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Nursery Culture of Tropical Anguillid Eels in the Philippines

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Foreword

Anguillid eel farming is reliant on wild-caught juvenile stages such as glass eel, elver and yellow eel. However, with the decline in the collection of temperate anguillid eel juveniles in recent years, tropical anguillids have drawn more attention to compensate for the shortage of seeds for eel farming. With the interest in tropical anguillids, proper conservation and management is essential to prevent overexploitation and listing in the CITES appendices.

SEAFDEC organized an international regional workshop on "Enhancement of sustainability of catadromous eel resources in Southeast Asia" on 27-29 April 2016 which identified the lack of baseline information on the status of anguillid eel fisheries and aquaculture among ASEAN Member States. There were also identified gaps on the management practices to ensure the sustainability of eel resources.

Following the workshop, a project on "Enhancing sustainable utilization and management scheme of tropical anguillid eel resources in Southeast Asia" was conceptualized with funding through the Japan-ASEAN Integration Fund (JAIF). To determine the status of tropical anguillids in the wild towards the proper management of eel resources in ASEAN Member States, baseline and regular surveys and compilation of catch statistics were conducted jointly by SEAFDEC's Secretariat and Inland Fishery Resources Development and Management Department. Meanwhile, SEAFDEC Aquaculture Department is tasked to improve aquaculture practices to improve survival rates and the compilation of good eel culture practices and technologies in a manual.

This manual documents the on-farm practices of anguillid eel farms in the Philippines as well as the results of rearing trials conducted at SEAFDEC/AQD to improve growth and survival. Species identification and health management approaches have also been documented. It is hoped that more efficient nursery practices will improve the income of local eel farmers and ease some of the pressure on wild stocks. Along with the proper management of wild anguillids, SEAFDEC/AQD looks forward to the further development of eel aquaculture towards a truly sustainable industry.

Dan D. Baliao
Chief
SEAFDEC/AQD

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Introduction

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. 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. 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 2011 and 2012 (Figure 1). This upward shift coincided with the imposition of restrictions on the fishery and trade of temperate eel species, particularly the European eels.

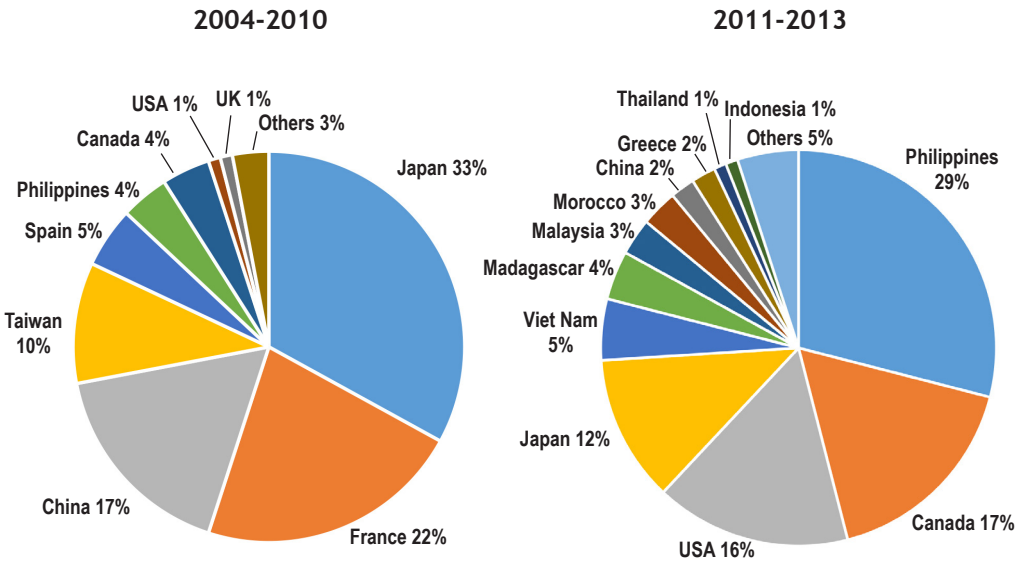

Figure 1. Percent contribution of various sources of live glass eels imported into mainland China, Taiwan, Japan and Korea. *Source: East Asian Customs data as cited by Crook, 2014.*

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 the 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 the Philippines is primarily targeted for export to East Asian countries as an alternative species to the Japanese eel. This technical publication will focus on nursery production of anguillid eels from glass eels to elver using data gathered from eel farm surveys and rearing trials conducted by SEAFDEC/AQD as part of the JAIF (Japan-ASEAN Integration Fund) project on Enhancing Sustainable Utilization and Management Scheme for Tropical Anguillid Eel Resources in Southeast Asia.

Biology, diversity and distribution

The genus Anguilla has 16 species distributed in both temperate and tropical areas of the world. Five species are classified as temperate: *Anguilla anguilla*, *A. australis*, *A. dieffenbachia*, *A. reinhardtii*, and *A. rostrata*. Tropical and subtropical species are *A. bengalensis*, *A. bicolor*, *A. borneensis*, *A. celebesensis*, *A. interioris*, *A. japonica*, *A. luzonensis*, *A. marmorata*, *A. megastoma*, *A. mossambica*, and *A. obscura*. Among these 16 species, three are further divided into two subspecies: (a) *A. bengalensis labiata* and *A. bengalensis bengalensis*; (b) *A. australis australis* and *A. australis schmidtii*; and (c) *A. bicolor bicolor* and *A. bicolor pacifica*. *A. luzonensis* is the newest addition to the species list having been discovered in Cagayan River in the northern part of Luzon Island in the Philippines in 2009. Regardless of geographic distribution, anguillids can be grouped into four distinct morphological characters as shown in Figure 2. Table 1 categorizes the various species of anguillid eels based on these morphological characteristics as well as the known geographic range of these species.

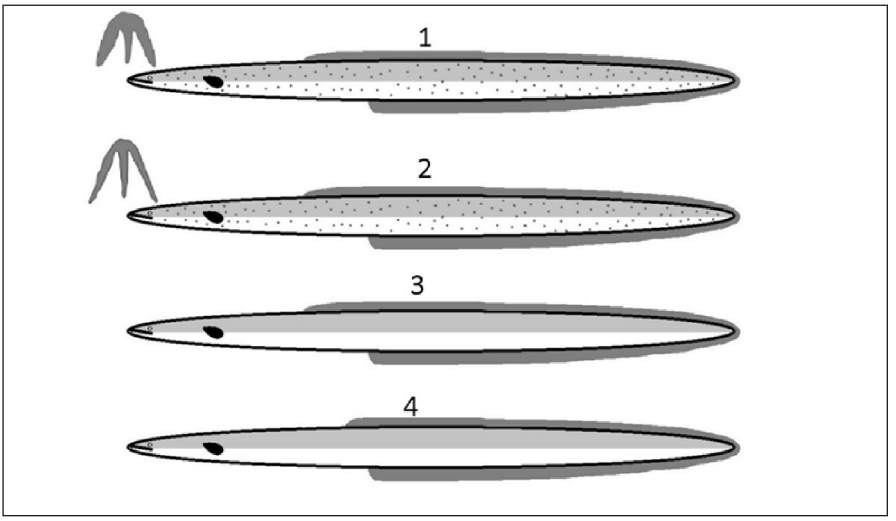

Figure 2. Classification of the genus *Anguilla* based on physical characteristics, *re-drawn from Arai (2016) based on the work of Watanabe (2003) and Watanabe et al, (2004).* 1: Mottled body, long dorsal fin, broad maxillary band of teeth; 2: mottled body, long dorsal fin, narrow maxillary bands of teeth; 3: Non-mottled body, long dorsal fin; and 4: non-mottled body, short dorsal fin.

Table 1. Grouping of anguillid eel species based on physical characteristics (Arai, 2016)

Group	Species	Geographical range
1 Mottled or variegated; broad maxillary bands of teeth; long dorsal fin	*A. celebesensis*	Indonesia, Philippines
	A. interioris	New Guinea
	A. megastoma	Solomon Islands, New Caledonia, Fiji, Cook Islands
	A. luzonensis	Northern Philippines
2 Mottled or variegated / narrow maxillary bands of teeth; long dorsal fin	*A. bengalensis bengalensis*	Sri Lanka, Bangladesh, India, Myanmar, Malaysia, Indonesia, Andaman Islands
	A. bengalensis labiata	Mid-southeastern part of Africa
	A. marmorata	Longitudinally from east coast of Africa to Marquesas Islands in southeast Pacific ocean and as far north as southern Japan
	A. reinhardtii	Eastern Australia, Northern New Zealand
3 Non-variegated skin; long dorsal fin	*A. borneensis*	Borneo Island
	A. japonica	Japan, China, Korea, Taiwan, Northern Philippines
	A. rostrata	North and South America
	A. anguilla	Europe, North Africa
	A. diffenbachii	New Zealand
	A. mossambica	Mid-southeastern Africa, Madagascar
4 Non-variegated skin; short dorsal fin	*A. bicolor pacifica*	Philippines, Sulawesi Island in Indonesia, New Guinea
	A. bicolor bicolor	Africa, India, Sri Lanka, Bangladesh, Myanmar, Malaysia, northwestern Australia, Greater Sunda Islands
	A. obscura	Northeastern Australia, New Caledonia, Fiji Islands, Samoa, Tahiti, Cook Islands, Maluku Islands
	A. australis australis	Southeastern Australia, Tasmania
	A. australis schmidtii	New Zealand, New Caledonia, North Norfolk Island

Knowledge on the biology of anguillid eels is mainly based on studies on temperate species, with information on tropical anguillids still limited. Of these species, the European eel *Anguilla anguilla* and the Japanese eel, *A. japonica* are well-studied in terms of biology, reproduction, and culture requirements. The nursery and grow-out culture technology for these two species are well developed. Most of the culture technology for tropical anguillid eels was patterned after the culture of these two species.

Life cycle

Anguillid eels are catadromous, spawning in marine environments with the young migrating to fresh water. Eels breed in marine waters, with the eggs first hatching into leptocephalus larvae (Figure 3), which eventually metamorphose into glass eels (Figure 4). All these biological processes occur in marine waters. The glass eels are the translucent and colorless stage of eel juveniles. The glass eels, depending on species, travel hundreds to even thousand kilometers to reach the mouth of rivers to start their inland migration to fresh waters. The glass eels upon arrival in fresh water further develop up until dorsolateral pigmentation across the top of the body is complete, by which time they are now considered elvers (Figure 5). The yellow eel stage follows the elver stage once brownish-yellow pigmentation develops at the lateral and ventral part of the body. The yellow eels sexually mature into silver eels, characterized by the gray/silver lateral pigmentation, while the ventral part is whitish. The silver eels migrate downstream in rivers to estuaries until they reach their spawning grounds in marine waters. Figure 6 shows a schematic representation of the life cycle of anguillids.

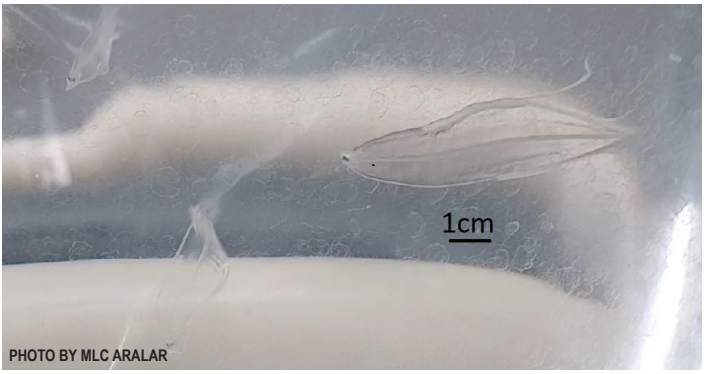

Figure 3. Thirty-eight-week-old leptocephalus larvae of *Anguilla japonica*.

Figure 4. Glass eel of tropical anguillid caught in Cagayan River, Cagayan Province, Philippines

Figure 5. Elver of tropical anguillid eel

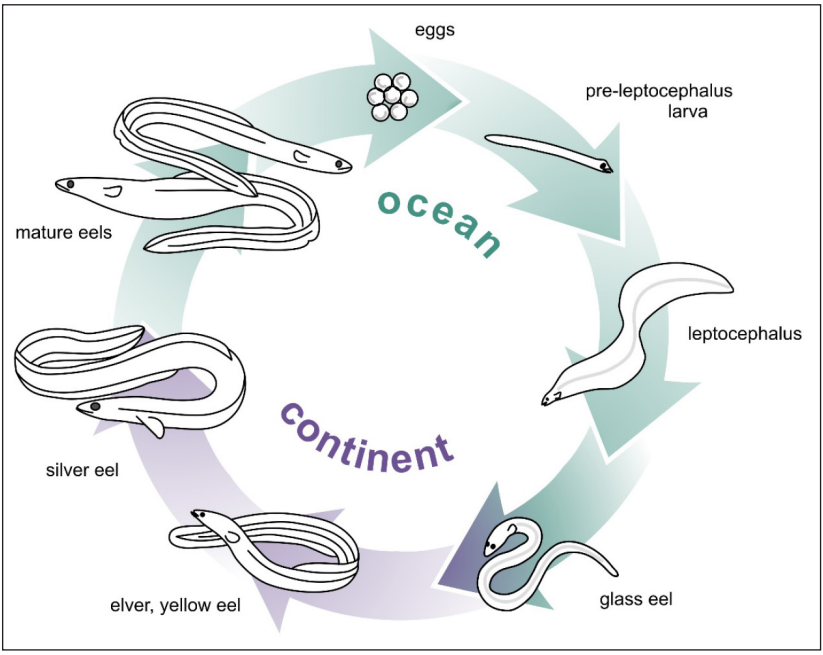

Figure 6. Life cycle of anguillid eels. *Source: Henkel et al., 2012.*

Breeding

The only well-documented work on the breeding and reproduction in captivity of anguillid eels are for the Japanese eel *A. japonica* led by Japanese scientists and, to a limited extent, European eel *A. anguilla*. Artificial breeding requires injection of hormones for both anaesthetized male and female broodstock (Figure 7). There have been attempts to hybridize *A. japonica* with *A. anguilla* and *A. australis* with *A. anguilla*, but no hatching took place despite successful fertilization. There are still no documented attempts on the captive breeding of tropical anguillid eels.

Figure 7. Artificial breeding of Japanese eel requires injection of hormones. **[Inset, top-bottom]** Anesthesthetic used for eel broodstock prior to hormone injection; and anesthetized broodstock.

Although technically feasible, the current status of the technology for artificial seed production of *A. japonica* is not yet economically viable due to very low survival of larval stages in the hatchery. Research is still on-going to address the problems in artificial seed production of the species.

Source of glass eels

The culture industry of anguillid species is still dependent on the supply of glass eels in the wild. In Southeast Asia, Viet Nam, Indonesia and the Philippines are the dominant countries in the culture of tropical anguillid eels from the glass eel stage. Other countries like Myanmar and Cambodia start their culture using yellow eel, also sourced from the wild. Among the fishing gears used by glass eel fishers are fyke net, scoop net or an aggregating device (Figure 8).

Figure 8. Some glass eel fishing gears: (a) fyke net set at the mouth of rivers to trap glass eels migrating upstream; (b) scoop net; (c) fish aggregating device such as old bunched up nets [arrow] to trap glass eels; and (d) fence net.

In the Philippines, glass eels fishers are found in the northern part of the country, particularly in Cagayan Province where the mouth of the Cagayan River in Aparri is the traditional fishing ground for glass eels. In the south, among the dominant sources of glass eels are rivers in Sarangani Province, North Cotabato and Zamboanga del Sur (Figure 9). Other areas in the Philippines where eels are known to be abundant are: Albay and Camarines Norte (eastern Luzon), Iloilo and Negros Occidental (central Philippines). Glass eel consolidators who act as middlemen collect glass eels from fishermen for eventual distribution to buyers. Glass eels range from 5000 to 6000 pcs per kilogram.

Figure 9. Major glass eel fishing areas: (1) Cagayan, (2) Sarangani; (3) North Cotabato; and (4) Zamboanga del Sur. **[Top]** Fishing site at the mouth of Cagayan River in Aparri and **[bottom]** fishing area at the mouth of Ladol River in Sarangani.

Species for culture and species preference

In the Philippines, species cultured are predominantly *Anguilla marmorata* and *Anguilla bicolor pacifica* (Figure 10). Indonesia cultures *Anguilla bicolor bicolor*, in addition to *A. marmorata*. Viet Nam cultures *A. marmorata* as this is the only species found in this country. There is a preference for the two *A. bicolor* subspecies, particularly in East Asian markets as these most resemble *A. Japonica* in appearance and flesh quality. The giant mottled eel, *A. mamorata*, comprise the bulk of the glass eel catch in eel fishing areas, particularly in the Philippines. Availability of *A. bicolor pacifica* in the Philippines is seasonal. In the Philippines, *A. bicolor pacifica* elvers generally fetch a higher market price than *A. marmorata*. Species preference is also reflected in the price of glass eels. Although most fishermen and consolidators are ill equipped to distinguish species in the glass eel stage, there are a handful, particularly in Mindanao, who are able to visually distinguish between *A. bicolor pacifica* and *A. marmorata* based on caudal pigmentation pattern (Figure 11) [*See detailed description in a later section*]. Pre-sorted glass eels according to species fetch a premium price compared to unsorted batches. Glass eels which are at least 90% *A. bicolor* pacifica are priced up to 10 times more than the prevailing market price of unsorted glass eels.

Figure 10. Commonly cultured species in the Philippines are *Anguilla marmorata* or the giant mottled eel (left) and *Anguilla bicolor pacifica* or short-finned eel (right).

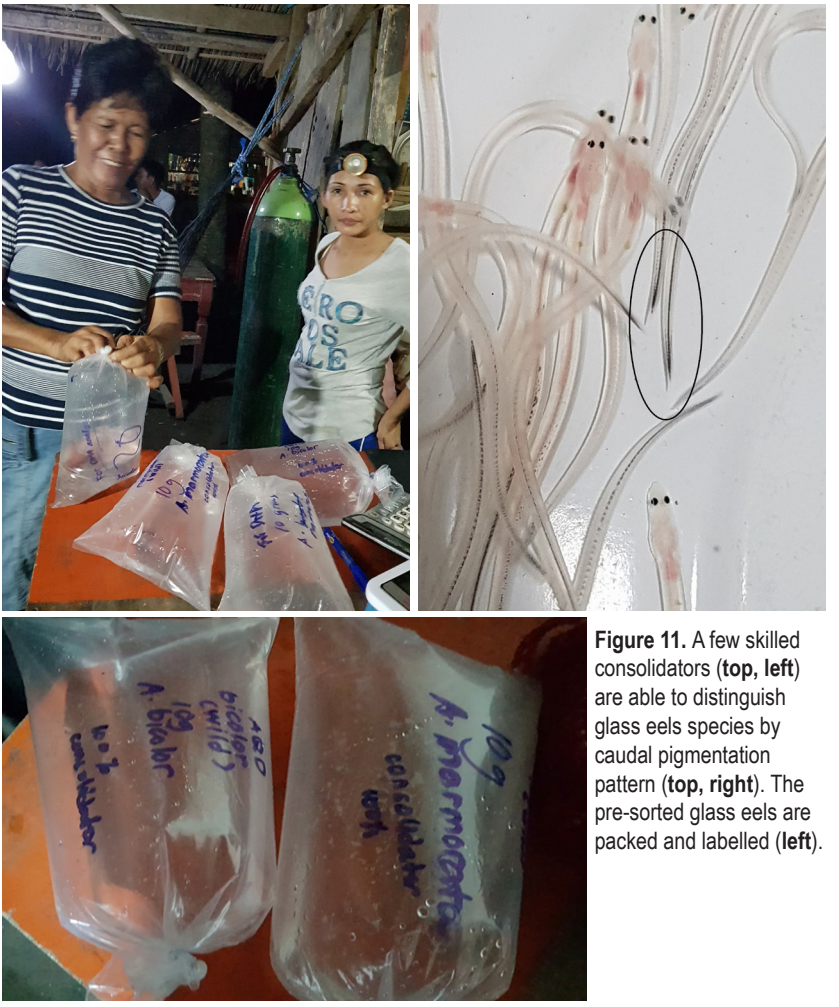

Figure 11. A few skilled consolidators (**top, left**) are able to distinguish glass eels species by caudal pigmentation pattern (**top, right**). The pre-sorted glass eels are packed and labelled (**left**).

Identification of glass eel species

For those who have difficulty in visually distinguishing anguillid species with one's naked eye, glass eels can be identified by way of microscopic examination and DNA analysis. Although both are technical methods of species identification, if one has access to a laboratory facility where such services are provided, one can refer to the following methods as technical guides:

A) *Microscope-aided species identification of glass eel samples based on external features and measurements*

Four of the sixteen anguillid eel species summarized in Figure 12 are found in the Philippines. These species can be distinguished from the Japanese eel in terms fin length, presence of pigmentation on the tail part of the glass eel as well as the ano-dorsal length divided by the total length of the glass eel (expressed in %). Figure 13 shows the schematic diagram of the tools used for identifying Anguillid glass eels using morphometric measurements based on a study of Leander et al in 2012.

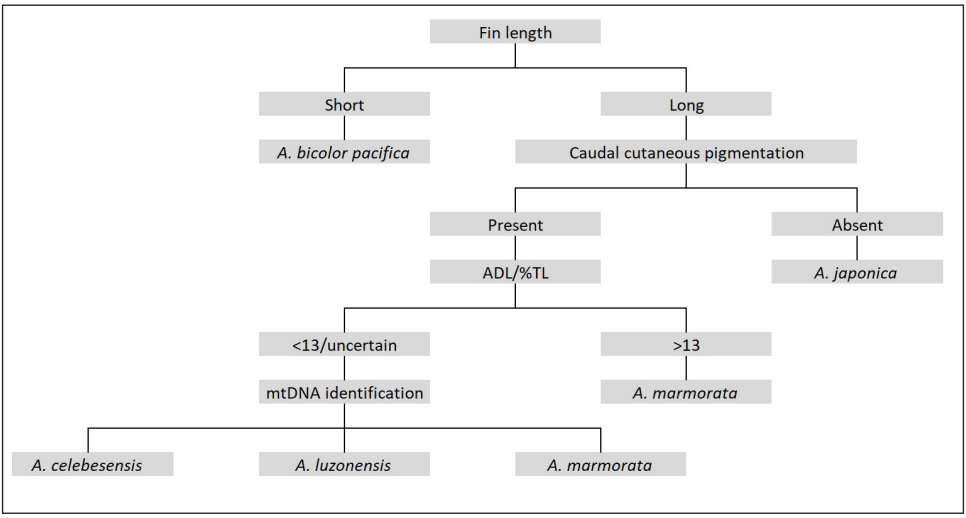

Figure 12. Illustration of method to identify species of anguillid glass eels. *Source: Re-drawn from Leander et al, 2012.*

The measurements required (ADL and TL) for the computation of the percentage values for ADL/TL are shown in the diagram (Figure 13) below:

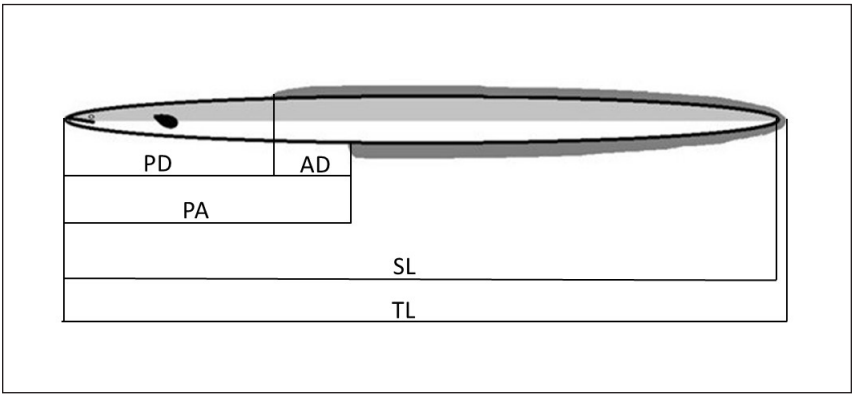

Figure 13. Schematic illustration of morphometric measurements of glass eel. AD-ano-dorsal length; PA-pre-anal length; SL-standard length; and TL-total length. *Source: Re-drawn from Lender et al, 2012*

All four Philippine anguillid eel species bear pigments on their tail or caudal fin. Figure 14 shows pigmentation patterns characteristic of *A. bicolor pacifica* as against the other three species. Since the three species *A. luzonensis*, *A. celebesensis* and *A. marmorata* have similar tail fin pigmentation patterns, accurate species identification can be made through DNA analysis.

B) *DNA analysis of glass eel specimens for species identification*

The cost of DNA analysis for species identification (in this case, it is called DNA barcoding) is costly and facilities for such assessments may not be readily available for fish farmers. Nonetheless, samples for DNA analysis can be prepared. Whole samples can be preserved from a batch of commercially procured glass eels using ethanol. Alternatively, one can have tissues from whole glass eel samples stored in ethanol, then processed for DNA extraction. If a DNA analysis laboratory is accessible, the DNA extracts can be sent to the laboratory for further processing by mtDNA sequence analysis (using e.g. cytochrome B or other genetic markers for glass eels). Once analysed, the genetic marker sequence information obtained can be compared with known sequences of glass eel species that have been described in open access databases and/or scientific publications.

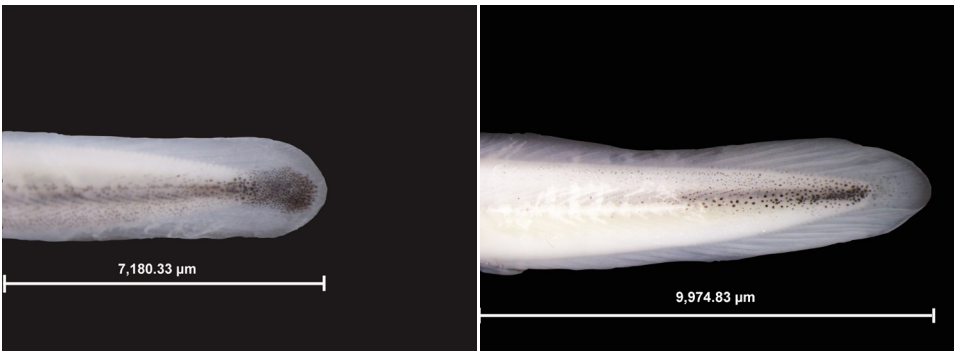

Figure 14. (Left-right) Pigmentation patterns for the caudal fin and tail bud of anguillid glass eels for *A. bicolor pacifica* and *A. marmorata, A. luzonensis* and / or *A. celebesensis*.

Holding and transport of glass eels

Since individual fishermen are unable to come up with the necessary volume of glass eels as they do not have the facility to keep the glass eels alive for extended periods, the catch is sold immediately to consolidators. The consolidators have holding facilities for the glass eels to enable them to gather enough volume for bulk selling. Glass eels are packed in oxygenated plastic bags for transport. The oxygenated plastic bags containing the glass eels are then packed into styrofoam boxes (Figure 15). Water temperature in the transport bags is lowered to about 18°C using ice packs. If the glass eels were well handled by the consolidator and properly packed, post transport survival is generally high ranging from 95% to almost 100%. For example, glass eels transported from both Aparri, Cagayan Province and General Santos City in Mindanao monitored over a week at SEAFDEC/AQD had survival rates ranging from 94 to 100%.

Figure 15. Glass eels are packed in plastic bags with oxygen. Plastic bags are in turn packed inside styrofoam boxes for air transport.

Site requirement

Since eel culture from glass eels to elvers is done in tanks, site selection is not as restrictive compared to earthen pond production systems. Like any aquaculture facility, sufficient source of good quality water is essential to enable appropriate water management. The tanks may be fully indoor or provided with shade against the elements. (Figure 16).

Figure 16. Indoor (left) and roofed outdoor nursery facility for anguillid eels

Water quality and management

Nursery of glass eels to elvers can be done in fresh water. Glass eels purchased from consolidators have been typically pre-acclimated in fresh water from the brackishwater salinity at the 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.

Nursery of glass eels to elver is done in fresh water. An efficient aeration system (Figure 17) 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 at ambient temperature. Glass eels have been reared in 19 to 30°C temperature with no overt sign of showing temperature stress.

Figure 17. An aeration system using ring blowers (**top-left**) or paddle wheel aerators (**top-right**) may be used in the eel nursery to ensure sufficient levels of dissolved oxygen. Some advanced nurseries provide liquid oxygen (**left**) delivered into the nursery tanks.

For farms with abundant water supply, flow-through systems can be used. This means water is constantly replaced in the rearing tanks. However, most farms use static-renewal type of water management. Water is often replaced 1-2 hours after feeding, with water replacement volume ranging from 50% to almost complete water replacement. This prevents water fouling such as ammonia build-up from excretory products and decomposition of unconsumed feeds. Ammonia build-up contributes to increased post-feeding oxygen consumption as well as growth suppression. Although common in Japan and Europe, recirculating systems for eel nursery in the Philippines are rare. This is due to the high cost of energy inputs required to keep the pumps and motors running. In addition, unreliable power supply particularly in rural areas where most farms are located is also an issue against investing in a recirculating facility. Recirculating systems should have the total volume of the water in the culture tanks replaced at least 10 times over a 24-hour period to ensure removal of wastes through both physical and biological filters.

Water levels in nursery farms is maintained at 50 to at most 100 cm depth.

Nursery tanks

Rearing tanks can be circular or rectangular. Size and volume depends on target production. In the Philippines, tank sizes range from as small as 4 m^3 to 500 m^3. Tanks should have a slightly sloping bottom towards the drain to facilitate accumulation of waste and eventual discharge during draining and cleaning. Figure 18 shows two typical circular tank designs with drainage. If the tanks are square or rectangular, it is recommended that inside corners be rounded and smooth to facilitate cleaning and disinfection between production cycles (Figure 19).

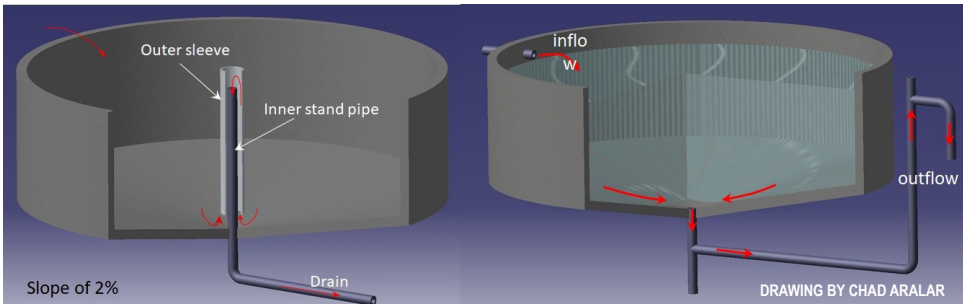

Figure 18. Some suggested design and lay-out of nursery tanks

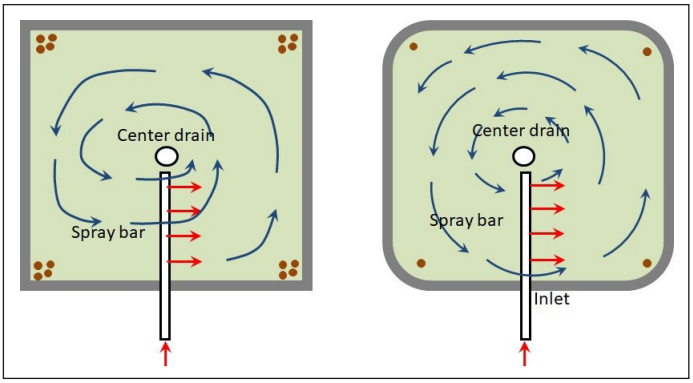

Figure 19. Rectangular or square tanks with rounded corners (**right**) have minimal waste accumulation due to better circulation compared to sharp angled corners.

Tank materials vary depending on the available capital. Tanks may be made of concrete, polyethylene and fiberglass or marine plywood lined with canvass or tarpaulin (Figure 20). Concrete tanks are the most common type. Volume depends on the farm area as well as the target volume of production.

Figure 20. Typical materials used for nursery tanks: (a) concrete; (b) polyethylene; (c) marine plywood covered with canvas or tarpaulin; (d) fiberglass

Acclimation, conditioning and pre-treatment

Upon arrival in the nursery, the plastic transport bags are allowed to float in the holding tank to reduce the temperature difference 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 the temperature difference between the water in the transport bag and the holding tank are equal, 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, the acclimated glass eels are allowed to swim out of the basin into the holding tank (Figure 21).

Figure 21. Newly arrived glass eel in transport box (top-right); Plastic transport bags floating in holding tank water (top-left); acclimated glass eels allowed to swim out to holding tank from basin (left).

Figure 22. Rock salt granules in shallow canvas tanks for salt bath preparation for glass eel pre-treatment upon arrival in the farm

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 (Figure 22). Duration of immersion is from 30 seconds to 1 minute. After immersion, the glass eels are transferred to clean untreated fresh water, 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. Figure 23 shows the post transport survival of glass eels air freighted from Cagayan and General Santos City, in the north and south of the Philippines, respectively all the way to the facilities of SEAFDEC/AQD in Binangonan, Rizal.

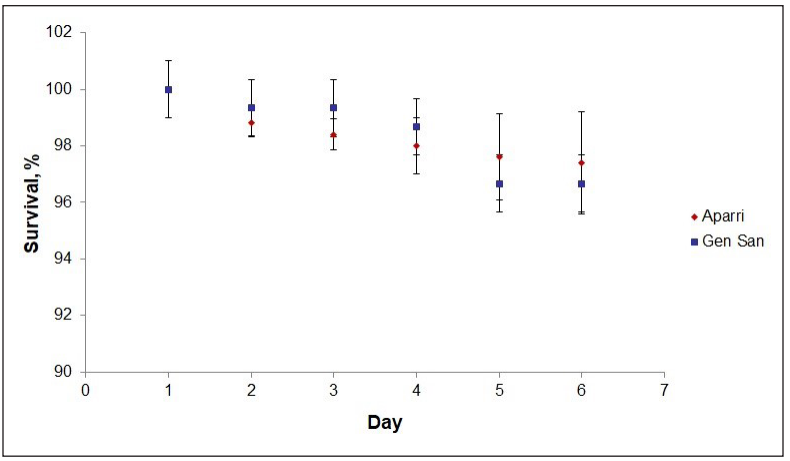

Figure 23. Survival of glass eels from two different sources upon arrival in the farm after acclimation, conditioning and pre-treatment.

Stocking density in nursery

Nursery farms in the 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. Size grading or sorting is done during the course of the nursery culture. Monthly size grading of eels is ideal to sort out fast-growing ones from the slower-growing individuals. Similarly-sized eels are grouped in tanks separate from other size groups. Size grading minimized cannibalism. For the farm using 12 pcs per liter stocking density, high mortality of eels in the nursery is observed, despite more frequent size grading of every two weeks. Size sorting is usually done manually, or by using varying mesh size nets or bar graders (Figure 24).

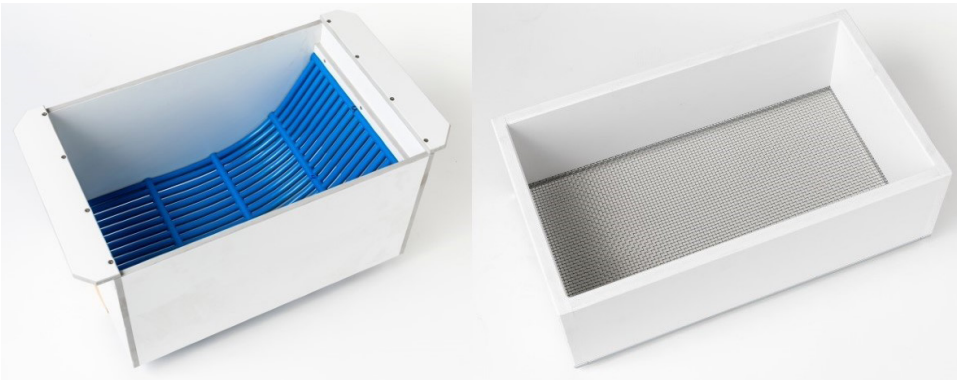

Figure 24. Sorting of elvers to different sizes is simplified using size graders: (left) bar grader and (right) mesh grader. *Source: www.aquacultureid.com/systemen/fish-grading-equipment/*

Feeds and feeding

Natural food is the preferred feed of newly stocked glass eels. Nurseries give live blood worm, *Tubifex* sp. (Figure 25) up to the first two weeks or until glass eels reach 0.3 g body weight before being gradually weaned to commercially formulated diets. Blood worms have to be thoroughly washed to ensure that they are clean, prior to feeding to the glass eels. Some farms feed the glass eels with blended tuna eggs (when available) for the first three days in the nursery. Mussel meat is used as starter feed for the first three days of rearing European glass eels. However, the use of tuna eggs and mussel meat can pollute the rearing water so extra care over water quality is needed. Feeding minced octopus flesh to *A. marmorata* glass eels as an alternative starter feed to blood worms is practiced in Chinese eel farms. Brine shrimp or *Artemia nauplii* is also used when available although growth rates of glass eel given this live feed is not satisfactory.

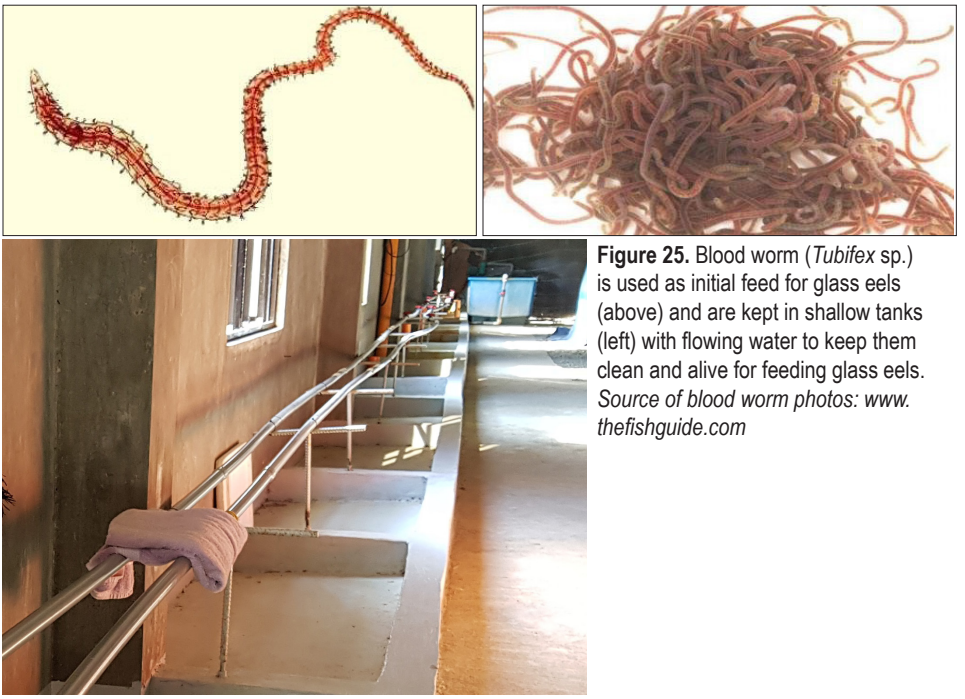

Figure 25. Blood worm (*Tubifex* sp.) is used as initial feed for glass eels (above) and are kept in shallow tanks (left) with flowing water to keep them clean and alive for feeding glass eels. *Source of blood worm photos: www.thefishguide.com*

Commercially formulated diets are usually prepared in dough form by adding water and binder to form into a ball. Alpha-potato starch is used as a carbohydrate source and binder in Japanese or Korean eel feeds but is expensive. Alternative binders such as bread, wheat or glutinous rice flours are pregelatinized to make the moist feed stable and to prevent leaching out of nutrients in water. The prepared feeds are placed in feeding trays or "cages" (Figure 26) which are lowered into the culture tanks. The feeding trays serve as a feeding and resting area for the glass eels. Eels are conditioned to feed at specific times and at fixed feeding areas.

Figure 26. Feeding trays (top) and "cages" (bottom-left) are used to hold the dough ball (bottom-right) feed to facilitate monitoring of feed consumption of glass eels and elvers

Commercially formulated diets for eels are available from a local fish feed manufacturer. Many farms import feeds from Japan, Korea, Taiwan and China as the growth performance is better than locally manufactured feed, based on experience by local farmers. However, imported feeds cost as much as 5 times more than locally manufactured feeds for eel. Some farms opt to wean the glass eels to commercial diets using imported feeds for a month before switching to locally available commercial eel feed. Initial feeding of glass eels on artificial diets resulted in slow growth and low survival. Feeding stimulants may facilitate the acceptance of locally available commercial eel feeds and may improve feed intake and growth performance of glass eels. Blended blood worms or mussel meat can be used as feeding stimulants. These blended ingredients are mixed with moist paste feed at 20-30% before it is fed to glass eels. Typical eel feeds contain at least 50% crude protein with fish meal as a dominant source of the

protein and 10% crude lipid. Feeding is done twice a day, typically one feeding in the morning and another in the late afternoon. The quantity of the daily-distributed feed is adjusted every 15 or 30 days based on weight gain. Partial or complete replacement of the water is done an hour after feeding to avoid fouling of the water (Figure 27).

Daily feed ration for glass eels using dry feed is at 5% to 10% of total biomass. This is reduced to 3% of total biomass as the elvers grow to 3 g. Some farms practice ad-libitum feeding to ensure high growth rates but this could be costly and may lower feed conversion efficiency. Using moist feed, daily feed ration is at 50% of total biomass. However, depending on the water temperature and feed consumption, feed ration should be adjusted accordingly. *A. bicolor pacifica* grow well at 30°C while *A. marmorata* requires temperature of 28°C for optimal growth.

Experimental nursery rearing of glass eels done at AQD used either small (30-L capacity) polyethylene tanks, half plastic drum (80-L capacity) and large polyethylene tanks (500-L capacity) in a static system. Mean initial body weight of glass eels at stocking is about 0.11 g. Glass eels are stocked from one (1) to seven (7) pieces per liter, regardless of the size of rearing tanks. Rearing tanks are filled with dechlorinated or aged fresh water or low saline water (3 ppt) at 30-40% of the total volume. Old nets, plastic mesh or old pvc pipes are provided as artificial substrate or shelter to reduce cannibalism and aggressive behavior among eels (Figure 28).

Figure 27. Partial or complete water change is necessary to maintain the acceptable water quality in the rearing tanks.

Figure 28. Provision of old nets as shelter or substrates can reduce cannibalism among eels. **[Top]** An eel with tail bitten off.

Tanks are covered with double-layered black plastic to reduce light intensity (Figure 29). This practice also prevents glass eels from self-injury as they tend to swim down in illuminated conditions.

Figure 29. Double-layer black plastic is used to reduce light intensity in the rearing tanks

A study of different feeding schemes has shown that blood worm is best for growth of *A. bicolor* glass eels when fed within two months. From 3rd to 5th month, formulated diet containing about 55% crude protein and 10% crude lipid supplemented with blood worm is most suitable for glass eels. The formulated diet contains ingredients such as Danish fishmeal, poultry by-product meal, yeast, skim milk powder, vitamin and mineral premixes and wheat flour. Feeds are prepared by mixing all the dry ingredients and adding oil (5 parts) and water (50-60 parts) to make a dough.

Eels also performed better when they are gradually weaned to semi-moist formulated diet (Figure 30) than moist and dry diets supplemented with blood worm, but survival rates are highest when fed moist formulated diet.

Figure 30. Feed type (left photo: dry feed pellet; right photo: semi-moist feed pellet) influences the growth performance and survival of glass eels in the nursery. *Based on SEAFDEC/AQD study*

Nutritional requirement

Success on culture of eels is dependent on nutritional needs, feeds and feeding practices. Information on the nutrient requirements of tropical anguillid eels is limited. Therefore, the development of artificial diet for tropical anguillid eels may be based on the known nutrient requirements of closely related species. The requirements for protein for other anguillid eels, such as Japanese eel (*A. japonica*), European eel (*A. anguilla*), and American eel (*A. rostrata*) have been reported to be 45%, 48%, and 47%, respectively. *A. marmorata* requires between 45 and 50% crude protein level, depending on the size of eels. The optimum protein to energy ratio determined for *A. japonica* is 24.1 mg protein/kJ. Eels also obtain its dietary energy requirement from carbohydrates, thus sparing protein.

Temperate eel species do not perform well when dietary lipid exceeds 15%. The total lipid requirement of *A. marmorata* is 8%, regardless of body weight. Anguillids require that essential fatty acids such as linolenic (18:3n-3) and linoleic (18:2n-6) be at least 0.5% of their diet. Arachidonic acid (20:4n-6) is also essential and has to be supplied at >0.69% or <0.71% of eel diet.

Most of the information on vitamin requirements has been derived from experiments using juveniles. Using DL-a-tocopheryl acetate as the dietary vitamin E source, a vitamin E requirement has been estimated to be >21.2 but <21.6 mg/kg diet. The dietary vitamin C requirement of eels, using L-ascorbyl-2-monophosphate as vitamin C source, ranges from 41.1-43.9 mg/kg diet.

Body composition of eels is dependent on species and location. Farmed *A. japonica* eels in Korea have high crude protein content of 16.6 to 17.70%; crude fat ranging from 10.85 to 19.44%. Wild *A. bicolor* in Indonesia has 17.68% crude protein and 28.29% crude fat.

Growth and survival

Glass eels are reared to elver size of about 15 mm (approximately 10 g) and survival may vary depending on farm management (Figure 31). Philippine farms report the highest survival rate of 90% whereas the average is about 60 to 80% survival. Farmers report that the most common cause of mortalities in the nursery are poor water quality management and diseases (Figure 32). Growth of glass eels to 15 mm elvers typically takes from 6 to 8 months. However, farms with poor water quality management may require 10 months or longer to achieve this size. Growth rate is also influenced by species. It was noted by many farmers that *A. bicolor pacifica* growth faster than *A. marmorata* and has better survival rates. Typically, *A. bicolor pacifica* reaches 15 mm elver size at an average of 6 months while that of *A. marmorata*, 8 months or longer.

Figure 31. Elvers in rearing tank

Figure 32. Elver mortalities from poor water quality management

Disease and disease management

Anguillid eels can be infected with parasites, fungi, bacteria and viruses.

Parasites

Trichodina spp.
It is a ciliated protozoan with a characteristic saucer-shaped body (Figure 33) and can be identified by preparing a fresh mount from the mucus and gills and examined using a compound light microscope.

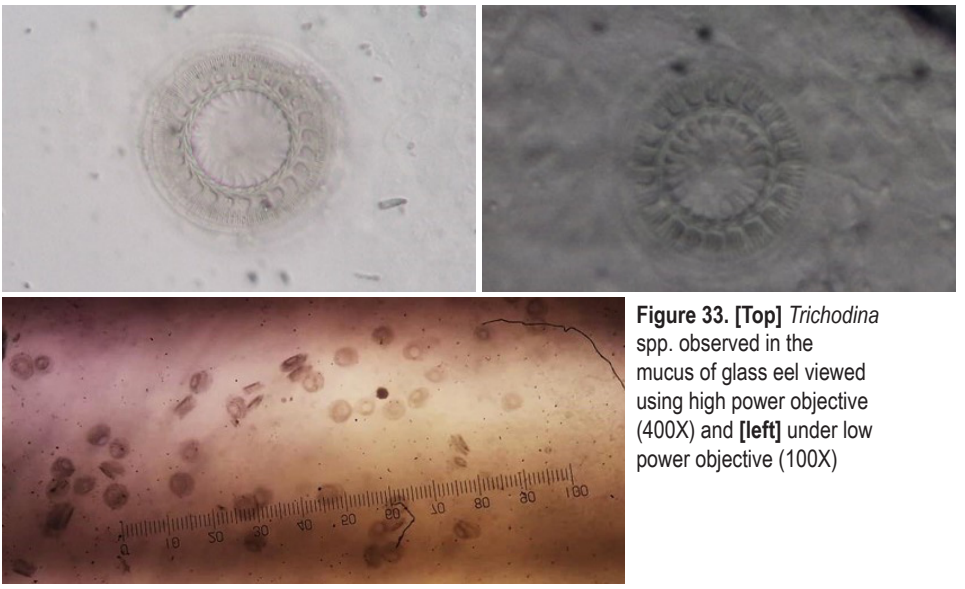

Figure 33. [Top] *Trichodina* spp. observed in the mucus of glass eel viewed using high power objective (400X) and **[left]** under low power objective (100X)

Heavily infected fish display lethargic behavior, weight loss and flashing. Flashing is usually observed in fish rubbing themselves on the bottom or sides of the tank trying to get rid of the parasites. Occurrence in the culture system is due to high stocking density, poor water exchange and accumulation of organic matter. Trichodiniosis may be prevented and controlled using salt water bath (2-3 % NaCl) for 2-5 min for 3-4 days or formalin treatments at 150-250 mg/L (150-250 ppm) for 30 min (Klinger and Francis Floyd, 2013). During formalin bath, fish must be closely monitored and vigorous aeration should be provided to maintain acceptable level of dissolved oxygen.

Monogeneans
These are ectoparasitic flatworms which can be found in the gills, skin, and fins of fish. They are <1-6 mm long with haptor armed with hooks or clamps which enable them to attach to their host (Figure 34). Diagnosis of the parasite is based

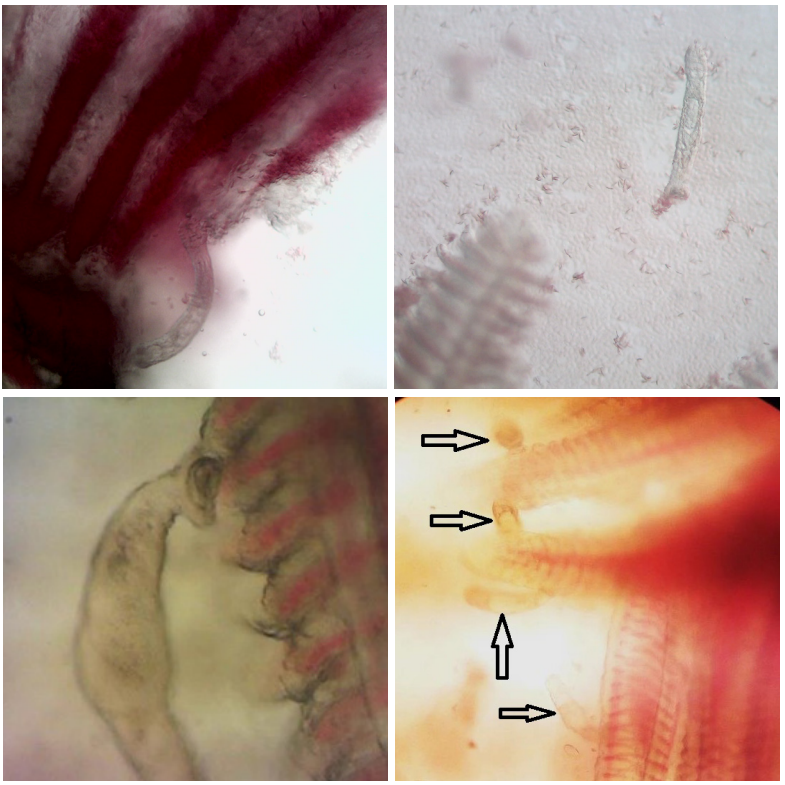

Figure 34. Monogeneans (arrows) attached to the gills of glass eel (fresh mount; 100X magnification)

on gross and microscopic examination of mucus and gills. Examination must be performed on live or freshly dead fish.

Morbidility and mortality in cultured fish caused by excessive loads of this parasite are usually associated with overcrowding, inadequate sanitation and poor water quality. Treatments include salt water bath at 5% NaCl for 5 min or formalin bath at 100-200 ppm for 30-60 min for 3 days. Quarantine protocols for newly arrived stocks can minimize introduction of parasites in the culture system.

Ichthyopthirius multifilis

These are protozoan parasites which cause "Ich" or "White Spot Disease" because of the presence of small white spots on skin and gills of cultured fish. They appear like small blisters on skin or fins. The parasite can be demonstrated by microscopic examination of wet mounts of gill filaments and mucus showing round or oval parasites, propelled by cilia and with its characteristic horse-shoe shaped nucleus (Figure 35). To prevent and control "Ich" the following treatments have been recommended: 100 ppm formalin bath for 1 hr for 2-3 days with aeration; increase water temperature to 30°C for 6 hr daily for 3-5 days;

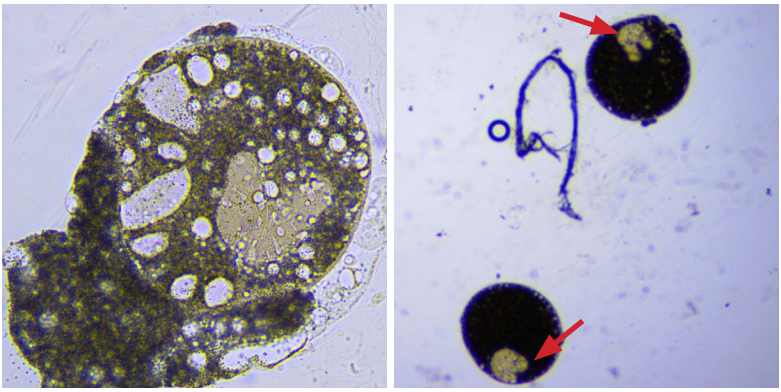

Figure 35. [Left] *Ichthyopthirius multifilis* from fresh water eel with its characteristic horseshoe-shaped macro nucleus (red arrow) as viewed in 400X and **[right]** 100X magnification. *Photo courtesy of Dr. Joselito Somga, Dr. Sonia Somga and Dr. Joseph Loja of Bureau of Fisheries and Aquatic Resources*

short salt water bath (3% or 30,000 mg/L NaCl solution) for 30 sec to several minutes or prolonged salt water bath at a lower concentration of 0.05% or 500 mg/L NaCl solution.

Bacteria

Aeromonas spp.
Aeromonas is a genus of gram-negative rod bacteria widely distributed in the environment. *A. hydrophila* and *A. punctata* usually caused Red fin disease among eels with clinical signs such as fin rot, tail rot and haemorrhagic septicaemia. Predisposing factors for *A. hydrophila* are stress, mishandling, overcrowding, transportation under poor conditions, poor nutrition and water quality. *Aeromonas* infection may be treated by feeding fish with oxytetracycline medicated feed at 3-5 g/kg feed for 5-7 days. However, definite diagnosis of the pathogen, treatment regimen, withdrawal periods and recording must be considered before using antibiotics. Bacterial infections can be prevented by maintaining good water quality, avoidance of overcrowding, reducing stress due to handling or transport and proper nutrition. Isolation or removal of affected or dead fish in the culture facility is necessary in order to prevent further transmission of the disease. Diagnosis of *Aeromonas* infection is based on gross examination and isolation of the bacterium in the kidney and other organs of the fish using culture media such as Nutrient Agar (NA), Tryptic Soy Agar (TSA), and Brain Heart Infusion Agar (BHIA). Glutamate Starch Phenol Red (GSP) agar can be used as selective medium for *Aeromonas* and *Pseudomonas*.

Pseudomonas spp.
Pseudomonas is a gram-negative bacterium which lives in diverse environments. *Pseudomonas anguilliseptica* is the causative agent for Red spot disease which was first reported in *A. japonica*. Infected fish shows petechial haemorrhages in the skin of ventral side of the body, mouth and area around vent. The disease is

usually associated with stress or improper management. Bacterium are usually isolated from kidneys, other organs, and lesions of the fish by culturing them in NA, TSA, and BHIA. GSP can be used as selective medium.

Vibrio spp.
Vibriosis caused by *V. vulnificus* shows external haemorrhages (Figure 36), exopthalmia, erosive lesions on the operculum and jaw region, and enlarged and congested spleen. Growth of this bacterium can occur in eel farms using brackish water to culture them and water temperature of 24^{0}C. It was reported in *A. japonica* and *A. anguilla*. Diagnosis of the pathogen can be performed by preparing an impression smear from organs like kidney, spleen, liver, necrotic muscle tissue and other organs. *Vibrio* species can be isolated by using culture media such as NA, BHIA, and TSA supplemented with 1-2% NaCl. Thiosulphate-Citrate-Bile Salt-Sucrose (TCBS) agar can be used as selective medium for *Vibrio*.

Figure 36. Eel with *V. vulnificus* infection showing hemorrhages on the skin. *Source: B. Fouz and C. Amaro as cited by Haenen et al., 2012*

Fungi

The most common fungal disease in eel culture is Saprolegniasis or also known as water mold, skin fungus or cotton wool disease. It is caused by a group of oomycetous fungi consisting of *Saprolegnia*, *Aphanomyces*, *Achyla*, *Pythium* and *Dichtyuchus*. The diagnostic feature is the presence of brown cottony or hairy patches on the skin, fins and gills of fish. Poor water quality and secondary infection are considered predisposing factors. Possible treatment for fungal infections is salt water bath (22 g/L for 30 min; 30 g/L for 10 min; 1-3 g/L indefinite) or formalin bath (0.4 – 0.5 ml/L 30% formaldehyde for 1 hr).

Viruses

Based on researches, the three most common viruses which causes disease in Anguillid eels are Eel Virus European (EVE), Eel Virus American (EVA) and Eel Virus European X (EVEX) and Anguillid Herpesvirus 1 (AngHV1). Eels infected with EVE shows clinical signs such as abnormal shape of trunk, congestion of skin and fins, enlargement of kidneys and petechial haemorrhages in the liver. So far, the virus was detected in *A. japonica*, *A. anguilla* and *A. rostrata*. EVA and EVEX are highly similar in terms of their characteristics based on their morphology and genetics. EVA infected eels typically show intense congestion in pectoral and anal fin and a tendency to bend head down. EVEX shows signs like haemorrhages, anemia and mortality up to 50%. EVEX has been shown to be pathogenic to *A. anguilla* and *A. japonica*. AngHV1 infected eel show signs such as apathy, skin and fin haemorrhages and congestion of gills. It was detected in *A. japonica*, *A. anguilla* and *A. rostrata*. Viral diseases in eel farms are usually triggered by stress and temperature. AngHV1 generally cause disease at higher water temperatures (around 26°C) while EVE and EVEX disease outbreaks mostly occurred at water temperatures ranging from 15 to 20°C. There was no reported treatment for these viral diseases.

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Mr. Dan Joseph Logronio started as Technical Assistant at the Fish Health Section of SEAFDEC/AQD and was promoted as Senior Technical Assistant last 2016. He is currently an Associate Researcher assigned at AQD's Binangonan Freshwater Station. He finished his Bachelor's degree in Biology major in Microbiology as cum laude at West Visayas State University in Iloilo City. He obtained his Master's degree in Genetics minor in Molecular Biology and Biotechnology at the University of the Philippines-Los Baños as a Department of Science and Technology-Accelerated Science and Technology Human Resource Development Program-National Science Consortium (DOST-ASTHRDP-NSC) scholar.

ABOUT SEAFDEC

The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 to promote fisheries development in the region. The member countries are Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

The policy-making body of SEAFDEC is the Council of Directors, made up of representatives of the member countries.

SEAFDEC has five departments that focus on different aspects of fisheries development:

- The Training Department (TD) in Samut Prakan, Thailand (1967) for training in marine capture fisheries
- The Marine Fisheries Research Department (MFRD) in Singapore (1967) for post-harvest technologies
- The Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines (1973) for aquaculture research and development
- The Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia (1992) for the development and management of fishery resources in the exclusive economic zones of SEAFDEC member countries, and
- Inland Fishery Resources Development and Management Department (IFRDMD) in Palembang, Indonesia (2014) for sustainable development and management of inland capture fisheries in the Southeast Asian region.

AQD is mandated to:

- Conduct scientific research to generate aquaculture technologies appropriate for Southeast Asia
- Develop managerial, technical and skilled manpower for the aquaculture sector
- Produce, disseminate and exchange aquaculture information

AQD maintains four stations: the Tigbauan Main Station and Dumangas Brackishwater Station in Iloilo province; the Igang Marine Station in Guimaras province; and the Binangonan Fresh water Station in Rizal province. AQD also has an office in Quezon City.

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