REPORT on

"Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia"

Southeast Asian Fisheries Development Center

REPORT

on the JAIF Project

“Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia”

Southeast Asian Fisheries Development Center

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Foreword

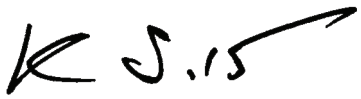
This final report contains the results of the activities of the project entitled ***"Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia"*** which was implemented by SEAFDEC with the support of JAIF (Japan ASEAN Integration Fund). The project period is two years between August 2017 and July 2019. The objective of the project is to strengthen the scheme in which ASEAN Member States (AMSs) manage tropical anguillid eel resources in Southeast Asia for sustainable use. The target countries of this project are six AMSs, namely Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam, which have fishery/aquaculture of tropical anguillid eels.

The activities of this project on tropical anguillid eels were to: a) survey their utilization; b) estimate eel stock abundance; c) describe eel genetic population structure; d) refine culture techniques to improve eel survival rate from glass eel to elver stages; and e) formulate resource management policies for AMSs. The results of project activities are reported in detail in this report.

Tropical anguillid eels are currently under discussion for regulation in CITES. Since 2009, the European eel *Anguilla anguilla* has been listed in Appendix II of CITES and was subjected to international trade restrictions. Tropical anguillid eels may also be subjected to CITES restrictions if resource abundance is at critically low levels.

It is envisioned that the findings and information from this report will help in the sustainable use and management of tropical anguillid eels in Southeast Asia.

Thank you for the cooperation of all the people involved in the project.



Kom Silapajarn, Ph.D.
Secretary-General
SEAFDEC

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List of Acronyms

AD	Ano-dorsal length
AMOVA	Analysis of Molecular Variance
AMSs	ASEAN Member States
AngHV1	Anguillid Herpesvirus 1
AQD	Aquaculture Department
ART	Artemia
ASEAN	Association of Southeast Asian Nations
ASWGFi	ASEAN Sectoral Working Group on Fisheries
BFAR	Bureau of Fisheries and Aquatic Resources (in the Philippines)
BW	Body Weight
CD	Commercial Diet
CFU	Colony Forming Units
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPUE	Catch per Unit Effort
DF	Dry Feeds
DFISH	Directorate of Fisheries
EVA	Eel Virus American
EVE	Eel Virus European
EVEX	Eel Virus European X
FAO	Fisheries Administrative Order
FAO	Food and Agricullture Organization of the United Nations
FCG/ASSP	Fisheries Consultative Group/ ASEAN SEAFDEC Strategic Partnership
FD	Formulated Diet
FiA	Fisheries Administration
FMP	Fisheries Management Plan
HS-code	Harmonized System Code
IFRDMD	Inland Fishery Resources Development and Management Department
IFReDI	Inland Fisheries Research and Development Institute
IUCN	International Union for Conservation of Nature
JAIF	Japan-ASEAN Integration Fund
LF	Live Feed
MAFF	Ministry of Agriculture, Forestry and Fisheries
MAFReDI	Marine Fisheries Research and Development
MF	Moist Feed

NDF	Non-detrimental finding
NFRDI	National Fisheries Research and Development Institute
NPOA	National Plan of Action
PCR	Polymerase Chain Reactions
PD	Paste Diet
TL	Total Length
SEAFDEC	Southeast Asian Fisheries Development Center
SMF	Semi-moist Feed
TUB	Tubifex
UN	United Nations
UN Comtrade	a pseudonym for United Nations International Trade Statistics Database
ZSL	Zoological Society of London

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Executive summary

The objective of the JAIF project "Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia" is to strengthen the resource management framework for sustainable tropical anguillid eel fisheries in ASEAN Member States (AMSs).

The activities of this project on tropical anguillid eels are to: a) survey the utilization; b) estimate abundance of eel stocks; c) describe the genetic population structure; d) refine culture techniques to improve the survival rate from glass eel to elver; and e) formulate resource management policies for AMSs. The accomplishments of this project are described below.

1. Utilization of tropical anguillid eel resources in Southeast Asia (Baseline survey)

Baseline surveys were conducted to collect information on the use of tropical anguillid eel resources in AMSs that have eel fishery/aquaculture. Six ASEAN Member States, namely Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam have tropical anguillid eel fishery/farming activities. In many ASEAN countries, there is no local statistical data that classify species of eels in the catch and farm production volume. Therefore, in the baseline survey, information on catch/farm production volume was collected from eel consolidators and eel farmers in each country through interviews. *Anguilla bicolor bicolor, A. marmorata*, and *A. bicolor pacifica* were the main species caught although occasionally *A. bengalesis* and *A. luzonensis* were also noted in the catches. Glass eels and elvers were shipped to eel farmers, while yellow eels were shipped to local and overseas markets. The distribution channel for eels involves consolidators because of the need to transport/trade eels in a living state. Therefore, distribution structures concentrated around consolidators. This suggests that collection of eel catch data was relatively easier than that of other fish species which had complex distribution channels. Through baseline surveys, key informants in each of the countries were identified and a data collection scheme for catch/farm production was established. Basic information on fisheries characteristics for tropical anguillid eels in ASEAN Member States was described and this would be useful for future stock assessment and management.

2. Trends in resources stock (Regular survey)

Catch data were collected from consolidators of glass eel from several countries to investigate trends of the abundance of tropical eel resources. In particular, catch and fishing effort data were collected from sites in Indonesia and Philippines, and the trend of tropical eel stock was analyzed by observing the change in catch per unit fishing effort. Collection of catch data, including long-term fishing effort data, is usually required in analyzing trends in the status of resources. Analysis of the five-year data collected through the regular survey does not clearly indicate a trend suggesting a decline in abundance based on catch per unit effort data.

3. Population genetics of tropical eels

Samples of *Anguilla bicolor bicolor* and *A. bicolor pacifica* were collected from Indonesia, Philippines, Viet Nam and Myanmar. The purpose of this DNA analysis is to determine the population genetic structure of the aforementioned eel species and provide supportive evidence for appropriate and sustainable resource management recommendations. This study found the evidence of genetic differences among samples coming from the three locations, indicating that these samples may belong to genetically different groups of *A. bicolor pacifica* and *A. bicolor bicolor*. In addition to the high genetic divergence among the samples, the study showed very high genetic diversity within the samples which was indicative that these subspecies were highly abundant.

4. Aquaculture technique to improve survival rate from glass eel to elver (Survival rate survey)

Interviews with eel farmers in Philippines and Viet Nam were conducted and data on eel farm practices were collected from which survival rates during the growth from glass eel to elver were noted to have improved.

In addition, pathogen occurrence in eel culture facilities have been documented and preventive measures as well as possible treatment were suggested. Effective schemes (using various diets) to improve survival rates in weaning glass eels were recommended based on the results of nursery trials. A manual on eel nursery operations summarizing techniques for improving survival rate among other protocol refinements was prepared and distributed to eel farmers.

5. International trade database analysis

The current status of international trade of tropical anguillid eels in the ASEAN countries was examined using UN Comtrade data.

According to the UN Comtrade data, a number of anguillid eels from ASEAN countries such as Indonesia, Myanmar and Philippines have been exported to other countries within as well as outside of Southeast Asia. However, it was found that the numbers were quite different compared to the catch data of each country according to the baseline survey results of this project. One possible explanation was that the quantities of these exports might include other families of eels such as swamp eel and snake eel.

It became clear that UN Comtrade data did not accurately reflect the quantity of import and export of anguillid eel in southeast Asia. It was suggested that the AMSs should develop a reporting system specific to anguillid eels to the UN Comtrade. In addition to that, since the international organizations such as CITES and IUCN have used the volume data of the international trades, including UN Comtrade, as one of the pertinent basis for regulating international trade, the need for accurate reporting in each of the AMSs is urgent.

6. Resources management measure (Policy guidelines for regional conservation and management of tropical anguillid eels in ASEAN Member States)

In order to sustainably use tropical anguilid eel resources, it is necessary for ASEAN countries to adopt effective resource management policies. In this project, policy guidelines and regulation/management measure of tropical anguillid eels in Southeast Asia were formulated and recommended. The guidelines were prepared based on the discussions of ASEAN countries, submitted to the ASEAN Secretariat and will be endorsed as a common policy of ASEAN.

1. Introduction

1.1 Project title

Enhancing Sustainable Utilization and Management scheme of Tropical Anguillid Eel Resources in Southeast Asia

1.2 Project period

2 years (August 2017 – July 2019)

1.3 Background and Justification

Tropical anguillid eels are drawing more attention to compensate for the shortage in the supply of eel seeds for aquaculture (eel farming) in recent years. However, there are no historical records on the status of tropical anguillid eel resources, catch statistics (especially on juveniles for seeds), and eel farming production in Southeast Asia.

This project will strengthen the statistical data collection system and clarify the basic resource condition of tropical anguillid eels. Also, it will attempt to improve survival rate of juvenile eels under aquaculture in ASEAN Member States (AMSs) by refining eel aquaculture technologies.

The overall objective of this project is to strengthen and consolidate eel resource management frameworks for sustainable provision of eel products and eel capture fisheries/eel farming in the AMSs. The overall goal of this project is to promote sustainable eel fishery in AMSs.

The project implementation period for the Southeast Asian Fisheries Development Center (SEAFDEC) is two years.

(a) Problem Analysis

Eel farming is reliant on wild-caught anguillid eels such as glass eels, elvers and yellow eels. Because of the rapid decrease of juveniles of temperate anguillid eels such as the Japanese eel (*A. japonica*), the European eel (*A. anguilla*) and the American eel (*A. rostrata*) in recent years, tropical anguillid eels have gained some attention as a consequence to the lack of eel seeds for eel farming. However, there are no historical records on the status of tropical anguillid eel resources, catch statistics (especially on juveniles for seeds), and eel farming production in Southeast Asia. Tropical anguillid eel resources have much potential as one of the favorable target species for commercial freshwater aquaculture through appropriate resource management for sustainable use. SEAFDEC held the Regional Workshop on *"Enhancement of sustainability of catadromous eel resources in Southeast Asia"* on 27-29 April 2016, to clarify the technical issues and confirm the need for

sustainable utilization of eel resources. In the workshop, it was confirmed that there were not enough statistical records on the status of exploited tropical anguillid eel resources, fisheries and eel farming production and no known effective measure for appropriate resource management have been carried out in the AMSs.

Hence as a consequence, it is imperative that tropical anguillid eel resources are properly conserved and managed to prevent overexploitation and listing under CITES appendices.

This project therefore fully aligns itself with the initiatives to "increase fishery/aquaculture production" and "enable sustainable production" referred in paragraph 57 of the "ASEAN Economic Community Blueprint 2025".

Finally, this project recognizes the need for technical advice and support from leading scientists/experts on Japanese eel fisheries/aquaculture to lay the groundwork in establishing cooperation among AMSs where eel fisheries exist.

(b) Regionality

The demands for anguillid eel products are expected to expand significantly in Japan, China and South Korea as well as within the AMSs. Since the main tropical anguillid eel producing countries are found in the AMSs, appropriate utilization of anguillid eel resources is required in this region.

(c) Participation

AMSs (Government officers working in both the capture fisheries and aquaculture departments, Fisheries bureau representatives who manage eel resources and develop national eel industry plans, scientists/researchers from the fisheries research agencies/institutes and universities, eel fishers/farmers)

SEAFDEC Secretariat, Inland Fishery Resources Development and Management Department (IFRDMD), and Aquaculture Department (AQD)

(d) Beneficiaries

Direct/immediate beneficiaries are eel fishers/farmers and government officers in AMSs Indirect beneficiaries are both the eel producing and eel consuming countries.

(e) Project History

The Regional Workshop on "Enhancement of sustainability of catadromous eel resources in Southeast Asia" (SEAFDEC) was held on 27-29 April 2016 to clarify the technical issues and confirm the need for sustainable utilization of eel resources. It was also clarified that there were not enough statistical records on the status of exploited tropical anguillid eel resources, fisheries

and eel farming production, apart from the lack of effective measures for appropriate eel resource management in the AMSs.

1.4 Objective

Resource management framework* for sustainable anguillid eel fisheries in AMSs is consolidated.

* *"Framework" is a scheme consisting of experts, technologies/methodologies and rules essential for sustainable eel fisheries/aquaculture.*

1.5 Expected Outputs, Indicators and Activities

Output 1 : The statistical data collection system is strengthened in AMSs to better understand the present status and past/future trends on tropical anguillid eels at each species and stage.

Indicator 1 : Number of qualified staff for statistical data collection has increased in each AMSs.

Activity 1-1: Strengthening the statistical information collection system on juvenile anguillid eel fishery with indices of fishing efforts

1-1-1) To study and analyze the methods and processes for collecting statistical information on juvenile anguillid eel fishery with indices of fishing efforts.

- To grasp the major fishing grounds of juvenile anguillid eels (glass eels and elvers).
- To investigate whether catch statistics on juvenile anguillid eels from major fishing grounds exist.
- To understand the commodity value chains of juvenile anguillid eels traded as seeds for eel farming.
- To find out the appropriate points for surveying/checking the quantity of daily/weekly/monthly catch of juvenile anguillid eels (at each stage) with fishing effort indices from the commodity chains of juvenile anguillid eels then collect an independent data on eel catch statistics (apart from the official catch statistics) if the official catch statistics are already available.
- To verify the accuracy of the existing catch statistics and the appropriateness of the contents/items of the data/information on catch of juvenile anguillid eels as well as the corresponding fishing effort indices; in obtaining such information, the need for additional data for cross-checking and monitoring the trend of both catch and efforts (to estimate the long-term chronological trend of Catch per Unit Effort (CPUE)) is likewise considered.

- To clarify the time series of the consecutive catch statistics of juvenile anguillid eels with appropriate fishing effort indices at each major eel seed fishing grounds.
- To analyze the trend of catch of juvenile anguillid eels and CPUE at each major fishing ground from the time series of catch statistics with fishing efforts, and evaluate the present status and trend of anguillid eel resources for each species at each fishing ground.

1-1-2) To recommend the appropriate statistical data collecting methods with the list of required items of the catch statistics of juvenile anguillid eels (including the indices of fishing effort) at each major fishing ground and/or country that has (or could have the potential of starting) juvenile anguillid eel fishery.

1-1-3) To support the national/local governments and/or fishers' committees to strengthen the system for statistical information collection with fishing effort indices at each country/fishing ground where juvenile anguillid eels inhabit.

Activity 1-2 : Strengthening the statistical information collection system on yellow and silver eel fishery with indices of fishing efforts

1-2-1) To study and analyze the methods and processes for collecting statistical information on yellow and silver eel fishery with indices of fishing efforts.

- To determine the major fishing grounds of immature/mature anguillid eels (yellow eel and silver eel). The information gathered should ideally contain data on anguillid eels used both as seeds for culture and as adults traded for consumption.
- To investigate whether or not any catch statistics on yellow/silver eels have been collected in the major fishing grounds.
- To have a grasp of the commodity chains for yellow/silver eels.
- To monitor the appropriate points for surveying/checking the quantity of daily/weekly/monthly catches of eels at each stage (yellow/silver eels) with the fishing effort indices from the commodity chains of yellow/silver eels then collect an independent data on catch statistics (apart from the official catch statistics), if official catch statistics are already available.

- To confirm as to whether catch statistics information on other species such as rice-paddy eels have been filtered out of the tropical anguillid data which should cover mainly anguillid eels.
- To verify the time series data on consecutive catch statistics for yellow and silver eels, together with appropriate fishing effort indices at each major fishing ground.
- To analyze the trend of yellow and silver eel catch and CPUE at each major fishing ground from the time series of catch statistics with fishing efforts and evaluate the present situation and trend of anguillid eel resources at each area and species.

1-2-2) To recommend the appropriate statistical information collecting methods with the list of required contents/items of the catch statistics of yellow/ silver eel (including the indices of fishing effort) at each major fishing ground and/or country that has (or may have the potential of starting) anguillid eel fishery.

1-2-3) To support the national/local governments and/or fishers' committees to strengthen the present system for statistical information collection with fishing effort indices at each country/fishing ground of yellow/silver eels.

Activity 1-3 : Strengthening the statistical information collection system on anguillid eel farming production for each species

1-3-1) To study and analyze the methods and processes for collecting statistical information on eel farming/production.

- To investigate whether statistics on eel farming production are available in each country.
- To check the accuracy of the statistics of eel production from eel farming, such as coverage of data collection at each anguillid eel species or not, checking the possibility of inclusion of other species like rice-paddy eel.

1-3-2) To urge the national/local governments and/or eel farmers' committees to establish the standard system for collecting/summarizing the statistics of eel production from eel farming at each species.

Activity 1-4 : Developing the decisive method for of accurate species identification of juvenile anguillid eels using DNA fingerprint techniques

1-4-1) To analyze the present situation of the studies on species identification of tropical anguillid eels in Southeast Asia.

- To assess/review scientific methods of identifying tropical anguillid eels at the glass eel stage using morphological, meristic and DNA-based genetic tools, examine the effectiveness of each technique and determine the need if any, to develop a standard, more practical yet accurate species identification method.
- To consider the appropriate measures/methods to obtain standard results among the scientists who handle tropical anguillid eels, and to develop the survey design of gathering juvenile anguillid eels (glass eel and elver) from the major fishing grounds for collecting eel seeds among the ASEAN Member States, with careful consideration of any limitations/ laws to regulate the handling of specimen and acceptance of foreign scientists at each AMSs.

1-4-2) To collect juvenile anguillid eel samples for analyses by DNA technology.

- To collect juvenile anguillid eels from the major eel seed fishing grounds in Southeast Asia as a specimen for analyses by DNA technology with support from DoFs of AMSs and SEAFDEC.
- To analyze the specimens by DNA technology then summarize the results into the (monthly/seasonal/annual) trends of species composition at each sampling site.

1-4-3) To estimate the actual quantities and trends of eel seeds catch at each species using the species composition ratio applying into the catch statistics of eel seeds.

Output 2 : Tropical anguillid eel aquaculture technologies are improved in AMSs

Indicator 1 : Main factors that cause or lead to poor survival rate of juvenile eels are identified and information are consolidated

Indicator 2 : Improved technologies for higher survival of eel juveniles are identified.

Indicator 3 : A manual is developed to propose improved eel farming technologies.

Indicator 4 : Staff in charge of eel aquaculture of all AMSs understand the technologies to improve survival rate of juvenile anguillid eels.

Activity 2-1 : To collect the data of survival rate of juvenile anguillid eels (from glass eel to elver stage) in the eel farms in various places in AMSs, with the additional information of species, source of seeds, handling methods, transportation methods, water condition, feed for initial seedling, and the other possible causes/reasons that might affect the survival of juvenile anguillid eels

Activity 2-2 : To identify critical factors that contribute to high mortality rates of eel juveniles (glass eels) in captive rearing conditions (eel farm).

Activity 2-3 : To develop strategies (or protocols) for improved survival of eel juveniles under captive rearing conditions

Activity 2-4 : To publish a manual on improved protocols for farming of eels, including handling and transport from collection grounds to the farm for use of eel farmers, government extension workers and other stakeholders

Output 3 : Knowledge on the methodologies for collecting statistical information and tropical anguillid eel resource management is enhanced at the central and regional level.

Indicator 1 : Methodologies on statistical information collection of tropical anguillid eels are better understood by government officials of AMSs.

Indicator 2 : Knowledge on tropical anguillid eel resource management is enhanced among AMSs

Activity 3-1 : To summarize the results of the trend of tropical anguillid eel resources at each species and stage obtained through Activities 1 and 2 then evaluate the present situation and trend of anguillid eel resources in AMSs

Activity 3-2 : To hold three different kinds of meetings as follows:

1) one regional statistics workshop and one regional resource management seminar (both in Bangkok, Thailand) to disseminate the methodologies on statistical information gathering system on anguillid eels for the official staffs who shall supervise the eel collectors and eel farmers, and
2) two training activities in Japan (one on DNA analysis and the other on aquaculture) and three regional meetings (Viet Nam, Philippines and Indonesia) to share the information and knowledge obtained through the activities among AMSs, Japan and related organizations,
3) two assessment committee meetings (both in Bangkok) to confirm and evaluate the progress of the project activities.

2. Baseline survey

2.1 Objectives

To describe the status of the utilization of tropical anguillid eels in ASEAN Member States, the following are the two main purposes for the baseline survey:

1) To confirm the existence of eel capture fisheries and farming in ASEAN Member States.
2) To collect information on anguillid eel catch (especially for glass eel), fishing operations and farm production in each country where such activities exist.

2.2 Methods

When target countries of baseline survey are selected, SEAFDEC firstly conducted the questionnaire survey to all ASEAN Member States. Then the countries which replied that anguillid eel fishery and/or farming have been existing were selected. These countries were Cambodia, Indonesia, Myanmar, Philippines, Viet Nam, and Thailand.

Survey and interviews targeting national local government, consolidator (collector of wild eels caught by fishers), and farmers were conducted based on information on sites where eel fishing and culture activities are conducted. Interview questions are as follows.

Common items :

- Fishing ground
- Fishing season
- Fishing gear, operation time, and duration
- Number of fishers/farms
- Target species and life stage (i.e. glass eel, elver/yellow eel)
- Export and import

For consolidators :

- Annual volume collected from fishers by species, life stage, and fishing ground
- Information on suppliers (i.e. fishers or sub-consolidators)
- Information on customers (i.e. sales destination)

For farm respondent :

- Annual purchase volume by species, stage and fishing ground
- Annual farm production volume by species and life stage
- Information on suppliers (i.e. fishers or consolidators)
- Information on customers (i.e. sales destination)

Based on the results of interviews, we described the characteristics of capture fishery, farming, and international trade of anguillid eels for each country.

2.3 Results

A total of 33 baseline surveys were conducted in this project and the summary of the results for each country are tabulated. We did not discriminate/identify between *A. bicolor pacifica* and *A. bicolor bicolor* because of the difficulty of identification based on morphological characteristics, thus describing them collectively as *A. bicolor* in this section. The list of baseline surveys is shown in Appendix 1.

Cambodia

Two (2) baseline surveys were conducted in 2017 and 2019 and we found that there was no tropical anguillid eel fishery and only one eel farm in Cambodia.

The eel farm is located in Stueng Trang District in Kampong Cham Province. This farm purchased elvers of *A. bicolor* (70%) and *A. marmorata* (30%) from Philippines (100kg in 2017) and produced yellow eels of 500kg in 2017. The production was consumed domestically (a local restaurant) (Figure 1, 2). According to the results from the baseline survey in 2019, there was no production in 2018 from this farm because the restaurant closed.

Table 1. Summary of baseline survey results in Cambodia.

Catch Data	Glass	No fishery			
	Elver/yellow	No fishery			
Fishing Operation Data	No of fishers	None			
	Season	-			
	Fishing gear	-			
Production of Eel Farm	No of eel farms	1 in Kampong Cham			
	Purchase	**Total: 100kg in 2017** (source: 1 farm)			
		Elver	*A. bicolor* 70%	From Philippines	70kg (2017)
			A. marmorata 30%		30kg (2017)
	Production	**Total: 500kg in 2017** (source: 1 farm)			
		Yellow	*A. bicolor* 70%	350kg (2017)	
			A. marmorata 30%	150kg (2017)	
		Total: None in 2018 (source: 1 farm)			
	Sales destination	A local restaurant			
Import and Export	Import	**Total: 100kg in 2017** (source: 1 farm)			
		Elver	*A. bicolor* 70%	Philippines	70kg (2017)
			A. marmorata 30%	Philippines	30kg (2017)
	Export	None			

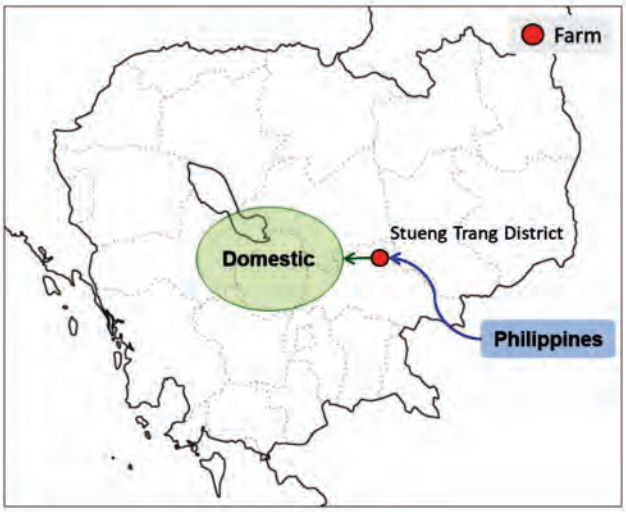

Figure 1. Map of main trade route of anguillid eels in Cambodia based on baseline survey

Figure 2. Schematic figure of main eel supply chain in Cambodia based on baseline survey

Indonesia

Eight (8) baseline surveys were conducted, and we found that there were five main fishing areas for eels in Indonesia: 1) Pelabuhan Ratu District in Sukabumi Regency, 2) Cilacap Regency, 3) Manado, 4) Palu and Poso Regency, and 5) Purworejo and Kebumen Regency (Figure 3).

In Sulawesi Island, both glass eel and elver/yellow eel fisheries were operated in Manado, Palu and Poso Regency. Dominant species was *A. marmorata*. In Palu and Poso Regency, annual catch in 2017 was 10t for glass eel and 42t for elver/yellow eel (source: local government, consolidator). In Manado, annual catch was 7.8t in 2017 for glass eel and 30.4t in 2016 for elver/yellow eel (source: local government, consolidator).

In Java Island, there were three main fishing grounds for glass eel and/or elver/yellow eels. The dominant species was *A. bicolor*. In Cilacap Regency, there were both glass eel and elver/yellow eel fisheries. Based on information from a local consolidator, the annual catch of elvers/yellow eels in 2015 was 76t and that of glass eels was under survey. In Purworejo and Kebumen Regency, annual catch in 2017 was 20kg for glass eels and 14t for elvers. In Pelabuhan Ratu District in Sukabumi Regency, only glass eel fisheries were operated, and annual catch was 1.5t on average.

Eleven (11) farms have been registered in Indonesia as of 2012 (1 in east Java and 10 in west Java). In addition, other farms were also noted in Kalimantan Island from the baseline survey in 2018. Farmed eels were exported to China, Japan, Hong Kong, Taiwan and other countries, and sold domestically.

For general eel supply chain in Indonesia, please see Honda *et al*, (2016).

Table 2. Summary of baseline survey results in Indonesia

Catch Data	Glass	**Total: >19t (2017)**		
		Mainly *A. marmorata*	**Sulawesi Island**	
			Manado	7.85t (2017)
			Poso Regency & Palu	10t (2017)
		Mainly *A. bicolor*	**Java**	
			Cilacap Regency	Under survey
			Purworejo Regency	20kg (2017)
			Sukabumi Regency	1.5t (~2017 Sep.)
	Elver/yellow	**Total: under survey**		
		Mainly *A. marmorata*	**Sulawesi Island**	
			Manado	30.4t (2016)
			Poso Regency & Palu	42.0t (2017)
		Mainly A. bicolor	**Java**	
			Cilacap Regency	76.2t (2015)
			Purworejo & Kebumen Regency	14t (2017)
Fishing Operation Data	No of fishers	**Total: under survey**		
		Glass	Manado	>50
			Sukabumi Regency	>1,000
		Glass, elver/yellow	Cilacap Regency	800-1,000
			Poso Regency	>200
	Season	**Total: under survey**		
		Glass	Manado	Under survey
			Sukabumi Regency	Peak in Sep-Dec
		Glass, elver/yellow	Cilacap Regency	Peak in Oct-Nov
			Poso Regency	Peak in Jul-Aug
	Fishing gear	Glass	Manado	Scoop net
			Sukabumi Regency	Scoop net
		Glass, elver/yellow	Cilacap Regency	Scoop net, PVC trap
			Poso Regency	Fyke net, barrier trap
Production of Eel Farm	No of eel farms	West Java	10 (officially registered as of 2012)	
		East Java	1 (officially registered as of 2012)	
		East Kalimantan	1 (surveyd in 2018)	
	Purchase	Under survey		
	Production	Yellow	*A. bicolor* 90% *A. marmorata* 10%	Under survey
	Sales destination	Export (China, Viet Nam, Hong Kong, Taiwan, Japan), domestic consumption		
Import and Export	Import	None		
	Export	China, Viet Nam, Hong Kong, Taiwan, Japan		

**Catch data were obtained from both baseline survey and regular survey.*

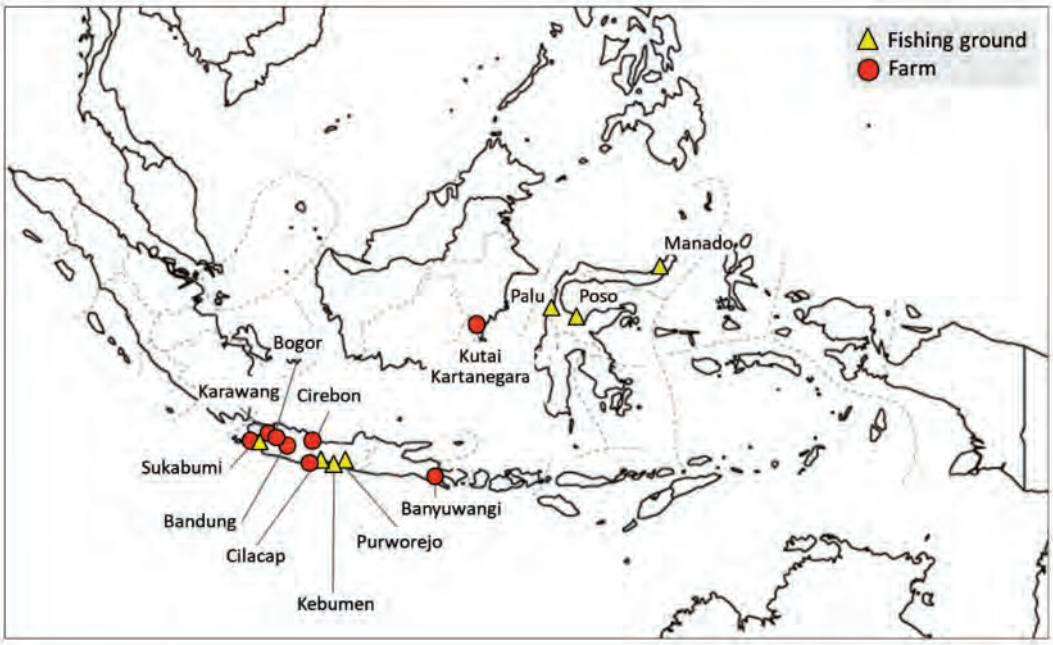

Figure 3. Locations of regency or city where fishing grounds and farms of anguillid eel exist in Indonesia based on baseline surveys

Myanmar

Six (6) baseline surveys were conducted in Myanmar. It was found that most eel fisheries and farming activities targeted swamp eels and snake eels and there were no specific fisherfolk catching tropical anguillid eels. Yellow eels were accidentally caught by stow net, crab trap, or longline hook in the rainy season. The dominant species of tropical anguillid eels was *A. bicolor*. Catch of yellow eel was approximately 12t in 2017 from the total of three divisions (Ayeyarwady, Yangon, and Tanintharyi Division) and more than 85% of the catch was from Ayeyarwady Division.

According to information from the government, there is one farm in Mandalay District in Mandalay Division. This farm purchased wild caught yellow eels smaller than 1kg and produced 15t of yellow eels bigger than 1kg of *A. bicolor* in 2017. They were sold for domestic consumption and to China. There was no farm production in 2018 because there was not collection of yellow eels smaller than 1kg.

Regarding international trade in Myanmar, there was no import in the past based on interviews. Farmed yellow eels were exported to China through the farm in Mandalay Division and some wild yellow eels caught in the central and southern part of Myanmar were directly exported to China.

In general, the main trade routes can be described by starting with yellow eels caught in Ayeawady, Yangon and Tanintharyi Division which were first sent to consolidators in Yangon and then divided into two size groups (Figure 4, 5). Yellow eels bigger than 1kg were sent for domestic consumption or exported to China. Yellow eels smaller than 1kg were sent to the farm in Mandalay Division, farmed to bigger than 1kg, and sold to the same destinations as that of the consolidator in Yangon.

Table 3. Summary of baseline survey results in Myanmar

Catch Data	Glass	**Total: >19t (2017)**		
		Mainly *A. marmorata*	**Sulawesi Island**	
			Manado	7.85t (2017)
			Poso Regency & Palu	10t (2017)
		Mainly *A. bicolor*	**Java**	
			Cilacap Regency	Under survey
			Purworejo Regency	20kg (2017)
			Sukabumi Regency	1.5t (~2017 Sep.)
	Elver/yellow	**Total: under survey**		
		Mainly *A. marmorata*	**Sulawesi Island**	
			Manado	30.4t (2016)
			Poso Regency & Palu	42.0t (2017)
		Mainly A. bicolor	**Java**	
			Cilacap Regency	76.2t (2015)
			Purworejo & Kebumen Regency	14t (2017)
Fishing Operation Data	No of fishers	**Total: under survey**		
		Glass	Manado	>50
			Sukabumi Regency	>1,000
		Glass, elver/yellow	Cilacap Regency	800-1,000
			Poso Regency	>200
	Season	**Total: under survey**		
		Glass	Manado	Under survey
			Sukabumi Regency	Peak in Sep-Dec
		Glass, elver/yellow	Cilacap Regency	Peak in Oct-Nov
			Poso Regency	Peak in Jul-Aug
	Fishing gear	Glass	Manado	Scoop net
			Sukabumi Regency	Scoop net
		Glass, elver/yellow	Cilacap Regency	Scoop net, PVC trap
			Poso Regency	Fyke net, barrier trap
Production of Eel Farm	No of eel farms	West Java	10 (officially registered as of 2012)	
		East Java	1 (officially registered as of 2012)	
		East Kalimantan	1 (surveyd in 2018)	
	Purchase	Under survey		
	Production	Yellow	*A. bicolor* 90% *A. marmorata* 10%	Under survey
	Sales destination	Export (China, Viet Nam, Hong Kong, Taiwan, Japan), domestic consumption		
Import and Export	Import	None		
	Export	China, Viet Nam, Hong Kong, Taiwan, Japan		

Figure 4. Map of main trade routes of anguillid eels in Myanmar based on baseline survey

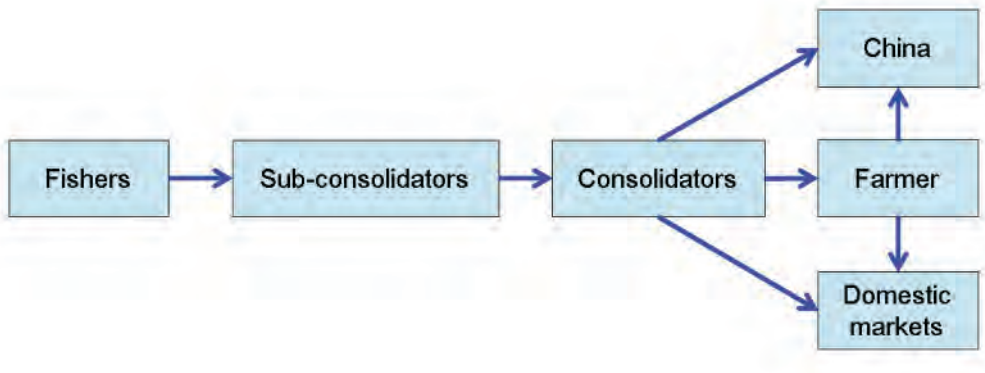

Figure 5. Schematic figure of main eel supply chain in Myanmar based on baseline survey

Philippines

Six (6) baseline surveys were conducted in Philippines and we learned that both glass eel and elver/yellow capture fisheries and farming activities were operated. Main fishing grounds were found in Aparri in northern Luzon Island and Cotabato City, General Santos and Davao City in Mindanao Island (Figure 6). The dominant species was *A. marmorata*.

The estimated total catch of glass eels in Philippines was 12t in 2017 and that of elvers/yellow eels was more than 0.6t. The number of fishers was more than 3,000 for glass eel and more than 400 for elver/yellow eel. Comparing the two islands, fishers in Mindanao Island (> 2,000 for glass eel, >300 for elver/yellow eel) were more than those in Luzon Island (>1,000 for glass eel, >100 for elver/yellow eel), and the catch in Mindanao Island (10t in 2017 for glass eel, >0.3t in 2017 for elver/yellow eel) was higher than that in Luzon Island (2t in 2017 for glass eel, 0.3t in 2017 for elver/yellow eel) accordingly.

It is important to note that, in 2012, the country reinstated the ban on the export of elvers with sizes of 15 cm or less by virtue of Fisheries Administrative Order (FAO) 242, Series of 2012, which significantly reduced the catch and export of anguillid eels in succeeding years.

A total of 28 farms have been registered in Philippines (16 farms in Luzon Island, 10 farms in Mindanao Island, and 2 farms in Visayas). Total farm production volume in Philippines was not available. Sales destinations from farms were mainly Japan, Korea, Taiwan and a few local markets. There was no import.

Table 4. Summary of baseline survey results in Philippines.

Catch Data	Glass	**Total: 12.5t (2017)**		
		A. marmorata 85-95% *A. bicolor* 10-15%	Luzon Is.	2.26t (2017) (source: survey data)
			Mindanao Is.	About 10.3t (2017) (source: official data)
	Elver/yellow	**Total: >0.64t (2017)**		
		A. marmorata 95% *A. bicolor* 5%	Luzon Is.	0.3t (2017)
			Mindanao Is.	>0.34t (2017)
Fishing Operation Data	No of fishers	Glass	**Total: >3,000**	
			Luzon Is.	>1,000
			Mindanao Is.	>2,000
		Elver/yellow	**Total: >400**	
			Luzon Is.	>100 (not only eels)
			Mindanao Is.	>300
	Season	Glass	**Whole: Peak in Apr-Aug**	
			Luzon Is.	Peak in Apr-Jul
			Mindanao Is.	Peak in Jun-Aug
		Elver/yellow	**Whole: Peak in Dec-Feb**	
			Luzon Is.	Jan-Feb
			Mindanao Is.	Dec-Feb
	Fishing gear	Glass	Luzon Is.	Fyke net, stow net
			Mindanao Is.	Fyke net, scoop net, push net
		Elver/yellow	Luzon Is.	Seine net
			Mindanao Is.	Bamboo trap, hook line, speargun
Production of Eel Farm	No of eel farms	**Total: 28**		
		Luzon Is.	16	
		Mindanao Is.	10	
		Visayas	2	
	Purchase	Glass	Luzon Is.	Under survey
			Mindanao Is.	Under survey
	Production	**Total: under survey**		
		Elver/yellow	*A. marmorata* 20% *A. bicolor* 80%	Mindanao Is.: under survey
				Luzon Is.: 20.23t (2017) (source: 7 farms)
	Sales destination	Mainly export (Japan, Korea, Taiwan), few local consumption		
Import and Export	Import	None		
	Export	*A. bicolor*	Japan, Korea, Taiwan	Under survey
		A. marmorata	Korea, China, Taiwan	Under survey

**Catch and farm production data were obtained from both baseline survey and regular survey.*

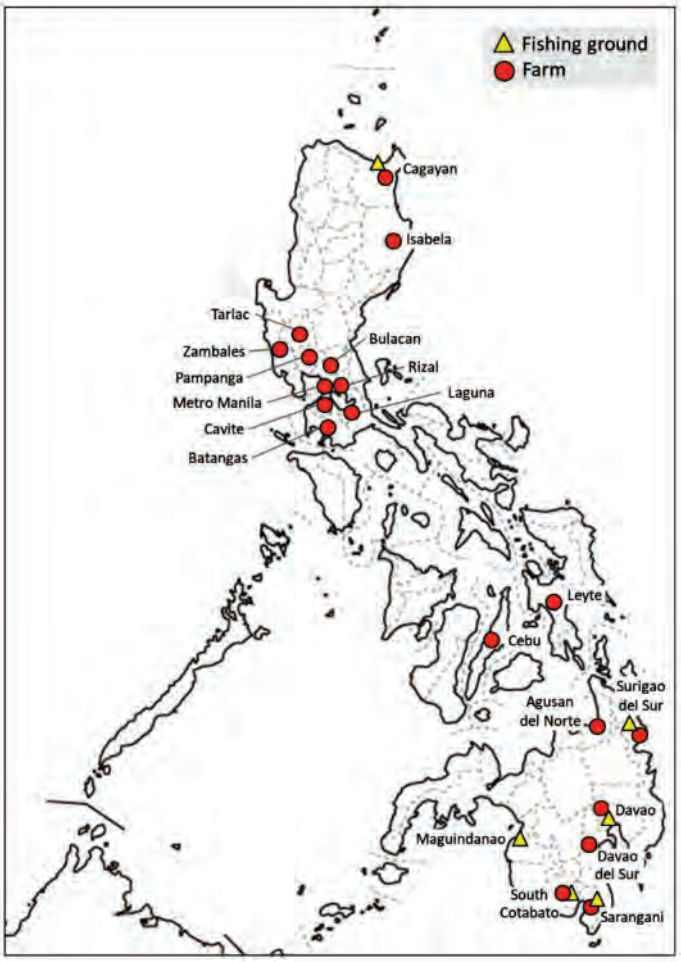

Figure 6. Locations of province where fishing grounds and farms of anguillid eel exist in Philippines based on baseline survey

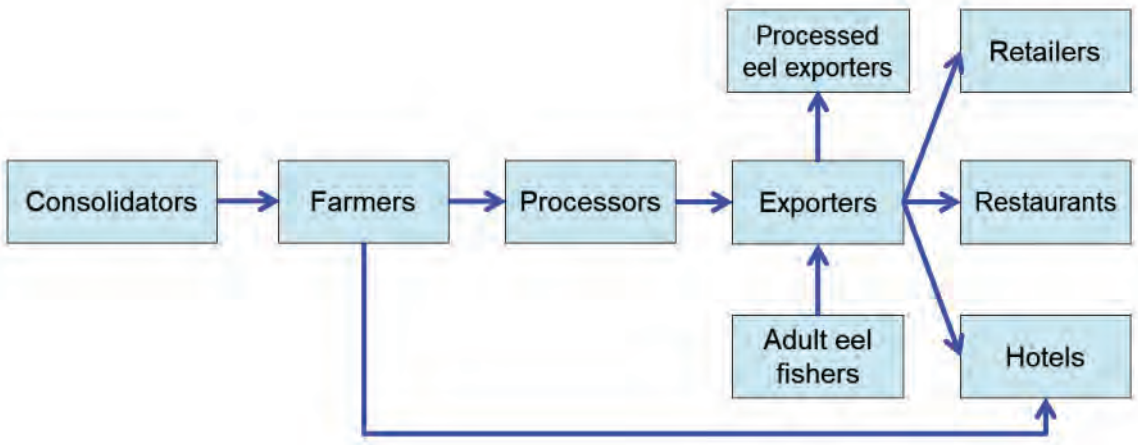

Figure 7. Schematic figure of main eel supply chain in Philippines based on baseline survey (personal communication)

Thailand

Five (5) baseline surveys were conducted in Thailand. It was found that there was no capture fishery catching mainly anguillid eels while one eel farm was noted to exist in Thailand.

According to consolidators, elvers/yellow eels of *A. bicolor* and *A. marmorata*/*A. bengalensis* were accidentally caught by trap in southern provinces of Thailand (Ranong, Phang Nga Phuket, Krabi, and Satun Province) between May and October. Catch volume was under survey.

There used to be three farms in Thailand before, however only one farm remained, which is located in Ranong Province. This farm purchased 700-900 kg/year of yellow eels (less than 1 kg/individual) caught in southern Thailand and from Myanmar. Production volume from this farm was 300-500 kg/year and it was consumed domestically. There was no export.

Main trade routes of anguillid eel in Thailand were as follows. Some of yellow eels caught in southern provinces and in Myanmar were sold to the farm in Ranong Province and farmed up to bigger than 1.5kg (Figure 8, 9). Farmed yellow eels were sent to trader(s) in Bangkok and consumed. There was also a trade route that wild caught yellow eels were directly sent for domestic consumption.

Table 5. Summary of baseline survey results in Thailand

Catch Data	Glass	No fishery			
	Elver/yellow	**Total: under survey**			
		A. bicolor		Ranong, Phang Nga, Phuket, Krabi, Satun Province	
		A. marmorata / *A. bengalensis*			
Fishing Operation Data	No of fishers	No specific fishers targeting Anguillid eel (only byatch)			
	Season	May-Oct			
	Fishing gear	Trap			
Production of Eel Farm	No of eel farms	1 in Ranong			
	Purchase	**Total: 700-900 kg/year** (source: 1 farm)			
		Yellow (400-1,000 g/ind)	*A. bicolor* 50% *A. marmorata* / *A. bengalensis*	From domestic catch	300-400 kg/year
				From Myanmar	400-500 kg/year
	Production	Yellow (1.5-2 kg/ind)	Anguilla spp.	300-500 kg/year	
	Sales destination	Domestic restaurants			
Import and Export	Import	**Total: 400-500 kg/year** (source: 1 farm)			
		Yellow	*A. bicolor* 50%	Myanmar	200-250 kg/year
			A. marmorata / *A. bengalensis* 50%	Myanmar	200-250 kg/year
	Export	None (source: 1 trader)			

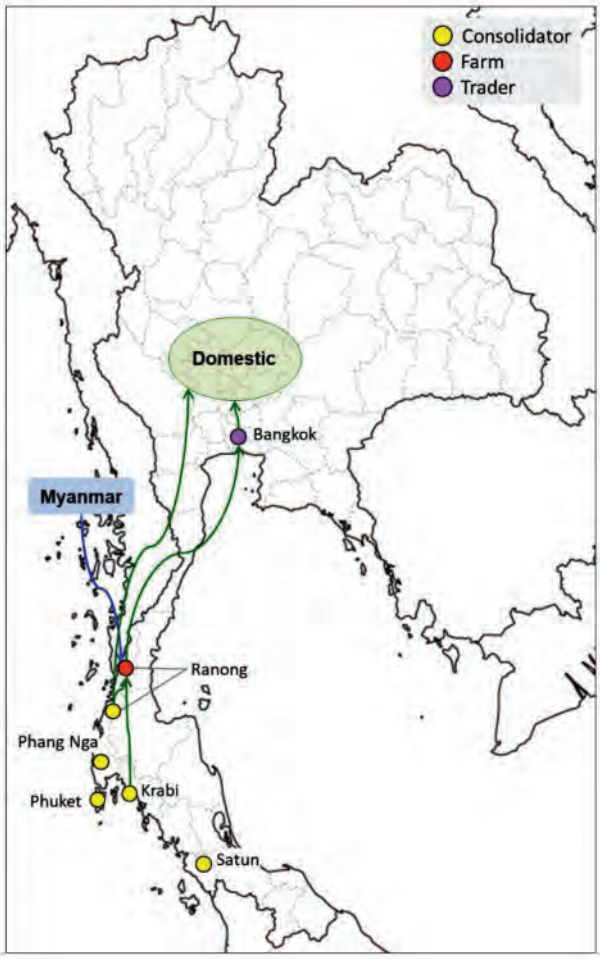

Figure 8. Main trade routes of anguillid eel in Thailand based on baseline surveys

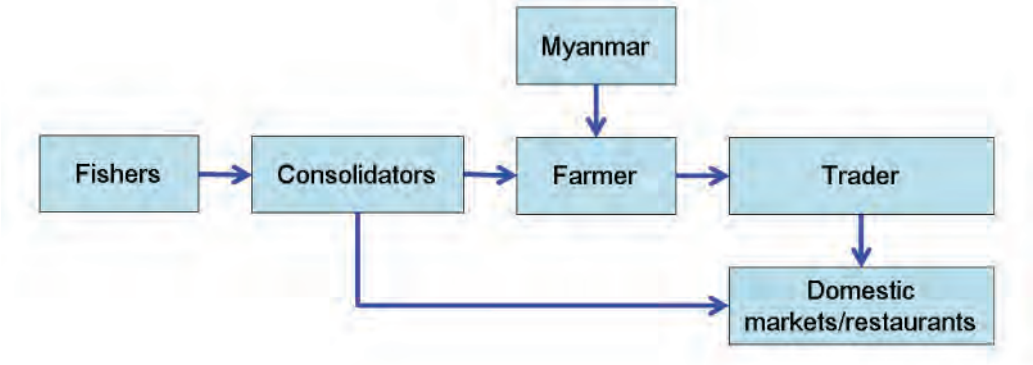

Figure 9. Schematic figure of main eel supply chain in Thailand based on baseline survey

Viet Nam

Six (6) baseline surveys were conducted in Viet Nam and glass eel fishery and farming activities were found.

According to the largest farm in Khan Hoa Province, main fishing grounds of glass eels were noted in Phu Yen Province with more than 80% of the total catch in Viet Nam. There were few catches in Binh, Dinh, Quang Ngai, Khanh Hoa, and Ninh Thuan Province. The annual catch of glass eels was 600-750kg on average and the main species in the catch was *A. marmorata*. Information on catch of elvers/yellow eels is not available.

There were more than 1,320 farms in total of Phu Yen, Binh Dinh, Khanh Hoa, and Ca Mau Province, but most of them were found in Ca Mau Province with about 1,300 farms (90% family scale). Farms in Phu Yen, Khanh Hoa, and Binh Dinh Province cultivated mainly glass eels caught in these provinces, to elvers and sell them to farms in Ca Mau Province (Figure 10, 11). Farms in Ca Mau Province then cultivated elvers to consumption size and sent them to Ho Chi Minh City. From Ho Chi Minh City, eels were sold for domestic consumption or exported to China and Taiwan. Total farm production volume in Viet Nam was under survey, however based on information from the provincial government of Ca Mau Province, farm production volume was 4,500t of yellow eels in 2018 in this province.

Table 6. Summary of baseline survey results in Viet Nam

Catch Data	Glass	**Total: 600-750 kg/year**		
		A. marmorata 95% *A. bicolor* 5%	Phu Yen (>80%)	480-600 kg
			Binh Dinh (10-15%)	60-113 kg
			Quang Ngai (2-5%)	12-38 kg
			Khanh Hoa (1%)	6-8 kg
			Ninh Thuan (1%)	6-8 kg
	Elver/yellow	Under survey: none in Ca Mau		
Fishing Operation Data	No of fishers	Glass	**Total: under survey**	
			Phu Yen	250-300 in peak, 150-170 in off
		Elver/yellow	Under survey	
	Season	Glass	**Whole: under survey**	
			Phu Yen	Peak in Nov-May
		Elver/yellow	Under survey	
	Fishing gear	Glass	**Whole: under survey**	
			Phu Yen	towing net, scoop net, fence net
		Elver/yellow	Under survey	
Production of Eel Farm	No of eel farms	**Total: >1,320**		
		Phu Yen	14 family scale farms, 5 farmers	
		Binh Dinh	Under survey	
		Khanh Hoa	One largest eel farm, other family scale farms	
		Ca Mau	1,300 farms (90% family scale) (source: provincial government)	
	Purchase	Glass	**Total: under survey**	
			Phu Yen	15,000 pieces (2017)
			Khanh Hoa	300,000 pieces (2017)
			Ca Mau	Under survey
		Elver/yellow	Under survey	
	Production	**Total: under survey**		
		Elver	Phu Yen	7-8 t/farm/year
			Binh Dinh	Under survey
			Khanh Hoa	200,000-300,000 inds/year
		Yellow	Ca Mau	4,500t (2018) (source: provincial government)
	Sales destination	Export (China, Taiwan), domestic consumption		
Import and Export	Import	Under survey		
	Export	China, Taiwan		

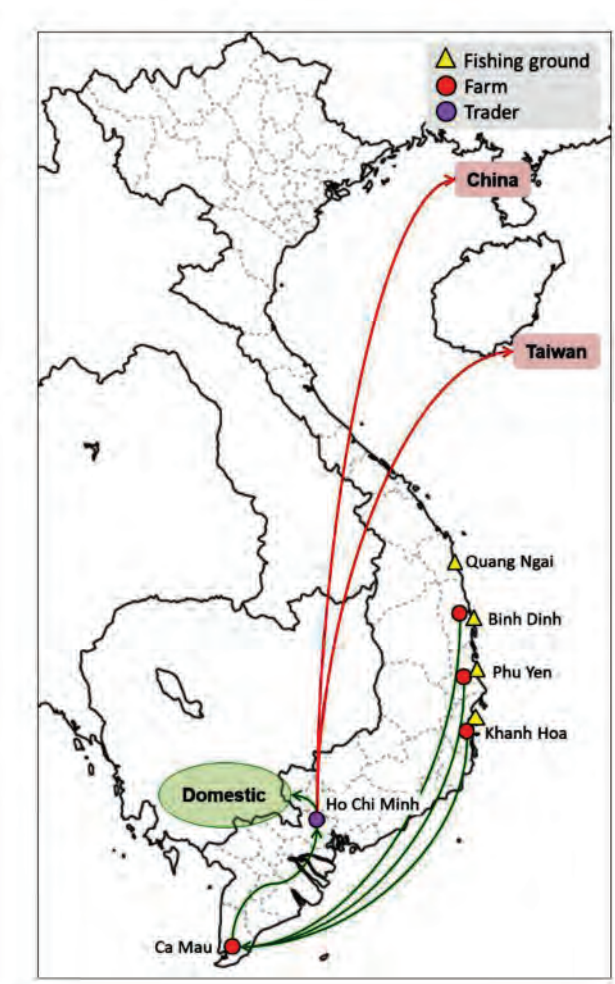

Figure 10. Main trade routes of anguillid eel in Viet Nam based on baseline surveys

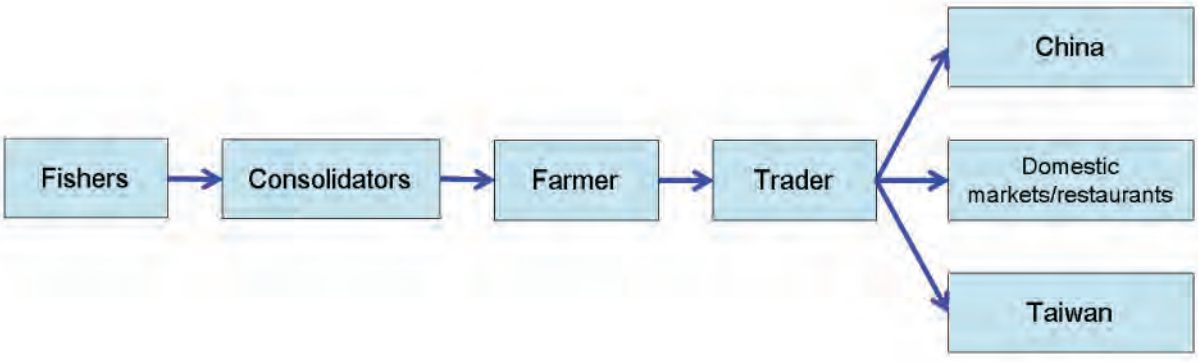

Figure 11. Schematic figure of main eel supply chain in Viet Nam according to the baseline survey

Comparison between countries for catch and farm production

Anguillid eel capture fisheries exist in Indonesia, Philippines and Viet Nam, while these species are considered as bycatch in Thailand and other eels (swamp eels, snake eels) dominated eel catch statistics in Myanmar. There was no eel fishery in Cambodia.

Although the years compared were different, annual catches of glass eels in Indonesia (>19t in 2017) and Philippines (12t in 2017) were much higher than that in Viet Nam (0.6-0.75 t/year). Species composition was similar between Philippines and Viet Nam, indicating that *A. marmorata* is a dominant species. Indonesia had different species composition by island.

We could confirm that farming activities were more active in Indonesia, Philippines, and Viet Nam than in Cambodia, Myanmar and Thailand. *A. bicolor* was the dominant catch species in Indonesia, Myanmar and Philippines, and *A. marmorata* in Viet Nam.

2.4 Conclusion

We described basic information on fisheries characteristics for tropical anguillid eels in ASEAN member states and this would be useful for future stock assessment and management in the light of insufficient and/or absence of official national statistics in most countries. It was seemed that information collection on eel catch, farming activities and trade was straightforward if the main persons for trading are identified because the eel supply chain might be not complicated (most of glass eels are collected by local consolidators to send them to farms alive) compared to other fishery resources. We could contact the main data source person in each country and develop a preliminary data collection scheme through this project. This achievement will be helpful for the development of a more comprehensive data collection system and for future resource management of tropical anguillid eels.

In the end, it is important to note that the data or information we obtained from the baseline survey came from the limited number of respondents and might not reflect national representative values. In addition, there were some discrepancies between respondents. For example, a farm in Thailand answered that they imported yellow eels from Myanmar, however no information on export was noted in surveys in Myanmar. Continued efforts to conduct further surveys and to develop a long-term data collection system are required to gain a better understanding of the status of eel fisheries in each country.

References

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3. Analysis Trends in Tropical Anguillid Eels Resources in Southeast Asia

3.1 Objectives

To strengthen and consolidate eel resource management framework for sustainable provision of eel capture fisheries in AMSs through the data collection system. The strengthened statistical data collection system is to better understanding the present status and past/future trends on tropical anguillid eels, there are following two main purpose of the regular survey:

1) Strengthening the statistical information collection system on anguillid eel
2) To summarize the result of the trend of tropical anguillid eel resources

3.2 Methods

The countries where the anguillid eel fishery has been existing: Indonesia, Myanmar, Philippines and Viet Nam will conduct information gathering on catch statistics on glass eel fishery at each pilot survey area:

1. Collect catch data, catch and corresponding efforts, of the anguillid eel fishery in the survey area. The interval/time unit of the data acquisition on catch data would vary with the real situation of glass eel fishery and commodity chains at each pilot survey area e.g. daily, once in a few days, weekly or monthly.
2. Summarize and compile the catch data and related information on glass eel fishery then send them to SEAFDEC every month via each DoF, after the verification of the data.
3. Check the data and information on glass eel fishery at each pilot survey area by DoF and SEAFDEC.

3.3 Results

Regular surveys were conducted in countries with Anguillid eel fisheries, namely: Indonesia, Myanmar, and Philippines, while Viet Nam is still in the process of establishing the data collection methodology. The initial observations are shown in Table 7. In Indonesia, four survey sites were identified. The first site is Palabuhan Ratu in Sukabumi Regency, West Java Province. The second is Cilacap, one of the regencies in Central Java Province. Located in the southwest coast of Java Island, Palabuhan Ratu and Cilacap also face the Indian Ocean. Cimandiri River in Palabuhan Ratu is a famous fishing ground for glass eels that are usually gathered from the river mouth every year. Cilacap Regency is a fishing ground for yellow eels through its rivers and swamps with varying widths. The other two location sites are Poso in Central Sulawesi, and Manado in North Sulawesi. These survey sites face the Pacific Ocean and are famous grounds for glass eel fishing. In Philippines, the Aparri River in Cagayan Province of Northern Luzon, and Cotabato City and General Santos City in Mindanao were chosen as survey sites because these areas are known not only as home of various eel species abut also as important eel habitats. In Myanmar, Yangon, Ayeyarwady, Tanintharyi and Mandalay Provinces were chosen. Yangon is the largest city in Myanmar, and eel fishers from Ayeyarwady and

Tanintharyi provinces send their harvest of Anguillid eels to collectors in Yangon. In Viet Nam, Phu Yen and Khanh Hoa provinces are chosen as survey sites not only because of their locations that face the South China Sea, but also because in these provinces, many areas are known to be glass eel fishing areas.

Table 7. Observations from the regular surveys

Country	Sampling areas	River	Period of observation	No of Observations	Fishing gear	Species	Stage
	Province/ District						
Indonesia	Bengkulu	Kungkai Baru	Feb 2016-June 2019	505	Hand line and Trap	*A. bicolor*	YE
		Arau Bintang	Apr 17-June 2019	156			
		Enggano	Apr 17	12			
	Sukabumi	Cimandiri	Nov 2013-March 2019	993	Scoop net	*A. bicolor*	GE
	Cilacap	Serayu	Jan 2017-June 2019	605	trap	*A. bicolor*	YE
	Poso	Poso Lake	Jan 2004- June 2019	395	trap	*A. marmorata*	YE
	Poso	Poso River	Dec 2017- June 2019	79	fyke net	*A. marmorata*	GE
	Manado	Poigar	Apr 17	2	fyke net	*A. marmorata*	GE
Myanmar	Pyapon	Ayeyarwady	Dec 2017-Jan 2018	36	Crab trap	*A. bicolor*	YE
	Labutta		Dec 2017-Sep 2018	57			
	Myaungmya		Jan 2017-Marc 2019	598			
	Myeik	Taninthrayi	Dec 2017	8			
	Yangon	Yangon	Nov-Dec 2017	14			
Philippines	Cagayan	Cagayan	Nov 2017-June 2019	769	Fyke net	*A. marmorata*	GE
	Cotabato		Feb 2018-July 2019	163			
	Sarangani		Feb 2018-May 2018	56			
	Barangay		April 2019-July 2019	75			
Viet Nam	Phu yen	Tam Giang	Jan 2019- June 2019	6	FAD	*A. marmorata*	GE
		Kylo and Ba	Jan 2019- June 2019	18	FAD, hook and line	*A. marmorata*	All stage

Note: GE=Glass eel, YE=Yellow eel

Myanmar

The study in Myanmar was carried out in 5 sampling sites namely Pyapon, Labutta, Pathein, Myaungmya, Myeik, and Yangoon. Based on the survey, Myanmar has no statistical data for anguillid eels so far. The Department of Fishery Myanmar records production data of anguillid eel together with other look-like species such as snake eel and rice paddy eel only. It is just divide based on its size e.g. yellow eel (200-250 gram) and more than 1 kg. Besides that, there is no fishing activity for glass eel in Myanmar. Furthermore, the last catch data that successful to collect until March 2019 only. Therefore, it should need a continuous regular survey to get appropriate data and information.

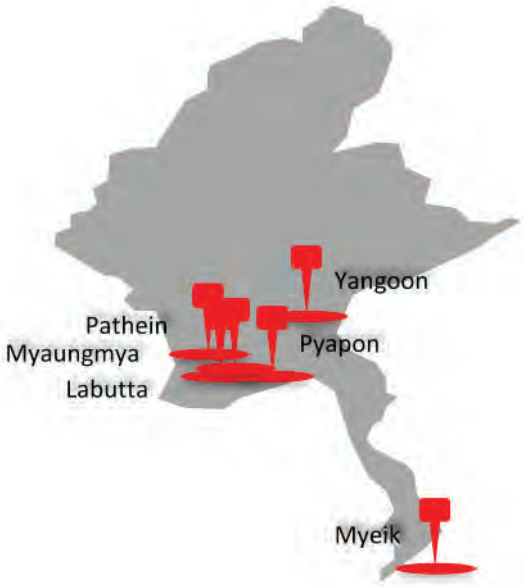

Figure 12. Myanmar's sampling sites

Species composition of Yellow eel in Myanmar

The study surveyed to collect the sample of yellow eel in February and October 2018 in Pathein and Myaungmya district, Ayeyarwady province. A total of 86 yellow eel specimens was collected from the consolidator in the sampling site in February and October, 20 and 66 specimens respectively. All the specimens were examined based on morphological character. Based on their percentage of ano-dorsal length to total length (AD/TL) was represent the short-finned and long-finned eel. But, it still forced difficulties to identify the species by morphological characteristics only due to the overlap of such characters among species.

The identification showed that the composition between shortfin and longfin in February was the same proportion (Figure 13). Furthermore, in October 2018 the composition of shortfin increase become 71% while longfin 29% only.

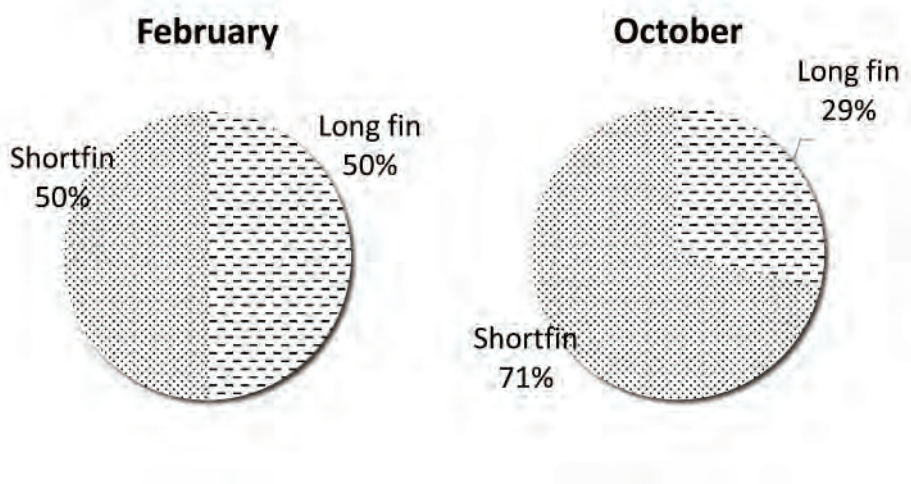

Figure 13. Composition of shortfin and longfin in Myanmar

Catch of yellow eels in Myanmar

Mostly, the sampling sites in Myanmar located in the branch of Ayeyarwaddy River. The fishers catch the anguillid eels in this river by using the crab trap, mixed with another look like species. The total catch was 351.12 kg. Labutta area is the highest catch of around 158.08 kg. It followed by Myaungmya, Pyapon, Pathein, and Myeik around 125.80 kg, 30.72 kg, 27.12 kg, and 9.92 kg respectively (Figure 14). The highest production in Labutta comparing to the other sites because it located near to the mouth river.

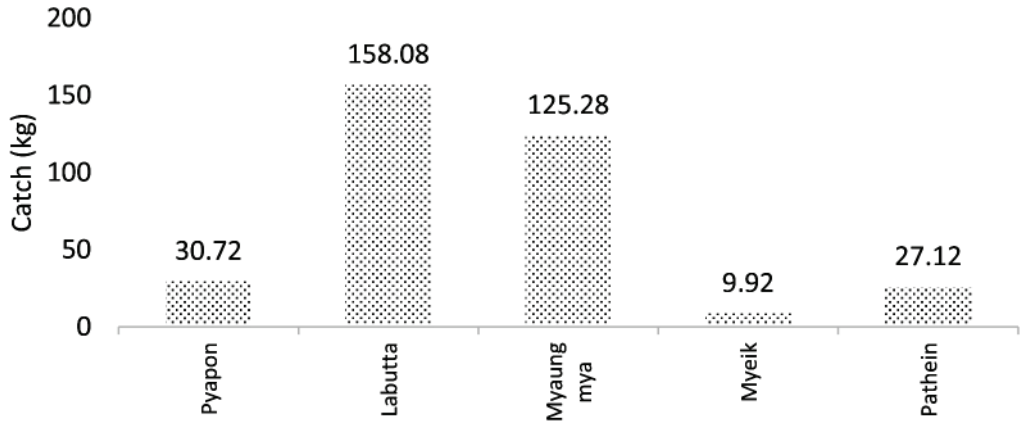

Figure 14. Catch of yellow eels in Myanmar

Data of catch on yellow eels with size 200-250 gram in Myanmar were collected from December 2017 until May 2018 in 5 sampling sites (Figure 15). The total catch in Myanmar in that period was 351.12 kg. The highest catch was 120.5 kg recorded in January 2018 while the lowest catch was 7.92 kg in April 2018. Nonetheless, there are several sites have no available data. According to the interview result, January to April is the lowest season production for the anguillid eels. Yellow eel with size less than 1 kg usually collected by the consolidator in Yangon and rearing in the Mandalay province. After reaching a size of more than 1 kg, the farmer will be sent to China when the Chinese lunar new year. The dominant species for this trade is *Anguilla bicolor*. In Myanmar, *A. bicolor* commands the best price compared with the other anguillid eels. The peak season for eel capture is from August to November, and eel breeding season coincides with the rainy season. Usually, small-sized eels are collected in April. The national production during this period is about 15 metric tons/day (Honda *et al*, 2016).

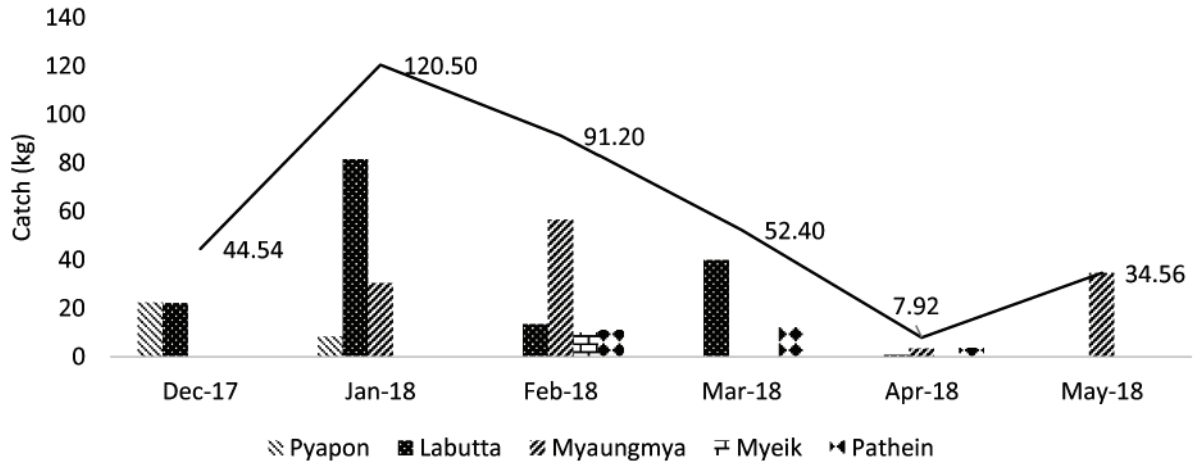

Figure 15. Catch of yellow eels with size 200-250 grams in Myanmar

The data of catch of yellow eels with size > 1 kg were collected from January 2017 until March 2019 from two locations only, Labutta and Myaungmya (Figure 16). The complete data successfully compiled only in Myaungmya district, hence Labutta has no data available in the certain month. According to the data, the catch of anguillid eels in Myanmar fluctuated. Total Catch was 1210.22 kg with the highest catch occurred on September 2017 and September 2018, 253 kg and 429.56 kg respectively. September is the peak season for the anguillid eel production because it related to the rainy season. Based on the data, Myaungmya has a higher catch than Labutta for anguillid eels with a size of more than 1 kg. It is due to the position of Myaungmya is located on the northern side of Labutta which is the upper stream part.

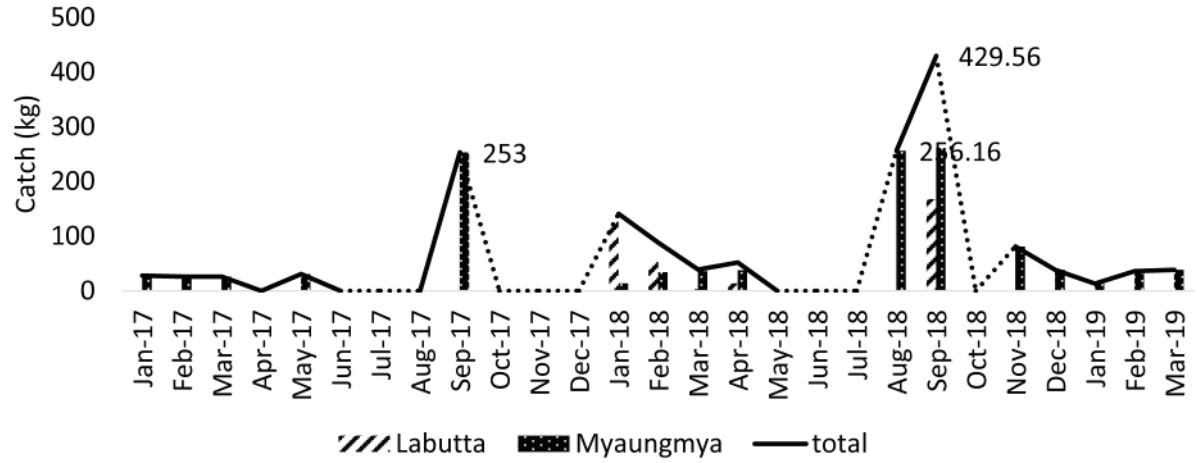

Figure 16. Catch of yellow eels with size > 1 kilogram in Myanmar

The catch composition on anguillid eel with size more than 1 kg was carried out in Myaungmya district from January 2017 until March 2019 (Figure 17). The dominant species in this area was long fin species (include *A. marmorata* and *A. bengalensis*). In September 2017, the catch of longfin was 171 kg, higher than short fin with 82 kg respectively. Moreover, catch amount data in September 2018 was increasing for longfin and decreasing for shortfin species, 180.36 kg, and 81.2 kg respectively.

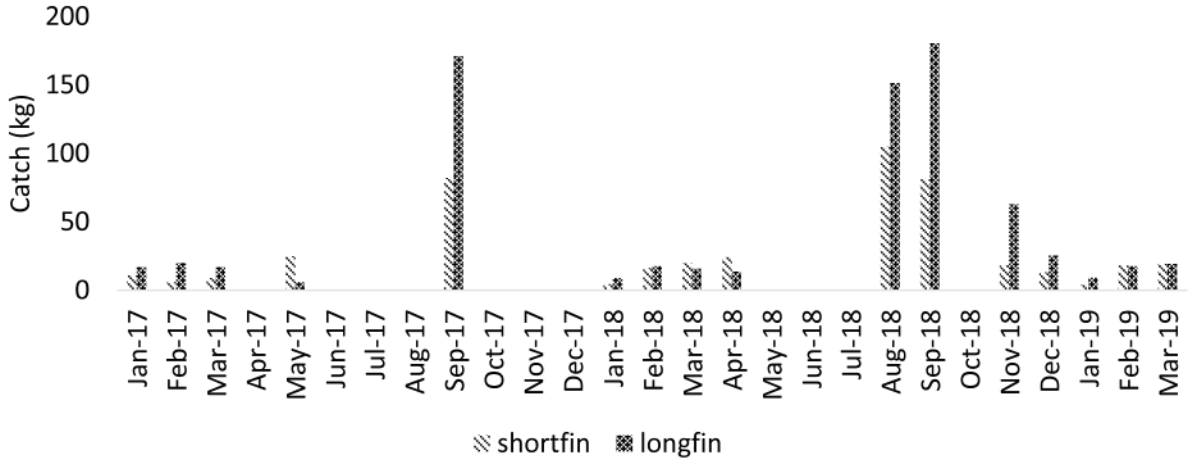

Figure 17. Catch Composition of anguillid eel (> 1kg) in Myaungmya District

Viet Nam

The study was conducted in two sampling sites, Phu Yen and Khanh Hoa province (Figure 18). These sites chosen because Phu Yen province is the main for fishing ground in Viet Nam, while Khanh hoa is the source for eel culture data. This study also forced same case as Myanmar, because there is no proper data statistic of anguillid eels in Viet Nam. The Department of Fisheries just collected the data and based on three stages of eel; glass eel, elver and yellow eel. As the purpose to provide sufficient data, the observation of catch and culture data is needed.

Figure 18. Viet Nam's sampling sites

Species composition on anguillid eels in Viet Nam

The study had been done in December 2018 located in Phuyen and Khanh Hoa province, Viet Nam. This survey has a purpose to get the information regarding species composition in Viet Nam. A total of 100 samples of anguillid eels was collected consist of 50 samples of glass eel and 50 samples of elver/yellow eel. The samples was collected from the consolidator in the sampling site. All the samples were examined based on their morphological character. The identification showed that the species composition of anguillids eel in Viet Nam were two species of Anguillid eel belong to *Anguilla bicolor pacifica* as shortfin eel and *A. marmorata* as longfin eel. Furthermore, the dominant species was *A. marmorata* with a percentage of more than 90%. According to Arai *et al*, (2013) *A. marmorata* and *A. bicolor pacifica* coexist in Vietnamese rivers and may share the same niches, use the same demersal habitats and forage for the same prey. Furthermore, the recent study was conducted by Nguyen *et al*, (2018) found 11 glass eels, one silver eel belong to *A. marmorata* and two yellow eels belong to *A. bicolor pacifica* in the Phu Yen site. These study also reviewed previous study by Hoa and Phung (2003) which found *A. marmorata*, *A. bicolor pacifica*, and *A. nebulosa* and another study by Dat and Ty (2008) which found *A. marmorata*, *A. bicolor bicolor*, and *A. malgumora* in the same region. Those study are still questionable considering the geographical range due to discovering *A. nebulosa, A. bicolor bicolor,* and *A. malgumora* in Viet Nam. Ege (1939) and Watanabe *et al,* (2014) revealed that geographic distribution of *A. nebulosa (A. bengalensis)* and *A. bicolor bicolor* are in the Indian Ocean. Whereas, *A. malgumora (A. borneensis)* is endemic to Borneo Island but its spawning area in Celebes Sea (Aoyama *et al*, 2003).

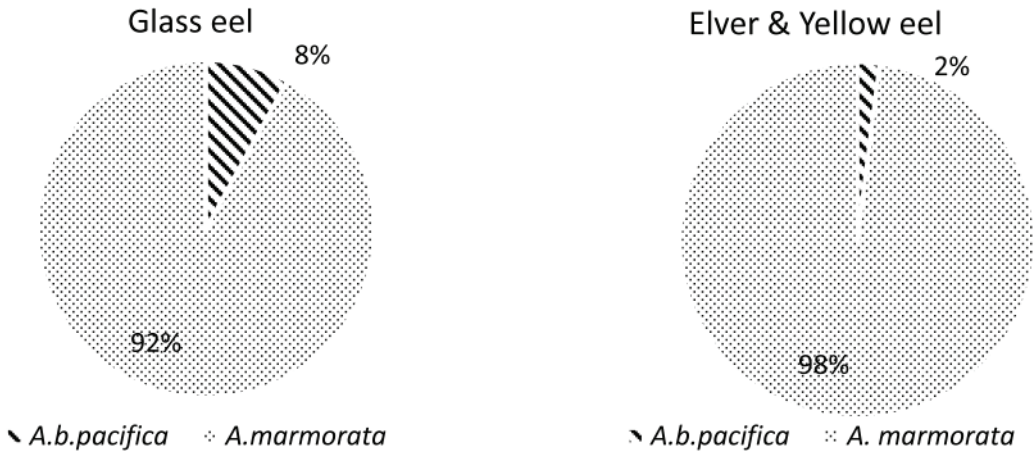

Figure 19. Species composition on anguillid eel in Viet Nam

Catch of yellow eels in Viet Nam

The data of anguillid eel catch in Viet Nam collected from Phu Yen and Khanh Hoa province. Phu yen is the highest area for catching anguillid eel in Viet Nam. Based on the baseline survey, it is approximately 80 % of the total catch in Viet Nam. According to the data that successfully compiled, the catch of yellow eel in Viet Nam fluctuated. The total amount of yellow eel catch from January 2018 to June 2019 was 189.17 kg. The highest catch amount occurred on March 2019, 82.8 kg. Nonetheless, there was no data available from August to December 2018.

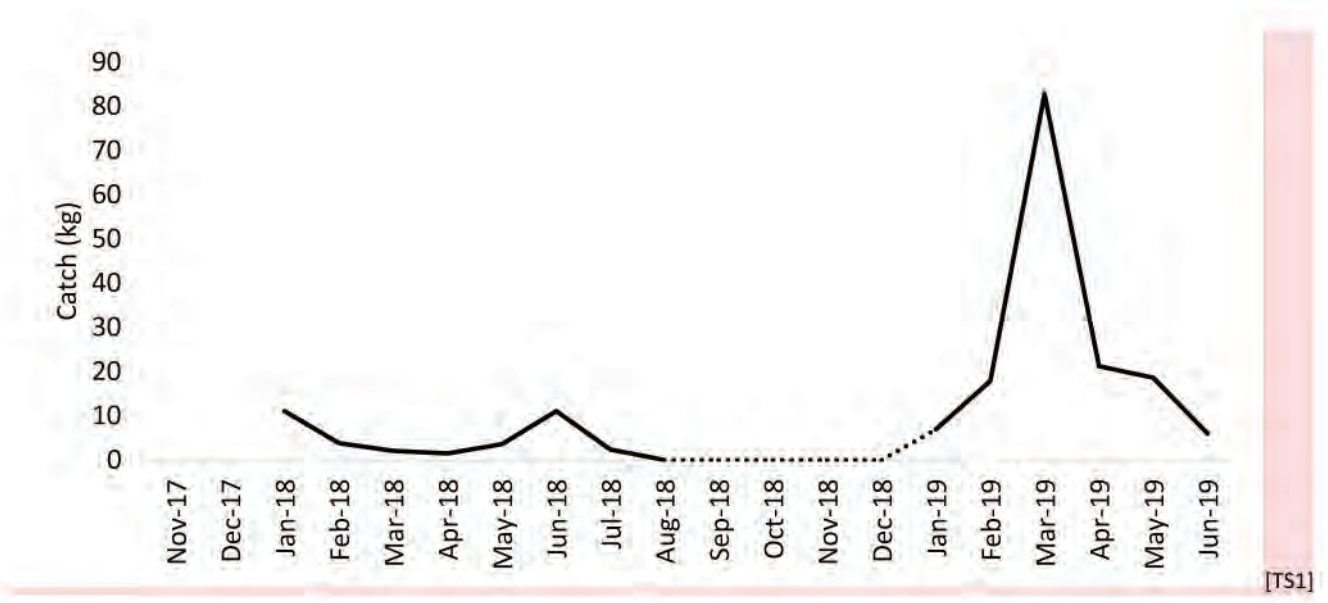

Figure 20. Total catch of yellow eel (kg) in Viet Nam

The total amount of elver catch from November 2017 to June 2019 was 4,335.96 kg (Figure 21). According to the data, the catch of elver in Viet Nam showed that there was two peak season of elver catch, in December 2017 and March 2018, with the total catch 1,850 kg and 1,730 kg respectively. Its trend due to the Northeast monsoon that brings rain to this region in this period. It is also supported by the interviewed result, the catch season occurred from November to April when the rainy season. The total catch amount of 2019 experienced decreasing compared with the data in 2017 and 2018. Meanwhile, there was no data available from August to December 2018.

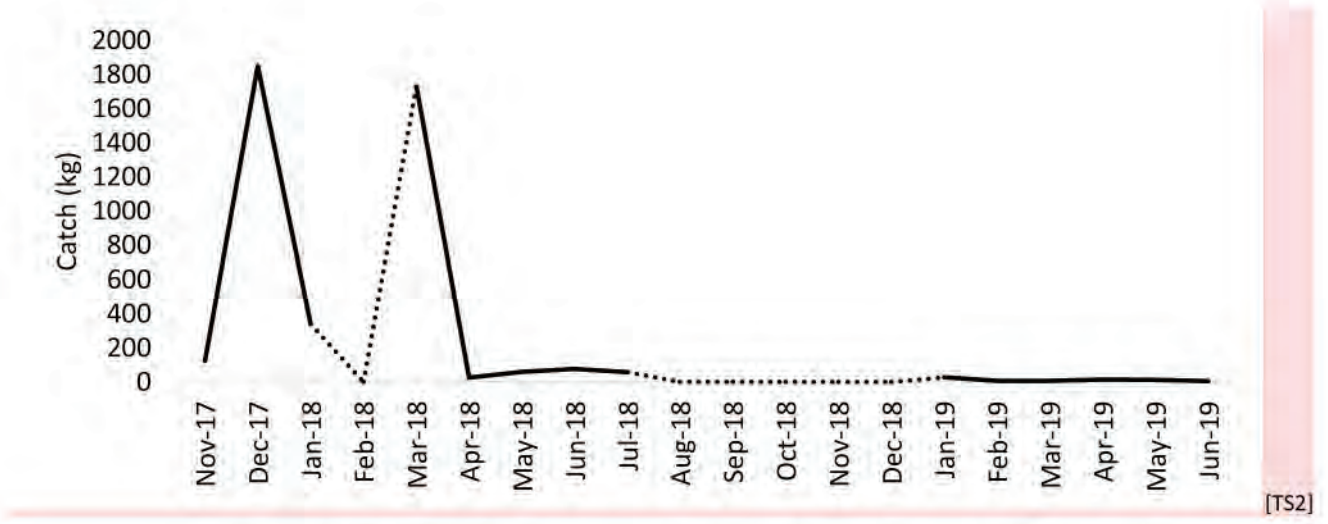

Figure 21. Total catch of elver (kg) in Viet Nam

The data collection was compiled from November 2017 until June 2019 (Figure 22). The total catch amount of glass eel for that period is 173.86 kg. The highest catch occurred in February 2019. There was no data available from August until December 2018. All the stages of anguillid eel are still needed more data to assist the population stock.

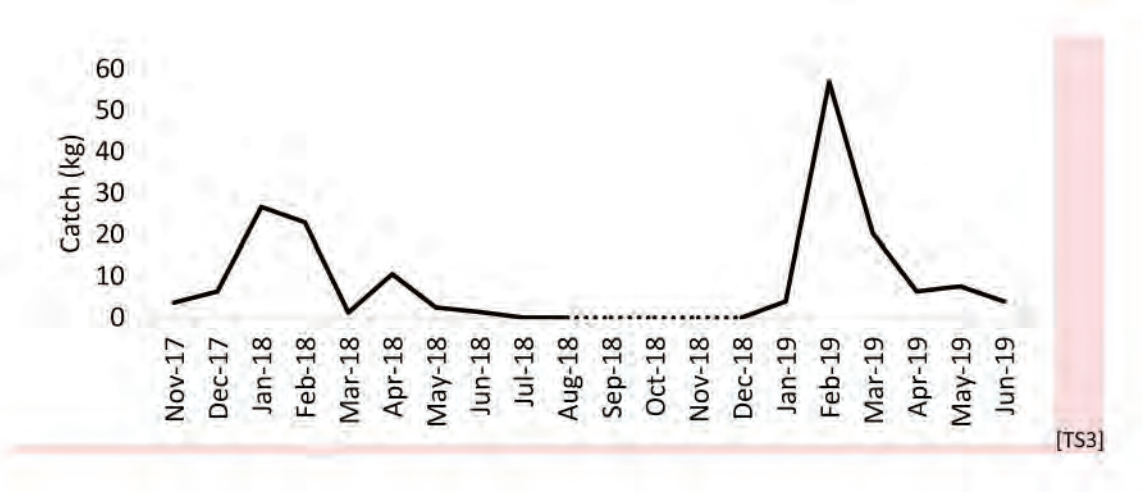

Figure 22. Total catch of glass eel (kg) in Viet Nam

Philippines

The study was conducted in three sampling areas which are Cagayan (Luzon is.), Cotabato and General Santos (Mindanao Is.). The Philippines catch datas is just available for glass eel stage whereas no data for elver and yellow eel so far.

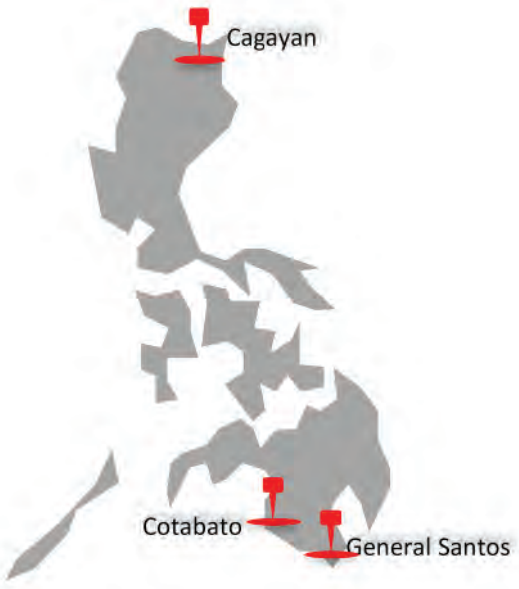

Figure 23. Philippines's sampling sites

Species composition of glass eel in Cagayan, Philippines

Cagayan province is one of three sampling sites for the study in Philippines. This study was carried out in September 2017 with 84 glass eel samples from a consolidator (Table 8). The result of the examination showed that there were three species of Anguillid eel and one species of non-anguillid eel. With percentage for *Anguilla luzonensis* 81%, *A.marmorata* 17%, *A.bicolor pacifica* 1% and non-anguillid eel 1%. Related to the Ame (2017) that found the percentage of Anguillid eel in September 2015 was *A.luzonensis* 80% and remaining *A.marmorata* and *A.bicolor pacifica*. *A. marmorata* and *A. luzonensis* have the same morphological characteristics specifically pigmentation pattern on the caudal peduncle only. It is supported by Valdes and Castillo (2016) that *A. marmorata* is most abundant, abundance index of 96.62%, frequency index of 100%, dominance index of 196.62%. Abundance index of *A. bicolor pacifica* 3.26%, frequency index of 42.86% and dominance index of 46.12%.

Furthermore, analysis by using the ano-dorsal length show their differentiation. Percentage of anodorsal length for *A. luzonensis* 10.85±1.41, *A. marmorata* 15.05±0.57 and *A.bicolor pacifica* -1.54. According to Kuroki *et al*, (2012), *A. luzonensis* has long larval duration and hatching was estimated to fall in February to May in Luzon Is. The offshore presence of the larvae and ocean current direction suggest that this species migrates to spawn in the north equatorial current (NEC).

Table 8. Species composition of glass eel in Cagayan, Philippines

Species	n	AD	Reff.
A. luzonensis	69	10.85±1.41	9.3 - 13.9
A. marmorata	13	15.05±0.57	12 - 20
A.bicolor pacifica	1	-1.54	-5 - 4
Non anguillid eel	1	35.04	

Catch of glass eel in Philippines

This study was compiled the total catch of glass eel in Philippines from November 2017 until June 2019. But, there was no data available in May and June 2018. The total catch in this period was 1884.6 kg. The peak season happened at the end of the rainy season and the beginning of the dry season. The highest catch occurred in March 2018 with the amount 482.9 kg. Ame (2013) reported that March is the peak season and May, June and July are the lowest seasons for catching glass eel. The total catch decreased in the next dry season due to the El Niño phenomenon. El Niño is a weather pattern associated with reduced rainfall. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) (2019) reported that unusually warm sea surface which started since November 2018 is expected to become a full-blown El Niño. Observation in several provinces in Luzon and Mindanao from September last year to mid-January 2019 It triggered by periodic warming in the eastern Pacific Ocean, could last for 5 months to 2 years.

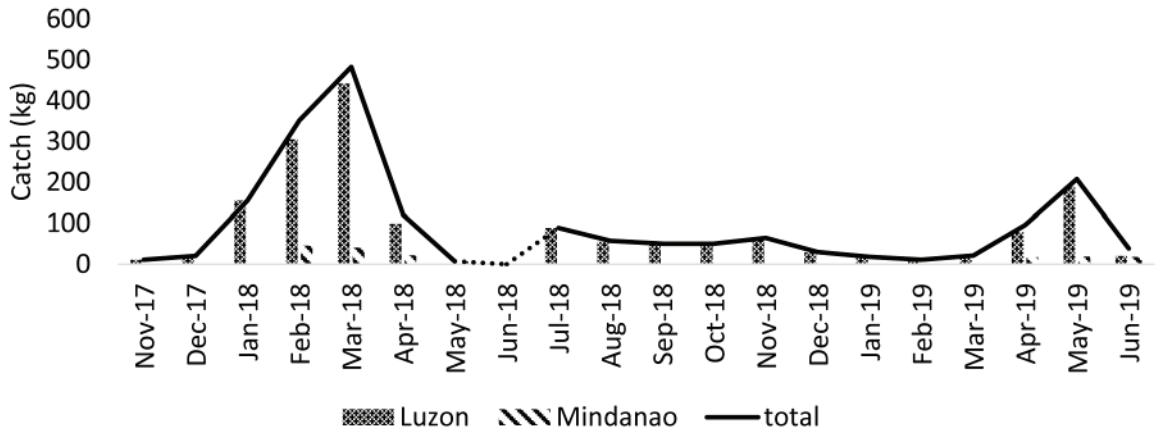

Figure 24. Catch of glass eel in Philippines

This study also requests to 5 fishers to collect the independence data in Cagayan, Luzon (Figure 25). They caught 8 days per month when the peak season of the glass eel. The data collection started from November 2017 to June 2019. There is no data available from October 2018 to March 2019. The pattern of catch by the fishers similar to the total catch.

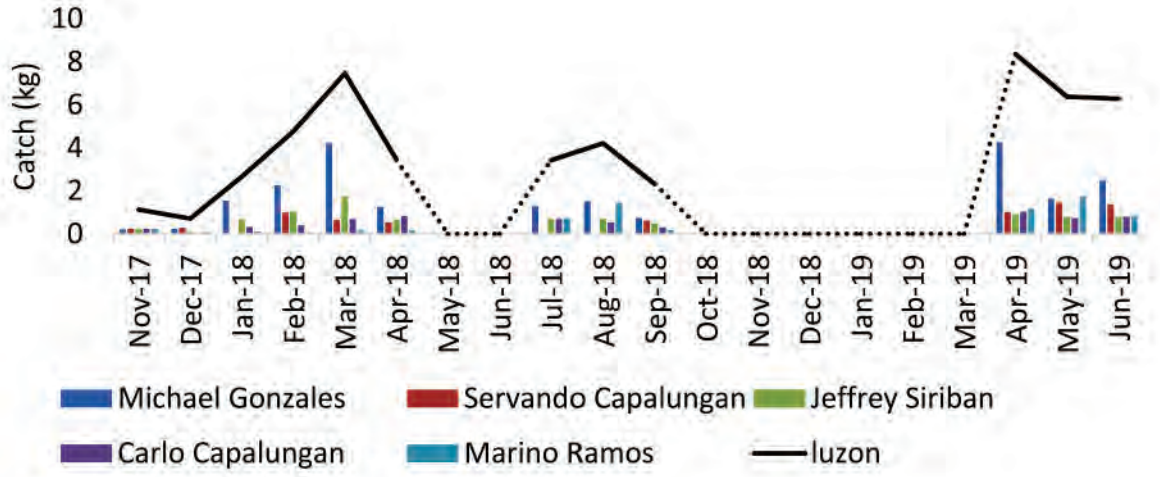

Figure 25. Luzon's experimental fishing

The study was conducted in Mindanao island especially in Cotabato and Sarangani Province. Fishers in those areas requested to record the catch amount of glass eel monthly. Mostly fishers will catch the glass eel around 4-9 days per month. The peak season ensued at the end of the dry season and the beginning of the rainy season (June to August). Since September glass eel catch amount decreased drastically due to the El Niño effect.

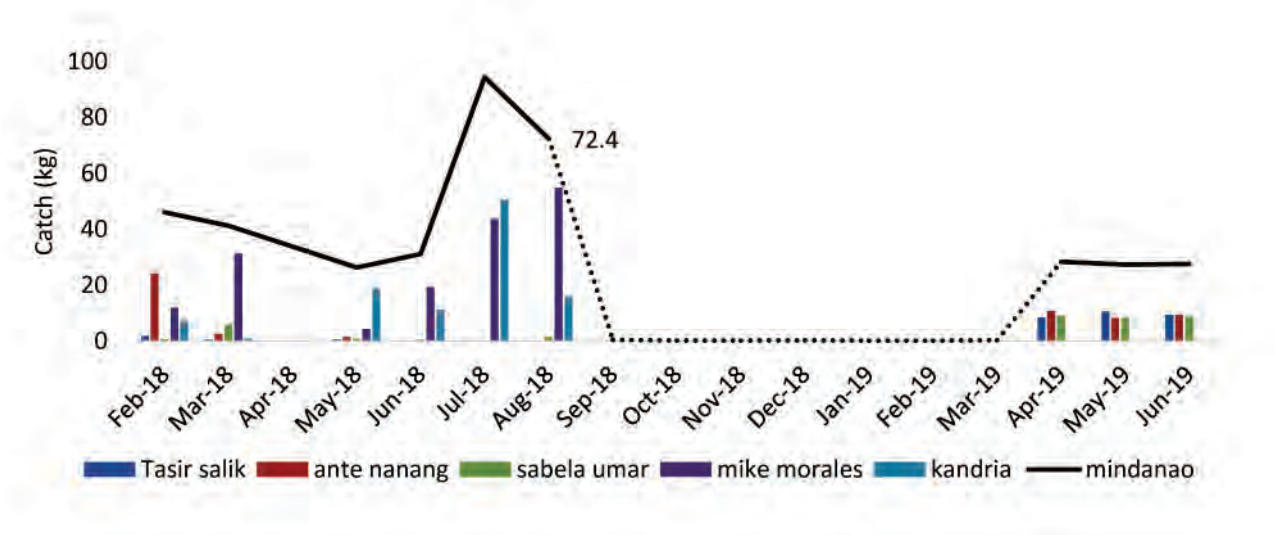

Figure 26. Mindanao Is. experimental fishing

Generally, the pattern of the total catch in Mindanao Is. is similar to Luzon Is. There was three peak season for catching glass eel. The first peak season happens from February to April, then the second peak comes up from July to August. Therefore, the total catch amount in Mindanao higher than Luzon. El Nino phenomenon occurred in Philippines in September 2018 till March 2019. It causes catch activity decreased in that period.

Indonesia

In Indonesia, four survey sites were identified. The first site is Palabuhan Ratu in Sukabumi Regency, West Java Province. The second is Cilacap, one of the regencies in Central Java Province. The other location is Bengkulu. Palabuhan Ratu, Cilacap and Bengkulu are facing the Indian Ocean and located on the southwest coast of Java Island. Cimandiri River in Palabuhan Ratu is a famous fishing ground for glass eels that are usually gathered from the river mouth every year. Moreover, Bengkulu and Cilacap Regency is a fishing ground for yellow eels through its rivers and swamps with varying widths. The other location site is Poso in Central Sulawesi. These survey sites face the Pacific Ocean and are famous grounds for glass eel fishing.

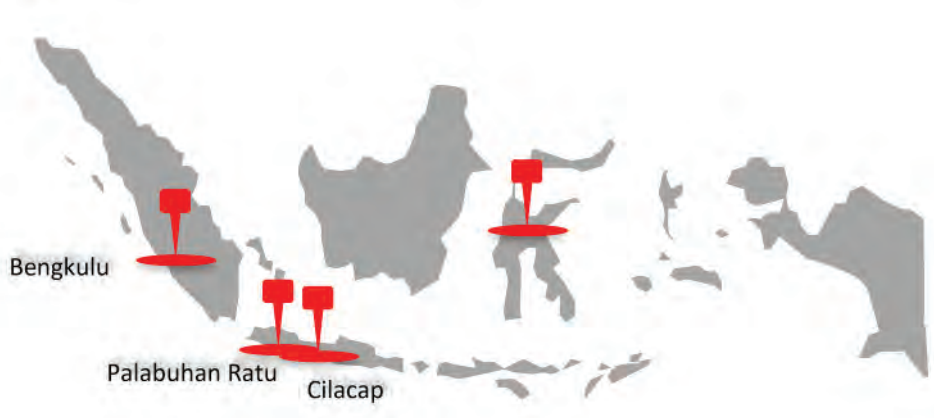

Figure 27. Indonesia's sampling sites

Species Composition on Glass Eel in Palabuhan Ratu based on Ano-dorsal Length and Image analysis

The research was carried out in Pelabuhan Ratu using glass eel specimens. A total of 1,597 glass eels were collected which around 100 specimens per month from April 2017 until December 2018 (Figure 28). The samples collected from the consolidator in the sampling site. Based on examination revealed that there were at least four species of Anguillid eel in Palabuhan Ratu as follows *A.bicolor bicolor*, *A.bengalensis*, *A.interioris* and *A.marmorata* which dominated by *A.bicolor bicolor*. According to Budimawan & Finiger (2007) *A. bicolor bicolor* was the dominant species of glass eel collected during early migration from the Indian Ocean to West Java. It is supported by Sugeha & Suharti (2008) *A. bicolor* is mainly distributed in the tropical region of Indonesian waters. *A. bicolor bicolor* dominated in the west, while *A. bicolor pacifica* dominated in the center and east Indonesian waters. According to Chino & Arai (2010), migration of anguillid eels into freshwater is not obligatory. Its habitat use is facultative among fresh, brackish and marine waters during the growth phase after recruitment to coastal areas similar to that for temperate eels.

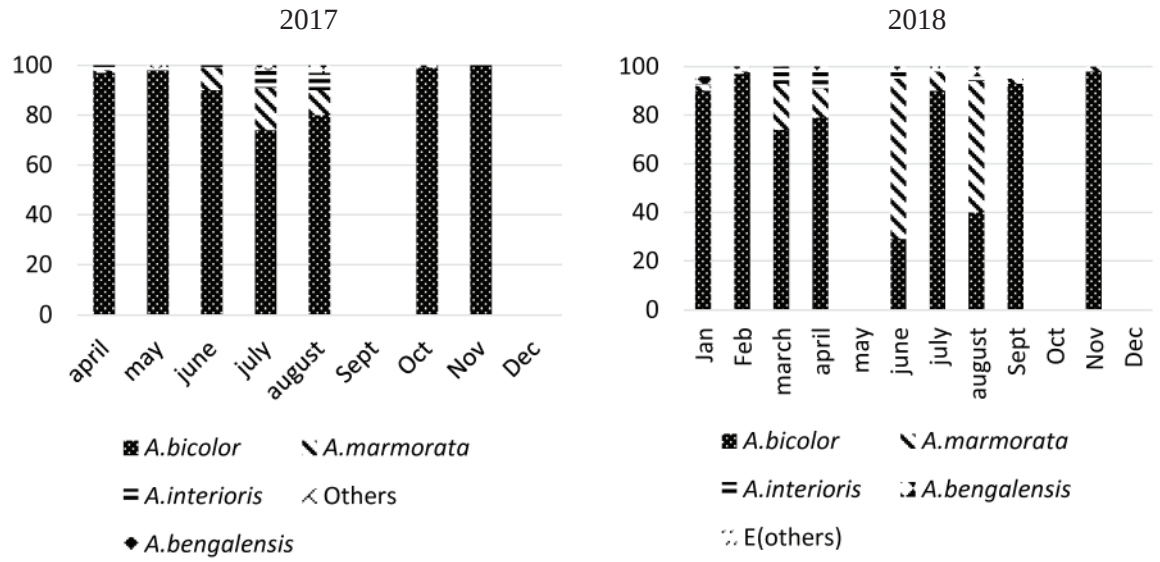

Figure 28. Species Composition on Glass Eel in Palabuhan Ratu based on Ano-dorsal Length and Image analysis

Catch of glass eel in Indonesia

Palabuhan Ratu is the main fishing ground for shortfin species. The sampling site of glass eel was conducted in the Cimandiri river, Palabuhan Ratu, West Java Indonesia continuously for 5 years. The catch of glass eel in this area fluctuated with an average of 188.11 kg per year (Figure 29). Whereas, the yield of glass eel showed a trend of decreasing from 2014 to 2016, but in the next two years it increases and shows the highest production of 254.65 kg in 2018. It is increased by 7.4 % compared to 2014. Arai and Kadir (2017) confirmed that final stage of maturation for seaward spawning migration occurred throughout the year in *A. bicolor bicolor.*

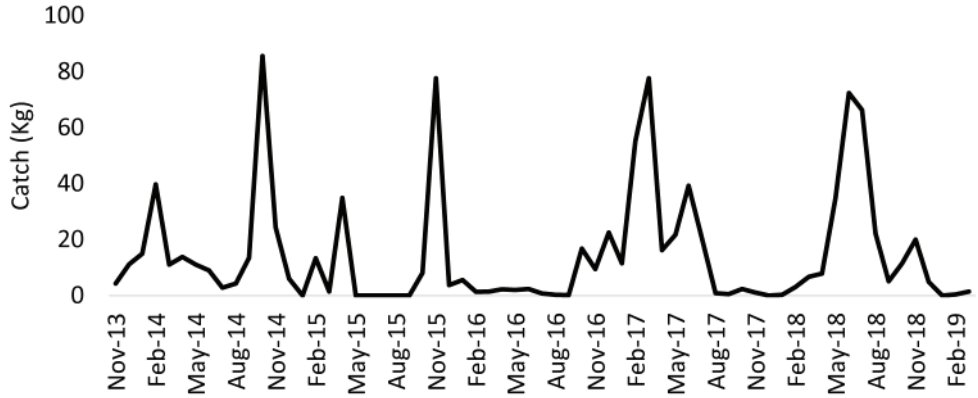

Figure 29. Catch of glass eel in Palabuhan Ratu, Indonesia

The survey of glass eel catch was carried out in Poso, Central Sulawesi facing to the Tomini Bay. This site is one of the main fishing ground for longfin species. The data was compiled from January 2018 to June 2019. The catch of glass eel in this area for the period fluctuated with the highest catch occurred in August 2018. Miller (2016) stated that the high biodiversity of leptocephali in Tomini Bay Indonesia in the center of the Coral Triangle. The semi-enclosed Tomini-Bay may facilitate self-recruitment of marine eels. There is seasonality of spawning by tropical anguillid eels around Sulawesi Island, Indonesia (Wouthuyzen *et al*, 2009).

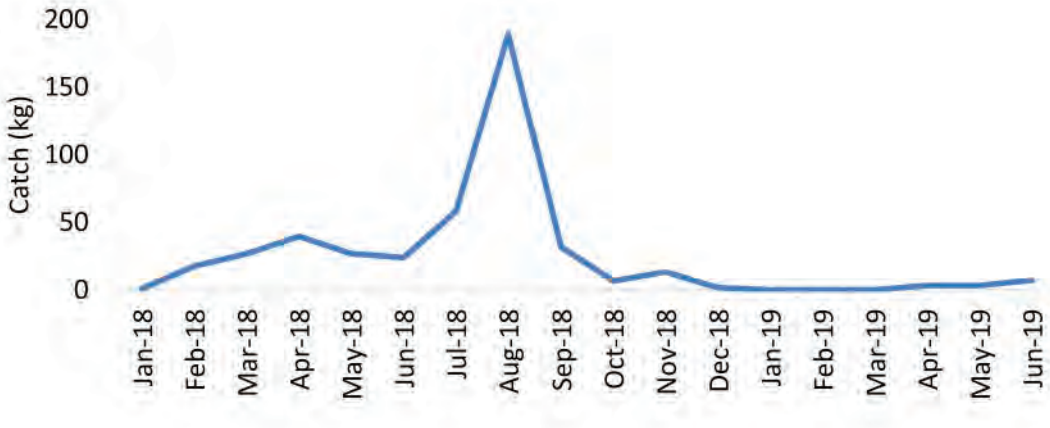

Figure 30. Catch of glass eel in Poso, Central Sulawesi

Elver and Yellow Eel Catch in Indonesia

The data of catch for elver and yellow eel collected in Bengkulu and Cilacap. These two areas are the main fishing ground for shortfin species (*A. bicolor*). The catch in Bengkulu and Cilacap on the period fluctuated with an average of 180.17 kg per month and 163.19 kg per month respectively (Figure 31). There was the same pattern of catch between Bengkulu and Cilacap. The Figureure showed that the highest catch ensued in January 2019. Arai *et al*, (2011) stated that *A.bicolor bicolor* spawn year round, migration may occur throughout the year in the Penisular Malaysia.

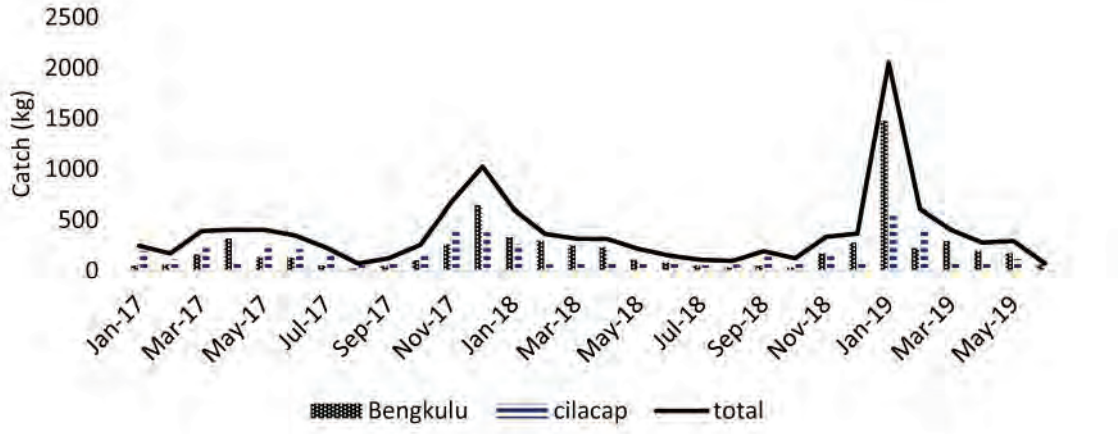

Figure 31. Catch of elver and yellow eel in Bengkulu and Cilacap, Indonesia

There was another yellow eel fishery in Poso lake, Central Sulawesi. Dominant species in this area are longfin species The catch data in this area fluctuated and decrease 50% in 10 years (Figure 32). It caused due to the operation of the Power Plant by Poso Energy company since 2013. Even though this company already built the fishway (special for the eel) in their Dam, nonetheless the effectiveness for eel migration still needs to be observed. Additionally, the existence of eel fishing gears "waya-masapi' at the outlet of the Poso lake has another influence on eel migration.

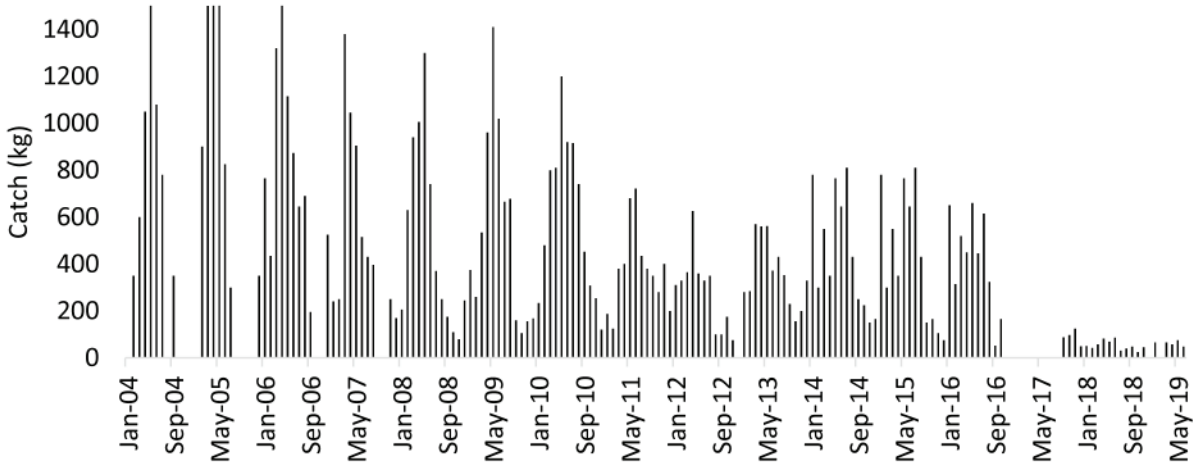

Figure 32. Catch of elver and yellow eel in Poso, Central Sulawesi

Stock status of tropical anguiliid eels

The data from Palabuhan Ratu in Indonesia have been used in the analysis for the CPUE due to the availability of data series since November 2013 to March 2019 (more than 5 years) (Figure 33.). According to certain eel farmers who were interviewed, the mouth of the Cimandiri River is one of the largest glass eel fishing grounds in Indonesia. There are more than 1,500 part-time fishers scooping the glass eels during the peak season using the scoop net as the fishing gear. Since there is only one fishing gear used, therefore gears standardization was not necessary. Fahmi and Hirnawati (2010) indicated that the dominant species of the glass eels caught in the Cimandiri River was *A. bicolor bicolor*, it is expected that such findings would be confirmed through the results of the regular surveys which will roughly show the total amount of *A. bicolor bicolor* glass eels and its fluctuation in the Cimandiri River.

For the analysis, the data from November 2013 to September 2017 (before the project) from the series had been extracted and number of fisher as effort decide by interview result. Moreover, this study requested the effort data from the enumerators in Cimandiri River in Sukabumi Regency of West Java directly from September 2017 to March 2019 (Figure 34). There was discrepancy result of CPUE between that period.

Before the study, the monthly CPUE result was fluctuate from November 2013 to September 2017. The highest CPUE is 3.32 kg/fisher occurred in March 2017. Furthermore, the CPUE was fluctuated and increased drastically after the study. The fluctuate CPUE during this period occurred due to changing the number of fishers. The highest is 36.14 kg/fisher in July 2018 and the lowest is 0.05 kg/fisher in September 2017. The study successful showed the real CPUE due to there is no significance difference between the trends of catch and CPUE on this period. It showed that even catch amount decrease drastically however the CPUE did not slightly decrease. Through this case study, it cannot be concluded that amount of glass eel resources decreasing or increasing.

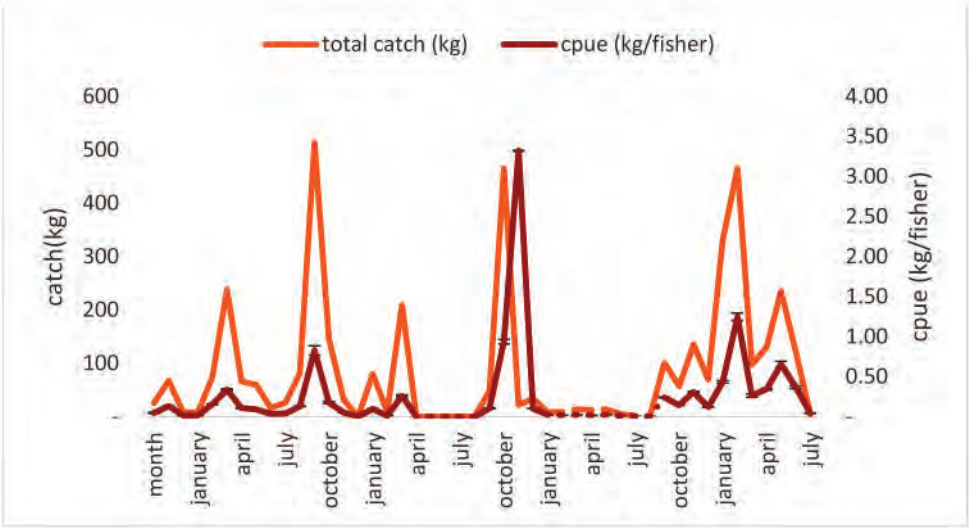

Figure 33. Trend of the CPUE and catch of Anguillid eel in Palabuhan Ratu, Indonesia during period November 2013-August 2017

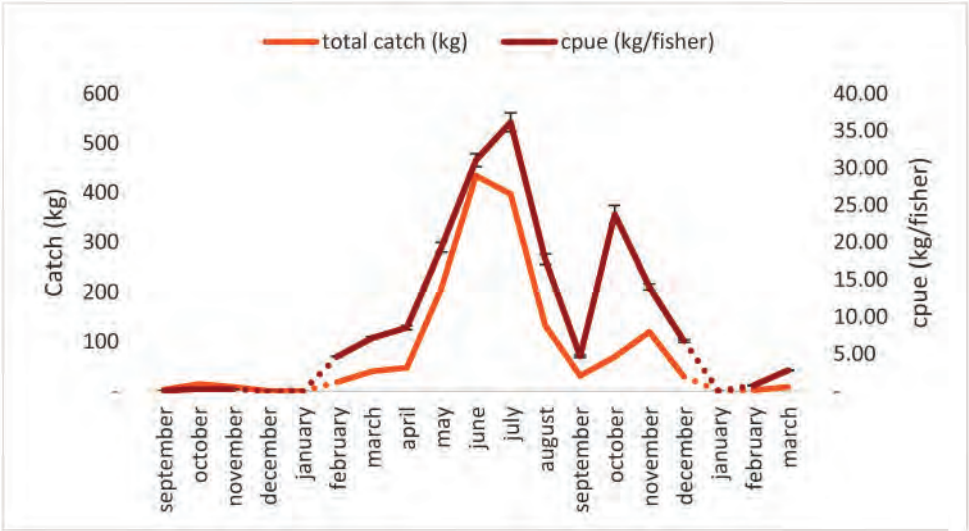

Figure 34. Trend of the CPUE and catch of Anguillid eel in Palabuhan Ratu, Indonesia during period September 2017-March 2019

Trend based on the dominant species

A comparison of the catch data from the regular survey was made by the similar characteristic such as location, dominant species and stage (Table 9). Several areas in the Southeast Asia region has the same dominant species according to the tropical eel that has widespread distribution. For instance, West Indonesia and Myanmar almost has same dominant species due to those areas facing to Indian Ocean (Figure 35).

Table 9. Comparison characteristic from catch data between countries

Stage	Short fin	Long fin
Glass eel	Indonesia	Indonesia, Philippines & Viet Nam
Elver & Yellow eel	Indonesia & Myanmar	Indonesia, Philippines & Viet Nam

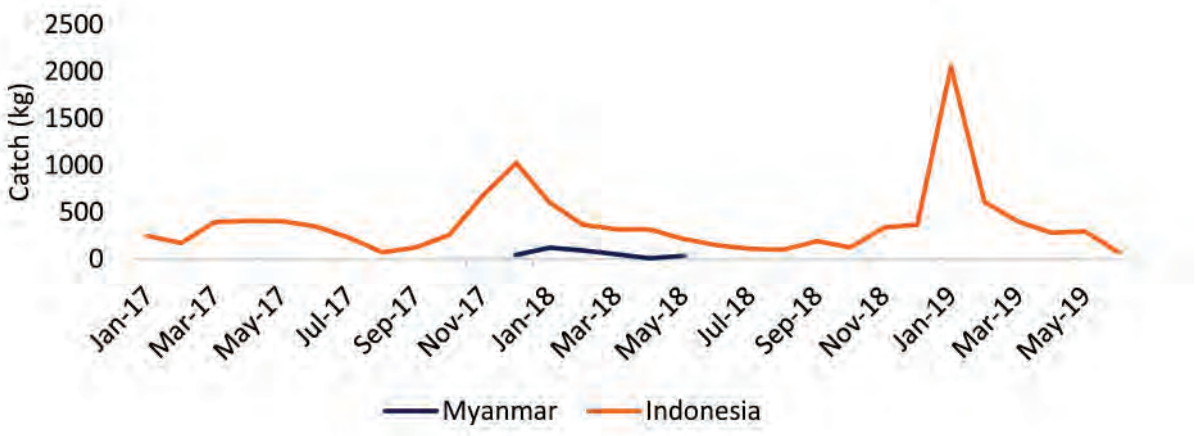

Figure 35. Catch of elver and yellow eel in Southeast Asia (shortfin)

Freshwater eels migrate among freshwater, brackish water, and seawater environments and it is now evident that their movement into freshwater is not an obligate migratory pathway but should be de need as an opportunistic catadromous, with marine and estuarine residents as eco phenotypes. Longfin species (include *A. marmorata* and *A. bengalensis*) is one of the dominant species that exploited in Viet Nam, Philippines, and Indonesia. *A. marmorata* is the most abundant tropical species with five subpopulations widely-distributed in the tropical Indian and Pacific Oceans (Minegishi *et al*, 2008 in Arai 2016). Arai and Chino (2018) confirmed the occurrence of marine resident eels that have never migrated into a freshwater habitat in *A. marmorata*. *A. marmorata* may have the same behavioural plasticity as temperate and other tropical anguillid species regarding whether to enter freshwater or to remain in estuarine and marine environments. Habitat preference of *A. marmorata* would not be a result of its phylogenetic traits but by its environmental adaptations to various habitats and salinities. Environmental factors as well as the interspecific interactions might influence the habitat use of fish. Specific differences in habitat use should be carefully interpreted because the difference might not be a simple interaction among competitors

At the same period, Indonesia which has wide area compare to other countries is the highest country that catch the glass eel with the average catch 184.87 kg/ month (Figure 36). The glass eel was used for supplying the eel farm which more developed in Indonesia, concentrated in Java island. Furthermore, Philippines catch the glass eel with 94.12 kg/month and Viet Nam 10.74 kg/ month. To avoid the over-exploitation of tropical glass eels for aquaculture, both the Philippine and Indonesian governments have prohibited the export of tropical glass eels to Asian countries for aquaculture.

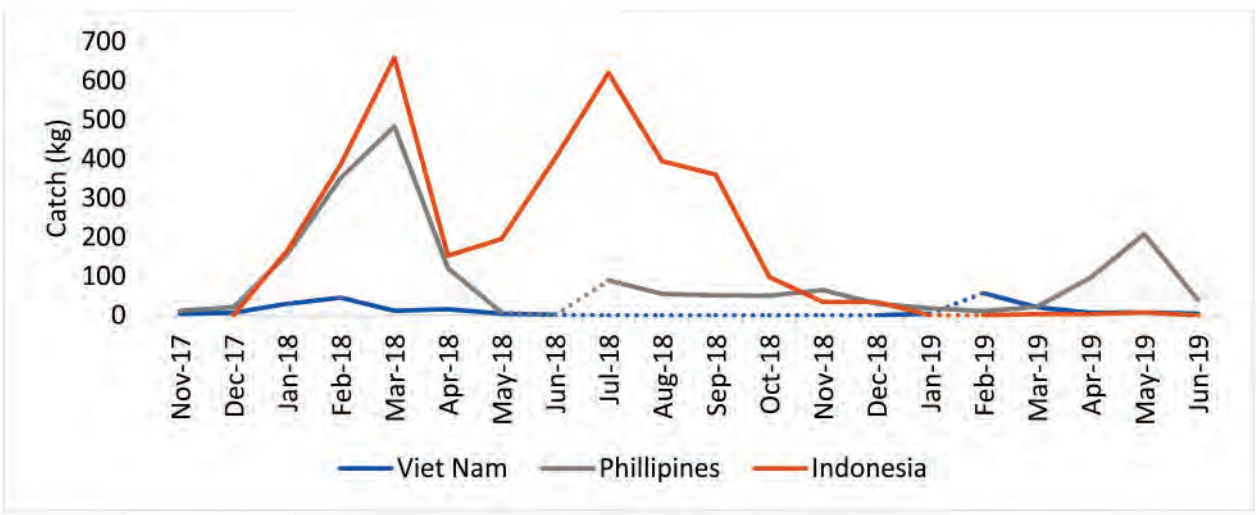

Figure 36. Catch of Glass eel in Southeast Asia (Longfin)

The study revealed that Indonesia and Viet Nam are the country which catch the longfin at yellow eel stage so far. Viet Nam can catch 14.55 kg per month while Indonesia can get 49.34 kg per month in same period (Figure 37).

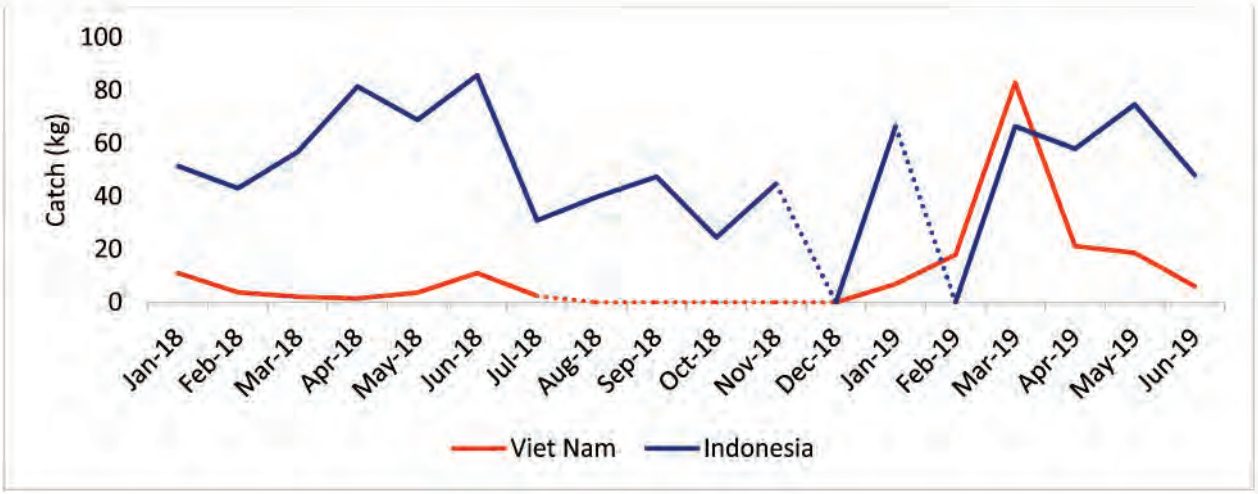

Figure 37. Catch of Yellow eel in Southeast Asia (Longfin)

3.4 Conclusion

This study collected information on continuous catch data in 4 countries. It is important to note that the data collection system of tropical anguillid eel through the regular survey is the initiation in Myanmar and Viet Nam. It will be help to get a clear understanding of the population status of eel in the region. It was seemed that information on effort data might be not completed in certain countries. The data collection in Indonesia and Philippines are running well. Meanwhile, certain sampling site in Indonesia showed incomplete data (without effort data). The study successful showed the discrepancy CPUE in certain sampling site in Indonesia by using different source of effort data due to there is no slightly difference between the trends of catch and CPUE on this period. It showed that even catch amount decrease drastically however the CPUE did not slightly decrease. Through this case study, it cannot be concluded that amount of glass eel resources decreasing or increasing. It needs supporting from whole countries to provide future catch data including the effort data. The achievement will be helpful to better understanding the present status and past/future trends on tropical anguillid eels.

4. Population genetics of *A. bicolor*

One of the mandates of SEAFDEC is to ensure the sustainability of fisheries and aquaculture in Southeast Asia. This includes commercial species such as tropical anguillid eels which is the species of interest for the SEAFDEC Project on the Conservation, Management and Sustainable Utilization of Eel Resources in Southeast Asia. The short-finned eel, *A. bicolor*, has a relatively wide geographic distribution compared to the 19 species and subspecies of the genus Anguilla. This species commands a high market price in international trade as it is an important, export commodity for some ASEAN member states. Information on the population structure of species through genetic studies, is required for the sustainable use and management of *A. bicolor* stocks. Lack of knowledge about stock structure will contribute to the failure of fisheries management and inappropriate harvest of stocks. Apart from protecting biodiversity, harvest and exploitation of stocks can be maximized if fish stock management is based on accurate information such as molecular studies.

Anguilla bicolor resource management is challenged by over utilization of *A. bicolor* stocks, pollution and various human activities resulting to reduction of resources and their genetic diversity. Moreover, *A. bicolor* has two subspecies (*A. bicolor pacifica* and *A. bicolor bicolor*) that are very similar based on morphometric traits but differ in terms of their genetic structure and habitat distribution. Molecular genetic analysis of natural populations of *A. bicolor* depends offer the possibility of investigating population structure, connectivity and distribution thus providing scientific data that can support policies for regulating species catch and protect weaker populations for sustainable long term management resource management. The study of *A. bicolor* genetic composition vis-a vis variation within and between populations and how these can be modified by anthropogenic causes (overexploitation etc), finds its importance in a scheme that calls for effective tropical anguillid eel resource management.

4.1 Objectives

The objective of this activity is to determine population genetic eel fisheries management strategies in Southeast Asia by characterizing the extent of genetic variation within and between populations, as well as within the subspecies of *A. bicolor* (*A. bicolor pacifica* and *A. bicolor bicolor*).

4.2. Methods

Sample collection

A total of 342 specimens of A. bicolor were used in this study for the analysis. The samples were collected from selected catching areas using fyke net. Samples were initially identified using morphological characters and their identities were later confirmed by molecular marker sequencing. Sample information is found in Table 10 and Figure 38. The muscle tissue samples collected from April 2018 until May 2019, were preserved in 95% ethanol before DNA extraction.

DNA extraction, PCR, and sequencing

Muscle tissues (~1.0g) were obtained from the dorsal portion of each fish and preserved in 1.5 ml Eppendorf tubes containing ethanol prior to extraction. DNA extraction was done using Quick-DNATM Miniprep Plus Kit (Zymo Research) following manufacturer's protocol. The hypervariable site of the mitochondrial DNA (mtDNA) control region (D-loop) for *A. bicolor* was amplified using published PCR primers (Tanaka *et al*, 2014).

The mtDNA control region was amplified in 50 µl polymerase chain reactions (PCR) containing 20 µl H2O, 25 µl Quick Taq® HS DyeMix of Toyobo, 1 µl forward primer, 1 µl reverse primer and 3 µl of DNA template. PCR conditions consisted of an initial denaturation at 94°C for 2 min, followed by 35 cycles of 94°C denaturation for 30 sec, 50°C annealing for 30 sec, 68°C extension for 1 min, and final extension of 94°C for 30 sec. After amplification, the PCR products were evaluated for quality and quantity using 1% agarose gels stained with SYBR green. The PCR amplicons were sent to PT Genetica Science Indonesia for purification and sequencing.

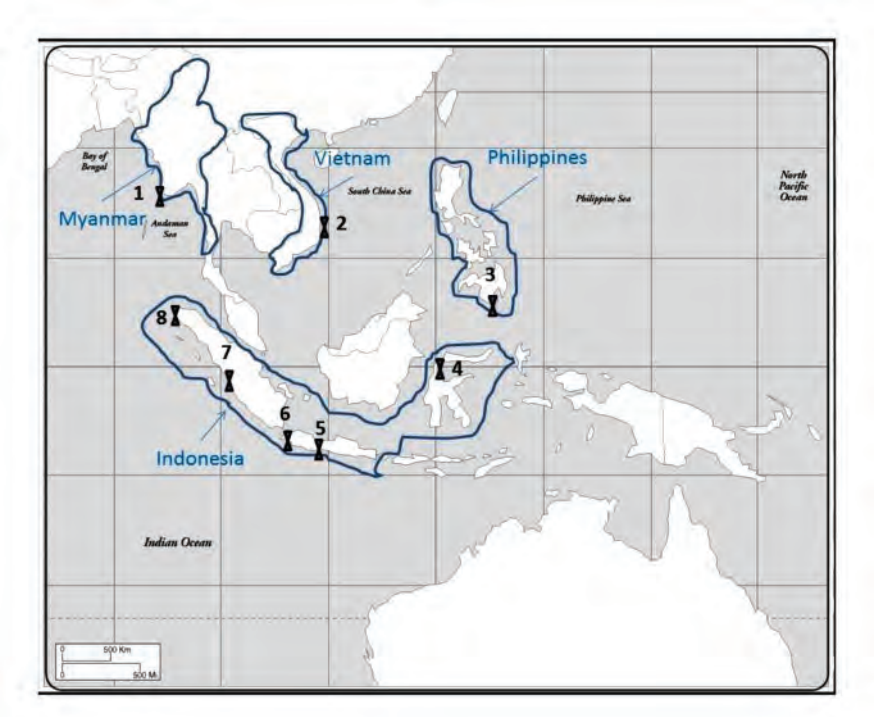

Figure 38. *Map of sampling sites for Anguilla bicolor in Southeast Asia*

Data Analysis

Consensus sequences were created using BioEdit v7.2.5 (Hall, 2013), aligned and edited using MEGA6 (Tamura *et al*, 2013). Genetic variability parameters such as the number of haplotypes and polymorphic sites were determined using DnaSP v5 (Librado and Roxas, 2009). Haplotype or gene diversity (h) and nucleotide diversity (π), and their corresponding variances were obtained using Arlequin 3.5 (Excoffier and Lischer 2010). Moreover, an analysis of molecular variance (AMOVA), was done using Arlequin 3.5 (Excoffier and Lischer 2010), where genetic differentiation indices (FST) and genetic variation partitioning within and among populations were obtained.

Table 10. Sources of eel (*Anguilla bicolor*) samples for genetic analyses

Country	Code	Name of site	Number of samples	Species	Stages of sample
Myanmar	1	Ayeyarwady	45	*Anguilla bicolor bicolor*	Elver-Yellow
Viet Nam	2	Phuyen	3	*Anguilla bicolor pacifica*	Elver-Yellow
Philippines	3	General Santos	52	*Anguilla bicolor pacifica*	Glass eel
Indonesia	4	Palu	53	*Anguilla bicolor pacifica*	Elver-Yellow
	5	Tasik Malaya	50	*Anguilla bicolor bicolor*	Glass eel
	6	Pelabuhanratu	36	*Anguilla bicolor bicolor*	Glass eel
	7	Aceh	52	*Anguilla bicolor bicolor*	Glasseel
	8	Bengkulu	50	*Anguilla bicolor bicolor*	Elver-Yellow
Total of samples			342		

Note: For the meaning of code numbers, please refer to Figure 38

4.3 Results and Discussion

A. bicolor consists of two subspecies. Morphologically, the two appear similar, but the two subspecies were observed to belong to different distribution areas. Therefore, in this study, a separate analysis was carried out for each of the two subspecies.

Genetic Diversity

A total of 94 haplotypes were identified in the 108 samples *A. bicolor pacifica* (Tables 11 and Appendix 2). All haplotypes were unique, no haplotype was shared between the different populations of *A. bicolor pacifica* found in Southeast Asia. The relationships between haplotypes are shown in the network tree (Figure 39) and results did not show any geographical structuring. Among the three studied populations (Palu, General Santos, and Phuyen), the General Santos population showed the highest haplotype number (52) while the lowest haplotype number (3) was observed in the Phuyen population. This result might have arisen from the basis of the geographical distribution of populations; given the high average geographic distance between the populations hence gene interactions between the populations examined were low (Figure 38).

About 219 haplotypes from 233 samples of *A. bicolor bicolor* were analyzed (Table 11). Most of the haplotypes are unique, while some samples shared haplotypes (haplotype 88 or H88, H106, H154, and H185) given that they originated from the same population. However, there were several haplotypes that are common with other populations e.g. H1 being shared with three populations (Aceh, Pelabuhan Ratu, and Ayeyarwady). The H33 haplotype is common between samples originating from the Pelabuhan Ratu and Ayeyarwady populations. H36 is shared between samples from Port and Bengkulu, H57 between samples from Tasikmalaya and Bengkulu while H128 and H109 haplotypes are both shared by populations from Aceh and Bengkulu. Finally, haplotype H130 is shared between populations from Bengkulu and Ayeyarwady (Appendix 2). Of the five populations of *A. bicolor bicolor* examined in the study (Ayeyarwadi, Aceh, Bengkulu, Pelabuhan Ratu, and Tasikmalaya) the population from Aceh had the highest number of haplotypes (51).

The lowest haplotype number was observed in the Pelabuhan Ratu population (36). This result might have arisen on the basis of the geographical distribution of populations, given that the average distance between the populations were relatively shorter, thus offering higher probabilities for gene interaction between the aforementioned populations (Figure 38). The relationships between haplotypes are seen in the network tree, where no geographical structuring can be observed (Figure 40).

Table 11. Subspecies of *A. bicolor*, sampling locality, number of sequences, gene diversity (h), nucleotide diversity (π) in Southeast Asia

Subspecies	Sampling locality	Number of sequences	Nucleotide diversity (%) (μ)	Genetic Diversity (h)
A.bicolor bicolor	Ayeyarwady	44	0.035	0.99
	Aceh	51	0.032	0.99
	Bengkulu	46	0.035	0.99
	Pelabuhan Ratu	36	0.035	1.00
	Tasikmalaya	50	0.035	1.00
A.bicolor pacifica	General Santos	52	0.030	1.00
	Phuyen	3	0.017	1.00
	Palu	39	0.028	0.99

Haplotype diversity was generally high for all populations in both sub-species of *A. bicolor* (0.99 to 1.00), while the values of nucleotide diversity were relatively low (0.017 to 0.035). Nucleotide diversity might be influenced by other factors such as ecological habits and life history of *A. bicolor.*

Population structure

An Analysis of Molecular Variance (AMOVA) on the genetic variability data enabled the identification of significant genetic structures in the hierarchical rearrangements examined in *A. bicolor pacifica*. The genetic variance within and among populations was significant ($P < 0.05$) (Table 12). The FST values computed for pairwise comparisons revealed low to moderate genetic differentiation. This analysis revealed low but highly significant differentiation between populations. The level of population genetic structure assessed by AMOVA indicated that the proportion of genetic variation among the *A. bicolor pacifica* populations was 0.47%, a significant value of 0.000 ($P<0.000$), and about 99.5% of the variance in the samples was attributable to within population variation.

Table 12. Analysis of molecular variance (AMOVA) of *A.bicolor pacifica*

Source of variation	d.f	Sum of squares	Variance components	Percentage of variation
Among population	2	1.129	0.00236 Va	0.47
Within population	104	51.750	0.49760 Vb	99.53
Total	106	52.879	0.49996	
FST	0.0047			
P-value	0.005			

As for *A. bicolor bicolor*, the genetic variance within and among populations was not significant at 0.134 (P> 0.05) (Table 13). The FST values (0.00043) computed for pairwise comparisons revealed very low genetic differentiation. This analysis revealed no significant differentiation between populations. The level of population genetic structure assessed by AMOVA indicated that the proportion of genetic variation among the *A. bicolor bicolor* populations was 0.04%, with a significance value of 0.116 (p>0.000), and about 99.9% of the variance in the samples was attributable to within population variation.

Table 13. Analysis of molecular variance (AMOVA) of *A. bicolor bicolor*

Source of variation	d.f	Sum of squares	Variance components	Percentage of variation
Among population	4	2.038	0.00022 Va	0.04
Within population	227	113.397	0.49955 Vb	99.9
Total	231	115.435	0.49976	
FST	0.00043			
P-value	0.134			

Tables 12 and 13 show very high within population genetic diversity which could be due to temporal differences among individuals within each of the populations that were examined. This is based on (haplotype frequency analysis as done through Arlequin). From the result, we can see that that there are population structure differences between the Southeast Asins populations of *A. bicolor pacifica* but not for the Southeast Asian populations of *A. bicolor bicolor* (Fig 39 and 40). The results of this study is similar to the findings of Minegishi *et al*, (2012) and Fahmi (2013) in that *A. bicolor bicolor* is genetically homogeneous in the whole Indian Ocean and the subspecies may belong to a single population using a single spawning area. In contrast, information related to population connectivity (in relation to reproduction) for *A. bicolor pacifica* has yet to be confirmed (Aoyama *et al*,, 2018).

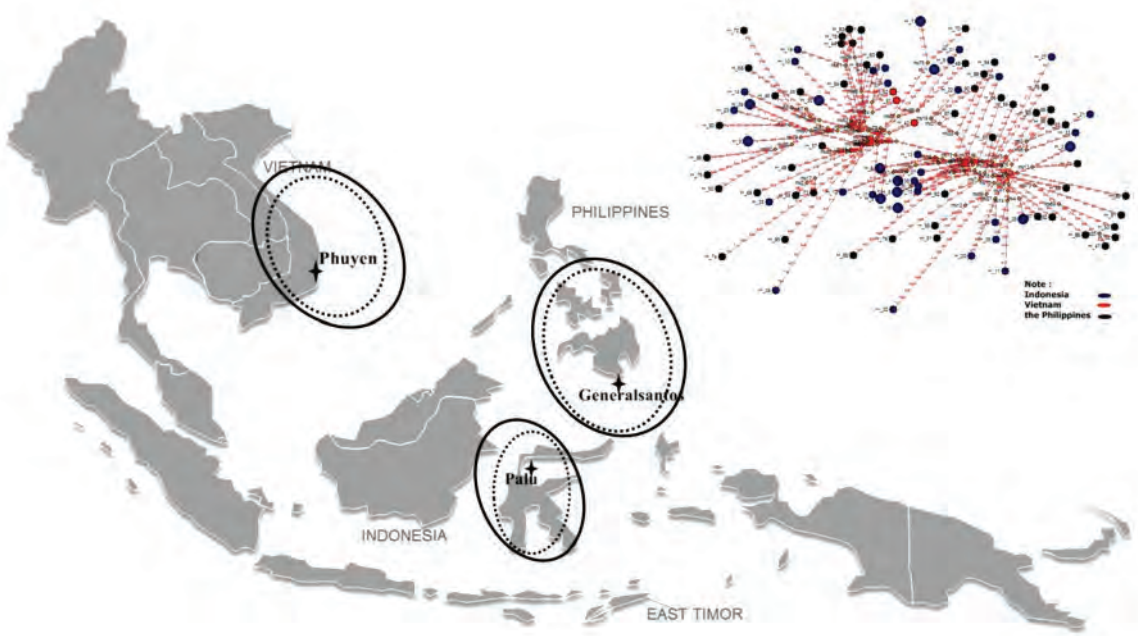

Figure 39. Genetic population structure of A. bicolor pacifica in Southeast Asia

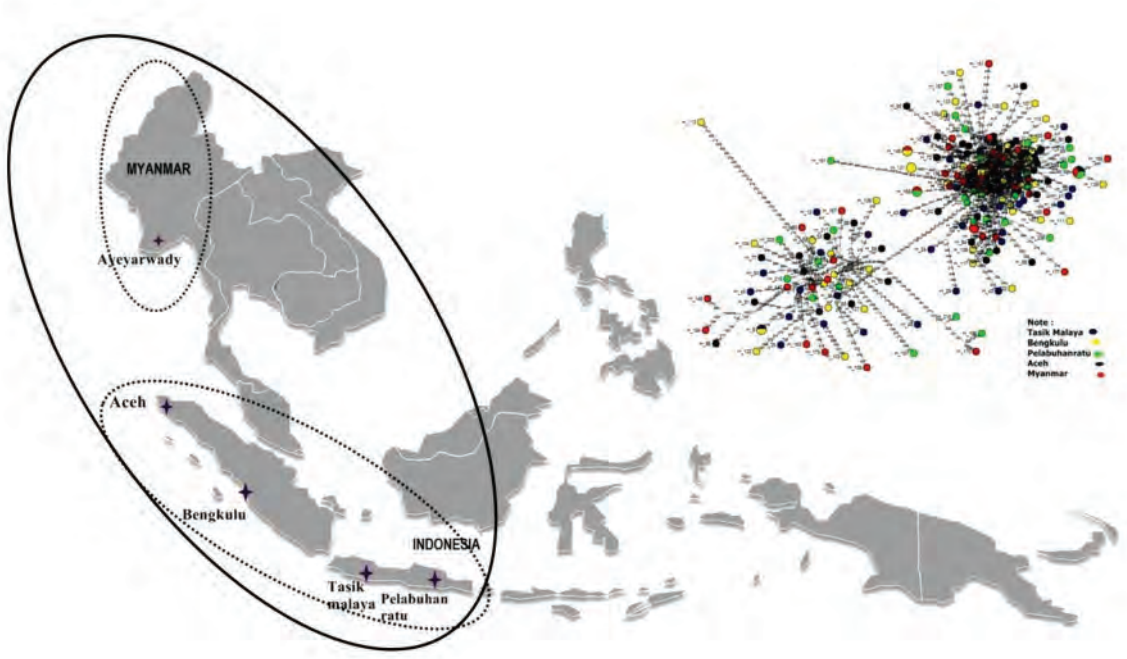

Figure 40. Genetic population structure of A. bicolor bicolor in Southeast Asia

In this regard, fisheries management for populations belonging to the two subspecies should be sub-species specific to be sustainable. Moreover, information related to the connectivity between populations of these subspecies in Southeast Asia should be taken into consideration prior to carrying out management actions.

Although mtDNA has been proven to be a very useful marker, its use is not without complications. Due to the exclusively maternal inheritance, mtDNA represents a marker strictly for historical process in females that can potentially introgress between species (Ballard *et al*, 2004; Jiggins, 2003), and symbiont-driven changes could occur in mtDNA variation over space specifically in arthropods (Hurst *et al*, 2005). Moreover, genetic analyses of species across this range are still few hence further studies that incorporate supporting evidence from nuclear markers, with an increased number of sampling locations around the Southeast Asia should be done to enable a more robust analysis.

4.4 Conclusion

There are two conclusions to be drawn from the results of this preliminary study, the first is that the tropical Anguillid eel Anguilla bicolor resources in Southeast Asia are still stable/healthy (value of genetic diversity both subspecies *A bicolor* are high). The second is that genetic structure differences exist in the Southeast Asian populations of *A. bicolor pacifica* (no shared haplotype; P-value <0.05) but no genetic population structure differences exist between the Southeast Asian populations of *A. bicolor bicolor* (many shared haplotypes; P-value>0.05). This means that formulating management plans for these two subspecies should be sub-species specific. To sustainably manage these resources requires cooperation among countries in Southeast Asia. Moreover, more studies using other molecular markers (preferably nuclear markers) in analysing more samples taken at several periods (to check for temporal variation) in the same collection site should be conducted to provide a better profile of the eel stocks/resources that need to be managed.

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Table 14. Haplotype distribution of *A.bicolor pacifica*

H	IND	PHL	VNM	H	IND	PHL	VNM	H	IND	PHL	VNM	H	IND	PHL	VNM	H	IND	PHL	VNM
H1	2			H21	1			H41			1	H61		1		H81		1	
H2	2			H22	1			H42			1	H62		1		H82		1	
H3	2			H23	1			H43			1	H63		1		H83		1	
H4	2			H24	1			H44		1		H64		1		H84		1	
H5	2			H25	1			H45		1		H65		1		H85		1	
H6	2			H26	1			H46		1		H66		1		H86		1	
H7	2			H27	1			H47		1		H67		1		H87		1	
H8	2			H28	2			H48		1		H68		1		H88		1	
H9	1			H29	1			H49		1		H69		1		H89		1	
H10	1			H30	2			H50		1		H70		1		H90		1	
H11	1			H31	1			H51		1		H71		1		H91		1	
H12	1			H32	1			H52		1		H72		1		H92		1	
H13	1			H33	1			H53		1		H73		1		H93		1	
H14	1			H34	1			H54		1		H74		1		H94		1	
H15	1			H35	1			H55		1		H75		1		H95		1	
H16	2			H36	1			H56		1		H76		1					
H17	1			H37	1			H57		1		H77		1					
H18	1			H38	1			H58		1		H78		1					
H19	1			H39	2			H59		1		H79		1					
H20	1			H40	1			H60		1		H80		1					

Noted: H (Haplotype); IND (Indonesia); PHL (Philippines); VNM (Vietnam)

Table 15. Haplotype distribution of *A.bicolor bicolor*

H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY
H1	1					H21	1					H41	1					H61		1			
H2	1	1				H22	1					H42	1					H62		1			
H3	1					H23	1					H43	1					H63		1			
H4	1					H24	1					H44	1					H64		1			
H5	1					H25	1					H45	1					H65		1			
H6	1					H26	1					H46	1					H66		1			
H7	1					H27	1					H47	1					H67		1			
H8	1					H28	1					H48	1					H68		1			
H9	1		1			H29	1					H49	1					H69		1			
H10	1					H30	1					H50	1					H70		1			
H11	1					H31	1					H51		1				H71		1			
H12	1					H32	1					H52		1				H72		1			
H13	1					H33	1					H53		1				H73		1			
H14	1					H34	1					H54		1				H74		2			
H15	1					H35	1					H55		1				H75		1	1		
H16	1					H36	1					H56		1				H76		1			
H17	1					H37	1					H57		1				H77		1			
H18	1					H38	1					H58		1				H78		1			
H19	1					H39	1					H59		1				H79		1			
H20	1					H40	1					H60		1				H80		1			

H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY
H81		1				H101			1			H121			1			H141			1		
H82		1				H102			1			H122			1			H142			1		
H83		1				H103			1			H123			1			H143			1		
H84		1				H104			1			H124			1			H144					
H85		1				H105			1			H125			1			H145			1		1
H86		1				H106			1			H126			1			H146					1
H87		1				H107			1			H127			1			H147					1
H88		1				H108			1			H128			1			H148					1
H89		1				H109			1			H129			1			H149					1
H90		1				H110			1			H130			2			H150					1
H91		1				H111			2			H131			1			H151					1
H92		1				H112			1			H132			1			H152					1
H93		1				H113			1			H133			1			H153					1
H94		1				H114			1			H134			1			H154					1
H95		1				H115			1			H135			1			H155					1
H96		1	1			H116			1			H136			1			H156					1
H97		1				H117			1			H137			1			H157					1
H98		1				H118			1			H138			1			H158					1
H99		1				H119			1			H139			1			H159					1
H100		1		1	1	H120			1			H140			2			H160					1

H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY	H	ITSK	IACH	IBKL	IPRT	MARY
H161					1	H181					1	H201				1		H221			1		
H162					1	H182					1	H202				1		H222					1
H163					1	H183					1	H203				1							
H164					1	H184					1	H204				1							
H165					1	H185					1	H205				1							
H166					1	H186				1		H206				1							
H167				1	1	H187				1		H207				1							
H168					2	H188				1		H208				1							
H169					1	H189				1		H209				1							
H170					1	H190				1		H210				1							
H171					1	H191				1		H211				1							
H172					1	H192				1		H212				1							
H173					1	H193				1		H213				1							
H174					1	H194				1		H214				1							
H175					1	H195				1		H215				1							
H176					1	H196				1		H216				1							
H177					1	H197				1		H217				1							
H178					1	H198				1		H218				1							
H179					1	H199				1		H219				1							
H180					1	H200				1		H220				1							

Noted: Haplotype (H); ITS (Indonesia Tasikmalaya); IACH (Indonesia Aceh); IBKL (Indonesia Bengkulu); IPRT (Indonesia Pelabuhanratu); MARY (Myanmar Arysuwandy)

5. Refinement of eel nursery techniques to improve survival rates

SEAFDEC/AQD conducted the following activities to assess and improve survival rates in the nursery of tropical anguillid eels as well as conduct genetic characterization of eel stocks used in the nursery rearing trials:

- Survey of anguillid eel nursery farms in Philippines
- Survey of anguillid eel farms in Viet Nam
- Nursery rearing trials using different feeds and feeding management
- Assess pathogens in cultured tropical anguillid eels and recommend health management protocols
- Identification of tropical anguillid eel species used in the nursery rearing trials through morphometric and genetic characterization

5.1 Survey of Eel Farms in Philippines

Various life stages of anguillid eels have been commercially exploited and traded internationally. Anguillid eel farming started in 1879 in Japan and in the 19th century in Italy and France (Liao *et al*, 2002). By the year 2000, at least 24 countries have been culturing eels. Expansion of the culture of anguillids is mainly market-driven. Anguillid eels have been traditionally cultured in East Asia, the United States and Europe. The bulk of world production is from aquaculture. However, supply of seed is dependent on collection from the wild. With the decline in the population of the temperate eel species like the European, Japanese and American eel, *Anguilla anguilla*, *A. japonica*, and *A. rostrata*, respectively, various conservation and management measures to protect these species from further decline have been put in place such as catch and trade limits. To fill the gap in the demand for the traditional anguillid eel species, the tropical anguillid eel fishery in Southeast Asia has been tapped (Jacoby *et al*, 2015). This resulted in a significant increase in the export of live eel fry from some Southeast Asian countries, the Philippines in particular. From a 4% contribution to live glass eel export to East Asian countries between 2004 and 2010, the Philippine contribution increased to 29% by the years 2011 to 2013 (Figure 41 from Crook, 2014). This upward shift coincided with the imposition of restrictions on the fishery and trade of temperate eel species, particularly the European eels.

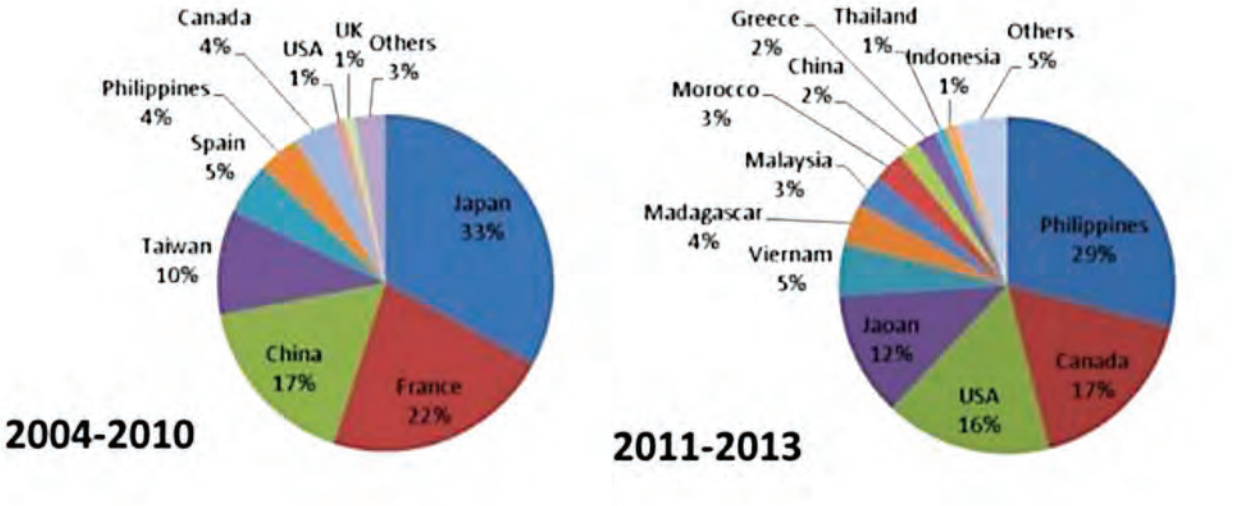

Figure 41. Percent contribution of various sources of live glass eels imported into mainland China, Taiwan, Japan and Korea. Source: East Asian Customs data as cited by Crook, 2014

The increased fishing pressure on glass eels in some Southeast Asian countries has resulted in regulatory and management measures for the species. For instance, regulations on the export of anguillid eels as a way to manage and conserve the resource have been put in place in some states. In Indonesia, legal size for export of glass eels is 150 g. In Philippines, the minimum legal size for export is above 15 cm elvers. Previous to this size limitation on export of anguillids, both countries had a thriving export industry for glass eels. The size regulation has prompted the development of the anguillid eel culture industry in these countries to achieve production volumes of the target legal export size. Tropical anguillid elver production in Philippines is primarily targeted for export to East Asian countries, as an alternative species to the Japanese eel.

5.1.1 Objectives

This activity focused on the production practices of anguillid eels from glass eels to elvers of nursery farms in Philippines to identify culture management practices and identify the needs and problems of the industry that should be addressed to improve survival rates.

5.1.2 Methods

A survey of existing Anguillid eel farms in various areas of Philippines was conducted. The following information were obtained during the survey/interview of the aquaculture farms:

- Farm Owner and location of farm
- Type of Farm
- Scale of operation
- Source of water and water quality management
- Farm capacity (number of rearing tanks, type, water treatment system, if any)
- Years in operation

- Source of glass eels (mode of collection from source/consolidator)
- Post-transport survival of glass eel
- Quarantine & Conditioning Practice upon arrival of glass eels
- Stocking density
- Feeds, ration, and feeding rate (live or artificial feeds (e.g., on-farm or commercial and price), feed type, feed proximate composition
- Survival of glass eel to elver
- Nursery rearing protocol
- Culture duration from glass eel to elver
- Suspected cause of mortalities; any observed/reported disease incidences; treatment (e.g. use of antibiotics such as oxytetracycline)
- Species identification (and percentage species composition); mode of identification/validation of identification
- Problems encountered by the industry

A total of fifteen anguillid eel farms in Philippines was surveyed from Luzon and Mindanao out of the 28 BFAR-registered eel farms.

5.1.3 Results and Discussion

Of the fifteen tropical anguillid eel farms surveyed, nine farms were in Luzon and the rest in Mindanao. The provinces/cities where the farms are located are: Laguna, Cagayan, Zambales, Pampanga, Agusan del Norte, Davao City, General Santos City, Sarangani, Rizal, Cavite and Batangas. Figure 42 shows the location of the farms. All surveys were conducted in coordination with Dr. Evelyn Ame of BFAR (Bureau of Fisheries and Aquatic Resources) Region 2 who is the National Eel Focal Person. All surveys were also accompanied by the respective BFAR Regional officers.

The following were the results of the survey:

Farm Ownership - Only about 47% of the anguillid eel farms in the country is solely owned by Filipinos, the rest are either in partnership with foreign nationals or solely owned by foreign nationals. Seven farms are owned solely by Filipinos; 2 farms each in partnership with Filipino and Japanese or Korean nationals; and 1 farm co-owned by Filipino and Taiwanese. One 1 farm each owned solely by a Japanese, Taiwanese and a Korean national.

Type of Farm - Most farms are indoor, with one farm having a combination of outdoor and indoor facilities. Of all the farms surveyed, only one farm is focused on grow-out with indoor nursery facilities and outdoor grow-out ponds. The nursery operations of five farms rely on static-renewal system of water change ranging from daily water change of 10 to 75% of the total water volume daily. One farm has a recirculating system and two farms have flow-through system.

Scale of operation and farm capacity - Glass eels stocking capacity of farms range from 10 to 300 kg of glass eels per year. At an estimated 5,000 to 6,000 pcs of glass eels per kg, this ranges from 50,000 to 1.8 million glass eels at stocking. Size of nursery culture tanks vary from 4m^3 to 500m^3.

Source of water and water quality management - Mainly deep-well or ground water are the sources of water for anguillid eel farms. Water levels in nursery farms is maintained at 50 to at most 100 cm depth. Nursery of glass eels to elvers is done in fresh water. Glass eels purchased from consolidators have been typically pre-acclimated in fresh water from the brackishwater salinity from at the fishing areas at river mouths where they are caught. Although some farms deliberately add some rock salt (NaCl) to the tanks to raise salinity up to 5 ppt, there are studies that show that growth rates of glass eels are higher in fresh water.

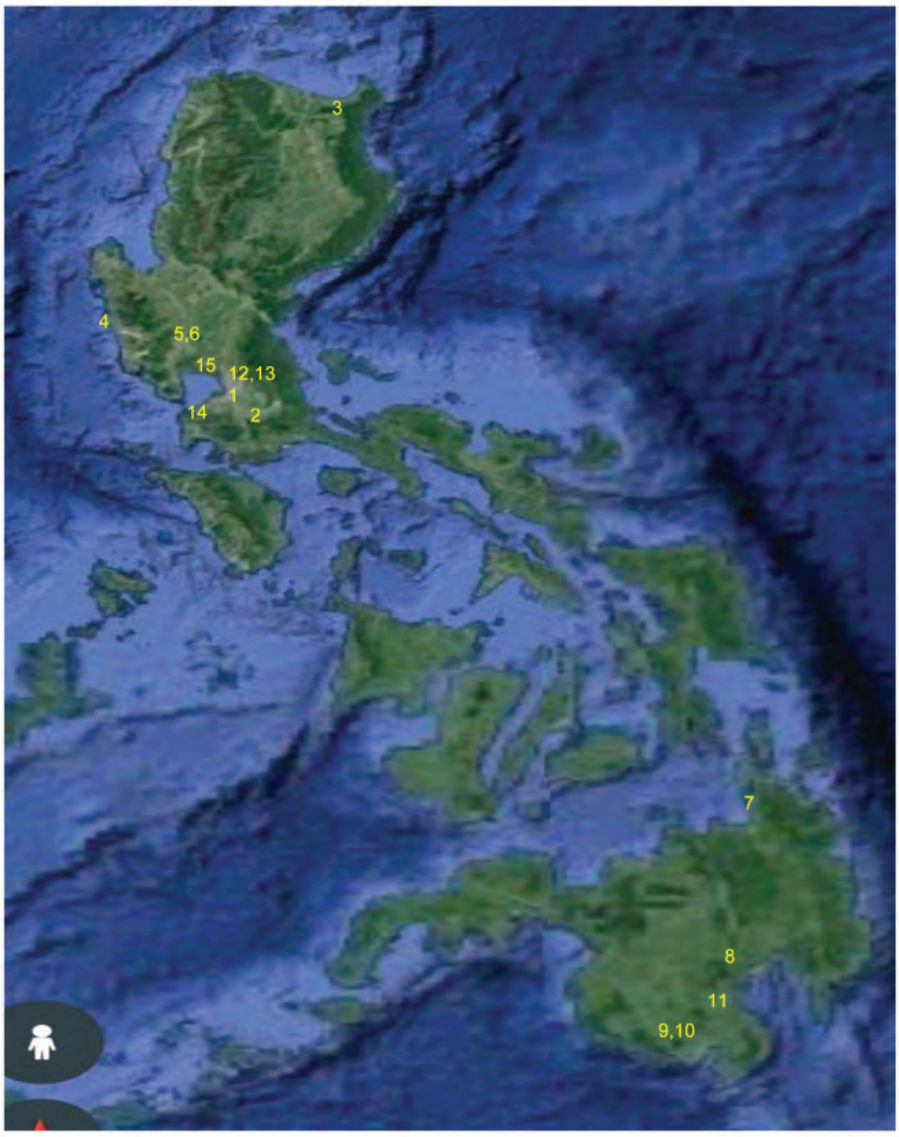

Figure 42. Location of tropical anguillid eel farms surveyed in Philippines. Number indicates the order in which the farms were surveyed. (From Google Maps®)

Nursery of glass eels to elver is done in fresh water. An efficient aeration system to deliver dissolved oxygen in the culture tanks is essential. Culture of tropical anguillid glass eels to elver size require minimum dissolved oxygen concentration of 5 mg/L. Juvenile eels succumb to oxygen concentrations below 2 mg/L. Unlike in temperate countries where eel culture requires water heated to 28 to 30°C during cold months, Philippine eel nursery farms do not control the temperature and eels are reared in ambient temperature. Glass eels have been reared in 19 to 30°C temperature with no overt sign of showing temperature stress.

Scale of operation and farm capacity - Glass eels stocking capacity of farms range from 10 to 300 kg of glass eels per year. A kilogram of glass eels range from 5,000 to 6,000 pcs. This means farm capacity has a minimum of 50,000 pcs to 1.8 million glass eels at initial stocking. Size of nursery culture tanks vary from $4m^3$ to $500m^3$.

Years in operation - Farms range from one to six years in operation

Source of glass eels - Mainly Aparri in Cagayan Province (Figure 43) and the following areas in Mindanao: General Santos, Sarangani, and Davao.

Figure 43. Glass eels from Aparri, Cagayan Province

Post-transport survival of glass eel - Farms generally have high survival rates at 95% to almost 100%. AQD conducted its own survival trials from two glass eel sources with similar results as shown in Figure 44.

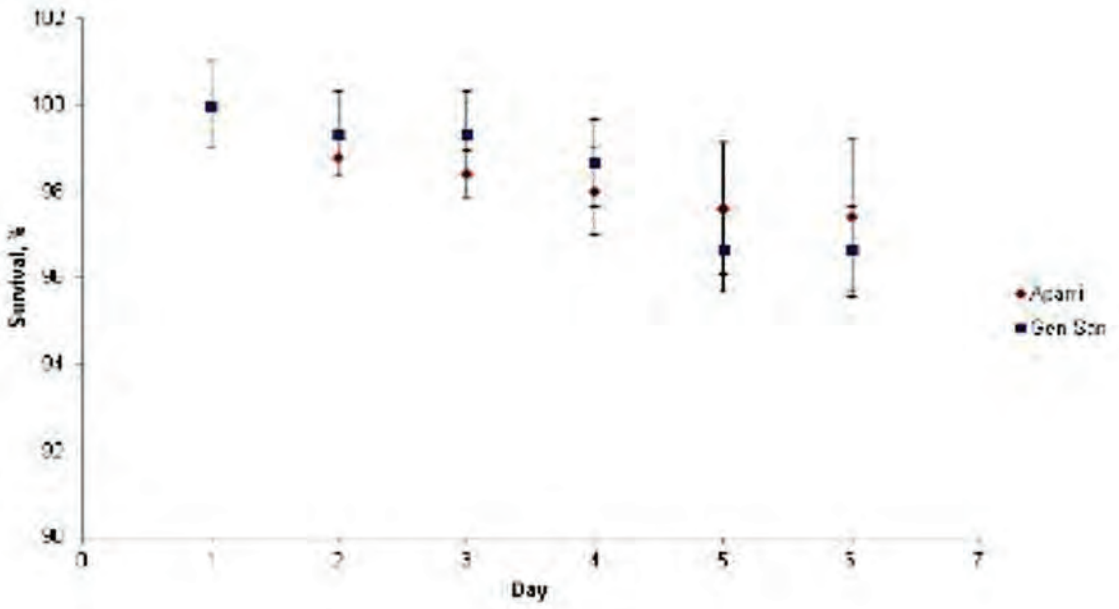

Figure 44. Post-transport survival of glass eels from two sources: Aparri and General Santos

Quarantine & Conditioning Practice upon arrival of glass eels - Four farms observe quarantine practices while others rely on treatment of newly arrived glass eels to salt bath. One farm admitted to the use of some antibiotic upon arrival of the glass eels in the farm.

Upon arrival in the nursery, the plastic transport bags are allowed to float in the holding tank to adjust for temperature differences between the transport water (usually cooled down to about 20°C) and the holding tank water (ambient temperature). The plastic bags are then opened and, the temperature measured. Once there is no temperature difference between inside the water in the transport bag and the holding tank, the glass eels may be transferred in a basin and water from the holding tank gradually added to the basin with the original transport water. Once the basin is filled up, the acclimated glass eels are allowed to swim out of the basin into the holding tank.

Successful eel nurseries in the Philippines practice pre-treatment of glass eels upon arrival in the nursery. Salt bath of 35 ppt (equivalent to full strength seawater) is prepared with vigorous aeration. Duration of immersion is from 30 seconds to 1 minute. After immersion, the glass eels are transferred to clean untreated fresh water, again provided with aeration. Newly acquired glass eels may carry parasites and other pathogens from their place of origin that can eventually proliferate and affect growth and survival in the nursery. Post transport survival of glass eels are generally above 90% if proper acclimation, conditioning and pre-treatment is observed.

Stocking density - Nursery farms in Philippines have a wide range of initial stocking densities from 1 to 12 pcs per liter. However, stocking no more than 5 pcs per liter (1 kg glass eel in 1000 liters of water) is recommended. For the farm using 12 pcs per liter stocking density, high mortality of eels in the nursery have been reported, despite more frequent size grading of every two weeks.

Feeds, Feed ration and feeding rate - Some Farms use tuna eggs, brine shrimp *Artemia* nauplii or blood worm *Tubifex* as initial feed for newly stocked glass eels, at least for a week to 10 days. The rest use commercially formulated diet while one farm formulates its own feed. In subsequent stages of the nursery rearing although there is a local feed company producing commercial diets formulated for tropical anguillid eels, most of the farms surveyed prefer to use feeds imported from China, Japan or Korea. The imported feeds give better results in terms of growth and survival according to the farm respondents. Feeding is normally done twice a day with the feed in dough form. One farm practice ad libitum feeding but the rest calculate feeding rate based on the standing biomass.

Survival of glass eel to elver (at least 15 cm) - Survival rates reported by the farms surveyed for 2017 ranged from 30 to 98%. Some farms had total mortalities at the initial stage of operation.

Nursery rearing protocol - Size grading or sorting is done during the course of the nursery culture. Monthly size grading of eels is ideal to sort out fast fast-growing ones from the slower slower-growing individuals. Similarly sized eels are grouped in tanks separate from other size groups. Size grading minimized cannibalism. Size grading or sorting during the nursery rearing is done by all the farms from as early as one month after stocking. One farm claims to sort the eels monthly while others at a lesser frequency of every 2 months.

Culture duration from glass eel to elver (at least 15 cm) - The shortest culture duration for fast-growing individuals is 3 months with the longest as 18 months. Most farms average 6 months to produce the elvers of the desired size. *A. bicolor pacifica* reaches the target size at a generally shorter culture period compared to *A. marmorata*.

Suspected cause of mortalities - Farmers interviewed suspect bacterial and fungal infection as contributing to mortalities in the nursery. Poor water quality in the culture tanks also lead to mortalities. Poor quality of glass eels delivered to the farm by the suppliers also result in initially high mortalities of the glass eel stocks.

Species identification - Except for one farm, all the farms surveyed are unable to identify visually the species of glass eels upon arrival at the farm. However, two consolidators in Mindanao claim to have skilled people who are able to visually sort glass eels enabling them to sell pre-sorted glass eels at a premium price as stated in the previous section.

Problems encountered by the industry - Based on the survey, among the problems that need to be addressed in the anguillid eel culture industry are:

- Species identification of glass eels - Farmers clamor to be trained in identifying species at the glass eel stage. Many farmers feel it is a waste of effort to culture *A. marmorata*, since species preferred by the East Asian market is *A. bicolor pacifica*. Except for a couple of farms in Mindanao who are able to identify species at the glass eel stage, the rest are at the mercy of anguillid eel traders/consolidators. Some farms rear the glass eels for at least a month before they are able to identify the species.
- Market promotion and value-adding for *A. marmorata* - Since the dominant catch in recent years is *A. marmorata*, farmers feel a need to promote the species in the East Asian market. Value adding to the species is also one strategy to improve its marketability.
- Lower the production cost - Most farms incur high production costs due to imported feeds, high cost of electricity, among others and therefore requests the development of strategies to reduce production costs in the farm.
- Ensure reliable source of bloodworm and other live food - All farms rely on live feed at the initial stages of stocking of glass eels in the nursery. Availability of bloodworm and other live food organisms should be stable.
- Reduce rearing period from glass eel to elver from 6 months to 3 months - This needs more research on improving growth rates of tropical anguillid eels in the nursery. This could be addressed by better quality feeds and more efficient nursery management techniques.
- Address disease problems e.g. gas bubble disease, fungal and bacterial infection
- Address illegal trade of anguillid eels, particularly glass eels - Despite the ban on the trade of glass eels, farmers report that there still exists smuggling of glass eels.
- Control unreliable suppliers/consolidators who promise to deliver goods - This is to address poor quality glass eels arriving in the farm where survival can be low. In addition, there are traders/consolidators who promise high percentage of the preferred species (*A. bicolor pacifica*) in the glass eels' batch, when in fact, the glass eels are mostly *A. marmorata*.
- Cost efficient feeds that will suit the needs of the tropical anguillid eel nursery. The imported feeds currently used by the farms are formulated for *A. japonica*.
- Stable power supply and at lower cost - Most farms prefer to install recirculating system, but this cannot be pursued due to the high cost of electricity in the country as well as erratic and unstable supply, which can damage expensive pumps and other equipment.

5.1.4 Conclusions and Recommendations

The best management practices obtained from the survey of Philippine anguillid eel nursery farms for improved survival are summarized in Table 16.

Table 16. Best farm management practices for improved survival in nursery rearing of glass eels to elvers based on farm surveys

Parameter	Best practice
Stocking density	Maximum of 5 pcs/l
Dissolved oxygen	Minimum of 5 mg/l
Disinfection and pre-treatment	glass eels upon arrival in the nursery are given a salt bath of 35ppt for 30 sec to 1 min with vigorous aeration; then transfer to clean aerated freshwater
Conditioning and acclimation	Gradual acclimation of glass eels to rearing tank conditions
Size grading	Done at least every two months or more frequently for faster growing juveniles
Feeding frequency	Twice a day; morning and afternoon
Water management	At least partial water replacement an hour after feeding

Philippines is not a traditionally eel-consuming country. The bulk of the nursery and even grow-out production is exported to mainly East Asian countries such as Japan, Korea, Taiwan and China. The country, the top source of tropical anguillid eels and will continue to be so with the current trend in *Anguilla japonica* resources. More efficient production systems for tropical anguillid eels are needed, accompanied by regulations and policies to maintain the sustainability of the production of this commodity. As it is, the culture industry of tropical anguillids is solely dependent on wild stocks. This means that availability in the wild is the major constraint in the growth of this industry. Captive breeding of tropical anguillids is largely unknown, although much resources have been provided for the research and development of breeding of the Japanese and European anguillids, with minimal success. Research initiatives on the breeding of the species is now timely.

5.2 Tropical Anguillid Eel culture in Viet Nam

5.2.1 Objectives

Eel fishery in Viet Nam has been in existence for decades, but the collection of eel juveniles from the wild for stocking in farms only started in the late 1990s and grew in the middle to late 2000s. Unlike Philippines where anguillid eel culture is mainly focused on the nursery rearing of glass eels to elvers, farming in Viet Nam primarily focus on grow-out. Only a few farms stock glass eels and rear these to yellow eel for selling to other farms for further grow-out. The objective of this activity is to characterize the anguillid eel culture industry in this country.

5.2.2 Methods

Some farms which stock glass eels for culture were surveyed in the middle and in the Mekong Delta of Viet Nam. One farm, the largest in the country is in Khánh Hòa province, and the other farm is in Phu Yen province. Both farms are more successful in the farming of anguillid eels compared to the others. The rest of the information on other eel farms and farm practices were obtained from information provided by Mr. Pham Truong Giang of the Research Institute for Aquaculture No. 3.

5.2.3 Results and Discussion

Collection sites and fishing gears. Glass eels are mainly caught and cultured in three provinces : Phu Yen, Binh Dinh and Khanh Hoa. PhuYen province eel fishery started in 2000 with 100 g size individuals. By 2005 glass eel collection started in Tuy An district. In 1998 and 2008, Koreans and Japanese, respectively, attempted to catch glass eels but failed. Prior to 2007 residents class glass eels only for chicken feed. By 2007, glass eel fishery has started to add to existing collection of elvers and yellow eels. The largest eel collector in the province started collection of glass eels in 2008. In Binh Dinh province, collection of elver and yellow eels started in 1997 and it was only in 2000 that glass eel collection started. Elvers were imported from China until 2011 in Khanh Hoa province. It was only in 2012 that glass eels collected in Phu Yen and Binh Dinh provinces were brought to Khanh Hoa.

Anguilla marmorata is the dominant species caught in the country comprising of 95% and 5% *A. bicolor pacifica*. while *A. japonica* is rarely caught in the country. The following are the estimated contributions of eels caught in different provinces in Viet Nam: Quang Ngai, 2 to 5%; Binh Dinh, 10 to 15%; Phu Yen, greater than 80%; Khanh Hoa, 1% and Ninh Thuan, 1%

The Ky Lo and Ba Rivers are the main fishing grounds in Phu Yen province (Figure 45). The main gears used in collecting glass eels are scoop net, brush bundle trap and fence net (Figure 46). Scoop nets are set at night (between 18:00 to 22:00h) and may be the triangle net type, which can be operated by a single person; or the rectangular net, operated by two persons. Brush bundle traps are made from branches with leaves or roots of mangrove. Fishermen set the traps on riverbeds and leave them for 24 hours during eel migration season. During the day fishers raise the traps and collect the eels caught. In Phu Yen province, an estimated 1000 fishers use the brush bundle trap, with each fisher setting about 200 to 1000 traps. Approximately half a million brush bundle traps are operated in the province. Each fisher has their own respective area so there is no conflict among them on the site to set their traps. In Binh Dinh province, only about 10 fishers use brush bundle trap within their own locality.

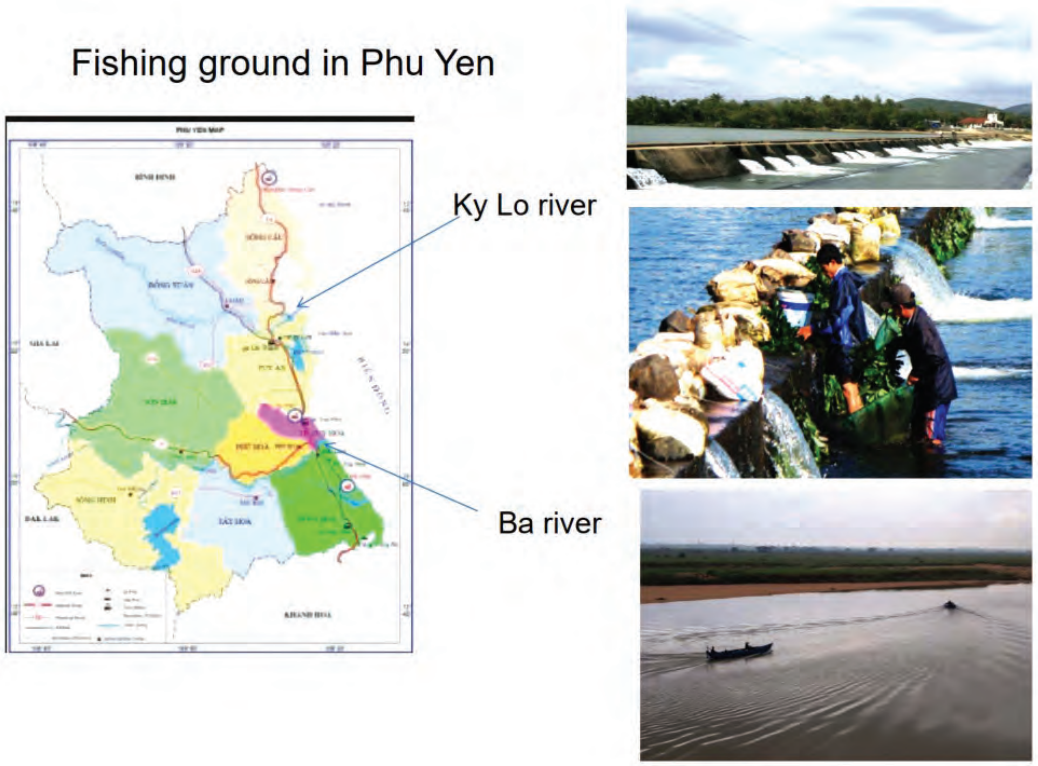

Figure 45. Anguillid eel fishing area in Phu Yen Province

Figure 46. Gears used in anguillid eel fishing: Scoop net (top) and brush bundle trap

Production and Market for eels

Glass eels and elvers collected are stocked in concrete tanks (>30 m^3), ponds (>2000 m^3) and in cage in ponds/reservoir (20 m^3) for culture (Figure 47). About 70% of yellow eels produced are for domestic consumption and supplied to local restaurants. The remaining 30 % are exported, mainly to Taiwan (80%) and China (20%). These figures depend on the demand as well as the period.

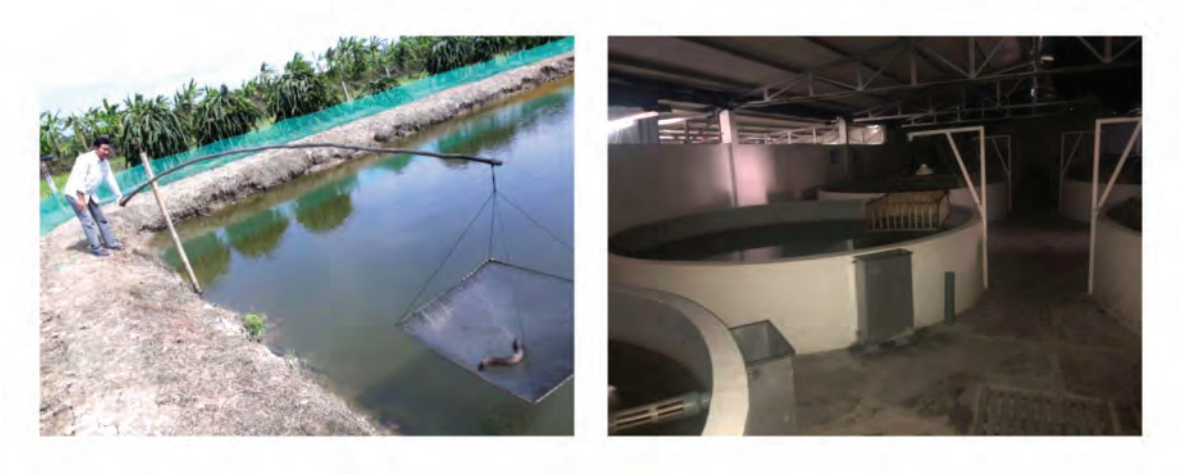

Figure 47. Pond (left) and concrete tanks for rearing anguillid eels

Eel aquaculture operations

The main species for culture is *Anguilla marmorata* as this comprise the bulk of anguillid eel fishery in the country. Consumers prefer this species since they grow to much bigger sizes than *A. bicolor*. Vietnamese consumers prefer large sized eels.

The Mekong Delta in the southern part of the country is the main grow-out area with Ca Mau province being the largest. The Van Xuan Company, a private eel aquaculture business, is trying to transfer technology and supply eel seed to support the needs in other areas such as the middle and northern part of Viet Nam.

Ca Mau province culture operations: About 1,100 farmers culture elvers to yellow eel. Culture of glass eels to elver is done by about 80 small farms, while only 20 farmers culture glass eel to yellow eel. About 95% of farmers procure elvers to grow to yellow eel and only 5% of farmers start culture from glass eel size. Culture period is at least 15 months and size at harvest is greater than 1 kg per piece.

From 90 to 98% of farms rely on by-catch as feed. Blood worm (*Tubifex* sp.), tilapia, small shrimp are also used. Only about 2 to 5% of farms use formulated feeds. The Van Xuan Company has its own feed formulation, but still lacks stability. Commercial feeds are also imported from China.

Khanh Hoa (Van Xuan Company) culture operations: Out of the 37 provinces in Viet Nam where eels are cultured, the Van Xuan Company sells cultured eels in over 30 provinces. In 2017, the farm purchased 300,000 and 250,000 pcs of glass eels in 2017 and 2018, respectively. These numbers of glass eels accounts of about 10 to 20% of Viet Nam's total glass eels catch. This farm produces 200,000 to 300,000 pcs of eels of various sizes. Fifty percent of this production is further sold to Ca Mau province farmers in the Mekong delta area for further on-growing.

Problems of anguillid eel culture

Among the problems identified by the anguillid eel culture industry in Viet Nam are the following:

- Unstable seed supply since it is dependent on availability in the wild
- High cost of seeds, on average US$20/kg
- Long culture duration (at least 15 months)
- Farming techniques need improvement
- Disease problems, particularly parasite infestation
- High cost of artificial feeds

The following are the recommended strategies for the sustainability of the anguillid eel culture industry in Viet Nam.

- Improve farming technology
- Improve quality of cost-efficient feeds
- Need to replicate commercial farming model similar to the Van Xuan Company
- Conduct research on artificial seed production
- Need to expand market, particularly the export industry
- Strengthen state governance by laws, decrees and circulars pertaining to eel fishery and culture

Recent regulations have prohibited the fishing of *Anguilla japonica* and *A. bicolor.* A closed season (from 1st March to 30th April) for *A. marmorata* and *A. bengalensis* has been put in place. Strengthen state fisheries governance, particularly at local levels for farming activities including eels farms will follow.

Re-stocking and stock enhancement of anguillid eels has also been put in place. Regulations for farming of eels are also being considered.

5.3 Nursery Rearing Trials of Philippine Anguillid Eels

In Philippines, farming of tropical native anguillid eels (*Anguilla marmorata* and *A. bicolor pacifica*) in some commercial eel farms basically follow the rearing procedures for Japanese and European eel species. Glass eels are raised to elvers, ready to be exported to eel farmers in other countries. Grow-out of elvers up to marketable size can be done in tank systems, in earthen ponds or even in

recirculating aquaculture systems (Suzuki et al, 2003; Kagawa et al, 2006). Unlike in temperate eel species (Degani et al, 1988; Ingram et al, 2001; Liao et al, 2002), there is no published information on the performance of farming these captive native eels at any stage of development. Information on the nutritional requirements of tropical anguillid eels is also limited.

5.3.1 Objectives

This study is part of the project entitled Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia. This study will determine the feasibility of nursing Philippine native glass eels in captivity. Specifically, it will compare growth and survivorship of native glass eel and young elvers on various feeding schemes and/or formulated diets. To address this objective, the following experiments were conducted:

- Determine suitable initial or pre-weaning and weaning diets of glass eels to formulated diets
- Assess the weaning duration of glass eels from live to formulated diets
- Examine the effect of live feed to formulated diet ratios on performance of glass eels
- Investigate the performance of glass eels and young elvers in outdoor tanks

All experiments, except for the on-farm trial which was done with a private cooperator farm in Malvar, Batangas, were conducted at the nursery facility of the Binangonan Freshwater Station of SEAFDEC Aquaculture Department in Binangonan, Rizal.

5.3.2 Methods

Initial or pre-weaning diets

Glass eels collected from Aparri, Cagayan were gradually acclimated to experimental conditions for three weeks during which they were fed with *Artemia* nauplii. Eighteen plastic tanks of 30-L capacity, each filled with 10 L of dechlorinated tap water were used in the experiment (Figure 48). Glass eels (initial weight of 0.08 g) sourced from Aparri, Cagayan were stocked at 50 pieces per tank. Stocking density of glass eels for all treatments was 5 pieces per liter. Six feeding treatments with three replicates were tested as follows: *Artemia* nauplii (ART); *Tubifex* sp. (TUB); formulated diet (FD; crude protein 52%; crude fat 10%; commercial diet (CD; crude protein 47%; crude fat 6%); formulated diet + *Artemia* (FD + ART); and formulated diet + *Tubifex* sp. (FD + TUB). FD was mixed with Tubifex paste and made into a paste diet. CD was moistened with water and added with binder before forming into a paste diet. All diets were fed *ad libitum* six days per week. Uneaten feeds were collected or siphoned 30 minutes after feeding and 50 to 70% of rearing water replaced. The feeding trial lasted for 24 weeks.

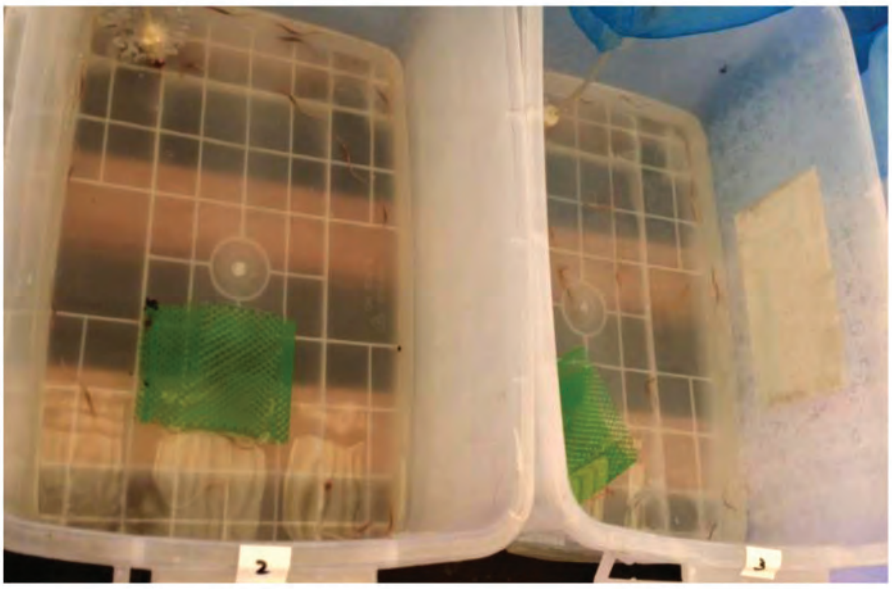

Figure 48. Experimental set-up used for the initial or pre-weaning diets experiment

Weaning diet types

Feeding trials of glass eel samples collected from General Santos City in Mindanao were conducted in nine 80-L capacity blue plastic drums filled with low saline water (3 ppt) (Figure 49). Each plastic drum was stocked with a total of 215 glass eels (or 7 pieces per liter). Glass eels (0.11-0.15 g initial body weight (BW)) were fed *Tubifex* sp. (50% BW) alone until week 2, tuna eggs (7% BW) and *Tubifex* sp. (37.5% BW) from week 2 to 8. From week 8 to 22, formulated weaning diet types (crude protein 50%; moist (MF), semi-moist (SMF) and dry feeds (DF)) were offered at 1.5 to 3% of BW in the morning and supplemented with *Tubifex* sp. at 12.5 to 25% BW in the afternoon. Feeding was done six days per week.

Figure 49. Set-up for the weaning experiment (left photo); semi-moist (middle photo) and dry diets (right photo) used in weaning tropical glass eels

Weaning duration

The effect of weaning duration on survival and growth of glass eels collected from Aparri, Cagayan was studied. Before the experiment, glass eels were acclimated in 4, one-ton capacity fiberglass tanks for one week during which they were fed squid meal powder and bloodworm *Tubifex* sp. About 600 glass eels (about 0.11 ± 0.01 g initial body weight (BW)) were randomly stocked and distributed into 500-L polyethylene tanks filled with 250 L of low saline water (3 ppt), resulting to an initial stocking density of 2.4 pieces per liter (Figure 50). Glass eels were reared for 8 weeks following these treatment groups at triplicates each:

Treatment 1 - *Tubifex* sp. (control group; fed at 50% BW for 60 days)

Treatment 2 - *Tubifex* sp. (fed at 50% BW for 14 days); 28 days gradual weaning to paste diet at increasing levels (1-10% BW) from day 15

Treatment 3 - *Tubifex* sp. (fed at 50% for 14 days); 42 days gradual weaning to paste diet at increasing levels (1-10% BW) from day 15

Live feeds were fed to glass eels four times daily (0900, 1100, 1300, and 1500 hours) at 50% of body weight. Formulated paste diet (60% crude protein) was placed on a plastic basket which was hanged in the middle to provide a feeding and resting station for the eels. Feces were siphoned daily before each feeding and rearing water (about 2/3 of the total volume) replaced. Sampling for BW and number of survivors were done every 2 weeks.

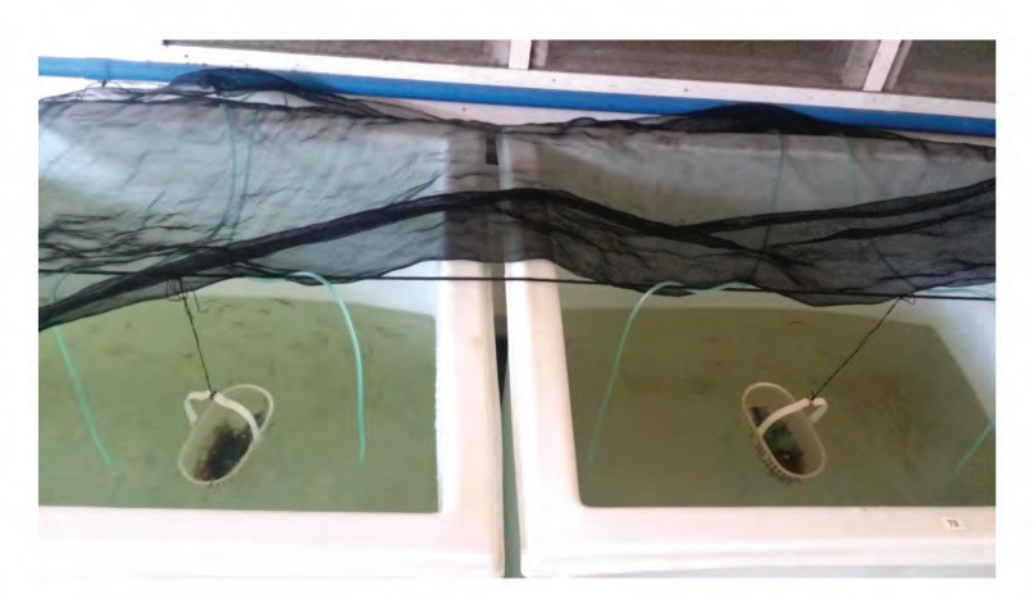

Figure 50. Set-up for the experiment on weaning duration of glass eels

Effect of live feed to formulated diet ratios on performance of glass eels

Anguilla bicolor pacifica glass eels collected from General Santos City, Mindanao were stocked at 490 individuals per tank (or 1.96 ind per liter) into nine, 500-L polyethylene tanks with 250 L low saline water (3 ppt). Glass eels were fed *Tubifex* sp. at 50% of estimated body weight four times (0900, 1100, 1300, and 1500 h) at six days per week for 10 weeks. *Tubifex* sp. was placed onto a plastic basket which provides a feeding and resting station for the eels. From week 10 to 24, three live feeds to formulated diet ratios were tested at triplicates each:

Treatment 1 (50:50 ratio)-Formulated paste diet (25% BW) + *Tubifex* sp. (25% BW)
Treatment 2 (60:40 ratio)-Formulated paste diet (30% BW) + *Tubifex* sp. (20% BW)
Treatment 3 (70:30 ratio)-Formulated paste diet (35% BW) + *Tubifex* sp. (15% BW)

Formulated paste diet (crude protein 55%; crude fat 10%) were placed on a floating tray for eels to feed on. Paste diet was offered at 0800 and 1300 hours; *Tubifex* sp. was given during the last feeding at 1600 hour (Figure 51). Feces were siphoned daily before feeding and rearing water (about 2/3 of the total volume) replaced. Sampling for BW and number of survivors were done every 2 weeks.

Figure 51. Glass eels actively feeding on bloodworm Tubifex sp. (left photo) and on formulated diet (right photo) developed in this study

Outdoor tank trials

A preliminary experiment was conducted to assess growth of Aparri glass eels reared in cages suspended in outdoor concrete tanks without supplemental feeding. Tank rearing water was preconditioned or aged for two weeks to allow natural plankton growth prior to stocking of glass eels. Each cage measuring 1.5 × 1 × 1.5 m was stocked with 400 glass eels with an initial body weight of 0.104 ± 0.004 g. Sampling of glass eels for survival and growth measurements were done after 8 and 12 weeks of rearing.

On-farm trial of A. marmorata young elvers

A. marmorata young elvers were transported in a private nursery farm for on-farm trial (Figure 52). The stocking density used was 200 pieces per tank (0.5 × 4 × 0.5 m). Young elvers (mean initial weight of

1.56 g) were fed at satiation with a commercial diet (crude protein 45%; crude fat 8%) fed as a paste supplemented with trash fish twice daily (0800 and 1600 hours). Sampling was conducted every month to monitor the survival, growth and to adjust the feed ration.

Figure 52. Stocking of A. marmorata young elvers in a private cooperator farm

5.3.3 Results

Initial or pre-weaning diets

Survival and growth of glass eels fed six initial or pre-weaning diets are presented in Table 15. Survival was highest in *Tubifex*- (77%), formulated diet and *Artemia*- (70%) and intermediate in *Artemia*-fed (62%) glass eels. Lowest survival was observed in formulated diet-fed glass eels at 2%. Glass eel in fed commercial diet did not survive beyond week 16.

In terms of growth performance, *Tubifex*-fed glass eels had the highest weight gain of 3679%, followed by formulated diet and *Tubifex*-fed glass eels at 2373%. Glass eels fed a combination of formulated diet and *Artemia* had 499% weight gain while *Artemia*- and formulated diet-fed glass eels had 422% and 9%, respectively. These suggests that live feeds are more effectively utilized by glass eels than artificial diets in the nursery. It also indicates that *Tubifex* is a more suitable live feed than *Artemia* nauplii. Supplementation of formulated diet with *Tubifex* also enhanced growth of glass eels.

Table 17. Growth and survival of glass eels from Aparri, Cagayan fed live food, artificial feeds, and their combination for 24 weeks

Diets	IBW (g)	FBW (g)	WG (%)	SGR (% /day)	Survival (%)
Artemia	0.06 ± 0.01	0.33 ± 0.05	422 ± 86	1.02 ± 0.10	62.0 ± 5.29
Tubifex	0.07 ± 0.01	2.72 ± 0.36	3679 ± 475	2.25 ± 0.08	77.3 ± 11.0
FD	0.09 ± 0.02	0.12	9	0.05	2.0
CD*	0.08	-	-	-	-
FD + *Artemia*	0.06 ± 0.02	0.38 ± 0.14	499 ± 205	1.09 ± 0.20	46.7 ± 11.7
FD + *Tubifex*	0.09 ± 0.01	2.17 ± 0.28	2373 ± 423	1.99 ± 0.10	70.0 ± 8.7

**All glass eels were dead by week 16; FD, formulated diet; CD, commercial diet*

Specimens were also examined for species identity and/or composition based on caudal pigmentation and measurement of external morphometric characteristics (e.g. dorso-anal length). Among 372 specimens examined, 272 (73.12%) were identified as the presumptive *Anguilla luzonensis*/*A. marmorata*, 99 (26.61%) were *A. marmorata*, and only one (0.27%) was *A. bicolor pacifica* (Table 16).

Table 18. Species composition of glass eels fed various live feeds, artificial diets, and their combination for 24 weeks based on morphological analysis

Diets[1]	%		
	A. bicolor pacifica	***A. marmorata***	***A. luzonensis/ A. marmorata****
Artemia	-	41.30	58.70
Tubifex	0.90	21.62	77.48
FD	-	100	-
CD[2]	-	-	-
FD + *Artemia*	-	22.22	77.78
FD + *Tubifex*	-	20.95	79.05

[1]Refer to Table 17 for details; 2Subject to further identification using genetic analysis

Weaning diet types

Table 19 shows the survival and growth of glass eels fed three weaning diet types supplemented with *Tubifex* sp. for 22 weeks. There was no consistent trend in the growth and survival of glass eels weaned onto different diet types. SMF-fed glass eels had the highest weight gain of 1171% followed by DF- (1089%) and MF-fed groups (1035%). Survival after 22 weeks of rearing was highest in MF at 89% and lowest in SMF group with only 84%. Further work is necessary to refine the MF formulation for glass eels undergoing weaning.

Table 19. Growth and survival of glass eels from General Santos City, Mindanao after 22 weeks of co-feeding various feed types and *Tubifex* sp.

Diets[1]	IBW (g)	FBW (g)	WG (%)	SGR (% /day)	Survival (%)
DF	0.12 ± 0.02	1.40 ± 0.41	1089 ± 494	1.82 ± 0.32	86.4 ± 3.2
SMF	0.12 ± 0.02	1.51 ± 0.51	1171 ± 441	1.88 ± 0.27	83.9 ± 4.0
MF	0.12 ± 0.02	1.40 ± 0.49	1035 ± 240	1.82 ± 0.15	89.0 ± 12.4

[1]DF, dry feed; SMF, semi-moist feed; MF, moist feed

Weaning duration

Growth in terms of final body weight, percent weight gain and specific growth rate was significantly higher in *Tubifex*-fed glass eels (control group) compared to those gradually weaned onto paste diet for 28 and 42 days (Table 20), suggesting that glass eels may require a relatively lengthy period of feeding on *Tubifex* sp. to improve growth. No significant difference was observed in survival rates of eel groups gradually weaned onto paste diet and that of the control group.

Table 20. Effect of weaning duration on growth and survival of Aparri glass eels after 8 weeks

Treatments	IBW (g)	FBW (g)	WG (%)	SGR (% /day)	Survival (%)
Control (*Tubifex* sp.)	0.11 ± 0.01	0.51 ± 0.06[a]	350 ± 56[a]	2.50 ± 0.21[a]	90.2 ± 4.6[a]
28 days*	0.11 ± 0.01	0.38 ± 0.03[b]	238 ± 29[b]	2.03 ± 0.14[b]	88.9 ± 3.3[a]
42 days*	0.11 ± 0.01	0.37 ± 0.01[b]	231 ± 31[b]	2.00 ± 0.06[b]	91.6 ± 3.1[a]

**weaning started at day 15*

Effect of live feed to formulated diet ratios on performance of glass eels

There were no significant differences on the growth performance in terms of weight gain and specific growth rate of glass eels. Glass eels from different groups were homogeneous in size distribution, but were dominated by 76-100 mm size group (Figure 53).

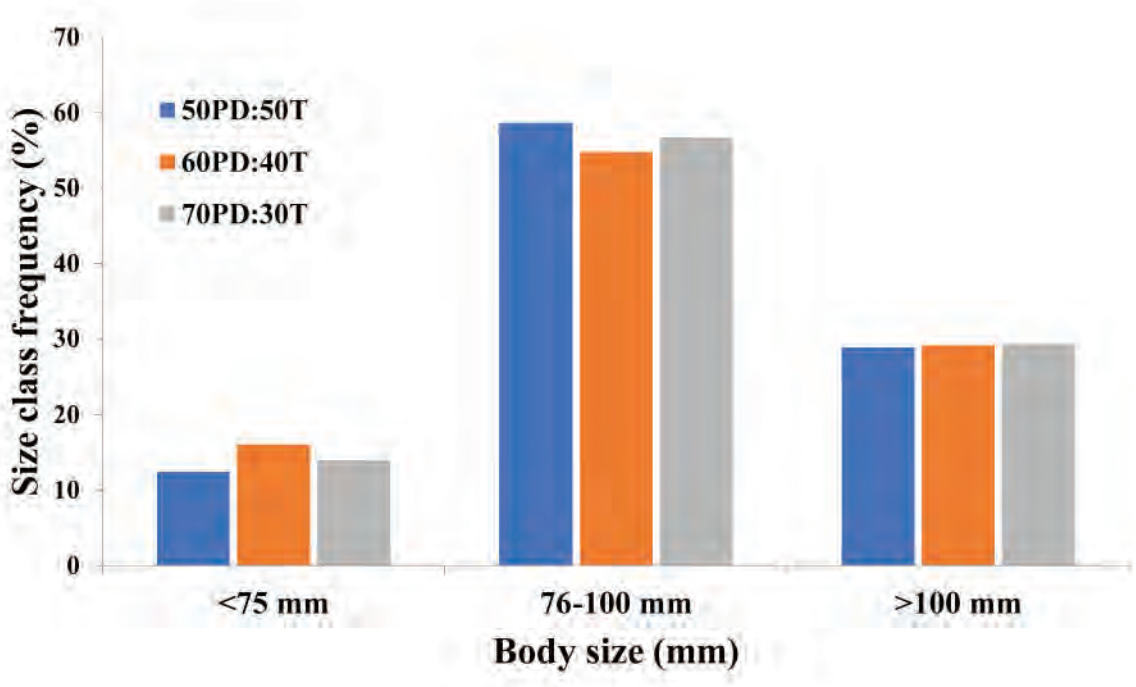

Figure 53. Size class frequency distribution of glass eels reared for 24 weeks and fed different past diet to live feed ratios

The paste diet to live feed ratios also did not significantly affect the survival rates (91.6 to 93%) of glass eels in all treatment groups (Table 21). Results suggest the acceptability and palatability of formulated paste diet for glass eels in the nursery, as indicated by the good results on growth and survival.

Table 21. Effect of different paste diet to live feed (PD:LF) ratios on the growth and survival of *A. bicolor pacifica* glass eels reared for 24 weeks

PD:LF ratio	IBW (g)	FBW (g)	WG (%)	SGR (% /day)	Survival (%)
50:50	0.06	1.30 ± 0.20	2084 ± 412	2.36 ± 0.15	91.6 ± 6.9
60:40	0.06	1.17 ± 0.06	1802 ± 221	2.26 ± 0.09	93.0 ± 2.0
70:30	0.06	1.17 ± 0.03	1748 ± 206	2.24 ± 0.09	92.8 ± 12.9

Outdoor tank trials

Mean (± SD) body weight of glass eel reared under natural conditions ranged from 0.101 g to 0.344 g, with the highest growth observed in Tank E3 (Figure 54, Table 22). Larvae in Tank E3 also exhibited the highest total length. Between 8 and 12 weeks, weight gain, specific growth rate and survival rates generally decreased in all tanks. Although the composition and abundance of food items in the rearing tanks were not determined, it was likely that food availability might have influenced the growth of glass eels in outdoor concrete tanks.

Figure 54. Three-month old glass eels reared in outdoor concrete tanks without supplemental feeding

Table 22. Growth and survival (mean ± SD) of Aparri glass eels reared in outdoor concrete tanks after 12 weeks without supplemental feeding

Parameter	Period (in weeks)	Tank			
		E1	E2	E3	Mean ± SD
Body weight (g)	0	0.102	0.101	0.108	0.104 ± 0.004
	8	0.230	0.239	0.366	0.279 ± 0.076
	12	0.267	0.212	0.344	0.274 ± 0.066
Total length (mm)	8	57.9 ± 3.58	60.2 ± 2.86	66.6 ± 2.62	61.6 ± 4.49
	12	58.4 ± 2.73	58.8 ± 3.42	65.7 ± 3.22	61.0 ± 4.11
Weight gain (%)	8	125	137	238	167 ± 62
	12	161	110	217	163 ± 53
Specific growth rate	8	2.33	2.39	2.70	2.48 ± 0.20
(% day-1)	12	1.21	1.00	1.41	1.20 ± 0.20
Survival (%)	8	59.25	69.75	76.75	68.58 ± 8.81
	12	51.75	57.00	69.75	59.50 ± 9.26

On-farm trial of A. marmorata young elvers

After 98 days, mean average body weight of young elvers increased from 1.56 g to 3.26 g, with percent weight gain and specific growth rate of 122 ± 79% and 0.33 ± 0.17%/day. Survival rates decreased from 100% to 94%. Monitoring of *A. marmorata* young elvers in a private cooperator farm provided information into the potential for grow-out production of this species.

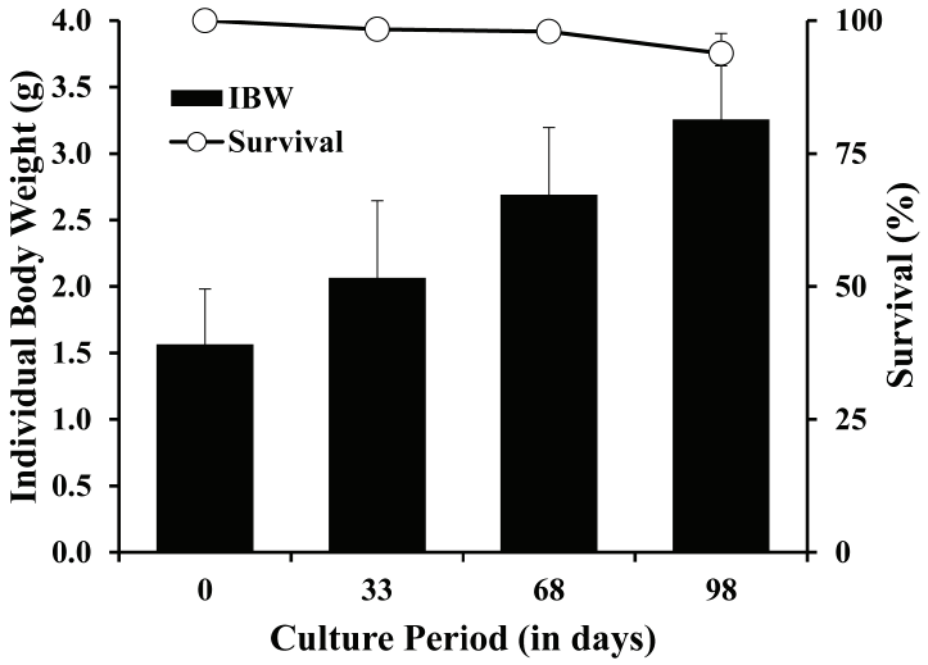

Figure 55. Growth and survival of A. marmorata young elvers reared in a private cooperator farm for 98 days

5.3.4 Conclusion

Laboratory tank studies have provided valuable information on basic husbandry techniques for tropical anguillid eels such as initial feeding, weaning and rearing of tropical anguillid eels up to young elvers. In summary, the key results identified in this study include:

- Live feed such as bloodworm *Tubifex* sp. was a suitable initial or pre-weaning diet for nursery rearing of glass eel than *Artemia* nauplii or artificial diets. Supplementation of formulated diets with live *Tubifex* improved diet acceptance that resulted in enhanced survival and growth of glass eels.
- Three weaning diet forms (e.g. dry, semi-moist and moist diet) tested in this study may provide adequate nutrition to glass eels as shown by reasonable growth and survival achieved in this study. Moist paste diet, however, provided the highest survival rates of glass eels suggesting that this was a suitable diet form for weaning tropical anguillid eels. As all the tested diets contained 50% crude protein level, refinement of this diet by increasing the crude protein up to 55% may sustain better growth than those obtained in this study.
- Gradual weaning of Aparri glass eels for 28 and 42 days from *Tubifex* onto formulated paste diet was not adequate given the slightly poor growth performance observed in this study. Although survival rates were relatively high, glass eels may require a relatively lengthy period of feeding on *Tubifex* prior to weaning onto formulated diets to improve growth.
- Formulated past diet (55% crude protein and 10% crude fat) provided at different ratios with live feed *Tubifex* from week 10 of rearing gave excellent results on growth and survival compared to those obtained from previous trials. A 60:40 paste diet to live feed ratio gave the best result in terms of survival. Feeding glass eels with *Tubifex* for 10 weeks followed by 60:40 paste diet to live feed ratio thereafter up to week 24 is suitable for rearing glass eels in the nursery.

Given the good performance in terms of acceptability and palatability of the formulated past diet developed in this study, further assessment of this diet on performance of young elvers in outdoor tanks should be considered. It is also necessary to determine the appropriate stocking densities in tank-based culture of young elvers. Our preliminary experiment on the tank-based culture of glass eels suggest the need for better culture strategies such as provision of artificial substrate to address the declining survival rate possibly due to cannibalism. Tank-based culture of *A. marmorata* young elvers in a private cooperator farm provided information into the potential for grow-out production of this species.

5.4 Diseases and Health Management of Tropical Anguillid eels in Philippines

5.4.1 Objectives

- To identify potential pathogens in eel nursery systems
- To develop health management protocols for anguillid eel nursery

5.4.2 Methodology

Live glass eels were collected from various commercial eel farms in Philippines and brought to the laboratory for parasitic and bacterial analysis. Farms were located in Luzon and Mindanao. Samples from on-going nursery trials at SEAFDEC/AQD Binangonan Freshwater Station were also collected monthly. Glass eels were anaesthetized using phenoxyethanol and processed for parasitic and bacterial analysis. Parasite analysis was performed by obtaining mucus and gill filaments. Microscopic ectoparasites were examined using compound light microscope. Prevalence, mean intensity and mean abundance were computed according to Bush *et al*, (1997).

For bacterial analysis, kidneys were aseptically collected, homogenized and serially diluted. Samples were plated onto Nutrient Agar and incubated for 18-24 hours at room temperature. After the incubation period, bacterial count was computed and expressed as Colony Forming Units per gram (CFU/g). Water samples from glass eel's rearing tanks were also analyzed for bacterial analysis using the same technique; however, bacterial count was expressed in CFU/ml. Colonies from positive samples were purified and processed for bacterial identification using gram staining, motility and biochemical tests (API20 NE kit).

5.4.3 Results

Parasite analysis

Table 23 shows the result of parasite analysis of glass eels collected from 4 commercial eel farms. *Trichodina* spp. an ectoparasitic ciliate (Figure 56) was detected in the mucus of glass eels in all farms. The parasite had a prevalence ranging from 30% to 90%. Mean intensity ranged from 3.0 ± 0.94 to 12.1 ± 4.67 while mean abundance were 0.9 ± 0.52 to 10.9 ± 4.44. Farms C had the highest prevalence, mean intensity and mean abundance for *Trichodina* spp. among farms.

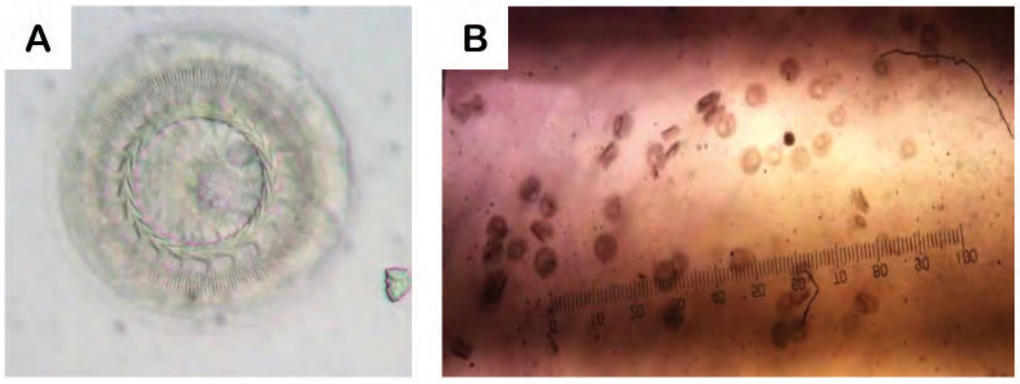

Figure 56. Trichodina spp. from glass eel's mucus as viewed in 400 X (A) and 100 X (B) magnification

Table 23. Prevalence, mean intensity, mean abundance of Trichodina spp. from eel's mucus sampled from commercial farms in the Philippines.

	Luzon			**Mindanao**
	Farm A	Farm B	Farm C	Farm D
Prevalence (%)	30	70	90	60
Mean Intensity (± S. E.)	3.0 ± 0.94	4.7 ± 1.41	12.1 ± 4.67	9.2 ± 3.69
Mean Abundance (± S. E.)	0.9 ± 0.52	3.3 ± 1.18	10.9 ± 4.44	5.5 ± 2.86

Monogenetic trematode (Figure 57) was also observed on the gills of glass eels cultured in the commercial farms. However, it was only detected in Farm C (Table 24) which was previously reported to have the highest prevalence, intensity and abundance for *Trichodina* spp.

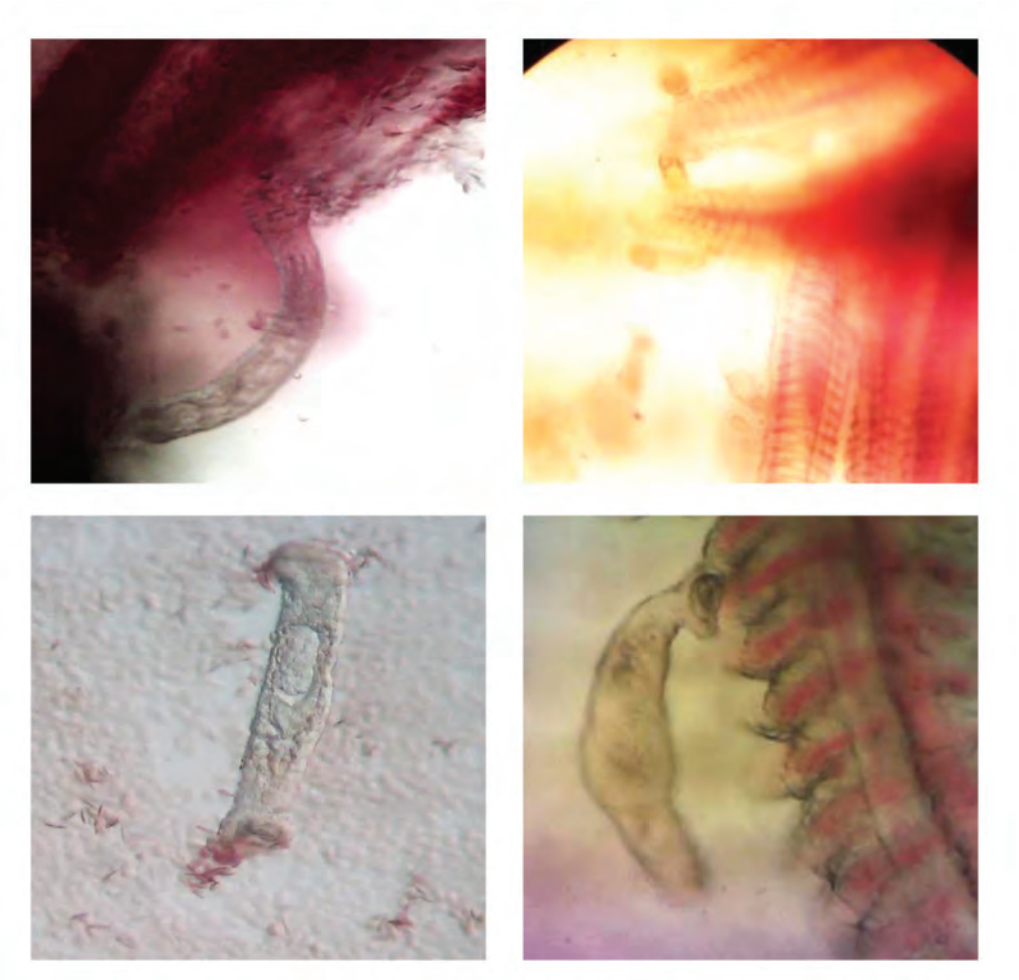

Figure 57. Monogeneans attaching on glass eel's gill filaments collected from a commercial farm in Luzon (100 X magnification, fresh mount)

Table 24. Prevalence, mean intensity, mean abundance of Monogeneans from eel's mucus and gills sampled from selected commercial farms in the Philippines

	Luzon			Mindanao
	Farm A	**Farm B**	**Farm C**	**Farm D**
Prevalence (%)	0	0	Mucus (20)	0
			Gills (40)	
Mean Intensity (± S. E.)	0	0	Mucus (2)	0
			Gills (13 ± 8.17)	
Mean Abundance (± S. E.)	0	0	Mucus (0.4)	
			Gills (5 ± 5.17)	0

Glass eels cultured at SEAFDEC/AQD Binangonan Freshwater Station for nursery and feeding trials were also sampled regularly for parasite analysis. Table 25 and 26 show result of parasite analysis for Aparri and General Santos stocks, respectively.

Table 25. Prevalence, mean intensity, mean abundance of *Trichodina* spp. from eel's mucus (Aparri stocks) reared at SEAFDEC/AQD sampled from July 2018-Jan. 2019

Treatments	**Prevalence (%)**			**Mean Intensity**			**Mean Abundance**		
	Range	Mean	S.E.	Range	Mean	S.E.	Range	Mean	S.E.
Control (Tubifex)	0-93	41.4	13.2	0-49	9.6	6.6	0-45	7.8	6.3
28 days* weaning period	0-100	59.1	14.4	0-107	36.3	17.0	0-93	33.5	15.9
42 days* weaning period	0-100	47.7	13.4	0-95	19.5	12.8	0-95	17.1	13.2

**During weaning period, feed ration for tubifex was gradually decreased while increasing feed ration for moist feeds*

**Moist feeds were applied for all treatments after the weaning periods at 50% BW*

Table 26. Prevalence, mean intensity, mean abundance of *Trichodina* spp. from eel's mucus (Gen. San. stocks) reared at SEAFDEC/AQD sampled from Nov. 2018-March 2019

Treatments (Feeds:Tubifex)	**Prevalence (%)**			**Mean Intensity**			**Mean Abundance**		
	Range	Mean	S.E.	Range	Mean	S.E.	Range	Mean	S.E.
50%:50%	0-20	4.5	3.3	0-2	0.6	0.4	0-0.3	0.08	0.05
60%:40%	0-13.3	3.3	2.3	0- 1.5	0.4	0.3	0-0.2	0.05	0.03
70%:30%	0-20	8.0	3.9	0- 3.3	1.1	0.6	0-0.7	0.17	0.13

stocks) reared at SEAFDEC/AQD sampled from Nov. 2018 - March 2019.

Prevalence, mean intensity and mean abundance of *Trichodina* spp. were observed to be higher in Aparri stocks compared to the General Santos stocks. The prevalence of *Trichodina* spp. for Aparri ranged from 0-100% while 0-20% was recorded for General Santos. Mean intensity of the parasite for Aparri (0-107) was higher compared to General Santos (0-3.3). *Trichodina* spp. had higher mean abundance in Aparri stocks (0-95) compared to General Santos stocks (0-0.7).

Ichthyopthirius multifilis was also reported among glass eels in Philippines. It is a large, ciliated protozoans characterized by a horseshoe-shaped nucleus (Figure 58). The parasite is known to cause "Ich" or "white spot disease". Possible risk factors for the disease are high stocking density, decreased water temperature (28°C), high organic load and handling stress.

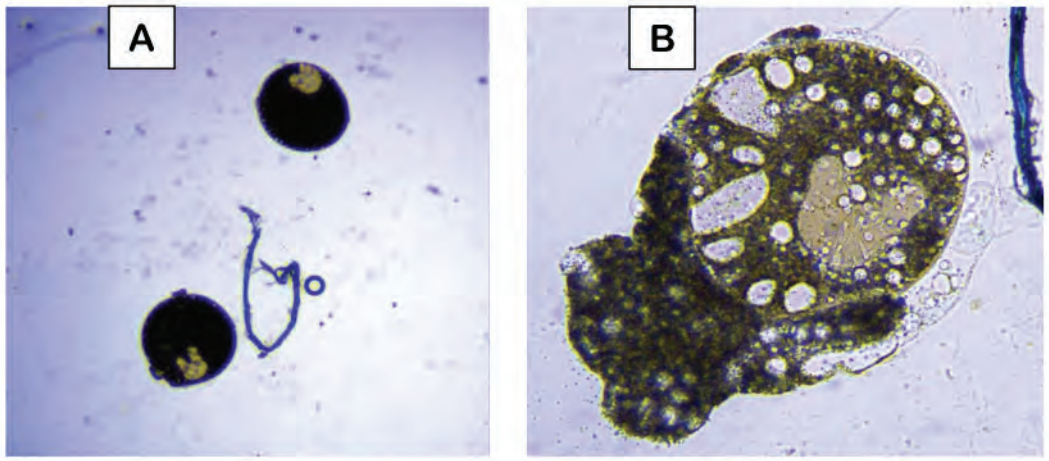

Figure 58. I.multifilis from eel's mucus viewed at 100 X and (B) 400 x magnification. (Photo courtesy of Dr. Joselito Somga, Dr. Sonia Somga and Dr. Joseph Adrian Loja of Bureau of Fisheries and Aquatic Resources)

Bacterial analysis

Bacterial analysis was performed in eel and water samples. Table 27 shows the result of bacterial analysis in eel and water samples collected from two commercial farms in Philippines. Farm C had higher bacterial counts in eel and water samples compared to Farm A. This farm was previously noted to have high prevalence, abundance and intensity for ectoparasites.

Table 27. Bacterial count of eel's rearing water and kidney sampled from selected commercial farms in Philippines

	Luzon	
Sample	Farm A	Farm C
Water, (CFU/ml)	6.00×10^3	1.09×10^4
Kidney, (CFU/g)	1.50×10^3	1.04×10^5

Bacterial analysis was also conducted for glass eels and rearing water of SEAFDEC/AQD setups.

Bacterial count in the kidney of Aparri stocks were 0 to 1.77 X 10^6 CFU/g while in General Santos stocks it ranged from 0 to 1.30 X 10^6 CFU/g (Tables 28 and 29). Pure cultures from water and eel samples were further analyzed for bacterial identification using various tests. Tables 32 and 33 show presumptive identification of bacteria isolated from water and eel samples, respectively. Bacteria isolated from rearing water were *Pseudomonas luteola*, *Aeromonas hydrophila*, *Aeromonas sobria* and *Stenotrophomonas maltophilia* while in kidney commonly isolated bacterium was *Plesiomonas shigelloides. Aeromonas, Pseudomonas* and *P. shigelloides* are ubiquitous bacteria in freshwater environment. They are also known to cause diseases in freshwater fish and prawns.

Table 28. Bacterial count of eel's rearing water (Aparri stocks) at SEAFDEC/AQD sampled from July 2018-Jan. 2019

Treatments	Bacterial count in CFU/ml		
	Range	Mean	S.E.
Control (Tubifex)	1.77 x 10^3-9.55 x 10^5	2.05 x 10^5	1.58 x 10^5
28 days weaning period	1.20 x 10^4-1.33 x 10^6	3.99 x 10^5	1.25 x 10^5
42 days weaning period	3.30 x 10^3-2.92 x 10^5	7.12 x 10^4	1.63 x 10^4

Table 29. Bacterial count of eel's rearing water (Gen. San. stocks) at SEAFDEC/AQD sampled from Nov. 2018-March 2019

Treatments	Bacterial count in CFU/g		
	Range	Mean	S.E.
Control (Tubifex)	0-3.9 X 10^4	2.87 X 10^3	1.88 X 10^3
28 days weaning period	0-1.33 X 10^6	1.22 X 10^5	6.78 X 10^4
42 days weaning period	0-1.77 X 10^6	1.11 X 10^5	8.40 X 10^4

Bacterial count in rearing water of Aparri stocks ranged from 1.77 x 10^3 to 1.33 x 10^6 CFU/ ml while in General Santos it varied from 4.0 X 10^3 to 1.78 X 10^6 CFU/ml. For kidney samples, Tables 30 and 31 show bacterial count in Aparri and General Santos stocks, respectively.

Table 30. Bacterial count of eel's kidney (Aparri stocks) reared at SEAFDEC/AQD sampled from July 2018-Jan. 2019

Treatments (Feeds: Tubifex)	**Bacterial count in CFU/ml**		
	Range	**Mean**	**S.E.**
50%:50%	6.8 X 10^3-1.78 X 10^7	1.76 X 10^6	1.44 X 10^6
60%:40%	4.0 X 10^3-1.73 X 10^6	4.35 X 10^5	2.32 X 10^5
70%:30%	1.32 X 10^5-3.56 X 10^6	7.77 X 10^5	5.12 X 10^5

Table 31. Bacterial count of eel's kidney (Gen. San. stocks) reared at SEAFDEC/AQD sampled from Nov. 2018-Mar. 2019

Treatments (Feeds: Tubifex)	**Bacterial count in CFU/g**		
	Range	**Mean**	**S.E.**
50%:50%	0-1.83 X 10^5	3.08 X 10^4	1.99 X 10^4
60%:40%	0-1.5 X 10^4	1.25 X 10^3	1.25 X 10^3
70%:30%	0-1.30 X 10^6	1.46 X 10^5	1.46 X 10^5

Bacterial count in the kidney of Aparri stocks were 0 to 1.77 X 10^6 CFU/g while in General Santos stocks it ranged from 0 to 1.30 X 10^6 CFU/g. Pure cultures from water and eel samples were further analyzed for bacterial identification using various tests. Table 32 and 33 show presumptive identification of bacteria isolated from water and eel samples, respectively. Bacteria isolated from rearing water were *Pseudomonas luteola, Aeromonas hydrophila, Aeromonas sobria* and Stenotrophomonas maltophilia while in kidney commonly isolated bacterium was *Plesiomonas shigelloides. Aeromonas, Pseudomonas* and *P. shigelloides* are ubiquitous bacteria in freshwater environment. They are also known to cause diseases in freshwater fish and prawns.

Table 32. Presumptive identification of bacterial isolates from glass eel's rearing tanks

Isolate Code	**Source**	**Gram Stain**	**Motility**	**Catalase**	**Oxidase**	**API 20 NE Biochemical Test**
T1W1-Zam1-18-19	Outdoor (Batangas)	-	+	+	-	*Pseudomonas luteola* (99.7%)
T5W1-Zam1-18-19	Outdoor (Batangas)	-	+	+	+	*Aeromonas hydrophila* (96.5%)
T4W2-AQD-8-29	Indoor (AQD)	-	+	+	+	*Aeromonas sobria* (99.1%)
T3W2-Zam-1-18-19	Outdoor (Batangas)	-	+	+	-	*Stenotrophomonas maltophilia* (99.9%)

Table 33. Presumptive identification of bacterial isolates from glass eel's kidney

Isolate Code	Source	Gram Stain	Motility	Catalase	Oxidase	API 20 NE Biochemical Test
F3T1k-B-AQD-S1218	Indoor (AQD)	-	+	+	+	*Plesiomonas shigelloides* (99.9%)
K4Zam1-1-18-19	Outdoor (Batangas)	-	+	+	+	*Plesiomonas shigelloides* (99.9%)
F10T5K-AQD-S-12-18	Indoor (AQD)	-	+	+	-	*Pseudomonas fluorescens* (86.9%)

5.4.4 Conclusion and Recommendation

Ectoparasites identified among glass eels sampled from commercial farms and SEAFDEC/AQD setups include *Trichodina* spp., monogeneans and *I. multifilis*. Commonly isolated bacteria in rearing water belong to genus *Aeromonas* and *Pseudomonas. P. shigelloides* was isolated in glass eel's kidney. These parasites and bacteria are ubiquitous in freshwater environment and reported to cause disease outbreaks in freshwater fish species. Treatment of parasitic infestation is usually performed using salt water bath (3% NaCl for 30 sec or 0.05% NaCl for prolonged exposure). Majority of the bacteria identified in this study are opportunistic pathogens. Hence, prevention such as maintenance of good water quality, avoidance of overcrowding, proper nutrition and improvement in host's resistance are highly recommended in order to mitigate disease occurrence in the culture facility. Table 34 is a summary of the risks, predisposing factors as well as prevention, control and treatment of various diseases affecting anguillid eels.

Table 34. Summary of risk/predisposing factors, prevention, control and treatment of diseases affecting Anguillid eels

Pathogen	Name	Risk/Predisposing Factors	Prevention, Control and Treatment
Ectoparasites	*Trichodina spp.*	• High stocking density • Poor water exchange • Accumulation of organic matter	• Salt bath (2-3% NaCl) for 2-5 min for 3-4 days • Formalin bath (150-250 mg/L) for 30 min • Obtain and maintain disease-free stock • Good management • Biosecurity
	Monogenea	• Overcrowding • Inadequate sanitation • Poor water quality	• Salt bath (5% NaCl) for 5 min • Formalin bath (100-200 ppm) for 30-60 min for 3 days • Obtain and maintain disease-free stock • Good management • Biosecurity

Pathogen	Name	Risk/Predisposing Factors	Prevention, Control and Treatment
	I.multifilis	• High stocking density • High organic load • Handling stress • Decreased water temperature (28°C)	• Increase water temperature to 30°C (6h daily; 3-5 days) • Saltwater bath (2-3% NaCl 2-5 min) • Formalin bath (100 ppm; 1 h; 2-3 days) • Obtain and maintain disease-free stock • Good management • Biosecurity
Bacteria	*Aeromonas* spp. *Pseudomonas* spp. *Vibrio* spp.	• Stress • Mishandling • Overcrowding • Transportation under poor conditions • Poor nutrition • Poor water quality • Brackish water culture (Vibriosis)	• Good water quality management • Avoidance of overcrowding • Reducing stress due to handling/ transport • Proper nutrition • Obtain and maintain disease-free stock • Improvement in host's resistance (e.g. immunostimulants) • Antibiotics • Biosecurity
Fungi	Oomycetous fungi	• Poor water quality • Secondary infections	• Saltwater bath (22g/L for 30 min; 30 g/L for 10 min; 1-2 g/L indefinite) • Formalin bath (0.4-0.5 ml/L 30% formaldehyde for 1 h) • Obtain and maintain disease-free stocks • Good management • Biosecurity
Virus*	Eel Virus European (EVE) Eel Virus American (EVA) Eel Virus European X (EVEX) Anguillid Herpesvirus 1 (AngHV1)	• Stress • Temperature • AngHV1 at 26°C • EVE and EVEX at 15 to 20°C	• No treatment so far • Maintain and obtain disease- free stock • Good management • Biosecurity

**Viral infections reported only in A. japonica, A. anguilla, A. rostrata*

5.5 Morphometric and genetic identification of glass eels used in aquaculture

Accurate identification of early stage Anguillid eels may prove to be difficult especially for many local fisherfolk collectors, consolidators and/or traders as well as eel farmers who do not have the trained eye to discern species differences based on physical characters alone. Trading of glass eels have become very lucrative, particularly to those who can distinguish *Anguilla bicolor pacifica* from less preferred species

e.g. *Anguilla marmorata, Anguilla luzonensis* etc. A trader in Philippines who can sell glass eels that are composed of 100% *A. bicolor pacifica* can earn 5 times more than those who sell mixed species stocks. The ability to detect species differences is therefore important not only to the those involved in the glass eel trading sector but more importantly to the eel farmer who needs to be assured that what he is rearing in the grow-out is the species that he requires. Species identification has been studied in eels and several tools for identification using morphological traits, size measurements and DNA marker analysis have been applied. We used some of these methods and the utility and applicability of such methods based on accuracy, is described in this report.

5.5.1 Objective

To determine the reliability of morphometric and genetic tools in identifying tropical Anguillid eel species used in aquaculture.

5.5.2 Methods

Identification of glass eel species using morphometric characters

Globally there are 16 species and three subspecies of Anguillid eels and among them are species that are important in Japan and in Southeast Asia, namely-the Japanese eel *Anguilla japonica*, giant mottled eel *A. marmorata*, Indonesian short fin eel *A. bicolor pacifica*, Celebes long fin eel *A. celebesensis* and the Luzon mottled eel, *A. luzonensis.*

To differentiate these five species, Leander et al (2012) summarized the physical characters that are unique to each in a schematic diagram (see Figure 59 below).

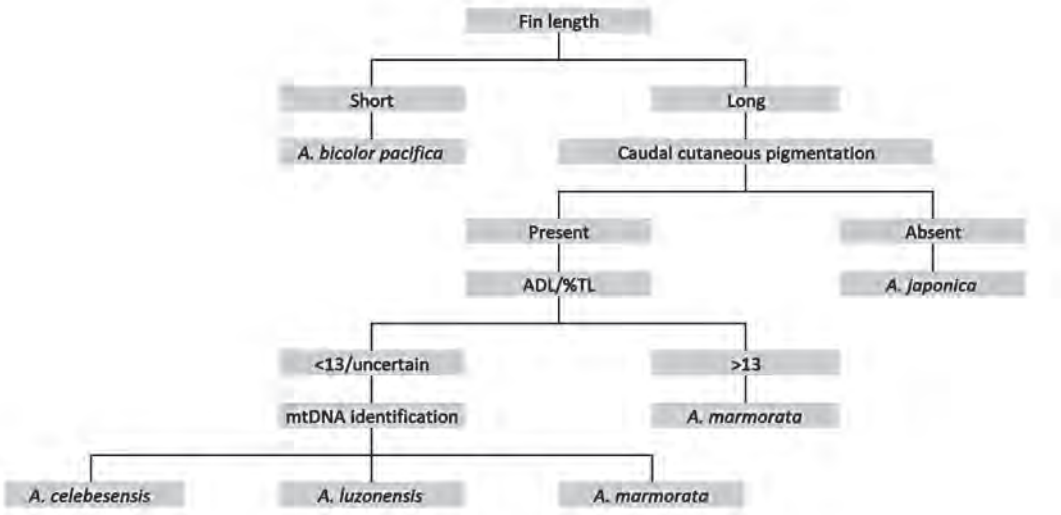

Figure 59. Schematic diagram describing physical features and size measurements used in identifying species of anguillid glass eels (re-drawn from Leander et al, 2012). AD refers to ano-dorsal length; TL, total length; and mtDNA, mitochondrial deoxyribonucleic acid

From the diagram, it can be noted that *Anguilla bicolor pacifica* can be distinguished from other species by way of its short fin length. The other four species (all having long fins), on the other hand, can be further identified with the presence or absence of tail pigmentation as well as with the key trait measurement such as percentage of ano-dorsal length (AD) over the total length (TL). Although glass eels with AD/TL >13 would be identified as *A. marmorata*, some *A. marmorata* could still have an AD/TL less than <13. For AD/TL less than 13, the species could either be *A. celebesensis*, *A. luzonensis* or *A. marmorata*. The remaining means for classifying the species further is through genetic analysis using mitochondrial DNA markers that would have sequences that could definitively classify the specimens into any of the three species.

Genetic analysis of glass eel specimens

Several molecular markers (cytochrome B, 16S rRNA, COI gene sequences) have been used in glass eel species identification (Shirotori *et al,* 2016, Aoyama *et al,* 2015, Yoshinaga *et al,* 2014, Leander *et al,* 2012, Jamandre et al, 2007). To enable processing of eel samples for DNA analysis, whole glass eel samples for a particular batch can be individually stored in ethanol, its DNA extracted, then extracts are prepared for the amplification of the target mtDNA gene marker (e.g. cyt B) which is then subsequently sequenced[1]. Once analyzed, the marker sequence information was compared with known sequences (using web-based sequence alignment software) of the glass eel species that have been described in open access databases. In this activity, the cytochrome B gene was used as the marker to allow species identification. The sections that follow summarize the results of the identification of glass eels collected from two sources, namely General Santos and Aparri (at one batch per source, per year).

5.5.3 Results

Species identification of batch 1 samples

In 2017, glass eel samples from Aparri, Cagayan in Luzon and General Santos City in Mindanao (n=100 pcs/stock) were collected. These were first checked for species identity through morphometric examination of some diagnostic characters (TL or total length; AD or ano-dorsal length and tail pigmentation patterns). Table 35 shows the results of the length ratio information for the samples.

Table 35. Identification of species based on length ratio information

Sample source	Species	N	Nhp	h	π
Aparri	*Anguilla luzonensis*	77	39	0.9477 ± 0.0145	0.0052 ± 0.0028

Once defined, samples from individuals showing traits that are representative of each presumptive species category based on the morphometric evaluation were further subjected to genetic analysis at the Onagawa Field Center, Tohoku University in Japan. DNA extraction and PCR amplification were done prior to mtDNA marker analysis. MtDNA sequence variation information at the cytochrome b marker gene were obtained. The mtDNA sequence information data were matched/compared with reliable databases using BLAST search for species identification and analysis of phylogenetic relationships. Results from the

[1]Detailed mtDNA analysis protocol found in Appendix 2

Aparri samples enabled the identification of 77 pcs *Anguilla luzonensis* among the stock, aside from 19 pcs. *A. marmorata*. Samples from General Santos City in Mindanao were composed of 95 pcs. *A. marmorata* and one *A. bicolor pacifica* based on cyt B sequence alignments. Table 36 shows the genetic diversity of the species examined in the study.

Table 36. Genetic diversity parameters for *A. luzonensis* and *A. marmorata* from Aparri and Mindanao based on sequence polymorphism of mitochondrial cyt b gene (Note: n = no. of samples; Nhp = no. of haplotypes; h = haplotype diversity; π = nucleotide diversity)

Source	Presumptive Species identification	n	TL (mm)	AD (mm)	AD/TL (%)
Aparri	*Anguilla luzonensis*	77	46.71 + 1.69	6.74 + 1.85	14.66 + 3.76
	A. marmorata	19	46.35 + 2.68	11.05 + 1.57	24.63 + 3.47
Mindanao	*A. marmorata*	94	49.16 + 1.74	7.48 + 1.02	15.31 + 2.07
	A. bicolor pacifica	1	46.9	0.21	0.45
	A. marmorata	19	16	0.9825 ± 0.0223	0.0039 ± 0.0023
Mindanao	*A. marmorata*	94	39	0.9385 ± 0.0130	0.0032 ± 0.0019
Total		190	94	2.8687 ± 0.0498	0.0123 ± 0.0070

Species identification of batch 2 samples

Glass eels (100 individuals per source) were again procured from Aparri and General Santos City in Mindanao in 2018. The individual samples were preliminarily identified into species based on distinguishing morphometric traits such as ano-dorsal length/total length percentage and caudal fin pigmentation. Tabulated below (Table 37) is a summary of the putative identities of the samples based on meristic traits:

Table 37. Putative identities of the glass eel samples from Aparri, Cagayan and General Santos City in Mindanao based on meristic characters.

PARAMETERS (Mean+ SD)	Source	
	Aparri	General Santos City (Mindanao)
Body weight (g)	0.1537 ± 0.0468	0.05573 ± 0.0210
Total length (mm)	48.3463 ± 2.1918	45.504 ± 1.8635
Ano-dorsal length (mm)	6.4896 ± 0.8344	0.4326 ± 0.2292
AD/TL (%)	13.4440 ± 1.7672	0.9498 ± 0.4998
Putative species composition	**30/100 (30%)**-to be identified further (either as *A. marmorata/ A. luzonensis/ A. celebesensis)* **70/100 (70%)** *A. marmorata*	100/100 (100%) *A. bicolor pacifica*

The samples were likewise identified into the different species through caudal fin patterns (see Figure 60 a and b).

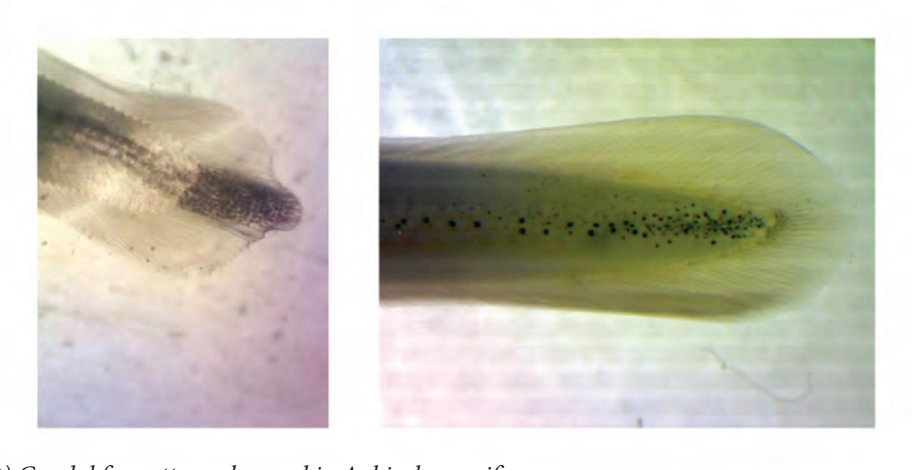

Figure 60 a. (left) Caudal fin pattern observed in A. bicolor pacifica
b. (right) caudal fin pattern noted in A. marmorata

When DNA marker analysis using cytochrome B was conducted, those from Aparri were confirmed to be composed of four *A. luzonensis* and 96 *A. marmorata* samples while the General Santos City samples were confirmed to be 100% *A. bicolor pacifica*, as initially declared as such by the trader who sold the stock.

5.5.4 Conclusion

Based on the foregoing results, the current technique that is most useful and can accurately identify anguillid eels at the glass eel stage is the mitochondrial DNA marker analysis. In instances where the eel farm operator would be uncertain about the identity of the glass eels he has procured for culture, then samples can be sent for confirmation using this molecular marker technique. However, considering the cost of genetic analysis, other farmer-friendly methods, more reliable than the conventional morphometric analysis technique should still be developed.

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6. Status of tropical anguillid eels (*Anguilla* spp.) in international trades

6.1 Objectives

Conservation and management of tropical anguillid eel resources have become a serious concern because the demand for *Anguilla* spp. mainly from East Asian countries has been increasing since the last decade. The recent listing of the European eel in CITES Appendix II in 2007 as well as the recent export ban of these eels from EU member states in 2010 may result to increased exploitation of the tropical eels. Utilization of alternative anguillid eel resources from Southeast Asia has increased especially in 2012-2013. However, results from the Regional Technical Meeting Sustainable Management of Eel Resources and Aquaculture Production in Southeast Asia held in 2014 by SEAFDEC under the support from Japanese Government showed ambiguous status and trends of the tropical anguillid eel resources, while habitat degradation and inadequate regulations/management measures for eels were examined.

In this regard, in order to support the data collection for the assessment of the status and trends of tropical anguillid eels in Southeast Asia, the trading profiles for tropical anguillid eels were reviewed using national trade data statistics for both eel exports and imports based on UN Comtrade[1] information. It is expected that, based on the available trade data of *Anguilla* spp. from Southeast Asian countries, we could better understand the status and trends of tropical anguillid eel fisheries and aquacultures. This paper therefore attempts to describe the status and trends of international trades of the tropical eels to help develop and implement sound eel management for sustainable use. This paper also attempts to compare the available data reported to UN and the data obtained from the baseline survey to help improve data collection and reporting systems.

6.2 Methods

Sources of data : This paper used the available trade statistics from the UN Comtrade. This paper focused on the export and import data of the live eels (*Anguilla* spp.). The live eels have the commodity code 30192. The trade data were obtained for all 10 ASEAN Member States (AMSs), namely, Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam. The period of data is dependent on the availability of data reported by each country to UN data system. The oldest information was from 1989.

6.3 Results

Export of Live Eels (Anguilla* spp.*) : Table 38 shows the export data in weight (kg) obtained from the UN Comtrade for the 10 AMSs. The data starts from 1989, but not all countries appeared to have submitted the data to the UN Comtrade regularly since then. The status of the data submission as well as the amount of the export differed among the countries.

[1]https://comtrade.un.org/data/

Figure 61 shows the export trends of the live eels (*Anguillid* spp.) of Indonesia, Malaysia, Philippines, and Thailand based on the data shown in Table 36. These countries were selected because they submitted the data more than 20 years to date. Among the four countries, Indonesia, Philippines, and Thailand indicated the increase in eel exports around 2013. The results of the exportation also indicated that Indonesia and Philippines are active in live eel exportation. In these two countries, the export data increased toward 2012-2014 and then decreased. The evidence of this increase in part appeared to match the restriction of trade of European eel, *Anguilla anguilla*, due to the listing of the European eel in 2007 by CITES in Appendix II for international trade followed by the EU ban of the exportation of this species from its member states in 2010. The tropical eel might have been used to compensate for the shortage of global supply of eel seeds for eel farming. In contrast to that, it is not clear why the amount then decreased.

In addition to these two countries, although there were only 4 years covered by the reported data, Myanmar also exported a large volume of the live eels in recent years.

Table 38. Export data (kg) available from UN Comtrade in the 10 AMSs

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
1989			22,276		0			226	22,956	
1990			3,706		0			13,937	14,737	
1991			5,502		1,995			2,059	8,125	
1992			34,335		221,729			4,656	17,187	
1993			74,085		603,000			1,956	18,834	
1994			38,737		0			35,610	17,624	
1995			107,987		0			0	58,648	
1996			83,566		575,222		15,940	5,603	282,374	
1997			30,076		432,214		34,273	2,224	124,671	
1998			368,625		527,528		19,185	15,380	100,503	
1999			459,063		307,568		32,291		18,663	
2000			1,062,104		24,948		47,466		66,226	
2001			1,523,252		1,736		74,498		196,187	
2002			314,116		2,789		205,541	54	17,857	17,342
2003			635,718		9,490		30,446	49	45,260	17,397
2004			311,266		17,259		65,552	1,310	5,706	
2005			106,867		30,386		111,118	30	121,654	
2006			13,294		46,070		165,606	80	14,793	
2007			44,625		38,721		350,226	62	12,599	
2008			46,067		1,515		312,174	14	3,044	
2009			256,782		5,325		254,057		7,002	
2010			3,341,075		5,254	1,498,993	446,779			
2011		580	2,068,680		6,861		1,432,435		35,168	
2012		617	4,037,285		32,441		5,123,219		96,142	
2013		1,665	6,092,933		23,797		11,426,334		35,238	
2014			4,365,686		5,256	2,172,265	14,265,247		268	16,012
2015			3,697,526		1,590		8,683,187		10,965	
2016			3,592,915		863	7,242,316	8,423,080		30,337	77
2017	100		2,295,649		34,562	8,899,732	8,002,122			32
2018	300		2,398,593				7,212,424		597	

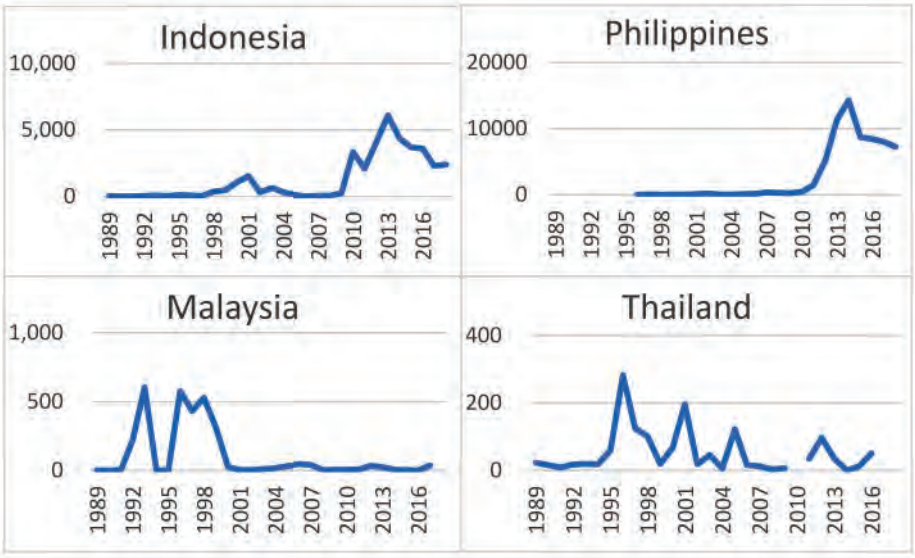

Figure 61. Trend of export data (in tons) in Indonesia, Malaysia, Philippines, and Thailand

Export Routes of Live Eels from Southeast Asia : Figure 62 show the trade routes of the live eels exported from Indonesia, Myanmar, and Philippines in 2017, respectively. These three countries showed evidence of eel trades in large quantities and exports to multiple countries. Most of the live eels from these countries were exported to China (80% from Indonesia, 89% from Myanmar, 72% from Philippines). The remaining countries that received exported eels in recent years were Japan, Rep. of Korea, Spain, Netherland, Switzerland, French, United Arab Emirates, and other Asian countries. From the other exporting countries, based on the Comtrade export data, the live eels were exported to Malaysia (Brunei Darussalam), Rep. of. Korea (Cambodia), Singapore (Malaysia), Viet Nam (Malaysia, Thailand) and Japan (Viet Nam).

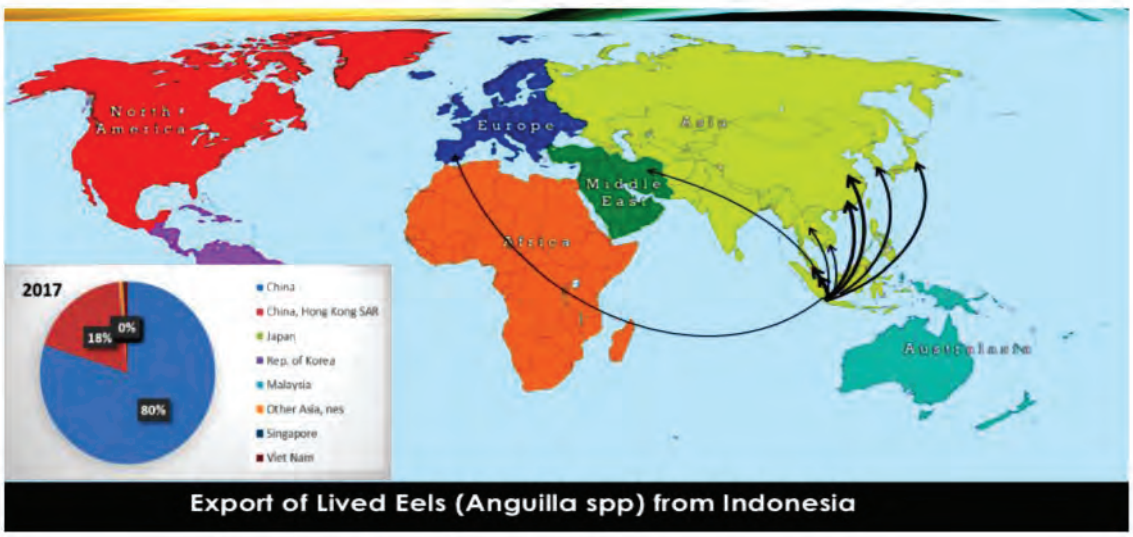

Figure 62. Export of live eels (Anguilla spp.) from Indonesia in 2017

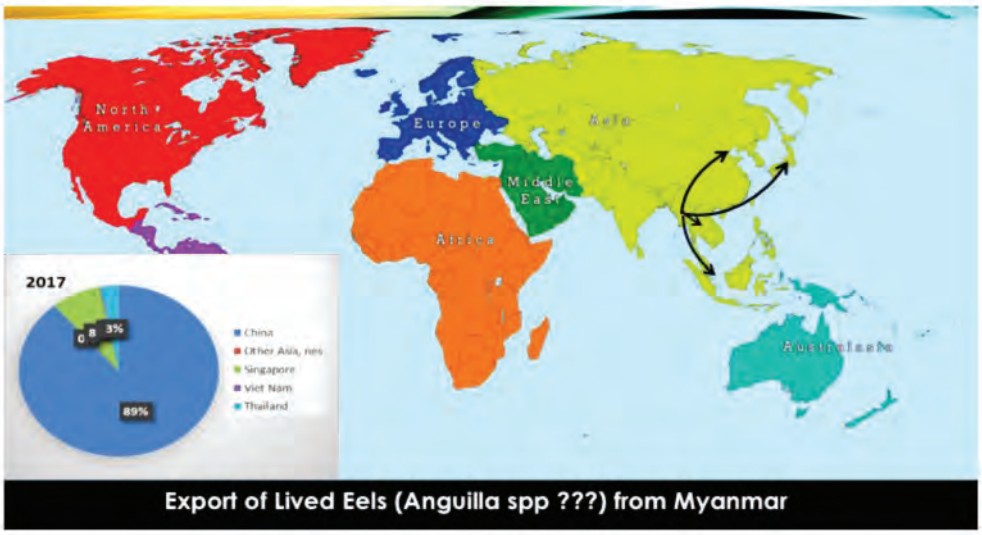

Figure 63. Export of live eels (Anguilla spp.) from Myanmar in 2017

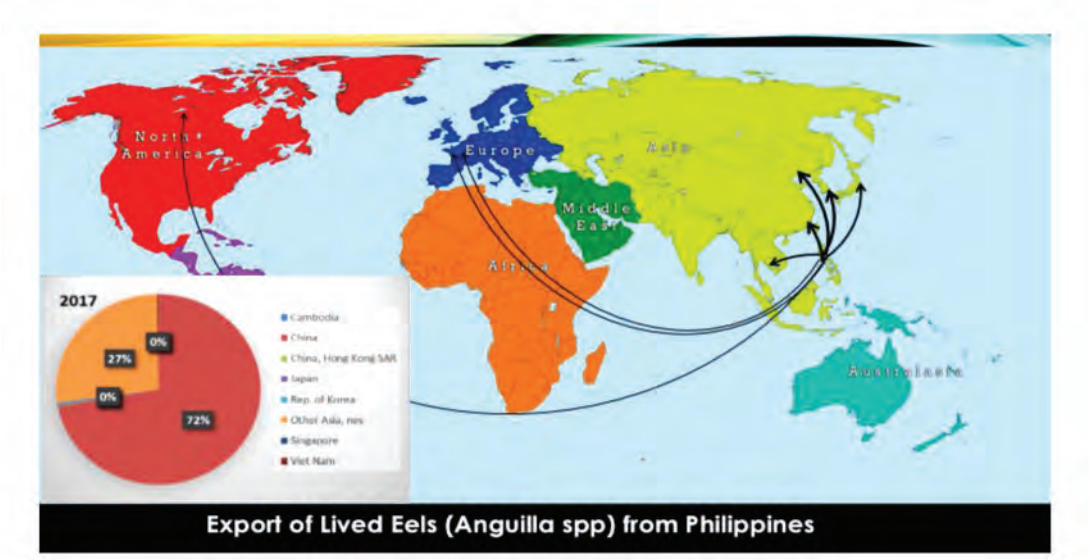

Figure 64. Export of live eels (Anguilla spp.) from Philippines in 2017

***Import of Live Eels (Anguilla* spp.) :** Table 39 shows the import data in weight (kg) obtained from the UN Comtrade for the 10 AMSs. Although the recorded data started in 1989, no country submitted data continuously until now since 1989. The status of the data submission as well as the volume of the import differed among the AMSs. Only two countries (Malaysia and Thailand) appeared to have submitted data to the UN Comtrade on a regular basis. These two countries together with Singapore suggest that their import trends are likely decreasing. In contrast, Viet Nam is importing large numbers of the live eels, although the information was based on few data.

Table 39. Import data (kg) available from UN Comtrade in the 10 AMSs

Year	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
1989			62		0			12,178		
1990					0			10,169		
1991			3		0			7,560		
1992	156		3,886		0			12,909		
1993	612		38,931		0			17,149		
1994	515		2,585		0			46,840		
1995			1,593		0			11,526		
1996			699		0			13,463	1,132	
1997			839		403,415			15,661	1,503	
1998			2,437		11,080			16,354	812	
1999			1,375		31,236			10,426		
2000					1,149			18,970		
2001								10,130		
2002					7,377		405	10,940		82
2003					8,306		580	27,921	1,666	
2004					2,543		103	25,300	85,764	
2005			136,943		1,540		323	20,206	135,014	
2006					45,353		8	46,680	160,286	
2007			228		940			30,169	139,111	
2008			5,860		4,002			960	165,648	
2009			2,744		42,423				207,205	
2010			2,604	*	16,038				228,097	
2011					2,664		5,369		232,732	
2012					47,867		480	130	256,185	
2013					2,800			40	127,820	
2014					1,271				38,622	
2015					167				17,465	
2016		1,320			327				2,251	211,074
2017	3,864				491	10,890				559,292
2018									9,462	

The UN Comtrade data indicated that the imports were made from multiple countries (data not shown). For instance, Philippines imported live eels from African and European countries such as Morocco in 2012 and France and Bulgaria in 2011. Evidence of imports from European countries were also obtained from Thailand. In 2017, Thailand imported live eels from France and Spain. The live eels from Europe appeared to be *Anguilla anguilla*.

Although there were only two years of the reported data, Viet Nam imported quite a large volume of the live eels mainly from China.

Unmatched reported data between sender and recipient countries : While the data were being extracted from UN Comtrade, it was found that the data did not match between the sender (exporting country) and the recipient (importing country). Table 40 shows some examples of such cases. For instance, Indonesia reported the amount of live eels exported to Malaysia in 2017 as 1815, whereas Malaysia reported the amount of the live eels imported from Indonesia as 401. The reported data from these two countries should have been same. Although these discrepancies in the data were found in several cases, it was difficult to explain why such cases happened.

Table 40. Comparison of data (kg) between the sender and recipient countries

Sender	Recipient	Reported by	
		Sender	Recipient
Indonesia	Malaysia	1,815	401
	Shingapore	2,500	No data
	Viet Nam	17,871	2,596 *
	Thailand	102	No data
Malaysia	Shingapore	21,412	No data
	Viet Nam	12,745	2,596 *
Myanmar	Shingapore	711,777	No data
	Viet Nam	18,837	2,596 *
	Thailand	262,011	600 (2016)
Philippines	Cambodia	2,000	1,320 (2016)
	Shingapore	1,500	No data
	Viet Nam	15,500	2,596 *

* Viet Nam reported the data as received from other Asia.

Comparison of data between Comtrade and the SEAFDEC baseline survey : UN Comtrade data from the AMSs was compared to those obtained from the SEAFDEC baseline survey. The SEAFDEC baseline surveys were conducted from August 2017 to May 2019 in the six AMSs, namely, Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam. Table 41 indicates the discrepancy of data between the UN Comtrade and the SEAFDEC baseline survey. The UN Comtrade data tends to show higher numbers than those reported from the baseline survey. For instance, in Philippines, the 2017 UN Comtrade data indicated 8,002 t of the live eel was exported to other countries whereas the data from the baseline surveys were two orders smaller than that of the UN Comtrade.

A few possible reasons can be raised for these discrepancies between the UN Comtrade and the baseline survey data. First, size composition of the eels in these data might have been different. The baseline survey collected the catch data of small glass eels more often than that of larger elver and yellow eels, while trading of eels usually involve eels of consumption size, that is, larger than glass eels. In addition to that, Indonesia and Philippines already banned the export of glass eels. The UN Comtrade data therefore likely contained data from larger eels, resulting in the difference in weight between the two data sources. Second, it was suspicious that the UN Comtrade data for live eels (*Anguilla* spp.) might have included not only *Anguilla* spp. but other different families of eels such as swamp eels and snake eels. Harvesting the swamp eels and snake eels and reporting them to national databases with the Anguillid eels has been confirmed in Myanmar, Philippines, and Indonesia during the baseline survey. This could happen due to the fact that the UN Comtrade does not have separate codes for the tropical eels and other eel families. Finally, in general, the departments/offices responsible for data collection and data reporting are different in these countries, so the level of understanding of the eel taxonomy may not be same. Interpretation of the official import/export data should be careful.

Table 41. Discrepancy between UN Comtrade and baseline survey data

Country	2017 UN trade stats (t)	Baseline survey
Cambodia	1.7 (2013)	No capture fishery in this country
Indonesia	2,399	Under survey
Myanmar	8,900	· Annual catch of yellow eels: 12t (2017) (Data source: Local government and a consolidator & farmer in Mandalay) · Annual export volume: 22t (2017) (Data source: a farmer in Mandalay) · No glass eel fishery and yellow eels are bycatch of other fisheries in Myammar.
Philippines	8,002	· Annual catch of glass eels in 2017: 2t in Luzon Is., 10t in Mindanao Is. (Data source: Survey and official data) · Annual catch of elvers/yellow eels in 2017: 0.3t in Luzon Is., >0.3t in Mindanao Is. (Data source: Official Data) · Export volume is under survey.
Thailand	50 (2016)	· No glass eel fishery and yellow eels are bycatch of other fisheries in Thailand. · No export (Data source: a trader)
Vietnam	0.032	· Catch of glass eels: 0.6-0.75 t/year (Data source: The largest eel farm in Khanh Hoa province) · Farm production volume of anguillid eels in Ca Mau Province: 4,500t (2018) (Data source: provincial government in Ca Mau)

6.4 Conclusion

This paper showed that the international trading of the live tropical eels was very active especially in some of the AMSs, indicating the fact that the tropical eel resource is economically very important to these countries. In order to receive the benefits from the eel resource for a long period as possible, the AMSs should ensure the long-term sustainable use of the resource by developing and implementing sound management of the resource. Proper control of the international trade of the eels are becoming one of the important factors in the management procedures.

This paper, however, indicated the challenges the AMSs should address, which is the data discrepancy in trading figures.

Fixing this glitch in the reporting system in a timely manner is very important because international trading is the one of the contentious issues in eel conservation and management. The AMSs concerned should understand that the evidence of the data discrepancy this paper demonstrated may cause overestimation of the risk for the continued use of the tropical eel resource. Catch statistics is one of the major factors for assessing the status of the eels. If the reported catch number is larger than the actual number, it is dangerous to rely on the reported number to estimate the status of the eels because that could lead to overprotection of the eel resources. One of the possible negative influence of this is that the tropical eels may be listed as threatened or endangered and could as a consequence, be prohibited from being traded freely even among

the AMSs. Delisting is generally very difficult once listed. CITES allows trading of the listed species on condition that the relevant countries should issue non-detriment findings (NDF). It is not easy to issue the NDF, however, because it requires to take into account, scientific, trade and enforcement considerations.

The data discrepancy mentioned above can simply be a procedural matter. If so, it is relatively easy to rectify. First, it is effective to strengthen inter- as well as intra-agency cooperation to control/monitor process of import-export flow of tropical anguillid eels. Second, it is useful to consider discussions with the UN authority to have separate an HS-code for swamp eels and snake eels followed by the development of an efficient domestic reporting system that can discriminate between non-*Anguilla* and *Anguilla* spp. The establishment of global and regional traceability systems will also contribute to the improvement of the reporting system.

We should realize that sustainable use of tropical eel resources requires the implementation of sound management protocols.

7. Policy guidelines and regulation/management measure of tropical anguillid eels in Southeast Asia

7.1 Regulation and management measures in each country

The present and future plans for formulating regulations and implementing management measures in ASEAN countries where fishery/aquaculture of tropical anguillid eel exist, are summarized in the Appendix 4.

7.2 Policy guidelines for management of tropical anguillid eels in ASEAN Member States

In order to continue sustainable use of tropical anguillid eel resources, it is necessary that the countries take effective management measures for eels. In the project, the ***"POLICY GUIDELINES FOR REGIONAL CONSERVATION AND MANAGEMENT OF TROPICAL ANGUILLID EEL RESOURCES IN SOUTHEAST ASIA"*** were formulated with the participation of each ASEAN country at the Second Regional Meeting in October 2018. This Policy guidelines is appeared in Appendix 5.

This guideline was submitted to the ASEAN Secretariat and will be endorsed as a common management policy for tropical anguillid eel of ASEAN.

8. Meeting activities

Activities such as regional meetings and workshops were held during the two-year project period. The contents of the meeting are described below.

1) Project planning meeting

This meeting was held on 4th August 2017 in Bangkok, Thailand, to finalize tasks with institutions involved in the project implementation. It was based on discussion in the preparatory meeting held in June 2017 in Palembang.

The participants were those persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam), Japan (Fisheries Agency of Japan), SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of this meeting was to confirm the project activities and design the detailed plans to start the project. The meeting agenda covered the project purpose, activities, activity schedules for the 2 years, methods and targets of baseline/regular surveys, refinement of techniques to improve survival rate of glass eel, and evaluate resource management policies.

2) The progress meeting of implementation activities on the project

This meeting was held on 11th December 2017 in Palembang, Indonesia. The meeting was conducted to determine the progress of the project activities, evaluate the results of the various activities thus far, compile and discuss plans for the future.

The participants were persons in charge of the project in the five countries (Cambodia, Indonesia, Myanmar, Philippines, and Viet Nam), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

3) The Assessment Committee Meeting

This meeting was held on 19th December 2017 in Bangkok, Thailand.

The participants were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam), Japan (Fisheries Agency of Japan), Assessment committee members (Dr. Jun Akamine, Dr. Shigeharu Senoo, Ms. Hiromi Shiraishi, and Dr. Duto Nugroho Suhardjo), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of this meeting was to arrange for the Assessment Committee Members and the participants of each ASEAN country to evaluate whether the research methods of the project were appropriate and effective in achieving the project purpose.

At the meeting, SEAFDEC project staff presented the results obtained the activities conducted. Mr. Akira Bamba from the Fisheries Agency of Japan, presented the resource management policy for Japanese eel, which this management measures can be used as guidance for tropical anguillid eel by ASEAN.

4) The First Regional Meeting

The meeting was held on 25th January 2018 in Bangkok, Thailand.

The participants of the meeting were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam), Japan (Fisheries Agency of Japan), Assessment committee members (Ms. Hiromi Shiraishi, and Dr. Duto Nugroho Suhardjo), FAO, Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of the meeting was to present the results obtained through the activities of the project, and to summarize the management policies for tropical anguillid eels that each country was implementing and planning. Among the results presented were those of the baseline surveys, regular surveys, DNA analysis, and refinement of techniques to improve survival rate. The participating countries where the eel fishery exist presented the current eel management policies and summary of data collection method. Each country also presented their proposed future management plan.

5) International Technical Workshop on Tropical Anguillid Eel in Southeast Asia

This meeting was held on 7th-8th June 2018 in Bangkok, Thailand.

The participants were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam), Mission of Japan to ASEAN, Assessment Committee Member (Dr. Duto Nugroho Suhardjo), FAO (Dr. Kim Friedman), Zoological Society of London- ZSL (Dr. Matthew Gollock), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of this meeting was to create the Information Document - “Status and Resources Management of Tropical Angullid Eels in Southeast Asia” based on the findings obtained through the activities of the project thus far for posting on the website of the CITES 30th Meeting of the Animals Committee. This Animals Committee Meeting was eventually held in July 2018.

The information document was shared in anticipation of the CITES Cop18 where discussions will be held on possible international trade restrictions for tropical anguillid eels. Therefore, it is necessary to present evidence that tropical eel resources are not yet threatened and thus should not be subjected to

international trade restrictions. The contents of the Information Document were presented by SEAFDEC to the Anguillid Eel Working Group at the 30th Meeting of the Animals Committee in CITES.

6) The Second Regional Meeting

This meeting was held on 18th-19th October 2018 in Bangkok, Thailand.

The participants were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam), Fisheries Agency of Japan (Mr. Hirohide Matsuhima, through skype), expert from Japanese Fisheries Research and Education Agency (Dr. Hiroshi Hakoyama), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The objectives of this meeting were to: 1) share the information obtained through the project activities and the information from the ASEAN countries, and 2) formulate a common policy guideline among ASEAN Member States to conserve and manage tropical anguillid eels.

The ASEAN common policy guidelines have been developed among the ASEAN countries through consideration based on the situation in each country. These guidelines were eventually submitted to the ASEAN Secretariat for the necessary endorsement process.

In this occasion, Dr. Hakoyama presented his lecture on extinction risk assessment of the Japanese eel.

7) Workshop on Statistics/Aquaculture of Tropical Anguillid Eel in Southeast Asia

This meeting was held on 23rd and 24th-25th April 2019 in Manila, Philippines.

The participants of the meeting were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam), Fisheries Agency of Japan (Mr. Yuto Furuzono, through skype), Eel experts (Dr. Hagi Yulia Sugeha, and Prof. Dr. Takaomi Arai), eel farmers (Indonesia, Philippines, and Viet Nam), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of this meeting was to present the various statistical information obtained from the activities of the project, as well as the results of refinement of techniques to improve the survival rate of glass eels. The technical publication on the Nursery of Tropical Anguillid Eels was also launched and distributed to all workshop participants especially the eel farmers.

At the meeting, Dr. Sugeha and Prof. Dr. Arai gave lectures on ecology and resource management of tropical anguillid eels to the participants. The workshop participants also visited an anguillid eel nursery farm in Batangas province.

8) The Third Regional Meeting

This meeting was held on 22nd-23rd July 2019 in Bangkok, Thailand.

The participants were persons in charge of the project in each country (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam), Fisheries Agency of Japan (Mr. Kazuya Fukaya), Mission of Japan to ASEAN (Mr. Noriyuki Takahashi), Assessment Committee Member (Dr. Duto Nugroho Suhardjo), eel experts (Dr. Hagi Yulia Sugeha, and Dr. Maria Lourdes Cuvin Aralar), Consultant-JANUS, SEAFDEC Secretariat, AQD and IFRDMD.

The purpose of this meeting was to present and evaluate the final results of the activities conducted in the project and to finalize the draft of the project report. The final results were presented by persons in charge of the project, and each participant evaluated the achievements of the project. The Information Document submitted to the CITES 30th Meeting of the Animals Committee will be updated and submitted to the 31st Meeting of the Animals Committee in 2020.

The final report will be submitted to the ASEAN Secretariat and will also be posted on the SEAFDEC website and published.

9. Other activities

9.1 CITES convenes international technical workshop on eels (*Anguilla spp.*) at Royal Botanic Gardens KEW, London, UK

SEAFDEC attended the "CITES convenes international technical workshop on eels (*Anguilla* spp.)" and participated in the discussion. The purpose of this workshop was to discuss the challenges and lessons learnt from the implementation of the Appendix II listing of European eel (*Anguilla anguilla*), to share their knowledge and experience on managing and trading in other eel species, as well as to reflect on the impact that the listing and subsequent ban on trade in European eel may have had on other *Anguilla* species.

Three working groups were formed to consider: (1) the implementation of the current listing of European eel (*Anguilla anguilla*) on CITES Appendix II; (2) illegal trade in *A. Anguilla*; and (3) the conservation and sustainable management of non-CITES listed Anguilla species. SEAFDEC attended the third working group. The report and recommendations from this workshop were made available for the meetings of the Animals Committee (16-21 July, Geneva) and the Standing Committee (1-5 October, Rosa Khutor, Sochi). The workshop report was posted on the CITES website, the Animals Committee, at address: https://cites.org/sites/default/files/eng/com/ac/30/E-AC30-18-01.pdf.

9.2 The 30th CITES Animals Committee (16th-21st July 2018 in Geneva)

The 30th Meeting of the Animals Committee of CITES was held in Geneva, Switzerland on 16th-21st July 2018, and the representative of SEAFDEC attended this meeting. SEAFDEC presented information on ecological and resources status of tropical anguillid eel obtained through the project activities at eel working group.

SEAFDEC posted the Information Document - **"Status and Resources Management of Tropical Anguillid Eel in Southeast Asia"** on the web site of Animals Committee of CITES. The document number is E-AC30-inf-11 and the website address is : https://cites.org/sites/default/files/eng/com/ac/30/Inf/E-AC30-Inf-11.pdf .

In the eel working group of the Animals Committee, the following issues were discussed:1) trade in European eel; 2) Trade in non-detriment findings - European eel; 3) trade in non-CITES *Anguilla* spp. The report of the working group was posted on the website of the Animals Committee of CITES. Document number is AC30 Com.5, and the website address is : https://cites.org/sites/default/files/eng/com/ac/30/com/E-AC30-Com-05.pdf.

10. Conclusion and Recommendations

The purpose of this project is to strengthen the resource management framework for the sustainable use of tropical anguillid eels. The following are the conclusions based on the results from each project activity and recommendations for future actions.

1. Understanding the utilization of tropical anguillid eels

Through baseline surveys in each country, information on eel catch, farm production and supply chain were collected and compiled.

The information on catch and distribution channels by species and life stage in each country made it possible to understand the current utilization status of eels. It also provided information on data sources in each country. A common system for catch and trade information has not been established in countries of the ASEAN region. Therefore, standard and systematic data collection scheme for resources management and traceability for all countries in the ASEAN region should be required.

2. Trends in the abundance of tropical anguillid eels

Fishing effort and catch data were collected in Indonesia and Philippines to analyze trends in abundance of tropical anguillid eels. No immediate threat on the abundance of tropical anguillid eels was detected based on catch per unit effort data.

In order to effectively manage and ensure sustainability of tropical anguillid eels, it is necessary to determine the catch quota (e.g. total allowable catch) that does not affect the recruitment and reproduction of tropical anguillid eel species. In the future, it is necessary to refine data collection and devise comprehensive stock assessment methods purposely for tropical anguillid eels based on abundance data.

3. Diversity in the area of tropical anguillid eel in Southeast Asia

The genetic study of *A. bicolor bicolor* and *A. bicolor pacifica* from different locations in Southeast Asia indicated very high genetic diversity within the samples and genetic differences among the samples.

These results suggest that genetically different populations of these subspecies studied might exist in Southeast Asia in contrast to the cases of European eels and Japanese eels. However, the final conclusion should be drawn after validating the current results using multiple genetic markers in analyzing temporally and spatially different samples. In addition to that, because it is also important to understand species` genetic variability, collection and analysis of samples from their entire ranges of distribution, including the regions where no historical and current evidence of eel fisheries has been reported in Southeast Asia, should be conducted.

4. Refinement of nursery techniques for glass eel to elver

Based on surveys of various eel nursery farms in Philippines and Viet Nam, as well as nursery rearing trials, appropriate culture management as well as weaning duration and appropriate weaning diets have been recommended to improve survival rates. Assessment of pathogens common in eel nursery farms was also conducted and appropriate risk management and prevention/treatment protocols were also provided. Genetic methods were also presented for identification of glass eels, since morphometric methods are not always accurate.

5. Discrepancy trade statistics of tropical anguillid eels

The current status of the international trade of tropical anguillid eels in Southeast Asia was examined using the trade data extracted from UN Comtrade dataset. When the catch data from the field survey was compared to the UN Comtrade data, there was a marked discrepancy between both datasets. One possible explanation for this discrepancy was that the UN Comtrade data might have included the data from different families of eels such as swamp eel and snake eel. The baseline surveys found that the numbers of swamp eel and snake eel catches were very large in some of the Southeast Asia countries, so mixed data from these species could have contributed to such large numbers in the UN Comtrade. Trade data from the international organization such as the UN Comtrade is an important source information for CITES to make decisions whether or not to list the target species for international trade regulations. In light of that, each ASEAN country needs to be cautious by validating the data prior to reporting to international trading databases.

6. Promotion of resource management policy of tropical anguillid eel in ASEAN

"Policy guidelines for regional conservation and management of tropical anguillid eel resources in Southeast Asia" was formulated with the participation of the representative of each ASEAN country for adoption as a common policy in ASEAN for the resource management of tropical anguillid eels.

In addition, it is important that each country sets appropriate catch quota that can maintain steady recruitment and the reproduction of the different species of tropical anguillid eels. It is necessary to create mutually agreed time bound targets to enable effective resource management measures in Southeast Asia.

List of Appendices

Appendix 1

List of Baseline Surveys

No	Year	Date	Country	Survey location	No of respondents
1	2017	17-20 Aug	Indonesia	**West Java Province:** Sukabumi Regency	1
2	2017	28 Aug-1 Sep	Cambodia	**Sihanoukville Province:** Prey Nob District **Kampong Cham Province:** Stueng Trang District	2
3	2017	3-7 Sep	Viet Nam	**Phu Yen Province:** Tuy An District, Phu Hoa District Khanh Hoa Province	7
4	2017	18-22 Sep	Philippines	*Luzon Is.* **Cagayan Province:** Aparri, Gonzaga	4
5	2017	27-30 Sep	Myanmar	**Yangon Division:** Southern District	3
6	2017	9-13 Oct	Indonesia	**Central Java Province:** Cilacap Regency	4
7	2017	23-28 Oct	Myanmar	**Tanintharyi Division:** Myeik District **Mandalay Division:** Mandalay District	6
8	2017	6-9 Nov	Viet Nam	**Hanoi** **Phu Yen Province**	3
9	2017	13-18 Nov	Philippines	*Luzon Is.* **Cagayan Province:** Aparri Metro Manila: Manila	2
10	2017	13-17 Nov	Indonesia	**Central Sulawesi Province:** Palu City, Poso Regency	8
11	2017	20-25 Nov	Myanmar	**Ayeyarwady Division:** Pyapon District, Labutta District	6
12	2017	28-30 Nov	Thailand	**Samut Prakan Province:** Phra Samut Chedi District **Ranong Province** **Phang Nga Province**	7
13	2017	27-28 Nov	Indonesia	**West Java Province:** Karawang Regency	3
14	2017	30 Nov-4 Dec	Philippines	*Mindanao Is.* **Maguindanao Province:** Cotabato City **South Cotabato Province:** General Santos **Davao del Sur Province:** Davao City	4
15	2018	8-13 Jan	Indonesia	**East Kalimantan Province:** Kutai Kartanegara Regency (Tenggarong District), Balikpapan City **North Sulawesi Province:** Manado City **South Sulawesi Province**	4
16	2018	17-19 Jan	Myanmar	**Yangon Division**	3
17	2018	29 Jan	Thailand	**Chachoengsao Province:** Plengyao District	1
18	2018	19-23 Feb	Myanmar	**Ayeyarwady Division:** Pathein District, Myaungmya District	3
19	2018	12-20 Mar	Philippines	*Luzon Is.* **Zambales Province:** Cabangan **Pampanga Province:** Magalang **Metro Manila:** Manila	7
				Mindanao Is. **Agusan del Norte Province:** Butuan City **Agusan del Sur Province:** Bunawan **Surigao del Sur Province:** Bislig City	
20	2018	24 Apr	Thailand	**Bangkok:** Wang Thonglang District	1
21	2018	9-11 May	Thailand	**Ranong Province**	4

No	Year	Date	Country	Survey location	No of respondents
22	2018	27-30 May	Indonesia	**Aceh Province:** Banda Aceh Regency	1
23	2018	16-23 Jul	Philippines	*Luzon Is.* **Zambales Province:** Cabangan **Tarlac Province:** Tarlac City **Rizal Province:** Antipolo City **Cavite Province:** Tanza	11
				Mindanao Is. **South Cotabato Province:** General Santos, Lake Sebu **Sarangani Province:** Alabel	
24	2018	25-29 Jul	Viet Nam	**Ca Mau Province:** Ca Mau City, Cai Nuoc District	8
25	2018	5-8 Sep	Viet Nam	**Binh Dinh Province:** Phu My District, Tuy Phuoc District	5
26	2018	12-16 Nov	Viet Nam	**Khanh Hoa Province** **Phu Yen Province:** Tuy Hoa City, Tuy An District	3
27	2018	13-17 Dec	Indonesia	**Central Java Province:** Purworejo Regency, Cilacap Regency, Kebumen Regency	6
28	2019	21-26 May	Myanmar	**Yangon Division** **Ayeyawady Division:** Pathein District **Mandalay Division:** Mandalay District	8
29	2019	15-18 May	Cambodia	**Kampong Cham Province:** Stueng Trang District	1
30	2019	5-8 Jun	Thailand	**Bangkok:** Wang Thonglang District **Ranong Province**	6
31	2019	15-20 Jun	Philippines	*Luzon Is.* **Cagayan Province:** Aparri, Santa Teresita **Bulacan Province:** Baliuag	3
32	2019	26-29 Jun	Viet Nam	**Ca Mau Province:** Ca Mau City	4
33	2019	8-13 Jul	Indonesia	**North Sulawesi Province:** Manado City	4

Appendix 2

Genetic Analysis Protocol for Tropical Anguillid eel samples using mtDNA marker cytochrome B

I. DNA EXTRACTION

(using Fujifilm QuickGene DNA tissue kit S (DT-S) and Fujifilm QuickGene-Mini80)

A. Lysate Preparation

1. Cut tissue.
2. Add 180 µL MDT (tissue lysis buffer) and 20 µL EDT (Proteinase K).
3. Incubate at 55°C overnight or more than 5 hours until tissue lyse completely.
4. Flash spin down for several seconds.
5. Add 180 µL LDT.
6. Shake vigorously by hand for 20 seconds and flash spin down for several seconds.
7. Incubate at 70°C for 10 minutes.
8. Flash spin down for several seconds.
9. Add 240 µL >99% ethanol.
10. Shake vigorously by hand for 20 seconds and flash spin down for several seconds.

B. Extraction using QG-Mini80

1. Set the cartridge holder, tube holder and 1.5 ml tube into QG-Mini80.
2. Transfer the whole lysate to each cartridge. (Make sure not to include the debris.)
3. Pressurize. (Rotate the rotary switch toward the front side to apply air pressure to the cartridges. Make sure that no lysate remains in the cartridges.)
4. Add 750 µL WDT to the cartridges and pressurize. Repeat 3 times.
5. Move the cartridge holder into the elution position.
6. Add 200 µL CDT (elution buffer) and wait 90 seconds.
7. Pressurize.
8. Genomic DNA collected should be stored until it is used for analysis.

II. PROTOCOL FOR PCR

The amplification protocol for cytochrome b was based on the paper of Jamandre et al. (2007)

Table 1 (below) shows the PCR cocktail for 1 sample:

Components	Volume (ul)
DNA	1
10X buffer	1.25
dNTP Mix	1.25
Primer F	0.25
Primer R	0.25
Taq	0.125
UPW	8.875
TOTAL	13

Table 2 (below) shows the thermal cycling profiles for cytb:

Step	Temperature and Time
Pre-denaturation	94°C for 2 min
35 cycles	
Denaturation	94°C for 1 min
Annealing	55°C for 1 min
Extension	72°C for 1 min
Final extension	72°C for 10 min

III. PURIFICATION OF PCR PRODUCTS

1. Transfer 10 µL PCR product in a new tube. Add 18 µL Agencourt CleanSEQ (brown solution with bead like components). Cover and mix.
2. Flash spin for several seconds. Wait for 5 minutes.
3. Place PCR product sample plate/tubes otop Agencourt SPRIPlate 96 Super Magnet Plate. Wait for 2 minutes. (This is to separate the beads from the solution.)
4. Aspirate the clear solution from the tube.
5. Add 70 µL 70% ethanol. Wait for 30 seconds and aspirate the ethanol. Repeat 2 times.
6. Dry up at room temperature.
7. Add 40 ul CDT.
8. Vortex until homogeneous (solution turns brown).
9. Flash spin (100 xg).

IV. CYCLE SEQUENCING

1. Mix the sample. Flash spin for several seconds. Wait for 1 minute.
2. Move the tubes atop Agencourt SPRIPlate 96 Super Magnet Plate.
3. Prepare master mix with the following amounts for cytb:

Premix _ __ __ __ __ __ __ __ __ __ __ __ __ __	0.4 ul
Primer (Forward primer only 50 picomolar) __ __	0.1 ul
Buffer (5x sequencing buffer) _ __ __ __ __ __ __	1.9 ul
UPW_ __ __ __ __ __ __ __ __ __ __ __ __ __ __	4.6 ul
PCr product __ __ __ __ __ __ __ __ __ __ __ __ __	4.0 ul (template is not included in the MM)
Total	11.0 ul

4. Add 4 ul of template after dispensing MM into each tube.
5. Flash spin (check that the bottom of the tubes have no bubbles).
6. Load samples on the thermal cycler.

V. PURIFYING EXTENSION PRODUCTS

1. Add 2 ul each of EDTA and 3M Sodium acetate (in any order).
2. Add 50 ul of 100% Ethanol.
3. Cover.
4. Invert 4 times.
5. Wait for 20 mins at room temperature.
6. Flash spin (200 x g at 4 °C).

   **invert the plate on a brown paper before putting it in the centrifuge in order to flash spin*
7. Add 70% ethanol.
8. Centrifuge (use Kubota; settings: 1790 xg, 45 min, 4 °C).
9. Remove plates gently.
10. Put new paper towels (brown and use the dry one).
11. Invert plates gently to the paper towel.
12. Centrifuge (200 xg, 1min, 4 °C).
13. Dry plates at room temperature for 20 mins.
14. Add 10 ul HD.
15. Vortex (1min).
16. Spin.
17. Denaturation (95 °C, 5 min).
18. Cold block (1min).
19. Change the cover to septa.
20. Load the samples in 3500 XL Genetic Analyzer.

Appendix 3

List of Farms Surveyed

Location	Date	Name of Farm	Respondent
Biñan, Laguna, Philippines	17 July 2017	Alpha Aquatique Corporation	Mr. Jaime Roxas
Victoria, Laguna, Philippines	17 July 2017	Cacayan Aqua Ventures	Mr. Jaime Cacayan
Gonzaga, Cagayan, Philippines	20 September 2017	Cagayan Aqua Ventures	Edison Go & Jury Tagnia
Cabangan, Zambales, Philippines	13 March 2018	Abalos Aqua Farm/ Oceans Ace Philippines	Mr. Eddie Kim
Magalang, Pampanga, Philippines	14 March 2018	Fresh Water Fishg Village and Resort	Mr. Waldo Feliciano
Magalang, Pampanga, Philippines	14 March 2018	Ayala Fish Farm	Mr. Kevin Wang
Cabadbaran, Agusan del Norte, Philippines	15 March 2018	Cabadbaran Aquatech Resources Corporation	Blaine Ratunil
Davao City, Philippines	18 March 2018	MON Eel and Aquatic Farm	Mr Reynaldo Bagares
General Santos City, Philippines	20 July 2018	Shizu-Tech Trading	Jonai Tetsuya
General Santos City, Philippines	21 July 2018	Pantas Eel Farm	Mr. Heron Pastor; Mrs. Charlie Pastor
Alabel, Sarangani	20 July 2018	Eel Rey Marketing	Mr Ronald A. Oso
Antipolo, Rizal, Philippines	18 July 2018	Eelspress Trading	Mr. Lito Miranda
Antipolo, Rizal, Philippines	18 July 2018	Good Eel Fishery Corporation	Mr. Baek Kim
Tanza, Cavite, Philippines	19 July 2018	Clean Water Eel Fish Farm	Mr. Christopher Ombing
Calaca, Batangas, Philippines	5 April 2019	SMO Pacific Trading	Richard Sorita
Suoi Cat commune, Cam Lam district, Khanh Hoa province, Vietnam	13 Nov 2018	Van Xuan Company	Mr. Hoang Van Duat
Phy Yen Province, Vietnam	14 Nov 2018	Phu Chinh Farm	Mr. Congty Thuy San

Appendix 4

Regulations and management measures in each ASEAN country 25th January 2018 At The First Regional Meeting

Cambodia

Country		Cambodia
Organization (Arrangement of the Staff in charge)	Current situation Name (title)	1. Dr. Kao Sochivi (Deputy Director General of Fisheries Administration (FiA)) 2. Mr. Buoy Roitana (Deputy Director, Inland Fisheries Research and Development Institute (IFReDI)) 3. Dr. Chea Tharith (Deputy Director, Marine Fisheries Research and Development Institute (MAFReDI), FiA)
	Future schedule	The officers in charge of eels have been assigned from both Central (Phnom Penh) and provincial (Kampong Cham) levels. The FiA needs capacity building for officers and data collectors.
Data Collection Scheme	Current situation	There is only one Anguillid eel culture farm in Cambodia. The farm sends data and information to Kampong Cham Fisheries Administration Cantonment and SEAFDEC through IFReDI.
	Future schedule	Data and information on the Anguillid eel culture is sent to IFReDI and Kampong Cham FiA Cantonment every month.
Regulation to manage the eel fisheries	Current situation	MAFF's Proclamation on aquaculture of aquatic animals (6 July 2016): number of culture of eel from 600-1000 heads need permission from fishery office at provincial level. And the number of more than 1000 heads, permission must be obtained from the FiA.
	Future schedule	If the culture of aquatic animals for export grows fast, exportation regulations will be needed.

Indonesia

Country		Indonesia
Organization (Arrangement of the Staff in charge)	Current situation Name (title)	1. Dr. Toni Ruchimat (former Director of Centre for Fisheries Research, Board of Marine and Fisheries Research, Ministry of Marine Affairs and Fisheries) 2. Ms. Sri Dyah Retnowati SP (former Head of Sub-directorate of Inland Water Fish Resources, Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries) 3. Mr. Muhammad Anas (Head of Subdivision of Data, Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries) Development Institute (MAFReDI), FiA)
	Future schedule	The staff in charge of eel have been assigned. The government will strengthen the capacity of local government officers working on eel fisheries and aquaculture.

Country		Indonesia
Data Collection Scheme	Current situation	• Data on eel fisheries production (adult eels) and eel culture production are collected through the national Data collection system, but not by species. • Data collection of glass eel has not yet been carried out.
	Future schedule	• the government considers that the system of collecting eel catch Data by species will be established within next few years. • the eel quantities of import and export will be collected by species soon.
Regulation to manage the eel fisheries	Current situation	• Ministerial Decree No. 19/2012 issued by Indonesia stating that the export of eel below 150 gram/individual is prohibited. • Indonesia has drafted its Fisheries Management Plan (FMP) on eels. • Indonesia has National Plan of Action (NPOA) for eel conservation.
	Future schedule	Under current general fishing law, detail of rules such as closed-season for fishing for glass eels and closed-area for adult eel fishing are being studied.

Myanmar

Country		Myanmar
Organization (Arrangement of the Staff in charge)	Current situation Name (title)	Mr. Myint Zin Htoo,,SEAFDEC Alternate Council Director for Myanmar, Mr. Htun Win Myint,SEAFDEC National Coordinator for Myanmar, Dr. Myint Than Soe,Contact person for Department of Fisheries.
	Future schedule	The Department of Fisheries will strengthen the capacity of local government staffs working on eel fisheries and aquaculture
Data Collection Scheme	Current situation	According to current situation in Myanmar, there are weaknesses in the statistic data collection system for Anguillid eel.
	Future schedule	Thus, the Department of Fisheries will make sure that collection system is improved and strengthened with support from SEAFDEC
Regulation to manage the eel fisheries	Current situation	Department of Fisheries, Myanmar issued the directories for collection of Anguillid eels during the spawning season from 1st June to 31st August. (Ngaka/Aqua.0 11/2006(1538)
	Future schedule	Under the new Union Fisheries Law, Department of Fisheries (DoF) will develop the specific regulation for the conservation and management of eel fisheries in Myanmar water.

Philippines

Country		Philippines
Organization (Arrangement of the Staff in charge)	Current situation Name (title)	1. Dr. Eduardo Gongona (Director of the Bureau of Fisheries and Aquatic Resources (BFAR)) 2. Ms. Drusila Esther Bayate (Asst. Director for Technical Services) 3. Dr. Evelyn C. Ame (Center Chief and Eel Focal Person for Philippines) 4. Dr. Mudjekeewis Santos (NFRDI in charge of DNA Analysis) 5. Dr. Macmod Mamalangkap (in charge of Eel survey in Mindanao)
	Future schedule	• The staff in charge of eels have been assigned. • The government will strengthen capacity of the local government units that have eel fisheries aquaculture under their jurisdictions. A plan has been made to develop and conserve the eel fisheries in the country. • Survey in Mindanao will be conducted.

Country		Philippines
Data Collection Scheme	Current situation	• There is a list of eel farmers in the country. However, data reported by the Philippine Statistics Office does not segregate the Anguillid eels from swamp eels.
	Future schedule	• The amount of import and export of eels will be collected by species by BFAR. • Traceability system will be imposed especially on the issuance of Local Transport Permits before any eel could be exported. Trade data will be used to segregate information on swamp and Anguillid eels.
Regulation to manage	Current situation	1. Fisheries Administrative Order (FAO) 242 - banning the export of elvers less than 15 cm 2. FAO 233 - Aquatic wildlife conservation which include eels 3. FAO 319 - includes the requirements for exporting live food fish and crustaceans 4. Philippine General Memorandum Circular Order No 2 S 2009 includes the requirements for the export of live aquatic animals
	Future schedule	Imposition of traceability system to include the Local Transport Permit; eel farm registration and collectors permit; and implementation of pertinent laws on transport of live aquatic products.

Viet Nam

Country		Viet Nam
Organization (Arrangement of the Staff in charge)	Current situation Name (title)	Directorate of Fisheries (DFISH), Ministry of Agriculture and Rural Development
	Future schedule	The Department of Fisheries will strengthen the capacity of local government staffs working on eel fisheries and aquaculture
Data Collection Scheme	Current situation	No official statistical data. Provincial Sub-Department of Fisheries gathers data on eel catch and aquaculture from District Division of Agriculture and Rural Development. Summary reports are prepared regularly or upon request.
	Future schedule	Statistical data on eel species' catch, aquaculture, import and export of eels will be collected and integrated with national fisheries management database system.
Regulation to manage the eel fisheries	Current situation	1. Fisheries Law 2003 (amended in 2017) (entry into force in Jan 2019) 2. Red Book Viet Nam: A. japonica 3. Ministry decision: No.57/2008/QĐ-BNN. Eel aquaculture 4. Ministry decision: No.82/2008/QĐ-BNN regulating list of rare and endangered aquatic species: EW: *A. japonica*; VU: *A. bicolor, A. borneoensis, A. marmorata* 5. Circular No 04/2015: regulating conditional export of *Anguilla spp*. including *A. marmorata, A. bicolor*, and *A. japonica* (only for aquaculture)
	Future schedule	Under the amended Fisheries Law 2017 (entry into force in Jan 2019), detailed rules and regulations on eel catching, aquaculture, import and export will be reviewed, amended and developed in line with the amended Law and regulations of International Conventions of which Viet Nam is a member.

Appendix 5

POLICY GUIDELINES FOR REGIONAL CONSERVATION AND MANAGEMENT OF TROPICAL ANGUILLID EEL RESOURCES IN SOUTHEAST ASIA

(Adopted at the 2nd Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia, 18-19 October 2018, Bangkok, Thailand)

1. BACKGROUND

Eel resources are mainly utilized for direct human consumption not only in Europe but also in East and Southeast Asia. European eels have become regulated species by CITES for international trade since 2009 due to resource decline and potential extinction. Recently, large consumption of the Japonica eel species in East Asia has led to the rapidly decreasing amount of glass eels. On the other hand, the demand for tropical anguillid eels in Southeast Asia, which has increased recently not only for domestic consumption but also for export to China, Korea, Taiwan, and Japan among others, could lead to the decline of the resource.

The development of this document took into consideration the Policy Recommendations on Conservation and Management of Catadromous Eel Resources and Aquaculture in Southeast Asia adopted by the Seventeenth Meeting of the Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership (FCG/ASSP) in December 2014, and the Twenty-third Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi) in June 2015. Moreover, attention was also paid on the recommendation of the CITES Animal Committee Meeting in 2018 on the need to strengthen the management of tropical anguillid eels to ensure their sustainable utilization.

In this connection, the need to strengthen the management for eel species worldwide has been recognized making it also necessary for the Southeast Asian region to take appropriate management measures for eel resources and their sustainable utilization. Considering that resources management measures for tropical anguillid eels have not yet been in place in the ASEAN Member Countries where the fisheries of tropical anguillid eel exist, and in order to develop and implement regional management measures for tropical anguillid eels, the necessary information on the tropical anguillid eel species, such as catch data, distribution areas, aquaculture production, and export data among others, should be compiled.

2. OBJECTIVE OF THE POLICY GUIDELINES

This Policy Guidelines is intended to propose a way of formulating and implementing effective regional management measures, as well as recommend the actions that should be taken for the sustainable utilization of tropical anguillid eels in the Southeast Asian region.

3. PROBLEM ANALYSIS FOR CONSERVATION AND MANAGEMENT OF TROPICAL ANGUILLID EELS

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

1. Inadequate statistical data on eel resource utilization such as catch data, as well as a systematic data collection scheme

Harmonized data on catch, species, life stages, fishing gear, and fishing effort (e.g. duration of fishing operation, number of fishing gears, number of fishers) are necessary for understanding the current status of glass and elver/yellow eel fisheries, and for carrying out stock assessment. Moreover, biological data such as length, weight, age of elver/yellow eels, are also important for stock assessment. However, more often than not, such biological and fisheries data on tropical anguillid eels are inadequate. Consolidators and/or fishers play an important role in compiling the relevant eel fishery data. The eels caught by local fishers are often collected by eel consolidators who in turn sell the eel catch to consumers or traders, as the case may be. Therefore, an effective registration and licensing system for eel consolidators is necessary in order that the consolidators will be obliged to compile the abovementioned data.

2. Limited information on eel aquaculture such as number of eel aquaculture farmers, eel culture production, and quantity of glass eels purchased and used by farmers

Data on aquaculture, such as the number of eel aquaculture farmers, eel culture production, and quantity of glass or elver eels purchased and used as inputs by farmers, are necessary to understand the current status of aquaculture and validate catch and international trade data. However, such information is insufficient for the tropical anguillid eels. It is therefore necessary that a data collection system for eel aquaculture activities should be established.

3. Geographic range of information on tropical anguillid eel species is insufficient

Information on natural habitat, spawning ground, and migration routes are fundamental for conservation and management of the eel stocks. However, spatial and temporal patterns of distribution of each tropical anguillid eel species are not well understood. Therefore, the geographic range of the tropical anguillid eel species in the region, should be examined based on the description of fishing areas, reproductive biology, and migration patterns.

4. Limited stock assessment studies on tropical anguillid eels

The status and trends of eel stocks are essential for stock management. However, such information is very limited for the tropical anguillid eels. Therefore, stock assessment, e.g. using CPUE analysis as an abundance index, should be conducted for tropical anguillid eels.

5. Limited effective conservation and management measures for tropical anguillid eels

Development of conservation and management measures for tropical anguillid eels should also be established for each country in the future, taking into consideration the results of the abovementioned stock assessment studies.

6. Mixed statistics on international trade of tropical anguillid eels

Considering that the existing trade data on anguillid eel species under the UN Comtrade Database include other eel species like swamp eel and snake eel, among others, there is a need to disaggregate such data in order to improve and confirm the appropriate trade data reporting system for the individual eel species.

4. RECOMMENDED POLICY GUIDELINES FOR CONSERVATION AND MANAGEMENT OF ANGUILLID EELS

The recommended actions to be taken by the ASEAN Member Countries for sustainable regional conservation and management of tropical anguillid eels include the following:

Issues	Recommended Actions
1. Inadequate statistical data on eel resource utilization such as catch data, as well as a systematic data collection scheme	**Establish catch data collection system for tropical anguillid eels** • Development and implementation of appropriate registration and reporting system for eel consolidators and fishers • Requiring eel consolidators and fishers to report their catch data and related information (e.g. fishing effort data, fishing area) to respective countries' competent authorities • Development of standard fisheries data collection system for tropical anguillid eels
2. Limited information on eel aquaculture such as number of eel aquaculture farmers, eel culture production and quantity of glass eel/elver/yellow eels purchased and used by farmers	**Establish data collection system for eel aquaculture** • Development and implementation of appropriate registration scheme including licensing and reporting system for eel farmers • Requiring eel farmers to report their production, buyers, target destination of the products, amount of glass/elver/yellow eels purchased, and other relevant information to respective countries' competent authorities
3. Geographic range information on tropical anguillid eel species is limited	**Determine the geographic range of tropical anguillid eel species** • Compilation of information on geographic range for each tropical anguillid eel species • Conduct of studies to correctly identify the eel species, describe the stock structure, and examine the migratory routes and spawning areas

Issues	Recommended Actions
4. Limited stock assessment studies on tropical anguillid eels	**Conduct stock assessment study on tropical anguillid eel** • Establishment of appropriate level of exploitation and indicators for managing eel stocks
5. Limited effective conservation and management measures for tropical anguillid eels	**Introduce and implement conservation and management measures for tropical anguillid eels** • Development and promotion of conservation and management measures (e.g. regulations for eel collection, management of nursery areas, closed fishing season and/or areas for eel fisheries, setting of upper limit on glass eel inputs for farms, trade regulations, etc.) taking into account results of stock assessment studies
6. Mixed statistics on international trade of tropical anguillid eels	**Improve the international trade statistical data reports** • Harmonization of trade data collection, coding and reporting to segregate statistics on tropical anguillid eels from those of the other eel species

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