

Enhancing the Management of the Indo-Pacific Mackerel Resources in the Gulf of Thailand: a synthesis

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In Southeast Asia, the Gulf of Thailand has one of the highest potentials in terms of pelagic fishery resources, due to its shallow topographic bottom features forming the Gulf into a large basin, the seasonal change in wind and current, and the several rivers that discharge water and nutrients into it. With a surface area of 320,000 km² (123,553 mi²), the Gulf of Thailand (GoT) is bordered by four countries, namely: Cambodia, Malaysia, Thailand, and Viet Nam. GoT is well recognized for its important habitats and abundance of marine aquatic resources, with fisheries sector that provides significant livelihoods, food security and nutrition to the people of the GoT countries. At present however, the fishery resources in GoT is declining due to fishing pressure, and the rampant practice of illegal, unreported and unregulated (IUU) fishing. In order to address such concerns, the bordering countries of GoT exerted efforts to manage the resources of the Gulf that include the promotion of collaborative fisheries management for commercially-important transboundary species such as anchovy, Indo-Pacific mackerel and blue swimming crab. This article focuses on the management of the Indo-Pacific mackerel (*Rastrelliger brachysoma*) resources in the Gulf of Thailand.

Series of consultations among the countries bordering the Gulf of Thailand (Figure 1) had been organized by SEAFDEC with support from the SEAFDEC-Sweden Project. In one of such consultations, it was agreed that the status of the fishery resources in the GoT should be assessed, with initial focus on three priority economically-important species, namely: anchovies, Indo-Pacific mackerel, and blue swimming crab or what is known as the AIB species (SEAFDEC, 2017a; SEAFDEC, 2017b). The SEAFDEC-Sweden Project therefore coordinated with the GoT countries, to



Figure 1. Gulf of Thailand bordered by Cambodia, Malaysia, Thailand, and Viet Nam

facilitate the conduct of human resource development activities to enhance the technical expertise of the countries with respect to the management of the AIB species. As a result, the GoT countries initiated the sustainable management activities for the Indo-Pacific mackerel as it is one of the most economically-important transboundary species in the Gulf of Thailand.

Indo-Pacific Mackerel Resources in the Gulf of Thailand

Indo-Pacific mackerel (*Rastrelliger brachysoma*), also known as short mackerel (Figure 2), is a species of mackerel in the family *Scombridae* having a typical appearance of a medium-sized fish and silver in color. The head is equal to or less than the body depth. Very long gill rakes could be seen when the mouth opens, and the snout is pointed. There are five dorsal and anal filets present, where the pectoral and pelvic fins are dusky, while the other fins are yellowish in color. The Indo-Pacific mackerel is distributed along the coastal areas, less than 50 m in depth. Even though pelagic in nature, the Indo-Pacific mackerel prefers to feed in estuarine habitats, and is a plankton feeder.

As noted during the series of consultations among the GoT countries (SEAFDEC, 2017b), the spawning season of the Indo-Pacific mackerel is all year round, and the spawning grounds are in the middle part of the GoT (Figure 3). The gravid fish moves from the inner Gulf to spawn to the Middle Gulf. The fertilized eggs float in the area of 20-80 meter depths and then the juveniles move into the inner Gulf. Fishing peak is usually highest in January-March and June-August.

The Indo-Pacific mackerel is among the major economically-important species in the Southeast Asian region, especially for Cambodia, Indonesia, Malaysia, Philippines, and Thailand. In the SEAFDEC Statistical Bulletin of Southeast Asia (SEAFDEC, 2014; SEAFDEC, 2015; SEAFDEC, 2017e; SEAFDEC, 2017f; SEAFDEC, 2018a) however, the data from Cambodia and Malaysia had not been included in the production of short mackerels as these had been reported under *Rastrelliger* spp. Nonetheless, the compiled information indicated that the total catch of short mackerels in the region contributed an average of



Figure 2. Indo-Pacific mackerel (*Rastrelliger brachysoma*)

about 2.5 % to the total marine catch of Southeast Asia during the past five years (*i.e.* 2.9 %, 2.6 %, 2.7 %, 2.3 %, and 2.1 %, in 2012, 2013, 2014, 2015, 2016, respectively), a trend which also conforms to the decreasing total production of all mackerels in the region (**Table 1**).

Based on the statistics shown in **Table 1**, production of the Indo-Pacific mackerel in GoT (reflecting data from Indonesia and Thailand only) had reduced during the period from 2012 to 2013, increased in 2014 but declined sharply from 2015 to 2016, in spite of the enforcement of seasonal fishing closure measures by most of the GoT countries. Thus, it could then be roughly assumed that the mackerel resource must have already reached its MSY level since 2010-2011 even if the catch increased in 2014, considering that the catch exhibited another decreasing trend since then. It should be noted however, that this trend does not include the status of the resource in Malaysia and Cambodia, where the catch of Indo-Pacific mackerel is lumped together with that of the other mackerels.



Figure 3. Spawning areas of the Indo-Pacific mackerel (*Rastrelliger brachysoma*) in the Gulf of Thailand

Source: Department of Fisheries Thailand

The review of the status of the Indo-Pacific mackerel resource in the Gulf of Thailand (SEAFDEC, 2017b) indicated that in Cambodia, catch of Indo-Pacific mackerel had been reported in Sihanouk Province with two high catch peaks, *i.e.* the first is in January and February; and second peak in July, September, and October, accounting for 86 % of the country's total pelagic catch in 2003-2004. In Kampot Province, where catch of Indo-Pacific mackerel is also reported, the high peak is in May, June, July and September, contributing about 63 % to the total pelagic catch as of 2004.

In Thailand, the fishing ground of Indo-Pacific mackerel is along the west coast of upper part of the Gulf of Thailand. In Malaysia, the catch of the Indo-Pacific mackerel in Tok Bali and Kuantan in 2005 accounted for 3 % and 1 %, respectively, to the total fisheries production of these States. In Viet Nam in 2003, the catch of Indo-Pacific mackerel from Ben Tre Province contributed 4.4 % to the total fisheries production of the Province.

Although Indo-Pacific mackerel is one of the major commercially-important species in the GoT, its production has been reported to be declining because of overfishing by the mackerel gill net, encircling gill net, purse seine, and pair trawl. The high fishing pressure had prompted the countries bordering the GoT to adopt conservation measures for the Indo-Pacific mackerel (*Rastrelliger brachysoma*), which is a very popular pelagic species in these countries.

Management of the Indo-Pacific Resources in the Gulf of Thailand Sub-region

In an effort to address the aforementioned concerns, the SEAFDEC-Sweden Project supported the GoT countries, *i.e.* Cambodia, Malaysia, Thailand, and Viet Nam, to embark on series of consultations to discuss the management of transboundary species towards the sustainability of the fishery resources. During the Fifth Meeting of Gulf of Thailand Sub-region in 2015 (SEAFDEC, 2017a), the GoT countries agreed to focus on target species, namely: anchovies, Indo-Pacific mackerel and blue swimming crab (also known as AIB species) and to

Table 1. Total production of short mackerel in Southeast Asia (in metric tons)

	2012	2013	2014	2015	2016
Indonesia (57) ^a	96,981	96,181	98,398	99,370	98,193
Indonesia (71) ^b	169,377	143,035	171,013	172,170	184,913
Philippines (71)	46,572	43,180	39,602	38,881	38,339
Thailand (57) ^c	14,196	20,593	25,507	16,851	4,463
Thailand (71) ^c	125,619	115,471	116,936	53,452	26,657
Production of short mackerel of Southeast Asia	452,745	418,460	451,456	380,724	352,565
Production of short mackerel of GoT	139,815	135,280	142,443	70,303	31,120
Production of all mackerels of Southeast Asia	1,018,026	1,080,358	1,063,810	1,034,974	874,770
Total: marine capture fisheries production of Southeast Asia	15,478,831	16,137,163	16,583,626	16,762,392	17,027,312

^a Fishing Area 57 includes: marine fishing areas of Myanmar, Thailand (Indian Ocean), Malaysia (West Coast of Peninsular Malaysia), Indonesia (Malacca Strait), Indonesia (West Sumatra and South Java), Indonesia (Bali-Nusa Tenggara)

^b Fishing Area 71 includes: Gulf of Thailand, marine fishing areas of Cambodia, Southwest and Southeast Viet Nam, East Coast of Peninsular Malaysia, Sarawak, Sabah, Singapore, Brunei Darussalam, Philippines (Luzon, Visayas, Mindanao), Indonesia (East Sumatra, North Java, Bali-Nusa Tenggara, South-West Kalimantan, South Sulawesi, North Sulawesi, Maluku-Papua)

^c Reported by Thailand as *Rastrelliger spp.* although classified as *Rastrelliger brachysoma* (Indo-Pacific mackerel)
Source: SEAFDEC (2014; 2015; 2017e; 2017f; 2018a)

immediately start working on the formulation of management actions for the Indo-Pacific mackerel including improvement of data collection to support long-term fisheries management. This led to the promotion of management measures for the Indo-Pacific mackerel in the GoT countries which comprises the implementation of closed season and closed area from 1 June to 31 July of every year, and the enforcement of regulations prohibiting the use of some commercial gears during the closed season and protecting the nursery grounds of the Indo-Pacific mackerel.

Moreover, during the subsequent Experts Group Meeting for Stock Status and Geographical Distribution of AIB Species in the GoT in 2016 (SEAFDEC, 2017b), it was agreed that study on the Indo-Pacific mackerel stock in the GoT should be pursued. This led to the recommendation that DNA studies on the stock structure of the Indo-Pacific mackerel in the GoT sub-region should be carried out, specifically to determine the stock population of Indo-Pacific mackerel in the GoT and identify the major populations that contribute to the total production of Indo-Pacific mackerel in the GoT Sub-region (SEAFDEC, 2017c).

DNA Studies on Stock Structure of Indo-Pacific Mackerel in the Gulf of Thailand

The Technical Meeting on Planning for Development of Stock Study for Anchovies, Indo-Pacific Mackerel and Blue Swimming Crab (AIB Species) in the Gulf of Thailand on 7-8 February 2017 in Bangkok (SEAFDEC, 2017c), identified the priority activities and information needs for AIB species management, and discussed the indications that there could be three or possibly four stocks of Indo-Pacific mackerel in the Gulf of Thailand. During the subsequent consultations among GoT countries in 2018, it was agreed that DNA collection and analysis for Indo-Pacific mackerel in the GoT should be pursued to better understand the stock status in Cambodia, Viet Nam, Thailand, and Malaysia.

In 2018, tissue samples of the Indo-Pacific mackerel were collected from four main spawning grounds in Thailand (Trat, Samut Songkhram, Prachuap Khiri Khan, Surat Thani), Pattani (Thailand), Cambodia, Malaysia, and Viet Nam. The results of the DNA analysis which were presented during the Gulf of Thailand Technical Meeting on Management of Transboundary Species: Indo-Pacific Mackerel on 19-20 December 2018 in Bangkok, Thailand, could serve as inputs for the proposed development of the draft regional action plan for the sustainable management of the Indo-Pacific mackerel in the Gulf of Thailand Sub-region. The Technical Meeting (SEAFDEC, 2018b) also came up with the recommendations and follow-up actions and needs towards the development of the sub-regional transboundary species management plan for Indo-Pacific mackerel (**Box 1**).

Results of DNA studies and data collection

Based on 436 samples collected monthly from Thailand, Cambodia, Malaysia, and Viet Nam, results of the analysis indicated that there could be different populations of Indo-Pacific mackerel in the Gulf of Thailand (SEAFDEC, 2018b, Kongseng S., *et al*, 2020). Specifically, the populations in Thailand were

found to be genetically different from each other at moderate levels, while the populations in Cambodia, Malaysia, Viet Nam, and Pattani (Thailand) showed to be genetically different from each other at low levels. Moreover, while the populations in Cambodia and Viet Nam could not be clearly separated genetically, but in view of the close geographical distance between the sampling localities, the results revealed that the mackerel population from Malaysia was genetically close to the mackerel from Pattani (Thailand). The aforementioned findings led to the recommendation for the conduct of genetic Mixed-Stock Analysis (MSA) of the Indo-Pacific mackerel in the Gulf of Thailand which could build upon the results of the Genetic Mixed-stock Analysis for Short Mackerel in the Upper Gulf of Thailand conducted from 2014-2016 (SEAFDEC, 2019c).

Considering the baseline populations of the Indo-Pacific mackerel in four major spawning grounds in the GoT (**Figure 4**), and the gene flow pattern of the Indo-Pacific mackerel in the waters of Thailand (**Figure 5**), there is the possibility that the same stock of mackerel is utilized by some countries in the GoT. This is based on results of genetic studies to determine the baseline

Box 1. Recommendations and follow-up actions and needs towards the development of the sub-regional transboundary species management plan for Indo-Pacific mackerel	
Recommendations	Follow up Actions
Mixed Stock Analysis (MSA) of Indo-Pacific mackerel populations in Cambodia, Malaysia, and Viet Nam	<ul style="list-style-type: none"> For discussion with the Fishery <i>Refugia</i> Project on the possibility of accommodating the activity in their workplan considering that the SEAFDEC-Sweden Project is already completed
Monitoring of tidal change, sea surface temperature, larval transport in the GoT	<ul style="list-style-type: none"> Consultation with GoT countries on the possibility of installing data logger in safe place of GoT countries or establish collaborative research on the aspect with the academic institutions
Simulation of chlorophyll-a, current, temperature, etc.	<ul style="list-style-type: none"> Strengthening of coordination and collaboration with GoT countries under the Fishery <i>Refugia</i> Project
Conduct of biological and physical studies in the GoT	<ul style="list-style-type: none"> Following-up progress and development with SWG physical oceanography and fish larvae expert of the JTF Project Establishing the hotspots of eggs and larvae in GoT (by referring to results of studies carried out by the M.V. SEAFDEC 2)
Continue stock assessment	<ul style="list-style-type: none"> Strengthening coordination with SWG (ASEAN-SEAFDEC) to carry out stock assessment through: conduct of population stock in the GoT; collect total landings; carry out MSA; and prioritization of the most important genetic stock
Establishment of database	<ul style="list-style-type: none"> Include all important data/information for management Establishment of Specialists Group

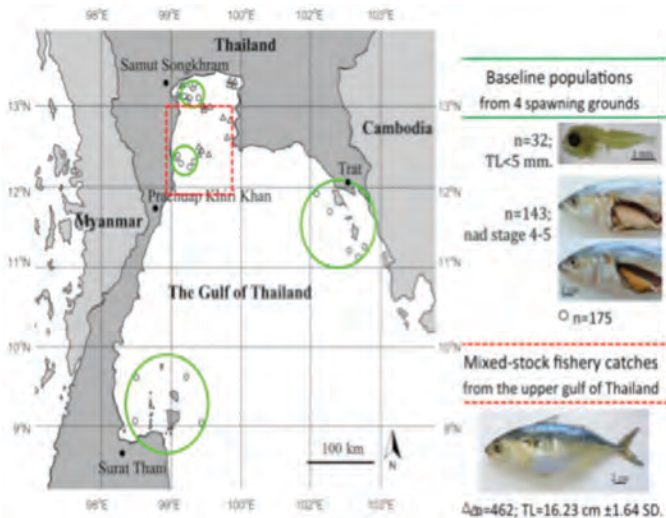


Figure 4. Baseline populations of Indo-Pacific mackerel in four major fishing grounds in the Gulf of Thailand

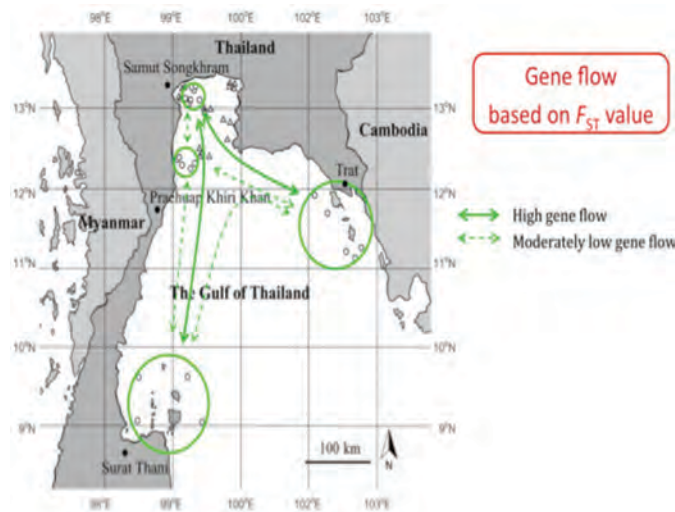


Figure 5. Gene flow of the Indo-Pacific mackerel in the Gulf of Thailand

populations, which suggested that there are possibly four (4) different populations in the GoT, namely from those from i) Trat, ii) Samut Songkhram, iii) Prachuap Khiri Khan, and iv) Surat Thani, and that the stocks between Trat and Samut Songkhram, Surat Thani and Samut Songkhram do migrate although little movement had been observed for the stocks between Trat and Prachuap Khiri Khan, and Surat Thani and Prachuap Khiri Khan.

More specifically, the genetic mixed-stock analysis for the short mackerel in the Upper Gulf of Thailand made use of samples collected from spawning grounds in Samut Songkhram, Prachuap Khiri Khan, Surat Thani, and Trat to identify the major populations contributing to the fish catch in the Upper Gulf using DNA information. Results showed that the population of short mackerel from Samut Songkhram has been the major contributor to the total catch of short mackerel in the Upper GoT. The populations from Trat and Surat comprise the second and third large contributor and also provide gene flow to the Samut Songkhram population (Figure 6). The population from Prachuap Khiri Khan has been the smallest contributor and has low gene flow to the other spawning areas.

Meanwhile, the results of the mixed-stock analysis (MSA) also showed that population of major, second and third contributors had high impact to the fishery catch in the upper GoT while the smallest contributor had low impact (Figure 6). Moreover, the nearshore waters of Prachuap Khiri Khan has been identified as the spawning ground for its local population while the offshore area is the migratory route for the populations from Samut Songkhram and SuratThani.

Many research studies had been conducted to understand the stock status, migration pattern and the spawning season of Indo-pacific mackerel resources in the Gulf of Thailand with the objective of achieving sustainability of the resources. Results of such stock studies that were presented during the 2018 Gulf of Thailand Technical Meeting (SEAFDEC, 2018b) are summarized in Box 2.

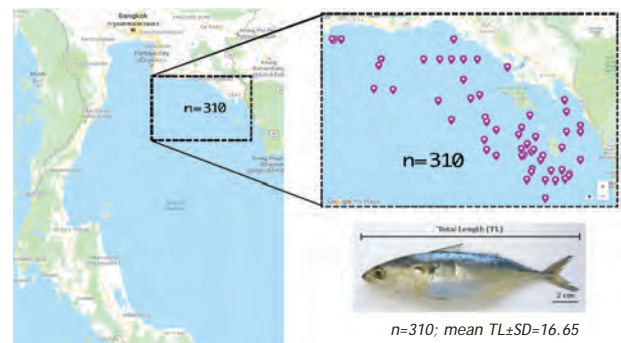


Figure 6. Mixed-stock analysis for the Indo-Pacific mackerel in the Gulf of Thailand

Way Forward

The Indo-Pacific mackerel is one of the important species in the Gulf of Thailand that should be managed for sustainable utilization. Several initiatives have already been done to realize the management of the species. In 2017, capacity building on stock assessment, species identification and genetic studies were conducted to enhance the capability of the human resources in the sub-region. SEAFDEC facilitated the compilation of the necessary information about the Indo-Pacific mackerel because of the insufficient information on its stock structure. In this regard, Malaysia and Thailand agreed to update their national initiatives on the management of transboundary/shared stocks (including Indo-Pacific mackerel). The countries also agreed to pursue exchange of data and establish MoU for the management of the mackerel resources in the Gulf of Thailand.

On the DNA analysis, Viet Nam recommended that sampling stations should cover more areas to obtain more information for all the countries involved. Cambodia, on the other hand pointed out that sampling should be done along the coastal areas of the provinces, although difficulties in implementing genetic studies maybe encountered due to the need for budget to continue the activity. In addition, it was suggested that a study on fish egg and larvae in the Gulf of Thailand should be conducted to provide a clear picture of the spawning and nursing ground of the species. In addition, it was also suggested that the results from DNA analysis

Study on Indo-Pacific Mackerel Resource in Relation to Sea Surface Environment in the Gulf of Thailand

The status of Indo-Pacific mackerel in the GoT in relation with sea surface environment was determined by looking at the changing population of the Indo-Pacific mackerel using satellite data. This involved examining the changes in the chlorophyll-a of the water surface, plankton, water quality, distribution of fish larvae, biological and ecological data of adult fish, and economic data. Results indicated that changes of the phytoplankton affected the distribution of fish larvae as it had some impacts on the optimum condition of water current in GoT, more particularly on the temperature (Figure 7, Figure 8). However, the area for fish larvae in the GoT should be identified through further research, as the results could be used to update the closed areas which might have to be shifted based on the data on the gonad development of female mackerel.

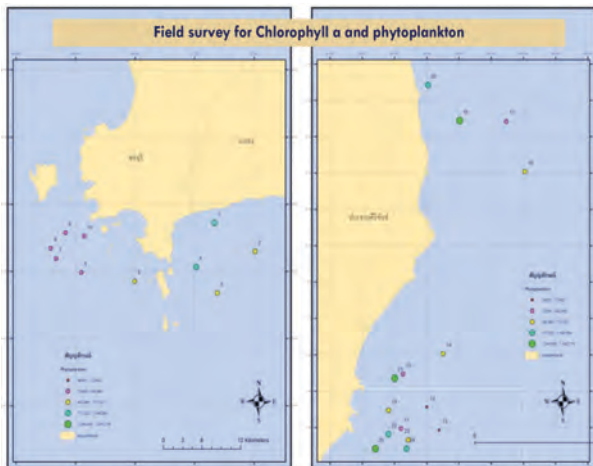


Figure 7. Sites of field surveys for chlorophyll-a and phytoplankton in the Gulf of Thailand

Source: Dr. Methee Kaewnern, Kasetsart University

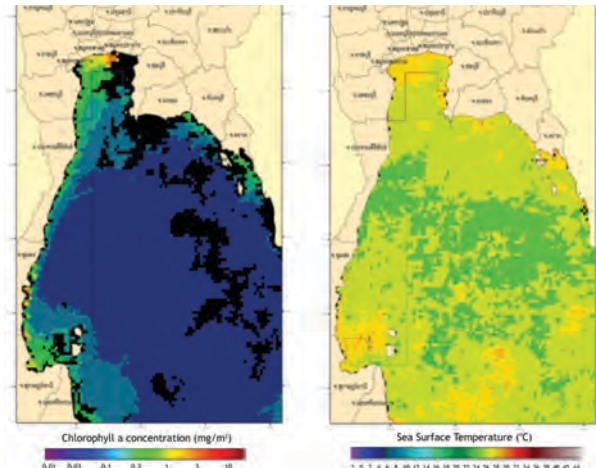


Figure 8. Chlorophyll-a (left) and sea surface temperature (right) in the Gulf of Thailand using satellite data

Age and Growth Determination of Indo-Pacific Mackerel Using Otolith Microstructure Technique

Otolith shape analysis technique which makes use of the otolith contour to classify the stock is considered more efficient than using morphological parameters. Firstly, the Otolith Microstructure Technique was used to determine the age and growth of Indo-Pacific mackerel. The research made use of two stocks (Gulf of Thailand and Andaman Sea) and considered the assumption that fish in different environments will have different growth pattern. Using t-test and multivariate analysis of variance, the results led to the conclusion that the sequence genetic identifier of the Andaman Sea stock was significantly higher than that of the Gulf of Thailand. Results also showed that the parameter of Von Bertalanffy Growth Function could be used to describe the growth rate in relation to the otolith size while the exponential model could be used to convert the total length to age, assuming that the fish continue to grow for infinitely long period of time. Secondly, the otolith microchemistry approach was used to classify the stock of short mackerel for the development of an effective regulation and management regime.

Stock Identification of Short Mackerel in the Gulf of Thailand by an Otolith Microchemistry Approach

An Otolith Microchemistry Approach is one of the methods used for stock identification of short mackerel in the Gulf of Thailand. This study is aimed at understanding the stock structure of *Rastrelliger brachysoma* in the GoT using otolith microchemistry as a classification method. The otolith was analyzed by extracting the microelement components such as lithium (Li), magnesium (Mg), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), strontium (Sr), barium (Ba), and uranium (U), and were normalized to calcium (Ca). For the analysis, MANOVA and Principal Component Analysis (PCA) were used to display the micro-chemical data of the sectioned otolith materials and detect the stock differentiations among the sampling sites and examine the relative importance of each variable, i.e. Linear Discriminate Function Analysis (LDFA) was used to classify individual fish with respect to their collection areas using micro-chemical values at the edge of the otolith sections and the whole otolith. The results showed that there are four (4) stocks of *R. brachysoma* in the Gulf of Thailand, i.e. Eastern, Upper, Central and Lower stocks. Members in each stock comprised individual fish from different origins of the larvae but grouped together, at least by 41 % (male) and 67 % (female) in their life span.

could be used as a scientific basis for *refugia* establishment and for coordination of management plans and measures. It was also proposed that the ASEAN Catch Documentation Scheme (ACDS) be established in the sub-region to have a compatible data scheme among GoT countries through the initiative of SEAFDEC. Moreover, as means of sharing information on transboundary species between the countries (especially between Thailand and Viet Nam), a formalized agreement on cooperation such as MoU, MoA or other format should be developed. High-level dialogue meeting was also encouraged to formally agree on the areas and objectives for cooperation.

As a means of managing transboundary species, the SEAFDEC and GoT countries have been conducting research activities in order to come up with an agreement on coordinated fisheries management measures. The DNA study for Indo-Pacific mackerel was aimed at understanding the stock structure in the sub-region and for the results to be used as a science based information in support of future management plans. Furthermore, development of joint management plan for Indo-Pacific mackerels in the GoT has been pursued to ensure the sustainability of the resources based on the available scientific evidence.

Acknowledgement

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