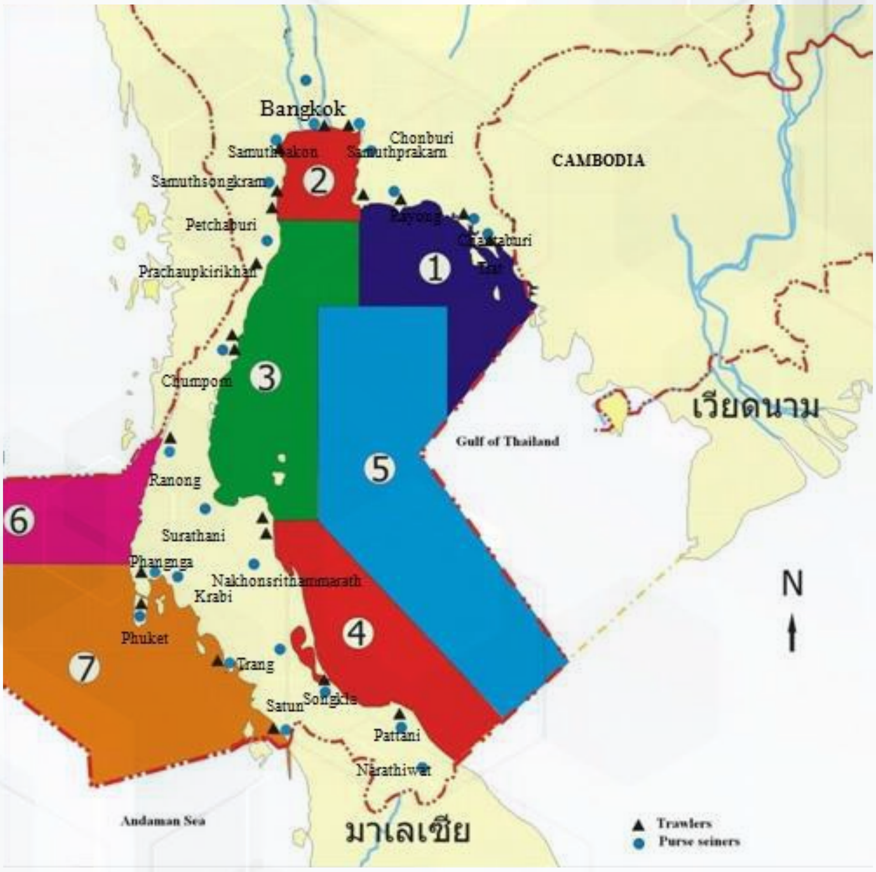


Figure 55. Fishing zones in the Gulf of Thailand (SCS) and Andaman Sea, Thailand.
Source: Purse Seine Fisheries in Thailand (Panjarat & Boonjohn, 2016).

VIII) Viet Nam

Viet Nam has a coastline of 3, 260 km that crosses 13 latitudes, from 8°23' N to 21°39' N. There are four (4) main fishing areas: Gulf of Tonkin, shared with China; Central Viet Nam; South-eastern Viet Nam; and South-western Viet Nam (part of Gulf of Thailand). The Mekong river delta provides over 75% of the total marine landings and therefore most of the fishing industry is concentrated in the southern provinces, from Khanh Hoa to Ca Mau. Figure 56 shows that PS fisheries are well developed in the Central and the Southeast while Gulf of Tonkin and the Southwest waters are considered as minor fishing areas for purse seiners.

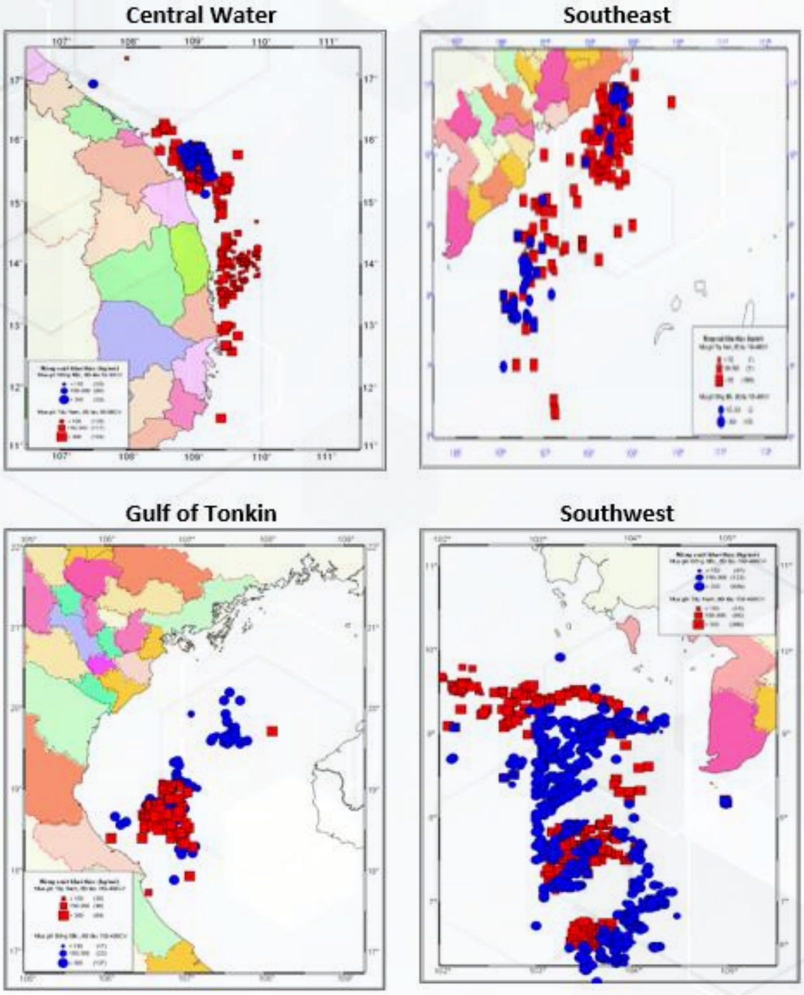


Figure 56. Fishing ground of purse seine fisheries in Viet Nam (Blue: NE; Red: SW).
Source: *The Report for the Purse Seine Fishery in the Viet Nam* (Phan, 2016).

3.4. Existing management measures on purse seine fisheries

3.4.1. Licensing and regulations

I) Brunei Darussalam

Under the Fisheries Order 2009, all fishing gear should be licensed. Department of Fisheries is responsible for issuing the fishing gear license. Fishing effort is controlled by limiting the number of licenses of purse seine, trawl and long line fishing vessels, and the catches are monitored through monthly catch logbooks that required to be complete by the master of the vessel (Cinco, Teh, Zylich, & Pauly, 2015).

The country has implements zonation with the specification on vessel and horse power (HP). PS fleets are allow to operate within Zone 2, 3 and 4 that has different length of nets requirement, but same minimum seine mesh size of 30 mm (Figure 57) (Noorizan & Nur-Aqilah, n.d.).

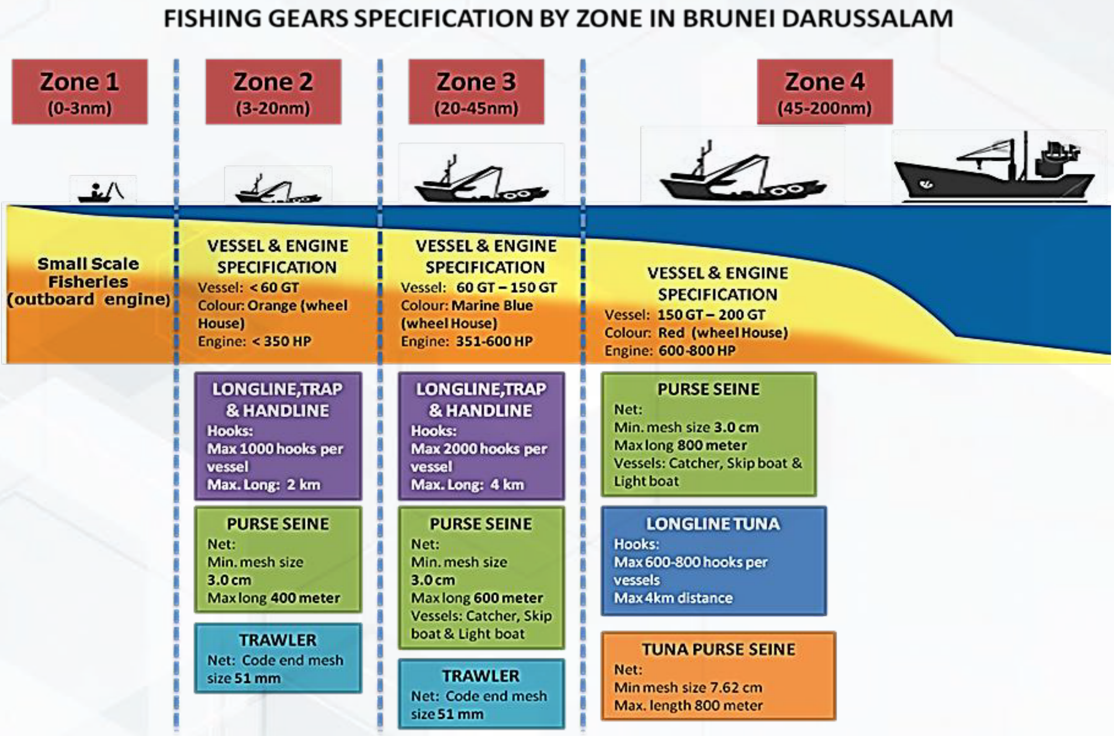


Figure 57. Fishing gears specification by zone in Brunei Darussalam.
Source: *The Purse Seine Fisheries in Brunei Darussalam* (Noorizan & Nur-Aqilah, n.d.).

II) Cambodia

The fishery management shall be under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries (MAFF). Under Article 45, all types of fisheries exploitations in the marine fishery domain, except subsistence fishing, shall be allowed only in the possession of a license and these exploitations shall follow the conditions and obligation in the fishing logbook. The fishers who fail to do so, or use fishing boat without registration from the Fisheries Administration, shall be subjected to a transactional fine in cash proportionately to fishing fees, as stated by Article 95 (Ministry of Agriculture Forestry and Fisheries, 2007). There are two systems exist of issuing the motorised fishing vessels licenses: (i) the license for all motorised vessels equipped with engine power under 33 HP was issued by the provincial fisheries office; (ii) license for all motorised vessels equipped with an engine power above 33 HP was issued by the Fisheries Administration (Table 10).

Table 10. The issuer for fishing vessel license.

	Horsepower (HP)	Issuer
Motorised vessels	< 33	Provincial Fisheries Office
	> 33	Fisheries Administration

Source: *Law on Fisheries (Unofficial Translation)* (Ministry of Agriculture Forestry and Fisheries, 2007).

III) Indonesia

The main government ministry responsible for administration and management of capture fisheries in Indonesia is the Ministry of Marine Affairs and Fisheries (MMAF), along with fisheries authorities at provincial and district levels. The country has implemented many regulations and made amendments few times to ensure National Fishery Policy is followed. The enforcement of Fishery Management Plan (FMP) was done through several Ministerial Regulations (MR) to oversee the conservation and management of fish stocks in the archipelagic and FMAs (Figure 58) (Suwarso, Imron, Duto, & Asep, 2018).

Indonesia also applies the zoning system for allocation of management responsibility to administrative levels (Law 32/2004 and Government Regulation 38/2007). There are three (3) fishing zones based on fishing areas, size of vessels and management authorities (Table 11) (Suwarso & Duto, n.d.).

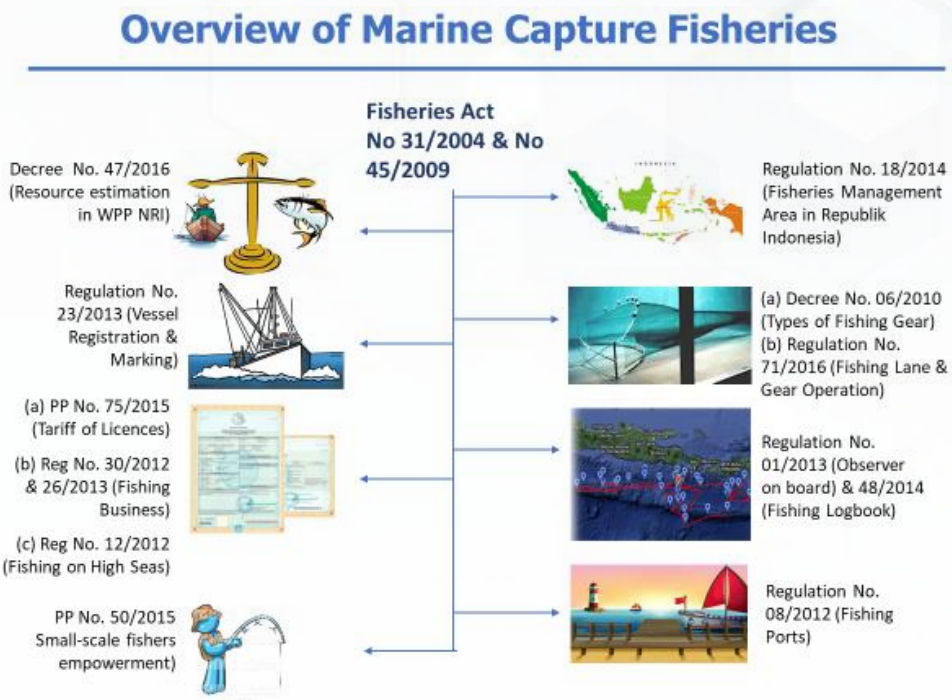


Figure 58. Some of Fisheries Act and regulations for marine capture fisheries in Indonesia.
Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

Table 11. Zoning system and issuance level for licensing fishing vessels in Indonesia water.

Administrative Level	Fishing Zone	Fishing Area (nm)	Vessel Specification (GRT)
District	Zone I	0 - 4	5-10
Provincial	Zone II	4 - 12	10-30
National	Zone III	≥ 12	> 30

Source: Indonesia Country Report (Suwarso & Duto, n.d.).

Since 2010, a temporary halt in issuing new fishing licenses (moratorium) was excuted, which including the license for PS vessel > 200 GRT and the FAD (*rumpon*) (OECD, 2013). Management measures for PS fisheries in Indonesia are stated in the MMAF Regulation no.30/2012, in which the technical measures are as follows: the mesh size should be larger or equal to one (1) inch, the float line must be less than 300 m, and the maximum light density should be less than 4,000 W. There is a clear definition between small pelagic and large pelagic PS based on different mesh sizes. Any large pelagic PS vessel should apply a minimum mesh size of three (3) inches, whereas small pelagic PS vessel uses a one (1) inch mesh size. Table 12 shows the vessel specification for single-boat PS and two-boat PS that is currently being enforced in Indonesia (Suwarso, Imron, Duto, & Asep, 2018).

Table 12. Purse seine vessels specification by GRT in Indonesia.

Vessel Size (GRT)	< 10	10-30	30-100
Single boat purse seiner			
Mesh size (inch)	≥ 1	≥ 1	≥ 1
Length (m)	≤ 300	≤ 400	≤ 600
Light (watt)	≤ 4,000	≤ 8,000	≤ 16,000
Fishing lane	I, II & III	II & III	III
Two boat purse seiner			
Mesh size (inch)	-	≥ 1	≥ 1
Length (m)	-	≤ 600	≤ 800
Light (watt)	-	≤ 8,000	≤ 16,000
Fishing lane	-	II & III	III

Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

IV) Malaysia

The fisheries management measures involving PS in Malaysia are based on the existing Fisheries Act 1985 (Act 317) (Sallehudin, 2019; Department of Fisheries Malaysia, 2015a). There are specific measures aimed at ensuring a balance among fishing effort, sustainability of resources, environmental conservation and livelihood of stakeholders (Department of Fisheries Malaysia, 2015b).

i. Direct limitation of fishing effort through fishing zonation and licensing scheme.
Fishing zones have been established through a licensing scheme. Currently, new fishing vessel licenses for Zone A, B and C, as well as application for permits for C2 (Deep Sea) zone are no longer issued. Only applications for permits for C3 (International Sea Waters) are still allowed at present (Sallehudin, 2019).

ii. Tightens re-new license requirements.
Started 2013, the PS license will be re-new based on yearly performance on two criterias which are the landing of fish must be at least 350 MT and the Mobile Transceiver Units (MTU) equipment activation must be over 80% of sea hours (Azura, 2017).

iii. Controls on size and power of fishing vessels.
Any attempt by fishers to change the tonnage or engine power of fishing vessels requires permission from the Director-General of Fisheries.

iv. Monitoring, Control and Surveillance Programme.
Malaysian Maritime Enforcement Agency (MMEA) has implored the Vessel Monitoring System (VMS) since 2014, and make compulsory installation of Automatic Identification System (AIS) since 2016 for all Zone B fishing boats, which including the FPS with < 40 GRT.

v. Resettlement of surplus fishers into the other sectors.
The Vessel Buy-back scheme helps to improve the likelihood of Malaysian fishers. This scheme is supervised by Fishers Transformation Unit (FTU) under Ministry of Agriculture and Agro-Based Industry Malaysia (Fisheries Development Authority of Malaysia, 2015). The surplus Malaysian fishers are relocating to sectors like agriculture, manufacturing, small-scale business, aquaculture and off-shore fishing.

V) Myanmar

Every fishing activity in Myanmar is controlled by the licensing and registration system to control both the fishing vessels and their gear, under the current Fisheries Law and Union of Myanmar Foreign Investment Law 1995. The Department of Marine Administration is responsible for the registration of fishing boats and fish carrier vessels carrying the flag of Myanmar, while the Department of Fisheries carry out the granting, suspending, and withdrawing of fishing licenses from fishing boats or carrier vessels. The current licenses are only valid for a year thus need to be re-new annually (1 April to 31 March for coastal and small-scale fisher, and 1 September to 31 August for deep-sea fishery) (Food and Agriculture Organization, 2010).

Fishing gear registration is included in the fishing licenses, where one fishing vessel is permitted to use only one unit of fishing gear. Any attempt by fishers to change the tonnage or engine power of fishing vessels or to construct the fishing vessels require permission from the Director General of DOF and nautical approval from the respective authority. The specification and limitation of fishing gears and other license conditions are stated in the fishing license card. Currently, the DOF is developing its licensing system in electronic format under the e-government system. A moratorium (temporary hold) has been placed on the issuance of new or additional fishing licenses for vessels to harvest in coastal waters. This is to reduce the high fishing pressure on the limited coastal fisheries resources.

Two fishing zones have been established through a licensing scheme whereby zones are designated for specific fishing gear, classes of fishing vessels and ownership. Basically, the two fishing zones in Myanmar marine water are: Fishing Zone 1, for coastal fisheries, extending from the shoreline to 5 nm in the northern area and to 10 nm in southern coastal areas; and Fishing Zone 2, from the outer limit of the Fishing Zone 1 out to the EEZ limit (Food and Agriculture Organization, 2010). The PS vessels operate in area beyond 10 nm to the EEZ and are more than 30 feet long powered by engine with more than 25 HP.

VI) The Philippines

The Philippines with Bureau of Fisheries and Aquatic Resources (BFAR) as the lead agency has executed numerous fisheries management plan in order to maintain the sustainability of fisheries resources including the Comprehensive National Fisheries Industry Development Plan 2008-2027 (CNFDIP) and five-year Fisheries Development Plan 2016-2020 (Rafael & Jonathan, 2019). Some management measures that have been implemented in the PS fisheries were National Tuna Fish Aggregating Device (FAD) Management Policy, Sardine Management Plans and Roundscad Management Plan. Aside from imposing policies and plans, the country also attempted at other initiatives including the port sampling, logsheets, Philippine Fisheries Observer Program, Vessel Monitoring System/VMM and Catch Certification (Eleserio & Romero, 2019). The national Fishing Regulations that have been enforced for proper management of PS fisheries were such as:

i. FAO 226, s 2008: Regulations on the Mesh Size of Tuna Purse Seine Nets and Trading of Small Tuna.
ii. FAO 236, s 2009: Rules and Regulations on the Operation of Purse Seine and Ring Net Vessels Using FADs (locally known as *Payaos*) during the FAD Closure Period as Compatible Measures to WCPFC CMM 2008-01.
iii. FAO 240, s 2012: Rules and Regulations in the Implementation of Fisheries Observers Program in the High Seas.
iv. FAO 241, s 2012: Regulations and Implementation of the Vessel Monitoring System (VMS) in the High Seas.
v. FAO 244 s. 2012: National Tuna Fish Aggregating Device (FAD) Management Policy.

VII) Thailand

Many regulations are enforced to manage the PS Thai flag, for example, the mesh size of the net, number of fishing day, and area FAD deployment. Fishing boat owners must renew their fishing license every two (2) years in order to exist and continue the PS fishing. The restriction on fishing net mesh size and fishing technique is one of the regulations used to conserve the juvenile fish. The mesh size for APS net larger than 6 mm is permitted, while the TPS's mesh size must equal to or larger than 25 mm. APS fishing is allowed only during daytime (Chumchuen & Noranarttragoon, 2019). The DOF Thailand has set up a Fisheries Monitoring Centre (FMC) equipped with VMS technology. No vessel above 30 GRT is allowed to operate without VMS equipment installed (Royal Thai Embassy, 2016).

The Thailand FMP identifies overcapacity of the fishing fleet and overfishing as the most critical challenges in Thai fisheries. The government has frozen registration of new commercial fishing vessels (moratorium) since August 2015. A vessel buy-back scheme has been prepared, with various compensation packages and new job training provided to different groups of affected fishers. The decommissioned vessels are being scrapped in order to ensure that they will be removed from fisheries sector permanently.

In addition, Thailand also implemented input control as stated in the National Policy for Marine Fisheries Management 2015 – 2019 (Department of Fisheries Thailand, 2015), in which has targeted to reduce 30% fishing effort in GOT (SCS) and 20% in ANS from the previous fishing effort level for pelagic fish. In order to achieve that, the government has undertaken a reform of the fishing license regime. Starting in April 2016, the issuance of new fishing licenses shall be consistent with the MSY stipulated in the FMP. The number of fishing licenses granted will not exceed the level of catch permitted by the MSY. To achieve the MSY, a vessel day scheme is introduced in the FMP to limit the number of days fishing vessels can operate. The number of allowable fishing days differs across different fishing gears (*e.g.,* trawlers, purse seiners and gillnets) and across the GoT (SCS) and the ANS.

VIII) Viet Nam

Viet Nam has applied a fishing license system since 1992 and the license is valid for a year. The offshore fishing boats of larger than 90 HP is licensed by the Department of Capture Fisheries and Fisheries Resources Protection (DECAFIREP), while the coastal fishing boats of less than 90 HP is licensed by the authority at province level (sub-DECAFIREP) (Nguyen, 2010).

The government has adopted the FAO Code of Conduct for Responsible Fisheries (CCRF) since 1995. Recently, the government has issued "Master Plan on Fisheries Development of Vietnam to 2020, Vision to 2030", in which stated that total number of fisheries boats needs to drop to 110,000 boats (2020), by 2030 falling to 95,000 boats, aimed to a reduction by 1.5% per year (Tuyen & Tam, 2019). Other management strategies that had been introduced were limitation in the number of fishing vessels, regulation of mesh size (Table 13), catch monitoring (Table 14), VMS, and log book.

Table 13. Minimum mesh size at the bunt for purse seine vessels in Viet Nam.

English name	Vietnamese name	Minimum mesh size at the bunt (mm)
Anchovy PS	*Lưới vây cá cơm*	10 mm
Luring PS	Lưới vây rút chì	18 mm

Source: *Country Presentation: The Purse Seine Fisheries in Viet Nam* (Tuyen & Tam, 2019).

Table 14. Minimum length of some small pelagic captured in Vietnamese waters.

Scientific name	Vietnamese name	Length (cm)
Sardinella jussieu	*Cá Trích xương*	8
Sardinella aurita	*Cá Trích tròn*	10
Anchoviella spp.	*Cá Cơm*	5
Decapterus maruadsi	*Cá nục sồ*	12
Selaroides leptolepis	*Cá Chỉ vàng*	9
Scomberomorus guttatus	*Cá Thu chấm*	32
Scomber japonicus	*Cá Thu nhật*	20
Auxis thazard	*Cá Ngừ chù*	22
Euthynnus affinis	*Cá Ngừ chấm*	36
Rastrelliger kanagurta	*Cá Bạc má*	15

Source: *Country Presentation: The Purse Seine Fisheries in Viet Nam* (Tuyen & Tam, 2019).

3.4.2. Closed season and closed area

I) Brunei Darussalam

Brunei Darussalam do not have any closed season due to the lack of data and research on the study lifecycle of fishes and limited water area. Regarding closed area, through Merchant Shipping Safety Zone and Fisheries Order 2009, area within radius 500 m away from any oil or gas platforms, pipelines and structures are established as safety zone thus no fishing activities are allowed. Besides that, any commercial fishing vessels are not allowed to fish in area 1 nm from oil platforms and pipelines (Figure 59) (Brunei Darussalam, 2013; Brunei Darussalam, 2009). This regulation allows the marine oil/gas structures to act as artificial reefs that provide habitat, food, protection from predation and spawning substrata to marine organisms (Scarborough Bull, 1989). One of the provisions of the Fisheries Order is the establishment and management of the marine reserves and marine parks. Since 2012, there are six (6) declared Marine Protected Areas (MPAs) which are Pulau Punyit, Pelong Rocks, Labu, Louisa Reef, Pulau Siarau and Selirong (The Forestry Department Brunei, 2014).

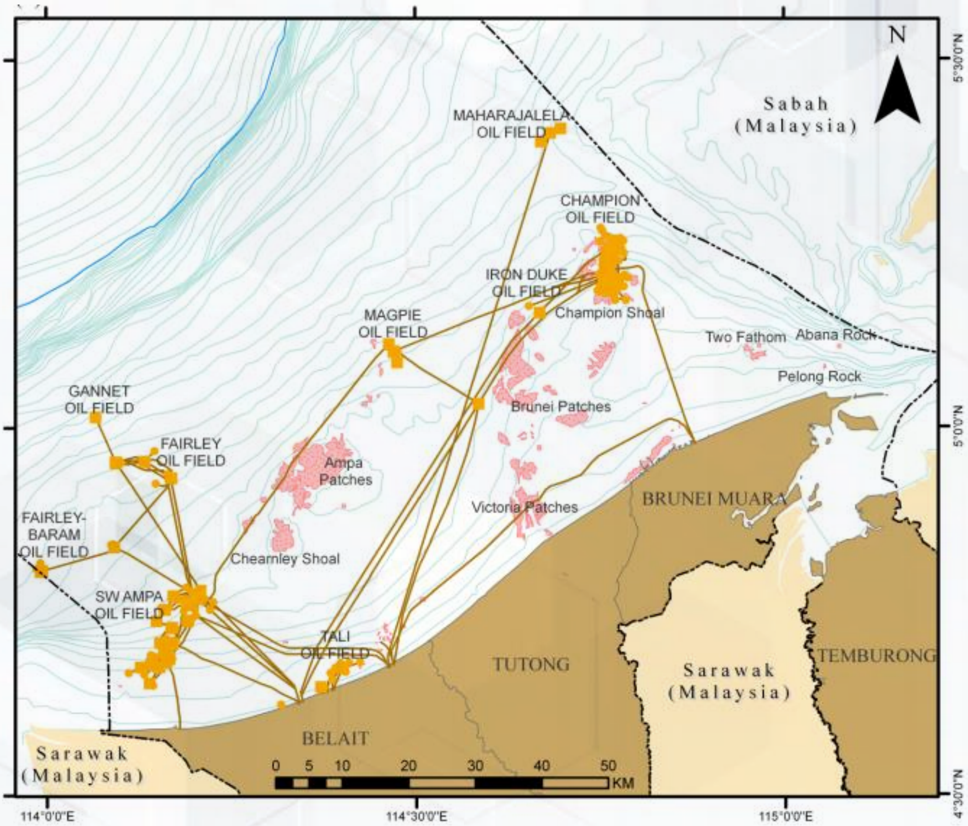


Figure 59. The location of oil/gas pipelines and platforms in Brunei Darussalam.
Source: *Assessment of demersal fishery resources in Brunei Darussalam* (Ebil, 2013).

II) Cambodia

Cambodia has introduced a closed spawning season for *Rastrelliger* spp. from 15 January to 31 March every year (Food and Agriculture Organization, 2011a). The short mackerel usually comes to the coastal areas between mid-January and the end of March in order to reproduce. Thus, to ensure the sustainability of the species, a temporary ban on mackerel fishing is implemented during the breeding period, and the Cambodia fishers complied to the ban since they admitted less mackerel catch in recent years indicating the declining stock of the species.

Regarding closed area, Cambodia has four (4) established MPAs totalling about 2,500 km^2; including Ream National Park that has significant coral reef resources, Botum Sakor National Park, Dong Peng Multiple Use Area and Peam Krasop Wildlife Sanctuary (FAO, 2011). In 2016, the Ministry of Agriculture, Forestry and Fisheries (MAFF) had established the country's first Marine Fisheries Management Area (MFMA) called Koh Rong Acrhipelago MFMA that covers seven (7) islands which are Koh Rong, Koh Rong Samloem, Koh Koun, Koh Touch, Koh Tatiem, Koh Mnoas Krav and Koh Mnoas Knong (Figure 60).

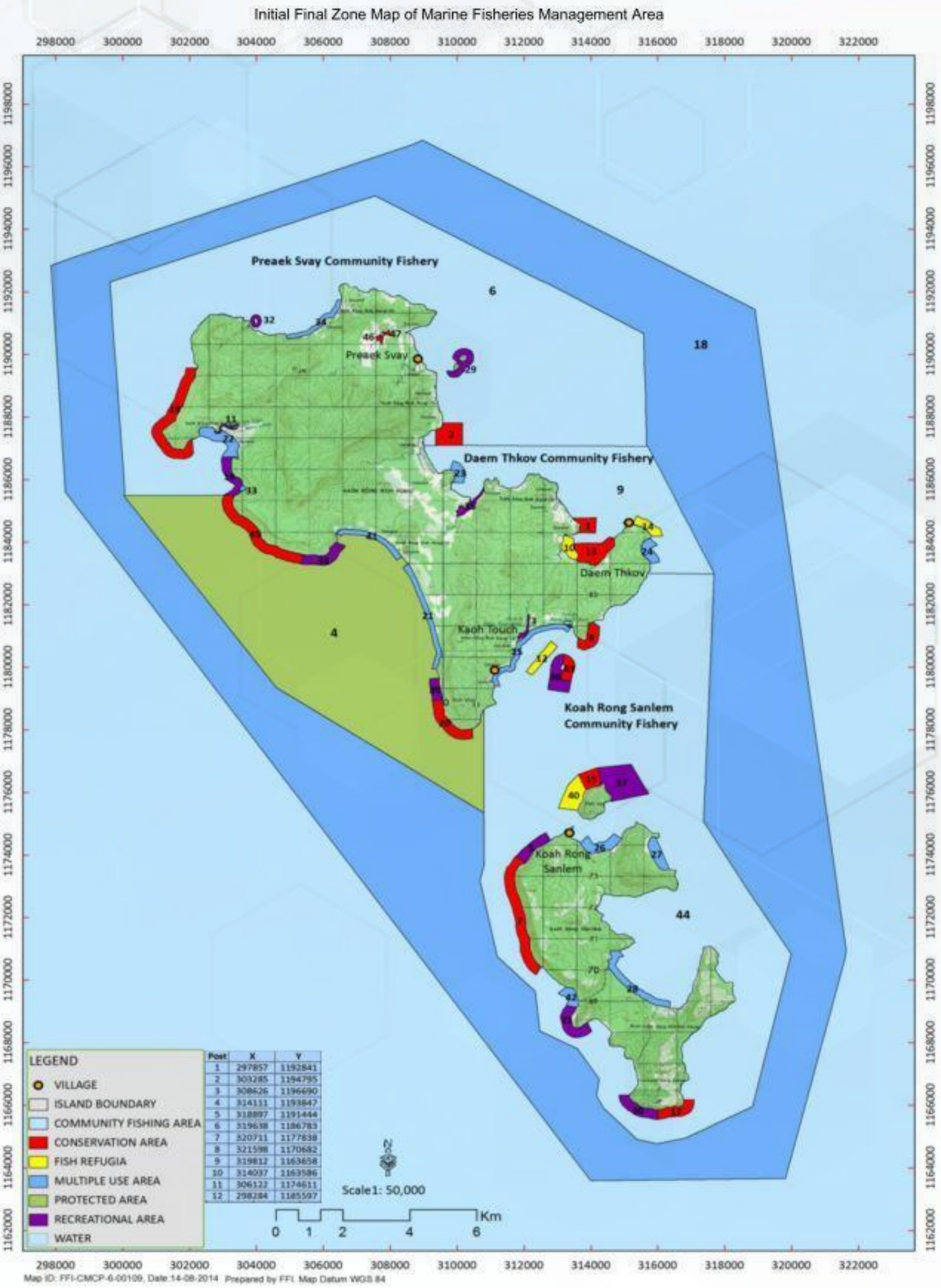


Figure 60. Koh Rong Archipelago Marine Fisheries Management Area.
Source: *'Marine park' off Koh Rong planned* by Khouth and Alessandro, 2017.

III) Indonesia

The closed season and closed area for some dominant species of small pelagic was declared based on the biological studies of the targeted species. For example, in 2011, to protect the fish roe and larva, Bengkalis Fishery and Maritime Affairs in Riau had prohibited fishers from catching the longtail shad fish, *Tenualosa macrura* (locally called *terubuk*) in mangrove areas on Bengkalis Island and around the Siak River estuary, between September and November, as *terubuk* usually breeds in brackish water, during the very short period for laying eggs, usually only three days. Yet, during the closed season as well as the ban of fishing in closed area, the fishing effort has been still high because *terubuk* meat and roe command a high price at market (Suwarso, Muhammad Taufik, & Akhmad Zamroni, 2017).

Up to 2007, the Central Government of Indonesia (Jakarta), administered by the Ministry of Forestry, has has established over 200 MPAs and five (5) Marine Managed Areas (MMAs), many of which are actually combined terrestrial and marine parks. Government data shows that Indonesia has declared 19.14 million hectares of MPAs as of December 2017, or 96% of its commitment to establish 20 million hectares of MPA coverage by 2020 (Kalistaningsih, 2018).

IV) Malaysia

The closed season has not been enforced yet but currently it is being evaluated and drafted for its effectiveness and suitability to the fisheries situation in Malaysia. In the past, the DOF Malaysia had gazetted Fisheries Regulation 1996, that had included a 'Closed Seasoned to catch Grouper Fry from November to December every year in the State of Kelantan and Terengganu' and 'Prohibition of Method of Fishing Grouper Fry' which allowed only fish traps to catch grouper fry along Malaysian coasts. However the enforcement was not established due to many constraints, particularly in term of financial factor (Manap, 2016).

Malaysia has more than 40 declared MPAs (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002). The Marine Park Department is the agency responsible for management of MPAs, together with related agencies from federal and states (Figure 61). The first MPA's declared in the country was the Tunku Abdul Rahman Park, Sabah in 1974. Fishing zonation system in WCPM has been revised in 2014 to authorize 0-1 nm from the shore in WCPM as No Take Zone. In the same vein, identifying the waters within 5 nm of the shore as the nursery grounds of juveniles of prawns and fish is to ensure survival of juveniles of commercially important fish species. Thus, the commercial fishing vessels such as FPS and trawl are prohibited in the nursery areas (Sallehudin, 2019; Department of Fisheries Malaysia, 2015a).

Besides that, Malaysia also develops her marine park, for example Redang Island and Perhentian Islands Marine Park in Terengganu, Payar Archipelago in Kedah, Pemanggil Island and Sibu Island in Johor, and Tun Mustapha Marine Park in Sabah. In adition, Fisheries Prohibited Area (FPA) has also been established, i.e. Tanjung Tuan and Pulau Besar FPA in Malacca as well as Rantau Abang FPA in Terengganu.

Latest approach by DOF Malaysia has identified Tanjung Leman in Johor (southeast of Peninsular Malaysia) as refugia site for lobster *Panulirus* spp, and Kuala Baram (northeast of Sarawak State) as refugia site for the penaeid shrimp *P. monodon*, although the concept of refugia is different from protected area (Manap, 2016). It is still in its initial stages and requires more intensive consultations and discussions on this newly introduced concept to get mutual agreement on management of the refugia.

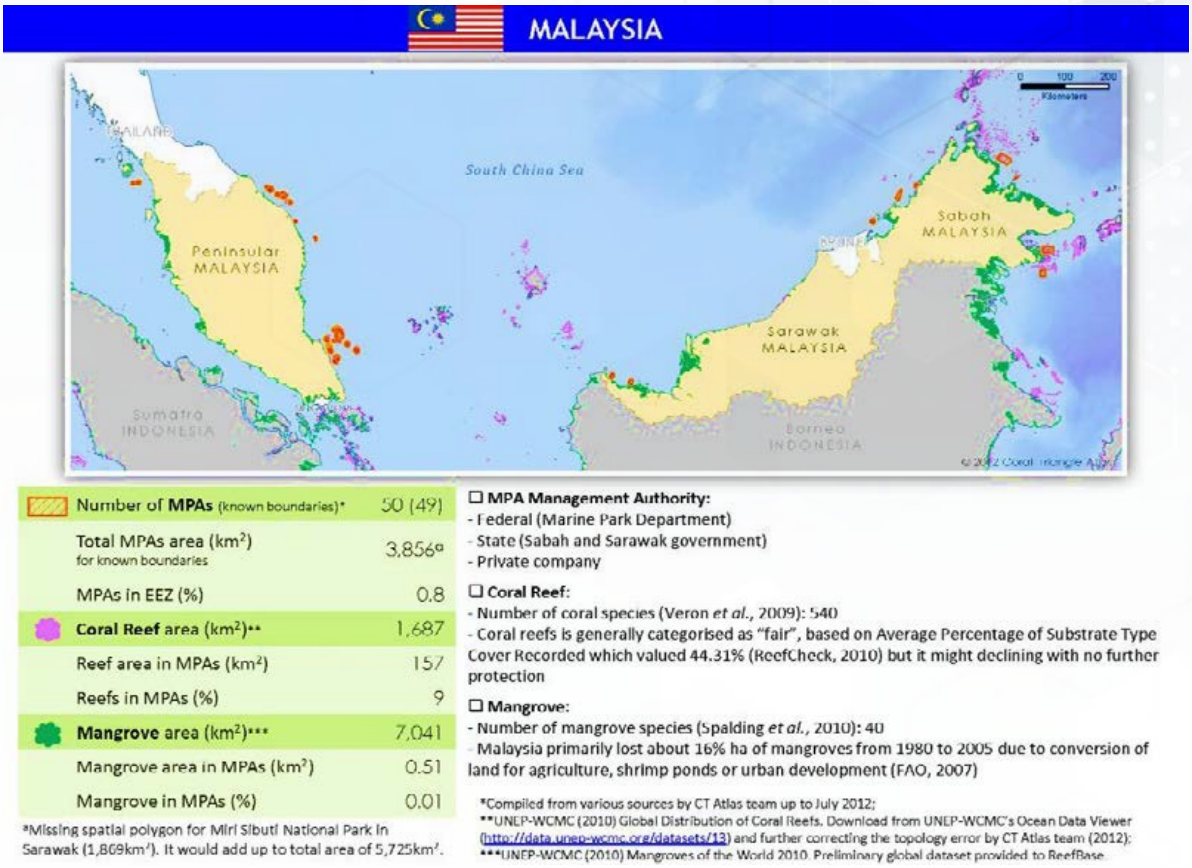


Figure 61. The Marine Protected Areas in Malaysia.
Source: *Map 04: Marine Protected Areas (MPAs) in Malaysia* by the Coral Triangle Atlas, n.d. (http://archive.constantcontact.com/fs028/1108454596610/archive/1111037468207.html).

V) Myanmar

Myanmar has enforced the closed season and closed area laws as indicated in Figure 62. Since 2013, the DOF Myanmar, under the Ministry of Agriculture, Livestock and Irrigation, has been declaring an annual 'no-fishing season' of three (3) months to allow the juvenile fish comes to mangrove area for feeding (Kyaw, 2018). There are one (1) fishing ground in Rakhine, four (4) in Ayeyarwady, two (2) in the Mon, and three (3) in Tanintharyi regions that have been gazetted as closed fishing areas from June to August. In 2018, the government designated specific period between 16 May to 15 August every year as the closed season. Earlier, fishing was totally restricted during the closed season, causing zero income to the families that rely on fishing. However, recently, this rule has been relaxed, allowing 20 % of fishing vessels to operate during the season which involves the traditional inshore fishing (Global New Light of Myanmar, 2019).

Currently, there are few closed areas in Myanmar which are also known as reserved fishing areas and MPAs. Nursery areas have been identified, and they have been protected and managed as reserved fishing areas. The country has four (4) declared MPAs (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002). Lampi island of the Tanintharyi coast has been designated as Marine National Park and Marine Reserve in 1996. Around three (3) nm of the island areas have been identified as fisheries protected areas whereby collection of marine fauna and flora are prohibited. Fishing in the protected areas is prohibited unless permitted to do so (Than, 2018; Food and Agriculture Organization, 2010).

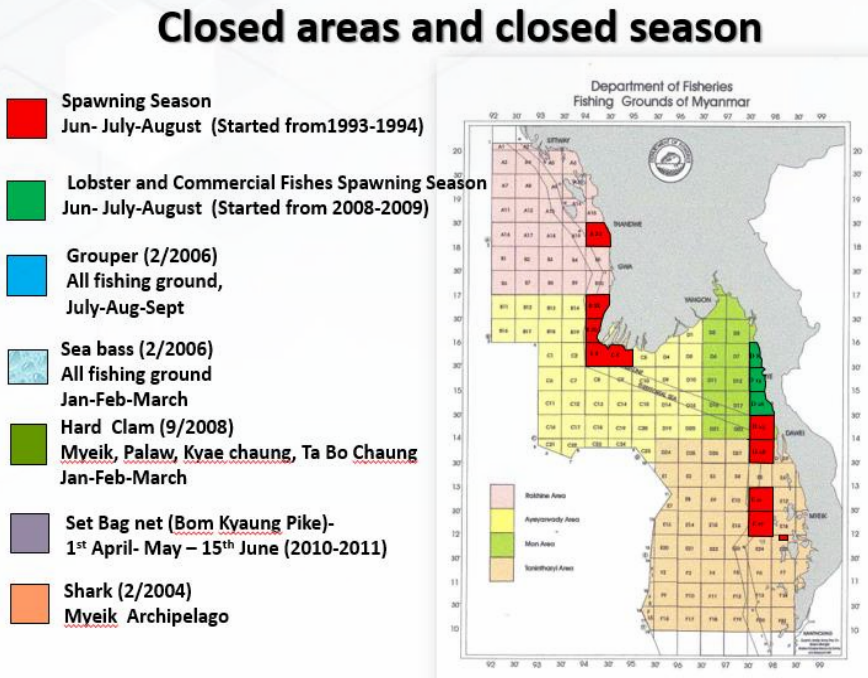


Figure 62. The closed areas and closed seasons implemented in Myanmar.
Sources: *Country Presentation: Purse Seine Fishery in Myanmar* (Kyaw, 2018).

VI) The Philippines

The protection and conservation of sardines, herrings and mackerels in the Visayan Sea through closed fishing season has been implemented since the late 1930s. On February 18, 1939, the then Department of Agriculture and Commerce, Bureau of Science Fish and Game Administration issued the Fish and Game Administrative Order No. 13 which promulgated the regulations establishing the closed season for the conservation of sardines and herrings (Department of Agriculture and Commerce, 1939). The policy was implemented for four months (November 15 to March 15) in selected areas of the Visayan Sea, north of the island of Negros and between the northern parts of the island of Panay and Cebu (Ani, 2016).

Still, in late 2000s, sardine population has dwindled in such an alarming rate, thus instigating BFAR to seriously implement a closed season for the sardine, together with the deployment of patrol boats. At the beginning, the ban started in Zamboanga Peninsula water, from 1 December 2011 to 1 March 2012 for three months, and in Visayan Sea and its surrounding waters on 15 November 2012 to 15 March 2013 for four (4) months. After the observance of closed season, there was about 20% increase in sardine production in Zamboanga Peninsula, and also gave many positive impacts like increased in catch of high value of non-sardines' species and increased in Filipinos fishers' income. After that, the three-month (3) closed fishing season of sardines, mackerels and herrings becomes annual agenda in the Visayan Sea and other municipalities where there are resources of the said species. Meantime, in Davao Gulf, started in 2014, have implemented the catch ban of some pelagic species locally known as *karabalyas*, *galunggong*, and *matang baka* among others from 1 June to 31 August every year. The annually declared closed fishing season for round scad is from 1 November to 31 January in Northern Palawan (Figure 63).

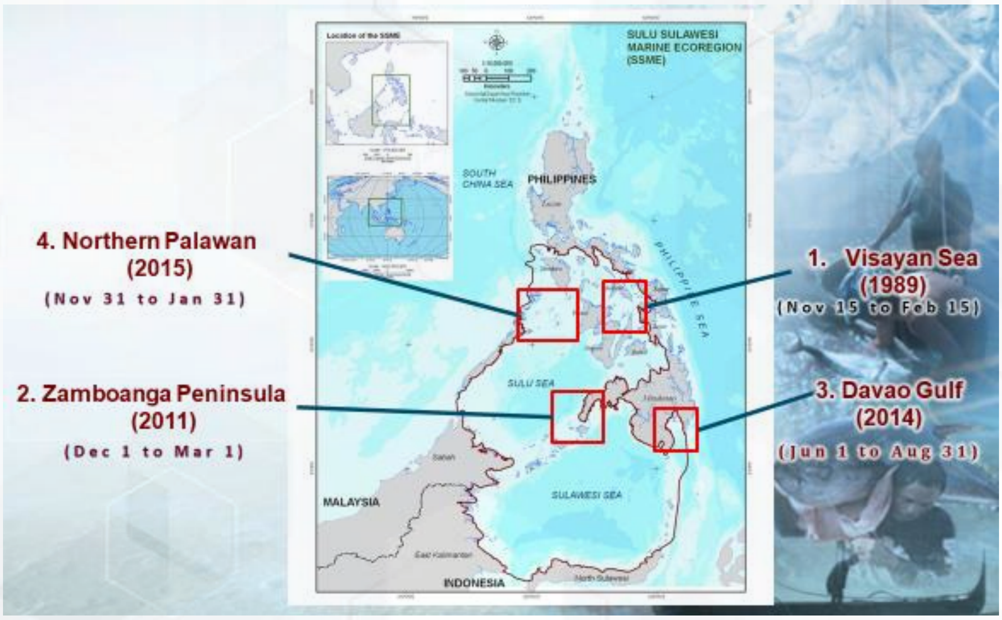


Figure 63. Closed seasons implemented in the Philippines.
Source: *Country Report: The Philippines: 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region* (Eleserio & Romero, 2019).

The country has estimated more than 180 declared MPAs (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002). The first marine park in SEA region is believed to be the Hundred Islands National Park on the west coast of Luzon Island, established in 1940 (White, 1979). The Department of Environment and Natural Resources (DENR) and the Department of Agriculture's Bureau of Fisheries and Aquatic Resources (DA-BFAR) are the two government agencies mainly responsible for the national planning, policies and evaluation of the Philippine marine environment. However, much of the actual management authority and implementation has been decentralized to the local government units (Municipal level) after the ratification of the Local Government Code of 1991.

VII) Thailand

Some closed seasons are enforced for PS fisheries, in which four (4) periods in SCS (GOT) and one (1) period in ANS as listed in Table 15 (Chumchuen & Noranarttragoon, 2019).

Presently, more than 25% of Thai waters are declared as protected areas (Panjarat & Saikliang, n.d.). The country has approximately 23 declared MPAs. The government agencies responsible for MPA management are the Royal Forest Department (RFD), which is responsible for marine park management, and the Department of Fisheries, which is responsible for aquatic resource management. The Marine National Park Division of the RFD is mandated to manage marine parks and implement the relevant laws and regulations (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002).

In case of closed area, PS fishing operations are generally prohibited within 3 nm from the shore, as well as within 1.5 nm around any island, which can be different in some areas depending on the announcement of provincial fisheries committee (Chumchuen, 2018). These areas are considered as the habitats for small-sized individuals or juveniles of pelagic fish which can be caught by purse seiners and trawlers.

Table 15. Implementation of yearly closed season for purse seine in Thailand.

SCS (GOT)	ANS
15 February – 15 May (Prachuap Khiri Khan, Chumphon, & Surat Thani Provinces) 16 May – 14 June (Prachuap Khiri Khan, Chumphon, & Surat Thani Provinces) 15 June – 15 August (Prachuap Kiri Khan, Petchaburi, Samut Songkram, & Samut Sakhon) 1 August – 30 September (Samut Sakhon, Bangkok, Samut Prakan, Cha Choeng Sao, & Chonburi Provinces)	1 April – 30 June (Phuket, Phang Nga, Krabi & Trang Provinces)

Source: *Purse Seine Fisheries of Thailand* (Yingyuad & Chanrachkij, 2010).

VIII) Viet Nam

According to Pham & Vu (2019), the closed season for fishing in Vietnamese waters are still under-studied, thus to date, there is no specific information. The country has 22 declared MPAs, administered and managed at the national level, through the National Marine Park Authority (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002). The examples of MPAs are Con Doa, Doa Cat Ba, Nha Trang Bay, Phu Quoc, Phu Quy Island and Ha Long Bay (Figure 64) (World Database on Protected Areas, n.d.). About 162,700 km^2 has been identified as restricted fishing area in Viet Nam (Funge-Smith, Briggs, & Miao, 2012).

Figure 64. Examples of Marine Protected Areas in Viet Nam.
Source: *An introduction of Marine Conservation in Vietnam* (Thanh, n.d.).

4. Population Parameters and Biological Information

4.1. Species composition

The species composition was generated using the catch data using PS vessels submitted by AMSs. The fish species composition showed that sardines, anchovies, Indo Pacific mackerels, round scads, neritic tunas, Indian mackerels, selar scads and hardtail scads are among dominating small pelagic fish exploited by PS in the SEA region. The rest of catch from PS was grouped into five different categories which are other pelagic species, mixed fish, trash fish, squids and crustacean.

I) Brunei Darussalam

The major pelagic species caught in Brunei Darussalam from 1996 to 2016 were sardines (27%), Indian mackerel (14%) and selar scads (10%), although other pelagic fish category dominated the catch (41%). Indo Pacific mackerel was the least dominant species, with less than one percent (Figure 65).

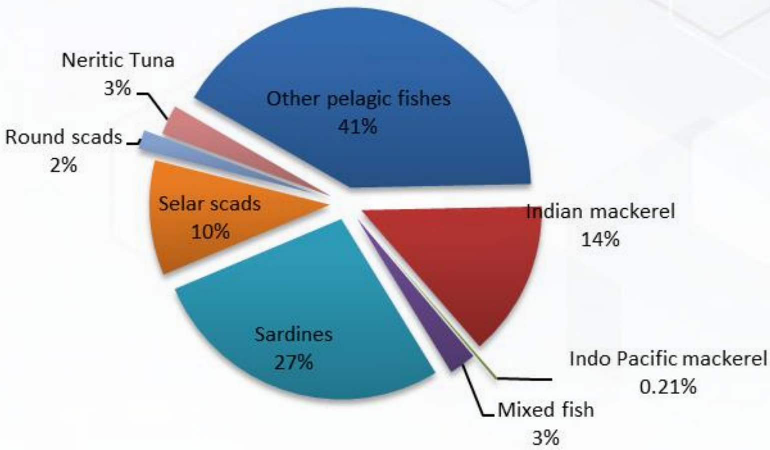


Figure 65. Species composition of pelagic fishes in Brunei Darussalam, 1996-2016.

II) Cambodia

Indian mackerel dominated 46% of pelagic fish caught in Cambodia by PS from 2003 to 2005, followed by other pelagic fish with 45%. The Indo Pacific mackerel recorded the lowest catch with less than one percent (Figure 66).

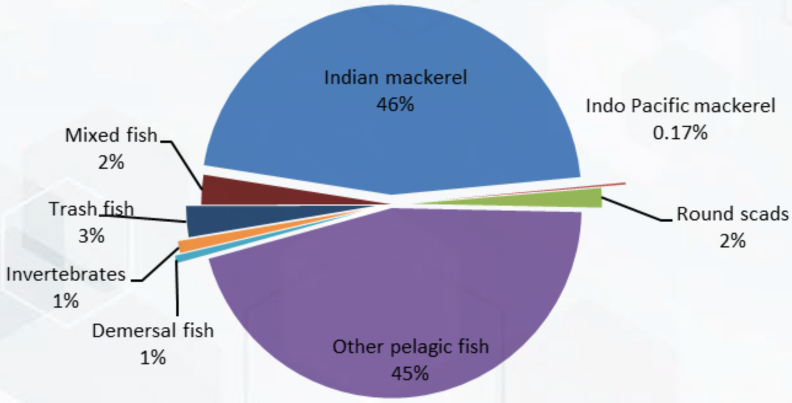


Figure 66. Species composition of pelagic fishes in Cambodia, 2003-2005.

III) Indonesia

In FMA 711 (SCS), the composition was Indo Pacific mackerel (11%), round scads (7%), Indian mackerel (1%) and selar scads (0.38%), while FMA 571 (ANS) was comprised of Indo Pacific mackerel (30%), round scads (20%) and Indian mackerel (0.45%). The other pelagic fish category is largely dominating to the species composition of pelagic fish in Indonesia water from 1996 until 2014 (Figure 67). Round scads and Indo Pacific mackerel were more evident in FMA 571(ANS) than FMA 711(SCS). Indian mackerel was more abundant in FMA 711 (SCS) than FMA 571 (ANS) though in pretty low percentage.

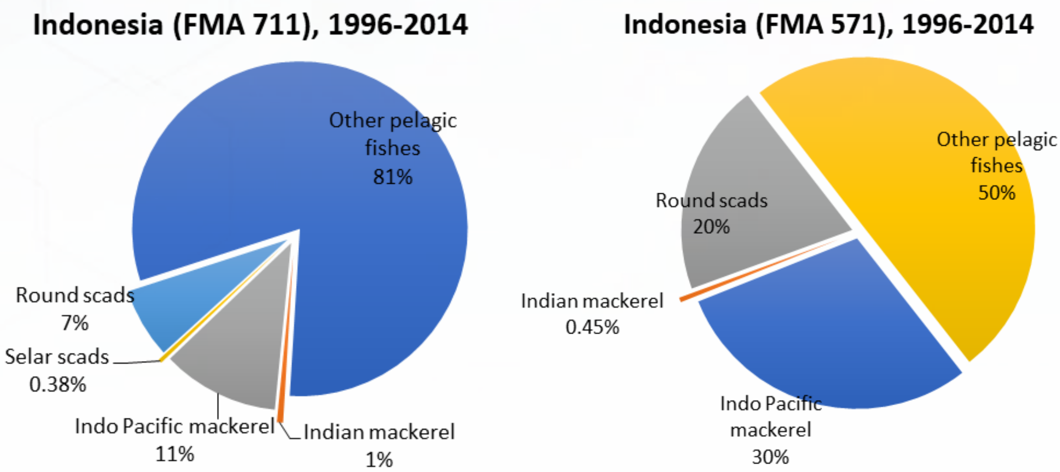


Figure 67. Species composition of pelagic fishes in Indonesia, 1996-2014.

IV) Malaysia

Figure 68 shows the species composition of pelagic fishes in Malaysia for two fishing grounds, with different time series, where SCS is from 1996 to 2016 and ANS from 2000 to 2016. The major species observed in the SCS were round scads (29%), sardines (16%) and neritic tunas (15%). Whereas in the ANS, Indo Pacific mackerel dominated the catch (27%) and followed by round scads (18%) and neritic tunas (11%). Indo Pacific mackerel was evident in ANS than SCS, while sardine was more evident in SCS. Anchovies took 3% in SCS and 5% in ANS.

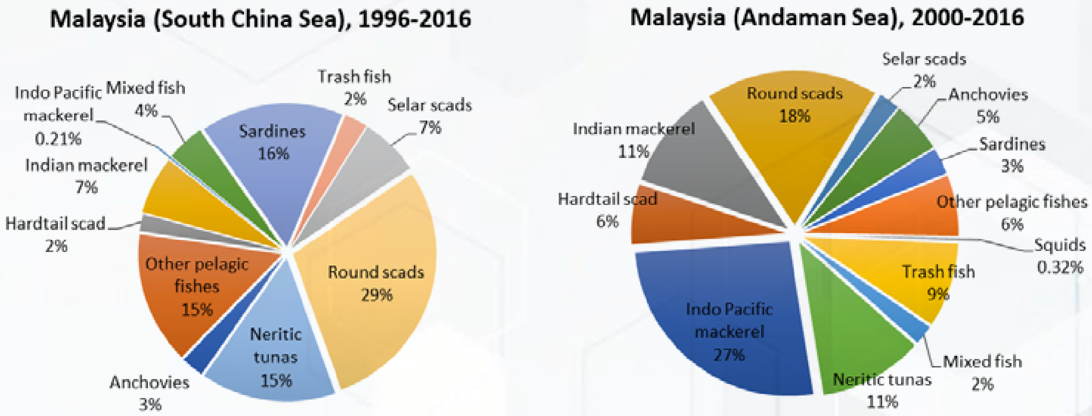


Figure 68. Species composition of pelagic fishes in Malaysia, 1996-2016 (SCS) and 2000-2016 (ANS).

V) Myanmar

The species composition of pelagic fish from PS catch in Myanmar from 2006 to 2014 is comprised of few species only, as indicated in the Figure 69. Anchovy was the most dominant species (43%), followed by other fishes (34%) and sardines (22%). The least pelagic fishes caught in Myanmar is Indian mackerel (1%).

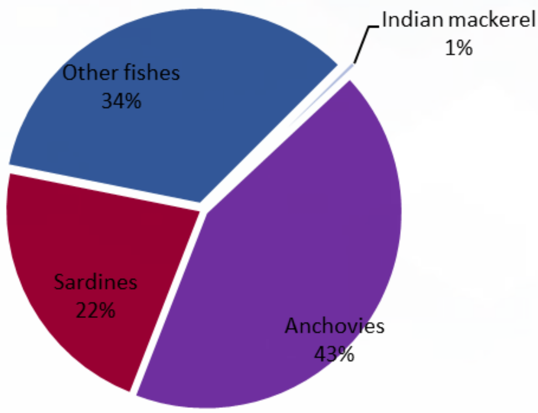


Figure 69. Species composition of pelagic fishes in Myanmar, 2006-2014.

VI) The Philippines

In the Philippines, species composition of pelagic fish is majorly comprised of neritic tunas (65%), followed by sardine (21%), other pelagic fish (6%), round scads (5%) and Indo Pacific mackerel (3%) (Figure 70). Neritic tuna fishery is well developed in the country.

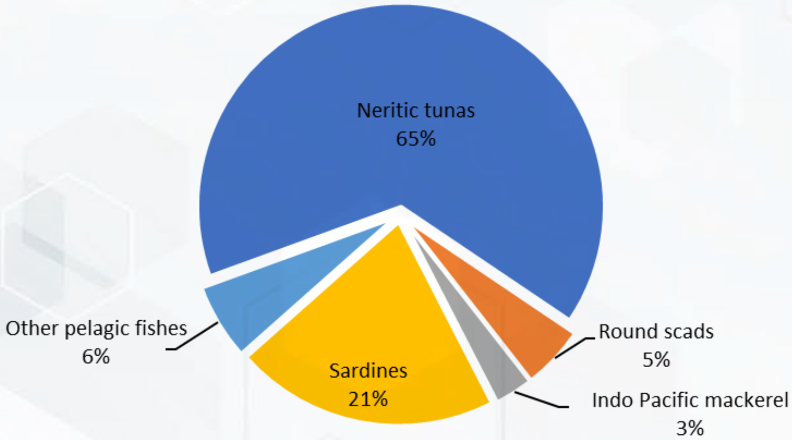


Figure 70. Species composition of pelagic fishes in The Philippines.

VII) Thailand

In general, the species composition of pelagic fishes from 1996 to 2016 is different according to the fishing area (Figure 71). Species composition of pelagic fishes in the GOT (SCS) was largely dominated by anchovies (28%), sardines (24%) and Indo Pacific mackerels (15%). The rest of the species accounted less than 7% for each species, with hardtail scads contributed the least (1%). Meanwhile, the catch in the ANS dominated by anchovies (17%), round scads (13%), Indo Pacific mackerel (11%) and sardines (11%). Selar scad was the least (2%). Round scads and hardtail scads were prominent in ANS than GOT (SCS).

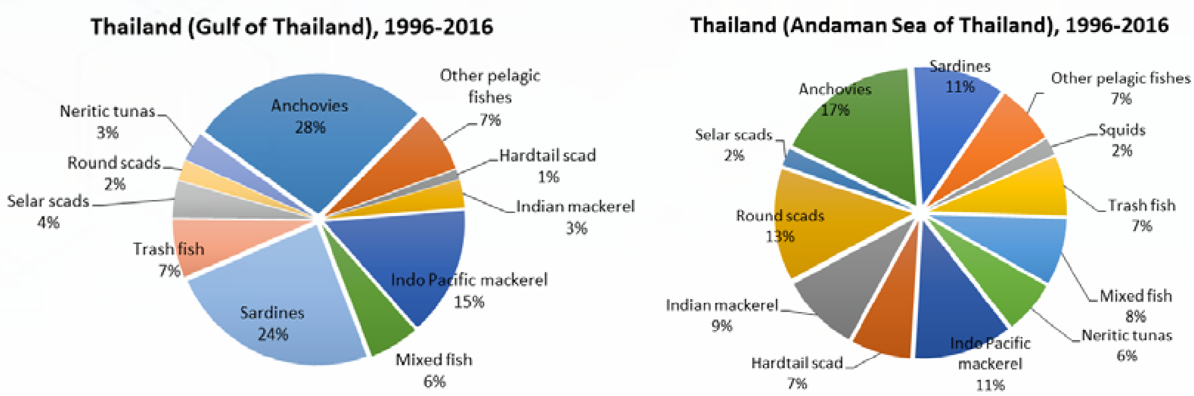


Figure 71. Species composition of pelagic fishes in Thailand, 1996-2016.

4.2. Biological information

4.2.1. Growth parameters, mortality parameters and exploitation rate

I) Brunei Darussalam

Table 16 presents the results of growth and mortality parameters of three pelagic species in Brunei Darussalam waters. The low value of K for *Decapterus* spp. ranged from 0.20 to 0.48 indicates an unusual slow growth rate for the local scads. Note the significant high values of Z (2.22 to 3.50) and F (1.60 to 3.03) indicating high fishing pressure among purse seiners in the country. The high exploitation rates E (0.72 to 0.86) indicates the overfishing of small pelagics in the country.

Table 16. Growth and mortality parameters of small pelagic species in Brunei Darussalam.

Species	Growth		Mortalities				Exploitation
	L_{oo}	K	Z	M	F	M/K	E=F/Z
Decapterus macrosoma	24.2	0.20	2.49	0.35	2.14	1.75	0.86
Decapterus maruadsi	25.5	0.32	3.50	0.47	3.03	1.47	0.86
Rastrelliger kanagurta	25.6	0.48	2.22	0.62	1.60	1.29	0.72

Source: *National Country Report for Brunei Darussalam* (Matzaini H. Juna, Ranimah H A Wahab, & Cinco, 2007).

II) Indonesia

The Indian scad (*D. russelli*) shows the decrease in mortalities parameters and exploitation rate in 2015 compared to 2005. In contrast, the shortfin scad (*D. macrosoma*) in 2015 had been highly exploited than in 2005. The bigeye scad was moderately exploited in Natuna Sea (Table 17). The recent studies reveal that overexploitation occurred for yellowstripe scad (*S. leptolepis)* in Belawan and *Rastrelliger* spp. in Malacca strait (Table 18).

Table 17. Estimation of growth and mortality parameters of few small pelagic species in FMA 711, South China Sea, Indonesia.

Species		Growth		Mortalities				Exploitation
	Year	L_{oo}	K	Z	M	F	M/K	E=F/Z
Decapterus russeli	2005[a]	22.60	1.2	4.94	2.21	2.73	1.8	0.55
	2015[b]	22.9	0.83	2.8	1.76	1.04	2.1	0.37
Decapterus macrosoma	2005[a]	21.5	1.2	4.35	2.25	2.11	1.9	0.48
	2015[b]	23.1	1.03	8.1	2.26	5.84	2.2	0.72
Selar crumenopthalmus	2015[b]	23.7	1.0	5.58	1.97	2.49	2.0	0.45

Source: [a] *National Country Report for Indonesia* (Wudianto, Suwarso, & Hariati, 2007); [b] *A Brief Notes on Small Pelagic Fish Purse Seine Fishery in Malacca Strait and Natuna Sea* (Duto, 2016).

Table 18. Estimation of growth and mortalities in Andaman Sea, Indonesia.

Species	Year	Growth		Mortalities				Exploitation	Site
		L_{oo}	K	Z	M	F	M/K	E=F/Z	
Decapterus russelli	2005[a]	25.5	1.2	4.58	2.14	2.44	1.8	0.53	Palembang
Decapterus macrosoma	2005[a]	25.0	1.2	4.35	2.25	2.11	1.9	0.48	Palembang
Selaroides leptolepis	2017[b]	18.2	1.1	4.34	1.20	3.13	1.09	0.72	Belawan
Rastrelliger brachysoma	2014[c]	19.1	1.22	13.39	2.81	10.58	2.30	0.79	Malacca Strait
Rastrelliger kanagurta	2014[c]	24.0	1.84	7.66	2.93	4.73	1.59	0.62	Malacca Strait

Source: [a] *National Country Report for Indonesia* (Wudianto, Suwarso, & Hariati, 2007); [b] *The growth and exploitation rate of yellowstripe scad (selaroides leptolepis cuvier, 1833) in the Malacca Strait, Medan Belawan Subdistrict, North Sumatera Province* (Tambun, Bakti, & Desrita, 2018); [c] *Fishery and biology of Indian mackerel (Rastrelliger kanagurta) in Indonesian BOBLME region. BOBLME-2015-Ecology-51* (BOBLME, 2015).

III) Malaysia

The study of 'Information Collection for Sustainable Pelagic Fisheries in the South China Sea (2007)' shows that the studied mackerels and scads during 2003-2005 had exploitation rate (E) of 0.5 and above, indicating overexploitation, except for Japanese scad (*D. maruadsi*) in Sabah that had rate of 0.27. The study also found that short mackerel (*R. brachysoma*) in Sarawak water had the highest exploitation rate which was 0.86. Nonetheless, the recent studies of Indian mackerel (*R. kanagurta*) and yellowtail scad (*A. mate*) in Marudu Bay, Sabah show a moderate exploitation (Table 19). On the other hand, the pelagic fish in northern Malaysia have been overexploited for many years. The latest study on neritic tuna (*E. affinis*) in 2019 shows decreased in mortality rates yet an increase in the exploitation rate (Table 20).

Table 19. Estimation of growth and mortality parameters of small pelagic in South China Sea, Malaysia.

Species	Site	Growth		Mortalities				Exploitation
		L_{oo}	K	Z	M	F	M/K	E=F/Z
Decapterus macrosoma	ECPM [a]	24.00	1.2	5.34	2.18	3.16	1.81	0.75
	Sabah [b]	21.95	0.76	1.73	0.87	0.86	1.13	0.50
Decapterus maruadsi	ECPM [a]	27.00	1.2	8.49	2.12	6.38	1.76	0.75
	Sarawak [c]	27.2	1.1	4.31	1.06	3.25	0.96	0.75
	Sabah [b]	25.0	0.51	0.51	0.65	0.14	1.27	0.27
Rastrelliger kanagurta	ECPM [a]	28.00	1.4	6.65	2.23	4.25	1.59	0.65
	Sarawak [c]	27.20	1.1	4.31	1.06	3.25	0.96	0.75
	Kota Kinabalu, Sabah [b]	29.83	0.51	3.49	1.23	2.26	2.41	0.65
	Marudu Bay, Sabah [d]	27.83	1.50	4.44	2.46	1.98	1.64	0.45
Rastrelliger brachysoma	Sarawak [c]	25.60	0.70	5.72	0.80	4.92	1.14	0.86
Atule mate	Sabah[e]	27.80	1.50	4.53	2.46	2.07	1.64	0.46

Source: [a] *National Country Report for Peninsular Malaysia* (Samsudin, 2007); [b] *National Country Report for Sabah* (Dr. Ahemad & Irman, 2007); [c] *National Country Report for Sarawak* (Hadil, 2007); [d] *Population Parameters of Rastrelliger kanagurta (Cuvier,1816) in the Marudu Bay, Sabah, Malaysia* (Amin, et al., 2014); [e] *Population Dynamics of Yellowtail Scad, Atule mate (Cuvier 1833) in Marudu Bay, Sabah, Malaysia* (Mohd Azim, Amin, Romano, Arshad, & Yusoff, 2017).

Table 20. Estimation of growth and mortalities of small pelagics in WCPM, Andaman Sea.

Species	Year	Growth		Mortalities				Exploitation
		L_{oo}	K	Z	M	F	M/K	E=F/Z
Rastrelliger brachysoma	1985 [a]	26.0	0.60	7.90	1.31	5.59	2.18	0.70
Rastrelliger kanagurta	1985 [a]	29.7	1.19	6.90	1.97	4.93	1.65	0.71
Decapterus spp.	1985 [a]	27.0	1.01	9.56	1.82	7.74	1.80	0.81
Euthynnus affinis	2015 [b]	60.4	0.26	0.80	0.33	0.47	1.26	0.59
	2018 [c]	61.3	0.22	0.75	0.30	0.47	1.36	0.61

Source: [a] *On the Status of the Rastrelliger and Decapterus Fisheries of the West Coast of Peninsular Malaysia in 1984-1985* (Mansor, 1987); [b] *Fishery, biology and population characteristics of Kawakawa in Perlis the West Coast of Peninsular Malaysia* (Sallehudin, Effarina, & Samsudin, 2016); [c] *Status of neritic tuna fishery and some biological aspects of Kawakawa (Euthynnus affinis) in the northern part of Peninsular Malaysia* (Effarina, Sallehudin, Noorul-Azliana, & Noor Hanis, 2019).

IV) Myanmar

The asymptotic length ($L\infty$) and growth co-efficient (K) for *T. ilisha* were estimated in three different study area respectively during October 2012 to September 2013 (Table 21). The asymptotic length ($L\infty$) varied from 59.85 cm to 60.90 cm. Slight variation was observed for natural mortality which ranged between 1.208 and 1.271. However, fishing mortality showed wider range from 1.873 to 2.198. The highest fishing mortality, 2.198 was observed in Sittwe while the lowest 1.873 was in Yae. The estimated exploitation rate (E) was varied from 0.596 to 0.646 in the three study areas, thus the stock of *T. ilisha* was considered to be overfished due to high value of E.

Table 21. Population parameters of *Tenualosa ilisha* in Myanmar water, from October 2012 to September 2013.

Species	Site	Growth		Mortalities				Exploitation
		L_{oo}	K	Z	M	F	M/K	E=F/Z
	Sittwe	60.90	0.8	3.464	1.266	2.198	1.58	0.635
Tenualosa ilisha	Yangon	59.85	0.74	3.415	1.208	2.207	1.63	0.646
	Yae	59.85	0.88	3.144	1.271	1.873	1.44	0.596

Source: *Stock assessment of Hilsa shad, Tenualosa ilisha in Myanmar BOBLME-2015-Ecology-22* (BOBLME, 2015).

V) The Philippines

Mortality rate for anchovies (*S. gibbosa* and *S. fimbriata*) and mackerels (*R. kanagurta* and *R. brachysoma*) in Manila Bay was higher than mortalities in other areas. Overfishing is, by far, the primary problem facing by The Philippines small pelagic fisheries. However, some small pelagic like scads (*S. crumonephthalmus*, *D. macrosoma* and *D. maruadsi*) in Tayabas Baywere moderately exploited in 2011-2013 (Table 22).

Table 22. Estimation of growth and mortality parameters of some small pelagic in different sites in the Philippines.

Species	Site	Growth		Mortalities				Exploitation
		L_{oo}	K	Z	M	F	M/K	E=F/Z
Sardinella fimbriata	Guimaras Strait [a]	22.30	0.90	2.49	1.78	0.71	1.97	0.29
	Manila Bay [b]	18.50	0.95	5.86	1.98	3.88	2.08	0.66
Sardinella gibbosa	Tayabas Bay [e]	19.54	0.77	3.04	1.7	1.34	2.20	0.44
	Manila Bay [b]	18.49	0.88	7.82	1.88	5.94	2.13	0.76
Rastrelliger kanagurta	Davao Gulf [c]	28.5	1.30	5.96	2.15	3.81	1.65	0.64
Rastrelliger brachysoma	Ragay Gulf [d]	24.50	1.28	6.09	2.16	3.93	1.68	0.65
	Manila Bay [b]	28.67	1.3	7.47	2.15	5.32	1.65	0.7
	Davao Gulf [c]	28.0	1.00	4.49	1.82	2.67	1.82	0.59
Selar crumenophthalmus	Tayabas Bay [e]	28.45	0.32	1.52	0.86	0.66	2.68	0.43
Decapterus macrosma	Tayabas Bay [e]	26.69	0.55	1.84	1.25	0.59	2.27	0.32
Decapterus maruadsi	Tayabas Bay [e]	21.71	0.9	2.37	1.83	0.54	2.03	0.23

Source: [a] *A comparative study of fish mortality rates in moderately and heavily fished areas of the Philippines* (Tandog-Edralin, Ganaden, & Fox, 1988); [b] *Fisheries Resources and Ecological Assessment of Manila Bay 2012-2015* (Santos, et al., 2017); [c] *Fish resource assessment and management recommendations for Davao Gulf* (Armada, 2004); [d] *Population parameters of commercially important fishes in Philippine waters [1985]* (Corpuz, Saeger, & Sambilay Jr., 1985); [e] *Assessment of the Tayabas Bay Fisheries* (Ramos, Mendoza, Fajardo Jr., & Lavapie-Gonzalez, 2018).

VI) Thailand

The scads and sardines in GOT (SCS) have exploitation rates exceeded 0.5 (Table 23), thus indicating overfished of the species, especially the goldstripe sardine (*S. gibbosa*) that had highest mortality rate of 9.91 and exploitation rate of 0.78. Meanwhile, in ANS, the anchovies *Encrasicholina* spp. had been overly exploited (Table 24).

Table 23. Estimation of growth and mortality parameters of small pelagic fish in Gulf of Thailand.

Species	Growth		Mortalities				Exploitation
	L_{oo}	K	Z	M	F	M/K	E=F/Z
Rastrelliger brachysoma [a]	22.0	2.5	6.12	N.A.	N.A.	N.A.	N.A.
Rastrelliger kanagurta [b]	26.98	1.6	5.32	2.56	2.76	1.60	0.52
Sardinella gibbosa [c]	21.68	1.61	9.91	2.21	7.7	1.37	0.78
Decapterus maruadsi [d]	27.75	1.01	6.43	1.89	4.54	1.87	0.71
Selar crumenophthalmus [e]	28.4	1.87	7.03	2.22	4.81	1.19	0.68

(Note: N.A = Not Available)

Sources: [a] Sinanun et al. (2012); [b] *Stock assessment of Indian mackerel (Rastrelliger kanagurta (Cuvier, 1817)) in the Gulf of Thailand* (Thongsila, Sinanun, Noranarttragoon, Boonjorn, & Khemakorn, 2012); [c] *Stock assessment of goldstripe sardinella, Sardinella gibbosa (Bleeker, 1849) resources in the Gulf of Thailand* (Boonjorn, Noranarttragoon, Sanitmajjaro, & Pankaew, 2013); [d] *Stock assessment of round scads, Decapterus maruadsi in the Gulf of Thailand* (Yamrungrueng, Leartkaitratchata, & Tes-a-sen, 2018); [e] *Stock assessment of big eye scad (Selar crumenophthalmus) in the Gulf of Thailand* (Khemakorn, Yamrungrueng, Bonjorn, & Pankaew, 2015).

Table 24. Estimation of growth and mortality parameters of anchovies in Andaman Sea, Thailand.

Species	Growth		Mortalities				Exploitation
	L_{oo}	K	Z	M	F	M/K	E=F/Z
Encrasicholina punctifer	10.8	1.85	11.35	2.9	8.45	1.57	0.74
Encrasicholina heteroloba	10.6	1.7	10.91	2.76	8.15	1.62	0.75
Encrasicholina devisi	10.54	1.8	9.59	2.88	6.72	1.60	0.70

Source: *Stock assessment of round scad, Decapterus maruadsi (Temminck & Schlegel, 1843) along the Andaman Sea Coast of Thailand* (Boonsuk, Jaiyen, Sumontha, & Nontapun, 2010).

VII) Viet Nam

The buccaneer anchovy (*E. punctifer*) in Central water and the short-mackerel (*R. brachysoma*) in Southwest water have very high mortality rate which were 7.33 and 7.75 respectively. The exploitation rate of species in Viet Nam water was in range of 0.44 to 0.78 (Table 25). The bullet tuna *A. rochei* was very overly exploited, thus some management measure should be taken in order to sustain the fish population. In overall, Southwest water was less exploited compared to other fishing grounds in Viet Nam.

Table 25. Estimation of growth and mortality parameters of small pelagic in Viet Nam, 2011-2015.

Species	Site	Growth		Mortality				Exploitation
		L∞	K	Z	M	F	M/K	E=F/Z
Decapterus maruadsi	Tonkin Gulf	27.8	0.97	3.95	1.76	2.19	1.81	0.55
	Central water	27.8	0.98	4.06	1.80	2.26	1.84	0.56
	Southeast	25.7	1.1	4.67	1.99	2.69	1.81	0.58
Rastrelliger kanagurta	Tonkin Gulf	26.8	1.2	6.36	2.08	3.15	1.73	0.50
	Central water	27.8	1.1	4.33	1.94	2.39	1.76	0.55
	Southeast	26.8	1.2	6.39	2.08	4.31	1.73	0.67
	Southwest	23.6	1.5	5.12	2.49	2.63	1.66	0.51
Rastrelliger brachysoma	Southwest	22.6	1.8	7.75	2.84	4.91	1.58	0.63
Auxis rochei	Central water	32.0	0.68	3.19	1.36	1.83	2.00	0.57
	Southeast	32.3	0.68	6.22	1.36	4.86	2.00	0.78
Auxis thazard	Southeast	45.7	0.62	2.31	1.16	1.15	1.87	0.50
Selaroides leptolepis	Southwest	16.3	1.2	4.24	2.39	1.85	1.99	0.44
Atule mate	Southwest	27.8	0.97	3.56	1.79	1.77	1.85	0.50
Encrasicholina heteroloba	Tonkin Gulf	10.5	1.5	6.22	3.07	3.15	2.05	0.51
	Southwest	8.4	1.8	6.96	3.74	3.22	2.08	0.46
Encrasicholina punctifer	Central water	11.0	1.7	7.33	3.34	3.99	1.96	0.54

Source: *Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea"* (Nghia, Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea", 2017).

4.2.2. Length at first maturity (Lm)

The length at first maturity (Lm) was determined by using UDUPA method. According to Udupa, the length at first mature varies among species and within species itself, as such that the individuals coming from one size/age class do not always achieve maturity in the same size (Udupa, 1986).

I) Brunei Darussalam

The Lm for Indian mackerel (*R. kanagurta*) was increased from 22.2 cm in 2003 to 23.1 cm in 2005 (Table 26). Meanwhile, Japanese scad (*D. maruadsi*) remained 19.2 cm in 2004 and 2005 (Department of Fisheries Malaysia, 2015a; Matzaini H. Juna, Ranimah H A Wahab, & Cinco, 2007).

Table 26. Length at first maturity of two pelagic species in Brunei Darussalam, 2003-2005.

Species	Length at first maturity, Lm (cm)		
	2003	2004	2005
Rastrelliger kanagurta	22.2	22.9	23.1
Decapterus maruadsi	N.A.	19.2	19.2

Source: *National Country Report for Brunei Darussalam* (Matzaini H. Juna, Ranimah H A Wahab, & Cinco, 2007).

II) Cambodia

The Lm of short mackerel (*R. brachysoma*) in the Cambodia water was estimated to be 15.7 cm for males and 17.0 cm for females (Table 27). The size of matured male fish were smaller size than the matured female fish (Fisheries Administration Cambodia, 2017).

Table 27. Length at first maturity of *Rastrelliger brachysoma* in Cambodia, 2004.

Sex	Length at first maturity, Lm (cm)
Female	15.7
Male	17.0

Source: *National Country Report for Cambodia* (Sereywath, 2007); *Size at first maturity and spawning season of short Mackerel Rastrelliger brachysoma (Bleeker, 1851) in coastal of Cambodia 2004* (Fisheries Administration Cambodia, 2017).

III) Indonesia

Table 28 shows the estimated Lm for three pelagic species in Natuna Sea, FMA 711(SCS). In 2014, Lm was estimated for Indian scad (*D. russelli*) as 20.3 cm and bigeye scad (*S. crumenophthalmus*) as 22.4 cm. In 2016, Lm values of three small pelagic species were estimated; Indian scad (*D. russelli*) as 17.4 cm, bigeye scad (*S. crumonephthalmus*) as 19.1 cm and short mackerel (*R. brachysoma*) as 15.0 cm. Recent publication of BOBLME project in Malacca Strait showed varied length of Lm between two species of scads (BOBLME, 2015). *R. kanagurta* was have longer Lm than *R. brachysoma*, which were 22.3 cm and 16.9 cm respectively (Table 29).

Table 28. Length at first maturity of common pelagic species in Natuna Sea, FMA 711(SCS), Indonesia.

Species	Length at first maturity, Lm (cm)	
	2014	2016
Decapterus russelli	20.3	17.4
Selar crumenophthalmus	22.4	19.1
Rastrelliger brachysoma		15.0

Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

Table 29. Length at first maturity for mackerels in Malacca Strait, ANS, Indonesia, 2014.

Species	Length at first maturity, Lm (cm)
Rastrelliger kanagurta	22.3
Rastrelliger brachysoma	16.9

Source: *Fishery and biology of Indian mackerel (Rastrelliger kanagurta) in Indonesian BOBLME region. BOBLME-2015-Ecology-51* (BOBLME, 2015).

IV) Malaysia

Table 30 presents the available information from three areas in the SCS off Malaysia waters which are ECPM, Sarawak and Sabah, while Table 31 presents the Lm for Indian mackerel in WCPM, ANS. For example, the Japanese scad (*D. maruadsi*) was recorded to attain Lm of 14.60 – 15.50 cm (female) and 16.60 – 17.50 cm (male) in ECPM, Lm of 22.7 cm (female) and 21.7 cm (male) in Sarawak, and Lm of 23.0 cm (female) and 26.0 cm (male) in Sabah. Furthermore, similar pattern was observed in shortfin scad (*D. macrosoma*) and Indian mackerel (*R. kanagurta*) where smaller size of those species was found in ECPM than in Sarawak and Sabah waters.

Table 30. Length at first maturity of common pelagic species in SCS, Malaysia waters.

Species	Sex	Length at first maturity (cm)		
		ECPM [a]	SARAWAK [b]	SABAH [c]
Decapterus maruadsi	F	14.60 – 15.50	22.67	23.0
	M	16.60 – 17.50	21.72	24.6
Decapterus macrosoma	F	15.50 – 16.30	19.50	20.2
	M	15.60 – 18.50	12.81	20.5
Decapterus russeli	F	NA	11.44	NA
	M		12.98	
Rastrelliger brachysoma	F	NA	22.46	NA
	M		22.46	
Rastrelliger kanagurta	F	18.30 - 18.40	18.50	26.3
	M	19.40 – 23.30	21.20	28.4

Sources: [a] *Country Report: Malaysia - East Coast of Peninsular Malaysia* (Sallehudin, 2019); [b] *Country Report: Malaysia - West Coast of Peninsular Malaysia* (WCPM) (Abdul-Wahab, Country Report: Malaysia - West Coast of Peninsular Malaysia (WCPM), 2019); [c] *National Country Report for Sabah* (Dr. Ahemad & Irman, 2007).

As indicated in the Table 31, the size of maturity for Indian mackerel (*R. kanagurta*) is varied in ANS, depending on the research year.

Table 31. Length at first maturity of *Rastrelliger kanagurta* in ANS, Malaysia waters.

Rastrelliger kanagurta	**Length at first maturity, Lm (cm)**
Male/Female	20.60 [a]
Male/Female	18.0-19.0 [b]
Male	22.80 - 23.20 [c]
Female	23.20 - 23.80 [c]

Source: [a] *Population Structure of Small Pelagic Fishes off the East Coast Peninsular Malaysia* (Mansor, Syed Abdullah, & Abdul Hamid, Population Structure of Small Pelagic Fishes off the East Coast Peninsular Malaysia, 1996); [b] *West Coast of Peninsular Malaysia : Acoustic, Fishery Oceanography and Bottom Substrate Surveys* (Abu Talib, Alias, & Mazalina, West Coast of Peninsular Malaysia : Acoustic, Fishery Oceanography and Bottom Substrate Surveys, 2009); [c] *Country Report: Malaysia - West Coast of Peninsular Malaysia* (WCPM) (Abdul-Wahab, Country Report: Malaysia - West Coast of Peninsular Malaysia (WCPM), 2019).

V) The Philippines

Table 32 presents the Lm for goldstripe sardinella (*S. gibbosa*), fringescale sardinella (*S. fimbriata*) and Indian mackerel (*R. kanagurta*) in Manila Bay. The mackerel was found to mature at the length of 24.5 cm (female) and 25.5 cm (male).

Table 32. Length at first maturity of some commercially pelagic species in the Manila Bay, the Philippines waters.

Species	Length at first maturity, Lm (cm)	
	F	M
Sardinella gibbosa	13.25	12.75
Sardinella fimbriata	12.75	12.25
Rastrelliger kanagurta	24.50	25.50

Source: *Country Presentation on Purse Seine Management in the Philippines* (Romero & Lopez, 2018).

VI) Thailand

The information in (Table 33) is shown by sex (male and female) and fishing grounds (GOT and ANS). However, the information of some species, including frigate tuna (*A. thazard*) and kawakawa (*E. affinis*) in GOT was not available. On the other hand, the Lm of buccaneer anchovy (*E. punctifer*) in GOT is only available for mixed-sex.

Table 33. Length at first maturity of some commercially important pelagic species in Thailand waters.

Species	Sex	Length at first maturity (cm)	
		GOT	ANS
Rastrelliger brachysoma	M	16.45[a]	16.09[a]
	F	17.95[a]	15.33[a]
Rastrelliger kanagurta	M	20.07[a]	17.83[a]
	F	17.12[a]	18.92[a]
Sardinella gibbosa	M	NA	12.27[c]
	F	10.35[b]	13.12[c]
Decapterus maruadsi	M	14.31[d]	15.92[e]
	F	13.19[d]	15.66[e]
Auxis thazard	M	NA	26.57[f]
	F	NA	28.88[f]
Euthynnus affinis	M	NA	37.74[f]
	F	NA	39.71[f]
Encrasicholina punctifer	M	6.51[g]	6.19[h]
	F		6.47[h]
Encrasicholina heteroloba	M	NA	6.09[h]
	F	7.49[h]	6.44[h]
Encrasicholina devisi	M	NA	6.44[h]
	F	7.81[i]	7.21[h]

Notes: GOT: Gulf of Thailand; ANS: Andaman Sea; M: Male; F: Female; NA: Not available

*Total length was measured; **Fork length was measured

Sources: [a] *Reproductive biology of short mackerel Rastrelliger brachysoma (Bleeker, 1851) and Indian mackerel R. kangurta (Cuvier, 1816)* (Krajangdara, Puntuleng, Chalee, & Hussadee, 2007); [b] *Reproductive biology of goldstripe sardinella (Sardinella gibbosa (Bleeker, 1849)) in the Gulf of Thailand* (Nasuchon, Puttharaksa, Sritakon, & Hussadee, 2010); [c] *Reproductive biological of goldstripe sardinella, Sadinella gibbosa (Bleeker,1894) in the Andaman Sea of Thailand* (Krajangdara & Chalee, 2004); [d] *Reproductive biology of round scad Decapterus maruadsi (Temminck & Schlegel, 1843) in the Gulf of Thailand* (Hussadee, Khongchai, Suppanirun, Charoensombat, & Khrueniam, 2015); [e] *Reproductive biology of round scad, Decapterus maruadsi (Timminck & Schlegel, 1842) and shortfin scad, D. macrosoma Bleeker, 1851, in the Andaman Sea of Thailand* (Supongpan, Karajangdara, & Chalee, 2003); [f] *Reproductive biology of frigate tuna (Auxis thazard (Lacepède, 1800)) and eastern little tuna (Euthynnus affinis (Cantor, 1849)) in the Andaman Sea Coast of Thailand* (Yakoh, Kongprom, & Kawmanee, 2016); [g] *Anchovy fisheries in the Gulf of Thailand* (Sinanun, Sinanun, Noranarttragoon, Boonjorn, & Tossapornpittakul, 2012),); [h] *Reproductive biology of anchovies (Encrasicholina punctifer, E. heteroloba and E. devisi) in the Andaman Sea Coast of Thailand* (Yakoh, Leartkaitratchata, & Tes-a-sen, 2014); [i] *Anchovy falling net with light luring fisheries and reproductive biology of the shot head anchovy in the Middle Gulf of Thailand, 2002* (Nasuchon & Puntuleng, 2005).

VII) Viet Nam

The Indian mackerel (*R. kanagurta*) matured at similar sizes in all fishing grounds ranging from 18.3 cm to 18.9 cm, except in Southwest in which the mackerel attained maturity at smaller size, 16.4 cm. The Lm for other pelagic fishes including scads, neritic tunas, anchovies and selar were indicated in the Table 34.

Table 34. Length at first maturity of small pelagic species in Viet Nam, 2014-2015.

Fish group	**Species**	**Length at first maturity (cm)**			
		Tonkin Gulf	**Central water**	**Southeast**	**Southwest**
Mackerels	*Rastrelliger kanagurta*	18.3	18.2	18.9	16.4
	Rastreliger brachysoma				14.5
Scads	*Decapterus maruadsi*	17.3	19.8	16.4	
Neritic tunas	*Auxis rochei*		21.6	21.6	
	Ausxis thazard			30.5	
Anchovies	*Encrasicholina heteroloba*	6.1			4.9
	Encrasicholina punctifer		5.3		
Selar	*Selaroides leptolepis*				9.8
	Atule mate				16.8

Source: *Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea"* (Nghia, Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea", 2017).

4.2.3. Spawning season

Fish are sensitive to sea water temperature to inhabit in the area and then breeding. Thus it leads to different time of spawning for same species. A number of fish have early reproduction age, one-year-old fish can reproduce, and most of fish reproduce many times in a year. The spawning season is estimated using the Gonado Somatic Index (GSI) and the percentage of maturity. Some spawning season lasts for long time, most of fish spawn during the monsoon season which coincides with rainy season when the seawater temperature is high, salinity is low, and phytoplankton is abundant to feed by small fishes in the initial growth period. The mainly breeding grounds are the near shore areas, especially in large estuaries.

I) Brunei Darussalam

The GSI value fluctuated from 0.01 to 3.8. The peak of gonad maturation is during the month of July. There are three cycles of gonadal maturation namely in April, July, and November, in which the local knowledge of spawning period of three small pelagic species were stated in Table 35. The spawning areas are found in all fishing zones in the Brunei Darussalam waters (Figure 72).

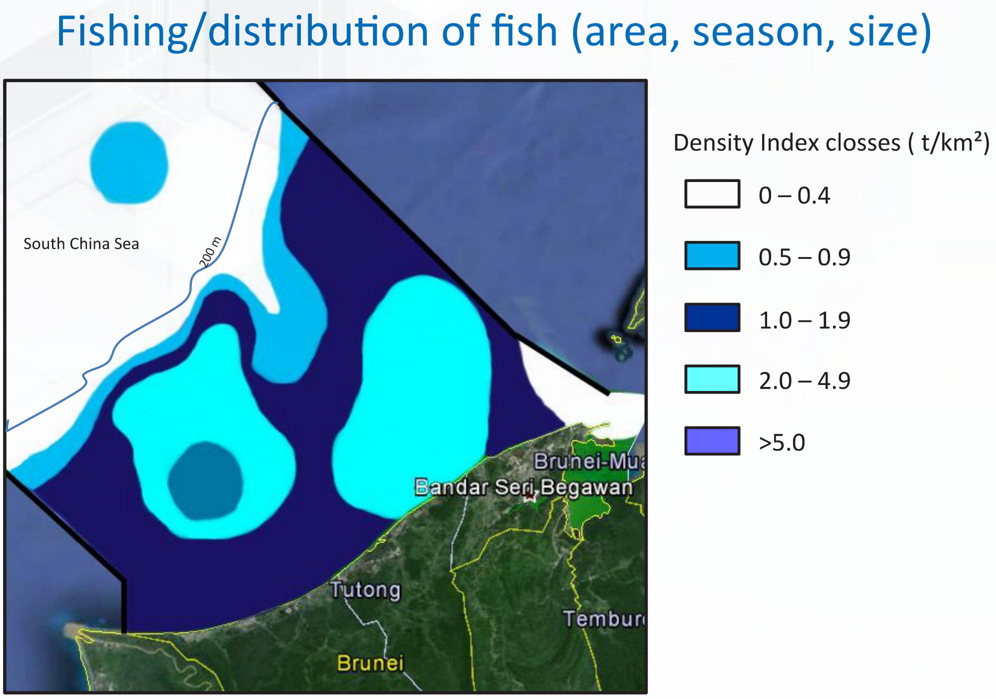


Figure 72. Spawning area in Brunei Darussalam.

Table 35. The local knowledge of spawning season for three small pelagic species in Brunei Darussalam.

Species	Major spawning
Rastrelliger kanagurta	July-August [a]
	October-December [b]
Decapterus maruadsi	October-December [a,b]
Decapterus macrosoma	March, May –July [a]

Source: [a] *National Country Report for Brunei Darussalam* (Matzaini H. Juna, Ranimah H A Wahab, & Cinco, 2007);[b] *Country Report for Brunei Darussalam* (Matzaini, 2013).

II) Cambodia

Table 36 presents the local knowledge on short mackerel *(R. brachysoma*) which shows that spawning occurs throughout the year with peaks from February to May (Fisheries Administration Cambodia, 2017).

Table 36. The spawning season for mackerel in Cambodia.

Species	Major Spawning	Minor Spawning	Fishing Ground
Rastrelliger brachysoma	February-May [a]		Sihanoukville & Kampot
	January-March	May-June [b]	Sihanoukville
	February-April	July [b]	Kampot
Rastrelliger kanagurta	January-March [c]		Sihanoukville

Source: [a] *Size at first maturity and spawning season of short Mackerel Rastrelliger brachysoma (Bleeker, 1851) in coastal of Cambodia* (Fisheries Administration Cambodia, 2017); [b] *National Country Report for Cambodia* (Sereywath, 2007); [c] *The Report for the Purse Seine Fishery in Cambodia* (Chea, 2016).

III) Indonesia

The spawning season for Indian scad (*D. russelli*) is estimated in mid-year, which is from July to September in Natuna Sea (SCS) (Table 37) while from April to October in Malacca Strait, ANS (Table 38). The shortfin scad (*D. macrosoma*) and bigeye scad (*S. crumenopthalmus*) spawn after mid-year in Natuna Sea (SCS). For Indian mackerel (*R. kanagurta*), August to November was spawning season in Natuna Sea (SCS), however it spawns almost year-round in Malacca Strait, ANS except in month of April and November.

Table 37. The estimated spawning season for few small pelagic species in Natuna Sea (SCS).

Species	Major Spawning	Minor Spawning
Decapterus russelli	March - June July	August – September [a,b]
Decapterus macrosoma	April – June May- November [c]	August - November[a]
Rastrelliger kanagurta	August – November [a]	
Selar crumenopthalmus	August – November [a,b] after May [d]	

Sources: [a] *Biological reproduction and estimation of spawning season for small pelagic fish in the South China Sea* (Suwarso, Zamroni, & Wudianto, 2008); [b] *Population dynamics on round scad in Natuna Sea* (Fauzi, Suwarso, & Zamroni, 2015); [c] *Study on the reproduction of "layang deles" shortfin scad (Decapterus macrosoma) in the Java Sea* (Atmaja & Sadhotomo, 2005); [d] *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto, & Asep, 2018).

Table 38. The spawning season in Malacca Strait (ANS).

Species	Major Spawning	Minor Spawning
Decapterus russelli	April - October	-
Rastrelliger kanagurta	May-October	December-March

Source: *A Brief Notes on Small Pelagic Fish Purse Seine Fishery in Malacca Strait and Natuna Sea* (Duto, 2016); *Some Reproduction Aspects of Roundscads (Decapterus ruselli) and Mackerel (Rastrelliger kanagurta) in Malacca Strait* (Hariati, Taufik, & Zamroni, 2005).

IV) Malaysia

Some small pelagic species shows different spawning time, as stated in Table 39 for SCS and Table 40 for ANS. The Japanese scad (*D. maruadsi*) spawned twice in a year at all sub-areas, which the spawning starts in March and July. However, the length of spawning time is differed, for example Japanese scad in ECPM has long spawning time which is from March to August, but in Sarawak, the species has shorter time which is only in May and Jun. Similar observations occurred for other species. The shortfin scad (*D. macrosoma*) spawned twice a year in SCS area, where the first spawning season ended in March. Samsudin (2007) and Hadil (2007) reported that in SCS, the spawning season of Indian mackerel (*R. kanagurta*) occurred twice a year (May to June, and July to September) but in the southern sub-area of SCS, the spawning season occurred only once in a year. The study also reported that spawning season of these three species occurred during the southeast monsoon from December to March, with spawning strategy is to match the calm and productive coastal water nursery area post-monsoon for the survival of the progenies.

Table 39. The estimated spawning season for species in SCS, Malaysia.

Species	Major Spawning	Minor Spawning	Fishing Ground
Decapterus maruadsi	March [a]	July [a]	ECPM
	May-June [a,b,c]		Sarawak
Decapterus macrosoma	March-May [a]	July-August [a]	ECPM
	September-October [b,c]		Sarawak
Rastrelliger kanagurta	May-June [a]	July- September [a]	ECPM
	July-September [a,c]		Sarawak
Rastrelliger brachysoma	September-October [a]		Sarawak

Source: [a] *National Country Report for Peninsular Malaysia* (Samsudin, 2007); [b] *National Country Report for Sarawak* (Hadil, 2007); [c] *Country Presentation on Purse Seine Fisheries in Sarawak* (Jamil, 2018).

Table 40. The estimated spawning season in ANS, Malaysia.

Species	Major Spawning	Minor Spawning
Rastrelliger kanagurta	September – February [a]	October – April [b]

Source: [a] *Country Report: Malaysia - West Coast of Peninsular Malaysia* (WCPM) (Abdul-Wahab, Country Report: Malaysia - West Coast of Peninsular Malaysia (WCPM), 2019).; [b] *Observations on the gonad maturity stages of female Rastrelliger kanagurta (Cuvier)* (Pathansali D., 1967).

V) Myanmar

The entire fisheries is closed during June, July and August to allow spawning and recruitment. All fishing activities are banned during spawning season. Thus, it can be estimated that many species in Myanmar spawn during this closing time, included the Hilsa scad (*T. ilisha*) that is very important pelagic fish in Myanmar (Table 41). This anadromous fish migrates from sea through the river system, particularly, the Ayeyarwady river complex, to the spawning ground (estuaries and rivers), therefore these grounds become closed area for fishing from June to August.

Table 41. The spawning time for Hilsa scad.

Species	Major Spawning	Fishing Ground
Tenualosa ilisha	June - August	Rakhine

Source: *Country Presentation: Purse Seine Fishery in Myanmar* (Kyaw, 2018).

VI) The Philippines

The three studied small pelagic fishes in Manila Bay seem to spawn twice a year. The sardines were observed to spawn at the beginning months of the year and at the end months of the year. Moreover, Indian mackerel (*R. kanagurta*) spawns during mid-year and late months of the year (Table 42).

Table 42. The spawning season for few small pelagic species in Manila Bay.

Species	Major Spawning	Minor Spawning
Sardinella gibbosa	March - April	October – December
Sardinella fimbriata	February - May	October - December
Rastrelliger kanagurta	October – December	May - June

Source: *Fisheries Resources and Ecological Assessment of Manila Bay 2012-2015* (Santos, et al., 2017).

VII) Thailand

Spawning seasons of important commercial fishes in Thailand are shown in Table 43 for GOT (SCS) and Table 44 for ANS. The fish can spawn all year round; however, each species has the peak of its spawning time. There are slight differences in the peak of spawning time for each species between GOT (SCS) and ANS. For example, the short mackerel (*R. brachysoma*) is estimated to mostly spawn from February to May in GOT (SCS) while it is from November to May in ANS, and the second spawning occurs from July to October in GOT while from July to September in ANS. In addition, the number of spawning time for same species also differs in different areas, for example, the scads (*D. maruadsi* and *S. crumenophalmus*) spawn twice in GOT (SCS) but spawn once in ANS. Some species spawns only once, like those anchovy species (*E. punctifer*, *E. heteroloba* and *E. devisi*) in ANS. Some spawns twice a year, observed in many species in Thai water. Some species spawn several times during a year, like Indian mackerel (*R. kanagurta*) in GOT (SCS) and goldstripe sardinella (*S. gibbosa*) in ANS.

Table 43. The estimated spawning season for five small pelagic species in GOT, SCS.

Species	Major Spawning	Minor Spawning
Rastrelliger brachysoma	February – May	July – October [a]
Rastrelliger kanagurta	January – March	May, July, Sept, Nov [a]
Sardinella gibbosa	March- December [b]	
Decapterus maruadsi	January – March	May – July [c]
Selar crumenopthalmus	March – June	October – November [d]

Sources: [a] *Reproductive biology of short mackerel Rastrelliger brachysoma (Bleeker, 1851) and Indian mackerel R. kangurta (Cuvier, 1816)* (Krajangdara, Puntuleng, Chalee, & Hussadee, 2007); [b] *Reproductive biology of goldstripe sardinella (Sardinella gibbosa (Bleeker, 1849)) in the Gulf of Thailand* (Nasuchon, Puttharaksa, Sritakon, & Hussadee, 2010); [c] *Reproductive biology of round scad Decapterus maruadsi (Temminck & Schlegel, 1843) in the Gulf of Thailand* (Hussadee, Khongchai, Suppanirun, Charoensombat, & Khrueniam, 2015); [d] *Reproductive biology of bigeye scad (Selar crumenopthalmus (Bloch, 1793)) in the Gulf of Thailand* (Puttharaksa, Nasuchon, Kongchai, & Pinputtasin, 2008).

Table 44. The spawning season for ten small pelagic species in ANS.

Species	Major Spawning	Minor Spawning
Rastrelliger brachysoma [a]	November – May	July- September
Rastrelliger kanagurta [a]	December - March	August -September
Sardinella gibbosa [b]	April - June	Aug, Sept, Nov, Jan
Decapterus maruadsi [c]	December – February	
Auxis thazard [d]	January - March	August- November
Euthynnus affinis [d]	January- March	October – December
Selar crumenopthalmus [e]	September	
Encrasicholina punctifer [f]	January	
Encrasicholina heteroloba [g]	July	
Encrasicholina devisi [f]	June	

Sources: [a] *Reproductive biology of short mackerel Rastrelliger brachysoma (Bleeker, 1851) and Indian mackerel R. kangurta (Cuvier, 1816)* (Krajangdara, Puntuleng, Chalee, & Hussadee, 2007); [b] *Reproductive biological of goldstripe sardinella, Sadinella gibbosa (Bleeker,1894) in the Andaman Sea of Thailand* (Krajangdara & Chalee, 2004); [c] *Reproductive biology of goldstripe sardinella (Sardinella gibbosa (Bleeker, 1849)) in the Gulf of Thailand* (Nasuchon, Puttharaksa, Sritakon, & Hussadee, 2010); [d] *Reproductive biology of round scad, Decapterus maruadsi (Timminck & Schlegel, 1842) and shortfin scad, D. macrosoma Bleeker, 1851, in the Andaman Sea of Thailand* (Supongpan, Karajangdara, & Chalee, 2003); [e] *Reproductive biology of bigeye scad (Selar crumenophthalmus (Bloch, 1793)) in the Andaman Sea coast of Thailand* (Chalee & Yakoh, 2013); [f] *Reproductive biology of anchovies (Encrasicholina punctifer, E. heteroloba and E. devisi) in the Andaman Sea coast of Thailand* (Yakoh, Leartkaitratchata, & Tes-a-sen, 2014); [g] *Reproductive biology of shorthead anchovy Encrasicholina heteroloba off Rayong Coast, the Gulf of Thailand* (Munprasit, 1996).

VIII) Viet Nam

Table 45 shows that Indian mackerel (*R. kanagurta*) spawns during February to May in Tonkin Gulf water which located at far north, March to May and September to October in Central water, February to July in Southeast water and June to August in Southwest water in the south. These findings could suggest that the spawning season for the mackerel in the northern water happens earlier than the southern water of Viet Nam.

Table 45. The spawning season for small pelagic species in different area in Viet Nam.

Species	Major Spawning	Minor Spawning	Fishing Ground
Rastrelliger brachysoma	February -April	August - October	Southwest
Rastrelliger kanagurta	February - May	September - October	Tonkin Gulf
	March - May		Central water
	February - July		Southeast
	June - August		Southwest
Decapterus maruadsi	March – May		Central water
	February - July		Southeast
Auxis rochei	July – August	April – May	Central water
	February - July		Southeast
Auxis thazard	February - July		Southeast water
Encrasicholina heteroloba	June - August	October - November	Tonkin Gulf
Selaroides leptolepis	January - May		Southeast

Source: *Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea"* (Nghia, Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea", 2017).

5. Existing Information on Pelagic Fisheries Resources

There are two types of data used in stock assessment, namely fishery-dependent data and fishery-independent data. The fishery-dependent data (FDD) require a long historical data i.e more than a decade period. The information is collected from the fishers of the commercial vessels and involves information of the total amount of fish removed from the ocean (catch and landings) and the level of fishing pressure (effort). On the other hand, the fishery-independent data (FID) usually involves the research vessels and chartered boats, and uses swept area methods in assessing the stock of demersal species and an acoustic survey for assessing the pelagic stocks (Sparre & Venema, 1992). The fishery-dependent data coupled with data from fishery independent surveys will provide a more accurate picture of stock status. All these methods of data collection have been widely used to assess the pelagic resources in the SEA region since 1970s.

At present, acoustics survey is used as the method of choice in assessing the pelagic fish stocks around the world. The acoustics method can be used to estimate the density of pelagic fish, by transmitting sound waves of a certain frequency (commonly 38 kHz) into the water column, and then measuring the reflected (backscattered) sound energy. The mean fish density per area is further multiplied with the size of the area surveyed, to calculate abundance. Several books such as MacLennan and Simmonds (1992) described the technique in details.

5.1. Brunei Darussalam

5.1.1. Existing Assessment

The first pelagic acoustic survey was conducted in 1989 to assess the pelagic stock, its status and potential for development, since prior to the survey, a few purse-seiners had been licensed using extrapolation from the neighbouring countries. The results from that first survey were being used for the existing pelagic development programme by the DOF Brunei Darussalam (Salleh, 1997). The next acoustic survey was done in 1996-1997. In addition, there was three (3) stock assessment surveys carried out in 1990, 2000 and 2006 to assess the fish stock in Brunei Darussalam (Noorizan & Nur-Aqilah, n.d.).

5.1.2. Biomass and Maximum Sustainable Yield (MSY)

The results from 1989 survey were listed in Table 46 although it was admitted to be preliminary as it was based on a single pelagic acoustic survey which may conceivably have missed the considerable seasonal fluctuation in abundance characteristic of small pelagics. The continental shelf waters were estimated to have 15,415 MT biomass of small pelagics (Silvestre, Matdanan, Sharifudin, De Silva, & Chua, 1992). However, the findings from 1990-2006 surveys revealed that the fish stock is continuously declining.

Based on the 2001-2013 annual catch and fishing effort data, the potential yield (MSY) of PS fisheries of Brunei Darussalam is estimated to be 888.65 MT. Meanwhile, the optimum fishing effort is estimated to be seven (7) unit of PS by using both Schaefer and Fox models (Figure 73) (Noorizan & Nur-Aqilah, n.d.). It was also observed that the Y/F ratio (yield per unit fishing effort ratio) tends to decline after every increase in the number of fishing units operating. There are few factors contributed to this situation such as overfishing by trawling activities and deteriorating of the demersal resources which in turn affected the pelagic resources due to their trophic relationship.

Table 46. The estimation of small pelagic biomass in the continental shelf waters of Brunei Darussalam, 1989.

Genera/group	Biomass (MT)	Relative abundance (%)
Dussumieria spp.	3,705	24.0
Carangoides spp.	3,580	23.2
Decapterus spp.	3,230	21.0
Ariomma spp.	2,550	16.5
Selar spp.	1,400	9.1
Rastrelliger spp.	270	1.8
Others	680	4.4
TOTAL	15,415	

Source: *The Coastal Resources of Brunei Darussalam: Status, Utilization and Management* (Silvestre, Matdanan, Sharifudin, De Silva, & Chua, 1992).

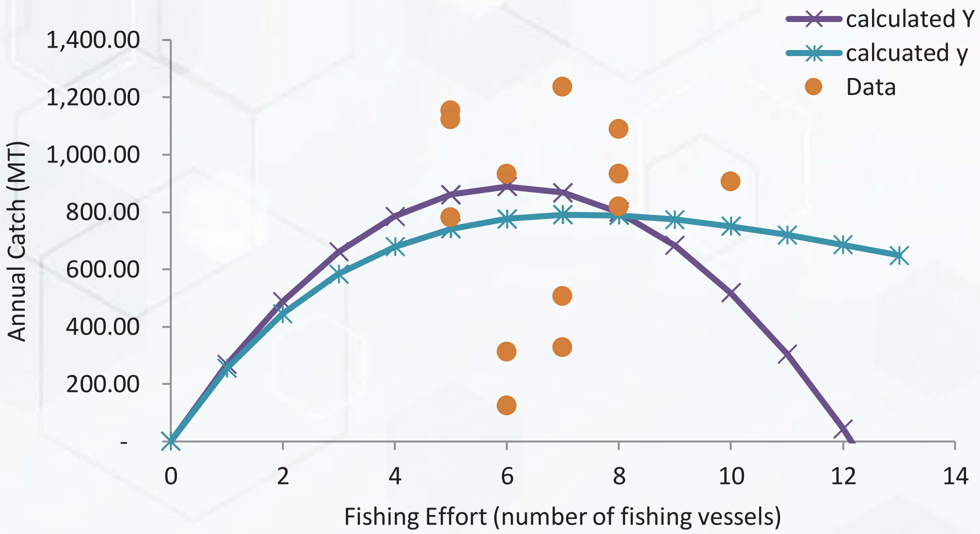


Figure 73. The MSY of PS fisheries using the number of vessels as standard fishing effort in Brunei Darussalam, 2001-2013.
Source: *The Purse Seine Fisheries in Brunei Darussalam* (Noorizan & Nur-Aqilah, n.d.)

5.2. Cambodia

5.2.1. Existing Assessment

Cambodia had evaluated the mackerels (*Rastrelliger* spp.) resource in 2007 using catch and effort data from 1992-2006 to estimate the MSY and determine the optimal utilisation of the mackerel fishery. The estimation of maximum economic and sustainable yield (MEY-MSY) is based on the steady-state relationship between resource stock size, fishing effort, and yield, adapted from Schaefer (1957) and Fox (1970). This methodology is widely known as bioeconomic modelling (Puthy & Kristofersson, 2007).

5.2.2. Biomass and Maximum Sustainable Yield (MSY)

The estimated MSY from mackerel study was equal to 5,876 thousand MT with an optimum level of fishing effort corresponding to approximately 152 unit of PS (Chea & Chhuon, Purse Seine Fishery in Cambodia, n.d.). According to both models, the effort level already surpassed the fMSY in 2005 (254 boats) and the yield was below MSY (Figure 74). In Cambodia, the actual mackerel fish biomass is not known but the virgin stock biomass was estimated at 15,467 MT. Both Schaefer and Fox models indicated the optimal biomass is higher than the current status of the mackerel fishery (Table 47). The results also indicate that the fishers were unlikely to leave fishing, more and more fishers will enter the fishery (unless other than more profitable opportunities are available to them), this will eventually lead to overexploitation of fisheries resource (Puthy & Kristofersson, 2007).

Table 47. Main results from estimation of the mackerel fisheries.

Categories	**Unit**	**Current**		**Optimal**		**Difference**	
		Schaefer	**Fox**	**Schaefer**	**Fox**	**Schaefer**	**Fox**
Biomass	1000 MT	4.2	9.7	8.8	9.0	4.6	−0.7
Harvest	1000 MT	4.7	4.7	5.8	5.0	1.1	0.4
Effort	Boat	187	187	143	213	0.0	0.0
Profits	m. US$	1.082	1.082	2.004	1.099	0.920	0.017
Rents	m. US$	1.158	1.158	2.080	1.176	0.922	0.017

Source: *Marine fisheries resource management potential for mackerel fisheries of Cambodia* (Puthy & Kristofersson, 2007).

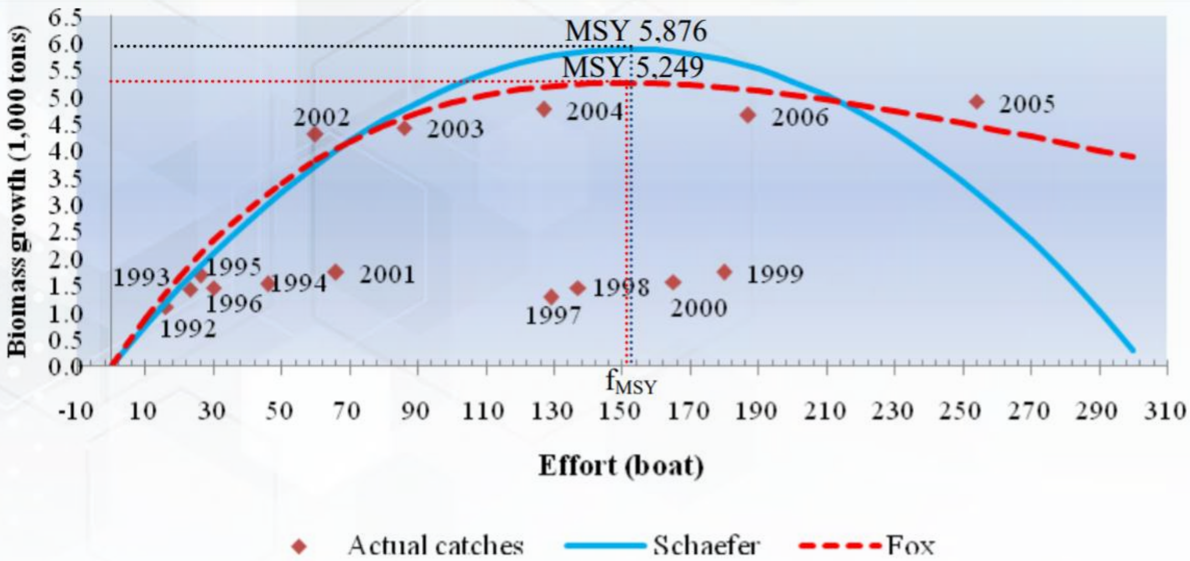


Figure 74. The maximum sustainable yield and actual catch of mackerel, 1992-2006.
Source: *Marine fisheries resource management potential for mackerel fisheries of Cambodia* (Puthy & Kristofersson, 2007).

5.3. Indonesia

5.3.1. Existing Assessment

In 2011 and 2013, a regular data collection through in-house research on enumeration program was carried out to get a quick result to estimate the pelagic fish biomass. Surplus production models were applied to estimate the stock status in all 11 FMAs (Research Institute for Marine Fisheries, 2013; Ministry of Maritime Affairs and Fisheries, 2011; Suwarso & Duto, n.d.). Next, recently in May 2016, an acoustic survey was conducted to assess the status of the pelagic fish resource in FMA 711 using research vessel MV.Madidihang 02 that was equipped with portable scientific echosounder SIMRAD EK 80 with a side mounted transducer. Raw data of acoustic was collected within 30 days from 42 stations, covered from 5 to 150 m depth (Figure 75) which were then analyzed by SONAR software version 5. These analyzed data then coupled with length-data from the land-based survey to estimate the pelagic fish stock.

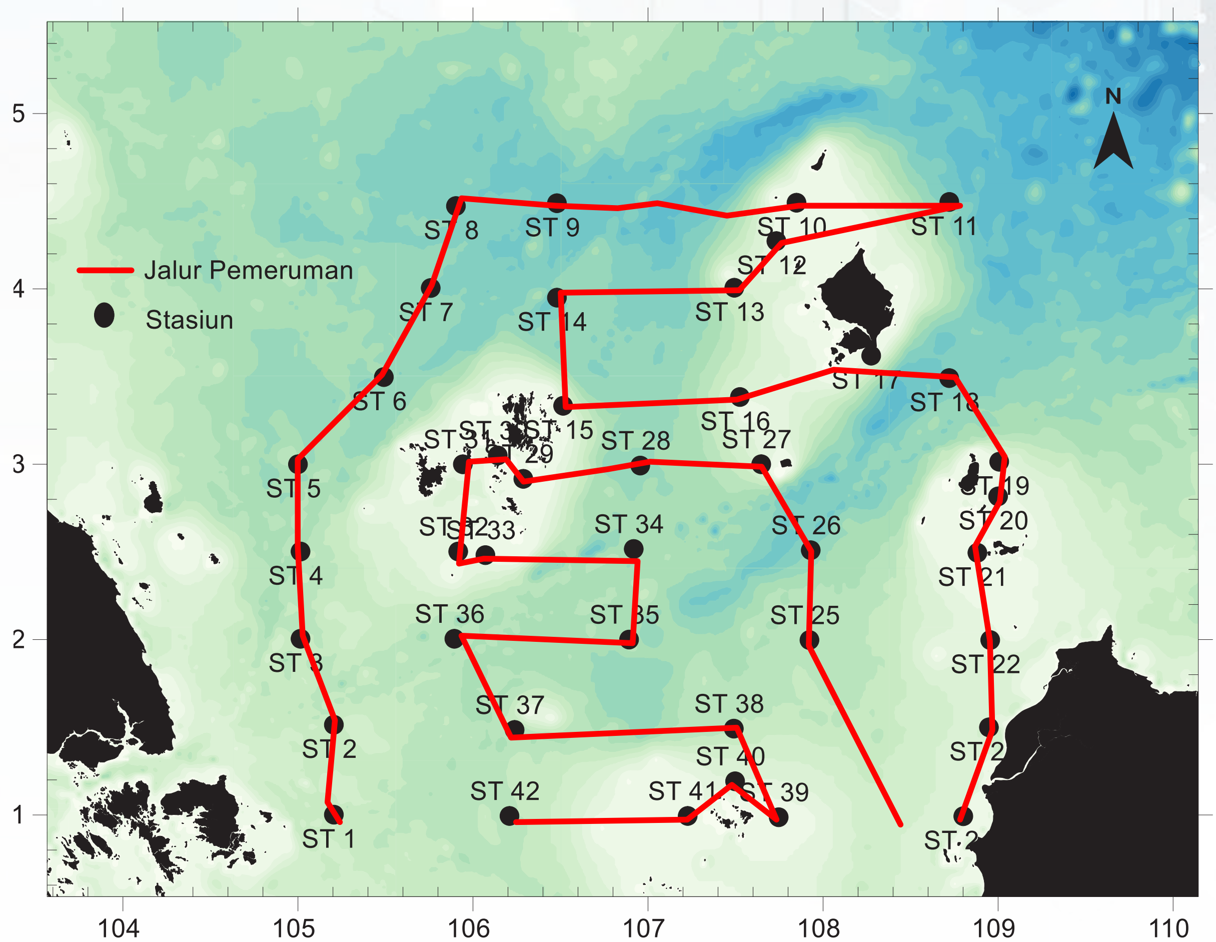


Figure 75. Cruise tracks of hydro-acoustic survey in the FMA 711, SCS in 2016.
Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

5.3.2. Biomass and Maximum Sustainable Yield (MSY)

In the past, using the annual statistical data from 1997 to 2007, the MSY of small pelagic group in Java Sea was estimated about 380,000 MT with the optimum effort was estimated to be 12,165 units of PS. Most of the fishing areas have been overexploited (Suwarso & Duto, n.d.). The results from 2011-2013 in-house study for SCS and ANS are listed in Table 48, shows the estimated MSY for large and small pelagic fish has reduced significantly in 2013 (Research Institute for Marine Fisheries, 2013; Ministry of Maritime Affairs and Fisheries, 2011; Suwarso & Duto, n.d.).

Table 48. The estimations of MSY of pelagic stock (non-tuna-fishes) through in-house study in 2011 and 2013.

Area	Year	Large pelagic	Small pelagic
FMA 571	2011	28,000	147,000
	2013	39,000	117,000
FMA 711	2011	66,000	622,000
	2013	32,000	363,000

Source*: A Brief Notes on Small Pelagic Fish Purse Seine Fishery in Malacca Strait and Natuna Sea* (Duto, 2016): *Indonesia Country Report* (Suwarso & Duto, Indonesia Country Report, n.d.); *Ministry Regulation No. PER 45/MEN/2011 On Estimation of Fish Stock in Indonesia FIsheries Management Zone* (Ministry of Maritime Affairs and Fisheries, 2011).

In addition, Table 49 and Table 50 summarizes the estimation for the stock status of small pelagic fish from 2005-2014 in FMA 571 (ANS) and FMA 711 (SCS) respectively, in which small pelagic was heavily exploited since 2005 in FMA 571 (ANS), while overexploitation occured started in 2012 in FMA 711 (SCS) (Duto, 2016). The recent results from 2016 acoustic survey in FMA 711 (SCS) has estimated the biomass of small pelagic was 427,830 MT with the MSY was 213,915 MT/year (Table 51), and highest density of pelagic fish was found in depth 5 m to 25 m (Figure 76) although highest biomass was found in depth 25 m to 50 m (Table 51).

Table 49. Estimated stock status for small pelagic group at FMA 571 (ANS).

Small Pelagic Group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014 ref
Estimated MSY (x 10^3 MT)										79
Estimated TAC x 10^3 MT)										63
Current catch (x 10^3 MT)	109	115	1105	106	1,106	105	178	186	176	165
Estimated optimum effort (unit)										2,017
Estimated current standard effort (unit)	2,166	2,896	2,761	2,845	3,300	2,518	2,297	2,622	2,514	2,136
Estimated status	1.1	1.4	1.4	1.4	1.6	1.2	1.1	1.3	1.2	1.1

Source*: A Brief Notes on Small Pelagic Fish Purse Seine Fishery in Malacca Strait and Natuna Sea* (Duto, 2016); *Indonesia Country Report* (Suwarso & Duto, Indonesia Country Report, n.d.).

Table 50. Estimated stock status of small pelagic group at FMA 711 (SCS).

Small Pelagic Group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014 ref
Estimated MSY (x 10^3 MT)										395
Estimated TAC x 10^3 MT)										316
Current catch (x 10^3 MT)	135	126	126	150	152	160	163	177	169	164
Estimated optimum effort (unit)										3,673
Estimated current standard effort (unit)	338	648	640	2,410	2,346	1,706	1,995	3,327	3,625	6,026
Estimated status	0.1	0.2	0.2	0.7	0.6	0.5	0.5	0.9	1.0	1.6

Source*: A Brief Notes on Small Pelagic Fish Purse Seine Fishery in Malacca Strait and Natuna Sea* (Duto, 2016); *Indonesia Country Report* (Suwarso & Duto, Indonesia Country Report, n.d.)

Table 51. Biomass and MSY of pelagic stock in FMA 711 (SCS) by acoustic survey in 2016.

Depth Strata	**Biomass (MT)**		**MSY (MT/year)**	
(m)	**Large Pelagic**	**Small Pelagic**	**Large Pelagic**	**Small Pelagic**
5-25	4,782	192,674	2,391	96,337
25-50	776,122	221,514	388,061	110,757
50-75	0	13,641	0.0	6,820
75-100	0	0.5	0.0	0.3
Sub Total	780,904	427,830	390,452	213,915
Total	1,329,870		664,935	

Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

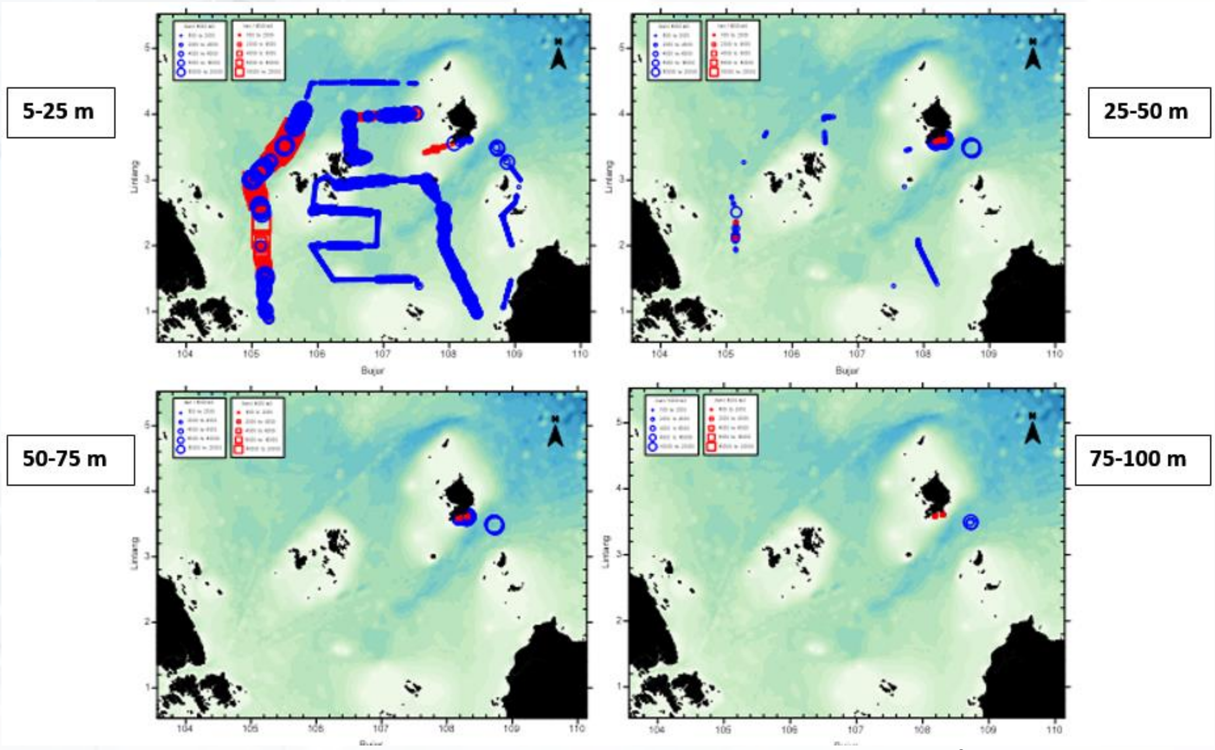


Figure 76. The horizontal distribution of pelagic fish density (fish/1000 m^3) in 4 depth layers, 2016.

Source: *Small Pelagic Purse Seine Fisheries Status in Natuna Sea and Adjacent Waters* (Suwarso, Imron, Duto & Asep, 2018).

5.4. Malaysia

5.4.1. Existing Assessment

The pelagic stock assessment had been carried out few times in Malaysia waters. Some examples are the 'Pelagic Stock Assessment by Hydroacoustic Method in the South China Sea 1995' which covered ECPM area (Albert, et al., 1999), the 'Stock Assessment by Hydro-Acoustic Method in the South China Sea Area II: Sabah, Sarawak, Brunei Darussalam' in 1996 and 1997 (Hadil, et al., 1999), the 'Pelagic Stock Assessment During North-East Monsoon in WCPM' in 2006 (Raja Bidin, Sallehudin, & Osman, Pelagic Stock Assessment During North-East Monsoon in WCPM, 2006) and the 'Pelagic fish stock assessment in ECPM' in 2009 (Raja Bidin, 2009). The latest survey was the acoustic surveys in all different areas of Malaysian marine waters from 2013-2015, conducted by using research vessel KK Senangin II equipped with a scientific echo sounder Furuno FQ80-M system installed onboard. However, since the pelagic fish are not only caught by the PS, but also by other gears especially trawl, the MSY should therefore be calculated on the pelagic fish as a unit stock as a whole (Alias, n.d.).

5.4.2. Biomass and Maximum Sustainable Yield (MSY)

The biomass of pelagic fish stock in WCPM in 1998 survey was estimated at 311,000 MT and MSY of 155,500 MT. Later on, the 2013 survey shows decrease in biomass to 235,438 MT and MSY to 112,684 MT (Abdul-Wahab & Sallehudin, n.d.).

ECPM had estimated biomass of pelagic stock of 733, 000 MT and MSY of 366,50 MT in 1999, then decreased to 237,000 MT biomass pre monsoon 2013 and 202,000 MT biomass post monsoon 2014 as shown in the Figure 52 (Sallehudin, 2016; Department of Fisheries Malaysia, 2015a).

The estimated biomass of pelagic fish off coastal Sarawak waters in 1999 was 100,000 MT pre-northeast monsoon and 360,000 MT post-northeast monsoon, with estimated MSY of 83,000 MT using Cadima's model (Hadil, et al., 1999). However, the 2013 survey shows biomass of 273,852 MT and MSY of 83,731 MT (Department of Fisheries Malaysia, 2015a), while the 2015 survey shows biomass of 150,627 MT with MSY of 79,192 MT (Jamil, 2018).

Table 52. The estimation on status of pelagic stock in Malaysia through acoustic surveys.

Area	Year	Biomass (MT)	Potential Yield (MT)
ECPM	1999	733, 000 [a]	366,50
	2013	518,209 [b]	237,490
	2014	405,332 [b]	202,466
WCPM	1998	311,000 [c]	155,500
	2013	235,438 [b]	112,683
Sarawak	2013	273,852 [b]	83,731
	2015	150,627 [d]	79,192
West Coast of Sabah	2015	232,598 [d]	37,296
East Coast of Sabah	2015	154,490 [d]	21,231

Sources: [a] *Multi-species fish stock assessment by acoustic method in the South China Sea Area I: Gulf of Thailand and east coast of Peninsular Malaysia* (Albert, et al., 1999); [b] *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a); [c] *Country Report: West Coast of Peninsular Malaysia* (Abdul-Wahab & Sallehudin, n.d.); [d] *Pelagic Resources Survey in the EEZ of Malaysia* (Jamil, et al., 2015)

5.5. Myanmar

5.5.1. Existing Assessment

The research vessel Dr Fridtjof Nansen previously visited Myanmar in 1979, 1980, 2013, 2015, and recently in 2018, primarily to measure fish resources at the start and end of the monsoon season. These voyages of marine research relied on simultaneous hydro-acoustic and trawl sampling (swept area method). Pelagic trawls are mainly targeted at dense pelagic fish schools, to investigate the catch composition. Demersal (or bottom) trawls also catch some pelagic fish, near the seafloor or in the water column while descending or ascending from the sea surface. Thus, trawl data from targeted trawls cannot be used for direct abundance estimation for this comparative study for management of PS fisheries.

5.5.2. Biomass and Maximum Sustainable Yield (MSY)

The research findings from 2013 visit compared with the 1979 and 1980 visits, showed a significant decline of fish in the waters around the country, in which coastal fish stocks had decreased 75% in 2013. The 1979/80 survey estimated a total exploitable biomass of 1.8 million MT with a sustainable yield of 700, 000 MT. The standing stock in 2013 was possibly only 10% of the biomass in 1980.

In latest 2015 survey, the estimated total biomass was only about 500,000 MT (Leadbitter, 2017). However, note that the methodology used during 1979-1980 surveys was different from recent surveys, thus the estimations cannot be compared directly.

Discussions between the EAF-Nansen survey team with Myanmar Fisheries Federation and the Myanmar Fisheries Department has associated the decreased biomass situation with the decreasing fish body size rates, declining catches and increasing fishing efforts. Figure 77 shows the acoustic distribution and abundance of two groups of pelagic fish in Rakhine coastal waters during 2013 survey. Fish likes Carangid and Scombrid were abundant in the Ayeyarwady Delta area and Rakhine coastal area (Table 53).

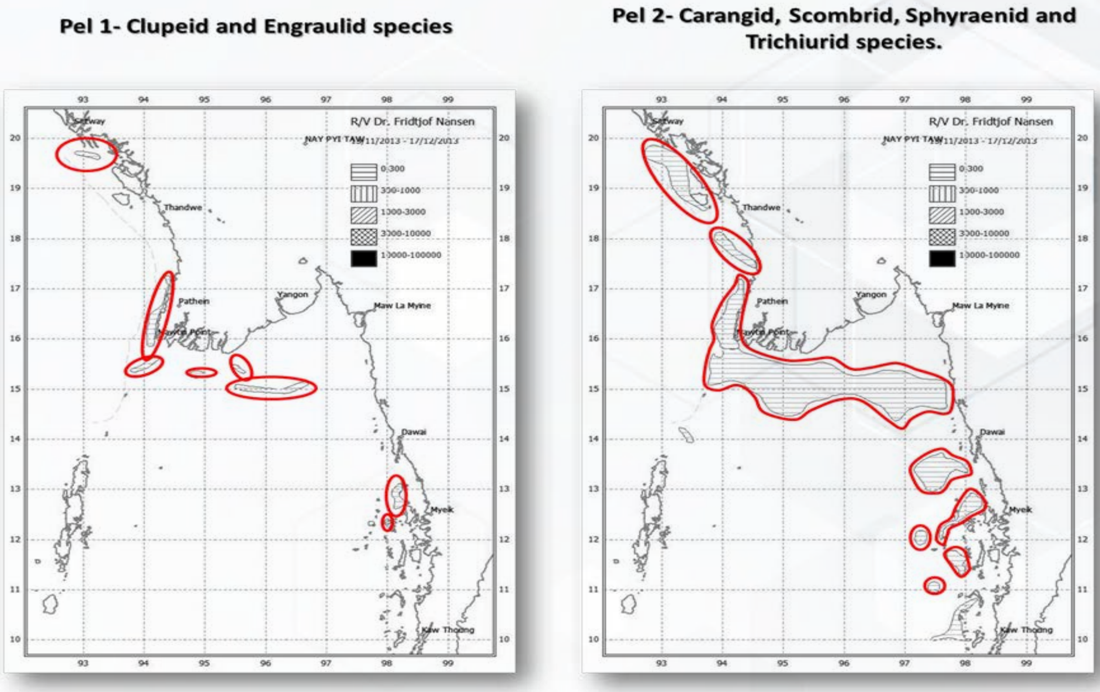


Figure 77. Acoustic distribution and abundance of two groups of pelagic species along the Rakhine coastal, 2013.
Source: Source: *Cruise Report "Dr. Fridtjof Nansen" (Myanmar Ecosystem Survey)* (Krakstad, et al., 2014).

Table 53. Biomass estimates of pelagic fish during the 2013 survey.

Region	**Pel 1- Clupeid and Engraulid species**	**Pel 2- Carangid, Scombrid, Sphyraenid and Trichiurid species**
The Rakhine Coast	10,000	22,500
The Ayeyarwady Delta area	18,000	34,000
The Tanintharyi coast	7,000	17,000
Total	35,000	73,500

Source: *Cruise Report "Dr. Fridtjof Nansen" (Myanmar Ecosystem Survey)* (Krakstad, et al., 2014).

5.6. The Philippines

5.6.1. Existing Assessment

It was reported that stock assessment program was halted in 1984 and restarted in 1997 at different fishing grounds; however the data is still in process (Belga, n.d.). Under the National Stock Assesment Program (NSAP), the updated status of Philippine small pelagic fishes was estimated using 2015 length-frequency data where it recorded the Exploitation (E) values according to the fishing grounds.

5.6.2. Biomass and Maximum Sustainable Yield (MSY)

Dalzell and Ganaden (1987) provided the estimated MSY of 550,000 MT for the small pelagic resources during the mid-1980. The MSY of 550,000 MT, when combined with MSY estimate of about 250,000 MT for lightly fished small pelagic resources in the late 1980's (i.e., southern parts of Mindanao, western Palawan waters, parts of the country's Pacific Coast), equals a countrywide MSY of about 800,000 MT (Dalzell & Ganaden, 1987). Subsequent refinements of the assessment essentially yielded the same result, as shown in Figure 78, that stated the MSY for small pelagic in Philippines in 1996 which was 0.55 million MT indicated the biomass in the Philippines water was abundant (Dalzell, Adams, & Polunin, 1996). However, comparison with a recent production was needed since it indicated the occurrence of biological and economic overfishing, particularly in inshore and traditional fishing grounds.

Report summarized from 2015 NSAP length-frequency data using the Exploitation grades (E) showed no fishing ground had mean E values less than 4, majority fishing ground in Philippines had Mean E values exceeded the Limit Preference Point (Figure 79), signified the biomass had been reduced significantly. Species-specific assessment of small pelagic fishes had resulted in very high exploitation ratios. Overfishing is, by far, primary problem facing by small pelagic fisheries in which the resources have been biologically and economically exploited beyond the level the resources can sustain.

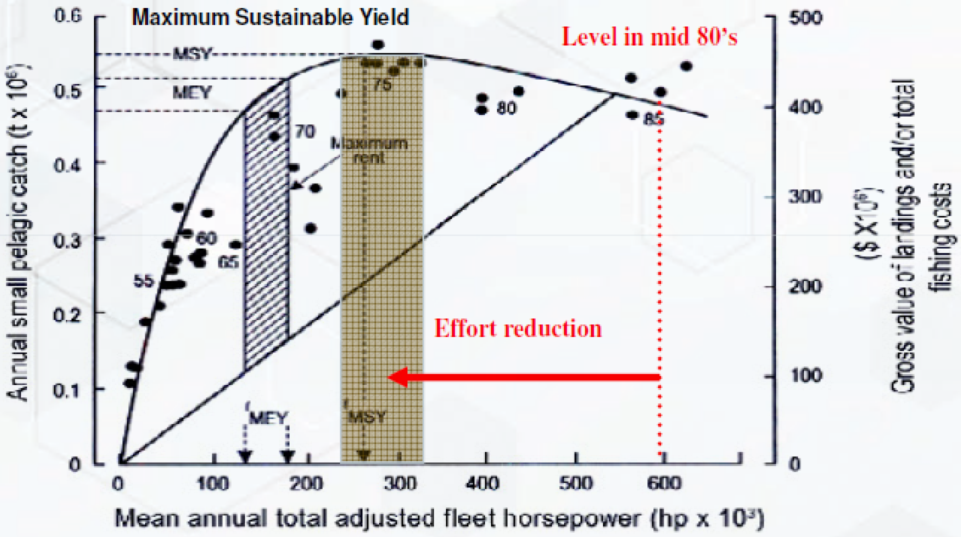


Figure 78. The MSY for pelagic species in The Philippines,1996.
Source: *Coastal Fisheries in the Pacific Islands* (Dalzell, Adams, & Polunin, 1996).

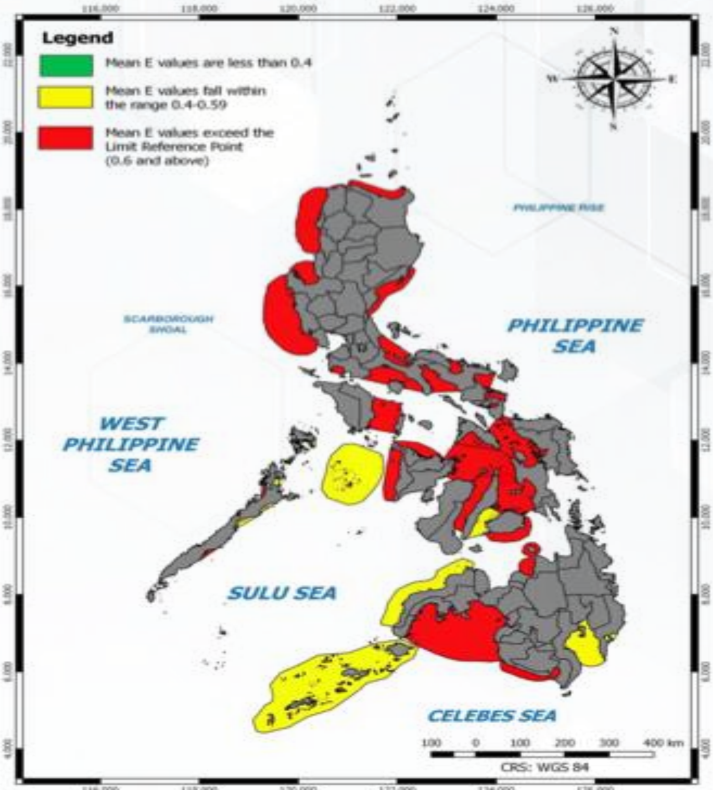


Figure 79. Status of Philippine small pelagic fishes by fishing ground based on Exploitation (E) values using NSAP length-frequency data in 2015.
Source: *Country Presentation on Purse Seine Management in the Philippines* (Romero & Lopez, 2018).

5.7. Thailand

5.7.1. Existing Assessment

The MSY assessment aims to estimate the biological reference point at which stocks can be harvested without any negative effect on resources and equilibrium with the production of nature in Thai waters. The MSY for the Gulf of Thailand (SCS) and the ANS was estimated by using the Fox surplus production model (Fox, 1970). This model requires statistical data and information on catch, CPUE and effort data of all fishing operations, particularly small-scale fishing gears and large-scale fishing gears of demersal fish, pelagic fishes and anchovies. The equilibrium yield is given by:

$$\frac{y_i}{f_i} = e^{c+d*f_i}$$

Where is f as fishing effort (hours), c and d are constants obtained by fitting a linear regression.

$$MSY = -(1/d)e^{c-1}$$
$$F_{MSY} = -1/d$$

Fishing effort estimates were based on the fishing vessel survey carried out in June and July 2015. A total number of 45,805 fishing vessels were found in the survey, but only 42,512 active vessels that operate in Thai waters were used for the MSY assessment (DOF and CCIF, 2016).

5.7.2. Biomass and Maximum Sustainable Yield (MSY)

Previously, in 2013, the DOF has reported overfishing for most of the pelagic fish in Thai waters (Table 54). The hardtail scad (*M. cordyla*) had input fishing effort that was over 60% of the optimum fishing effort in the ANS. The level of exploitation for goldstripe sardine (*S. gibbosa*) at GOT (SCS) and ANS was under the optimum MSY level in 2013.

However, the recent data showed that actual catch did not reach the overall MSY of pelagic fishes and anchovies. Table 55 and Table 56 presents the MSY of pelagic fishes and anchovies for all fishing gears in Thai waters for 2017 and 2018 respectively. The MSY for pelagic and anchovies in GOT (SCS) and ANS in 2018 was higher than 2017. The actual catch in both areas were also managed to be reduce drastically in 2018, except pelagic fishes in ANS that recorded increasing amount of catch in 2018 and exceeded its MSY value.

Table 54. Status of pelagic fish stocks in Thai waters, 2013.

Scientific name	**Fish name**	**Status *(%)**	
		ANS	**GoT**
Enrasicholina devisi, *E. punctifer* & *E. heteroloba*	Anchovies	(−20)	ND
Rastrelliger kanagurta	Indian mackerel	(−30)	(−10)
Selaroides leptolepis	Yellowstripe scad	(−30)	ND
Decapterus maruadsi	Round scad	(−30)	ND
Megalaspis cordyla	Hardtail scad	(−60)	(−50)
Selar crumenophthalmus	Bigeye scad	(−30)	ND
Sardinella gibbosa	Sardine	(+40)	(+20)
Loligo chinensis & *L. duvaucelli*	Squids	(−25)	(−15)

Notes: ND = No available data; the negative symbol (−) indicates the percentage of input fishing effort over the optimum fishing effort for the MSY; the positive symbol (+) indicates the percentage of input fishing effort under the optimum fishing effort for the MSY.
Source: *Current Status of Purse Seine Fisheries in the Southeast Asian Region* (Department of Fisheries Malaysia, 2015a); *Purse Seine Fishery in Thailand* (Panjarat & Saikliang, n.d.).

Table 55. Maximum sustainable yield of pelagic fishes and anchovies for all fishing gears in Thai waters, 2017.

Fish group	**Fishing area**	**MSY (MT)**	**Actual catch (MT)**	**Actual catch/MSY**
Pelagic fishes	GOT	248,176	245,986	0.99
	ANS	118,477	99,039	0.84
	All	366,653	345,025	0.94
Anchovies	GOT	191,785	183,216	0.96
	ANS	32,944	33,903	1.03
	All	224,729	217,119	0.97

Source: *Country Presentation: Purse Seine Fisheries in Thailand* (Chumchuen, 2018)*; Marine Fisheries Management Plan of Thailand - A National Policy for Marine Fisheries 2015-2019* (Department of Fisheries Thailand, 2015).

Table 56. Maximum sustainable yield of pelagic fishes and anchovies for all fishing gears in Thai waters, 2018.

Fish group	**Fishing area**	**MSY (MT)**	**Actual catch (MT)**	**Actual catch/MSY**
Pelagic fishes	GOT	250,739	199,507	0.80
	ANS	118,755	121,400	1.02
	All	369,494	320,907	0.87
Anchovies	GOT	201,564	108,212	0.54
	ANS	33,294	13,570	0.41
	All	234,758	121,782	0.52

Source: *Country report on purse seine fisheries in Thailand* (Chumchuen & Noranarttragoon, Country report on purse seine fisheries in Thailand, 2019); *Estimation of maximum sustainable yield (MSY) 2017 and status of fishery resources utilization in Thai waters* (Marine Fisheries Reserach and Development Division (MFRDD), 2018)

5.8. Viet Nam

5.8.1. Existing Assessment

A collaborative hydroacoustic survey between the Research Institute of Marine Products (RIMP), Viet Nam and the Marine Fishery Resources Development and Management Department (MFRDMD) of SEAFDEC was carried out in Viet Nam waters from 29 April to 29 May1999. Survey was conducted by using the scientific echo sounder, FQ70 installed on board of MV SEAFDEC (Raja Bidin, et al., 2001). Next, Viet Nam conducted an acoustic survey on small pelagic fish from 2012 to 2013 (Nghia, n.d.). In addition, recently, a comprehensive survey was carried out in 2011-2015 in the marine waters of Viet Nam to assess three main groups of fishery resources, which were small pelagic fish, demersal fish and oceanic pelagic fish (Nghia, Project Completion Report I.9, “Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea”, 2017).

5.8.2. Biomass and Maximum Sustainable Yield (MSY)

Pelagic biomass in Vietnamese waters in 1999 was estimated at 9.26 million MT with the average density of 15.93 MT/km^2. The estimation was based on the dominant species of Japanese scad (*D. maruadsi*) (Raja Bidin, et al., 2001). Furthermore, the 2012-2013 acoustic survey found that anchovy was the most dominant species in south area with scads dominated the north area. The anchovy groups migrated toward northern area during the northeast monsoon (Nghia, n.d.).

From the 2011-2015 survey, the estimated standing biomass of marine fisheries resources in the whole Viet Nam marine water was at 4.36 million MT, where the small pelagic was around 2.650 million MT. The Southeast water has the highest estimated biomass of small pelagics, which was around 900,000 MT (Table 57). In comparison to the 2000-2005 data, the 2011-2015 biomass of small pelagics showed an increasing of more 200,000 MT in each area, except for Southwest water that had decreased in biomass by 45 % from 945,400 MT to 510,500 MT (Tuyen, 2018).

Table 57. The estimated small pelagic fish stock in Viet Nam, 2011-2015.

Area	**2011-2015**		**2000-2005**
	Biomass	**MSY**	**Biomass**
Gulf Tonkin	626,000	375,600	433,100
Central water	616,400	369,900	595,500
Southeast	891,500	534,900	770,800
Southwest	510,500	306,300	945,400
Total	2,644,400	1,586,700	2,744,800

Source: *The Purse Seine Fisheries in Viet Nam* (Tuyen, 2018); *Project Completion Report I.9, "Overall assessment of current status and fluctuations of marine resources in Vietnamese Sea"* (Nghia, 2017).

6. Synthesis for Catch and Effort Information

Initially, this project intended to collect three decades of catch and effort information for PS from the AMSs. Nevertheless, there were some issues on the reliability of the compiled data because some countries were not able to fulfill all of the parameters requested, especially on the number of vessels for fish purse seine and anchovy purse seine. Thus, data analysis for catch and effort information only included available data from 1996 to 2015 (two decades).

6.1. Trend of landings by purse seine

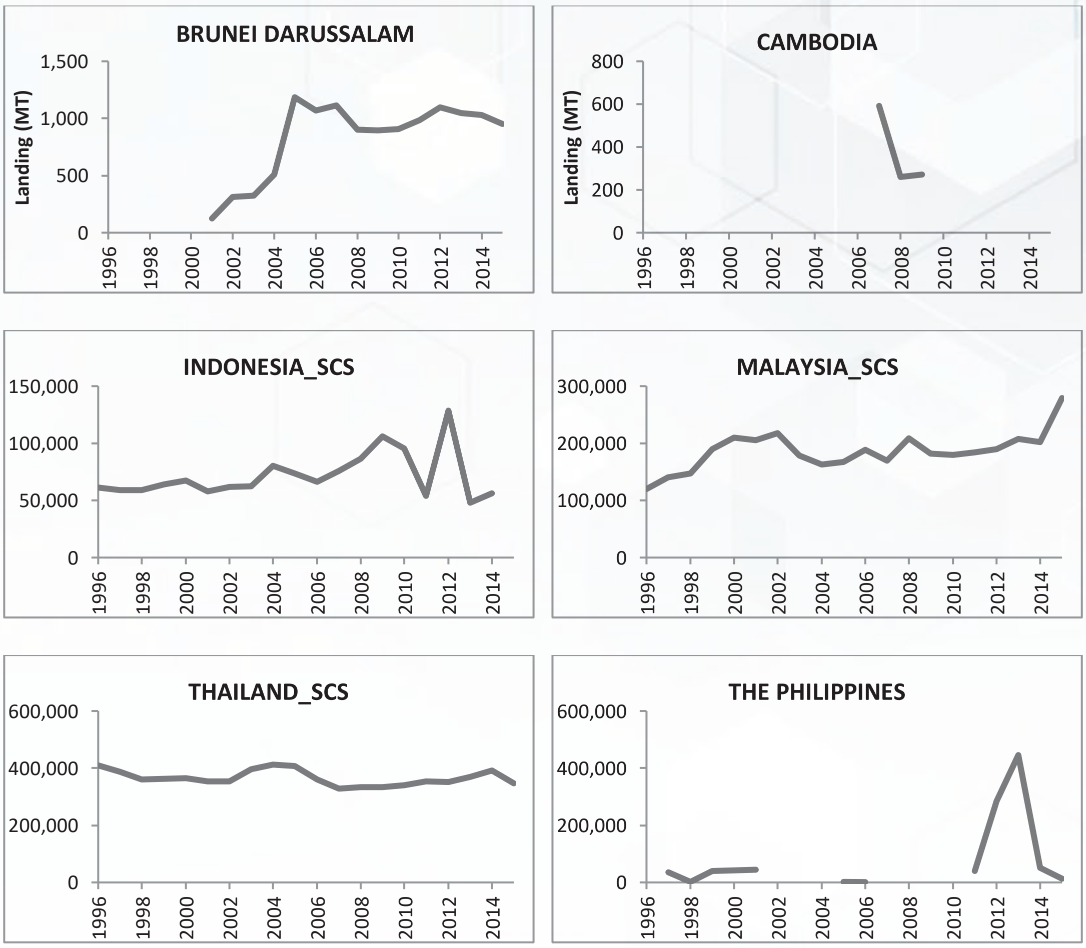
Table 58. The landing of capture fisheries by purse seine in Southeast Asian region, 1996-2015.

Year	Landing (MT)												
	South China Sea (SCS)								Andaman Sea (ANS)				
	Brunei Darussalam	**Cambodia**	**Indonesia**	**Malaysia**	**The Philippines**	**Thailand**	**Viet Nam**	**TOTAL SCS**	**Indonesia**	**Malaysia**	**Myanmar**	**Thailand**	**TOTAL ANS**
1996	74		61,223	119,941		410,693		**591,931**	88,620	58,436		171,806	**318,862**
1997			59,055	140,077	34,400	388,009		**621,541**	88,345	58,152		164,701	**311,198**
1998			58,764	147,423	1,233	360,118		**567,538**	86,364	78,498		170,879	**335,741**
1999			63,888	189,314	39,954	363,236		**656,392**	86,042	81,075		168,971	**336,088**
2000			67,457	210,216	43,193	363,900	322,389	**1,007,155**	94,152	55,223		184,129	**333,504**
2001	124		57,916	205,768	44,965	352,789	330,435	**991,997**	96,570	54,861		173,533	**324,964**
2002	311		61,554	218,170		353,724	222,638	**856,397**	84,607	84,854		174,243	**343,704**
2003	326		62,558	178,751		397,276	278,622	**917,533**	95,056	91,276		155,265	**341,597**
2004	511		80,018	163,146		412,411	245,187	**901,273**	60,973	114,263		161,510	**336,746**
2005	1,186		73,764	167,560	2,400	407,296	101,532	**753,738**	61,049	128,180		181,798	**371,027**
2006	1,069		66,369	188,085	1,040	359,983	257,453	**873,999**	70,175	143,428	7,092	166,986	**387,681**
2007	1,113	592	75,940	169,754		328,305	149,100	**724,804**	68,237	175,522	7,707	149,105	**400,571**
2008	901	260	86,731	209,316		334,070	178,700	**809,978**	65,872	180,580	16,224	145,988	**408,664**
2009	895	270	106,280	181,952	22,400	333,466	191,300	**836,563**	65,690	176,884	137,887	153,467	**533,928**
2010	908		95,346	179,911		341,274	212,000	**829,439**	69,522	191,667	72,124	162,512	**495,825**
2011	986		53,897	184,190	39,400	353,161	237,000	**868,633**	91,279	149,271	51,978	148,771	**441,299**
2012	1,095		128,576	189,790	284,867	352,314	215,200	**1,171,842**	98,824	149,237	27,580	150,517	**426,158**
2013	1,049		47,991	208,005	445,811	369,431	226,900	**1,299,186**	101,136	135,471	16,132	133,017	**385,756**
2014	1,032		56,128	201,880	51,552	391,653	256,200	**958,444**	96,191	140,946	185,583	142,593	**565,313**
2015	949			279,218	13,367	347,960	434,200	**1,075,695**		140,735	10,892	134,203	**285,830**

Table 58 shows that in general, there was an increase in total marine catch over two decades although some decrease in amount was reported that might be due to no data from some countries during those particular years. Nevertheless, in 2009 where data from all AMSs were available, Thailand recorded the highest landing by PS with a total catch of 486,933 MT (sum of landings from SCS and ANS), followed by Malaysia with 358,836 MT and Indonesia with 171,970 MT.

I) South China Sea

Figure 80 shows inter-annual variation of landing for seven AMSs in SCS ecosystem from 1996 to 2015. Over the years, the landings revealed fluctuating trends, with increasing pattern for Brunei Darussalam, Malaysia and Vietnam while Thailand showed relatively a linear pattern. A sharp rise observed in Indonesia and the Philippines from 2010 to 2012.



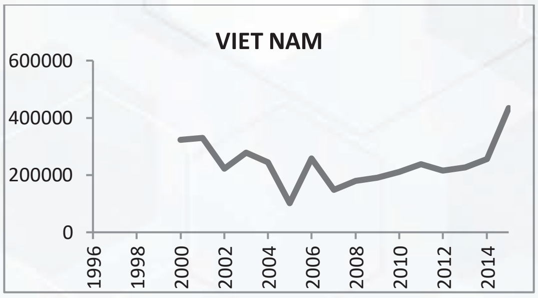


Figure 80. Inter-annual variation of landing (MT) for seven AMSs in the SCS ecosystem.

II) Andaman Sea

Indonesia, Malaysia and Thailand show a fluctuating trend with only slight changes over the year. Unlike those, Myanmar had two peak of landings which were in 2009 and 2014 (Figure 81).

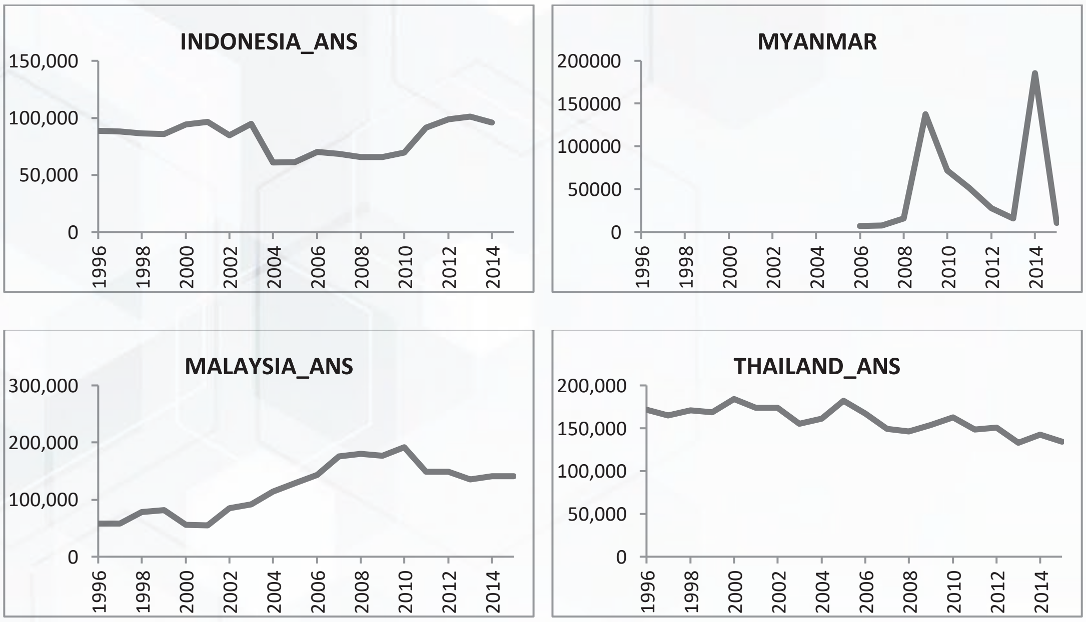


Figure 81. Inter-annual variation of landing (MT) for four AMSs in the ANS ecosystem.

6.2. Trend of fishing effort by unit (no. of vessel)

Table 59 shows the trends for number of PS vessel (unit) from 1996 to 2015. In general, the trend was increasing although some years had a decrease from previous year, for example in 2011. Started from one (1) unit in 1996, Brunei Darussalam had increased the vessels to 14 units in 2013. The opposite trend observed in Cambodia where the 16 units in 1996 was reduced to only one (1) unit registered in 2014. The PS units increased drastically in some countries in SCS region especially

Indonesia, and noticeably the ANS ecosystem off Indonesia was steadily had more than 1,500 units of PS vessels every year.

Table 59. The number of PS vessels (unit) in Southeast Asian region, 1996-2015.

Year	**Number of Vessels (unit)**												
	South China Sea (SCS)								**Andaman Sea (ANS)**				
	Brunei Darussalam	**Cambodia**	**Indonesia**	**Malaysia**	**The Philippines**	**Thailand**	**Viet Nam**	**TOTAL SCS**	**Indonesia**	**Malaysia**	**Myanmar**	**Thailand**	**TOTAL ANS**
1996	1	16	47	726		1,077		**1,867**	1,558	276		250	**2,084**
1997		15	58	689	18	1,157		**1,937**	1,811	270		345	**2,426**
1998		15	66	602	2	1,064		**1,749**	2,003	288		225	**2,516**
1999		8	64	736	17	1,134		**1,959**	1,918	309		420	**2,647**
2000		10	110	767	15	1,178		**2,080**	2,131	311		326	**2,768**
2001	2	14	110	734	24	1,039		**1,923**	2,198	306		410	**2,914**
2002	6	10	96	755		1,239		**2,106**	1,570	316		447	**2,333**
2003	6	12	81	747		1,295		**2,141**	2,942	312		342	**3,596**
2004	7	10	181	722		1,298		**2,218**	2,262	305		401	**2,968**
2005	8	10	222	734	1	1,210		**2,185**	1,519	320		335	**2,174**
2006	9	6	426	744	1	1,169		**2,355**	2,031	371	368	321	**3,091**
2007	9	4	421	766		1,162		**2,362**	1,936	374	367	279	**2,956**
2008	9	1	1,585	861		1,170	6,033	**9,659**	1,995	397	527	304	**3,223**
2009	10	1	1,543	834	6	1,120	7,155	**10,669**	2,314	413	532	364	**3,623**
2010	8	4	1,122	837		1,223	8,348	**11,542**	1,766	420	536	405	**3,127**
2011	13	1	1,312	795	4	1,135	5,261	**8,521**	1,611	440	545	363	**2,959**
2012	12	1	2,188	812	268	1,148	5,123	**9,552**	1,839	441	639	443	**3,362**
2013	14		2,383	801	930	1,175	4,726	**10,029**	1,763	443	640	373	**3,219**
2014	13		3,963	791	11	1,296	4,696	**10,770**	1,498	416	647	417	**2,978**
2015	9			800	23	1,297	4,992	**7,121**		394	580	431	**1,405**

I) South China Sea

Figure 82 shows the inter-annual variation for number of PS vessels (unit) for seven (7) AMSs in the SCS ecosystem. The trends were increasing for Brunei Darussalam and Indonesia, almost linear for Malaysia and Thailand as well as decreased for Cambodia and Viet Nam. The Philippines revealed one peak, which was in 2013.

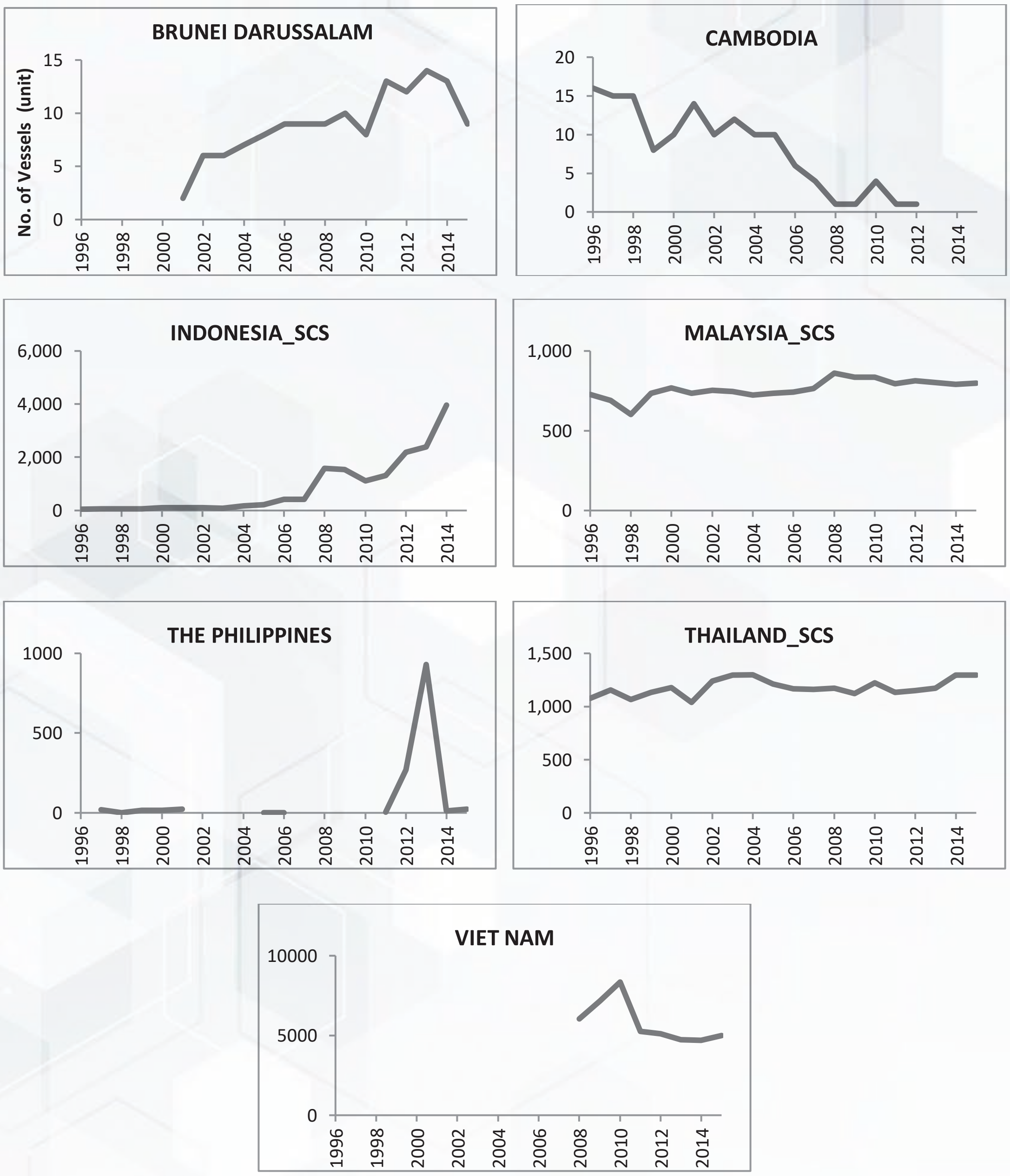


Figure 82. Inter-annual variation for no. of PS vessels (unit) for seven AMSs in the SCS ecosystem.

II) Andaman Sea

The number of registered PS vessels was fluctuated but increasing for all four AMSs in ANS over years, thus indicted that purse seine fisheries in ANS are in stable and dynamic phase (Figure 83).

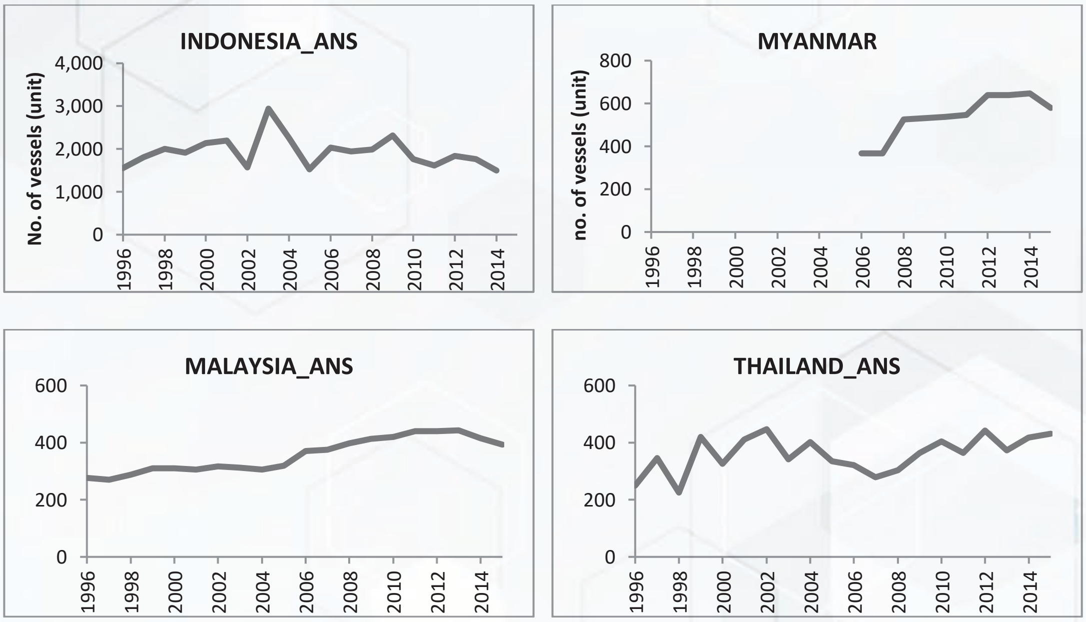


Figure 83. Inter-annual variation for no. of PS vessels (unit) for four AMSs in the ANS ecosystem.

6.3. Trend of fishing effort by trip

Data of fishing effort by trip were only available for certain AMSs in SCS and ANS ecosytems. Malaysia and Thailand have quite extensive of two decades' historical data from 1996 until 2016 in both ecosystems. However, Brunei Darussalam is lacking data in 1997 to 2000, and their number of trips per year is noticeably very low compared to other AMSs. The large difference of number of trips between Brunei Darussalam and other AMSs is due to the fact that Brunei Darussalam mainly focused on small scale fisheries. In case of Indonesia, historical data is available only from 2005 until 2014 in both ecosystems (Table 60). The highest number of PS trips recorded in Brunei Darussalam was 1,507 trips in 2012 whereas Indonesia (SCS) recorded 89,562 trips in 2014. Thailand, on the other hand, experienced big drop of number of PS trips after 2011 in both SCS and ANS where purse seiners stayed in the sea longer by increasing fishing days per trip, due to the increasing of fuel cost and the development fish well onboard.

Table 60. Available historical data for fishing effort by trips in the SCS and ANS ecosystems.

Year	TRIPS (trips)								
	South China Sea (SCS)					Andaman Sea (ANS)			
	Brunei Darussalam	Indonesia	Malaysia (ECPM)	Thailand	TOTAL SCS	Indonesia	Malaysia	Thailand	TOTAL ANS
1996	124		37,413	130,586	**168,123**		43,265	75,371	**118,636**
1997			39,572	139,059	**178,631**		45,441	79,472	**124,913**
1998			27,587	104,620	**132,207**		39,964	81,122	**121,086**
1999			39,083	96,342	**135,425**		33,491	74,982	**108,473**
2000			38,562	84,715	**123,277**		33,067	77,817	**110,884**
2001	169		38,983	84,067	**123,219**		37,706	76,773	**114,479**
2002	578		36,483	93,746	**130,807**		44,808	76,950	**121,758**
2003	857		34,876	119,399	**155,132**		42,054	81,268	**123,322**
2004	862		27,855	115,915	**144,632**		43,904	68,471	**112,375**
2005	1,071	9,384	28,028	119,676	**158,159**	137,813	45,918	90,423	**274,154**
2006	980	18,954	30,667	104,692	**155,293**	90,957	46,112	85,644	**222,713**
2007	964	19,524	25,868	94,549	**140,905**	85,751	50,653	66,704	**203,108**
2008	1,035	28,615	27,655	106,442	**163,747**	226,803	48,047	65,763	**340,613**
2009	1,048	43,048	21,583	105,420	**171,099**	193,400	42,203	68,144	**303,747**
2010	1,009	35,342	21,481	103,817	**161,649**	240,228	49,731	65,111	**355,070**
2011	1,263	47,866	18,988	121,425	**189,542**	190,642	45,031	61,964	**297,637**
2012	1,507	67,777	21,089	48,926	**139,299**	61,908	46,257	37,724	**145,889**
2013	1,134	81,137	20,478	46,956	**149,705**	70,057	43,775	34,434	**148,266**
2014	1,199	89,562	19,210	50,876	**160,847**	59,050	44,143	33,650	**136,843**
2015	758		15,109	71,754	**87,621**		37,924	59,138	**97,062**

* Data for Malaysia was compiled from ECPM only.

I) South China Sea

In general, the inter-annual variation number of trips for Brunei Darussalam and Indonesia show an increasing trend although in Brunei Darussalam, the number of trips decreased in recent years. In contrast, the number of trips in Malaysia and Thailand has decreased gradually over the years. Thailand especially experienced a sharp decrease in 2012 as indicated in the Figure 84.

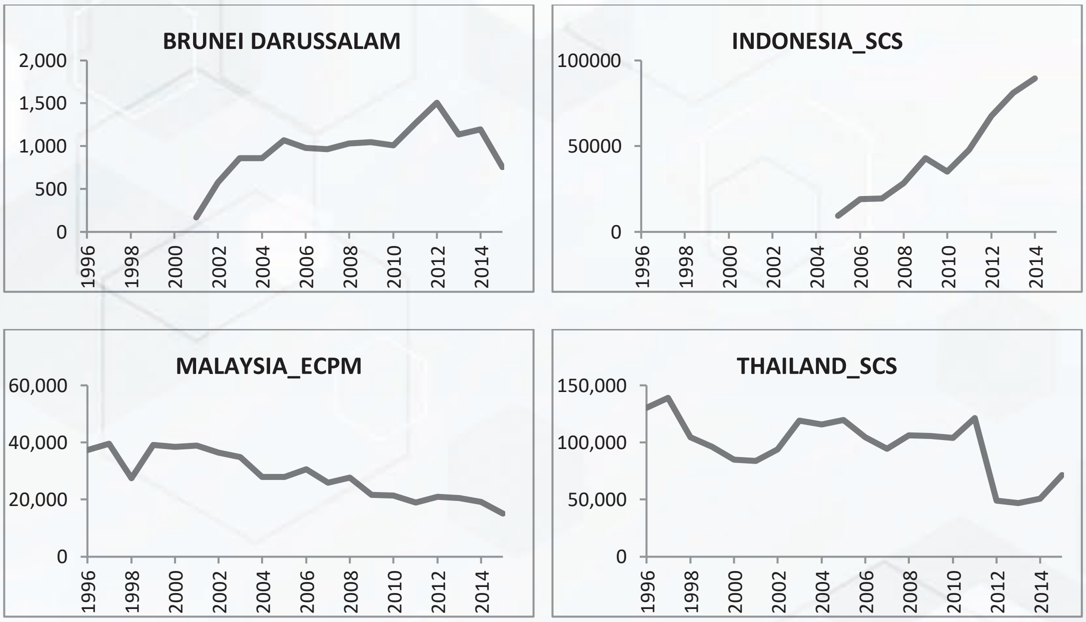


Figure 84. Inter-annual variation for trip (trips) of four AMSs in the SCS ecosystem.

II) Andaman Sea

Only Malaysia show stable trend over the years, meanwhile trend for number of trips in Indonesia and Thailand are highly fluctuated with decreasing trend. Note that Indonesia has insufficient data on number of PS trips before 2005 (Figure 85).

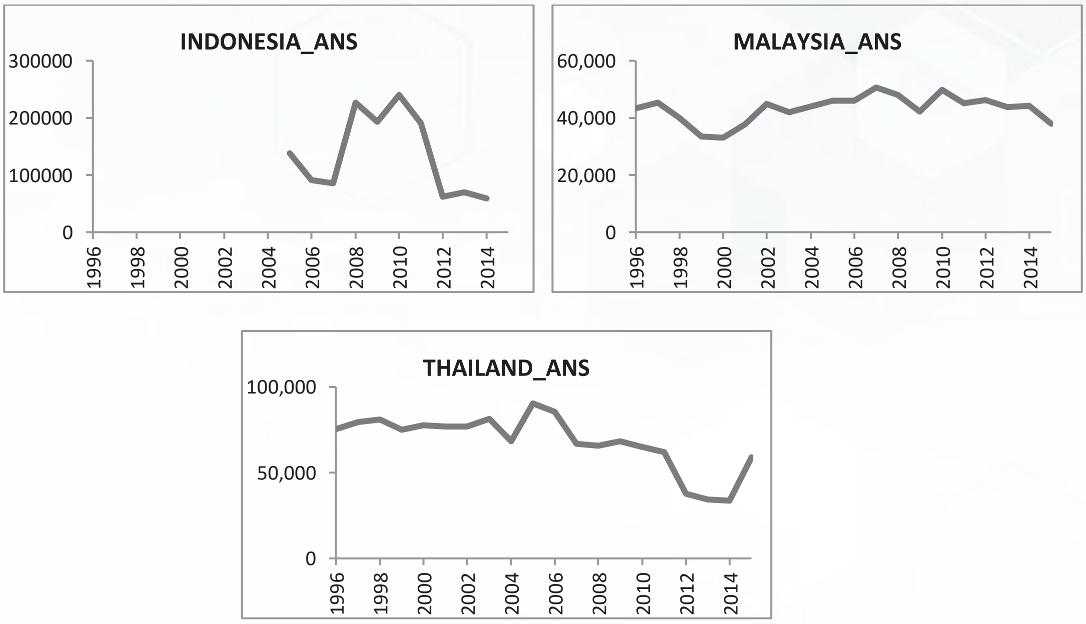


Figure 85. Inter-annual variation for trip (trips) of three AMSs in the ANS ecosystem.

6.4. Trend of CPUE by country (trip)

This section shows plots of CPUE index (C/F) against year for both SCS and ANS ecosystem. In this case catch (C), refers to the annual catch measured in units of MT and effort (F) refers to number of trips per year. Deciding which CPUE index to be used is considered as one of the important aspects in this project's component as it holds the key to the Production Model analysis, which is detailed in section 6.5.

I) South China Sea

Trend of CPUE by trip for Brunei Darussalam, Indonesia, Malaysia and Thailand in the SCS ecosystem was revealed in Figure 86. Ten (10) years of historical data were used to determine trend of CPUE for Brunei Darussalam and Indonesia whereas longer period (20 years) was used for Malaysia and Thailand, according to data availability and reliability. Apparently, Brunei Darussalam had the most stable trend of CPUE. Malaysia and Thailand also showed stable trend of CPUE but drastically changed at latter years. Malaysia had a steep increase in 2015, thus analysis for Malaysia comprised data from 1996 until 2014 only, for more reliable result. In addition, a fluctuated trend of CPUE was observed for Thailand from 2011 until 2015. Indonesia, on the other hand, had decreasing CPUE over years despite of having high landings from PS vessels.

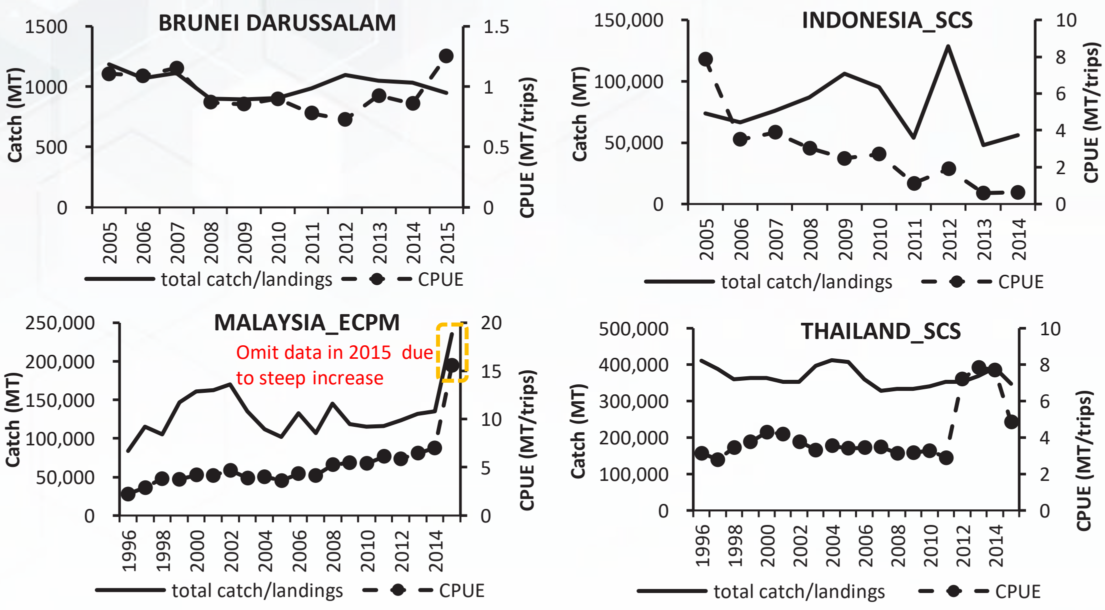


Figure 86. Trend of CPUE (by trip) for four AMSs in the SCS ecosystem.

II) Andaman Sea

Figure 87 shows that the three AMSs in ANS had different time-setting of historical data. Trends of CPUE for Indonesia and Malaysia show that their data are unreliable to be used in subsequent analysis due to various reasons. In case of Indonesia, their data is insufficient and trend of CPUE is highly fluctuated throughout the ten years. As for Malaysia, trend of CPUE indicated that there is positive relationship between landings and CPUE, thus resulting in unreliable result for subsequent analysis. Hence, only Thailand is appropriate for further analysis as its trend of CPUE shows rather a stable pattern for most of the years.

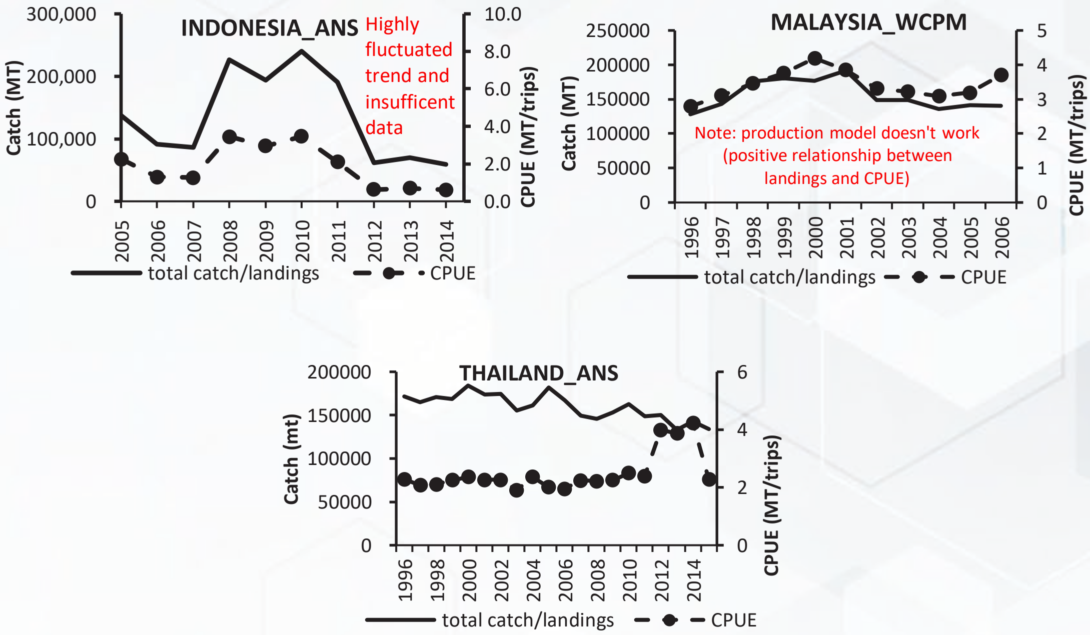


Figure 87. Trend of CPUE (by trip) for three AMSs in the ANS ecosystem.

6.5. Production Model (Fox model and Schaefer model)

Result of trend analysis of this project in section 6.1 till 6.4 was presented and discussed with the resource persons (RP). In the beginning of PM analysis, both Fox model (1970) and Schaefer model (1954) were applied to the CPUE data (by trip) calculated by using the empirical formula stated in section 2.3.5 of Material and Methodology. The analysis revealed that the two models gave slightly different results. Hence, only Fox model was chosen to illustrate the pelagic status in selected AMSs as its r^2 values are more precise and it gives the best fit to the data when compared to the Schaefer model.

6.5.1. Analysis by Fox model

Based on CPUE analysis in section 6.4, only Brunei Darussalam, Indonesia SCS, Malaysia (ECPM), Thailand (SCS and ANS) have fulfilled the required parameters of the PM analysis, whereby the analysis can be done only when the data is accurate, reliable and sufficient. Brunei Darussalam and Indonesia (SCS) have catch and effort data set of 2005-2015 and 2005-2014 respectively. Meanwhile Malaysia and Thailand have longer catch and effort data set, from 1996 to 2015.

Results of the analysis were divided into SCS and ANS regions as shown in the Table 61 and Figure 88. From Fox model, we were able to estimate the MSY, and then could determine the level of effort MSY (fMSY). The illustrated Fox model showed that the current catches for all AMSs were still below the MSY level, except for Malaysia that had slightly exceeded the estimated MSY level in 2014.

As per recommendation by Sparre and Venema (1992) the safe level of exploitation (target fishing effort, 0.8 fMSY) is 20% lower than the fishing effort that gives the MSY value. It was found that the current effort (F) for Thailand SCS was 71,754 trips, had reached the target effort level (0.8 fMSY) of 71,429 trips. On the other hand, the current effort levels for Brunei Darussalam, Malaysia (ECPM) and Thailand (ANS) were still below than the target effort (0.8 fMSY).

In case of Indonesia SCS, the current effort (F) for Indonesia SCS in 2014, was 89,562 trips which had extremely exceeded the target effort level (0.8 fMSY) of 28,777 trips. However, the current catch (56,128 MT) was below the estimated MSY level (95,147 MT).

Table 61. Estimation of the MSY and target fMSY by Fox model for four AMSs in the SCS and ANS.

Country	Ecosystem	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	1045	1319	**1055**	96	9.2
Indonesia	SCS	2005-2014	56,128	89,562	0.8641	95,147	35,971	**28,777**	39,019	41
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

Note: *Target effort is much lower than current effort for ID_SCS.

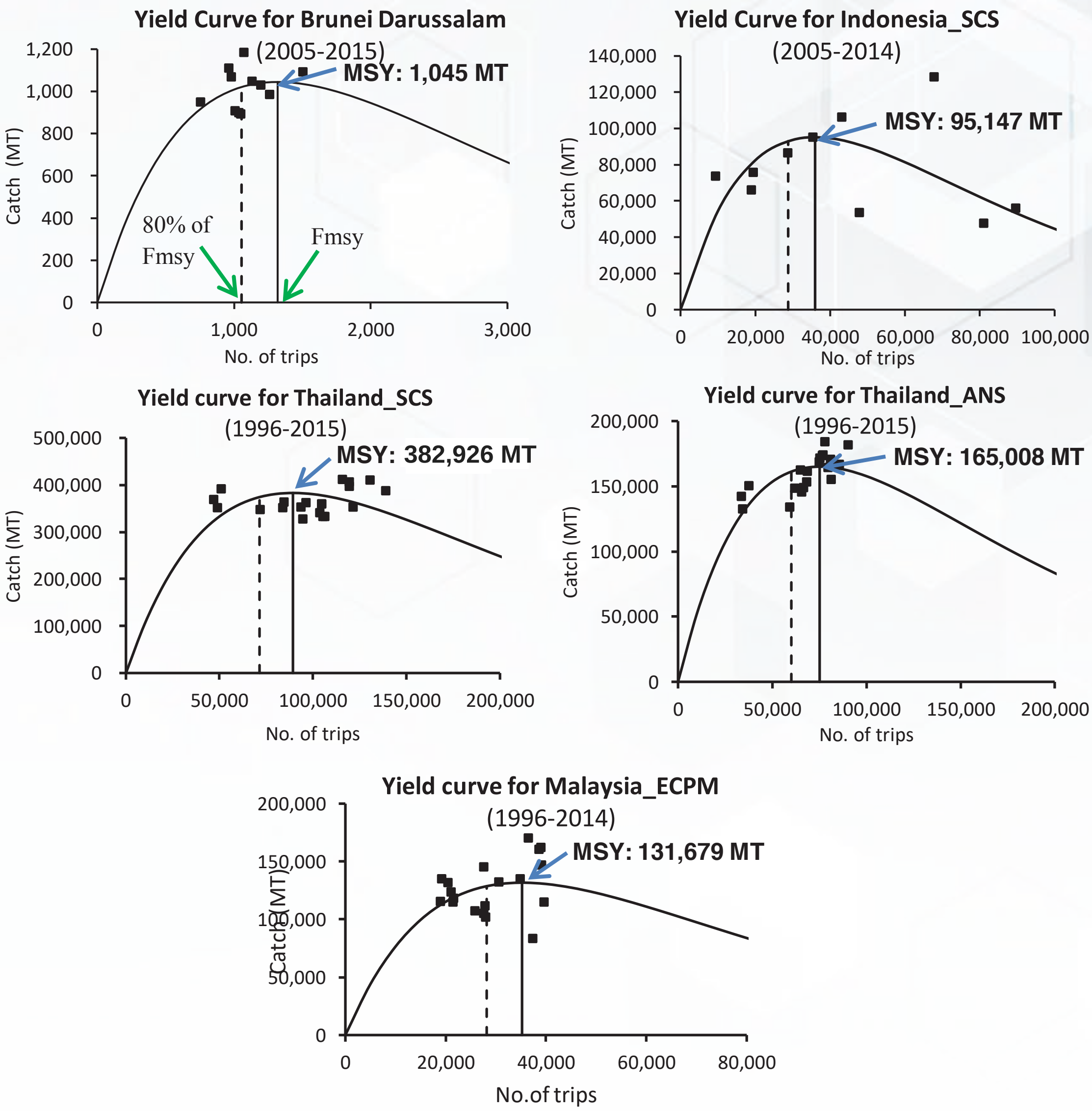


Figure 88. Fox Models illustrated by the pelagic fisheries off SCS and ANS for four AMSs.
(Note: Dotted line shows 80% of Fmsy as recommended by Sparre and Venema, 1992).

6.5.2. Discussion on results of the Production Model analysis

Results from Fox models revealed that the current fishing effort (F, by trip) in Indonesia (SCS) had extremely exceeded the target fMSY level although the current catch was below the estimated MSY level (Table 61). It is assumed that the pelagic stock in that area has been overfished since long time ago. It brings the concern that due to low productivity, pelagic stock in this area will collapsed in future if this trend of excessive fishing effort continues without any proper monitoring system by the Indonesia authorities.

According to the RP, Prof. Dr. Matsuishi, the current situation of the stock for purse seine fishery in Indonesia is represented by orange line in Figure 89. If the effort by trip increases, the orange will become A1. Further increasing the effort, the line would become A2, and will eventually approach the Y axis. The biomass will become very low, due to the biomass will reduced each time effort is increased. However, different situation will occur when the effort is decreases. The green line shows where MSY and BMSY values are at the optimum level. In general, when the effort is decreased, the orange line will approach or even or lower the green line. During this time, the biomass value will recover and increase since the effort is reduced.

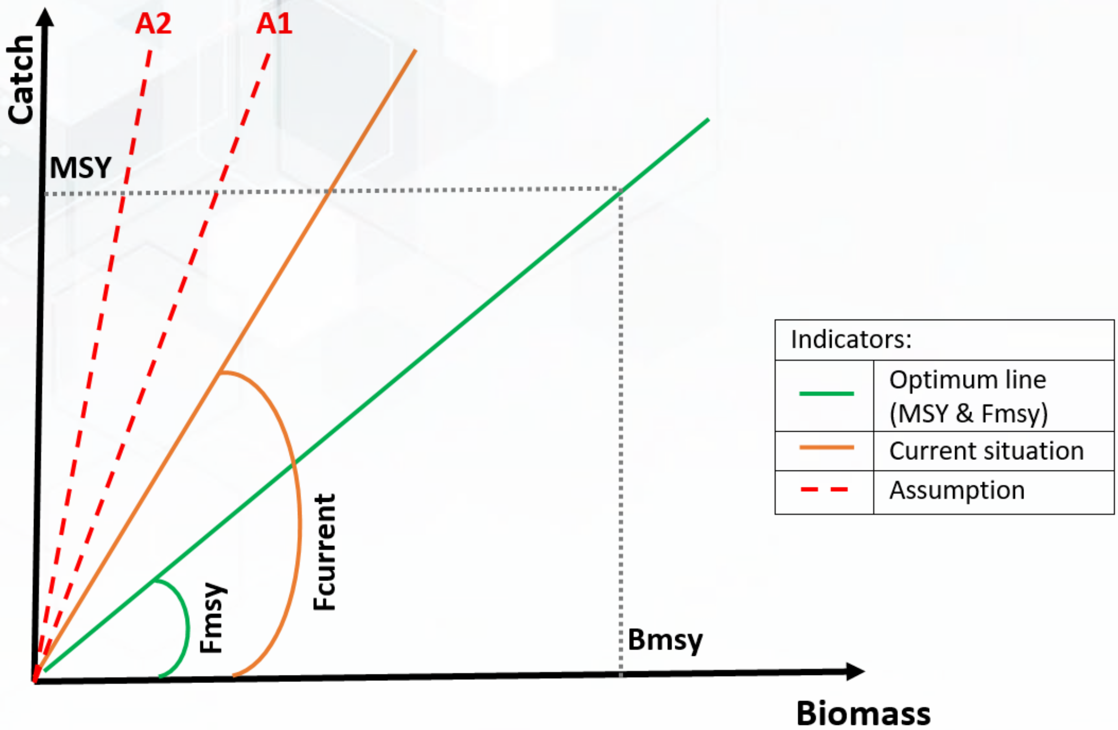


Figure 89. The graph of Biomass vs Catch for situation of purse seine fishery in Indonesia SCS (Graph illustrated by Prof. Dr. Matsuishi).

The current effort for Thailand SCS and ANShad reached estimated fMSY level in 2015. However, Thailand authorities already implemented Marine Fisheries Management Plan (2015-2019) which aimed to reduce the fishing capacity and fishing effort (Department of Fisheries Thailand, 2015).

On the other hand, the estimated MSY and target fMSY level of Brunei Darussalam showed that her pelagic fishery resource is at sustainable level. The fisheries authorities in Brunei Darussalam may increase the fishing capacity and fishing effort to further exploit the pelagic stock.

In the case of Malaysia (ECPM), her pelagic resource is fully exploited since estimated MSY level had been already reached in 2014. Malaysian authority is advised to not increase the current fishing effort. Instead, reducing the fishing effort and current catch is the best option for conservation purpose towards sustainable pelagic fishery.

6.6. Feedback Control (Rule 2-2)

Due to the fact that several AMSs were unable to provide sufficient and reliable data needed to do analyses of PM Model and Feedback Control (Rule 2-1), the RP recommended to use of Rule 2-2 as it is more appropriate and complements the data scarcity condition for some AMSs. Rule 2-2 was used at country and ecosystem level, which elaborated in the section 6.6.1 and 6.6.2.

6.6.1. Analysis by country

In the case of Indonesia (ANS) and Malaysia (ANS), only catch data were available and reliable, thus Rule 2-2 analyses were chosen as being more appropriate to examine their sustainability level. From the analyses, they showed that the current catches in Indonesia (ANS) and Malaysia (ANS) had already reached the estimated ABC level, indicating the pelagic stock in these areas have been well exploited over the years (Table 62 and Figure 90).

Table 62. Estimation of ABC (MT) for Indonesia (ANS) and Malaysia (ANS) in the SEA region.

Country	Ecosystem	Year	Current Catch (MT)	ABC (MT)	Deficit/Surplus	%
Indonesia	ANS	1996-2014	96,191	95,550	-641	-0.67
Malaysia	ANS	1996-2015	140,735	142,067	1,332	0.94

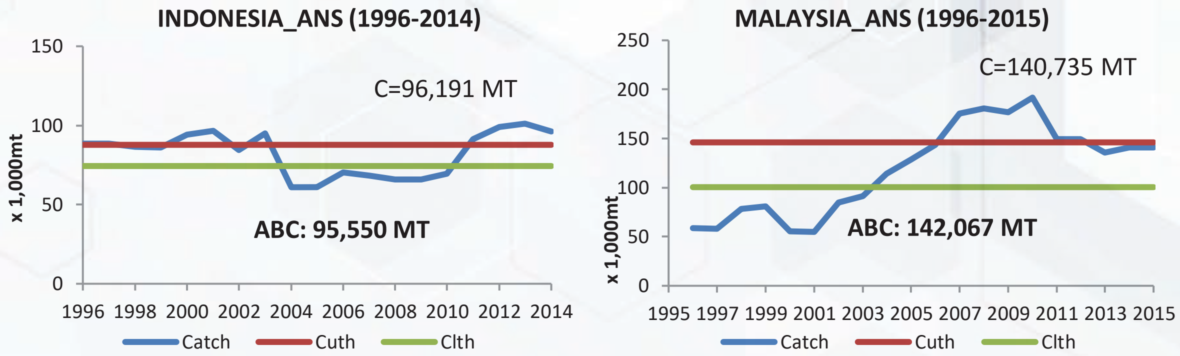


Figure 90. Feedback Control Analysis (Rule 2-2) for Indonesia (ANS) and Malaysia (ANS).
Notes: C = current landing; Cuth = Catch Upper Threshold; Clth = Catch Lower Threshold

6.6.2. Analysis by ecosystem

Feedback Control Analysis (Rule 2-2) by ecosystem were also done to estimate the ABC for whole SCS and ANS, as indicated in Table 63 and Figure 91. However, the analysis by ecosystem were only moderately analysed since several AMSs could not provide the relevant information.

In the SCS, catch and effort data from four AMSs namely Brunei Darussalam, Indonesia, Malaysia and Thailand were compiled and analysed as whole SCS. The estimated ABC for SCS was 645,413 MT, which is just 5,000 MT lower than the current catch in 2014, which was 650,692 MT.

Likewise, analysis for the ANS counted in only three AMSs which were Indonesia, Malaysia and Thailand. Similar pattern was also observed for whole ANS as the estimated ABC, 375,054 MT is approximately 4,000 MT lower from its current catch of 379,730 MT. Hence, it can be assumed that the pelagic resources in both SCS and ANS are at sustainable level since the current catches were around the estimated ABC.

Table 63. Estimation of ABC (MT) for SCS and ANS ecosystem.

Ecosystem	Year	Country	Current Catch (MT)	ABC (MT)	Deficit	%
SCS	1996-2014	BR, ID, MY, TH	650,692	645,413	-5,279	-0.8
ANS	1996-2014	ID, MY, TH	379,730	375,054	-4,676	-1.3

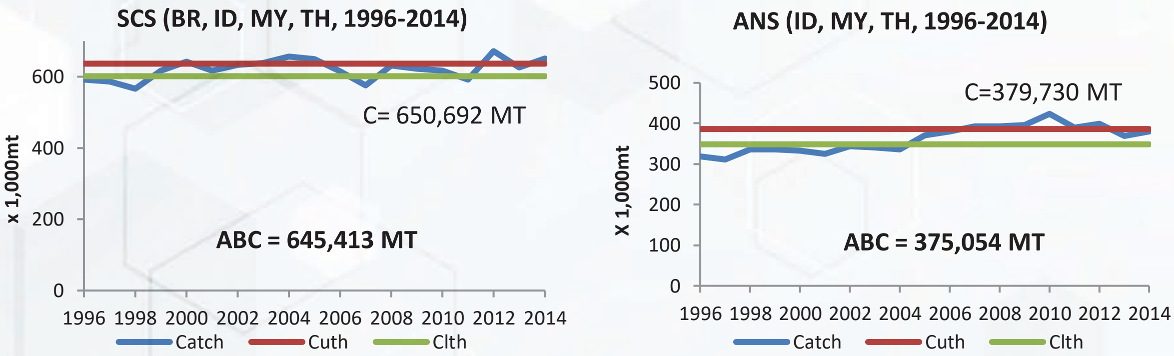


Figure 91. Feedback Control Analysis (Rule 2-2) for SCS and ANS ecosystems.

6.6.3. Discussion on results of the Feedback Control analysis

Through Feedback Control Analyses (Rule 2-2), the ABC value was calculated for the SCS and ANS ecosystem to predict a general overview of pelagic stock status in the SEA region. Nevertheless, data grouping according to the ecosystem might cause some uncertainties on data and process in this analysis. Thus, analysis at country level is ought to be more appropriate evaluation when proposing a management measure, especially in this project.

The ABC values were estimated at country level only for Indonesia (ANS) and Malaysia (ANS) due to data scarcity condition. It is worth noting that these country analyses used data until 2014 and 2015 as the current catch, respectively. The results of the analyses showed that the pelagic stock in Indonesia (ANS) and Malaysia (ANS) had been well exploited, indicating that their resources are still sustained (Table 62 and Figure 90).

Analyses at ecosystem level also showed that the current catch in 2014 already reached the estimated ABC for both SCS and ANS ecosystem (Table 63). Theoretically, it can be assumed that the pelagic resources in both SCS and ANS are still sustained. However, in reality, the accuracy of the analyses is questionable due to: i) biasness (the region was not represented by all AMSs); ii) high dispersion; and iii) uncertainties of data. Thus, this project could not provide comprehensive evidence to assist stakeholders in developing the fisheries management plan at ecosystem level.

All these ABC analyses, at country and ecosystem level do not represent the present (2019) status of pelagic fish in the SEA region. The present status might be different from results of these analyses.

7. Management Measures for Purse Seine Fisheries

In general, fisheries sustainability indicators would be used to reveal and monitor the conditions and trends in the fishery sector (Garcia, 1996) and could also referred as practical tool as stated by SEAFDEC (2006). There is mutual linkage between policy objectives and the selected indicators in achieving sustainable development goals, thus it is important to choose the indicators that are more practical, easily understood and supported by the stakeholders (SEAFDEC, 2006). Recognizing the insufficient management measures for PS fisheries in the SEA region, there is a need to adopt stronger appropriate measures. In the process of adopting management measures for PS fisheries, the best scientific evidence available should be taken into account in order to evaluate the current state of the fishery resources and the possible impact of the proposed measures on the resources (SEAFDEC/MFRDMD, 2003). Hence, the AMSs should use the best scientific evidence available in the evaluation of the status and trend of fishery resources, that also included the up-to-date models as well as new indicators.

For this project, MFRDMD only assists the AMSs by providing the scientific advices based on the results gathered from two analyses. Reference points for this project refer to the MSY and target fMSY from Production Model analysis, as well as the ABC value from Feedback Control analysis. The results of both analyses shall not be compared with each other due to different parameters used, thus scientific advices will be recommended independently.

7.1. Common constraints and issues

There are few factors that influence the outcomes of this project. Since this project involves the historical catch and effort data involving PS fishing gear, therefore comprehensive and reliable data became the main factor in influencing the degree of analysis results. Besides that, some issues like changes of fishing gears in certain AMSs that occurred during the research duration also effected the analysis.

7.1.1. Constraints on data resource

1) Insufficient historical time-series data.

   Many data sent by representatives of AMSs during regional meetings, workshop and through emails were patchy and insufficient time series (catch and effort data). This has caused analysis on stock assessment could not be done for all AMSs. It was found that only Brunei Darussalam, Indonesia, Malaysia and Thailand had the sufficient time series data needed to do the CPUE and Production Models analyses.

2) Data integrity (validity, reliability and accuracy).

   In some cases, the data submitted were questionable, thus bring the concern of data integrity. In certain cases, no response was given when a request for data verification was sent. The reliable catch and effort data are vital to be used in the stock assessment model. Due to unreliable statistical data and lack of accuracy, MFRDMD cannot determine the fishery sustainability indicators for all AMSs.

3) Data standardization.

   Some data sent was not in the format requested thus make difficult to analyze for all AMSs. Currently, AMSs used different types of unit effort which cause the data non-uniformity.

4) Statistical database system for catch and effort.

   AMSs are still struggling in building up fisheries management systems especially in pelagic fishery due to the nature of multi-species and multi-gear fisheries. The high catch of miscellaneous fish in the statistics reflects the problem to analyse the species composition in the catch.

7.1.2. Changes of major fishing gear

Cambodia has changed from PS to gill nets in their small pelagic fisheries since 2013. This can be seen from Table 60 in which the number of PS vessels was gradually decreased from 2004 to only one (1) unit in 2008 onwards. Besides that, the Philippines too has focus on the use of ring nets instead of PS to exploit its small pelagic resource, thus explained the very few PS vessels in 2014 onwards, as indicated in Table 60. The change of major fishing gear during the project duration had caused the good historical PS catch and effort data for two decades could not be completed by aforestated countries.

7.1.3. Multi-species situation in the SEA region

The multispecies situation in pelagic fishery in SEA region has caused huge species aggregation on catch categories which lead to incapability of providing species-separated data. Multispecies fisheries are subject to widely distributed and homogenously mixed fish stocks which lead to non-selective exploitation. Thus, the implementation of TAC for specific species in SEA region could not be possible.

7.2. Recommendations for purse seine fishery management

7.2.1. Scientific advices based on results from analyses

The stock assessment analyses reveal that exploitation of pelagic resources by purse seiners in Brunei Darussalam, Malaysia and Thailand are already at sustainable level. According to the Fox models (6.5.1), only Brunei Darussalam can increase their catch and effort to achieve the estimated MSY. In the case of Malaysia (ECPM) and Thailand (SCS and ANS), the stakeholders are advised to maintain their current fishing effort in order to sustain the pelagic stocks. In contrast, the pelagic resources in Indonesia (SCS) is not at sustainable level, thus it is highly recommended for them to reduce their fishing effort as much as possible until become one third (1/3) of the current effort. Whilst, the Feedback Control analysis (6.6.1) indicated that currently the PS fishery of Malaysia (ANS) and Indonesia (ANS) are at sustainable level. Nevertheless, further exploitation of pelagic fish by purse seine is not recommended.

Based on ecosystem, Feedback Control analyses (6.6.2) showed that the current landings in SCS and ANS ecosystems are almost equivalent to the estimated ABC levels. Thus, it is highly recommended not to increase fishing effort for both ecosystems but reduction in fishing effort is preferable. Every AMS should independently develop a special program to periodically monitor the performance of their PS vessels.

The Production Model analysis aims to determine the optimum level of effort while Feedback Control analysis aims to creates the sustainable fishery. It is recommended to AMSs that have sufficient and reliable data to use Production Model for tock assessment, while for AMSs that have data scarcity situation, the use of Feedback Control method is acceptable.

7.2.2. Recommendations for data and information collection

1) Through this project, it is clear to all AMSs about the importance of reliable catch and effort data collection. Thus, it is recommended that all AMSs should improve their statistical data collection especially on catch and effort data.

2) AMSs should ensure that data collection is timely and accurately and in accordance to international standards and practices to enable sound statistical analyses. Such data should be updated regularly and verified through an appropriate system.

3) AMSs should consider sharing of the catch and effort data to all AMSs and other interested parties in accordance to the agreed procedures.

4) AMSs should consider the observer onboard program which is a requirement for traceability made by Regional Fisheries Management Organization (RFMO). This program will help to acquire more accurate and complete catch and effort data with catch composition, fishing gears and bycatch.

7.2.3. Recommendations for input controls (fishing capacity)

5) Enchance the licensing scheme.
   This involves the licensing of the fishers, fishing gear and fishing vessels. Though most AMSs already implemented the fisheries law or act or regulation that only fishing vessels with valid license are allowed to catch the fish. It is recommended that all categories of PS vessels including the small size PS vessel have to be licensed.

6) Control the number of PS vessels.
   Limit the number of fishing vessels will reduce fishing pressure. Control the number of PS vessels will indirectly control the number of fishers. Controlling number of fishers will produce an effective limited entry into the fishing industry.

7) Limit the size of PS vessels.
   This is closely related to the gear specification control, includes the limit on the PS vessel engine power. The maximum continuous engine power (MCEP) must be declared to the fisheries authority.

8) Limit the allowable fishing days.
   Limit amount of time PS vessels are allowed to fish will help to reduce the catch. Usually the number of days allowed at sea is stipulated along with the TACs. However, the setback of limiting the fishing days is it does not take into account important factors such as the weather. In addition, limit the fishing effort during spawning season for targeted species can be done to ensure the recruitment of fish.

7.2.4. Recommendations for output controls (catch)

9) Introduce the catch quota system.
   Control or limit the catch amount is an effective and efficient method for sustainable PS. The implementation of catch quota system through Total Allowable Catch (TAC) allocation is commonly applied, though facing many difficulties in implementing successful catch quota system. Individual quota (IQ) indicates a catch limit of quota is allocated to an individual fisher. Though, IQ is not yet implemented for PS in SEA region.

10) Improve the bycatch handling (non-target species).
   Although it is very small percentage of bycatch or non-target species that being caught in PS operation in SEA region, like dolphin, turtles, small whales, sharks and rays, for conservation purposes, it is important to improving the handling practices for all bycatch species caught during the operation in which all fishers are expected to take all reasonable steps to ensure that bycatch is returned to the water as quickly as possible and in a manner which does not reduce its chance of survival. The guideline of handling bycatch which was published by Bycatch Management Information System (BMIS) has include the safe release technique of turtles, sharks and rays (Workshop on WCPFC Bycatch Mitigation Problem-Solving, 2018).

7.2.5. Recommendations for technical controls

11) Use larger mesh size.
   Introducing a larger mesh size than existing mesh used for PS fishery is encouraged for the sake of pelagic fish rehabilitation by reducing the catches especially juveniles. The 25 mm (1 inch) mesh size is widely used in most of the AMSs although certain AMSs still use 18 mm mesh size. A bigger mesh size that is more than 25 mm is highly recommended for Fish Purse Seine.

12) Limit the length and depth of seine net.

Limit on the length and the depth of the seine net will help to reduce the catch.

13) Register and control number of FADs.

It is a requirement for the all owner of PS vessels to register their FADs. Although there has not been any evidence of major negative impact following the steady development of FAD-fishing, it has been associated with the high mortality of small pelagic and bycatch of undesired sensitive species such as sharks, turtles, and other fish species that can be discarded dead at sea (Amandè et al. 2010; Amandé et al., 2012; Hall and Roman, 2013). It makes sense to assume that the number of FADs is a basic component of the fishing gear, thus their reduction would ultimately result in reduced fishing mortality, especially the juveniles.

14) Control the total light intensity for spotlight.

The use of artificial lights (e.g. metal halide, incandescent and LED lamps) has been found to be environmental-unfriendly due to catching of immature stocks. The total light intensity or lux should be limit at maximum of total watt is allowed, although it may differs depending on AMSs fisheries's authorities. The light intensity also can be limit by controlling the horsepower allowed on the genset (generator set) used to generate electricity for spotlight.

15) Encourage establishment of a zoning system (with gear specification).

Management of a zoning system should be based on the GRT of fishing vessels, engine power (horsepower, HP) of the vessels, type of fishing gears used and ownership patterns. AMSs like Brunei Darussalam, Indonesia, Malaysia and Thailand that already implemented zoning system may have revised their zoning system from time to time according to their fishery situation. Meanwhile some AMSs which didn't have zoning systems yet may refer to these countries as guidelines when introducing new zoning systems in their waters.

16) Identify and establish closed areas.

AMSs are encouraged to identify some areas to be permanently or temporarily closed due to their critical importance to the life cycle of specific species including spawning, nursery grounds or areas of habitat required for the maintenance of brood stock. MPA and refugia are commonly introduced under closed area (SEAFDEC, 2006). Also, no take zone could be set in order to protect the adult or matured fish.

17) Encourage AMSs to introduce a closed season for specific species.

A closed season is referred as banning of fishing activity for a certain period of time, usually to protect juveniles or spawners. Spawning closures may be particularly relevant in over-exploited stocks where there is a risk that recruitment is impaired. Seasonal fishing closures were applied for commercially pelagic species like mackerels in Thailand, and sardines and herrings in the Philippines. For stocks which there is no indication that recruitment is impaired, spawning closures may still be relevant to protect the older (and larger) individuals, protect spawning habitat structure, or prevent evolutionary change (Overzee and Rijnsdorp, 2014).

7.2.6. Recommendations for strengthening PS fisheries management

18) Review Legal Framework periodically.

Recognizing the significance of managing the fisheries resources sustainably, Fisheries Act in each AMS should be reviewed periodically either once for every five or ten years as the fishery resources is rapidly changing, using the assistance from development and innovation of the modern fisheries technology nowadays.

19) Establish the Fisheries Management Plan (FMP) for PS fisheries.

Results of this project could be used as the fundamentals and reference for AMSs in developing their FMPs for PS fishery. Each AMS holds its own responsibility in developing the FMP within the government's authority. All stakeholders are involved during the whole process of developing the plan. It should be noted that developing the FMP is a complex process comprises of multiple aspects such as biological, economic, geo-politic and social aspects.

20) Strengthen the monitoring, control and surveillance (MCS) activities among national enforcement agencies.

Each AMS should establish its respective national fisheries MCS measures, including law enforcement, and where appropriate, other useful management measures like observer programs, inspection schemes and vessel monitoring systems (VMS). Such measures should be promoted and implemented by country or RFMOs in accordance with procedures agreed by stakeholders. For conversation and management of fisheries resource, AMSs need to ensure that effective legal and administrative framework is implemented at local and national level (SEAFDEC/MFRDMD, 2003). This will help in control and combat the overfishing situation for pelagic fisheries in the region.

21) Integrate the MCS networking among the AMSs within the same ecosystem
The integrated MCS networking among countries that share the same ecosystems, i.e. the SCS ecosystem and the ANS ecosystem, will help to increase the efficiency of the MCS activities. The AMSs in the same ecosystem should use the same standard of procedures (SOP) in their MCS activities.

22) Assessment on PS fishing capacity.
In practice, capacity is often expressed in terms of physical characteristic of fishing vessels (e.g. tonnage, power etc), in term of yield (catch) and in economic terms (e.g. capital costs). The assessment on PS fishing capacity will allow to check for the excess or overcapacity. Only very few countries in the world have undertaken a systematic assessment of their eventual fishing capacity, either by segments of the industry, by region or at national level (Dominique Gréboval, 1999). Each AMSs assess and revise its own PS fishing capacity respectively.

23) Control of fishing capacity.
This plan can be accomplished by conducting moratorium (temporary ban) of new licenses for PS gears and vessels. It might be benefit to multi-species fishery, since it will reduce mortality among all species included in fishery. However, it has setback, for example, the existing fleets still can target the depleted stocks (Harlyan & Matsuishi, 2017).

24) Introduce the exit plan.
An exit plan is aimed to prevent fishing capacity from increasing, in particular in contexts where conservation and management measures are not effective enough to regulate the use of fishing capacity through enforceable input (such as licenses) and output measures (such as quotas). This include the resettlement of surplus fishers into other economic sectors and the vessel buy-back scheme that has been implemented in Malaysia and Thailand.

25) Enhance the capacity building.
Identify and train personnel including young researchers on analytical assessment of pelagic stocks. More training courses could be provided in national, regional and international level.

26) Encourage co-management involving coastal fishing communities.
It is more applicable for AMSs to consider developing coastal fishing communities, like Japanese coastal fisheries (Fisheries Cooperative Association) and Malaysian fishery

volunteers *(Sukarelawan Perikanan* - SUPER). The fishing community consists of local fishers and supervised by the district authorities. The fishers are part of co-management, in which they govern their rights voluntary and self-imposed including conducting monitoring and sanction clauses. This might reduce the monitoring cost and strengthen community awareness to their fishery assets (Harlyan & Matsuishi, 2017).

GENETIC STUDY OF *Amblygaster sirm* INFERRED BY MITOCHONDRIAL DNA (mtDNA) IN SOUTH CHINA SEA AND ANDAMAN SEA

Prepared by:

Ms. Wahidah Mohd Arshaad*
Ms. Noorul Azliana Jamaludin*
Ms. Masazurah Ab Rahim
Ms. Nur Ayuni Ariffin*
Mr. Adam Luke Pugas*
Ms. Nik Zuraini Nawawi @ Omar*
Ms. Annie Nunis Billy
Mr. Muhammad Taufik
Mr. Achmad Zamroni*
Ms. Noor Adelyna Mohammed Akib, Phd
Mr. Danial Hariz Zainal Abidin
Ms. Siti Azizah Mohd Nor, Phd

**Analysis team for this component*

Corresponding author:
Wahidah Mohd Arshaad
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia
wahidah@seafdec.org.my

ABSTRACT

Amblygaster sirm or spotted sardinella is a marine pelagic species from family Clupeidae. It is one of the sardine species that have economic value to Southeast Asian region. However, limited population information of this species is available, though it is fished at both commercial and artisanal scales at various intensities within its range and utilized for human consumption. In this study, tissue samples of 35 fishes of *A. sirm* from each site were collected from ten localities in the South China Sea (Muara, Brunei Darussalam; Kuching, Kuantan, Kudat, Malaysia; Songkhla, Thailand; Palawan, Zambales, The Philippines); two sites in Andaman Sea (Ranong, Thailand and Banda Aceh, Indonesia) and one site in Java Sea (Pekalongan, Indonesia). The partial mitochondrial DNA (mtDNA) *Cytochrome b* sequences (1016 bp) and *Cytochrome c oxidase subunit I* (665 bp) were used in the analysis. A total of 356 *(Cyt b*) and 125 (*COI*) samples were sequenced and produced 202 and 78 haplotypes respectively. The haplotype diversity (*hd*) was high for all populations but the values of nucleotide diversity (π) were generally low for both markers. The results from this study revealed two highly genetic divergent stock; Ranong versus the rest of the populations.

1. Introduction

The main target among fishery managers is to ensure sustainability of resources and avoid depletion of fisheries stock (Reiss *et al*., 2009) hence maximizes the economic returns to the people (Ward & Grewe, 1994). Defining the stock is very important in conservation as to avoid depletion of subpopulations due to overharvesting or overfishing activities in certain areas. Therefore, determination of fish stock assessment through genetic structure is fundamental for fisheries management (Reiss *et al*., 2009; Roldán *et al*., 2000; Bailey, 1997). Fisheries management is getting difficult due to over utilization of fish stocks, water pollutions and various human activities. According to Roldán *et al*. (2000), determination of population genetic structure is essential to underpin the resources recovery and to aid delineation and monitoring the population for fisheries management. Once the population genetic structure is determined, the identification of management units (MUs) can be conducted for some selected species.

A stock is defined as "an intraspecific group of randomly mating individuals with temporal or spatial integrity" (Ihssen *et al*., 1981). Larkin (1981) defined a stock as "a population of organisms which share a common gene pool, is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed". In fisheries management, a unit of stock is normally regarded as a group of fish exploited in a specific area or by a specific method (Carvalho & Hauser, 1995). The general goals of population genetic studies are to characterize the extent of genetic variation within species and account for this variation (Weir, 1996).

Population genetics is the study of genetic variation within populations, and involves the examination and modelling of changes in the frequencies of genes and alleles in populations over space and time. Genetic variation is the raw material in species and populations that enables them to adapt to the changes in their environment. New genetic variation arises in a population, from either spontaneous mutation of a gene, or by immigration from genetically different individuals. The number and relative abundance of alleles in a population is the measure for genetic variation (Ciftci & Okumus, 2002).

Fish for human consumption is mostly obtained through exploitation of wild populations. Reduction in the genetic resources of wild fish populations, caused by various human activities, has become an important issue in fisheries management. Fishing can also alter genetic diversity within populations, moreover many thousands of species have been extirpated due to habitats destructions, pollutions, overfishing exploitations and blockage of the migration routes (Ferguson, 1995).

Water currents, different spawning and feeding grounds as well as fish behaviour may cause the invisible boundaries resulting in discrete structured populations that could be determined by mitochondrial DNA or mtDNA. Since 1980s, mtDNA has been a widely utilized marker in genetic studies. The use of mtDNA marker than other markers for molecular diagnostic gives several advantageous characteristics such as ease to isolate, haploidy, maternally inherited and one-fourth the effective size compared to nuclear DNA, thus makes this marker easy to detect population differences (Park & Moran, 1994). The DNA in the mitochondrial (mtDNA) is evolving five to 10 times faster than the DNA in the nucleus (Kochzius, 2009; Brown *et al*., 1979). Moritz *et al*. (1987) also suggested this molecular DNA as one of the best macromolecules to be studied in evolution due to its of varying amount of divergence among mtDNA sequences. The widely studied mitochondrial gene are cytochrome *b* (*Cyt b*) and *Cytochrome C Oxidase* Subunit I (*COI*) to determine the genetic structure of selected species. Genetic populations study on sardines species by using mtDNA were reported for *Sardinella zunasi* (Wang et al., 2008), *Sardinella hualiensis* (Willette *et al*., 2011), *Sardinella tawilis* (Quilang *et al*., 2011), *Sardinella gibbosa* (Thomas *et al*., 2014), *Sardinella longiceps* (Sukumaran *et al*., 2016) and *Sardinella pilchardus* (Jerome *et al*., 2003). The Philippines is among the most diverse countries for *Sardinella* biodiversity in the world followed by India (Willette *et al*., 2011).

Amblygaster sirm (Walbaum, 1792) or *spotted sardinella* is a marine pelagic species from family Clupeidae that occurs widely across the Indo-Pacific from the eastern coast of Africa to Australia, Fiji and New Caledonia (www.fishbase.org & www.FAO.org). It occurs throughout the Southeast Asian (SEA) region except in the Strait of Malacca (Carpenter & Niem, 1999). It has slender body, somewhat cylindrical; rounded belly with 16-17 prepelvic and 13-15 postpelvic somewhat weak scutes. It has smooth opercle, without bony radiating striae. Its colour is dark blue-green dorsally, silvery ventrally and series of 10-20 blackish spots laterally on trunk; a clear feature that facilitate the identification of this species compare to the other sardine species. It is one of economically important sardine in SEA region. Sardines species are mainly school near the bottom of a lagoon during the day (Conand, 1988) then disperses into the mid and upper waters of the lagoon during the night to feed on copepods and other zoo- and phyto-planktons (myBIS). Maximum length for this species is 23 cm but it is commonly found at 20 cm of length.

However, limited information of this species is available, though it is fished at both commercial and artisanal scales at various intensities within its range and utilized for human consumption (www.iucnredlist.org). Given that this species is widely distributed with a geographic range that overlaps with existing marine protected areas, *A. sirm* is assessed as Least Concern in IUCN Red list.

The objective of this study was to ascertain the genetic structure of *A. sirm* is exist in the South China Sea (SCS) and Andaman Sea (ANS) or there is just one panmictic population, using the mtDNA marker.

2. Materials and Methodology

2.1. Tissue sample collection

There were nine sampling sites for the South China Sea and three for Andaman Sea as indicated Figure 92. No samples from Viet Nam due to unavailability of the sample during sampling period. Maximum 35 tissue samples (fin clip) of *A. sirm* (Figure 93) were collected from every sampling site. The tissue samples were collected by the technical officers of the respective countries following strictly same standard operating procedure supplied (Abu-Talib *et al*., 2013). Details of the tissue samples collected were shown in Table 64. A small amount of fin clip tissue sample was fixed in vials containing preservation buffer (70% ethanol). The collected tissues were sent to SEAFDEC/MFRDMD for further analysis.

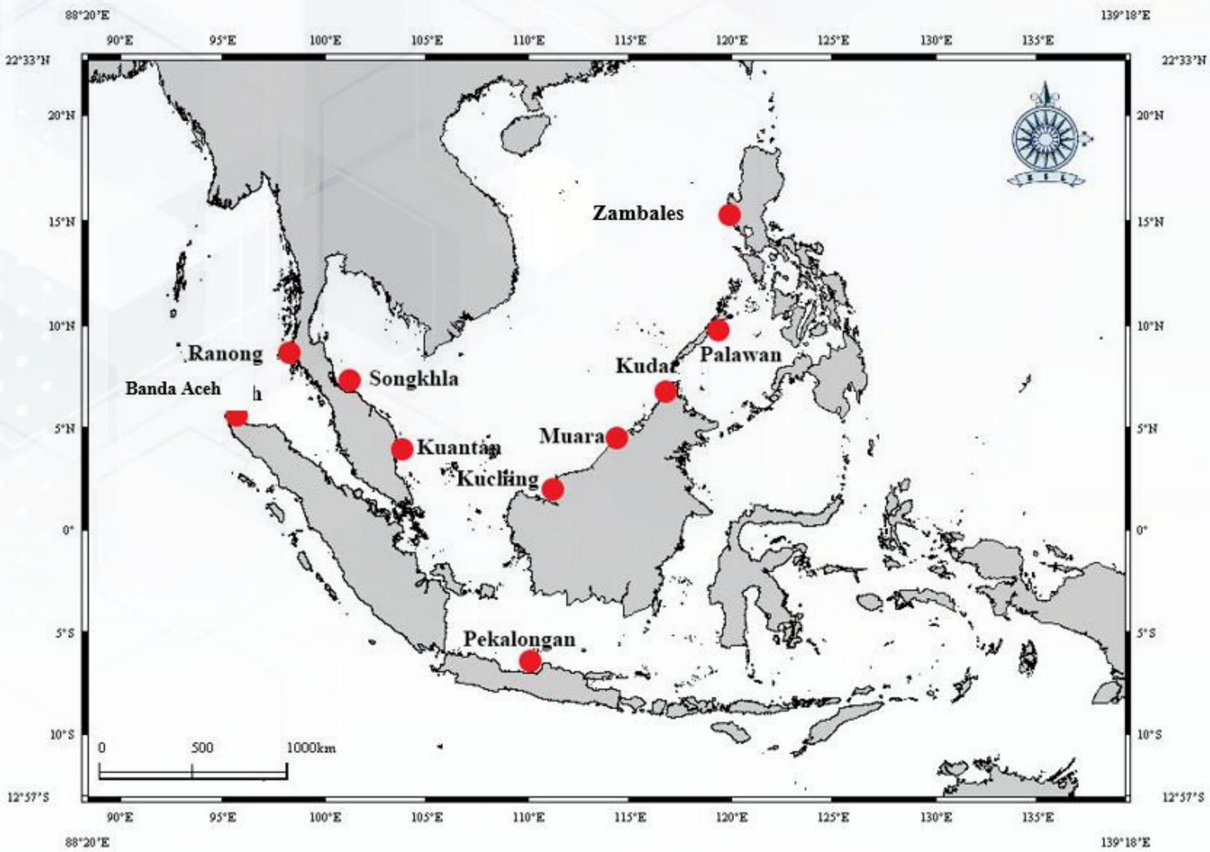


Figure 92. Sampling locations of *Amblygaster sirm* amplified for mtDNA gene analyzed in the present study.

Figure 93. The spotted sardinella (*Amblygaster sirm*).

Table 64. Sampling sites, sampling date, coordinates and number of specimens from Andaman Sea, South China Sea and Java Sea.

Country		Sampling Site	Sampling Site Code	Sampling Date	Lat Long	No. of Specimen
Andaman Sea (ANS) Sub-Region						
Indonesia	1	Banda Aceh	SBA	25 Aug 2017	5°35’N, 95°18’E	35
Myanmar	2	Yangon	SMN	04 Nov 2014	18°27′ N, 94°20′ E	35
Thailand	3	Ranong	SRG	09 May 2015	9°56’N, 98°35’E	35
			SRG	23 Sep 2016	9°56’N, 98°35’E	50
			SRGM	26 Jun 2018	9°56’N, 98°35’E	50
South China Sea (SCS) and Gulf of Thailand (GOT) Sub-Region						
Brunei	4	Muara	SBR	16 Jun 2015	5°1’N, 115°4’E	35
Cambodia	5	Sihanoukville	SSV	04 Jan 2016	10°37’N, 103°31’E	36
Malaysia	6	Kuantan	SKT	29 Jan 2015	3°51'N, 103°25'E	35
	7	Kuching	SKC	2016	1°35’N, 110°37’E	34
	8	Kudat	SKD	11 May 2015	6°52’N, 116°50’E	35
Philippines	9	Palawan	SPL	2015	9°52’N, 118°55’E	23
	10	Zambales	SZB	2015	15°30’N, 119°58’E	24
Thailand	11	Songkhla	SSL	22 May 2015	12°14’N, 102°31’E	36
Out-group (Java Sea, JS)						
Indonesia	12	Pekalongan	SPN	10 May - 10 Aug 2017	1°10’N, 108°58’E	35
					Total	**498**

2.2. DNA Extraction

The genomic DNA from the collected tissue samples was isolated using MasterPure™ DNA Purification Kit (Epicentre, USA) according to the manufacturer's protocol and stored at -20 ˚C until further use in Genetic Conservation Lab at SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia. For samples from Banda Aceh and Pelakongan, Indonesia, the DNA extraction and further analyses were done in Lab Genetika at Research Institute for Marine Fisheries, Indonesia.

2.3. PCR analysis

2.3.1. *Cytochrome b* (*Cyt b*)

Mitochondrial *Cyt b* gene was amplified by forward primer WMA15-F (5' ACC GTT GTA ATT CAA CTA TAG AAA C 3'), whereas the reverse primer was TruCytb-R (5' CCG ACT TCC GGA TTA CAA GAC CG 3') by Jerome *et al.* (2003). PCR amplification was carried out in 25 µL containing 1 µL DNA template, 1 x MyTaq™ PreMix (Epicentre, USA) with PCR conditions of one cycle at 95 ºC (15 secs), 35 cycles of 95 ºC, (40 secs), 52 ºC (40 secs), 72 ºC (10 secs) and one cycle at 72 ºC for 10 minutes.

2.3.2. *Cytochrome c Oxidase* Subunit *I (COI)*

The DNA template was PCR-amplified for the mitochondrial *COI* gene by primers NAJS17-F (5' GTT CCT GAG CAG GGA TGG TA 3') and NAJS17-R (5' GGG AGA TGA GTG ATC CAA TAG AGG 3') in total reaction 25 µL volumes containing 10-100 ng DNA template, 0.2 µm of each primer and 1x MyTaq™ PreMix (Epicentre, USA) with PCR conditions (touchdown) of 94 ˚C (3 mins), 7 cycles of of 94 ºC, (30 secs), 59 ºC* (30 secs), 72 ºC (1 min). For annealing temperature (*) was gradually reduced 1 ºC per every second of each cycle. The amplification was then continued with 25 cycles of (94 ºC (30 secs); 55 ºC (30 secs), 72 ºC (1 min) and 72 ºC (2 mins) and hold at 10 ºC.

2.4. DNA Sequencing

The quality of PCR products was visualized on 1.5% agarose gels stained with 1 to 3 µL of GelRed^{TM} Nucleic Acid Gel Stain (Biotium Inc., USA). The non-purified PCR amplicons were sent to Repfon Technologies Sdn Bhd (Malaysia) for purification and DNA sequencing.

2.5. DNA Sequence Analysis

Both forward and reverse *Cyt b* and *COI* sequences were edited in MEGA 6 (Tamura et al., 2013). The compiled sequences were aligned by ClustalW that was integrated within MEGA 6. The aligned sequences were translated into protein to ensure accurate alignment and detection of stop codons if present. The complete aligned dataset was then screened for nucleotide variable sites, parsimony informative sites, number of transitions and transversions and nucleotide frequencies in MEGA 6. The same software was used to estimate genetic diversity within and among populations based on a K2P model. Number of haplotypes and haplotype distributions for sampled populations were assessed and summarized using DnaSP 5.10 (Librado & Rozas, 2009). Genetic diversity was estimated using two estimators in Arlequin 3.1 (Excoffier *et al*., 2005) including; 1) haplotype diversity (*hd*) that measures the probability of uniqueness of a haplotype in a given population and 2) nucleotide diversity (π) which is the mean number of pairwise nucleotide differences among individuals in a sample. Both nucleotide and conventional F_{ST} distance measures were used to calculate within and among population diversity.

Phylogenetic relationships among haplotypes were constructed using Neighbour-Joining (NJ) method in MEGA 6 with a confidence level assessed using 1000 bootstrap replications. To view the haplotype relationships, a phylogenetic network of all haplotypes was constructed based on median joining calculation in Minimum Spanning Network (MSN) (Bandelt *et al*., 1999). The genetic diversity that was included the gene diversity and the nucleotide diversity were retrieved in Arlequin 3.1. The genetic distance estimates within and between sampled populations were calculated using a Kimura 2 parameter distance method in MEGA 6. An analysis of molecular variance (AMOVA) was performed to estimate molecular variance among sampled populations using Arlequin 3.1. The AMOVA partitioned the total genetic variance into three measures of haplotypic diversity; F_{ST} describes variation between populations within total, F_{SC} describes variation among populations within region and F_{CT} describes variation among regions within total (Excoffier *et al*., 2005).

Spatial structure was examined further using Spatial Analysis of Molecular Variance (SAMOVA) v.1.0 (Dupanloup *et al*., 2002) to identify groups of sample sites that were most similar and that was geographically meaningful. The SAMOVA uses the statistics derived from AMOVA and incorporated the geographical information on sampling sites with a simulated annealing approach to maximize the F_{CT} among groups of populations as well as identifying possible genetic barriers between them, without predefining populations (Dupanloup *et al*., 2002).

3. Results

During the midway of the project, it was found that the Yangon and Sihanoukville samples were not *A. sirm* (misidentification), thus they were excluded from further analyses.

3.1. Data analysis from mtDNA *Cytochrome b* (*Cyt b*)

3.1.1. Nucleotide composition

Data analysis of 1016 bp of the *Cyt b* gene obtained from 10 localities produced 356 sequences that defined 202 haplotypes. Of these, a total of 231 variable sites (22.7%) was identified and 135 (13.3%) were parsimony informative. The details of molecular index were shown in Table 65.

The number of haplotypes and polymorphic nucleotides per site ranged from 15 to 30 and 17 to 78 respectively. Very high haplotype diversities (*hd* = 0.9092 to 0.9815) was observed. The nucleotide diversity was observed being lowest in Kudat (0.002382) and highest in Ranong (0.006858).

Table 65. Molecular diversity index generated by ARLERQUIN version 3.11.

	South China Sea							Andaman Sea		Java Sea
	SBR	**SKC**	**SKT**	**SKD**	**SPL**	**SZB**	**SSL**	**SRG**	**SBA**	**SPN**
N	34	34	35	35	21	24	34	69	35	35
Number of haplotypes, *h*	23	25	24	21	15	19	20	40	30	30
Number of polymorphic sites	35	37	29	25	17	24	28	78	38	44
Number of transitions	30	33	28	24	16	22	25	59	35	40
Number of transversions	5	4	2	1	1	5	3	22	4	5
Haplotype diversity (*hd*)	0.9447	0.9643	0.9445	0.9092	0.9190	0.9601	0.9305	0.9561	0.9815	0.9748
Nucleotide diversity (π)	0.003195	0.003630	0.002645	0.002382	0.002578	0.003370	0.002746	0.006858	0.003553	0.003997

3.1.2. Haplotype distribution

A total of two hundred and two (202) haplotypes were detected from 356 samples amplified by mtDNA *Cyt b* gene, where thirty (30) were shared and one hundred and seventy-two (172) were unique or singleton. Six dominant haplotypes (Hap05, Hap06, Hap11, Hap23, Hap163 and Hap168) were detected. The distributions of shared haplotypes were shown in Table 66. The details of haplotypes were listed in Appendix VI.

Table 66. Distribution of shared haplotypes for 10 populations of *A. sirm* inferred from mtDNA *Cyt b* gene. The highlighted box are the major haplotypes.

Haplotype	South China Sea							Andaman Sea		Java Sea	Total	Haplotype frequency/ Total (%)
	SBR	SKC	SKT	SKD	SPL	SZB	SSL	SRG	SBA	SPN		
Hap03	1								1		2	1.0
Hap05	2		1	1	2	2	2				10	5.0
Hap06	6	4	6	4	6	1	6		1		34	16.8
Hap11	6	5	6	10	2	5	7		5	6	52	25.7
Hap12	1				1						2	1.0
Hap16	1		1								2	1.0
Hap18	1					1					2	1.0
Hap23	1	3	3	3	1	1	2		1	1	16	7.9
Hap29		2		1							3	1.5
Hap52				1					1		2	1.0
Hap54				1					1		2	1.0
Hap65			1				1				2	1.0
Hap67			1				1				2	1.0
Hap91							2				2	1.0
Hap102						1				1	2	1.0
Hap128									1	1	2	1.0
Hap136									1	1	2	1.0
Hap139									2	1	3	1.5
Hap140									1	1	2	1.0
Hap163								12			12	5.9
Hap165								4			4	2.0
Hap168								7			7	3.5
Hap169								2			2	1.0
Hap170								2			2	1.0
Hap175								3			3	1.5
Hap179								2			2	1.0
Hap182								2			2	1.0
Hap186								2			2	1.0
Hap189								2			2	1.0
Hap190								2			2	1.0

3.1.3. Phylogeography and phylogenetic relationships

The NJ tree revealed two clusters identified (Figure 94) from the regional sharing haplotype, which was clade A and B, and tree rooted by Genbank *S. gibbosa* (NC 037131.1) and *S. longiceps* (NC 033407.1), with the best fit model was K2P (Kimura 2-parameter) model obtained from MEGA 6 (Tamura *et al*., 2013; Nei & Kumar, 2000).

The Minimum Spanning Network (MSN) yielded clearly two separated groups of 202 haplotypes produced (Figure 95). The further investigation showed that the haplotypes from Ranong was completely distinct with many mutational changes (52) from the observed network.

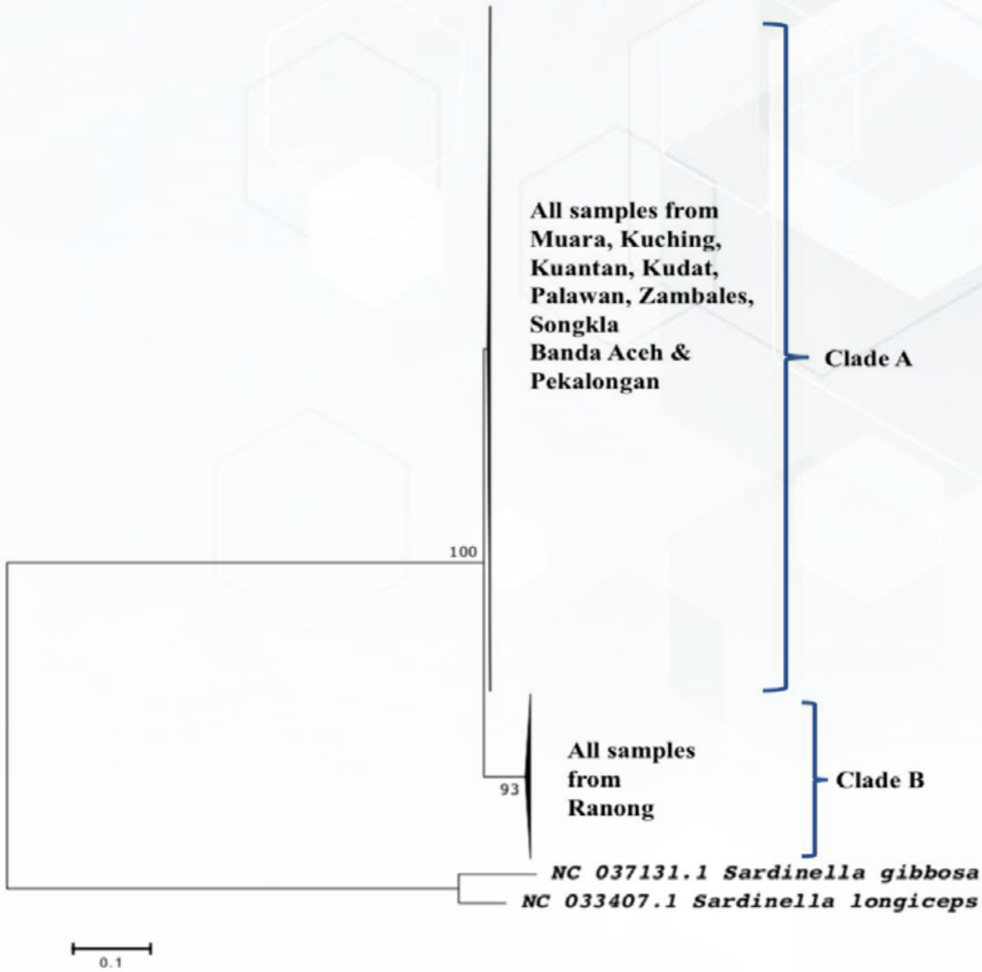


Figure 94. Evolutionary history as inferred using Neighbor- Joining method (K2P distance) with 1000 bootstrap replicates between mtDNA *Cyt b* haplotypes in *A. sirm* rooted with Genbank *Sardinella gibbosa* (NC 037131.1) and *Sardinella longiceps* (NC 033407.1). The number of each node represented bootstrap proportions for NJ analysis.

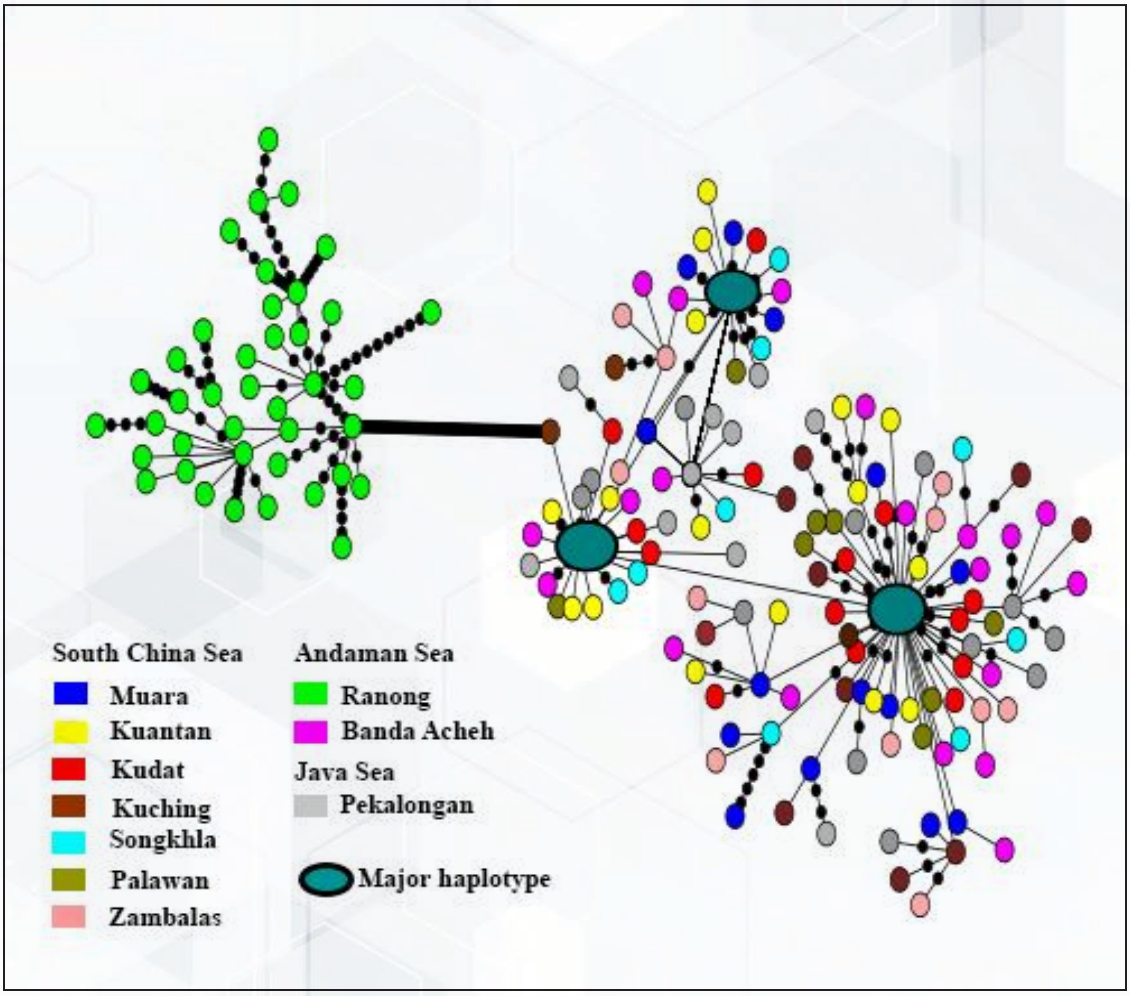


Figure 95. Minimum Spanning Network (MSN) inferred from mtDNA *Cyt b* gene. Coloured close circles represented different region (refer to the legend).

3.1.4. Genetic diversity within and among sites

The genetic diversity was calculated to give a better explanation beside 3.1.2. The genetic diversity within populations ranged from 0.3% to 0.7%, with Ranong has the highest within-population genetic diversity (0.7%).

Meanwhile, for among-population, genetic diversity ranged from 0.2% to 7.1%, with Ranong population was the most deviated from other populations. This supported and explained finding in 3.1.2. The Ranong population was the most divergent when compared to other populations ranging from 7.1% to 7.6%. Hence, if Ranong was excluded from the analysis, the genetic diversity ranged only from 0.2% to 0.4%. This clearly showed that the Ranong population from Northern ANS was the most divergent compared to other remaining sites (Table 67).

Table 67. Genetic distance within population (highlighted cells) and among population of *A. sirm* inferred by mtDNA *Cyt b.*

		South China Sea							Andaman Sea		Java Sea
		SBR	**SKC**	**SKT**	**SKD**	**SPL**	**SZB**	**SSL**	**SRG**	**SBA**	**SPN**
South China Sea	**SBR**	0.003									
	SKC	0.003	0.003								
	SKT	0.003	0.003	0.003							
	SKD	0.003	0.003	0.002	0.003						
	SPL	0.003	0.003	0.002	0.003	0.003					
	SZB	0.003	0.003	0.003	0.003	0.003	0.006				
	SSL	0.003	0.003	0.003	0.003	0.002	0.003	0.003			
Andaman Sea	**SRG**	0.070	0.070	0.070	0.070	0.071	0.071	0.071	0.007		
	SBA	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.071	0.004	
Java Sea	**SPN**	0.004	0.004	0.003	0.003	0.003	0.004	0.003	0.071	0.004	0.004

3.1.5. Genetic differentiation

Since there was a completely two genetic structure between Ranong (Northern ANS) with other populations, the F_{ST} analysis was used to detect the genetic differentiation between these two genetic structures. The F_{ST} value between South China Sea waters including Banda Acheh (southern ANS) and Pekalongan (Java Sea) *vs* Ranong (northern ANS) was ranged from 0.00076 to 0.91963.

Likewise, the comparison between Ranong and other populations in the pairwise genetic differentiation was also significant. The population pairwise between population (F_{ST}) was shown in Table 68. This approved that there was a major genetic structure between Ranong population *vs* the remaining population with strong significant value from the analysis.

Table 68. Population pairwise (F_{ST}) based on *Cyt b* sequence (highlighted box indicates significant ($p < 0.05$) F_{ST} values).

		South China Sea							Andaman Sea		Java Sea
		SBR	**SKC**	**SKT**	**SKD**	**SPL**	**SZB**	**SSL**	**SRG**	**SBA**	**SPN**
South China Sea	**SBR**	0									
	SKC	0.00252	0								
	SKT	-0.00458	0.00214	0							
	SKD	-0.00536	-0.00076	-0.01111	0						
	SPL	0.01784	0.00605	0.01678	0.03349	0					
	SZB	-0.00275	-0.00656	0.00728	0.00591	0.02594	0				
	SSL	-0.00247	0.01002	-0.0058	-0.01198	0.0456	0.00722	0			
Andaman Sea	**SRG**	0.91576	0.91298	0.91818	0.91963	0.91256	0.91119	0.91744	0		
	SBA	0.00981	-0.00868	0.00639	0.0111	0.00281	-0.00929	0.01618	0.91384	0	
Java Sea	**SPN**	0.02008	0.00117	0.01663	0.01625	0.03857	-0.00789	0.01364	0.91198	-0.00454	0

3.1.6. Assessment of population groups

The AMOVA and SAMOVA were performed to identify the genetic groups of population. The AMOVA for all ten populations yielded a significant F_{ST} value of 0.84781 ($p<0.001$), indicating significant genetic division among these ten populations (Table 69). Samples were divided into two groups based on result genetic distance, and F_{ST} value (Table 67 and Table 68) (Ranong was isolated from other nine populations) revealed non-significant values of F_{CT}. In addition, non-significant F_{ST} value is also observed when AMOVA was run using one group that excluded Ranong. The AMOVA analysis of two groups showed that the most of molecular variance was found among group variation (94.07%) and within populations was only 5.94%. While, if Ranong was excluded from the analysis, the most of molecular variance was change to within populations (99.41%) and the variation between populations was very low, less than 1% (0.59%).

Table 69. The results of AMOVA testing genetic structuring based on *Cyt b* data.

Source of variation	df	Sum of Squares	Variance components	Variation (%)	Fixation indices	Probability
(1) One group						
Among populations	9	3480.86	10.95 Va	84.78	F_{ST}: 0.84781	<0.001
Within populations	346	680.15	1.97 Vb	15.22		
(2) Two groups (Group 1: SBR, SKC, SKT, SKD, SPL, SZB, SSL, SBA & SPN) (Group 2 : SRG)						
Among populations	1	3465.72	31.14 Va	94.07	F_{CT}: 0.94068	=0.09677
Among populations within groups	8	15.14	-0.002 Vb	-0.01	F_{SC}: -0.00117	=0.10753
Within populations	346	680.15	1.97 Vc	5.94	F_{ST}: 0.94061	<0.001
(3) One group but without Ranong						
Among populations	8	17.14	0.01 Va	0.59	F_{ST}: 0.00585	=0.10362
Within populations	278	443.24	1.59 Vb	99.41		

Based on estimates of k = 2 to 6 in the SAMOVA analysis, each group represented a statistical discrete phylogeographic grouping (Table 70). However, k = 2 yielded the highest and non significant F_{CT} value (F_{CT} = 0.94079, p>0.05), indicated a very clear signal that there was two genetically different *A. sirm* stocks among the sampled populations namely Group 1: SBR, SKC, SKT, SKD, SPL, SZB, SSL, SBA & SPN and Group 2: SRG.

Table 70. Population structured based on *Cyt b* differentiation in spatial analysis of molecular variance (SAMOVA).

No. of groups, k	Structure	Variation (%)	F_{CT}
2	(SBR, SKC, SKT, SKD, SPL, SZB, SSL, SBA, SPN), (SRG)	94.08	0.94079
3	(SBR, SKC, SKT, SKD, SZB, SSL, SBA, SPN), (SRG), (SPL)	92.55	0.92549*
4	(SBR, SKC, SKT, SKD, SSL, SBA, SPN), (SRG), (SPL), (SZB)	90.99	0.90989*
5	(SBR), (SKC, SKT, SKD, SSL, SBA, SPN), (SRG), (SPL), (SZB)	89.17	0.89169*
6	(SBR, SKC, SKT, SKD, SBA), (SPN), (SSL) (SRG), (SPL), (SZB)	87.71	0.87710*

*p<0.05

3.2. Data analysis from mtDNA *Cytochrome c Oxidase* Subunit I (*COI*)

3.2.1. Nucleotide composition

To support result from 3.1, one hundred and twenty-five (125) fin clip samples from eight locations was used for further analysis with another mtDNA gene marker which was *Cytochrome c oxidase* subunit I (*COI*). The eight locations were Muara (SBR), Kuching (SKC), Kuantan (SKT), Kudat (SKD), Palawan (SPL), Zambales (SZB) and Songkhla (SSL) which representing the SCS sub-region, and Ranong (SRG) representing the ANS sub-region. Banda Acheh and Pekalongan were excluded for *COI* gene analysis. From these sequences, 665 bp of *COI* gene was found, which defined 78 haplotypes. A total of 93 variable sites (14%) was identified and 61 (9.2%) were parsimony informative. Molecular diversity index for these 125 sequences were shown in Table 71.

The number of haplotypes and polymorphic nucleotides per site ranged from 4 to 16, and 3 to 26 respectively. Similar to the result inferred by mtDNA *Cyt b*, a very high haplotype diversity (*hd* = 0.3956 to 0.9905) was observed while nucleotide diversity was very low (π =0.0006 to 0.0073).

3.2.2. Haplotype distribution

A total of seventy-eight (78) haplotypes was detected from 125 samples amplified by mtDNA *COI* gene with twelve (12) were shared and sixty-six (66) were unique or singleton. Three dominant haplotypes were found for these 125 samples which were Hap12, Hap38 and Hap49. The distributions of shared haplotypes were shown in Table 72. The details of the haplotypes were listed in Appendix VII.

3.2.3. Phylogeography and phylogenetic relationships

The NJ tree revealed that only one cluster was identified (Figure 96). However, there was a subclade consisted of haplotypes from Ranong only. The phylogenetic tree was rooted by *Dussumieria elopsoides*, *S. gibbosa* and *S. aurita* with the best fit model is K2P (Kimura 2-parameter) model obtained from MEGA 6 (Tamura *et al*., 2013; Nei & Kumar, 2000).

The subsequent analysis using Minimum spanning network (MSN) yielded two separated groups of 78 haplotypes as shown in Figure 97. Based on these findings, haplotypes from Ranong are completely distinct with many mutational changes (31), similar to the result inferred by mtDNA *Cyt b* in 3.1.3

Table 71. Molecular diversity indexes generated by ARLERQUIN version 3.1.

	South China Sea							Andaman Sea
	SBR	SKC	SKT	SKD	SPL	SZB	SSL	SRG
N	15	15	15	15	14	14	15	22
Number of haplotypes, *h*	14	14	8	10	4	12	6	16
Number of polymorphic sites	22	18	8	16	3	15	9	26
Number of transitions	16	11	5	12	2	6	5	21
Number of transversions	7	8	3	4	1	9	4	7
Haplotype diversity (*hd*)	0.9905	0.9905	0.8381	0.8571	0.3956	0.978	0.7048	0.9610
Nucleotide diversity (π)	0.0066	0.0051	0.0026	0.0034	0.0006	0.0064	0.0025	0.0073

Table 72. Distribution of shared haplotypes for 8 populations of *A. sirm* inferred from mtDNA *COI* gene. The highlighted box are the major haplotypes.

Haplotype	South China Sea							Andaman Sea	Total	Haplotype frequency/ Total (%)
	SBR	SKC	SKT	SKD	SPL	SZB	SSL	SRG		
Hap03	2								2	2.6
Hap12	1	2		6					9	11.5
Hap22		1		1					2	2.6
Hap37			2						2	2.6
Hap38			6		11	2	8		27	34.6
Hap40			2						2	2.6
Hap49								4	4	5.1
Hap53								2	2	2.6
Hap55								2	2	2.6
Hap58							3		3	3.8
Hap66						2			2	2.6
Hap77								2	2	2.6

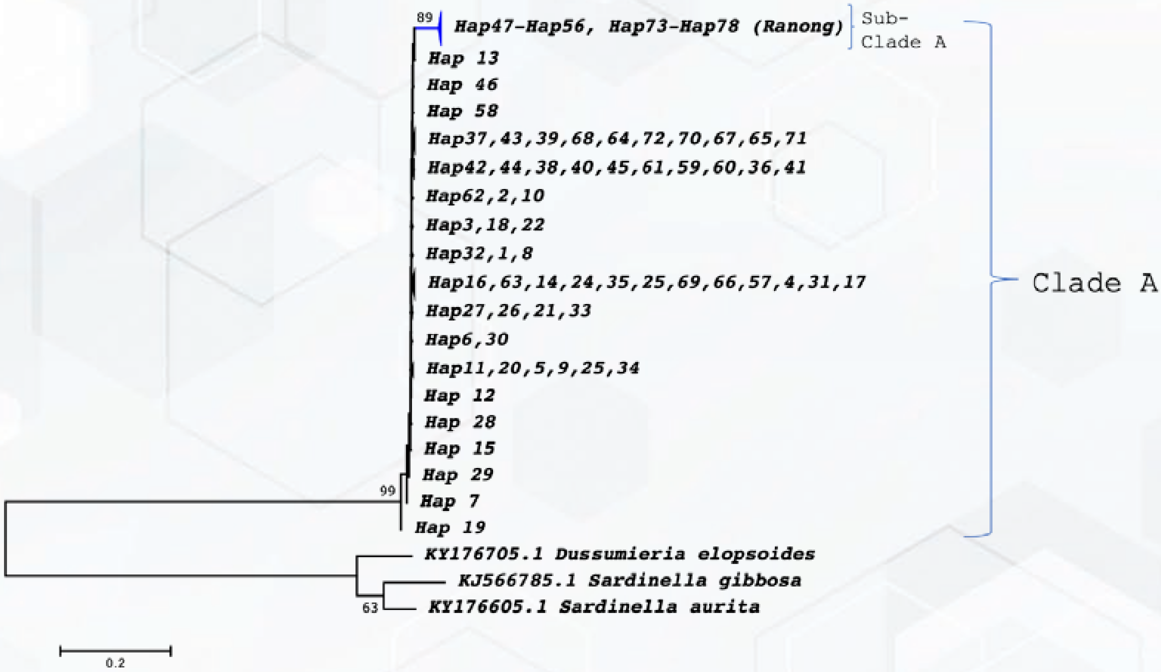


Figure 96. Evolutionary history as inferred using Neighbor-Joining method (K2P distance) with 1000 bootstrap replicates between mtDNA *COI* haplotypes in *A. sirm* rooted with Genbank *Dussumieria elopsoides*, *Sardinella gibbosa* and *Sardinella aurita*. The number of node represents bootstrap proportions for NJ analysis (nodes less than 50% are omitted).

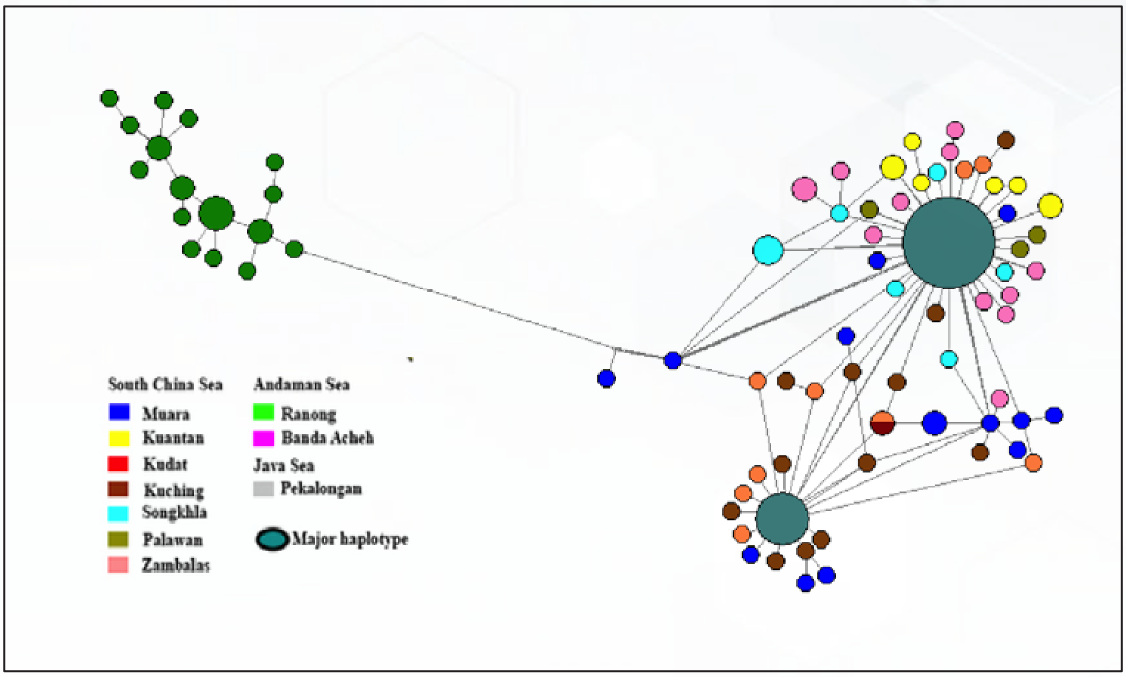


Figure 97. Minimum Spanning Network (MSN) inferred from mtDNA *COI* gene. Colored close circles represented different region (refer to the legend).

3.2.4. Genetic diversity within and among sites

The genetic distance within populations ranged from 0.1% to 0.7%, with Muara and Ranong had the highest within-population genetic distance (0.7%) while Palawan had lowest (0.1 %).

Meanwhile, the among-population genetic distance was ranged from 0.2% to 5.6%, with Ranong population was the most deviated from other populations. This support finding in 3.1.4. The Ranong population was the most divergent when compared to other populations ranging from 0.2% to 0.9%. This clearly showed that the Ranong population from Northern ANS was the most divergent (Table 73).

Table 73. Genetic distance within population and among population of *A. sirm* inferred by mtDNA *COI*.

		South China Sea							Andaman Sea
		SBR	**SKC**	**SKT**	**SKD**	**SPL**	**SZB**	**SSL**	**SRG**
South China Sea	**SBR**	0.007							
	SKC	0.006	0.005						
	SKT	0.007	0.007	0.003					
	SKD	0.005	0.004	0.006	0.003				
	SPL	0.006	0.006	0.002	0.005	0.001			
	SZB	0.009	0.009	0.006	0.008	0.005	0.006		
	SSL	0.007	0.007	0.003	0.006	0.002	0.006	0.003	
Andaman Sea	**SRG**	0.054	0.055	0.053	0.054	0.053	0.056	0.055	0.007

3.2.5. Genetic differentiation

The F_{ST} analysis was done to see the genetic differentiation in order to support finding in 3.1.5. From the analysis, it was completely showed that the F_{ST} value between South China Sea waters *vs* Ranong (northern Andaman Sea) was ranged from 0.0026 to 0.9092. However, the results were significant ($p<0.05$) for most of the populations including the two genetic structure generated between the SCS populations and Ranong that represented the ANS. Therefore, it could be concluded that there was a genetic structure existed between these populations of *A. sirm*. The population pairwise between population (F_{ST}) were shown in Table 74.

Table 74. Population pairwise (F_{ST}) based on *COI* sequence. (highlighted box indicates significant ($p < 0.05$) F_{ST} values).

		South China Sea							Andaman Sea
		SBR	SKC	SKT	SKD	SPL	SZB	SSL	SRG
South China Sea	SBR	0.0000							
	SKC	0.0347	0.0000						
	SKT	0.2887	0.4059	0.0000					
	SKD	0.0640	0.0026	0.4893	0.0000				
	SPL	0.3322	0.4718	0.0543	0.5758	0.0000			
	SZB	0.2751	0.3235	0.2678	0.3982	0.3328	0.0000		
	SSL	0.2916	0.4127	0.0728	0.4884	0.0631	0.2692	0.0000	
Andaman Sea	SRG	0.8661	0.8786	0.8973	0.8908	0.9092	0.8734	0.8973	0.0000

3.2.6. Assessment of population groups

The AMOVA for all eight populations yielded a high F_{ST} value of 0.78818 ($p < 0.001$), indicating a significant genetic division among these eight populations. Non-significant value of F_{CT} was observed when Ranong was excluded from other seven populations (0.87992, $p>0.05$) (Table 75).

Table 75. The results of AMOVA testing genetic structuring based on *COI* data.

Source of variation	df	Sum of Squares	Variance components	Variation (%)	Fixation indices	Probability
(1) One group						
Among populations	7	620.14	5.59 Va	78.82	F_{ST}: 0.78818	<0.001
Within populations	117	175.87	1.50 Vb	21.18		
(2) Two groups (Group 1: SBR, SKC, SKT, SKD, SPL, SZB, SSL, SBA & SPN Group 2 : SRG)						
Among populations	1	561.59	15.13 Va	87.99	F_{CT}: 0.87992	=0.1447
Among populations within groups	6	58.55	0.56 Vb	3.26	F_{SC}: 0.27183	<0.001
Within populations	117	175.87	1.50 Vc	8.74	F_{ST}: 0.91256	<0.001
(3) One group but without Ranong						
Among populations	6	58.55	0.58 Va	30.69	F_{ST}: 0.30687	<0.001
Within populations	96	124.69	1.3 Vb	69.31		

Based on estimates of k = 2 to 6 in the SAMOVA analysis, each group represented a statistical discreate phylogeographic grouping (Table 76). The results were consistent with the *Cyt b* analysis, in which k = 2 yielded the highest and non significant F_{CT} value (F_{CT} = 0.87598, p>0.05). It was clear signal that there was two genetically different *A. sirm* stocks among the sampled populations namely Group 1: SBR, SKC, SKT, SKD, SPL, SZB, SSL, SBA & SPN and Group 2: SRG.

Table 76. Population structured based on *COI* differentiation in spatial analysis of molecular variance (SAMOVA).

No. of groups, k	Structure	Variation (%)	F_{CT}
2	(SBR, SKC, SKT, SKD, SZB, SSL, SPN), (SRG)	87.60	0.87598
3	(SBR, SKC, SKT, SKD, SSL, SPN), (SRG), (SZB)	82.62	0.82623*
4	(SBR, SKC, SKD), (SKT, SSL, SPN), (SRG), (SZB)	80.92	0.80922*
5	(SBR, SKC), (SKD), (SKT, SSL, SPN), (SRG), (SZB)	79.71	0.79713*
6	(SBR, SKC, SKD), (SKT), (SSL), (SPN), (SRG), (SZB)	78.43	0.78431*

*p<0.05

4. Discussion

In overall, a total of 498 samples was collected from 12 locations across Southeast Asia region. However, samples from Sihanoukville, Cambodia and Yangon, Myanmar were excluded, due to species misidentification. The sample collections from Ranong were done thrice for validation purpose.

In this study, mtDNA *Cyt b* and *COI* were used in the analyses. The haplotype diversity (*hd*) was high for all populations but the values of nucleotide diversity (π) were generally low for both markers. High haplotype diversity value should reduce the extinction risk for these populations (Frankham *et al*, 2002; McNeely *et. al*, 1990).

This study revealed high *hd* and low π values for all populations that then categorized them in the second category, which indicated the rapid population growth and accumulation of mutations (Grant & Bowen, 1998).

Genetic distance is a measure of the genetic divergence between species or between populations within a species. The greater the genetic distance between populations, the less breeding there is between them and the more isolated they are from one another. The lower the genetic distance between populations, the more breeding there is between them and the less isolated they are from one another.

Based on the genetic distance analysis between Ranong and other populations, the value of more than 7% (*Cyt b*, Table 67) and 5% (*COI*, Table 74) strongly supported the existence of different taxon or sub-species of *A. sirm* of Ranong population. However, when Ranong was omitted from genetic distance analyses, the genetic diversity was ranged only from 0.2% to 0.4%. This clearly showed that the Ranong population from Northern ANS was the most divergent from other remaining sites.

For *Cyt b* phylogenetic analysis, Clade A was composed of widely distributed populations throughout SCS, Java Sea and southern ANS, while Clade B geographically restricted to Ranong which situated at northern part of ANS. For *COI* phylogenetic analysis, it was observed that all haplotypes belong to a single clade, but a subclade was formed from Ranong samples. These clades showed a strong bootstrap value of 89%.

The assessment of populations group was performed using AMOVA and SAMOVA analyses. The AMOVA results showed high values of F_{ST} and F_{CT} outcomes, indicated the presence of genetic structure among populations of *A. sirm*. The analyses of AMOVA and SAMOVA for both mtDNA markers revealed two groups of *A. sirm*; the first group was comprised all the South China Sea populations including Banda Aceh (southern Andaman Sea) and Pekalongan, Indonesia (Java Sea) *versus* a second group comprised of Ranong (northern Andaman Sea) alone. In general, the patterns found in the AMOVA and SAMOVA analyses were consistent with the phylogenetic trees of populations.

In other words, it was discovered that *A. sirm* population in Ranong was either isolated from the other populations across the region, or it could possibly a cryptic species. According to Carpenter and Niem (1999), *A. sirm* is distributed throughout Southeast Asia region except on the Straits of Malacca waters. Among numerous definitions of the term 'cryptic′ (hidden) species, the most widely accepted is that 'two or more species are "cryptic" if they are, or have been, classified as a single nominal species because they are at least superficially morphologically indistinguishable′ (Bickford *et al.*, 2007). Genetic diversity within a 'species also implicates underappreciated mechanisms of morphologically static cladogenesis (i.e. diversification of new species without morphological change). One of most common assumptions is most cryptic species was resulted from speciation that happened so recently/newest that the morphological traits or other diagnosable features have yet not evolved. Although undoubtedly true for some taxa, the view on cryptic species was challenged by studies of bonefish (Colborn *et al.*, 2001), amphipods (Lefebure *et al.,* 2006), animal (Bannikova *et al.,* 2019) and copepods (Rocha-Olivares *et al.,* 2001) which showed apparently ancient divergences among cryptic species.

The importance of identifying cryptic species complexes for conservation purpose should not be underestimated. The cryptic species requires a special consideration in conservation planning because the prevalence of cryptic complexes is already endangered the nominal species, caused a dual problem: (i) the endangered or threatened-listed-species might be composed of multiple species that are even more rare than previously supposed; and (ii) the different species might require different conservation strategies (Schonrogge *et al*., 2002).

There are many factors that could have attributed to the existence of the sub-species or taxon. Such factors were:

i. Hybrid

Hybridization between maternal of *A. sirm* with a closely related species.

ii. Faster rate of genetic evolution

Faster rate of genetic evolution of the spotted sardine compared to morphological evolution thus only the former could be detected.

iii. Discovery of new or cryptic species

It was reported an existence of a cryptic species of *S. gibbosa* in The Philippine archipelago (Thomas *et al.,* 2014). Thus it could imply that *A. sirm* at Ranong maybe a cryptic species.

The present study cannot choose or clarify the real cause among those three postulates mentioned above. Thus, it is suggested that future studies should includes the nuclear DNA such as microsatellites and RAG to provide paternal origin information. The samples from Cambodia and Viet Nam are very important in order to identify a complete picture of this species stock structure in this region. Additional samples from Bay of Bengal could help to verify the results from this study. It also suggested to further study on sardine species complex in this region. A more detailed morphological investigation is also crucial to identify any subtle differences between the two clades.

5. Conclusion

The *Cyt b* and *COI* gene markers used in this study revealed the two highly genetic divergent stocks; Ranong *versus* the rest of populations i.e included South China Sea (Muara, Kuantan, Kuching, Kudat, Palawan, Zambales and Songkhla), Java Sea (Pekalongan) and southern Andaman Sea (Banda Aceh). It is suggested that these stocks should be independently managed. Further study is highly recommended to identify the possibility of *A. sirm* in Ranong being a cryptic species in this region.

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CONCLUSIONS OF THE PROJECT

1. The TAC system was found not suitable due to multispecies situation of PS fisheries in the SEA region, thus other management measures i.e Production Model and Feedback Control analyses were decided being more applicable. The Production Model enables AMSs to determine the optimum level of effort (fMSY) when they have sufficient and reliable catch and effort data. However, if the data are insufficient, AMSs may use the Feedback Control (Rule 2-2) which determine the Allowable Biological Catch (ABC).

2. The Production Model (Fox) analysis revealed that exploitation of pelagic resources by purse seiners in Brunei Darussalam, Malaysia and Thailand are already at sustainable level, thus increasing the fishing effort is not recommended. However, the pelagic resources in Indonesia (SCS) is not at sustainable level, thus it is highly recommended for them to reduce their fishing effort as much as possible until it reaches one third (1/3) of its current effort.

3. Two analyses (Production Model and Feedback Control) should be repeated in the future project after improvement of data collection. Insufficient data and information will decrease the accuracy of results from the stock assessment analysis.

4. The *Cytochrome b* and *Cytochrome c oxidase* subunit I (COI) gene markers used in the genetic study of *Amblygaster sirm* revealed the two highly genetic divergent stocks; Ranong (northern of Andaman Sea) *versus* the rest of populations i.e included South China Sea (Muara, Kuantan, Kuching, Kudat, Palawan, Zambales and Songkhla), Java Sea (Pekalongan) and southern Andaman Sea (Banda Aceh). It is suggested that these stocks should be independently managed. Further study is highly recommended to identify the possibility of *A. sirm* in Ranong being a cryptic species in this region.

PROJECT OUTCOMES

Objective 1: To compile and compare annual and/or monthly catch per unit effort (CPUE) data for the last three decades in Malaysia and Thailand where historical catch-effort statistics had been collected by SEAFDEC and to interpret the resources trends in the region.

- ➔ MFRDMD only manage to compile and analyses historical catch and effort data for two decades in all eight AMSs. But not all AMS were able to fulfil all the parameters requested in the questionnaires. Furthermore, only annual data were collected and analysed.

Objective 2: To assess which unit of effort is most appropriate for Malaysia, Thailand, and other member countries and to examine other indicators for stock assessment.

- ➔ Number of trips is the most appropriate unit of effort. It is also the most available index provided by some AMSs as compared to other effort unit in this project.

Objective 3: To compare existing management systems/measures of purse seine fisheries including total allowable catch (TAC) systems in the world to examine which management system/measure is applicable for management of purse seine fishery in the region.

- ➔ Due to multi-species situation of the tropical fisheries in Southeast Asian region, TAC system is found to be not applicable, therefore Production Model and Feedback Control Method were considered more suitable as the alternative approaches.

Objective 4: To compare the genetic structures of commercially important small pelagic species in the region by studying one species of the commercially important sardines.

- ➔ Tissue samples of 35 fish of *Amblygaster sirm* from each site were collected from ten localities in the South China Sea (Muara, Brunei Darussalam; Kuching, Kuantan and Kudat, Malaysia; Songkhla, Thailand; Palawan and Zambales, The Philippines); two sites in Andaman Sea (Ranong, Thailand and Banda Aceh, Indonesia) and one site in Java Sea (Pekalongan, Indonesia).
- ➔ The DNA markers (*Cytochrome b* and *Cytochrome c oxidase* Subunit I) used in this study revealed two highly genetic divergent stocks; Ranong (northern Andaman Sea)

versus the rest of populations i.e included South China Sea (Muara, Kuantan, Kuching, Kudat, Palawan, Zambales and Songkhla), Java Sea (Pekalongan) and southern Andaman Sea (Banda Aceh).

Objective 5: To propose management strategies for sustainable purse seine fisheries in the Southeast Asian region based on available data.

- ➔ Each AMS should improve and enhance its fisheries statistical data and information collection system for better stock assessment.
- ➔ For sustainable PS fisheries in the AMSs, the member states should use the Production Model when they have sufficient and reliable catch and effort data. However, if the data are insufficient, AMSs may use the Feedback Control method.
- ➔ The regional management measures on PS fisheries are hardly to be implemented. PS fisheries should be managed independently as each country have different natures of PS fisheries and geopolitics.
- ➔ Scientific advices shall be considered by each AMS's stakeholders as seems fit to their present situation.

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APPENDICES

Appendix I. Questionnaires for Catch and Effort

REMARKS

Dear Honourable AMSs, we would like to follow up with the data submission to SEAFDEC/MFRDMD as follows;

The data submission involves:

1. Trend of landings/total catch (At least last 2 decades, including the latest data)
2. Trend of number of vessels (At least last 2 decades, including the latest data)
3. Trend of landings/total catch by **GRT** (At least last 2 decades, including the latest data) *
4. Trend of number of vessels by **GRT** (At least last 2 decades, including the latest data) *
5. Trend of CPUE (landings/number of vessels/year)
6. Species composition
7. Growth Parameters
8. Length at first maturity, Lm
9. Maximum Sustainable Yield, **MSY**
10. Spawning season

* Data by GRT is required for data standardization. Kindly please fill in the data according to your GRT classification in your country. Template provided is for sample purpose only.

Notes: Please submit data for all parameters requested. However, if it is not possible (as some data may available in certain area only), please provide some justification or clarification.

For your information, I'm Mr. Mohammad Faisal Md. Saleh acting as the JTF6 Project Coordinator. Ms. Nadwa was given the task to compile all those data, any inquiries, please don't hesitate to email us at mohd_faisal@seafdec.org.my and awdanadwa@gmail.com.

Fishing effort of Fish Purse Seine									
year	no. of vessels	trips	days	hauls	hours	total catch/ landings (MT)	CPUE (MT/vessel)	CPUE (MT/ trip)	CPUE (kg/day/boat)
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
2003									
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2007									
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2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016									
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Graphical information

Fishing effort of Anchovy Purse Seine									
year	no. of vessels	trips	days	hauls	hours	total catch/ landings (MT)	CPUE (MT/vessel)	CPUE (MT/ trip)	CPUE (kg/day/boat)
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001									
2002									
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2006									
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2009									
2010									
2011									
2012									
2013									
2014									
2015									
2016									
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Graphical information

Landings and fishing efforts of Fish Purse Seine (by GRT)

Year	Landings, MT						Number of licensed vessel						No. of trips					
	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total
1993																		
1994																		
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2016																		

* *Kindly please fill in the data according to your GRT classification in your country. Template provided is for sample purpose only.*

Landings and fishing efforts of Anchovy Purse Seine (by GRT)																		
Year	Landings, MT						Number of licensed vessel						No. of trips					
	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total	0-9.9 GRT	10-24.9 GRT	25-39.9 GRT	40-69.9 GRT	70 GRT and above	Sub total
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* *Kindly please fill in the data according to your GRT classification in your country. Template provided is for sample purpose only.*

Catch composition (%) of Fish Purse Seine

Species (group)	Total	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Indo-pacific mackerel	0																								
Hardtail scad	0																								
Indian mackerel	0																								
Round scad	0																								
Selar scad	0																								
Tuna	0																								
Anchovies	0																								
Sardines	0																								
Other fishes	0																								
Squids	0																								
Crustacean	0																								
Trash fish	0																								
Mixed fish	0																								
Grand total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Catch composition (%) of Anchovy Purse Seine

Species (group)	Total	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Indo-pacific mackerel	0																								
Hardtail scad	0																								
Indian mackerel	0																								
Round scad	0																								
Selar scad	0																								
Tuna	0																								
Anchovies	0																								
Sardines	0																								
Other fishes	0																								
Squids	0																								
Crustacean	0																								
Trash fish	0																								
Mixed fish	0																								
Grand total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Biological Information

Growth parameters for targeted species								
sites	year	growth		mortalities				exploitation
		L_{∞}	K	Z	M	F	M/K	E=F/Z

Spawning season			
Targeted species	Area		
	spawning season	Lm (cm)	Sources

Length at first maturity, Lm				
Targeted species	Area			
	Lm (cm)	Female (cm)	Male (cm)	Sources

Maximum Sustainable Yield, MSY				
Area	Year	Targeted species	Total catch (MT)	MSY (MT)

Appendix II. Report and Technical Papers

The 1st Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region

26 – 28 August 2014, Kuala Lumpur, Malaysia

INTRODUCTION

1. The Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region was organized by SEAFDEC/MFRDMD at Furama Hotel, Kuala Lumpur, Malaysia from 26 to 28 September 2014. The meeting was attended by the representatives from Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, The Philippines, Thailand, Viet Nam; as well as resource persons from Japan and Malaysia; the representatives from SEAFDEC/SECRETARIAT and SEAFDEC/TD; the Chief, Deputy Chief and Officials from SEAFDEC/MFRDMD. The List of Participants appears as Annex 1.

OPENING OF THE MEETING

2. The Chief of SEAFDEC/MFRDMD, Ms. Mahyam Mohd Isa, welcomed everyone to the meeting. She expressed her gratitude to all SEAFDEC member countries for overwhelming response and attendance to this meeting. She gave a brief overview on the previous projects and the outcomes that brings the initiation of this project on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region. She hopes all resources person and participants will share their knowledge and experience in this meeting.

3. The meeting was officially opened by the Mr. Tsuyoshi Iwata, Senior Expert and Technical Coordinator of SEAFDEC/Sec. He asked every participant to provide suggestions to make this project successful. He hoped that all participants will participate actively in the discussion to get good outcomes. The opening address appears as Annex 2.

ADOPTION OF AGENDA AND OVERVIEW OF THE PROGRAM ACTIVITY

4. The Chairperson, Ms. Mahyam Mohd. Isa introduced the Provisional Agenda and Arrangement of the meeting as proposed by the meeting secretariat. The proposed agenda was adopted without any changes.

5. Mr. Raja Bidin Raja Hassan, the Project Coordinator presented an overview of the project on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region (Japanese Trust Fund VI Program). He highlighted that this project was started in 2013, until 2017 and targeting the small pelagic fishes. Formulation of TAC will be based on survey and monitoring program. At present, only few countries and RFMO's had implemented TAC quota i.e. Japan, Norway, Portugal, CCSBT and ICES. He elaborated on the proposed project activities for 2014 – 2017. He also explained in detail about the case study of the purse seine fisheries in Malaysia and Thailand. The case study was based on data from the SEAFDEC Statistical Bulletin. More data is needed from all participating member countries for a regional analysis. Ultimately, this project will determine the best option that could be implemented for management of purse seine fisheries in this region. The Overview appears as Annex 3.

6. Dr. Takashi Matsuishi, the resource person form Hokkaido University, Japan presented "TAC Management in Japan". His presentation appears as Annex 4. He highlighted that there are two types of fisheries management in Japan i.e. Top Down Control and Bottom Up Control, but most management practiced in Japan is the Bottom Up Control.in Japan, TAC was introduced in 1997 based on recommendation by UNCLOS. He also explained in detailed the Japanese TAC and Allowable Biological Catch (ABC) regulations. ABC is calculated based on the stock assessments made by the Fisheries Research Agency (FRA). The ABC limit, ABC target and other options are indicated during the assessment. TAC in Japan only targeted eight species from 19 stocks. It was determined based on ABC and taking into account the socio-economic consideration. He also explained the differences between ABC and TAC. If ABC is exceeded, FRA will advise no to overfish, but if TAC is exceeded, fishing activity will be stop or the fishers will be fine if they did not comply. He gave a few suggestions to avoid overfishing and for better implementation of TAC system. He also expressed his willingness to assist SEAFDEC to formulate TAC case study for the region after completing data collection.

COUNTRY REPORT PRESENTATIONS

7. Mr. Ibrahim Johari, Senior Research Officer from Fisheries Research Institute, Penang, Malaysia presented on “Cost and Earning of the Purse Seine Fisheries in Malaysia. He highlighted the fishing effort was based on the type of purse seines, tonnage class and fishing area. The calculation of effort was according to the number of trip per month and the number of day per trip. He then explained the case study on the costs and earnings of the purse seine fishery in Kuala Perlis and Perak. The study was conducted using landing and survey data. The cost (opportunity, operation, fixed); income (gross, net, return); catch composition; percentage of yield and price index were then calculated. Based on these results, the minimum annual catches for the purse seine fishery were determined. He also showed that the payback period needed for a new purse seine vessel is 10 years. The meeting was informed that a new wooden fishing vessel can be used for 30 years. His presentation appears as Annex 5.

8. Ms. Noorizan Abd Karim, Senior Research Officer from Fisheries Department of Brunei Darussalam presented on “The Purse Seine Fisheries in Brunei Darussalam”. The annual trend of fish production and prices of marine fishes fluctuated with the lowest in July. The purse seine fishery in Brunei Darussalam employed 100% foreign workers. The number of fishing vessels increased to 30 vessels in 2013 from 28 in 2012, of which 12 were purse seiners. She later described the management measures for the purse seine fishery. She then elaborated on the species composition of the small pelagic fishes, the biological information, fishing effort for fish ad tuna purse seine, and also status of the pelagic fish stock. The fish stock in Brunei Darussalam is declining mainly due to the trawl activities. Her presentation appears as Annex 6. The meeting was informed that the numbers of fishing vessel license were allocated according to the fishing zones. The meeting also informed that calculation for MSY only can be done if the species composition was known throughout the year.

9. Dr. Chea Tharith, Deputy Director of Marine Fisheries Research and Development Institute, Cambodia presented “Purse Seine Fishery in Cambodia”. His presentation appears as Annex 7. The Cambodian fisheries provided employment up to six million people and 81% of animal diet, where the per capita fish consumption in Cambodia is 63 kg. He briefly described the number of vessels, production and trend of landing and CPUE of purse seine fishery, fish composition and biological information for mackerel. The numbers of purse seine vessels were declining from 13 vessels in 1992 to only one vessel unit in 2012. This is due to overexploitation of the target species and the increased use of pair trawls and light luring purse seines on the offshore waters of Cambodia. The estimated MSY is 5,867 MT with efforts equal to 152 vessels. Mackerels was the most dominant species (86%). He suggested to conduct more survey or study to collect more information with support from MFRDMD.

10. The Country Report for Indonesia was presented by Mr. Duto Nugroho. A Fisheries Biologist from the Fisheries Centre for Fisheries Management and Conservation, Indonesia. His presentation appears as Annex 8. Total number of purse seine in Indonesia waters is 28,000 vessels. The highest productivity of purse seine is 35 MT/gear/year of 16% of the total gears from the Java Sea. He highlighted the management measure based on the various laws and regulations. There are three fishing zones based on the fishing areas, size of vessel and management authorities. Trend of landing showed slight increase due to additional number of purse seine vessels and shift of target species from small pelagic fish to tuna and tuna-like species in deep sea waters. He also described the stock status based on the fishing area and size of pelagic fishes. He also listed few problems in fisheries management.

11. The Report for the East Coast of Peninsular Malaysia (ECPM) was presented Mr. Sallehudin Jamon, a Senior Researcher from FRI Kg. Acheh, Perak. Purse seine vessels were categorized based on tonnages and types of FADs used. He stated that the management measures were based on the Malaysian Fisheries Act 1985. The newly proposed fishing zones are as follows: MPA (0 - 1 nm); Zone A (1 - 8 nm); Zone B (8 – 15 nm); Zone C (15 & above) Zone C3 (Indian Ocean). He also described the trend of landing (total and top five species), fishing effort (total, by categories and cumulative) and CPUE by fishing categories. The trend of total landing by fishing categories increased but the catch per unit effort (CPUE) decreased. His presentation appears as Annex 9.

12. The Report for Purse Seine Fishery of the West Coast Peninsular Malaysia (WCPM) was presented by Mr. Abud Wahab Abdullah, a Senior Researcher from FRI Kg. Acheh, Perak. He highlighted on the trend of landings and CPUE according to the size and category of purse seine vessels. The density of pelagic stock in 2013 decreased by 0.67% as compared to the survey in 2006 but decreased by 22% when compared to survey in 1998. More assessment is needed and should be conducted on a regular basis. Most FADs were used by purse seine vessels large than 70 GRT. He also described the marine park and fisheries protected areas in the WCPM. His presentation appears as Annex 10.

13. The Report for Purse Seine Fishery in Sarawak, Malaysia was presented by Mr. Jamil Musel, a Senior Research of FRI Bintawa, Sarawak. The main landings of pelagic fishe by purse seine are *Decapterus* spp., *Rastrelliger* spp. and *Sardinella* spp. He also highlighted the biological information for the small pelagic fishe namely *Decapterus* spp. and *Rastrelliger* spp. He elaborated on the fishing effort, biomass, MSY, local knowledge and existing management strategies for small pelagic. His presentation appears as Annex 11.

14. Mr Mohd Zamani Nayan, Fisheries Officer from Department of Fisheries Sabah, Malaysia presented on the "Purse Seine Fisheries in Sabah". He briefly described the total marine fish landings, landings by purse seines and number of fishing vessels for the year 2011 and 2012. He also described the fishing effort and management strategies for the purse seine fisheries. His presentation appears as Annex 12.

15. Mr. Than Chaung, the Assistant Director from Department of Fisheries Myanmar presented on "Purse Seine Fishery in Myanmar". There are two types of purse seine i.e. fish purse seine and anchovy purse seine. He briefly described the number of purse seine vessels, the main targeted species (e.g. Hilsa, mackerel, sardines, anchovy and scads), fishing area and fish production. He also presented the status of pelagic stock according to the pelagic fishing groups and fishing area. There are few management measures being practiced in Myanmar i.e. close area and season. He also emphasized on problems such as lack of up-to-date data, accuracy of collection, knowledge of scientific data collection and lack of fund. Meeting was informed that the joint venture program between Myanmar and Thailand has stopped since 2013. His presentation appears as Annex 13.

16. Mr. Prudencio B. Belga, an Aquaculturist II, Bureau of Fisheries and Aquatic Resources of the Philippines presented on "The Status of Philippines Small Fish Stock". Out of 1.3 million MT of landed marinen fishes, 60% were caught by purse seines. He described the annual commercial and municipal landings of small pelagic fishes from 1976 – 1984 and restarted in 1997 at different fishing grounds; however, the data is still being process. His presentation appears as Annex 14.

17. Ms. Sampan Panjarat, a Senior Fisheries Biologist from Andaman Sea Fisheries Research and development Center, Thailand presented on "Purse Seine Fishery in Thailand". Purse seine fishery contributed about 33% of national catch. She explained the types of purse seine based on fishing category, area and sizes. She briefly presented on the fishing ground and trend of landing for pelagic fishes, fishing effort, annual catch and CPUE. Most of the pelagic fishes landing in Thai waters were above the MSY level. She also stated the status of pelagic fish stock in Thai waters and the management measures for fish purse seine fishery. Presently, more than 25% of Thai waters were declared as protected areas. Her presentation appears as Annex 15.

18. Mr. Nguyen Viet Nghia, the Head of Department of Marine Fisheries Resources from Research Institute for Marine Fisheries, Vit Nam presented on "The Purse Seine Fisheries in Viet Nam". He briefly described the fishing ground and annual landing of purse seine fisheries. He also showed the trend of CPUE of purse seine, the list and biological information of the dominant species. In 2012 and 2013, Viet Nama conducted an acoustic survey on small pelagic fishes, in which the most dominant species caught were anchovy in the south area and scads in the north area. The anchovy groups migrated toward northern area during the northeast monsoon. He also

described the management measures and issues for the purse seine fishery and the Vienamese joint venture programs with Thailand and China. His presentation appears as Annex 16.

19. Ms. Mari Yoda from Seikai National Fisheries Research Institute, FRA Japan presented on “Stock Assessment and ABC Determination in Japan – Purse Seine CPUE in the East China Sea Pelagic Fish Assessment”. She briefly described the procedures to estimate TAC quota starting with data from the fish market, measurements in the laboratory, stock assessment and calculation of ABC and finally the determination of TAC quota. The meeting was informed that stock assessment was conducted once a year ad the TAC quota was adjusted in the middle of the year. In Japan, TAC is estimated for target fish species and not the fishery as a whole, as it is difficult to control and manage. TAC quotas were allocated to large scale prefectural fisheries organization, for controlling the number of boats and reporting the catches. Analysis using VPA and CPUE were conducted but he emphasized that sometimes CPUE analysis can be difficult when data is inadequate. Her presentation appears as Annex 17.

20. The meeting noted that some fish stocks in the region are overfished, so urgent action for management of pelagic fishes are required. One of the important goals for fisheries management id to develop and establish a database system for catch landing. During assessment, official and scientists should check the catch and CPUE trends and use the calculated MSY as references. TAC is one of the options for managing fishery resources; there are other options that countries may consider for fisheries management. The stakeholders need to understand the importance of fisheries management.

DATA COMPILATION AND ANALYSES

21. Dr. Alias Man, a Senior Research Officer of FRI Batu Maung, Penang, Malaysia, presented on “Proposed Methodology on TAC Determination for Purse Seine Fishery in Malaysia”. As long-term scientific information is not available, TAC is determined based on the CPUE and MSY. He described briefly the case study for the Purse Seine Fishery in the WCPM. It was observed that there was an increasing trend of the engine horsepower used on purse seine vessels. Pelagic fishes were not only caught using purse seine, so MSY should be calculated using pelagic species as a unit stock. More data are needed and must be standardised. Socio-economic factor should also be considered in the analysis. His presentation appears as Annex 18.

22. Ms. Wahidah Mohd Arshaad, a Senior Researcher at MFRDMD presented on

"Genetic Study on *Sardinella* spp. in Southeast Asian Region". *Sardinella* is a genus of small, coastal pelagic, planktivirous fishes that from large school over the continental shelf shallower than 200 m. this genus contains 21 recognized species and 11 species were reported in this region. The major fishing gear employed to catch *Sardinella* are purse seines, gillnets and bag-nets. She also mentioned that there are six published papers on genetic population study and DNA barcode of *Sardinella* spp. in the Southeast Asian and other region. His presentation appears as Annex 19.

23. Ms. Noorul Azliana Jamaludin, a Research Officer at MFRDMD presented on "Sampling Procedures for the Genetic Study". The Standard Operating Procedure (SOP) serves as a guidelines and main references for tissue sample collection and preservation in the fields in their countries. Sampling materials will be provided to all MCs to collect the samples in their countries. She then explained in detail the procedures for taking samples. MFRDMD will request each participating SEADEC Council to appoint a focal point for DNA sample collection for spotted sardinella (*Amblygaster sirm)* for genetic study and the tissue specimens need to be sent by courier to MFRDMD. The meeting agreed that the country representative will act as focal point until the official focal point is appointed by their respective Council Director. Mr. Nguyen Viet Nghia from Viet Nam agreed tp provide the SOP for morphological study of *Amblygaster sirm*. MFRDMD will distribute the SOP to the country's focal points and ask whether they are capable to collect the morphological data. Her presentation appears as Annex 12.

24. Mr. Mohammad Faisal Md Saleh, a Research Officer at MFRDMD presented on the "Outputs for the Andaman Sea". This is the compilation of country reports from MCs in the Andaman Sea which included Indonesia, Malaysia, Myanmar and Thailand. He summarized the five aspects covered in the country reports which are: i) fisheries (general, major commercial gear); ii) type of purse seines, size of purse seine vessels and landings by purse seine; iii) biology (species or catch composition, length of first maturity, status of biomass); iv) fishing effort (number of all types of purse seine vessels, number of trips, number of days, number of hauls, number of hours, average of CPUE, status of exploitation); v) management (fishing zone, restriction of fishing gear and technique, close season, joint venture) and local knowledge (high and low catch season, perception). His presentation appears as Annex 21.

25. Mr. Raja Bidin Raja Hassan, the Project Coordinator of this project, from MFRDMD presented on "Outputs Presentation for South China Sea". This compilation was based on country reports fringing the South China Sea areas which include Brunei Darussalam, Cambodia, Indonesia, Malaysia, the Philippines, Thailand and Viet Nam. Overall, *Rastrelliger* spp. and scads were abundant but scads were more dominant in the region. The meeting agreed that he information in the basic data format has been sent to the MCs must be validated to confirm that all data are accurate and up-to-date. His presentation appears as Annex 22.

26. Dr. Masaya Katoh, the Deputy Chief from MFRDMD informed the meeting that the SEAFDEC Council directors will be informed on the future genetic study of *A. sirm*. All MCs are requested to collect and send the tissue samples to MFRDMD for analysis. The boxes containing all equipment needed for tissue sampling were given to all AMSs during the meeting and the budget for the sampling will be transferred later.

27. Mr. Tyoshi Iwata, a Senior Expert and Technical Coordinator of SEAFDEC/Sec presented on the "Example of TAC Distribution I Japan". He described in detail an example of TAC quota for jack mackerel in 2014 according to the minister control and prefectural governor control. There are 47 prefectures but only 6 prefectures have history on allocated TAC. For the other prefectures, there were no specific TAC allocated. His presentation appears as Annex 23.

28. The meeting was informed that other indicators to manage fisheries are MSY and CPUE. Every country should know the exact fishing ground, effort, method and movement of the fish and share this information to develop a management plan. The meeting suggested SEAFDEC to collaborate with the MCs and organize a survey in this region using MV SEAFDEC 2. SEAFDEC/TD could plan the research with support from Japanese Trust Fund (JTF) or other donors.

CLOSING OF THE MEETING

29. The Report of the Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region will be e-mailed to all participants for their feedback and then will be finalized by MFRDMD.

30. Ms. Mahyam Mohd. Isa, the Chief of MFRDMD, expressed her sincere appreciation to everyone for their cooperation and active participations during the meeting. MFRDMD is willing to conduct training on stock assessment. She the thanked the Japanese government for funding this project, to all participants as well as members of the secretariat for making this meeting a success. Lastly, she wished everyone a safe journey home and declared the meeting closed.

The 2nd Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region

9 – 11 August 2016, Kuala Lumpur, Malaysia

Adopted Report

INTRODUCTION

1. The Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region was organized by SEAFDEC/MFRDMD at Furama Hotel, Kuala Lumpur, Malaysia from 9 - 11 August 2016. The meeting was attended by the representatives from Cambodia, Indonesia, Malaysia, The Philippines, Thailand, Viet Nam and an observer from Lao PDR; as well as resource persons from Japan and Malaysia, the representatives from SEAFDEC/Secretariat, SEAFDEC/TD, DOF Malaysia, the Chief, Deputy Chief and Officials from SEAFDEC/MFRDMD. The List of Participants appeared in Annex 1.

2. The objectives of the meeting are; sharing of the latest information on characteristics of catch and effort of small pelagic purse seine fishery in the region, and to compare between application of TAC, TAE and other management options for its data requirement. Understanding the population structure of major species is also attempted.

OPENING OF THE MEETING

3. The Deputy Chief of SEAFDEC/MFRDMD, Dr. Osamu Abe, welcomed everyone to the meeting. He expressed his gratitude to all SEAFDEC participating member countries for their effort to attend this meeting. His welcome remarks appeared in Annex 2.

4. The meeting was officially opened by the Chief of SEAFDEC/MFRDMD, Mr. Ahmad Adnan Nuruddin. He emphasized that purse seine fishery is very important and need to manage regionally. He appreciates the attendance of resource persons from Japan and Malaysia for sharing their experiences in managing pelagic resources in this region. His opening address appeared in Annex 3.

ADOPTION OF AGENDA AND OVERVIEW OF THE PROGRAM ACTIVITY

5. This session was chaired by the Chief of SEAFDEC/MFRDMD. Meeting agenda was presented by Dr. Osamu Abe, Deputy Chief of SEAFDEC/MFRDMD. The agenda was adopted without any amendment as in Annex 4.

6. Project Coordinator, Mr. Raja Bidin Raja Hassan, presented the Overview and Progress of the project as appeared in Annex 5. He emphasizes an urgent requirement for catch and effort data submission in a timely manner and complies with the data format as provided by SEAFDEC/MFRDMD. He also highlighted several activities and outputs from this project especially on trend of landing and CPUE for purse seine fishery in this region. One publication entitled "Current Status of Purse Seine Fisheries in the Southeast Asian Region" was published in 2015 and has been disseminated to all SEAFDEC member countries.

REVIEW OF PURSE SEINE MANAGEMENT SYSTEMS

7. Dr. Takashi Matsuishi, the invited resource person from Japan presented the "Comparison and Requirement for Catch and Fishing Effort Management Strategies for Purse Seine Fisheries". He elaborated few types of fishery management systems applied in Japan. He also explained in detail about output control and Japanese Allowable Biological Catch (ABC) calculation rule. He proposed an input control "Allowable Biological Effort" (ABE) as a potential management system for pelagic resources in this region. He concluded that effort control will be easier to implement and population model is applicable for multispecies fisheries. His presentation slides appeared in Annex 6.

8. Mr. Mohd Noor Noordin, the invited resource person from Department of Fisheries Malaysia presented a paper entitled "Management of Purse Seine Fisheries in Malaysia". He elaborated the current scenario of capture fisheries in Malaysia including the management system used to manage purse seine fisheries. The presentation slides appeared in Annex 7.

COUNTRY PRESENTATIONS

9. Dr. Chea Tharith, the Deputy Director of Marine Fisheries Research and Development Institute, Cambodia presented "Purse Seine Fishery in Cambodia". His presentation appeared in Annex 8. The Cambodian fisheries dominated by inland fisheries which contributed about 570,000 MT compare to marine capture fisheries which only contributed about 120,000 MT. Cambodia recorded highest CPUE for pelagic fishes in January. Cambodia implement closed season for mackerels in January-March annually. Cambodia intended to establish quota for Total Allowable Catch (TAC) or Total Allowable Effort (TAE) in near future.

10. The Country Report for Indonesia was presented by Mr. Duto Nugroho, a Senior Fisheries Biologist from the Center for Fisheries Research and Development, Indonesia. His presentation appeared in Annex 9. His presentation only focused on two sub-areas namely Malacca Strait and Natuna. Indonesia recorded dominant species caught by

purse seine are *Decapterus* spp. and *Rastrelliger* spp. Indonesia reported that heavy exploitation of pelagic fish occurred in Malacca Straits. Indonesia also has carried out acoustic survey to assess pelagic stock around Natuna Island.

11. The Report for the East Coast of Peninsular Malaysia was presented by Mr. Sallehudin Jamon, Senior Research Officer from FRI Kg. Acheh, Perak. Purse seine vessels were categorized based on tonnages and types of FADs used. He highlighted the management measures were based on the Malaysian Fisheries Act 1985. He also described the trend of landing and CPUE for top 7 pelagic species in the East Coast of Peninsular Malaysia. He reported that spawning season occurred twice a year. His presentation appeared in Annex 10.

12. The report for the Purse Seine Fishery of the West Coast of Peninsular Malaysia was presented by Mr. Abdul Wahab Abdullah, a Senior Research Officer from FRI Kg. Acheh, Perak. He highlighted on the current trend of landings and CPUE for purse seine vessels on the West Coast of Peninsular Malaysia. His presentation appeared in Annex 11.

13. The report for the purse seine fishery in Sarawak, Malaysia was presented by Mr. Jamil Musel, Senior Research Officer of FRI Bintawa, Sarawak. The main landings of pelagic fish by purse seine are *Decapterus* sp., *Rastrelliger* sp. and *Sardinella* sp. He also highlighted the biological information for the small pelagic fish namely *Decapterus* sp. and *Rastrelliger* sp. He elaborated on the fishing effort, biomass, MSY, local knowledge and existing management strategies for small pelagic. He mentioned that the trend of landing decreased recently due to labour shortage. His presentation appeared in Annex 12.

14. Mr. Mohd Zamani Nayan, Fisheries Officer, Department of Fisheries Sabah, Malaysia presented on the "Purse Seine Fisheries in Sabah". He briefly described the total marine fish landings, landing by purse seines and number of fishing vessels for the year 2013 and 2014. He also described the fishing effort and management strategies for the purse seine fisheries. His presentation appeared in Annex 13.

15. Country report of the Philippines was presented by Mr. Napoleon Lamarca. Based on his presentation, ring net is the most used fishing gear in the Philippines. He also showed the CPUE of the ring net fishery in Sindangan and Zamboanga areas. As for management purpose, BFAR only authorizes the commercial fishing activities beyond 15 kiloms from the shoreline. His presentation appeared in Annex 14a. Mr. Francisco Torres, from National Fisheries Research and Development Institute (NFRDI) of the Philippines also presented the report on national production of small pelagics. He reported that production for pelagic fish is quite stable for municipal fishery. He mentioned that BFAR has to come out with Target Reference Point (TRP) as stipulated in their national law. TRP will be used as management tool for purse seine fisheries in the Philippines. His presentation appeared in Annex 14b.

16. Ms. Sampan Panjarat, Senior Fisheries Biologist, Andaman Sea Fisheries Research & Development Center, Thailand presented on "Purse Seine Fishery in Thailand". She reported the pelagic fish production increased in late 70's but decreased recently in 2010. She highlighted Thailand's Royal Ordinance on Fisheries 2558 (2015) has been used in the management of purse seine fisheries. Thailand has introduced Maximum Allowable Catch (MAC) as one of the potential management tools. She also mentioned that Observer on Board Program has already been initiated for vessel operating outside EEZ of Thailand. Her presentation appeared in Annex 15.

17. Mr. Phan Dang Liem from Research Institute for Marine Fisheries (RIMF), Vietnam presented on "The Purse Seine Fisheries in Vietnam". He briefly described the fishing ground and annual landing of purse seine fisheries. He also showed the trend of landing and CPUE of purse seine fisheries, the list and biological information of the dominant species. Vietnam recorded the highest number of purse seine vessel in 2010 and the number decreased drastically in 2011 due to changes in type of fishing gear for catching pelagic fish. His presentation appeared in Annex 16.

DATA REQUIREMENT AND REGIONAL SYNTHESIS

18. Professor Emeritus Dr. Mohd Azmi Ambak talked on the procedure for catch and effort data analyses.

19. Mr. Mohammad Faisal Md Saleh Senior Researcher at SEAFDEC/MFRDMD presented on the Regional Synthesis for Andaman Sea. His presentation appeared in Annex 17.

20. Mr. Raja Bidin Raja Hassan, Special Departmental Coordinator of SEAFDEC/MFRDMD presented the "Regional Synthesis for South China Sea". Landings for small pelagic were observed quite stable, however CPUE showed decreasing trend especially in Malaysia. All participating member countries were requested to submit their complete data timely, so that MFRDMD could proceed for a comprehensive regional synthesis. Existing data is not sufficient to conclude a strong basis for management regime for pelagic fish in the South China. His presentation appeared in Annex 18.

21. Ms. Wahidah Mohd Arshaad, a Senior Researcher at SEAFDEC/MFRDMD presented on "Genetic Population on Spotted Sardine (*Amblygaster sirm*) in Southeast Asian Region". The preliminary result based on four sampling locations (namely Muar in Brunei Darussalam; Kuantan and Kudat in Malaysia, and Songkla in Thailand) found that *Amblygaster sirm* is a single evolutionary unit and therefore can be regarded as a single conservation unit for the management of sustainable fisheries. She also highlighted the issues regarding species misidentification and difference in legislation on sample export to MFRDMD. Her presentation appeared in Annex 19.

MANAGEMENT STRATEGY OF PURSE SEINE FISHERY

22. Dr. Takashi Matsuishi, the resource person from Japan presented "Case Studies and Some Application of Catch and Fishing Effort Management Strategies for Purse Seine Fisheries". He demonstrated the calculation of ABE to the meeting. His presentation appeared in Annex 20.

CLOSING SESSION

23. This session was chaired by Special Departmental Coordinator of SEAFDEC/MFRDMD, Mr. Raja Bidin Raja Hassan. The way forward and new project activity were identified and presented as below;

No.	Activities	Time frame	Remarks
1	Catch and effort data submission	30 Sept 2016	1. All participating member country 2. Develop baseline data
2	Mini workshop	December 2016	Budget availability - to include scientist
3	Publication of regional synthesis for purse seine fishery	November 2016	
4	Submission of genetic samples to MFRDMD	End December 2016	Viet Nam, Cambodia, Myanmar and Thailand
5	Analysis of DNA samples	End February 2017	Indonesia will analyze the sample by themself and the rest by MFRDMD
6	Submission of DNA report	August 2017	
7	Core Expert meeting	August 2017	- to include scientist and manager
8	Project terminal report	December 2017	Include suggestions and recommendations for pelagic fishery management strategy

Issues

1. Capacity building – related to activities for a mini workshop
2. Cost estimation of mini workshop

New project activity

1. Establishment of scientific working group for small pelagic at regional level

3rd Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region

12-14 September 2017, Kuala Lumpur, Malaysia

Adopted report

INTRODUCTION

1. The Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region was organized by SEAFDEC/MFRDMD at Furama Hotel, Kuala Lumpur, Malaysia from 12 to 14 September 2017. The meeting was attended by the representatives from Cambodia, Indonesia, Malaysia, Myanmar, The Philippines, Thailand and Viet Nam; as well as resource persons from Japan and Malaysia, the representatives from SEAFDEC/TD, the Chief, Deputy Chief and Officials from SEAFDEC/MFRDMD. The List of Participants appeared in Annex 1.

2. The objectives of the meeting were: to share the latest information about landings and CPUEs of purse seine fisheries in the region, to compile the current management measures for purse seine fisheries in the region, to share experience on data processing for management of purse seine fisheries and to understand the population structure for *Amblygaster sirm*.

OPENING OF THE MEETING

3. In his welcome message, the Deputy Chief of SEAFDEC/MFRDMD, Dr. Kenji Taki expressed his gratitude to all participants from the SEAFDEC participating member countries for their efforts to attend this meeting and expected to deepen his knowledge on Purse Seine management that he thinks is more applicable in the ASEAN region. His welcome remarks appeared in Annex 2.

4. The meeting was officially opened by the Chief of SEAFDEC/MFRDMD, Mr. Raja Bidin Raja Hassan. He hoped participating Member Countries could share on the latest information about pelagic fisheries and management of purse seine fishery. He emphasized the important to examine the fishing capacity for Purse Seine and some management measures to address the common issues faced in this region and hoped delegates could tap valuable information from invited resource person from Japan appeared in Annex 3.

ADOPTION OF AGENDA AND OVERVIEW OF THE PROGRAM ACTIVITY

5. This session was chaired by Chief of SEAFDEC/MFRDMD and the meeting agenda was presented by Dr. Kenji Taki, Deputy Chief of SEAFDEC/MFRDMD. The agenda was adopted with a little amendment as in Annex 4.

6. Project Coordinator, Mr. Mohamad Faisal Md. Saleh, presented Overview of Project as appeared in Annex 5. Besides reporting the background of the project, he also reviewed the availability of statistics data of landing data, fishing effort and catch per unit effort (CPUE) in the region that will be the focus of this project. The presentation also viewed the case study in Malaysia for landing trend and CPUE standardization. Species composition in the region was also presented and current statistics data that had been collected and compiled by MFRDMD were also showed. Based from the issues and challenges raised up, all the Member Countries were aware of very importance of the reliable data statistics to come out with good management on Purse Seine fisheries. One report on "2nd Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region 2016" was published in 2017 and had been disseminated to all SEAFDEC member countries.

COUNTRY PRESENTATIONS

7. Dr. Chea Tharith, from Cambodia presented Purse Seine Fishery in Cambodia. The presentation was appeared in Annex 6. In his presentation, purse seine fishery in Cambodia was highlighted. With three purse seine boats operated in two provinces with 2-5 days per trip and 9 to 10 trips per month, catch trends from long-tailed boat (Gill net) was presented. The species that mainly had been caught by purse seine boat in Cambodia were scads, sardines, *Rastrelliger* spp. and anchovies; and biological information such as spawning season and length at first maturity of *Rastrelliger brachysoma* in 2004 and trend of CPUE was also highlighted in his presentation. It was also informed in this presentation that fishery resources in Cambodia were declining while number of small-scale boat was increasing and motorized. Capacity building in Cambodia on determining TAC for Purse Seine was also still lacking.

8. The first part of country report from Indonesia was presented by Mr. Imron Rosyidi as in Annex 7. His presentation mainly focuses on overview of Purse Seine fisheries management in Indonesia. For the second part of the country report from Indonesia presented by Mr. Suwarso was highlighted on the purse seine fishery management in Natuna Sea and adjacent waters. The meeting was also informed that currently, there are three kinds of Purse Seine; small, medium and large to catch the pelagic species in Indonesia. The catch trend in Pemangkat as an example was viewed besides biological information such as species composition together with management measures implemented in the country from the study conducted in 2014 through national project and from 2003 to 2005 through SEAFDEC project was also presented. A biological sampling was done from 2014-2016 on reproduction aspects (length of maturity) of

Decapterus russelli, R. kanagurta and Selar crumenopthalmus. A CPUE trend on the species was also conducted in 2013. Moreover, the meeting was informed that the implementation of Observer on board program conducted by Indonesia was concordant with requirement by other International Commissions such as the IOTC. Likewise, currently a special unit responsible in harmonizing the landing data collected and to manage 34 provinces in Indonesia, management measure such as vessel registrations is responsible by central government and registration book by province government. Regarding the design of fishing gears in their country, Mr. Suwarso stressed that the design emanated from the local fisherman with approval from the central government.

9. The Report for the East Coast of Peninsular Malaysia was presented by Mr. Sallehudin Jamon from Fisheries Research Institute (FRI) Kg. Acheh, Perak. He reported that catch trend of pelagic fish and anchovy in East Coast Peninsular Malaysia based from statistical data from Department of Fisheries, Malaysia. Other information such as CPUE and biological information was also presented. Currently, the status of pelagic fish in East Coast Peninsular Malaysia according to biomass was 405,332 MT and MSY was 202,466 MT. The meeting was informed that the study for the close season on pelagic species e.g. *R. kanagurta* is on-going that started from 2015 to 2020. The presentation appeared in Annex 8.

10. The report for the Purse Seine Fishery of the West Coast of Peninsular Malaysia was presented by Mr. Abdul Wahab Abdullah from FRI Kg. Acheh, Perak. He started with information on type of purse seine vessels, zoning and fishing areas and partly on latest relevant rules and regulations. The meeting was informed that the West Coast zoning system has been revised in 2014, among others to create a conservation zone of 1 nm from the shoreline and to change the zoning boundaries. The trend of vessels, landings and also CPUE and catch composition for purse seine vessels were also highlighted. His presentation appeared in Annex 9.

11. The country report on Purse Seine Fishery in Sarawak, Malaysia was presented by Mr. Jamil Musel from FRI Bintawa, Sarawak. He reported on overview of catch trend in Sarawak by purse seine. He also presented the result for CPUE of pelagic in Sarawak, Malaysia and status of pelagic fish stock in Malaysia based on the acoustic survey conducted in 2014 and published in 2015. Chief of MFRDMD suggested doing FISAT analysis and cover all categories because it was presumed that during data analysis did not cover certain range of size and this can give bias to the result generated by FISAT, therefore can have better result and thus can view the true scenarios of resource in Sarawak. His presentation appeared in Annex 10.

12. Mr. Mohd Zamani Nayan from Department of Fisheries Sabah, Malaysia presented on the "Purse Seine Fisheries in Sabah". He briefly described fishing effort of PS from 2009 to mid of 2017. The status of pelagic stock in Sabah also was showed from the acoustic method. However, the data and biological information (e.g. length of first maturity and spawning season) was currently unavailable. Information on management strategy such

as control of licensing and enforcement and the closed season approach that still on planning was also reported. Chief of MFRDMD also informed that based from the acoustic survey conducted the status of pelagic fisheries in Sabah is still encouraging and the resource is still enough. In addition, final report of acoustic study from Peninsular Malaysia, Sabah and Sarawak are already completed and will be published soon. His presentation appeared as Annex 11.

13. The country report from Myanmar was presented by Mr S. Julius Kyaw entitled Purse Seine Fishery in Myanmar. He elaborated that purse seine fishery management in Myanmar, landing trend, CPUE and biological information of pelagic species. The meeting was informed fishing area in Myanmar was divided into four regions with Rakhine was abundant for anchovy, Ayeyarwady for hilsa; and Taninthayi for sardinella and mackerel. The presentation was appeared as Annex 12.

14. Mr. Ronnie Romero presented Country report of the Philippines. Based on his presentation he provided an overview of the Philippines Capture Fisheries specifically on Purse Seine Fisheries. Fishing effort of purse seine, status of pelagic stock in Philippines and existing management strategies for purse seine were also highlighted in his presentation. He informed that starting 1998, Philippines had started the National Stock Assessment Program (NSAP) which provided significant data towards the establishment of a close season for roundscad in Palawan, Philippines in Sulu Sea. He also presented the CPUE trend of purse seine based from the National Stock Assessment Program (NSAP) of the Philippines from CY 1998 to CY 2016. Moreover, the dominant species caught during this period was presented. He further reported that there are two types of Purse Seine used in the Philippines, the Sardine/ Scad/ Mackerel Purse Seine and Tuna Purse Seine. Moreover, the Meeting was informed that aside from the Catcher Boats, Carrier, Lighboat and Sonar boats more than 3 GT are also required to apply for license from the BFAR. His presentation appears as Annex 13.

15. Dr. Watcharapong Chumchuen from Thailand reported 35% from marine capture production of Thailand were managed by purse seine which can be divided into two types; Thai Purse Seine (Black Seine) with mesh size greater than or equal to 25 mm that mostly catch Indo-Pacific mackerel, Indian mackerel, sardines, scads, bonitos, black pomfret and ponyfish with three fishing techniques (free school, light lurling and fish aggregating device operations) and Anchovy Purse Seine with mesh size greater than or equal to 6 mm specifically catch anchovies with two types of anchovy purse seiners. In the presentation he also informed that the fishery act in Thailand was revised in 2015. For purse seine, the regulations were enforced to control the fishing power (gear and effort) whereby boat owners must renew their fishing license every 2 years. The landing trend by purse seiner from 1993 to 2014 was also presented besides species composition, length at first maturity, fishing effort and status of pelagic fish in Thailand. Meeting was also informed that Thailand had practice in time-area closure as their fisheries management strategy. The presentation as appeared in Annex 14.

16. Mr Pham Van Tuyen presented the country report from Viet Nam. In this report, an overview of marine fisheries particularly purse seine fisheries in four areas; Gulf of Tonkin, Central, Southeast and Southwest Viet Nam was presented. Meeting was informed that the marine product from the purse seine was about 20.6% total catch and the main species of the local and commercial types of surrounding net are small pelagic fish and include: sardines, mackerels, round scads, neritic tunas, anchovies etc. There are two types of purse seines; luring purse seine that target on anchovy (anchovy purse seine) and luring purse seine that catch for small pelagic fishes. Meanwhile, second type of purse seine (searching purse seine) also target small pelagic fishes besides tuna.

    Biological information from the survey conducted such as information on spawning season, fishing effort and fishery management strategies was also presented. Viet Nam representative also highlighted the important of future works to raise continuously knowledge especially among local fisherman, strengthening capacity for various stakeholders and collaborative study for management to manage pelagic resources in a sustainable manner. His presentation appeared in Annex 15.

17. General discussion of pelagic fisheries based on country presentations:

    i) Stock Assessment
    Resource Person, Prof Dr Takashi Matsuishi informed unreliable data on landing and fishing effort will give a big impact to the management interpretation. Therefore, a detail review should be implemented to avoid any mistakes. Due to poor data collection by some country, Dr Takashi Matsuishi suggested to divide into good data and unreliable data (bad poor) so that accurate analysis for management on Purse Seine fisheries can be analyzed and come out with better result. Furthermore, Deputy Chief of MFRDMD suggested environmental data such as water temperatures in the fishery grounds should also be considered because this might clarify the reason of yearly big gap of the landing.

    Meanwhile, Chief of MFRDMD suggested adding information from the hydro-acoustic survey for better understands the status of pelagic resource in the region. He also strengthened that the requirement of capacity building for stock assessment of pelagic fish in the region and informed that SEAFDEC willing to help Member Countries to access pelagic stock assessment by other method. e.g. surplus model.

    ii) Biological aspects
    Resource Person, Prof Dr Takashi Matsuishi recommended Member Countries to get updated report for length of maturity. Based from the Member Countries' presentation, there were some of the different in length at first maturity among countries, Chief of MFRDMD suggested to find out the factor such as geography factor that may possible to cause the fish to mature early.

iii) Management strategies and regulation

Member countries highlighted the issue on regulation of fishery management strategies such as number of person on board need to be decreased (currently about 20 to 30 persons per boat) and fishing technique that need to be managed carefully. Representatives from Malaysia and The Philippines also recommended to look up on the issue of transshipment. As in SEA scenarios that their catch based on multispecies, Resource Person suggested fishery managers in the region to regulate what is the depleted species so that the fishery management of multispecies in this region could be easily to manage.

REVIEW ON CURRENT PURSE SEINE MANAGEMENT SYSTEMS (THAILAND & THE PHILIPPINES)

18. Cdr. Pornchai Singhaboon from Thailand presented Experience and Lesson-Learned on TAC implementation. In the presentation, he shared on how TAC was applied in Thailand that involves three processes; 1. Determination of Maximum Sustainable Yield (MSY) for three groups of marine resource (pelagic group, benthic group and anchovy group), 2. TAC consideration from about 90% of MSY and 3. TAC submission to National Fishery Committee for approval. Based on four types of allocation to the fishers for all fishing activities, in Gulf of Thailand 230,803 (t) for pelagic and 172,607 (t) for anchovy whilst in Andaman Sea 110,184 (t) for pelagic and 29,650 (t) was approved for TAC. The meeting was informed that the MSY determination was calculated using monthly monitoring system data collection using surplus model. The resource utilization according to two management areas and right-allocation for anchovy purse seiners in Gulf of Thailand was also presented. The implementation of TAC was started since 2016 in Thailand that every two years is the time for fishers to renew their fishing license and the next the right-allocation will be reviewed in 2018. However, due to some limitations in TAC system, Total Allowable Effort (TAE) system was indirectly applied instead of TAC system in order to manage pelagic resource in Thailand. The meeting was informed that the TAE was easily to monitor and control using port in - port out (PIPO) system. At this time, the improvement of TAC is still in progress and soon TAC system will be fully established. As for suggestion, Chief of MFRDMD recommended to use electronic system for effective monitoring system in future. The presentation as in Annex 16.

19. Representative from The Philippines, Mr Ronnie Romero presented on Experience and Lesson-Learned based on Target Reference Points (TRP). He explained that Harvest Control Rules (HCR) could be implemented if this Limit Reference Point (LRP) is reaching its target as the most sustainable point. He reported that the Philippines is till on process of coming up with a Reference Point using exploitation values. Moreover, a legislation on the HCR Management Practice is on its final revision.

    He expressed that MSY is the most ideal RP but due to the absence of a reliable inventory of fishing boats and gears in the Philippines, MSY cannot yet be used as RP as there is a need to come up with a comprehensive estimation of the fisheries production in the country. He also informed the Meeting that data analysis is continuing and MSY calculation will be ready probably the year after Fishing Boat and Gear Inventory in 2018 is done.

In connection to the LRP uing e values, the reference data was collected from the National Stock Assessment Program (NSAP) and was expected to be mainstreamed in the BFAR regional office who conducts their individual regional analysis. In his presentation, he highlighted the concept of HCR and its implementation besides the example for Reference Point (RP) using exploitation value in the Philippines. His presentation also showed the proposed Limit Reference Point for Philippine small pelagic fishes, neritic and oceanic tuna by fishing ground based on Exploitation (E) values using length-frequency data in 2015. A few case studies were also presented according to close seasons implemented in selected areas. He also stressed that strengthened participation of stakeholders and players of the industry such the Local Government Units (LGU) played significant roles in mainstreaming EAFM, FMA and Establishment of RPs. Moreover, consistent support from Regional Field Offices for the establishment of comprehensive fisheries management systems was vital in the successful implementation of BFAR Management Activities. His presentation appeared in Annex 17.

REGIONAL DATA ANALYSIS

20. Resource person of this project, Prof Dr Takashi Matsuishi from Hokkaido University, Japan presented Examples of Pelagic Stock Management in Japan. As an example, he presented stock assessment of Sardine in Pacific Coast of Japan for year 2016 focus on estimation on catch at age (Age Length Key, ALK). Virtual Population Analysis (VPA), estimated biomass (B) and exploitation rate (E), stock recruitment relationship and population dynamic prediction for deciding allowable biological catch (ABC) which is the scientific recommendation for TAC. However, he highlighted that for the tropical species, the application of ALK could be difficult. The presentation as in Annex 18.

21. Ms. Wahidah Mohd Arshaad from SEAFDEC/MFRDMD, presented “Genetic study of *Amblygaster sirm* inferred by mitochondrial DNA Cytochrome *b* (cyt *b*) in South China Sea and Andaman Sea”. In this presentation, she highlighted there were separated management unit of *Amblygaster sirm* in Southeast Asia based on genetic result. A few recommendations had been suggested before this conclusion can be confirmed such as additional sampling locations especially in Andaman Sea. Additional recommendations to use other gene other than cyt *b* could be considered for confirmation. The meeting has been informed that the analysis from Indonesia will be done by Indonesia representative and will be ready for next year. Chief of MFRDMD had recommended to use other study such as morphometric study to confirm the stock structure of the selected species in the region. Her presentation appeared in Annex 19.

RELATED TO MANAGEMENT STRATEGY OF PURSE SEINE FISHERY

22. Prof Dr Takashi Matsuishi presented TAC Management for Multispecies Fisheries. He

highlighted the scenarios happened to purse seine fishery in Malaysia that catch several species at one haul and selected fishery management of Pacific Bluefin Tuna *Thunnus orientalis* on how its regulation in Japan as an example. In Japan, this species was catch by purse seine and set-net fishery and quota for this species for Hokkaido was 58 tonnes during July 2017 to June 2018. A few solutions have been taken to manage this species whereby the total catch has exceeded its quota in only 4 days. Therefore, based on the example, he recommended a few points for Purse Seine management such as; (i) Understand of the multispecies situations, (ii) Flexibility in the implementation and (iii) Monitoring scheme. Member countries also shared some of their country's experiences on the use of set-net in their country. His presentation appeared in Annex 20.

23. Chief of MFRDMD, Mr Raja Bidin Raja Hassan presented Introduction to the Concept of Fisheries Management Plan (FMP). In his presentation, he highlighted the steps and process of FMP. The examples of FMP practices in Australia and USA were also presented as an example in his presentation. His presentation appeared in Annex 21.

As for management of purse seine fisheries, Chief of MFRDMD informed the meeting that FMP for specific species is the main target for the future JTF project.

Capacity building for stock and risk assessment will be one of the activities proposed for this new project. In this regards, Indonesia representative strongly agreed that scientific data is needed to support FMP and recommended FMP at the national level (e.g. FMP in Cambodia and Thailand) should be developed before FMP at the regional level could be initiated. However, harmonization on the specific objective of FMP for pelagic fish should be considered as a high priority in terms of to stop overfishing and upgrade habitat for sustainable fishery.

Meeting also agreed to include other type of fishing gear (e.g. ring-net in Philippines or surrounding net in Thailand) that has similar function or mechanism as purse seine in the FMP. The meeting agreed, that MFRDMD as the center management for regional level should lead this activity.

24. A few points had been highlighted as for general discussions for management strategies such as:

i) Chief of MFRDMD suggested *Rastrelliger* spp and *Decapterus* spp need the management strategy for the region based from the finding of the shared stock. Example such as close season practice in Thailand, Myanmar and Viet Nam could be taken as an example as the strategy for the sharing stocks among Member Countries.

ii) Member Countries need to get complete set of information on catch and effort in order to come upwith a more reliable Purse Seine estimation in the region. This output will be used for final output for JTFVI program.

iii) MFRDMD will re-send the template for the data input and Member Countries were requested to give at least 20 years' series of data according to two ecosystems; South

China Sea and Andaman Sea. Member Countries will give fully support the proposal of FMP for Purse Seine Fisheries.

25. This session was chaired by Chief of SEAFDEC/MFRDMD, Mr. Raja Bidin Raja Hassan. Way forward were discussed and presented as below:

No.	Activities	Time frame	Remarks
1.	To collect complete set of information from MCs for Catch & Effort data for PS fishery	End of 2017	• MFRDMD will resend the template to MCs after this meeting • Include C&E data of ring nets (The Philippines) • Separate data according to the ecosystem (SCS and AS)
2.	Regional synthesis	Q1 of 2018	• MCs will submit the country report after the meeting • Involve one representative from MCs for workshop. • Will include the synthesis of total catch and species composition in the SCS and AS. • Data standardization
3.	Publication on current status of PS fishery	Q2 of 2018	•
4.	Genetic study	Q3/Q4 of 2018	• Workshop for final report (invite delegates from Indonesia) • DNA barcoding to confirm cryptic species depends on the budget available
5.	CEM	Q4 of 2018	• Invite all MCs (two representatives)

CLOSING SESSION

26. Closing remark by Deputy Chief of SEAFDEC/MFRDMD. He conveyed his thanks to all the participants, resource person and secretariat of the meeting for their hard work and contribution to the workshop, which was very much helpful for upgrading the fisheries management in the region. His closing remarks appeared in Annex 22.

4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region

18-19 September 2018, Melia Hotel, Kuala Lumpur, Malaysia

Adopted report

INTRODUCTION

1. The 4th Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region was organized by SEAFDEC/MFRDMD at Melia Hotel, Kuala Lumpur, Malaysia from 18 to 19 September 2018. The meeting was attended by the representatives from Brunei Darussalam, Cambodia, Malaysia, Myanmar, The Philippines, Thailand and Viet Nam; as well as resource persons from Japan and Malaysia; the representatives from SEAFDEC/SECRETARIAT and SEAFDEC/TD; the Chief, Deputy Chief and Officials from SEAFDEC/MFRDMD. However, the representative from Indonesia could not join this meeting due to other commitment. The List of Participants appears as Annex 1.

2. The objectives of the meeting were: to share the latest information about landings and CPUEs of purse seine (PS) fisheries in the region, to provide explanation for any misleading data/information from all participating Member Countries, to share latest/additional output based on the regional synthesis of purse seine fisheries in the region, to discuss the most appropriate management measures for purse seine fisheries in the region, and to understand the population structure for *Amblygaster sirm*.

OPENING OF THE MEETING

3. In his welcome message, the Chief of SEAFDEC/MFRDMD, Mr. Raja Bidin Raja Hassan expressed his gratitude to all participants from the SEAFDEC participating Member Countries for their efforts to attend this meeting and expected to deepen his knowledge on purse seine management which he thinks is more applicable in the ASEAN region. His welcome remarks appear as Annex 2.

4. The meeting was officially opened by the Deputy Chief of SEAFDEC/MFRDMD, Dr. Kenji Taki. He hoped the participating Member Countries could share on the latest information about pelagic fisheries and management of purse seine fishery. He emphasized on the importance to examine the fishing capacity for purse seine and some management measures to address the common issues faced in this region and hoped delegates could tap valuable information from invited resource persons from Japan and Malaysia. The opening address appears as Annex 3.

ADOPTION OF AGENDA AND OVERVIEW OF THE PROGRAM ACTIVITY

5. This session was chaired by Chief of SEAFDEC/MFRDMD and the meeting agenda was presented by Dr. Kenji Taki, Deputy Chief of SEAFDEC/MFRDMD. The agenda was adopted with a little amendment as in Annex 4.

6. Project Coordinator, Mr. Mohammad Faisal Md. Saleh, presented the Overview of Project, as appears as Annex 5. Besides reporting the background and objectives of the project, the expected goals of this project were also informed. The activities that have been done so far also been reported. In his presentation, he also emphasized the need of completing data input from the member countries in order to get a clear picture to formulate the management strategies for small pelagic fisheries in the region, as one of the expected goals of the project. For example, Myanmar was requested to provide a complete data input, and he also hoped that the genetic samples of *Amblygaster sirm* should be determined since this is very important to confirm the genetic population structure of this selected species in this region. The meeting members were informed that all outputs will be reported in a terminal report to be published in 2019 and the report will be disseminated to all SEAFDEC member countries. His presentation received a few comments and suggestions, which was agreed by all meeting members. One of the resource person, Prof. Dr. Takashi Matsuishi recommended to use multispecies management instead of selected major species as the new objective for this project, in lined with the progress of other project that involved Purse Seine fisheries management for multispecies in this region. This new approach lead to future research such as Fisheries Management Plan (FMP), will be applicable to all SEAFDEC Member Countries' situation. Chief of MFRDMD, Mr. Raja Bidin Raja Hassan also agreed with the suggestion, furthermore, he added that if the use of major selective species still need to be proceed, the common species like tuna and sardine could be chosen as new subjects to study. The meeting was informed that currently, only one species of *Amblygaster sirm* or spotted sardinella had been selected to study the population structure in the region by using the genetic approach. Dr. Worawit Wanchana from SEAFDEC/SEC suggested sufficient data such as CPUE, biological data, etc. should come out with a standard guideline to reflect effective observations for FMP. He gave an example of ecolabelling schemes approach through Marine Stewardship Council (MCS) as an effort by Member Countries towards sustainable fisheries. The meeting was also informed and requested by Mr. Chhuon Kimchhea from Cambodia for further funding and technical support on this project in future. MFRDMD will take this request as consideration for future.

COUNTRY REPORT PRESENTATIONS

7. The first country report was presented by Mr. Marzini Haji Zulkipli from Brunei Darussalam as in Annex 6. His presentation mainly focused on the overview of fisheries management measures in Brunei Darussalam. The meeting was informed of the landing trend and CPUE of purse seine in Brunei Darussalam from 1993 to 2017. The major composition of industrial purse seine which had compiled the national

reports since 1995 in Brunei Darussalam was also presented. He explained that the data in 1992 was collected from the former employees from DoF Brunei Darussalam and informed most of the catches was from trawl vessels. However, in recent years, Brunei Darussalam encouraged the Purse Seine operators to explore deeper sea for yellowfin and big eye tuna and this initiative will be improved in future management strategies. He also stated the current status of marine capture fisheries in Brunei Darussalam had decreased from 14,966 MT in 2016 to 13,796 MT in 2017. The capture was using the small scale and commercial fishing vessels in which the former comprises of 66% from the total of marine capture fisheries production.

Resource Person, Prof. Dr. Takashi Matsuishi from Hokkaido-University, emphasized that the country report presentation was very crucial in order for member countries' representative to explain their current data information. He was impressed with the way that Brunei Darussalam managed their vessels although the country adopts small-scale fisheries and this could be a good example of excellent data collection for other countries. The meeting had been informed by Brunei Darussalam's representative about the situation happened in 1997 to 2000 whereby no data of purse seine fisheries collected due to high unit pricing of the targeted species, hence the operators were reluctant to catch the species. Some suggestions were made by Prof. Dr. Takashi Matsuishi in order for the results would not be affected if the case of no available data. He also emphasized that the investigation of interannual variations of species composition was very important and strongly recommended species by species data collection in the future.

Mr. Marzini Haji Zulkipli explained the type of vessels used according to fishing zones in Brunei Darussalam whereby Zone 1 is allowed for small scale fishery vessels only whilst big boats and vessels operated in Zones 2 to 4. The fluctuation in number of vessels in Brunei Darussalam was due to some factors, for instance, the lack of operators for technical and vessels ability, weather and manpower. Mr. Chhuon Kimchhea from Cambodia informed that they will start the zoning systems using the examples from other Member Countries like Brunei Darussalam.

8. The second country report was presented by Dr. Chea Tharith, the first representative from Cambodia. His presentation as in Annex 7, focused mainly on overview of purse seine fisheries in Cambodia. Besides showing the statistics of vessels and marine capture production in Cambodia from 1993 to 2015, he also shared the challenges and constraints faced in Cambodia in regards to fisheries management. However, he added that necessary management actions were implemented. Currently, Cambodia is revising the fisheries legislation and in drafting the National Plan of Action against IUU fishing (NPOA-IUU) for 2018-2022. He discussed the need to hire some experts to prevent the IUU and PSM.

The upgraded marine fishery policy in Cambodia was introduced in the meeting by

Mr. Chhuon Kimchhea, the second representative from Cambodia. The country just hired the international consultant from European Union (EU) and just proposed the 1st draft for marine fishery policy whereby all fishing vessels operated must be registered. He also added that the upgraded marine fishery policy was using the existing National Marine Policy as the template. He answered to Dr. Worawit Wanchana's query regarding the number of vessel licenses were more than number of existing fishing gears. In his response, the meeting members had been informed that some of the vessels do not require to be registered their fishing gears. He also added that Minister of Public Work and Transport is responsible for vessels registration while Department of Fisheries is only responsible for fishing registration.

9. The report for the East Coast of Peninsular Malaysia (ECPM) was presented by Mr. Sallehudin Jamon from Fisheries Research Institute (FRI) Kg. Acheh, Perak, as in Annex 8. He started his presentation with general Malaysia Fisheries profile followed by landing trend of pelagic fishes and anchovies including species composition. Biological data such as length at first maturity and spawning season of mackerel and scads were also included in his presentation. Other than that, trend of fishing effort for purse seine fisheries in ECPM was also reported. The meeting was informed that the current status for pelagic fish in ECPM using Kobe I Plot is still in green zone. Meanwhile, the risk assessment attempted to allow the increase of catch up to 20% for the next ten years. The management measures for purse seine in ECPM were also presented.

   Responding to Prof. Dr. Takashi Matsuishi regarding the declining of fishing effort that affected the relationship between catch and standardized CPUE in 2017, Mr. Sallehudin Jamon clarified that was due to the catch of Indian mackerel and short mackerel was low during that year. However, ECPM has taken note to improve the data analysis after a few suggestions from the Resource Person.

10. The report for the Purse Seine Fishery of the West Coast of Peninsular Malaysia (WCPM) was presented by Mr. Abdul Wahab Abdullah from FRI Kg. Acheh, Perak. His presentation appears as Annex 9. He started with information on type of purse seine vessels, zoning and fishing areas and also on latest relevant rules and regulations. The meeting was informed that according to Kobe I Plot, the current status of the West Coast is overfished based on pelagic survey data in 2013. Besides that, biological data information such as length at first maturity and spawning season of Indian mackerel were also reported in his presentation. The issues of challenge for pelagic resources in WCPM had also been addressed in his presentation.

    The meeting had also been informed by Mr. Sallehudin Jamon that the contrast situation of resource status between WCPM and ECPM was because of many reasons. One of the reasons was political disputes on the license issued to the fishermen. Nevertheless, Chief of MFRDMD added that the finding of overfishing in WCPM was consistent with reports during acoustic survey and it is an alarm for WCPM to reduce number of fishing efforts and fishing vessels, hence the managers had come out with a proposal of closing season for certain species. He also suggested collaboration with the neighbouring countries (Thailand and Indonesia) for management purpose plan.

11. The country report on Purse Seine Fishery in Sarawak, Malaysia was presented by Mr. Jamil Musel from FRI Bintawa, Sarawak. Kobe I Plot from 2009-2017 showed pelagic status of Sarawak waters is still in green zone category. Another analysis using risk assessment showed the green zone for three years if the current catch level remains around the same, but overfishing will happen if the catch increases up to 20% in the next ten years. The interannual variations of total biomass using Kobe I Plot was also presented besides the existing management strategies practiced in Sarawak. His presentation appears as Annex 10. The meeting members were discussed some of the issues and challenges in purse seine fisheries in Sarawak such as the issue of foreign worker employment due to new regulations as well as the sea condition in Sarawak waters itself was not suitable for purse seine which lead to the low number of PS vessels operated. He added that there was a discussion among Sarawak's authority regarding the development of purse seine fisheries in Sarawak. In addition to that, he also reported that as an alternative, some of the fishermen tried to use stick sea cassnet as a new fishing gear but it is still under trial phase. Nevertheless, that new fishing gear managed to catch higher number of squid and mackerels (e.g. 400-500kg/haul).

12. Mr. Mohd Zamani Nayan from Department of Fisheries Sabah, Malaysia presented the "Purse Seine Fisheries in Sabah". He described briefly on the fishing zone in Sabah which is divided into three zones; West Coast (WC) Zone, East Coast (EC) Zone and Tawau (TW) Zone. He addressed some issues and challenges of fishery scenario in Sabah. Kobe Plot showed EC Sabah is in yellow/recovery area. Meanwhile TB/TBmsy and F/Fmsy are in green area, however, unlimited catch will result in overfishing for the next ten years. The Kobe I Plot analysis had also revealed the landing trend of pelagic fish in Sabah from 2009 to 2017 for three types of gears. The existing management strategies in Sabah are same with the rest of Malaysia, for example, joint venture program and building up management plan.

    Mr. Mohd Zamani Nayan also expressed his concern on the issue of safety in Sabah waters may affect the number of captures for some time. Mr. Sallehudin Jamon also added the same situation happened in IOTC waters particularly among the fishermen in Somalia. In terms of data analysis, Mr. Supapong Pattarapongpan from SEAFDEC/TD had suggested to use other model instead of depending solely on ASPIC model and he mentioned the same situation had happened before to Gulf of Thailand (GoT) data analysis. In this case, the use of ABC model was more appropriate. However, Mr. Mohd Zamani Nayan clarified that the data has been corrected since 2010 and gave the same negative correlation. His presentation appears as Annex 11.

13. The country report from Myanmar was presented by Mr. Myint Shwe entitled The Management of Purse Seine Fishery in Myanmar. He elaborated that the purse seine operation in Myanmar can be divided into Fish Purse Seine to catch species like Hilsa and Purse Seine Anchovy to catch anchovies in inshore coastal waters. He also showed the major capture pelagic fishes in Myanmar waters as well as fishing season for Indian mackerel. The offshore and inshore purse seine catch activities and CPUE were also presented. The current pelagic stock status from research vessels survey data in 2013 was revealed and he informed that presently there was also a survey conducted near Myanmar coastal waters which yielded 1.5 million MSY (Maximum Sustainable Yield) for both pelagic and demersal. His presentation appears as Annex 12.

14. Mr. Ronnie Romero from the Philippines presented his country report on the purse seine fisheries. Based on his presentation, he provided an overview of the Philippines capture fisheries and scenarios of purse seine fisheries. He also discussed the status of pelagic fish and existing management measures in the Philippines. The meeting agreed that reference points (RP) had been used and the implementation would be a good example of management measures taken to fisheries management in the Southeast Asian region. His presentation appears as Annex 13.

15. Dr. Watcharapong Chumchuen from Thailand reported the Purse Seine Fisheries in Thailand. He briefly explained about the catch and effort statistics, biological information, status of pelagic fish stock and existing management measures in Gulf of Thailand (GoT) and Andaman Sea (ANS). Dr. Worawit Wanchana from SEAFDEC/TD recommended to acquire data from Thai Meteorological Department to determine the exact time of sunset and sunrise for anchovy purse seine's daytime fishing operation. In response to Sarawak Malaysia's delegate, Dr. Watcharapong Chumchuen informed that the MSY calculation was done yearly for pelagic fishes, demersal fishes and anchovies in Thai waters. The meeting was also informed the increasing of number of days per trip in 2011 to 2012 in GOT may due to fishery resource status, fuel cost and improvement of the storage on the fishing vessels thus the fishermen can stayed longer at the sea compared to the previous years of 1-2 days per trip. His presentation appears as Annex 14.

16. Mr. Pham Van Tuyen presented the country report from Viet Nam. In his report, an overview of marine fisheries was explained particularly on the purse seine fisheries in Viet Nam. The total number of fishing boats and purse seiner was revealed besides the landing trends from 2000 to 2017. In addition, trend of CPUE, biological information, current stock status of pelagic resources and existing rules and regulations were also reported. He also shared that Viet Nam is still struggling in the implementation of proper rules and regulations. However, there are many workshops, meetings and discussions conducted by Viet Nam's authority to overcome some issues, such as the implementation of minimum length of the fish capture for some species. The ideas and suggestions from meeting members are always welcome in

order to help Viet Nam in this matter. His presentation appears as Annex 15.

17. General discussion of pelagic fisheries based on country presentations:

I. Catch and effort statistics

i) Chief of MFRDMD, Mr. Raja Bidin Raja Hassan advised Brunei Darussalam to get more information on catch and effort data statistics for better output from the data analysis and the result can be used to determine the performance of purse seine fisheries in the region. He added a combination with more comprehensive data from Brunei Darussalam and other Member Countries can be a good reference on the actual performance of purse seine industry in the region.

ii) Deputy Chief of MFRDMD, Dr. Kenji Taki advised Thailand to use different method of analysis by using each category of vessel size for purse seine, to take example after Brunei Darussalam that used zone division for CPUE and catch effort in their analysis.

iii) Representative from SEAFDEC/TD, Mr. Supapong Pattarapongpan suggested to come out with standardized method since all meeting members were aware that different countries have different management measures. Therefore, it was advised to double-check all the result analysed by respected country in best possible way to find out the reference point and then decided which management measure is most suitable before the standardized method or model at regional level is determined.

iv) Dr. Worawit Wanchana suggested as a way forward, to come out with a manual or template for the data analysis and he believed the pattern analysis used by Malaysia can be a good example for the data analysis for fish stock analysis at regional level.

v) Dr. Watcharapong Chumchuen gave some suggestions to use CPUE unit as smallest effort unit as possible, for example haul, day or trip, because the large unit (vessel) has large variance when different data sources were analysed together. Mr. Mohammad Faisal Md. Saleh responded that MFRDMD had tried to used effort index as number of vessels and other type of efforts; however, after several internal discussions, MFRDMD found that the suggested effort index as number of units or vessels and other types of effort were not reliable for regional analysis except effort index as number of trips. Dr. Kenji Taki, however, added that the number of days is the best index for Thailand scenario and his suggestion was agreed by Thailand's representatives although the fleets used different strategies. Representative from Malaysia, Mr. Sallehudin Jamon also agreed that the finding by using number of units and trips resulted in good outcome as compared to other efforts.

II. Biological information

i) Mr. Mohammad Faisal Md. Saleh highlighted for Member Countries to submit biological information with references as shown by Thailand and Viet Nam in their presentations. He informed that the references are needed to be included in the terminal report publication.

ii) Dr. Kenji Taki added geographical difference should be included for maturity size and spawning season information for next step of analysis.

iii) Prof. Dr. Takashi Matsuishi reminded all meeting members to be extra careful in the accuracy of estimations that seems different from the previous reference/historical data information.

III. Stock status

i) Dr. Kenji Taki mentioned the new approach using ASPIC and Kobe Plot model by Malaysia was the first time presented in the meeting and showed a good progress so far with some revision needed for future analysis.

ii) Mr. Ronnie Romero added they appreciated the production model proposed by Malaysia, however, he suggested that Malaysia could come out with some recommendations for sustainable fisheries (e.g. management strategies on how to sustain livelihood without affecting the ecological balance).

iii) Mr. Fileoner O. Eleserio from Philippines also expressed his concern on methods of fishing such as the use of light and sonar, as example. He suggested that lots of variables need to be examined for particular fishing gears and number of days at the sea. In addition, Dr. Kenji Taki favored Malaysia's examples in using three different gears for their analysis on CPUE and suggested to consider further categorization of the gears.

Chief of MFRDMD recommended to come out with standardized unit/effort for different methods for better result of regional analysis.

IV. Management strategies:

i) Chief of MFRDMD also highlighted the need of all Member Countries to report the progress or impacts on the management measures implemented by their country in the future. As an example, implementation of close seasons approach in Thailand, so that the comparison between before and after implementation can be observed and used as a reference to the other Member Countries.

MANAGEMENT MEASURES FOR PURSE SEINE FISHERIES

18. Ms. Wahidah Mohd Arshaad from SEAFDEC/MFRDMD, presented "Genetic study of *Amblygaster sirm* in South China Sea and Andaman Sea". In her presentation, she highlighted there was separated management unit of *Amblygaster sirm* in Southeast Asia region based on genetic result inferred by Cytochrome *b* (Cyt *b*) DNA marker. She also informed that the extra analysis using other DNA Marker which was Cytochrome C oxidase subunit I (COI) was also done to reconfirm the result. From both DNA markers used, it was concluded that there was a separated population structure of *A. sirm* between South China Sea (including Banda Acheh) and Andaman Sea (particularly from Ranong). However, this finding was not agreed by genetic experts during the Genetic Workshop that took place in Langkawi, Malaysia from 6 to 8 August 2018 previously. From that genetic workshop, it was assumed that the existing of new species/sub-species of *A. sirm* is due to its high genetic distance between these two ecosystems which are South China Sea (including Banda Acheh) and northern Andaman Sea water (Ranong). Therefore, it was decided that a few factors may contributed to the population genetic break such as hybridization, faster rate of genetic evolution or there was the discovery of new or cryptic species. Future studies were recommended for clear result such as using another DNA marker (e.g. microsatellite), morphology study and additional of larger geographical areas. Therefore, she also emphasized the important of samples collected from Myanmar as it was unavailable currently. The meeting was also informed according to FAO, this *A. sirm* species was not found along the Straits of Malacca and it was confirmed by Mr. Sallehudin Jamon based from the local knowledge and this finding would make the study more exciting to be carried out. Dr. Worawit Wanchana also shared the microsatellite study done for *Rastrelliger brachysoma* in GoT waters revealed the different stock structures. Dr. Worawit Wanchana offered to assist in morphology without using any extra cost study from Myanmar and Thailand, however MFRDMD will discuss with Indonesia for further collaboration. Her presentation appears as Annex 16.

19. Mr. Abu Talib Ahmad, the former Senior Director from Malaysia Fisheries Research Institute, Department of Fisheries Malaysia, presented on Rapid Assessments – Risk and Fisheries overview Towards Development of Fisheries Management Plan. From his presentation, rapid assessments for management was reviewed which divided into Risk Assessment and Fisheries Assessment. He also showed the example been used for fisheries assessment for Purse Seine Fishery scenario (multispecies) in WCPM. He also clarified that the high result of Risk Assessment for *Rastrelliger kanagurta* was due to trawl gear used as the main fishing gear for small pelagic, however, under susceptibility that the data was overlapping when compared to gillnet that was not allowed in coastal areas WCPM. He also explained that the Risk Assessment must be done by species, therefore to do the Productivity-Susceptibility Analysis (PSA), all parameters must be considered, however this is not applicable to regional level, therefore, further studies need to be done in future for this subject. The meeting also

had been informed that the method used for pre-assessment was only inspired by the method developed by the Europeans for proper management plan and was not to be applied to Southeast Asian purse seine fisheries' scenarios. All meeting members agreed to use this method of assessment for future project lead by MFRDMD. His presentation appears as Annex 17.

20. Mr. Mohammad Faisal Md. Saleh presented the Outputs Based on Regional Synthesis, as appears as Annex 18. In his presentation, he showed the current result of regional analysis done by MFRDMD using calculation of Allowable Biological Catch (ABC) Rule (Rule 2-2) for selected areas in SCS and ANS and also the preliminary analysis using Production Model (Fox Model) for selected areas. Dr. Worawit Wanchana supported the finding found by MFRDMD, however raised issue of the accuracy of the data due to data fluctuations to be used for upcoming JTF VII project. Mr. Mohammad Faisal Md. Saleh responded that MFRDMD have taken note on the mentioned issue, nevertheless the main constraints to get more precise and accurate data were cost and manpower. Chief of MFRDMD then reminded and emphasized Member Countries to follow the right steps during data collections for sake of data accuracy. Mr. Ronnie Romero recommended to come out with standardized method with different modelling to accommodate various situation data. Prof. Dr. Takashi Matsuishi stressed on the precision of data input in order to improve the results' effectiveness. He also added that the regional analysis can be considered as a scientific trial however it is not enough to be used as a scientific evidence for management of pelagic fishes in each Member Countries.

21. Prof. Dr. Takashi Matsuishi presented results from Land Based Survey conducted in 2017 and 2018 on East Coast of Peninsular Malaysia (ECPM). His presentation received some comments from Mr. Abu Talib bin Ahmad on extra analysis of statistical data but cautioned on the accuracy of the data used. His presentation appears as Annex 19.

22. Prof. Dr. Takashi Matsuishi continued with his second presentation on Latest Topic of Stock Assessment, as in Annex 20. In his presentation, he reviewed the feedback on fisheries management strategy applied for mixed species data. The Feedback Control Management is applicable to mixed species data and poor data situation, which seems to be fit with current situation of purse seine fisheries in the Southeast Asian region. At the end of his presentation, he also stated that multi-gear situation fishery management should be considered for the sake of sustainable fishery.

23. Chief of MFRDMD presented the Fishery Management Plan (FMP) for Small Pelagic in the South China Sea. In his presentation, he explained the requirements needed to execute a successful FMP. He emphasized the need to consider the multiple aspects and issues related to the targeted fishery management plan. Implementation arrangements for FMP also were briefly described. His presentation appears as Annex 21.

24. Prof. Dr. Takashi Matsuishi continued with his presentation on Possible Management Measures for Purse Seine Fisheries in ASEAN Region, as in Annex 22. In his presentation, he explained some issues on different condition between biomass and MSY relationship due to high productivity to some cases. Mr. Abu Talib Ahmad then highlighted on the observation of the multispecies scenarios of the purse seine fisheries. He emphasized on the use of standardized efforts for management purposes. Prof. Dr. Takashi Matsuishi was cautious in using the standardized efforts because it will causes the FMP to become more complicated, as FMP involves multi-gears, however he will look further regarding this matter. Dr. Kenji Taki suggested special consideration on species with lower intrinsic rate (r) species (e.g. *Thunnus tonggol*) and Prof. Dr. Takashi Matsuishi agreed to use multispecies management with special care for the status of tuna-like and shark species with lower intrinsic rate (r) from his simulations. MFRDMD agreed on the need to consider the suggestion for more examinations before develop management plans in the regions. Mr. Ronnie Romero also added the Ecosystem Approach Fisheries Management (EAFM) can also be considered by including the human components, ecological and good governance in developing FMP. All meeting members agreed that developing a FMP is not an easy step and will take some time before it is stabilized, nevertheless MFRDMD will get fully support from all Member Countries on this matter.

WAY FORWARD

25. Deputy Chief of MFRDMD, Dr. Kenji Taki presented the summary of the meeting and the way forward or actions need to be taken for this project, as appears in Annex 23. In addition, Dr. Worawit Wanchana mentioned the need of the otolith/age determination study for as it is beneficial to many people and will attracts innumerable personnel to conduct the study.Therefore, he suggested to include this study in the next project (JTF VII) project. MFRDMD responded that some of their officials will attend a course arranged by national university for learning capacity on this matter. The meeting also discussed the consideration for other minor operating gears if needed, depending on the percentage of catch. Lastly. Dr. Kenji Taki suggested to include the trawl catch in the future project, subjects to the budget availability.

26. A few points had been highlighted in general discussion for management strategies such as:

i) Deputy Chief of MFRDMD questioned which type of production model needs to be used for the regional analysis. As response, Prof. Dr. Takashi Matsuishi stated that Schaefer Model will be preferred because sometimes Fox Model produces exceeded value or too optimistic for fMSY.

ii) Members of the meeting have been reminded again on the importance of standardized method development for analyzing their own data management before FMP to be developed.

CLOSING SESSION

27. Closing remark was delivered by Deputy Chief of SEAFDEC/MFRDMD. He conveyed his thanks to all the participants, resource persons and secretariat of the meeting for their hard works and contributions to the workshop, which were very much helpful for upgrading the purse seine fisheries management in the SEA region. His closing remarks appear as Annex 24.

Fish for the People (2017; Volume 15; Number 3)

Managing Purse Seine Fisheries in the Southeast Asian Region: a joint effort among ASEAN Member States

Mohammad Faisal Md. Saleh, Wahidah Mohd Arshaad, Raja Bidin Raja Hassan, Noorul Azliana Jamaludin, and *Nurul Nadwa Abdul Fatah*

Production from marine capture fisheries of the Southeast Asian region is derived from the fishing grounds in the South China Sea and Andaman Sea of the Indian Ocean (Fig. 1), comprising FAO Fishing Area 57 (Indian Ocean, Eastern), Area 61 (Pacific, Northwest), and Area 71 (Pacific, Western Central). In the Southeast Asian region, small pelagic fishes such as round scads, mackerels, sardines, and anchovies are considered as important components of the marine ecosystem and pelagic fishery resources. The migratory behavior of small pelagic fishes had made them known as "shared stocks" since they migrate across the exclusive economic zones (EEZs) of neighboring countries. Considering the likelihood that such stocks are shared by the bordering countries within the same ecosystem, *i.e.* in the South China Sea and the Andaman Sea, effective management of the shared stocks would require appropriate measures at the regional level. Nevertheless, delaying the regional approach in managing these stocks will further expose the small pelagic fishes to overexploitation that are now probably at unsustainable level (SEAFDEC, 2012).

Purse seine is one of the major fishing gears used to exploit small pelagic fishes in the region. Many types of purse seines are used to catch small pelagic fishes, among them are fish purse seine, anchovy purse seine, Thai purse seine, luring purse seine, tuna purse seine, and others. Commonly, purse seine operations are associated with fish aggregating devices (FADs), luring lights, and other devices. Nowadays, modern purse seines are equipped with radar, depth sounder, sonar transceiver, and satellite navigational instruments (SEAFDEC, 2017). However, management of purse seine fisheries has not been considerably pursued because of inadequate information on the stocks of the small pelagic fishes (Raja Bidin and Latun, 2016).

In an effort to establish a management plan for commercially important small pelagic fishes, the Marine Fishery Resources Development and Management Department (MFDRMD) of SEAFDEC was given the mandate to embark on the seven-year project "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region" starting 2013. Funded by the Japanese Trust Fund VI (JTF-6), the project involves eight ASEAN Member States (AMSs) that border the South China Sea (SCS), an important fishing area of these coastal states, namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Thailand, Philippines, and Viet Nam. As this point in time, the project has compiled the catch-effort statistics and reviewed the appropriate measures for management of small pelagic fisheries in the Southeast Asian region. In addition, a genetic study is being conducted to verify the extent of connectivity among the commercially important small pelagic fishes targeted by purse seine fisheries.

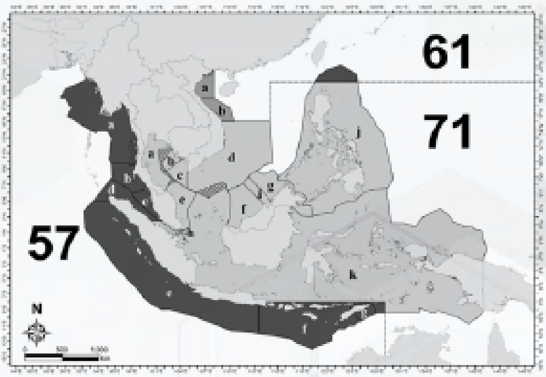

Fig. 1. Fishing areas 57, 71 and 67, with respective sub-areas (SEAFDEC, 2008; adapted from FAO)

The results would provide scientific background for concerted actions of the AMSs for the management of shared stocks of small pelagic fishes as well as development of appropriate management strategy for purse seine fisheries in the region.

Compilation of Catch-effort Statistics for Purse Seine Fisheries

Considering that fisheries catch-effort statistics are available in some AMSs and catch per unit effort (CPUE) is an indirect measurement of abundance of a target species, MFRDMD has examined the trend of resource level using the CPUE. At the same time, MFRDMD also reviewed the purse seine fisheries management systems including total allowable catch (TAC) and other measures to analyze the most appropriate system or measure that is applicable for the management of small pelagic fisheries in the Southeast Asian region (Raja Bidin and Latun, 2016). Taking place from 2013 until now, MFRDMD had continuously collected the updated information on purse seine fisheries from the AMSs as well as assessed the data for regional synthesis to recommend stock indicators and management systems that are suitable in the region. Every AMS has therefore been requested to provide updated and detailed information on their respective purse seine fisheries by complying with the parameters established by MFRDMD as shown in **Table 1**.

Nevertheless, there are some issues on the reliability of the compiled data because some countries are not able to fulfil all of the parameters, especially on the number of vessels for fish purse seine and anchovy purse seine. If this constraint continues to occur, it may affect the final analysis because the fishing efforts will be used in calculation of CPUE which is the key component of the project. The CPUE that will be analyzed from the catch and

Table 1. Parameters necessary for the management of purse seine fisheries in the Southeast Asian region

Parameters	Details
Landing of purse seine fisheries	• Trend of landing • Species composition • Biological information - length at maturity (Lm) - spawning season
Fishing effort for purse seine fisheries	• No. of vessels (fish purse seine, anchovy purse seine) • Weight of vessels (GRT) • No. of days/trip • No. of trips/month • No. of hauls/day • Trend of CPUE - by vessel - by trip - by days
Status of pelagic fish stock	• Biomass • Maximum sustainable yield (MSY)
Existing management strategies	• Closed Season • Closed Area • Survey-explorations • Joint venture program

effort statistics (*i.e.* number of vessels) will be used to calculate the allowable biological catch (ABC). The calculated ABC shall then serve as a scientific guide to set the annual TAC for the management of purse seine fisheries in this region.

The most recent information based on the parameters indicated in **Table 1** was presented by each AMS and discussed during the Third Core Expert Meeting on "*Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region*" in September 2017 in Kuala Lumpur, Malaysia. Based on the issues and challenges raised during the meeting, all of the AMSs were aware of the importance of reliable statistics to develop an appropriate management of purse seine fisheries. Thus, a detailed catch-effort statistics in the region should be prioritized to uphold accurate information.

Genetic Study

The spotted sardinella, *Amblygaster sirm* (**Fig. 2**) was chosen for genetic study because of its recognizable morphological features. *A. sirm* can be distinguished easily from other species of sardines by the presence of a series of 10 to 20 gold spots (in live or fresh specimens) or black spots (in preserved specimens) along the lateral line, but sometimes the spots are missing. This species is widespread in tropical Indo-West Pacific from the Red Sea and Madagascar, eastward to Indonesia, Gulf of Thailand, New Guinea, and the Philippines; north to Taiwan Province of China, and Okinawa (Japan); southward to northern coasts of Australia and New Caledonia; eastward to Kiribati and Fiji (Carpenter and Niem, 1999) as shown in **Fig. 3**.

In carrying out the genetic study of *A. sirm*, sampling locations were established in the South China Sea (Zambales and Palawan in the Philippines; Kudat, Kuching, and Kuantan in Malaysia; Muara in Brunei; and Songkhla in Thailand), and in the Andaman Sea (Ranong in Thailand) as shown in **Fig. 4**. The samples were collected from the South China Sea (n = 217) and the Andaman Sea (n = 35) from January to September 2015. *A. sirm* specimens were analyzed using DNA mitochondrial cytochrome *b* marker.

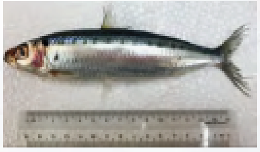

Fig. 2. Spotted sardinella (*Amblygaster sirm*)

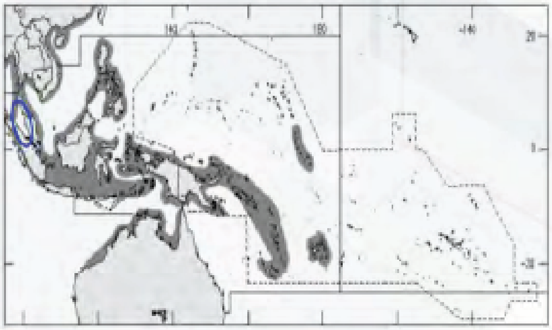

Fig. 3. Distribution of spotted sardinella, *Amblygaster sirm* (highlighted in dark gray). *A. Sirm* could not be found in the Strait of Malacca, in blue circle (Carpenter and Niem, 1999)

Based on the 1016 bp inferred by mitochondrial DNA cytochrome *b*, the stocks of *A. sirm* between the South China Sea and the Andaman Sea are separate genetic units. This indicates that the populations in the South China Sea are not associated with the populations in the Andaman Sea. It should be noted that this species could not be found in the Strait of Malacca (Carpenter and Niem, 1999) which could be the main reason of separation of the stock structure.

As for the management of sustainable fisheries, *A. sirm* in the South China Sea and the Andaman Sea should be regarded as a separate fishery resource that can be managed separately. Therefore, factors that affect the population in the South China Sea, such as fishing pressure, will not affect the population in the Andaman Sea, and vice versa. However, this is only a preliminary result due to limited number of samples. Therefore,

Fig. 4. Sampling locations of spotted sardinella (*Amblygaster sirm*) in the South China Sea and the Andaman Sea for genetic study (in blue dots)

it is recommended that additional specimens are needed especially from the Andaman Sea that would be sourced from the waters of Indonesia and Myanmar. Hence, the use of other methodologies using different DNA markers could be applied to confirm the initial findings.

Recommendations and Way Forward

The migratory behavior of small pelagic fishes poses a great challenge in the development and management of sustainable fisheries. Even though the preliminary result of genetic study found that populations of one of the target species, *A. Sirm*, in the South China Sea and the Andaman Sea are separate stocks, majority of the pelagic fishes are being shared by many countries in the region. Since purse seine is the main fishing gear used to exploit the small pelagic fishes, it is possible that purse seines operating in both ecosystems (the South China Sea and the Andaman Sea) might exploit the same stocks of small pelagic fishes. Hence, it is necessary that such shared stocks should be well managed to prevent overexploitation that could probably lead to the decline of the stocks.

In order to promote the fisheries management in the region, acknowledging the shared stocks is vital (SEAFDEC, 2017). Thus, in view of direct impact of purse seine fishery on the shared stocks of small pelagic fishes, it is essential to implement suitable management measures exclusively for purse seine fisheries in the region (SEAFDEC, 2012). In the early stages of the project, MFRDMD and AMSs reviewed the TAC as a possible measure to manage purse seine fisheries in the Southeast Asian region. However, it was found that TAC is not applicable due to the multispecies catch composition of the purse seine fisheries, thus other management measures must be considered. Among other management measures are the total allowable effort (TAE), allowable biological catch (ABC), and allowable biological effort (ABE).

Upon consultation with *Dr. Takashi Matsuishi* from Hokkaido University, Japan, the Resource Person for the Project, it was agreed that either ABC or ABE would be the most appropriate management measure for multispecies catch composition of purse seine fisheries in the Southeast Asian region. It was based on the feedback control that was introduced by *Dr. Matsuishi* which refers to cause-effect relationship. In fisheries, feedback control exemplifies the actions taken by managers according to the current state of the fisheries, management objectives, and a decision algorithm in a feedback control loop, typically aiming to stabilize annual catches and population abundances at desired levels (Holt and de la Mare, 2009). In the project's feedback control, Rule 2-1 and Rule 2-2 were constructed based on two assumptions, namely: (1) CPUE is proportional to the population; and (2) catch trend will correspond to short term population trend, respectively. These rules are being considered as the most applicable and appropriate for the management of purse seine fisheries utilizing the available data.

Since MFRDMD plans to publish a regional synthesis of purse seine fisheries in Southeast Asia, an internal workshop will be organized during the first quarter of 2018 for the preparation of the said regional synthesis. Besides, MFRDMD will also convene a Core Expert Meeting in late 2017 year or early 2018 to report on the information gathered during the project period and discuss about purse seine fisheries management in the Southeast Asian region. As for the genetic study, the analysis of specimens from other locations will be continued.

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About the Authors

Mr. Mohammad Faisal Md. Saleh is a Research Officer at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. He is also the Project Coordinator for the "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region."

Ms. Wahidah Mohd Arshaad is a Research Officer at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. She is the Leader of the Genetic Component of the Project "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region."

Mr. Raja Bidin Raja Hassan is currently the Chief of SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. He was the former Project Coordinator for the "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region."

Ms. Noorul Azliana Jamaludin is a Research Officer at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. She is a member of the Genetic Component of the Project "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region."

Ms. Nurul Nadwa Abdul Fatah is a Contract Officer for "Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region" at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia.

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Purse Seine Fisheries in Southeast Asian Countries:
A Regional Synthesis

Raja Bidin Raja Hassan and *Abdul Razak Latun*

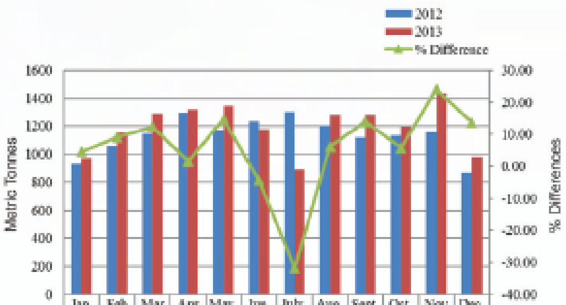
Several Southeast Asian countries, namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Thailand, Philippines, and Viet Nam surround the South China Sea (SCS) which is one of the most important fishing areas for these coastal states, and where some of its fishery resources form shared stocks among these bordering countries. SCS encompasses a portion of the Pacific Ocean stretching roughly from Singapore and the Strait of Malacca in the Southwest, to the Strait of Taiwan (between Taiwan and China) in the northeast. The hydrography of SCS consists of continental shelf of 200 meters deep, continental slopes and deep waters down to more than 2,000 meters. In the SCS, small pelagic fisheries dominate by about 20% of the total marine capture fisheries. Living in the surface and mid-water column of ocean or inland ecosystem, pelagic fishes range in size from small coastal foraging fishes, such as herrings and sardines, to large apex predator oceanic fishes, such as the Southern Bluefin tuna and oceanic sharks. These pelagic fishes are usually agile swimmers with streamlined bodies, and capable of sustained cruising on long distance migrations. In many countries surrounding the SCS, purse seine has been commonly used to capture these pelagic fishes. The status of purse seine fisheries in the countries bordering the SCS is summarized in this article based on the information provided by the concerned countries and compiled by the SEAFDEC Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD) during the Core Experts Meeting for Comparative Study on Purse Seine Fishery in the Southeast Asian Region organized by SEAFDEC/MFRDMD in Kuala Lumpur, Malaysia on 26-28 August 2014. The same information had also been reflected in a subsequent publication entitled "Current Status of Purse Seine Fisheries in the Southeast Asian Region" (SEAFDEC/MFRDMD, 2015). It should be noted that the term "South China Sea" is used in its geographical sense and does not imply recognition of any territorial claims within the area. A way forward to bring in long-term sustainable purse seine fisheries in Southeast Asia, more particularly in the SCS and Andaman Sea, is also being highlighted.

Based on FAO definition, purse seine is "made of a long wall of netting framed with floatline and leadline (usually, of equal or longer length than the former) and having purse rings hanging from the lower edge of the gear, through which runs a purse line made from steel wire or rope which allow the pursing of the net." FAO also claimed that "for most of the situation, purse seine is the most efficient gear for catching large and small pelagic species that is shoaling." In Southeast Asia, purse seines had been used since the nineteenth century, to catch pelagic fishes as alternative to trawl fishing targeting demersal fish stocks that had been declining. Earlier, the fisheries make use of various surrounding nets that had been modified into purse seines, and later, the use of commercial purse seines had been picked up by many countries in the region.

Discussed in the article is the development and status of purse seine fisheries in Southeast Asian countries that surround the South China Sea (SCS). Moreover, a way forward for long-term sustainable purse seine fisheries management in the South China Sea and Andaman Sea is also outlined based on the five-year project being carried out by the Marine Fishery Resources Development and Management Department (MFRDMD) of the Southeast Asian Fisheries Development Center (SEAFDEC). At the outset, it is crucial to take a look at the status of marine capture fisheries, especially purse seine fisheries in eight Southeast Asian countries that border the SCS area, namely: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Thailand, Philippines, and Viet Nam.

Brunei Darussalam

Located in the northwestern part of Borneo, Brunei Darussalam has a land area of 5,765 km² with 161 km long coastline fronting the South China Sea. Its total marine territorial area is about 41,188 km² covering the so-called Brunei Fisheries Limits with potential yield of about 21,300 metric tons (MT). Contributing more than 70% to the country's total fish production, capture fisheries had been identified as one of the most important industries for the diversification of its economy. The overall performance (in terms of production and values) in 2012 and 2013 of the country's major commercial



	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
2012	929.4	1057	1147	1296	1175	1233	1304	1205.	1122	1133	1159.	865.1
2013	971.9	1153	1288	1316	1348	1178	889.8	1279	1278	1197	1438	983.4
% Difference	4.58	9.11	12.32	1.53	14.73	-4.44	-31.7	6.08	13.93	5.68	24.04	13.67

Fig. 1. Production from marine capture fisheries of Brunei Darussalam in 2012-2013

Fig. 2. Various types of purse seine vessels used in Brunei Darussalam waters

fishing vessels, namely trawlers, longlines and purse seiners are shown in Fig. 1.

The total production of Brunei Darussalam from marine capture fisheries had increased from 13,626 MT in 2012 to 14,320 MT in 2013 using small-scale and commercial fishing vessels, with the number of vessels increasing from 28 to 30, respectively. However, the main contributor of about 80% to the country's total marine capture fisheries production is the small-scale fisheries.

Small pelagic fishes comprise one of the most important components of the fishery resources of Brunei Darussalam. Among the commercial vessels, the major fishing gears being used to catch small pelagic fishes include purse seine and ring net, while gill net and drift net are used by small-scale fishers. Purse seine fishing in Brunei Darussalam started in 1985 with seven (7) licensed vessels. The areas where purse seine fishing and where specific fishing gears as well as engine capacities could operate, are specified by zones. Fish purse seine and tuna purse seine are the two types of purse seines operating in Brunei Darussalam waters. Fish purse seine was introduced in 1985 with only one licensed vessel, but no proper data recording of catch was made in the past. Fish purse seine was improved in early 1990s with the use of luring lights in fishing operations. Tuna purse seine started only in 2013 with two licensed vessels. The Department of Fisheries of Brunei Darussalam started providing incentives to fishers in the early 2000s to encourage them to record the necessary information during fishing operations. As a result, relevant fisheries data had already been compiled starting in 2001.

Commercial purse seiners in Brunei Darussalam (Fig. 2) operate on daily basis due to the size limitation of fish holds onboard and the high demand for good quality of fish landed. Commercial purse seine fisheries make use of fish aggregating devices (FADs) and lights as fishing aids to catch small pelagic fishes. Reports indicated that most of the country's purse seine vessels are made of wood and constructed in foreign countries, *i.e.* Malaysia, Viet Nam and Taiwan.

Cambodia

Covering an area of 181,035 km² including land and water, Cambodia has a coastline of 435 km which stretches between its borders with Viet Nam in the south to Thailand in the west. Four provinces of the country are located along this coastline, namely: Koh Kong covering a coastal length of 237 km, Sihanoukville with 105 km coastline, Kampot with 67 km, and Kep with 26 km. As reported, 525 species of marine fishes, 20 species of marine crabs, 42 species of marine gastropods, 24 species of marine bivalves, and 11 species of marine mammals, are found in the country's oceanic waters. The Kingdom of Cambodia has its Exclusive Economic Zone (EEZ) that extends from the shoreline to 200 nautical miles and covers an area of 55,600 km².

Cambodia is endowed with inland and marine fishery resources that play very important role in the economy and food security of the country. The fisheries sector provides employment and economic benefits to a large number of people who are involved in fishing and its ancillary activities. Due to the physical characteristics of the country's EEZ,

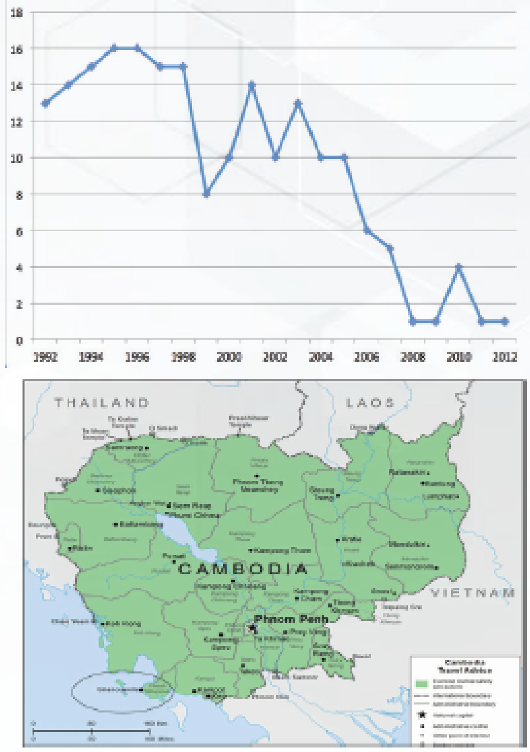


Fig. 3. Total number of purse seine vessels (*top*) recorded in Sihanoukville, Cambodia (*above*)

marine fisheries in Cambodia are mostly pelagic and their productivity contributes about 20% to the national fish production annually. Its marine fisheries could be classified by types of fishing gears, namely: small-scale, middle-scale and large-scale fishing gears operating mostly through foreign fishing ventures. Local vessels use variety of fishing gears including trawl nets, drag nets, purse seines, anchovy purse seines, gill nets, hooks and lines, and traps. In recent years, majority of coastal fishing vessels have been motorized, as a result, non-motorized vessels had reduced drastically from 3,312 in 1996 to 227 in 1999. Production of the country's marine capture fisheries had increased from 75,000 MT in 2009 to 110,000 MT in 2013 (SEAFDEC, 2015). However, it should be noted that most of the catch derived from Cambodian waters might not have been recorded in the country's national statistics considering that being harvested by foreign fishing vessels, the catch could have been shipped directly to the vessels' flag states, *e.g.* Thailand, Viet Nam.

Modern fishing technologies introduced to Cambodia sometime around the 1950s, comprise the bottom trawl and purse seine. Currently, purse seine, gill nets and long lines are the major fishing gears used by the country's coastal fishers since the early stage of fishing technology development. Generally, small-scale fishers operate from 1.0 to 45.0 km from the shoreline with water depths of 4.0 to 30.0 meters. The national fisheries statistics indicated that only one purse seine was registered in 2012 in Sihanoukville (**Fig. 3**). The number of purse seine vessels had decreased as a result of over-exploitation of targeted species due to increased use of pair trawls and light luring purse seines in the country's offshore waters. These gear types are commonly used at night, while most purse seine vessels use other fishing gear such as trawl or gill nets.

Fig. 4. Purse seine fisheries operating in Silhanoukville waters: regular fishing vessels (*top*) and long-tail vessels (*above*)

In the waters of Sihanoukville, purse seine vessels are mostly operated in the same inshore areas (**Fig. 4**). However, purse seine vessels from Kampot Province rarely operate in Kampot waters but mostly operate in Sihanoukville waters instead. Usually, one fishing operation trip of a purse seine takes about 2 to 5 days. Most purse seines operate about 5-6 trips per month.

Indonesia

Indonesia is one of the tropical countries with vast marine waters, accessing to a maritime area of 5.8 million km² and 3.1 million km² of EEZ. For fisheries management purposes, the Indonesian waters are divided into 11 fisheries management zones (**Fig. 5**) by virtue of Ministerial Decree No. PER.1/MEN/2009. Its marine fisheries mostly relate to the characteristics of the continental shelf. In general, there are three types of shelves in Indonesia's marine waters: the shallow waters (<200 m) of Sunda shelf (Java, Natuna Seas and Malacca Strait) in the western part, Sahul shelf (Arafura and Aru Seas) in the eastern part, and the deep-sea waters in between.

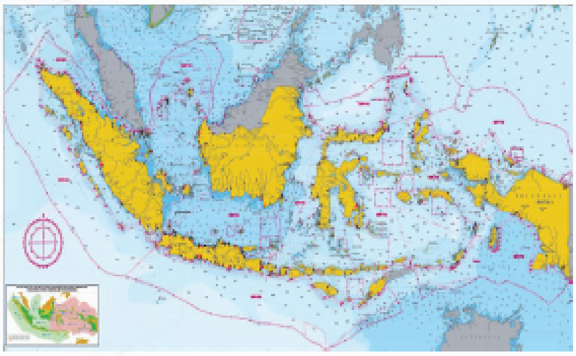


Fig. 5. Fisheries management zones of Indonesia

The characteristics of the shelves influence the fishing activities in Indonesia's waters and indicated by the use of different fishing gears. The country's capture fisheries statistics showed that its marine fish production in 2013 was about 5.7 million MT. Small pelagic species dominate the national annual landings with an estimated volume of 31% of the total fish production. In 2007, the total number of fishers at 2.2 million was mostly involved in small-scale fisheries. Purse seine fishery in the north coast of Java Sea is one of the most productive fisheries in Indonesia. Development of the country's purse seine fishery began in Central Java using large and medium purse seines (GT> 30 tons). From 1973 to

1983, pelagic fishing was only done in Java Sea but later this expanded from the west into the South China Sea (around Natuna Island, Tarempa, Pejantan) and in the shallow waters of western Makassar Strait (approximately in Lumu-Lumu, Samber Gelap, Lari-larian). However, expansion of the Javanese purse seine fishing grounds reached its maximum in 1995. Thus, most of the existing purse seiners previously operating in Java Sea changed their target species from small pelagic fishes to small tuna and tuna-like species, and among the various kinds of fishing gears, gill net and longline are used in fishing operations. The number of purse seine vessels operating in Java Sea of about 28,000 units, contributes about 2.6% to the total number of fishing vessels used in Indonesian waters.

Malaysia

The fishing areas of Malaysia are divided into several sub-regions, namely: the West Coast and East Coast of Peninsular Malaysia, and Sabah and Sarawak. Located on the West Coast of Peninsular Malaysia, Malacca Strait embraces the north Andaman Sea and the Indian Ocean, and bordered by the State of Perlis which is the country's main landing site for neritic tunas followed by Kedah, Penang, Perak and Selangor. The East Coast of Peninsular Malaysia faces the South China Sea and the country's EEZ in the SCS consists of continental shelf of 200 m deep, continental slopes and the deeper waters down to more than 2,000 m. This EEZ which extends 200 nm offshore is covered mostly by the continental shelf except the areas on the north of Sarawak and Sabah. For Sabah, the continental shelf areas only extend as narrow as 12 nm from the shoreline. The total EEZ area or continental shelf in the East Coast of Peninsular Malaysia is about 115,217 km^2 (**Fig. 6**). Vitally important to Malaysia, its fisheries sector contributes to the national economy in terms of income, foreign exchange and employment, as well as ensuring protein and food supply for the future generation. In 2012, the country's total marine landings increased by 7% from 1,373,105 MT in 2011 to 1,472,240 MT. Meanwhile, inshore fisheries contributed 64% and 60% in terms of quantity and value, respectively to the national food fish sector while deep-sea fisheries contributed only 19% and 16%, respectively. Pelagic fishes contributed about 38% (562,732 MT) of the country's total marine production and the rest was contributed by demersal fishes, mollusks, crustaceans, and others. Landings from purse seine vessels recorded an increase of 7% in the East Coast of Peninsular Malaysia from 110,565 MT in 2011 to 118,698 MT in 2012.

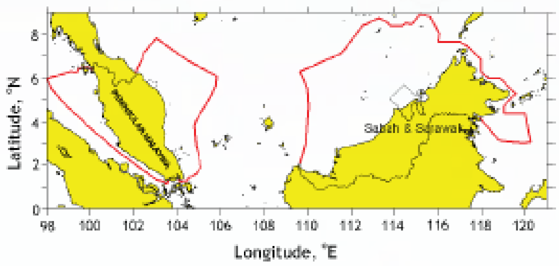


Fig. 6. EEZ boundaries of Malaysia

Four major fishing activities in Malaysia are defined according to the fishing techniques adopted, namely: fish trawl, shrimp trawl, fish purse-seine, and anchovy purse-seine fishery. Fish purse seine is the main fishing gear used in catching pelagic fishes in Peninsular Malaysia, Sabah and Sarawak. Purse seines are the second most efficient fishing gears that contribute to the country's total fish landings after trawlers. **Table 1** shows the number of purse seine vessels which had significantly reduced from 1,280 units in 2012 to 1,238 units in 2013. The country's purse seine vessels have been categorized based on their gross tonnage (GRT), *i.e.* 25.0-39.9 GRT (beyond 8 nm offshore), 40.0-70.0 GRT (15 nm offshore), and above 70.0 GRT (above 30 nm offshore). Two types of methods are adopted during purse seine operations, *i.e.* using fish agregating devices (FADs) and without FADs or free searching (free school). FADs are normally set in areas where the water depths exceed 40 m. Luring materials for FADs are made from coconut leaves anchored using several concrete sacks.

Table 1. Number of purse seine vessels in Malaysia (2012-2013)

Area	2012	2013
East Coast of Peninsular Malaysia	495	487
West Coast of Peninsular Malaysia	441	443
Sabah	301	274
Sarawak	43	34
Total	**1,280**	**1,238**

Myanmar

The fisheries sector in Myanmar is one of the major components that significantly contribute to the country's economy. Fish provides a major source of animal protein in the diet of Myanmar people who largely consume rice and fish in their daily life with annual fish consumption of about 51.0 kg per capita in 2012. As promulgated, the Myanmar Special Economic Zone for Marine Fishing has been established from the shoreline to 200 nautical miles offshore. The territorial sea of Myanmar extends 12 nautical miles from the shoreline. The total area of its fishing ground including its EEZ is about 486,000 km^2. Myanmar's coastline is divided into three coastal regions, namely: Rakhine Coastal Region, the Ayeyarwady and Gulf of Mottama (the Delta Zone), and Tanintharyi Coastal Region (**Fig. 7**). The country's marine capture fisheries sector is categorized into two major types: coastal or inshore fisheries, and offshore or deep-sea fisheries.

Purse seine is a major fishing gear used to exploit the pelagic fish resources of the waters of Myanmar. The two main types

Fig. 7. Map of Myanmar showing its coastal regions

of purse seines employed in Myanmar waters are fish purse seine to catch pelagic species like hilsa, and anchovy purse seine (two-vessel seine) to catch anchovies and operate in coastal waters, especially in the northern area of Rakhine State. Most fish purse seine vessels are about 50 to 100 GRT, and are operated in a traditional manner without the use of FADs. Most purse seiners have a skipper with expertise in searching fish schools using sonar. Hilsa is the major species caught by purse seine from October to May. Anchovy purse seine vessels are normally operated by two vessels in shallow inshore areas and mainly target the anchovies *Stolephorus* spp. **Table 2** shows the landings of anchovy purse seine fisheries in Myanmar.

Light luring is also used in purse seines to attract free-schooling fish at night, and mainly harvesting the small mackerels and sardines, particularly along the northern coast of Rakhine Coastal Region. **Table 3** shows the number of purse seine vessels operating in the offshore waters of Myanmar.

Philippines

In 2011, the Philippines ranked 11th among the top fish producing countries in the world with total production of 4.97 million MT comprising fishes, crustaceans, mollusks, and aquatic plants, contributing about 3.0% to the total world production of 178.2 million MT. In 2012, the Philippines' total fisheries production of 4.87 million MT was about 2.2% lower compared with the previous year's production. Three major fishing sectors contributed to the country's annual fisheries production, namely: the commercial sector with increased production of 0.9% (1.04 million MT) compared to previous year's production of 1.03 million MT, the aquaculture sector which produced 2.5% lower than the previous year's level, and the municipal sector with production that reduced by 3.9% during the same period. The country's fishing industry employs a total of 1,614,368 fishing operators and fishers nationwide of which the municipal fisheries sector accounted for more than one million (1,371,676), while the commercial and aquaculture sectors added some 16,497 and 226,195 operators and fishers, and fish farmers, respectively.

The growth of Philippine fisheries production showed a decreasing trend from 5.1 million MT in 2009 to 4.7 million MT in 2013 (SEAFDEC, 2015). In terms of value, the country's fisheries production in 2013 was valued at US$5.4 billion (about 245 billion Philippine Pesos (PHP); US$1.00=PHP45.00) had increased compared to US$4.3 billion (or PHP 194 billion) in 2009. The major fishery

Table 2. Landings of anchovy purse seine fisheries (2005-2014) of Myanmar

Year	Number of vessels	Catch (MT)				Total (MT)
		Anchovy	Sardines	*Rastrelliger* spp.	Others	
2005-2006	368	4,505	1,457	100	1,030	7,092
2006-2007	377	1,978	1,842	30	3,857	7,707
2007-2008	375	5,024	1,028	58	3,022	9,132
2008-2009	374	6,188	2,215	44	2,170	10,617
2009-2010	375	6,973	3,216	20	3,998	14,215
2010-2011	377	7,873	3,926	32	4,301	16,132
2011-2012	366	5,031	1,816	53	5,812	12,712
2012-2013	362	4,205	2,510	79	4,098	10,892
2013-2014	360	2,156	4,773	124	6,899	13,952

Table 3. Number of purse seine fishing vessels of Myanmar engaged in offshore fisheries

No	Type of Gear	Year					
		2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
1	Fish Purse Seine	152	158	161	168	273	278
2	Anchovy Purse Seine	375	374	375	377	366	362

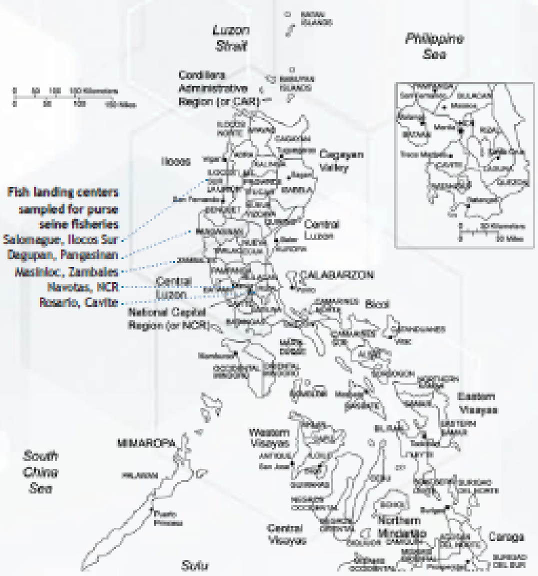


Fig. 8. Map of the Philippines showing the fish landing centers used for sampling purse seine fisheries

resources exploited in the Philippines are the small pelagic species, tunas and other large pelagic fishes, demersal fishes, and invertebrates. The country's small pelagic fisheries have been contributing significantly to its total fisheries production, and are also considered the major source of inexpensive animal protein for lower-income groups of people in the Philippines. In 2003, the Philippines established four sampling sites in landing centers of purse seines and ringnets as the target fishery in the South China Sea (**Fig. 8**). These are in Rosario (Cavite), Navotas (National Capital Region or NCR), Masinloc (Zambales), and Salomague (Ilocos Sur). Sampling in Masinloc and Salomague was however discontinued effective August 2003 as the purse seine landings have indicated deficiency of the five target species. Subsequently, Dagupan fish landing was added to cover the major landings of roundscads as well as mackerels from the Danish seine fishery in Lingayen Gulf. In 2013, there were 73,464 fishing gears operated by 68,315 small-scale fisheries, fisherfolk associations and cooperatives. **Table 4** shows the distribution of the country's fishing gears.

Table 4. Distribution of fishing gears in the Philippines

Fishing gears	Units
Gillnets	16,404
Hook and lines	9,449
Lambaklad	7
Fishpots	3,659
Payao	1,828
Squid jigger	1,005
Motorized bancas	1,044
Fish traps	488
Multiple handlines	2,842
Tuna handlines	4,122
Marine engines	4,019
Crab lift nets	2,000
Crab pots	24,297
Non-motorized bancas	1,674
Others	626

Thailand

Several years before 2007, Thailand was among the top ten countries in terms of marine capture fisheries production with annual landings of more than 2.5 million MT, but this figure had slightly decreased since then. Apart from the changing of catch report format where catch from waters outside the country's EEZ had been excluded from the national marine capture production statistics, the decreasing fishery resources became a major issue. The EEZ of Thailand covers 420,280 km^2: 304,000 km^2 in the Gulf of Thailand (GoT) and 116,280 km^2 in the Andaman Sea Coast of Thailand (ASCoT). There are 23 coastal provinces surrounding these two main fishing areas, 17 of which are in the GoT with total coastline of approximately 2,700 km, and 6 provinces in ASCoT covering 865 km of coastline. The fishing grounds are divided into seven (7) zones, namely: zone 1 to zone 5 in the GoT, and zone 6 to zone 7 in the ASCoT (**Fig. 9**).

Catches from the Gulf of Thailand and Andaman Sea together make up the country's total production from marine capture fisheries. Currently however, such production showed decreasing trend from both fishing grounds. In 2011, the total pelagic catch was 564,956 MT of which GoT contributed 70% and ASCoT shared the other 30% (**Fig. 10**, **Table 5**).

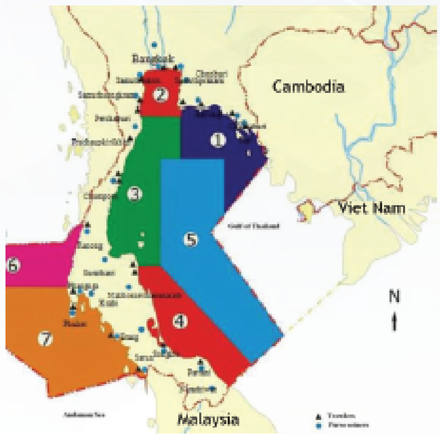


Fig. 9. Fishing zones in Thailand waters

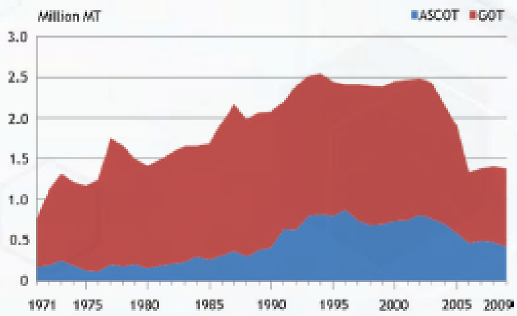


Fig. 10. Total pelagic catch from GoT and ASCoT

Table 5. Catch of marine capture fisheries (2011)

Category	Catches (MT)	Percentage (%)
Pelagic fish	564,956	41.2
Demersal fish	144,881	10.6
Cephalopod	138,344	10.0
Crustacean	76,714	5.6
Other food fish	108,297	7.9
Other miscellaneous fishes	51,006	3.7
Trash fish	287,430	21.0
TOTAL	1,371,628	100.0

In 2011, the Marine Fisheries Research and Development Bureau (MFRDB) of the Department of Fisheries of Thailand conducted a survey of the country's fishing grounds, and the corresponding database has been revised regularly in order to publish up-to-date data. Based on the current database, there are 56,979 fishing vessels, 60% of which are small-scale fishing vessels. Purse seines are the major fishing gear used for catching pelagic fishes in coastal areas. The total number of purse seine vessels as of 2011 was 1,641 comprising small vessels (10-25 m) and large vessels (>25 m). In 2011, a total of 1,224 vessels were operating in GoT and 417 vessels in ASCoT (**Table 6**).

Thailand's purse seine fisheries could be categorized into six types (**Table 7**), namely: Thai purse seines (TPS), coconut leaves luring purse seines (LPS), light luring purse seines (LLPS), day-anchovy purse seines, night-anchovy purse seines, sardines purse seines, silverside purse seines, and acetes purse seines. TPS, LPS and LLPS are the major types of purse seines and commonly found in the GoT and ASCoT. TPS, LPS and LLPS mostly employ 1.0 inch mesh size nets to harvest common pelagic fishes. However, some TPS use 4.0-inch mesh size nets to target neritic tunas.

Viet Nam

Viet Nam has a coastline of 3,260 km and the EEZ that covers more than one million km². Based on its natural characteristics, the waters of Viet Nam could be divided into five regions, namely: Gulf of Tonkin, Central waters, Southeast waters, Southwest waters, and Central of Bien Dong (**Fig. 11**). Its fisheries sector plays an important role in the country's social and economic development contributing 3% to the GDP of Viet Nam, and fish provides about 40% of the animal protein consumption of its people.

Table 6. Number of purse seine vessels by size operating in the waters of Thailand (2011)

Type of Gear	Number of vessels by length				
	Total	10-14 m	14-18 m	18-25 m	>25 m
ASCoT	417	47	78	271	21
GoT	1,224	231	171	759	63
Total	1,641	278	249	1,030	84

Table 7. Total number of purse seine by types in Thailand

Type of purse seines	Total number	Number of vessel by Areas	
		GoT	ASCoT
Thai purse seine, TPS	584	373	211
Luring purse seines	534	422	112
Coconut leaves luring purse seine, LPS	344	315	29
Light luring purse seine, LLPS	190	107	83
-lamp	6	5	1
-electric bulb	184	102	82
Anchovy purse seines, APS	484	396	88
Sardines purse seine	19	18	1
Silverside purse seine	14	14	-
Acetes purse seine	6	1	5
Total	1,641	1,224	417

Fig. 11. Map of Viet Nam showing Gulf of Tonkin and other coastal regions

Starting with traditional fishing with small artisanal vessels operating mainly in near-shore areas, marine capture fisheries of Viet Nam has developed rapidly, while fishing efficiency and the quality of marine catches have also improved considerably. Policies established by the Government for offshore fishing and resources stability in coastal areas encouraged fishing operators to invest in building new vessels with high engine capacity to explore fishing operations in open seas. Thus, the number of fishing vessels had increased from 79,996 to 128,363 in 2002 to 2011, respectively but started to decrease in 2011 (**Table 8**).

The annual total catch from marine capture fisheries in Viet Nam had increased during the past decade. From a total catch of about 1.99 million MT in 2005, this increased to 2.59 million MT in 2007, and further increased to 3.12 million MT in 2009 (**Table 9**). During 2007-2009, the catch from purse seine fisheries was about 16-22% of the country's total annual catches.

Purse seine is one of the most important types of fishing gear for marine capture fisheries in Viet Nam. It is also one of the potential fishing gears for offshore fishing operations. Marine production from purse seine fishery is about 20.6% of the country's total marine catch. The main species landed by local and commercial purse seine operations are small pelagic fishes comprising sardines, mackerels, roundscads, skipjack, and anchovy, among others. The country's purse seine fishery makes use of two types of fishing methods, either using luring techniques or searching method. Based on the structure and size of the nets, the country's purse seine could be categorized into searching purse seine for catching small pelagic fishes or tuna.

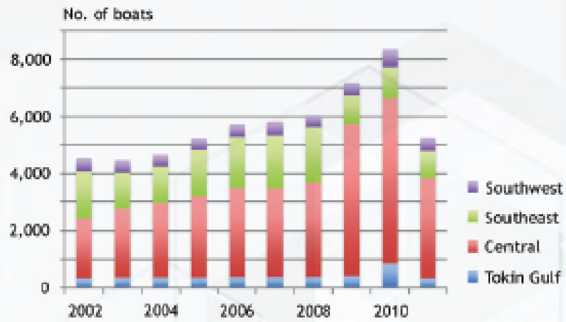


Fig. 12. Number of purse seine vessels in Viet Nam (by fishing areas)

Fig. 12 shows the number of purse seine fishing vessels in Viet Nam from 2002 to 2011, which had its lowest in 2003 (4,471 units) and highest in 2010 (8,348 units). Contributing about 4.1-6.9% of the country's total fishing vessels, purse seine fisheries are well developed, especially in the Central and the Southeast waters. Purse seine fisheries in the Gulf of Tonkin and the Southwest waters have been quite stable throughout the last decade. In the Central waters, the number of purse seine vessels were observed to increase from 2002 to 2010 while those in the Southeast waters, the number has been fluctuating with the highest number recorded in 2008.

Table 8. Total number of fishing vessels in Viet Nam

Year	Total number of fishing vessels	Year	Total number of fishing vessels
2002	79,996	2008	99,589
2003	75,053	2009	120,326
2004	71,905	2010	128,021
2005	80,968	2011	128,363
2006	85,705	2012	123,125
2007	84,224	2013	117,016

Table 9. Annual catches of the marine capture fisheries in Viet Nam by fishing areas

Year	Annual catches (MT)				
	Gulf of Tonkin	Central waters	Southeast waters	Southwest waters	Total
2007	386,838	724,097	937,903	544,829	2,593,667
2008	416,507	1,100,997	918,066	436,860	2,872,430
2009	553,377	1,103,883	910,130	550,164	3,117,554

Conclusion and Way Forward

Small pelagic fishes such as the Indian mackerels, scads and sardinellas are commercially-important commodities in the Southeast Asian region. In 2010 for example, more than 800,000 MT of mackerels (*Rastrelliger* spp.), 700,000 MT of scads (*Decapterus* spp.) and 800,000 MT of sardinellas (*Sardinella* spp.) were captured in the waters of Southeast Asia. Capture fisheries targeting these fishes are of fundamental importance to the Southeast Asian region in terms of employment and livelihood of fishers. Purse seine is one of the major fishing gears used to catch small pelagic fishes. However, management of purse seine fisheries has not yet been developed because information on the stocks is still inadequate.

Expanding the catches of small and large pelagic species by purse seine fisheries could still be carried out as long as national governments enforce control and management of their respective fishing fleets. It is therefore necessary to establish a management plan, although such effort would require developing the best way to assess the size and state of the stocks for accurate total allowable catch (TAC) allocation and to find the most applicable TAC system for purse seine fisheries in the Southeast Asian region. Considering the likelihood that such stocks are shared by the bordering countries with the same ecosystems, *i.e.* of the Andaman Sea and the South China Sea, effective management of the shared stocks would require appropriate measures to be taken for the whole coverage areas which are beyond the national waters.

In an effort to attain the aforementioned goal, SEAFDEC/MFRDMD embarked on a five-year project in 2013 on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region. With the cooperative involvement of the eight aforementioned countries, the project compiles and compares the region's annual and/or monthly CPUE where data are available for the last three decades.

The project would analyze and benchmark such information with the purse seine fisheries management systems/measures including TAC systems and other management measures that have been successfully adopted in the world's fisheries. Moreover, the project would also carry out a genetic study of commercially-important pelagic species, and develop management strategies for sustainable purse seine fisheries in the Southeast Asian region.

Considering that catch-effort statistics are available in Malaysia and Thailand, and CPUE is an indirect measurement of abundance of a target species in fisheries, MFRDMD has attempted during the last three decades, to examine the trend of resource level using the CPUE. At the same time, MFRDMD is also reviewing the purse seine fishery management systems including TAC systems and other management measures in the world to examine which management system/measure is applicable for the management of small pelagic fisheries in the Southeast Asian region.

As for the genetic study, this is aimed at verifying the extent of connectivity of commercially-important pelagic species targeted by purse seine fisheries, and providing the scientific background for concerted management actions of the SEAFDEC Member Countries for shared stocks of small pelagic species. The results would also be used for the development of appropriate management of purse seine fisheries in the Southeast Asian region. It is expected that by the end of the MFRDMD Project, a review of the available information including stock levels would be at hand to be used by the Member Countries in evaluating the management strategies for sustainable purse seine fisheries for the Southeast Asian region.

It should be noted that this MFRDMD Project corresponds to ASEAN-SEAFDEC Resolution #10 which encourages the ASEAN and SEAFDEC 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 Plan of Action #22 on the need 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.*"

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About the Authors

Raja Bidin Raja Hassan is the Head of Marine Biology and Stock Assessment Section, and Special Departmental Coordinator for MFRDMD based at the SEAFDEC Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD) in Taman Perikanan Chendering, Kuala Terengganu, Malaysia.

Mr. Abdul Razak Latun is the Head of Fishery Oceanography and Resource Enhancement Section of SEAFDEC/MFRDMD also in Taman Perikanan Chendering, Kuala Terengganu, Malaysia.

Appendix III. List of Participants Attending Meetings and Workshops

THE 1st REGIONAL CORE EXPERT MEETING ON COMPARATIVE STUDY ON PURSE SEINE FISHERY IN THE SOUTHEAST ASIAN REGION

26 - 28 August 2014, Furama Hotel, Kuala Lumpur

BRUNEI DARUSSALAM

1	**Mrs. Hajah Noorizan Haji Abd Karim** Head, Capture Fisheries Industry Division	Fisheries Department Ministry of Industry and Primary Resources Marine Fisheries Complex Simpang 287-53 Jalan Peranginan Pantai Serasa Kampong Serasa Brunei Darussalam Muara BT1728 Brunei Darussalam Tel : 673-2770066/7/8/9 Ext: 125 Fax : 673-2770065 E-mail: noorizan_karim@fisheries.gov.bn noor6263@gmail.com
2	**Ms. Nur Aqilah Timbang** Assistant Fisheries Officer	Fisheries Department Ministry of Industry and Primary Resources Marine Fisheries Complex Simpang 287-53 Jalan Peranginan Pantai Serasa Kampong Serasa Brunei Darussalam Muara BT1728 Brunei Darussalam Tel : 673-2770066/7/8/9 Ext : 152 Fax : 673-2770065 E-mail: aqilah.timbang@gmail.com

CAMBODIA

3	**Dr. Chea Tharith** Deputy Director of the Marine Fisheries Research and Development Institute (MaFReDI) of Fisheries Administration	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: +855 11467648 E-mail: cheatharith88@gmail.com
4	**Mr. Chhuon Kimchhea** Deputy Director of Department of Fisheries Affairs	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: +85517272896 E-mail: kimchhea@yahoo.com

	INDONESIA	
5	**Mr. Duto Nugroho** Fisheries Biologist	Research Centre for Fisheries Management and Conservation, Agency for Marine Fisheries Research and Development, Balitbang KP II Building, 2nd Floor Jl. Pasir Putih II, Ancol Timur Jakarta 14430 Tel. : 62-21-64700928 ext: 1132 Fax : 62-21- 64700929 E-mail: dutonugroho@gmail.com
5	**Mr. Suwarso** Fisheries Biologist	Research Institute for Marine Fisheries, Jakarta, Indonesia Tel : +62-21-660 2044/ +62-852-1698 0875 Fax : +62-21-64700929 E-mail: swarsorimf@gmail.com
	MALAYSIA	
6	**Mr. Jamil Musel** Research Officer	Fisheries Research Institute Sarawak Jalan Perbadanan, Bintawa Peti Surat 2243 93744 Kuching Sarawak, Malaysia Tel: +082 33 4144 / +6013 8097132 Fax: +082 33 1281 E-mail: jamilmusel@dof.gov.my deemsebakau@gmail.com
7	**Mr. Mohd Zamani Nayan** Research Officer	Ibu Pejabat Perikanan, Jabatan Perikanan Sabah, Aras 4, Blok B, Wisma Pertanian Sabah, Jalan Tasik Luyang (Off Jln. Maktab Gaya), 88624 Kota Kinabalu, Sabah, Malaysia Tel: +088 23 5966 / +6013 549 4110 Fax : +088 24 0511 E-mail: mzamani.nayan@gmail.com mohdzamani.nayan@sabah.gov.my
8	**Mr. Sallehudin Jamon** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: sallehudin_jamon@dof.gov.my dinjamon@rocketmail.com

9	**Mr. Abdul Wahab Abdullah** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: wahab@dof.gov.my wahab@ymail.com
	MYANMAR	
10	**Mr. Than Chaung** Assistant Director	District Fisheries Department, Thandure District, 8516909 Tel : 0095-98516909
11	**Mr. Soe Myint Thein** Fishery Officer	Department of Fisheries, Sin-Min Road, Ahlone Township, Yangon, Myanmar Tel : +059-01-222962, 95-01-22824 0095-9428123629 Fax : 95-67-418536 E-mail : soemyintthein.dof@gmail.com
	PHILIPPINES	
12	**Mr. Prudencio B. Belga** Aquaculturist II	BFAR RFO 7, Arelldho Bwd, Cebu City, Bureau of Fisheries and Aquatic Resources, PCA Compound, Elliptical Road, Quezon City, Philippines. Tel : (02) 9299597/9295847 Fax : (02) 9298074 (032) 2562776/ 2562772 E-mail : pbdgjr@yahoo.com.ph
	THAILAND	
13	**Mr. Pirochana Saikliang** Senior Expert on Marine Fisheries	Marine Fisheries Research & Development Bureau, Department Of Fisheries, Thailand Tel : 66 25612962 Fax : 66 25612962 E-mail : pirochas@hotmail.com
14	**Ms. Sampan Panjarat** Senior Fisheries Biologist	Andaman Sea Fisheries Research & Development Center (Phuket), 44 Sakdidej Rd, Vichit Sub-District Maung Phuket, 83000 Thailand. Tel : +66 46 391138 Fax : +66 46 391139 E-mail : spanjarat@yahoo.com

VIET NAM		
15	**Mr. Nguyen Viet Nghia** Head, Dept. of Marine Fisheries Resources	Research Institute for Marine Fisheries (RIMF), 224 Le Lai Street Hai Phong City, Viet Nam Tel: +84-316-579528 Cellular Phone: (00)84-982-728365 Facsimile : +84-313-836812 E-mail: nvnghia@rimf.org.vn
16	**Mr. Pham Hung**	Department of Capture Fisheries and Resources Protection Fisheries Administration, 10 Nguyen Cong Hoan, Ba Dinh, Hanoi, Vietnam. Tel : +84-37711579 Fax : +84-4-37345120/37245374 E-mail : hungfam83@gmail.com
RESOURCE PERSONS		
17	**Prof. Dr. Matsuishi Takashi Fritz** Resource Person	Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5505 Fax: +81 138 40 5505 Email: http://bit.ly/2fritz
18	**Ms. Mari Yoda** Resource Person	Seikai National Fisheries Research Institute, Fisheries Research Agency, Taira-machi 1551-8, Nagasaki-shi, Nagasaki 851-2213, JAPAN Tel : +81-95-860-1600 Fax : +81-95-850-7767 E-mail : myoda@affrc.go.jp
19	**Dr. Alias Man** Senior Research Officer	Fisheries Research Institute Batu Maung, Penang, Malaysia. Tel : 05-6912093 Fax : 05-6914742 E-mail : alias01@seafdec.org.my
20	**Mr. Ibrahim Johari** Senior Research Officer	Fisheries Research Institute Batu Maung, Penang, Malaysia. Tel : 04-6263925 E-mail : ibrahimj@seafdec.org.my ibrahimjohari@yahoo.com

SEAFDEC Secretariat		
21	**Dr. Somboon Siriraksophon** Policy and Progam Coordinator	SEAFDEC Secretariat 50 Department of Fisheries Ladyao, Chatuchak Bangkok 10900, Thailand Tel : +66 2940 6333 (Direct Line) +66 2940 6326 Ext. 110 Fax : +66 2940 1602 Cell Phone: +66 819003361 E-mail : somboon@seafdec.org ssiriraksophon63@gmail.com
22	**Mr. Tsuyoshi Iwata**	SEAFDEC Secretariat, 50 Department of Fisheries, Ladyao, Chatuchak, Bangkok 10900, Thailand Tel :+66 2940 6326 Fax :+66 2940 6336 E-mail : iwata@seafdec.org
SEAFDEC/TD		
23	**Dr. Worawit Wanchana** Head of Capture Fishery Technology Division	SEAFDEC Training Department, P.O. Box 97, Phrasamutchedi, Samut Prakan, 10290, Thailand Tel : (66-2) 4256140 Fax : 88 6 4256110 E-mail: worawit@seafdec.org
24	**Ms. Siriporn Pangsorn** Fishing Ground Information Scientist	SEAFDEC Training Department, P.O. Box 97, Phrasamutchedi, Samut Prakan 10290, Thailand Tel : (66-2) 4256140 ext 144 Fax : (66-2) 4256100-1 E-mail : psiriporn@seafdec.org
SEAFDEC/MFRDFMD		
25	**Mr. Mahyam Mohd. Isa** Chief of SEAFDEC/MFRDMD	SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) Taman Perikanan Chendering 21080 Kuala Terengganu, Terengganu, Malaysia Tel: +609 6175940, 6177867 Fax: +609 6175136 E-mail: mahyam@seafdec.org.my
26	**Dr. Masaya Katoh** Deputy Chief of SEAFDEC/MFRDMD	E-mail: katoh@seafdec.org.my

27	**Mr. Raja Bidin bin Raja Hassan** Special Departmental Coordinator (Project Coordinator)	E-mail: rbidin@seafdec.org.my
28	**Mr. Abdul Razak Latun** Head of Oceonography and Resource Enhancement Section	E-mail: abdulrazaklatun@seafdec.org.my
29	**Ms. Wahidah Mohd Arshaad** Senior Research Officer	E-mail: wahidah@seafdec.org.my
30	**Ms. Mazalina Ali** Senior Research Officer	E-mail: mazalina@seafdec.org.my
31	**Mr. Mohammad Faisal Md. Saleh** Senior Research Officer	E-mail: mfaisal@seafdec.org.my
33	**Ms. Noorul Azliana Jamaludin** Research Officer	E-mail: noorul@seafdec.org.my
34	**Mr. Tamimi Ali Ahmad** Research Officer	E-mail: tamimi@seafdec.org.my
35	**Mr. Nadzri Seman** Secretariat of the Meeting	E-mail: nadzri@seafdec.org.my
36	**Mr. Adam Luke Pugas** Secretariat of the Meeting	E-mail: adamlp@seafdec.org.my
37	**Mr. Mohd Ridzuwan Rahim** Secretariat of the Meeting	E-mail: ridzuwan@seafdec.org.my
38	**Ms. Sharifah Nurulasma Sayed Mohd Yatim** Secretariat of the Meeting	Email: nurulasma@seafdec.org.my

THE 2nd REGIONAL CORE EXPERT MEETING ON COMPARATIVE STUDIES FOR MANAGEMENT OF PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

09 – 11 August 2016 , Furama Hotel, Kuala Lumpur, Malaysia

	CAMBODIA	
1	**Dr. Chea Tharith** Deputy Director of the Marine Fisheries Research and Development Institute (MaFReDI) of Fisheries Administration	Fishery Administration, P.O.BOX: 582 # 186, Norodom Blvd, Phnom Penh Cambodia Tel: 855 12 467 648 E-mail: cheatharith88@gmail.com
	INDONESIA	
2	**Mr. Duto Nugroho** Fisheries Officer	Center for Fisheries Research & Development 2nd Building of AMFRD Jalan Pasir Putih II, Ancol Timur Jakarta Indonesia Tel: +62 21 647 00928 Fax: +62 21 647 00929 E-mail: dutonugroho@gmail.com
	LAO PDR	
3	**Mr. Phouthong Singhakham**	Nam Ngum Reservoir Fisheries Center, Division of Agriculture and Forestry Vientiane Province P.O. Box 6644, Vientiane 01000 Lao PDR Tel: 856 23 431 024 E-mail: SINGHAKHAM59@hotmail.com
	MALAYSIA	
4	**Mr. Jamil Musel** Research Officer	Fisheries Research Institute Sarawak Jalan Perbadanan, Bintawa Peti Surat 2243 93744 Kuching Sarawak, Malaysia Tel: +082 33 4144 Fax: +082 33 1281 E-mail: sebakau@yahoo.com.my deemsebakau@gmail.com
5	**Mr. Mohd Zamani Nayan** Research Officer	Pusat Penyelidikan Perikanan Likas 89400 Likas Sabah, Malaysia Tel: +088 42 8416 E-mail: MohdZamani.Nayan@sabah.gov.my
6	**Mr. Sallehudin Jamon**	Bahagian Penyelidikan Perikanan Tangkapan

	Research Officer	Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 2093 Fax: +605 691 4742 E-mail: sallehudin_jamon@dof.gov.my
7	**Mr. Abdul Wahab Abdullah** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 2093 Fax: +605 691 4742 E-mail: wahab@ymail.com
		PHILIPPINES	
8	**Mr. Napoleon Salvador J. Lamarca** Aquaculturist II	PCA Building ANNEY, DILIMAN, Quezon City, Philippines. Tel: +632 929 4296 Fax: +632 929 4296 E-mail: nsjlamarca@yahoo.com
9	**Mr. Francisco Torres, Jr.** Aquaculturist I	Corporate 101 Bldg., 101 Mother Ignacia St., Brgy. South Triangle, Quezon City, Philippines. National Fisheries Research and Development Institute (NFRDI) Tel: +632 376 1178 Fax: +632 372 5063 / 376 1178 E-mail: francisco_torresjr@yahoo.com
		THAILAND	
10	**Ms. Sampan Panjarat** Fishery Biologist, Senior Professional Level	Andaman Sea Fisheries Research and Development Center 77 Sakdidej Rd., Vichit Sub-District Muang District, Phuket 83000 Thailand Tel: +66 7639 1138 / 7639 1140 Fax: +66 7639 1139 E-mail: spanjarat@yahoo.com
11	**Mr. Nuntachai Boonjorn** Fishery Biologist, Professional Level	Chumphon Marine Fisheries Research and Development Center (DOF) 408 Moo 8, Paknam, Muang, Chumphon 86120, Thailand Tel: +668 1916 2971 / +667 7522 006 Email: nuntachai_b@yahoo.com

VIETNAM		
12	**Ms. Nguyen Tien Thang**	Directorate of Fisheries No 10 Nguyen Cong Haan, Ba Dinh District Hanoi, Vietnam Tel: 084 09 8307 8117 E-mail: thangcomeon@gmail.com
13	**Mr. Phan Dang Liem**	Research Institute for Marine Fisheries (RIMF) 224 Le Lai Street Hai Phong City Viet Nam Tel: 084 09 8376 7469 Fax: 084 34 3836 612 E-mail: pdliemrimf@gmail.com
RESOURCE PERSON		
14	**Dr. Matsuishi Takashi Fritz**	3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5505 http://bit.ly/2fritz
15	**Mohd Noor Nordin**	Marine Resource Management Division Department of Fisheries Level1, Block 4G2, Wisma Tani, 62628 Putrajaya Tel: +603 8870 4401 / 012 6784028 Fax: +603 8889 1233 E-mail: mnn@dof.gov.my
16	**Prof. Emeritus Dr. Mohd Azmi Ambak** Director of Tropical Aquaculture Institute	Tropical Aquaculture Institute University Malaysia Terengganu (UMT) 21030 Kuala Terengganu Terengganu, Malaysia Tel: +609 668 3501 Fax: +609 668 3390 E-mail: ambak@umt.edu.my
OBSERVER		
17	**Wu Dengke**	3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5585 E-mail: wu.dengke@fish.hokaido.ac.jp

SEAFDEC Secretariat		
18	**Dr. Somboon Siriraksophon** Policy and Program Coordinator	SEAFDEC Secretariat 50 Department of Fisheries Ladyao, Chatuchale Bangkok 10900, Thailand Tel: +66 29406333 Fax: +66 29401602 E-mail: somboon@seafdec.org
SEAFDEC/TD		
19	**Sutee Rajruchithong**	SEAFDEC Training Department (TD) P.O. Box 97, Phasamutchedi Samut Prakan 10290, Thailand Tel : +662 4256 170 Fax : +662 4256 110 E-mail: sutee@seafdec.org
SEAFDEC/MFRDMD		
20	**Ahmad Adnan Nuruddin** Chief of SEAFDEC/MFRDMD	SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) Taman Perikanan Chendering 21080 Kuala Terengganu, Terengganu, Malaysia Tel: +609 6175940, 6177867 Fax: +609 6175136 E-mail: adnan@seafdec.org.my
21	**Dr. Osamu Abe** Deputy Chief of SEAFDEC/MFRDMD	E-mail: abe@seafdec.org.my
22	**Raja Bidin Raja Hassan** Special Departmental Coordinator for MFRDMD Biology and Resource Assessment Section	E-mail: rbidin@seafdec.org.my
23	**Wahidah Mohd Arshaad** Head of Biology and Genetics Unit	E-mail: wahidah@seafdec.org.my
24	**Mohammad Faisal Md. Saleh** Head of Resource Assessment Unit	E-mail: mfaisal@seafdec.org.my
25	**Abdul Aziz Yusof** Senior Assistant Research Officer Information Management Unit	E-mail**:** abdulaziz@seafdec.org.my

26	**Kamariah Ismail** Senior Assistant Research Officer Resource Assessment Unit	E-mail: kamariah@seafdec.org.my
27	**Adam Luke Pugas** Assistant Research Officer Biology and Genetics Unit	E-mail: adamlp@seafdec.org.my
28	**Mohd Ridzuwan Rahim** Assistant Accountant Financial Unit	E-mail: ridzuwan@seafdec.org.my

THE 3RD CORE EXPERT MEETING ON COMPARATIVE STUDIES FOR PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

12 – 14 September 2017, Furama Hotel, Kuala Lumpur, Malaysia

	CAMBODIA	
1	**Dr. Chea Tharith** Deputy Director of the Marine Fisheries Research and Development Institute (MaFReDI) of Fisheries Administration	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: 855 12 467 648 E-mail: cheatharith88@gmail.com
2	**Mr. Tum Pothea** Officer of Kampong Som Fishery Administration (in charge of data collection)	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: 855 70 478 203 E-mail: tumpothea@gmail.com
	INDONESIA	
3	**Mr. Suwarso**	Research Institute for Marine Fisheries, Kamp. Raiser Ikan Hias, Jl. Raya Bogor, KM. 49, Nanggewer Mekar, Ciburiong Bogor Tel: +62 852 1698 0875 E-mail: swarsorimf@gmail.com
4	**Mr. Imron Rosyidi** Director General of Capture Fisheries, MMAF	Ministry of Marine Affairs and Fisheries Jl. Medan MerdekaTimur No. 16, Mina Bahari Building 2 (9th Floor), Jakarta 10110, Indonesia Tel: +62 858 1154 6766 Fax: +6221 352 0726 E-mail: r_impong@yahoo.com
5	**Mr. Purwan Sugiyanto**	Ministry of Marine Affairs and Fisheries Direktorat Fishing Vessel and Fishing Gear, Jl. Medan MerdekaTimur No. 16, Mina Bahari Building 2 (9th Floor), Jakarta 10110, Indonesia Tel: 0812 8713 4562 Fax: +6221 352 0726 E-mail: purwan_sugiyanto@gmail.com

MALAYSIA		
6	**Mr. Jamil Musel** Research Officer	Fisheries Research Institute Sarawak Jalan Perbadanan, Bintawa Peti Surat 2243 93744 Kuching Sarawak, Malaysia Tel: +082 33 4144 / +6013 8097132 Fax: +082 33 1281 E-mail: jamilmusel@dof.gov.my deemsebakau@gmail.com
7	**Mr. Mohd Zamani Nayan** Research Officer	Ibu Pejabat Perikanan, Jabatan Perikanan Sabah, Aras 4, Blok B, Wisma Pertanian Sabah, Jalan Tasik Luyang (Off Jln. Maktab Gaya), 88624 Kota Kinabalu, Sabah, Malaysia Tel: +088 23 5966 / +6013 549 4110 Fax : +088 24 0511 E-mail: mzamani.nayan@gmail.com mohdzamani.nayan@sabah.gov.my
8	**Mr. Sallehudin Jamon** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: sallehudin_jamon@dof.gov.my dinjamon@rocketmail.com
9	**Mr. Abdul Wahab Abdullah** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: wahab@dof.gov.my wahab@ymail.com
MYANMAR		
10	**Mr. Julius Kyaw**	Department of Fisheries, Ministry of Agriculture Livestock and Irrigation, Building No. (36), Ministerial Zone, Nay Pyi Taw, Myanmar Tel: +09 519 2876 Fax: +043 202 2406 E-mail: joker.007.kyaw@gmail.com

11	**Mr. Naing Win Thein**	Department of Fisheries, Ministry of Agriculture Livestock and Irrigation, Building No. (36), Ministerial Zone, Nay Pyi Taw, Myanmar Tel: +09 592 5060 0646 Fax: +043 202 2406 E-mail: naingwintheindof@gmail.com
	PHILIPPINES	
12	**Mr. Ronnie O. Romero**	National Fisheries Research and Development Institute (NFRDI), 101 Corporate BLDG, Mother Ignacia Avenue, South Triangle, Quezon City, Philippines Tel: +632 376 1138 Fax: +632 376 1138 E-mail: ronnsromero@yahoo.com
13	**Ms. Grace De Veyra Lopez**	National Fisheries Research and Development Institute (NFRDI), 101 Corporate BLDG, Mother Ignacia Avenue, South Triangle, Quezon City, Philippines Tel: +632 376 1178 Fax: +632 376 1178 / +632 372 5063 E-mail: gmvlopez@yahoo.com gmvlopez60@gmail.com
	THAILAND	
14	**Dr. Watcharapong Chumchuen**	Fishing Technnology Development Unit, Department of Fisheries, 50 Plodprasap Building 6th Floor, Phahol Yothin Road, Lad Yao, Chatuchak, Bangkok 10900 Thailand Tel: +66 84 195 4449 Fax: +66 2 561 0880 E-mail: w.chumchuen@fisheries.go.th
15	**CDR. Pornchai Singhaboon, RTN**	Department of Fisheries, Phosprasop 7th Floor, Kasetsart University Campus, Chatuchak, Bangkok 10900 Thailand Tel: +66 2 940 6148 Fax: +66 2 940 6148 Email: pornslek@hotmail.com
	VIET NAM	
16	**Mr. Pham Van Tuyen**	Research Institute for Marine Fisheries (RIMF), 224 Le Lai Street Hai Phong City, Viet Nam Tel: 09 86 568 189 / +084 986 568 189 E-mail: pvtuyenvhs@gmail.com pvtuyen@rimf.org.vn

17	**Mr. Nguyen Dang Kien**	Department of Capture Fisheries, No. 10 Nguyen Cong Hoon Street, Ba Dinh District, Hanoi, Viet Nam Tel: +084 967 503 866 E-mail: nguyendangkien2001@gmail.com
	RESOURCE PERSON	
18	**Dr. Matsuishi Takashi Fritz**	3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5505 Email: http://bit.ly/2fritz
	SEAFDEC/TD	
19	**Mr. Sutee Rajruchithong**	SEAFDEC Training Department (TD) P.O. Box 97, Phasamutchedi Samut Prakan 10290, Thailand Tel : +662 4256 100 Fax : +662 4256 110-1 E-mail: sutee@seafdec.org
	SEAFDEC/MFRDMD	
20	**Mr. Raja Bidin bin Raja Hassan** Chief of SEAFDEC/MFRDMD	SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) Taman Perikanan Chendering 21080 Kuala Terengganu, Terengganu, Malaysia Tel: +609 6175940, 6177867 Fax: +609 6175136 E-mail: rbidin@seafdec.org.my
21	**Dr. Kenji Taki** Deputy Chief of SEAFDEC/MFRDMD	E-mail: taki@seafdec.org.my
22	**Ms. Wahidah Mohd Arshaad** Head of Biology and Genetics Unit	E-mail: wahidah@seafdec.org.my
23	**Ms. Mazalina Ali** Head of Fishery Resources Management Advisory Section	E-mail: mazalina@seafdec.org.my
24	**Mr. Mohammad Faisal Md. Saleh** Project Coordinator of JTF6	E-mail: mfaisal@seafdec.org.my
25	**Ms. Noorul Azliana Jamaludin**	E-mail: noorul@seafdec.org.my

	Research Officer of Biology and Genetics Unit	
26	**Mr. Adam Luke Pugas** Assistant Research Officer of Biology and Genetics Unit	E-mail: adamlp@seafdec.org.my
27	**Mr. Ahmad Firdaus Siregar bin Abdullah** Assistant Research Officer of Information Management Unit	E-mail: afirdaus@seafdec.org.my

THE 4TH CORE EXPERT MEETING ON COMPARATIVE STUDIES FOR PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

18-19 September 2018, Melia Hotel, Kuala Lumpur, Malaysia

BRUNEI DARUSSALAM		
1	**Mr. Sheikh Al-Idrus Sheikh Nikman** Fisheries Officer	Kompleks Perikanan Muara Simpang 287-53 Jalan Peranginan Pantai Serasa Kampung Serasa Brunei Darussalam Muara BT1728, Negara Brunei Darussalam Tel: +673 2770066 Fax : +673 2770065 E-mail: idrus.nikman@fisheries.gov.bn
2	**Mr. Marzini Hj. Zulkipli** Assistant Fisheries Officer	Kompleks Perikanan Muara Simpang 287-53 Jalan Peranginan Pantai Serasa Kampung Serasa Brunei Darussalam Muara BT1728, Negara Brunei Darussalam Tel: +673 8902054 Fax : +673 2770065 E-mail: marzini.zulkipli@gmail.com
CAMBODIA		
3	**Dr. Chea Tharith** Deputy Director of the Marine Fisheries Research and Development Institute (MaFReDI) of Fisheries Administration	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: +855 11467648 E-mail: cheatharith88@gmail.com
4	**Mr. Chhuon Kimchhea** Deputy Director of Department of Fisheries Affairs	Fishery Administration, # 186, Preach Norodom, Sangkat Tonle Bassac, Khan Chamcar Mon, Blvd. P.O. Box 582, Phnom Penh, Cambodia Tel: +85517272896 E-mail: Kimchhea@yahoo.com
MALAYSIA		
5	**Mr. Jamil Musel** Research Officer	Fisheries Research Institute Sarawak Jalan Perbadanan, Bintawa Peti Surat 2243 93744 Kuching Sarawak, Malaysia Tel: +082 33 4144 / +6013 8097132 Fax: +082 33 1281 E-mail: jamilmusel@dof.gov.my deemsebakau@gmail.com

6	**Mr. Mohd Zamani Nayan** Research Officer	Ibu Pejabat Perikanan, Jabatan Perikanan Sabah, Aras 4, Blok B, Wisma Pertanian Sabah, Jalan Tasik Luyang (Off Jln. Maktab Gaya), 88624 Kota Kinabalu, Sabah, Malaysia Tel: +088 23 5966 / +6013 549 4110 Fax : +088 24 0511 E-mail: mzamani.nayan@gmail.com mohdzamani.nayan@sabah.gov.my
7	**Mr. Sallehudin Jamon** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: sallehudin_jamon@dof.gov.my dinjamon@rocketmail.com
8	**Mr. Abdul Wahab Abdullah** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: wahab@dof.gov.my wahab@ymail.com
	MYANMAR	
9	**Mr. Myint Shwe** Deputy Director of DOF	Head Office Tanintharyi Region Department of Fisheries (DOF) Ministry of Agriculture Livestock and Irrigation, Building No. (36), Ministerial Zone, Nay Pyi Taw, Myanmar Tel: +095 9449004650 Fax: +043 9449559535 E-mail: myintshwedo5@gmail.com
10	**Mr. Aung Moe Kyaw** Deputy Fishery Officer of DOF	Department of Fisheries (DOF), Ministry of Agriculture Livestock and Irrigation, Building No. (36), Ministerial Zone, Nay Pyi Taw, Myanmar Tel: +095 95092289 Fax: +095 673408477 E-mail: aungmoekyawdof@gmail.com

	PHILIPPINES	
11	**Mr. Fileonor O. Eleserio** Senior Aquaculturist	Bureau of Fisheries and Aquatic Resources 3rd Floor, PCA Building, Diliman, Quezon City, Philippines Tel: +63 02 929 4296 E-mail: Releserio@yahoo.com
12	**Mr. Ronnie O. Romero** Aquaculturist I	National Fisheries Research and Development Institute (NFRDI), 101 Corporate BLDG, Mother Ignacia Avenue, South Triangle, Quezon City, Philippines Tel: +632 352 3596 Fax: +632 352 3596 E-mail: ronnsromero@yahoo.com
	THAILAND	
13	**Dr. Watcharapong Chumchuen** Fisheries Biologist, MFRD	Marine Fisheries Research and Development Division, Department of Fisheries, 50 Phahol Yothin, Lad Yao, Chatuchak, Bangkok 10900 Thailand Tel: +66 2 561 0880 Fax: +66 2 561 0880 E-mail: w.chumchuen@fisheries.go.th
14	**Dr. Pavarot Noranarttragoon** Fisheries Biologist, MFRD	Marine Fisheries Research and Development Division, Department of Fisheries, 50 Phahol Yothin, Lad Yao, Chatuchak, Bangkok 10900 Thailand Tel: +66 81 735 3431 Fax: +66 2 940 6148 Email: pavarotn@gmail.com
	VIET NAM	
15	**Mr. Pham Van Tuyen** Researcher of RIMF	Research Institute for Marine Fisheries (RIMF), 224 Le Lai Street Hai Phong City, Viet Nam Tel: +084 986 568 189 E-mail: pvtuyenvhs@gmail.com pvtuyen@rimf.org.vn
16	**Mr. Vu Van Tam** Officer of Capture Fisheries Department	Directorate of Fisheries (D-Fish), No. 10 Nguyen Cong Hoon Street, Ba Dinh District, Hanoi, Viet Nam Tel: +084 24 3834 5953 E-mail: bgvantam@gmail.com

RESOURCE PERSONS		
17	**Prof. Dr. Matsuishi Takashi Fritz** Resource Person	Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5505 Fax: +81 138 40 5505 Email: http://bit.ly/2fritz
18	**Mr. Abu Talib** Resource Person	No. 142 Persiaran Mayang Pasir MK12. Bandar Bayan Baru 11950 Bayan Lepas, Pulau Pinang. Email: abutalib.ata@gmail.com
SEAFDEC Secretariat		
19	**Dr. Worawit Wanchana**	SEAFDEC Secretariat P.O. Box 1046 Kasetsart Post Office, Chatuchak Bangkok, 10903, Thailand Tel : +66 29 406 326 Ext. 110 Fax : +66 29 406 326 E-mail: worawit@seafdec.org
SEAFDEC/TD		
20	**Mr. Supapong Pattarapongpan**	SEAFDEC Training Department (TD) P.O. Box 97, Phasamutchedi Samut Prakan 10290, Thailand Tel : +66 87 156 6230 E-mail: supapong@seafdec.org
SEAFDEC/MFRDFMD		
21	**Mr. Raja Bidin bin Raja Hassan** Chief of SEAFDEC/MFRDMD	SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) Taman Perikanan Chendering 21080 Kuala Terengganu, Terengganu, Malaysia Tel: +609 6175940, 6177867 Fax: +609 6175136 E-mail: rbidin@seafdec.org.my
22	**Dr. Kenji Taki** Deputy Chief of SEAFDEC/MFRDMD	E-mail: taki@seafdec.org.my
23	**Ms. Wahidah Mohd Arshaad** Head of Biology and Genetics Unit	E-mail: wahidah@seafdec.org.my

24	**Mr. Mohammad Faisal Md. Saleh** Project Coordinator of JTF6	E-mail: mfaisal@seafdec.org.my
25	**Ms. Noorul Azliana Jamaludin** Research Officer of Biology and Genetics Unit	E-mail**:** noorul@seafdec.org.my
26	**Mr. Adam Luke Pugas** Assistant Research Officer of Biology and Genetics Unit	E-mail**:** adamlp@seafdec.org.my
27	**Mr. Ahmad Firdaus Siregar bin Abdullah** Assistant Research Officer of Information Management Unit	E-mail**:** afirdaus@seafdec.org.my

REGIONAL WORKSHOP ON COMPARATIVE STUDIES FOR PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

7-8 Mac 2017, Dorsett Hotel, Kuala Lumpur, Malaysia

	CAMBODIA	
1	**Mr. Samreth Sambo** Deputy Director of Marine Fisheries Research and Development Institute (MAFReDI)	Marine Fisheries Research and Development Institute (MAFReDI), Fisheries Administration, No. 186 Preah Norodom Blvd, P.O. Box: 582, Phnom Penh, Cambodia. Tel / Fax: (+855)23 215 470
	INDONESIA	
2	**Mr. Duto Nugroho** Fisheries Biologist	Research Centre for Fisheries Management and Conservation, Agency for Marine Fisheries Research and Development, Balitbang KP II Building, 2nd Floor Jl. Pasir Putih II, Ancol Timur Jakarta 14430 Phone. : 62-21-64700928 ext: 1132 Fax. : 62-21- 64700929 E-mail: dutonugroho@gmail.com
	MALAYSIA	
3	**Mr. Jamil Musel** Research Officer	Fisheries Research Institute Sarawak Jalan Perbadanan, Bintawa Peti Surat 2243 93744 Kuching Sarawak, Malaysia Tel: +082 33 4144 / +6013 8097132 Fax: +082 33 1281 E-mail: jamilmusel@dof.gov.my deemsebakau@gmail.com
4	**Mr. Sallehudin Jamon** Research Officer	Bahagian Penyelidikan Perikanan Tangkapan Fisheries Research Institute Kg. Acheh (FRIKA), Kompleks Perikanan Kg. Acheh, 32000 Setiawan Perak, Malaysia Tel: +605 691 4752 Fax: +605 691 4742 E-mail: sallehudin_jamon@dof.gov.my dinjamon@rocketmail.com

	MYANMAR	
5	**Mr. Myint Shwe** Deputy Director of DOF	Head Office Tanintharyi Region Department of Fisheries (DOF) Ministry of Agriculture Livestock and Irrigation, Building No. (36), Ministerial Zone, Nay Pyi Taw, Myanmar Tel: +095 9449004650 Fax: +043 9449559535 E-mail: myintshwedo5@gmail.com
	PHILIPPINES	
6	**Mr. Ronnie O. Romero** Aquaculturist I	National Fisheries Research and Development Institute (NFRDI), 101 Corporate BLDG, Mother Ignacia Avenue, South Triangle, Quezon City, Philippines Tel: +632 352 3596 Fax: +632 352 3596 E-mail: ronnsromero@yahoo.com
	THAILAND	
7	**Dr. Watcharapong Chumchuen** Fisheries Biologist, MFRD	Marine Fisheries Research and Development Division, Department of Fisheries, 50 Phahol Yothin, Lad Yao, Chatuchak, Bangkok 10900 Thailand Tel: +66 2 561 0880 Fax: +66 2 561 0880 E-mail: w.chumchuen@fisheries.go.th
	VIET NAM	
8	**Mr. Pham Hung**	Department of Capture Fisheries and Resources Protection Fisheries Administration, 10 Nguyen Cong Hoan, Ba Dinh, Hanoi, Vietnam. Telephone : +84-37711579 Facsimile : +84-4-37345120/37245374 E-mail: hungfam83@gmail.com
	RESOURCE PERSONS	
9	**Prof. Dr. Matsuishi Takashi Fritz** Resource Person	Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 5505 Fax: +81 138 40 5505 Email: http://bit.ly/2fritz

OBSERVER		
10	**Ms. Ledhyane Ika Harlyan**	Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato, Hokodate, Hokkaido 041-8611 Japan Tel: +81 138 40 8857 Fax: +81 138 40 8857
11	**Dr. Kenji Taki**	E-mail: taki@seafdec.org.my
SEAFDEC Secretariat		
12	**Dr. Somboon Siriraksophon**	SEAFDEC Secretariat P.O. Box 1046 Kasetsart Post Office, Chatuchak Bangkok, 10903, Thailand Tel : +66 29 406 333 Fax : +66 29 406 336 E-mail: somboon@seafdec.org
SEAFDEC/TD		
13	**Mr. Sutee Rajrichitong**	SEAFDEC Training Department (TD) P.O. Box 97, Phasamutchedi Samut Prakan 10290, Thailand Tel : +662 4256 100 Fax : +662 4256 110-1 E-mail: sutee@seafdec.org
14	**Mr. Supapong Pattarapongpan**	SEAFDEC Training Department (TD) P.O. Box 97, Phasamutchedi Samut Prakan 10290, Thailand Tel : +66 87 156 6230 E-mail: supapong@seafdec.org
SEAFDEC/MFRDFMD		
15	**Mr. Raja Bidin bin Raja Hassan** Chief of SEAFDEC/MFRDMD	SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) Taman Perikanan Chendering 21080 Kuala Terengganu, Terengganu, Malaysia Tel: +609 6175940, 6177867 Fax: +609 6175136 E-mail: rbidin@seafdec.org.my
16	**Dr. Osamu Abe** Deputy Chief of SEAFDEC/MFRDMD	E-mail: abe@seafdec.org.my

17	**Mr. Abdul Razak Latun** Special Departmental Coordinator	E-mail: abdulrazaklatun@seafdec.org.my
18	**Mr. Mohammad Faisal Md. Saleh** Project Coordinator of JTF6	E-mail: mfaisal@seafdec.org.my
19	**Mr. Adam Luke Pugas** Assistant Research Officer of Biology and Genetics Unit	E-mail: adamlp@seafdec.org.my
20	**Mr. Ahmad Firdaus Siregar bin Abdullah** Assistant Research Officer of Information Management Unit	E-mail: afirdaus@seafdec.org.my

Appendix IV. List of Focal Points for Genetic Study

No.	Country	Name	Institution
1.	Brunei Darussalam	Mrs. Noorizan Abd Karim	Fisheries Department Ministry of Industry & Primary Resources Kompleks Perikanan Muara Simpang 287-53, Jalan Peranginan Pantai Serasa, Muara BT 1726 E-mail: noor6263@gmail.com
2.	Cambodia	Mr. Suy Serywath	Marine Fisheries Research and Development Institute 186 Norodom Blvd, Sangkat Tonle Basac Khan Chamcar Mon, Phnom Penh Tel: +855 12 710800 Fax: +855 23 219256 E-mail: serywath@gmail.com
3.	Indonesia	Mr. Thomas Hidayat	Research Marine Institute of Marine Fisheries, Balai Penelitian Perikanan Laut Komp Pelabuhan Nizam Zachman, Jln.Muara Baru Ujung Komplek Pelabuhan Perikanan Nizam Zachman, Jakarta Tel: +62 081806043030; +62 216602044 Fax: +62 21 665912 E-mail: thomas.hidayat@yahoo.com
		Mr. Muhammad Taufik	Research Institute for Marine Fisheries Komplek Raiser Jl. Raya Bogor KM.47 Nanggewer Mekar Cibinong-Bogor, Indonesia Tel: +6281314741441 Email: taufik.brpl@gmail.com
4.	Malaysia	Mr. Sallehudin Bin Jamon	Fisheries Research Institute, Kampung Acheh, Kompleks Perikanan, Kg. Acheh, Jabatan Perikanan 32000 Sitiawan Perak, Malaysia Tel: +60 56914752 Fax: +60 56914742 E-mail: sallehudin_jamon@dof.gov.my
		Mr. Jamil Musel	Fisheries Research Institute Sarawak, Jalan Perbadanan, Bintawa, P.O.Box 2243, 93744 Kuching, Sarawak, Malaysia Tel: +082-334144 Fax: +082-331281 E-mail: jamilmusel@dof.gov.my
			Department of Fisheries Sabah

		Mr. Mohd Zamani Nayan	Level 4, Block B, Wisma Pertanian Sabah, Jalan Tasik, 88624 Kota Kinabalu Sabah Tel: +088 235966 Fax: +088-425890 / +088-240511 Email: mohdzamani.nayan@sabah.gov.my
5.	Myanmar	Dr. Htun Thein	Research and Development Division Department of Fisheries, Ministry of Livestock, Fisheries and Rural Development Sin-Min Road, Ahlone Township, Yangon, Myanmar Telephone : 95 9 5027889 E-mail : htunthein.akyab@gmail.com
6.	Philippines	Dr. Mudjekeewis D. Santos	Bureau of Fisheries and Aquatic Resources PCA Compound, Elliptical Road, Dilman, Quezon City, Philippine Tel.: +639299597 Fax: + 639298074 E-mail: mudjiesantos@gmail.com
7.	Thailand	Miss Ratanavaree Poonsawat	Upper Gulf Marine Fisheries Research and Development Center, Marine Fisheries Technology Research and Development Institute, Marine Fisheries Technology Research and Development Institute Bureau, Thailand Tel.: +66 8 9767 6516 Fax: + 662 940 6558 E-mail: ratvaree@yahoo.com
8.	Viet Nam	Mr. Nguyen Khac Bat	Research Institute for Marine Fisheries 224 Le Lai, Ngo Quyen, Hai Phong, Vietnam Mob: +84-916497967 Fax: +84-31-3836812 Email: nkbat@rimf.org.vn; nkbat2005@gmail.com

Appendix V. Standard Operating Procedure for Genetic Study of *Amblygaster sirm*

SAMPLING PROCEDURE FOR THE GENETIC STUDY

INTRODUCTION

This Standard Operating Procedure (SOP) serves as a guideline and main reference for those involve in tissue sample collection in the field at identified sampling/landing sites and tissue preservation either in the field or at laboratory. Collected and preserved samples from the respective country are to be sent via air courier to SEAFDEC/MFRDMD in Malaysia for further laboratory works.

SAMPLING SITES

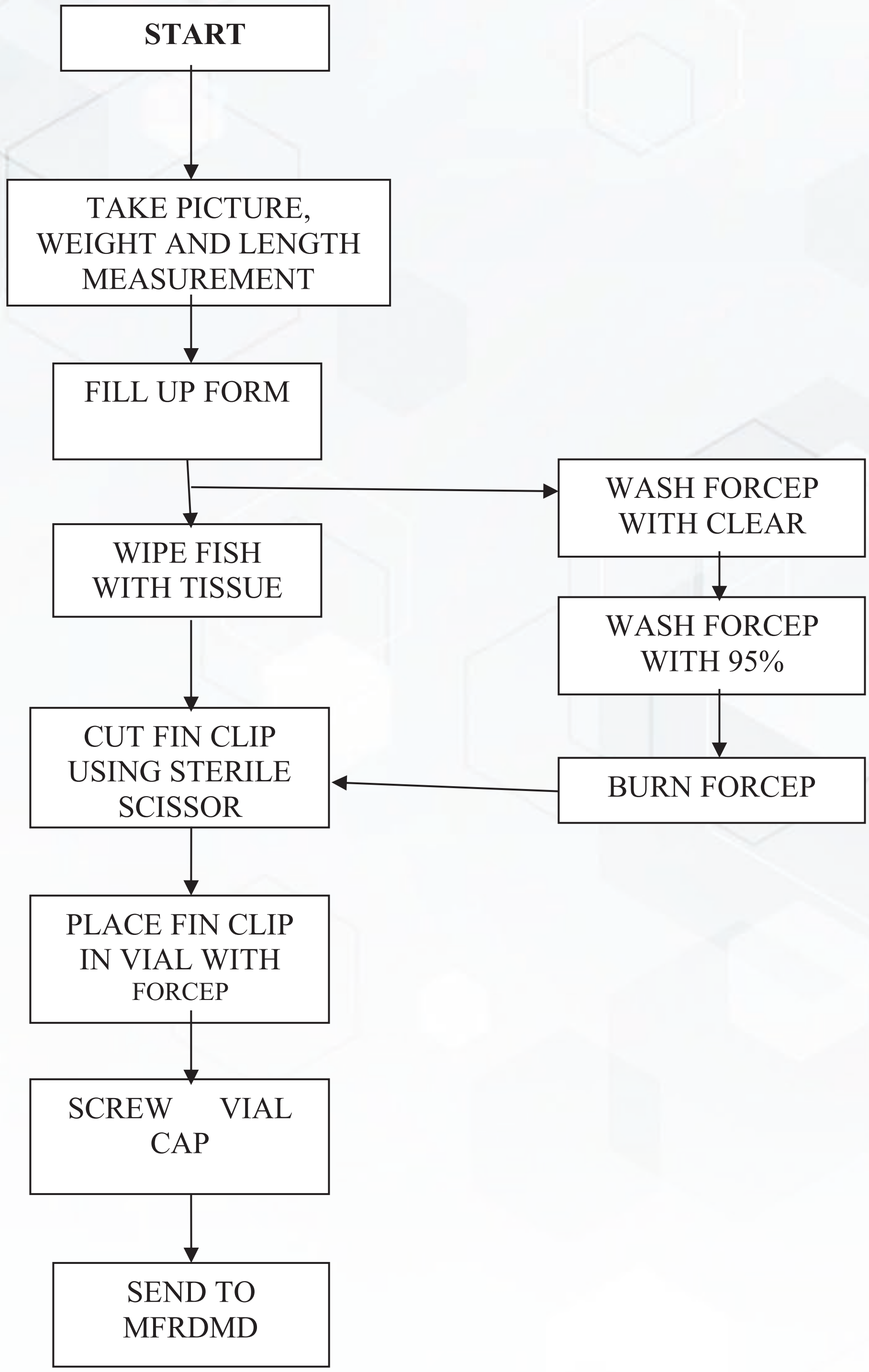
Selected species : *Amblygaster sirm*

The complete list of sampling sites as shown in Table 1.

Table 77. Sampling sites and number of samples to be collected covering both the South China Sea and the Andaman Sea.

No.	Country	Sampling sites
1.	Brunei Darussalam	Muara
2.	Cambodia	Sihanouk Ville
3.	Indonesia	Banda Acheh
		Pekalongan
4.	Malaysia	Kuantan
		Kuching
		Kudat
		Pangkor
5.	Myanmar	Yangon
6.	The Philippines	Bataan
		Palawan
7.	Thailand	Ranong
		Songkhla
8.	Vietnam	Khanh Hoa
		Nghe An
	TOTAL	

Flow Chart for Tissue Sample Collection Procedure



Southeast Asian Fisheries Development Center
Marine Fisheries Resources Development and Management Department

Tissue Samples Collection Form

Country :	Sampling area :
Species :	Total number of samples :
Technical Officer In Charge :	
Agency :	
E-mail Address :	Contact No. :

Vial No.	Date of sampling	Lat & Long	Weight	Length	Sex & Gonad stage (If possible)		Remark/s
					Sex	Gonad stage	
1							
2							
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35							

Any enquires please contact:

Ms Wahidah binti Mohd Arshaad
Research Officer
Marine Fishery Resources Development and Management Department
(SEAFDEC-MFRDMD)
Fisheries Garden, Chendering
21080 Kuala Terengganu, Terengganu.
Tel: 609-617 5940 Fax: 609- 617 5136
http://www.seafdec.org.my/seafdecv4E-mail: noorul@seafdec.org.my

Gonad Stage

Five-point Maturity Scale for Partial Spawner

Identify sex and gonad stage of fish through visual censes. As for the characteristic of gonad stages, refer to the standard maturity scale as Five-Point Maturity Scale For Partial Spawner.

Stage	State	Description	
I	Immature	Ovary and testis about 1/3 length of body cavity. Ovaries pinkish, translucent; Testis whitish. Ova not visible to naked eye.	
II	Maturing	Ovary and Testis about ½ of body cavity. Ovary pinkish, tanslucent; Testis whitish, more or less symmetrical. Ova not visible to naked eye.	 
III	Ripening	Ovary and testis about 2/3 of body cavity. Ovary pinkish-yellow colour with granular appearance, Testis whitish to creamy. No transparent or translucent ova visible.	 
IV	Ripe	Ovary and testis about 2/3 to full length of body cavity. Ovary orange-pink in colour with conspicuous	

		superficial blood vessels. Large transparent, ripe ova visible. Testis whitish-creamy soft.	
V	Spent	Ovary and Testis shrunken to about ½ length of body cavity. Wall loose. Ovary may contain remnants of disintegrating opaque and ripe ova, darkened or translucent. Testis blood shot and flabby.	

Appendix VI. Haplotype Distribution mtDNA *Cyt b*

Haplotype	No.	Samples Identity
Hap1	1	SBR01
Hap2	1	SBR02
Hap3	2	SBR03 SBA26
Hap4	1	SBR04
Hap5	10	SBR05 SBR24 SKD18 SKT07 SPL22 SPL23 SSL01 SSL31 SZB07 SZB11
Hap6	34	SBR06 SBR08 SBR13 SBR15 SBR16 SBR33 SKC03 SKC09 SKC20 SKC24 SKD03 SKD20 SKD26 SKD33 SKT01 SKT09 SKT29 SKT31 SKT32 SKT33 SPL02 SPL08 SPL09 SPL13 SPL17 SPL21 SSL03 SSL06 SSL13 SSL23 SSL27 SSL32 SZB12 SBA34
Hap7	1	SBR07
Hap8	1	SBR09
Hap9	1	SBR11
Hap10	1	SBR12
Hap11	52	SBR14 SBR17 SBR19 SBR22 SBR32 SBR34 SKC05 SKC07 SKC15 SKC32 SKC36 SKD01 SKD02 SKD04 SKD10 SKD11 SKD12 SKD23 SKD24 SKD25 SKD35 SKT02 SKT03 SKT21 SKT22 SKT27 SKT34 SPL01 SPL06 SSL11 SSL15 SSL19 SSL22 SSL24 SSL25 SSL28 SZB02 SZB10 SZB13 SZB19 SZB22 SPN7 SPN9 SPN12 SPN16 SPN17 SPN34 SBA3 SBA9. SBA11 SBA13 SBA17
Hap12	2	SBR18 SPL07
Hap13	1	SBR20
Hap14	1	SBR21
Hap15	1	SBR23
Hap16	2	SBR25 SKT23
Hap17	1	SBR26
Hap18	2	SBR27 SZB09
Hap19	1	SBR28
Hap20	1	SBR29
Hap21	1	SBR30
Hap22	1	SBR31
Hap23	16	SBR35 SKC14 SKC16 SKC30 SKD06 SKD14 SKD16 SKT05 SKT17 SKT25 SPL16 SSL07 SSL16 SZB03 SPN5 SBA8
Hap24	1	SKC01
Hap25	1	SKC02
Hap26	1	SKC04
Hap27	1	SKC06
Hap28	1	SKC10
Hap29	3	SKC12 SKC31 SKD15
Hap30	1	SKC13
Hap31	1	SKC17
Hap32	1	SKC18
Hap33	1	SKC19
Hap34	1	SKC21
Hap35	1	SKC22
Hap36	1	SKC23
Hap37	1	SKC25
Hap38	1	SKC26
Hap39	1	SKC27
Hap40	1	SKC28
Hap41	1	SKC29

Hap42	1	SKC33
Hap43	1	SKC34
Hap44	1	SKC35
Hap45	1	SKD05
Hap46	1	SKD07
Hap47	1	SKD08
Hap48	1	SKD09
Hap49	1	SKD13
Hap50	1	SKD17
Hap51	1	SKD19
Hap52	2	SKD21 SBA12
Hap53	1	SKD22
Hap54	2	SKD27 SBA7
Hap55	1	SKD28
Hap56	1	SKD29
Hap57	1	SKD30
Hap58	1	SKD31
Hap59	1	SKD32
Hap60	1	SKD34
Hap61	1	SKT04
Hap62	1	SKT06
Hap63	1	SKT08
Hap64	1	SKT10
Hap65	2	SKT11 SSL36
Hap66	1	SKT12
Hap67	2	SKT13 SSL17
Hap68	1	SKT14
Hap69	1	SKT15
Hap70	1	SKT16
Hap71	1	SKT18
Hap72	1	SKT19
Hap73	1	SKT20
Hap74	1	SKT24
Hap75	1	SKT26
Hap76	1	SKT28
Hap77	1	SKT30
Hap78	1	SKT35
Hap79	1	SPL04
Hap80	1	SPL05
Hap81	1	SPL10
Hap82	1	SPL11
Hap83	1	SPL12
Hap84	1	SPL14
Hap85	1	SPL15
Hap86	1	SPL18
Hap87	1	SPL19
Hap88	1	SSL02
Hap89	1	SSL04
Hap90	1	SSL05
Hap91	2	SSL09 SSL33
Hap92	1	SSL10
Hap93	1	SSL12
Hap94	1	SSL14
Hap95	1	SSL18
Hap96	1	SSL21

Hap97	1	SSL26		
Hap98	1	SSL29		
Hap99	1	SSL30		
Hap100	1	SSL34		
Hap101	1	SSL35		
Hap102	2	SZB01	SPN24	
Hap103	1	SZB04		
Hap104	1	SZB05		
Hap105	1	SZB06		
Hap106	1	SZB08		
Hap107	1	SZB14		
Hap108	1	SZB16		
Hap109	1	SZB17		
Hap110	1	SZB18		
Hap111	1	SZB20		
Hap112	1	SZB21		
Hap113	1	SZB23		
Hap114	1	SZB24		
Hap115	1	SZB25		
Hap116	1	SPN1		
Hap117	1	SPN2		
Hap118	1	SPN3		
Hap119	1	SPN4		
Hap120	1	SPN6		
Hap121	1	SPN8		
Hap122	1	SPN10		
Hap123	1	SPN11		
Hap124	1	SPN13		
Hap125	1	SPN14		
Hap126	1	SPN15		
Hap127	1	SPN18		
Hap128	2	SPN19	SBA28	
Hap129	1	SPN20		
Hap130	1	SPN21		
Hap131	1	SPN22		
Hap132	1	SPN23		
Hap133	1	SPN25		
Hap134	1	SPN26		
Hap135	1	SPN27		
Hap136	2	SPN28	SBA25	
Hap137	1	SPN29		
Hap138	1	SPN30		
Hap139	3	SPN31	SBA5	SBA16
Hap140	2	SPN32	SBA29	
Hap141	1	SPN33		
Hap142	1	SPN35		
Hap143	1	SBA1		
Hap144	1	SBA2		
Hap145	1	SBA4		
Hap146	1	SBA6		
Hap147	1	SBA10		
Hap148	1	SBA14		
Hap149	1	SBA15		
Hap150	1	SBA18		
Hap151	1	SBA19		

Hap152	1	SBA20
Hap153	1	SBA21
Hap154	1	SBA22
Hap155	1	SBA23
Hap156	1	SBA24
Hap157	1	SBA27
Hap158	1	SBA30
Hap159	1	SBA31
Hap160	1	SBA32
Hap161	1	SBA33
Hap162	1	SBA35
Hap163	12	SRG01 SRG46 SRG47 SRG49 SRG51 SRGM08 SRGM19 SRGM26 SRGM27 SRGM35 SRGM40 SRGM43
Hap164	1	SRG02
Hap165	4	SRG36 SRG62 SRGM05 SRGM33
Hap166	1	SRG37
Hap167	1	SRG39
Hap168	7	SRG40 SRG43 SRG44 SRG56 SRG64 SRG69 SRGM29
Hap169	2	SRG41 SRG45
Hap170	2	SRG42 SRGM10
Hap171	1	SRG48
Hap172	1	SRG50
Hap173	1	SRG52
Hap174	1	SRG53
Hap175	3	SRG54 SRGM11 SRGM17
Hap176	1	SRG57
Hap177	1	SRG58
Hap178	1	SRG59
Hap179	2	SRG60 SRG61
Hap180	1	SRG63
Hap181	1	SRG65
Hap182	2	SRG66 SRG70
Hap183	1	SRG67
Hap184	1	SRG68
Hap185	1	SRGM02
Hap186	2	SRGM03 SRGM09
Hap187	1	SRGM04
Hap188	1	SRGM06
Hap189	2	SRGM07 SRGM21
Hap190	2	SRGM12 SRGM41
Hap191	1	SRGM13
Hap192	1	SRGM14
Hap193	1	SRGM15
Hap194	1	SRGM16
Hap195	1	SRGM18
Hap196	1	SRGM20
Hap197	1	SRGM24
Hap198	1	SRGM28
Hap199	1	SRGM34
Hap200	1	SRGM37
Hap201	1	SRGM42
Hap202	1	SRGM48

Appendix VII. Haplotype Distribution mtDNA *COI*

Haplotype	No.	Samples Identity
Hap1	1	SBR01
Hap2	1	SBR02
Hap3	2	SBR04 SBR11
Hap4	1	SBR05
Hap5	1	SBR06
Hap6	1	SBR07
Hap7	1	SBR08
Hap8	1	SBR09
Hap9	1	SBR10
Hap10	1	SBR12
Hap11	1	SBR13
Hap12	9	SBR14 SKC02 SKC04 SKD03 SKD04 SKD06 SKD08 SKD10 SKD11
Hap13	1	SBR15
Hap14	1	SBR16
Hap15	1	SKC01
Hap16	1	SKC03
Hap17	1	SKC05
Hap18	1	SKC06
Hap19	1	SKC07
Hap20	1	SKC09
Hap21	1	SKC10
Hap22	2	SKC11 SKD01
Hap23	1	SKC12
Hap24	1	SKC13
Hap25	1	SKC14
Hap26	1	SKC15
Hap27	1	SKC16
Hap28	1	SKD02
Hap29	1	SKD05
Hap30	1	SKD07
Hap31	1	SKD09
Hap32	1	SKD12
Hap33	1	SKD13
Hap34	1	SKD14
Hap35	1	SKD15
Hap36	1	SKT01
Hap37	2	SKT02 SKT03
Hap38	27	SKT04 SKT05 SKT08 SKT10 SKT11 SKT13 SPL01 SPL02 SPL04 SPL05 SPL07 SPL08 SPL09 SPL10 SPL11 SPL12 SPL15 SSL04 SSL05 SSL07 SSL08 SSL09 SSL10 SSL11 SSL13 SZB01 SZB02
Hap39	1	SKT06
Hap40	2	SKT07 SKT15
Hap41	1	SKT09
Hap42	1	SKT12
Hap43	1	SKT14
Hap44	1	SPL06
Hap45	1	SPL13
Hap46	1	SPL14
Hap47	1	SRG02
Hap48	1	SRG01
Hap49	4	SRG03 SRG06 SRG07 SRG10
Hap50	1	SRG05
Hap51	1	SRG08

Hap52	1	SRG09
Hap53	2	SRG11 SRG14
Hap54	1	SRG12
Hap55	2	SRG15 SRG29
Hap56	1	SRG30
Hap57	1	SSL01
Hap58	3	SSL02 SSL03 SSL06
Hap59	1	SSL12
Hap60	1	SSL14
Hap61	1	SSL15
Hap62	1	SZB03
Hap63	1	SZB04
Hap64	1	SZB05
Hap65	1	SZB06
Hap66	2	SZB07 SZB14
Hap67	1	SZB08
Hap68	1	SZB09
Hap69	1	SZB11
Hap70	1	SZB12
Hap71	1	SZB13
Hap72	1	SZB16
Hap73	1	SGRM04
Hap74	1	SGRM05
Hap75	1	SGRM06
Hap76	1	SGRM07
Hap77	2	SGRM08 SGRM17
Hap78	1	SGRM09

Appendix VIII. Overall Project Activities

Activities	Sub-activities	2013	2014	2015	2016	2017	2018	2019
Activity 1: Comparative Studies for CPUE and TAC	Sub-activity 1.1 Case studies for CPUE in the Southeast Asian region	X	X					
	Sub-activity 1.2 Suitable CPUE and other indicators for resource levels in member countries			X	X			
	Sub-activity 1.3 Comparison of TAC systems in the world (including other management measures)	X	X	X	X	X	X	
Activity 2: Genetic Data Collection and Analysis	Sub-activity 2.1: Equipment preparation for genetic study	X						
	Sub-activity 2.2: Sample collection		X	X				
	Sub-activity 2.3: Genetic study		X	X	X			
	Sub-activity 2.4: Data compilation and analysis					X	X	
Activity 3: Meetings for Effective Program Implementation	Sub-activity 3.1: Core Expert Meeting/Workshop		X		X	X	X	
Activity 4: Recommendation for Purse Seine Fisheries Management in the Southeast Asian region	Sub-activity 4.1: Recommendation for fisheries management							X
	Sub-activity 4.2: Preparation and publishing of terminal report							X

Appendix IX. Poster of the Project

COMPARATIVE STUDIES FOR MANAGEMENT OF PURSE SEINE FISHERIES IN THE SOUTHEAST ASIAN REGION

Mohammad-Faisal, M. S., Wahidah, M. A., Raja-Bidin, R. H., Abdul-Fatah N.N. and Taki, K.
SEAFDEC/MFRDMD
Taman Perikanan Chendering, 21080 Kuala Terengganu, Malaysia

INTRODUCTION

Purse seine is one of the major fishing gears used to exploit small pelagic fishes in the Southeast Asian region.

Figure 1. Purse Seine vessel in Malaysia

Involves compilation and comparison of annual and/or monthly CPUE of pelagic fisheries to examine the trend of resource level for the last three decades in the region

Compare purse seine fisheries management systems including TAC systems and other management measures in the world and conduct the genetic study of a commercially important pelagic species.

Review available information including stock levels, and examine applicable management strategies for sustainable purse seine fisheries in the Southeast Asian region

DATA ANALYSIS

Collect purse seine fisheries information from all participating Member Countries (MCs) in the SEA region → Compile and compare annual CPUE of pelagic fisheries → Statistical data analysis

- Statistical data
- Biological information

- examine the trend of resource level in the SEA region

- Allowable Biological Catch, ABC (Rule 2-2)
- Production Model, PM (Fox)

ABC Rule 2-2 (Matsuishi, 2017)

$ABC = \delta_2 \times C \times \gamma_2$

δ_2 = 1.0 (High)
1.0 (Middle)
0.8 (Low)
C = current catch
$\gamma_2 = 1 + 0.5\,(b/I)$
-b: tangent of the Catch for recent 3 years
-I: Average of the Catch for recent 3 years

PM, Fox model (Rumeaida, 2018)

Regression data
Y = bx + a

MSY = (-1/b)exp [a-1]
fmsy = -1/b
Opt. CPUE = MSY/fmsy

OUTPUTS AND DISCUSSION

OUTPUT FROM ABC RULE 2-2

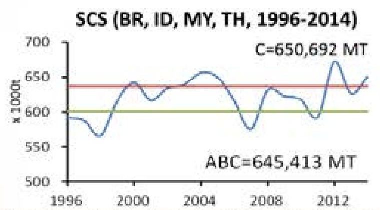

Figure 2. Interannual variation of catch level and ABC of synthesized South China Sea (SCS)

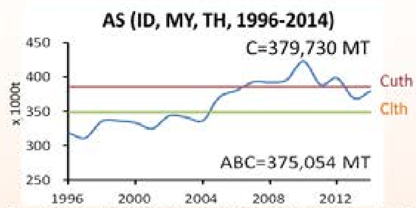

Figure 3. Interannual variation of catch level and ABC of synthesized Andaman Sea (SCS)

ABC is calculated as 645k tonnes and 375k tonnes for synthesized SCS and AS, respectively

OUTPUT FROM PM MODEL (FOX)

Table 1. Current status, MSY, and target FMSY for 4 MCs in the South China Sea (SCS) and Andaman Sea (AS)

Country	Ecosystem	Year	Current landing, MT	Current Effort, trips	R^2	MSY		Target
						MSY (MT)	F_{MSY}	0.8 x F_{MSY}
BR	SCS	2005-2015	949	758	0.7061	1045	1319	1055
ID	SCS - FMA 711	2005-2014	56,128	89,562	0.8641	95,147	35,971	28,777
MY	SCS (ECPM)	1996-2015	235,328	15,109	0.5961	135,199	26,455	21,164
TH	SCS - GoT	1996-2015	347,960	71,754	0.8876	382,926	89,286	71,429
	AS - ADS	1996-2015	134,203	59,138	0.8744	165,008	75,188	60,150

Status of pelagic fishery resources for Malaysia (ECPM), 1996-2015

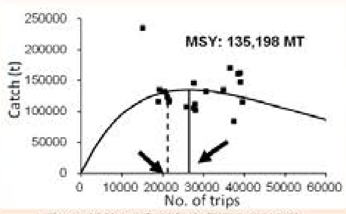

Figure 4. Yield curve for Malaysia (ECPM), 1996-2015

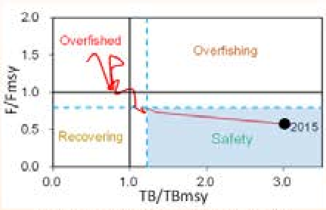

Figure 5. Kobe I Plot for Malaysia (ECPM), 1996-2015

Dotted line shows 80% of Fmsy as recommended by Sparre and Venema (1992)

Current (2015) status shown as black point is in the safety target zone shown as the pale-blue area.

CONCLUSION

- Statistical data from 4 MCs (SCS and AS) was used for ABC Rule 2-2 analysis by: i) Selected MCs; ii) 3 areas of MY off SCS; iii) synthesized SCS and AS.
- Production Model analysis was done for 4 MCs in SCS and only Thailand in AS. The current status was determined by using the Kobe I Plot with target zone index (less than 80% of Fmsy).
- With support and assistance from participating MCs, further investigation for the reason of fluctuation of interannual variation of fishery data is necessary to improve analysis in the future.

ACKNOWLEDGEMENT

The authors would like to express our gratitude to all participating Member Countries for their untiring support and contribution in completing this project. We are grateful to the Department of Fisheries Malaysia, and our resource persons from Hokkaido University and Universiti Malaysia Terengganu for their guidance in carrying out this project. This project was funded by JTF6 from Government of Japan. Also, our sincere appreciation to all officers and staffs in SEAFDEC/MFRDMD for their hardwork and cooperation to ensure the completion of this project.

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Genetic study of *Amblygaster sirm* inferred by mitochondrial DNA (mtDNA) in South China Sea and Andaman Sea

Wahidah M.A., Noorul-Azliana J., Nur Ayuni A., Mohd-Faisal M.S., Taki, K.
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia

Abstract

Amblygaster sirm or spotted sardinella is a marine pelagic species from family Clupeidae. It is one of the sardine species that have economic value to Southeast Asian region. However, limited population information of this species is available, though it is fished at both commercial and artisanal scales at various intensities within its range and utilized for human consumption In this study, tissue samples of 35 fishes of *Amblygaster sirm* from each site were collected from ten localities in the South China Sea (Muara, Brunei Darussalam; Kuching, Kuantan, Kudat, Malaysia; Songkla, Thailand; Palawan, Zambales, The Philippines); two sites in Andaman Sea (Ranong, Thailand and Banda Aceh, Indonesia) and one site in Java Sea (Pekalongan, Indonesia). The partial mitochondrial DNA (mtDNA) cytochrome *b* sequences were amplified using Asirm15 and TruCytb-R primer produced 1016 bp. A total of 323 samples were sequenced and produced 187 haplotypes where 186 variable sites were identified and 109 were parsimony informative. A high haplotype diversities (h=0.9092 to 0.9815) were observed while the nucleotide diversity range from (π =0.0023 to 0.0068). The differences among sampling sites were assessed using Arlequin 3.11 and DnaSP 5.10. The results from this study revealed two highly genetic divergent stock; Ranong vs the rest of the populations.

Objective

To ascertain of genetic structure of *Amblygaster sirm* is exist in the South China Sea and Andaman Sea or there is just one panmictic population by using mtDNA marker

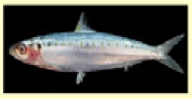
Introduction

The main target among fishery managers is to ensure sustainability of resources and avoid stock depletion (Reiss *et al.*, 2009) hence maximizes the economic returns to the people (Ward & Grewe, 1994. Hence, defining the stock is very important in conservation so as to avoid depletion of subpopulations due to overharvesting or overfishing activity in a certain area. Therefore, determination of fish stock assessment through genetic structure is fundamental in fishery management (Reiss *et al.*, 2009). According to Roldán *et al.* 2000, determination of population genetic structure is essential in order to underpin resource recovery and to aid delineation and monitoring population for fishery management. Once the population genetic structure is determining, identification of management units (MUs) can be started for the selected species. Water currents, different spawning and feeding grounds and behavior may cause invisible boundaries resulting in discrete structured populations that could be determined by mitochondria DNA or mtDNA. The use of mtDNA markers for molecular diagnostic gave several advantageous characteristics over other marker types such as ease of isolation, haploidy, maternally inherited and one-fourth the effective size compared to nuclear DNA which makes it easy to detect population differences (Park & Moran, 1994).

Materials & Method

1. Sample collection

Maximum 35 tissue samples (fin clip) of spotted sardinella (*Amblygaster sirm)* from 10 selected representative sampling sites were cut and fixed into vial tubes containing preservation buffer (70% ethanol).



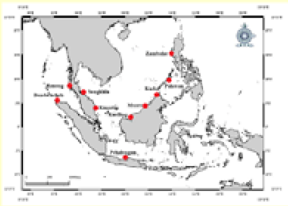


Figure 1:Ten sampling locations of *Amblygaster sirm* amplified for mtDNA.

2. Laboratory analysis

[1]DNA Extraction → [2]PCR → Sequencing

[1]DNA extraction was done by using Masterpure Epincentre Kit.

[2]mtDNA Cytochrome b were amplified by using primer Asirm15 (5' ACC GTT GTA ATT CAA CTA TAG AAA C 3') and TruCytb-R (5' CCG ACT TCC GGA TTA CAA GAC CG 3').

3. Data analysis

The sequence data were edited in MEGA 6, aligned by cluster W and estimated by using Alerquin version 3.1.

Results & Discussion

1. Data analysis of 1016 bp of the Cyt *b* gene obtained from 10 localities produced 323 sequences that define 187 haplotypes. Of these , a total of 186 variable sites (18.3%) were identified and 109 (10.7%) were parsimony informative. (Table 1)

Table 1 : Number of samples (N), haplotypes, polymorphic sites, haplotype diversity (h) and Nucleotide diversity.

	South China Sea							Andaman Sea		Java Sea
	SBR	SKC	SKT	SKD	SPL	SZB	SSL	SRG	BA	PKL
N	34	34	35	35	21	24	34	35	35	35
Number of haplotypes, *h*	23	25	24	21	**15**	19	20	23	30	**30**
Number of polymorphic sites	37	38	29	24	**18**	27	29	44	40	**45**
Haplotype diversity (hd)	0.9447	0.9697	0.9479	**0.9092**	0.9428	0.9601	0.9304	0.9529	**0.9815**	0.9748
Nucleotide diversity (π)	0.0033	0.0036	0.0027	**0.0023**	0.003	0.0037	0.0028	**0.0068**	0.0037	0.0042

2. The number of haplotypes and polymorphic nucleotides per site ranged from 15 to 30 and 18 to 45 respectively.

3. A total of 187 haplotypes were detected from 252 samples amplified by mtDNA Cyt *b* gene with 17 were shared and 125 were unique or singleton.

4. A haplotype diversities ranges from (h=0.9092 to 0.9815) while nucleotide diversity range between π =0.0023 to 0.0068.

Table 2 : Genetic diversity within population and among population of *A. sirm* inferred by mtDNA Cyt *b.*

	Muara	Kuching	Kudat	Kuantan	Palawan	Songkhla	Zambalas	Pekalongan	Banda Acheh	Ranong
Muara	0.030									
Kuching	0.003	0.004								
Kudat	0.003	0.003	0.002							
Kuantan	0.003	0.003	0.002	0.003						
Palawan	0.003	0.003	0.003	0.003	0.003					
Songkhla	0.003	0.003	0.003	0.003	0.003	0.003				
Zambalas	0.003	0.003	0.003	0.003	0.003	0.003	0.003			
Pekalongan	0.004	0.004	0.003	0.003	0.003	0.003	0.004	0.004		
Banda Acheh	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.004	0.004	
Ranong	0.071	0.071	0.070	0.070	0.071	0.071	0.071	0.071	0.071	0.007

5. Genetic differentiation (distance) shows **very high divergence (~ 7%)** between Ranong and other locations. (Table 2)

6. From the Minimum Spanning Network (MSN) yielded a clearly two separated groups of 187 haplotypes produced.

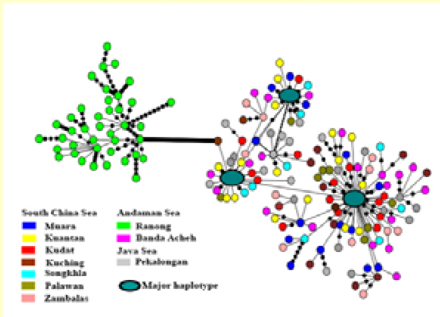


Figure 2: Minimum Spanning Network (MNS) inferred from mtDNA Cyt *b* gene. Colored close circles represent different region (refer to the legend)

7. The haplotypes from Ranong, was completely distinct with many mutational changes from the network observed (Figure 2).

8. Based on the result, a larger geographical coverage is essential for the Andaman Sea (northern).

Conclusion

This study revealed **two highly genetic divergent stocks**; Ranong *vs* the rest of the populations (South China Sea, Java Sea and Andaman Sea (southern part). It is recommended that these stocks should be independently managed.

Acknowledgement

The authors would like to thank the Government of Japan for funding this project under the Japanese Trust Fund Program (Trust Fund II, Tagging Program for Economically Important Pelagic Species in the South China Sea and Andaman Sea) and Focal Point for each member countries.

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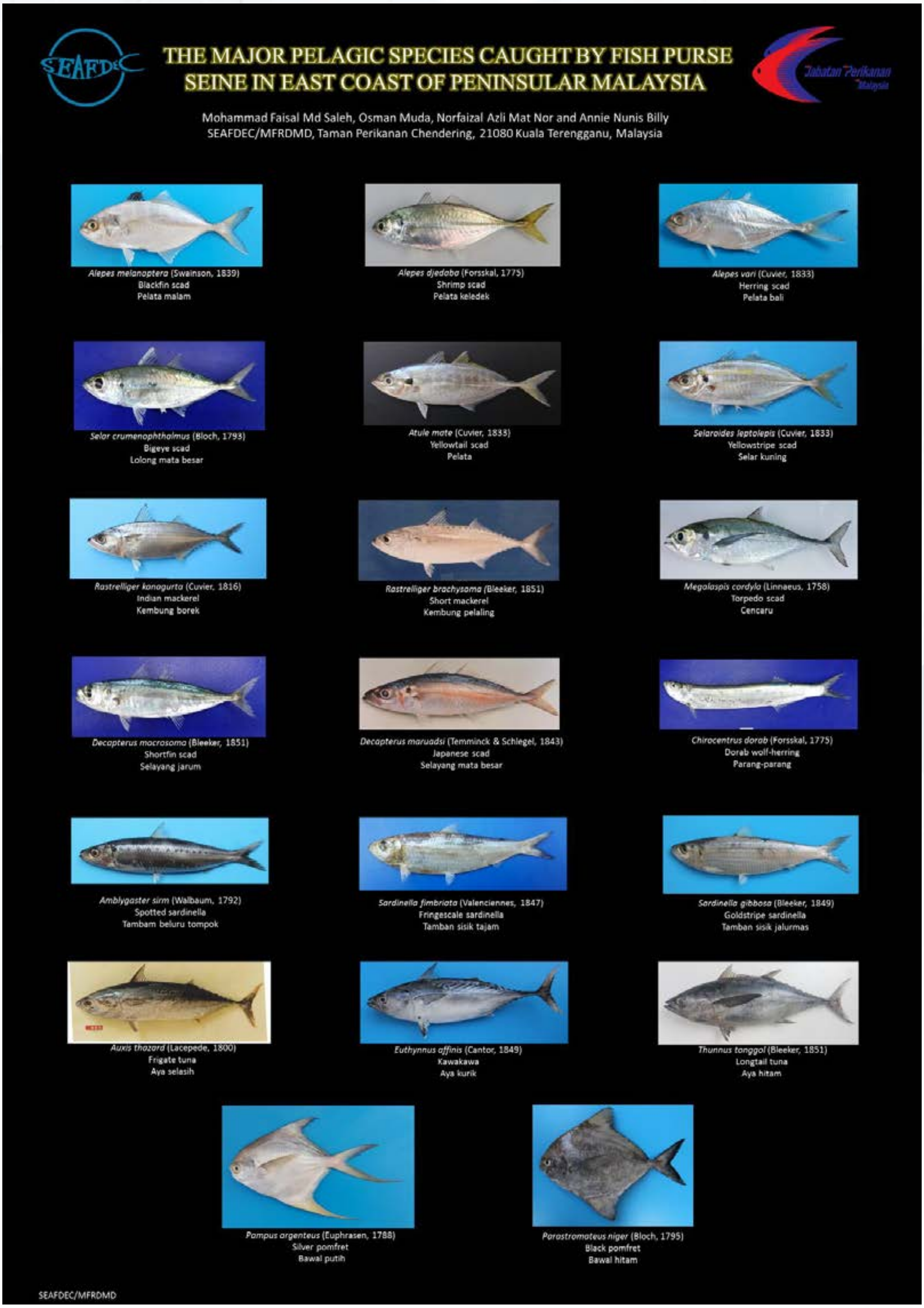
SEAFDEC
THE MAJOR PELAGIC SPECIES CAUGHT BY FISH PURSE SEINE IN EAST COAST OF PENINSULAR MALAYSIA
Jabatan Perikanan Malaysia
Mohammad Faisal Md Saleh, Osman Muda, Norfaizal Azli Mat Nor and Annie Nunis Billy
SEAFDEC/MFRDMD, Taman Perikanan Chendering, 21080 Kuala Terengganu, Malaysia
Alepes melanoptera (Swainson, 1839) Blackfin scad Pelata malam
Alepes djedaba (Forsskal, 1775) Shrimp scad Pelata keledek
Alepes vari (Cuvier, 1833) Herring scad Pelata bali
Selar crumenophthalmus (Bloch, 1793) Bigeye scad Lolong mata besar
Atule mate (Cuvier, 1833) Yellowtail scad Pelata
Selaroides leptolepis (Cuvier, 1833) Yellowstripe scad Selar kuning
Rastrelliger kanagurta (Cuvier, 1816) Indian mackerel Kembung borek
Rastrelliger brachysoma (Bleeker, 1851) Short mackerel Kembung pelaling
Megalaspis cordyla (Linnaeus, 1758) Torpedo scad Cencaru
Decapterus macrosoma (Bleeker, 1851) Shortfin scad Selayang jarum
Decapterus maruadsi (Temminck & Schlegel, 1843) Japanese scad Selayang mata besar
Chirocentrus dorab (Forsskal, 1775) Dorab wolf-herring Parang-parang
Amblygaster sirm (Walbaum, 1792) Spotted sardinella Tambam beluru tompok
Sardinella fimbriata (Valenciennes, 1847) Fringescale sardinella Tamban sisik tajam
Sardinella gibbosa (Bleeker, 1849) Goldstripe sardinella Tamban sisik jalurmas
Auxis thazard (Lacepede, 1800) Frigate tuna Aya selasih
Euthynnus affinis (Cantor, 1849) Kawakawa Aya kurik
Thunnus tonggol (Bleeker, 1851) Longtail tuna Aya hitam
Pampus argenteus (Euphrasen, 1788) Silver pomfret Bawal putih
Parastromateus niger (Bloch, 1795) Black pomfret Bawal hitam
SEAFDEC/MFRDMD

Appendix X. Project Related Activities

The 1st Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region
Furama Hotel, Kuala Lumpur, Malaysia, 26 – 28 August 2014


demand
Proper range
TAC
ABC
Fishing Pressure
北海道大学
SEAFDEC/MFRDMD


SEAFDEC/MFRDMD

The 2nd Core Expert Meeting on Comparative Studies for the Management of Purse Seine Fisheries in the Southeast Asian Region
Furama Hotel, Kuala Lumpur, Malaysia, 9 – 11 August 2016

Technical visit to Malaysia Meteorological Department, Petaling Jaya, Selangor

Technical visit to Malaysia Meteorological Department, Petaling Jaya, Selangor

3rd Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region
Furama Hotel, Kuala Lumpur, Malaysia, 12-14 September 2017


SEAFDEC/MFRDMD


SEAFDEC/MFRDMD

4TH Core Expert Meeting on Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region
Melia Hotel, Kuala Lumpur, Malaysia, 18-19 September 2018


SEAFDEC/MFRDMD


SEAFDEC/MFRDMD

The Regional Workshop on 'Comparative Studies for Management of Purse Seine Fisheries in the Southeast Asian Region'
Dorsett Hotel, Kuala Lumpur, Malaysia, 7 -8 March 2017

Consultation with the Regional Resource Person, Prof. Dr. Matsuishi Takashi Fritz
Biosecurity Fisheries Center Kuala Lumpur, Malaysia, 19 - 20 November 2019

The Genetic Analysis Workshop for *Amblygaster sirm* and *Thunnus tonggol* in Southeast Asian Region
Grand Continental Hotel, Langkawi, Malaysia, 6 - 9 August 2018.

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

Meeting Genetic Study on Neritic Tunas and Amblygaster sirm at Selected Sampling Sites in Indonesian Waters
Research Institute of Marine Fisheries (RIMF) in Jakarta, Indonesia, 17 January 2017

Images photographed by: Ms. Wahidah Mohd Arshaad

Purse seine activities

Images photographed by: Mr. Osman Muda

Images photographed by: Mr. Osman Muda

Images photographed by: Mr. Mohammad Faisal Md Saleh

Genetic Study Sampling

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

Images photographed by: Ms. Nik Zuraini Nawawi @ Omar

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