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R&D in Ornamental Fish and Aquatic Plants

Message from THE EDITOR

DEAR READERS,

Fish signify dynamism and positivity. It is believed that if we look at fish swimming cheerily in an aquarium, it could sooth us, transfer positive vibes, and increase productivity. This is why aquarium keeping is amongst the most popular hobbies with millions of enthusiasts worldwide. It is an exciting and rewarding business in terms of foreign exchange and source of employment. According to Grand View Research. Com, the global ornamental fish market was valued at USD 5.88 billion in 2022 and is expected to expand at a Compound Annual Growth Rate (CAGR) of 8.5% from 2023 to 2030. The growing desire for colourful aquarium ornamental fish among millennia as part of a posh lifestyle is anticipated to continue to be a major driver of the industry development. The COVID-19 pandemic had a huge impact on the ornamental fish industry. As the pandemic progressed, a report by American Pet Products Association suggested that people in the U.S. adopted new pets, influenced by the extra time they had on hand due to lockdowns. This increase in pet adoption, including ornamental fish, is likely to favour market growth.

Aquatic plants continue to be an up-and-coming part of the industry. The market for farm-raised plants is growing with new 'tissue culture' products becoming more readily available. With increased availability in plant nutrients and more people focusing on indoor underwater gardens, aquatic plants are becoming more popular. Based on this importance, our latest issue of Fisheries Research Institute - FRI Newsletter, Volume 26 (2023), focuses on the R&D on ornamental fish and aquatic plants, and several other scopes related to this topic.

The editorial team is continuously striving to improve the newsletter; thus, any comments or feedback would be gratefully appreciated. I can be reached via e-mail at norhana@dof.gov.my or wannorhana@yahoo.com. I look forward to continuous contributions of articles, suggestions on themes, and other valuable inputs from all FRI researchers. We wish all of you a productive reading.

Wan Norhana Md Noordin

What's Inside?

TECHNICAL PAPER

EFFECTS OF SEA ANEMONE ON FITNESS OF CLOWN ANEMONEFISH *AMPHIPRION OCELLARIS* IN CAPTIVITY

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INTRODUCTION

Malaysia's ornamental fish industry has been an important sub-sector of aquaculture and played a significant role in the national economy and this industry is now enjoying rapid growth (Othman et al., 2017). However, most of the marine ornamental fish are wild caught, hence increasing the chances for overfishing. The definitive answer for long term sustainable trade lies in the development of culture technology (Ghosh et al., 2011; Ismail et al., 2023; Martinez, 2021).

Over the years, a number of different clownfish species have been successfully spawned and reared in captivity (Wittenrich, 2007). One of the most popular fish involved in the aquarium trade is the clown anemonefish (*Amphiprion ocellaris*) (Raheem et al., 2021). Over the last few years, *A. ocellaris* has been successfully bred and scaled-up for hatchery production.

Clownfish in natural environments are associate with sea anemones through symbiotic relationships, in which both animals benefit from living together (Nguyen et al., 2019). The clown anemonefish is found in association with *Radianthus magnifica, Stichodactyla gigantea*, and *S. mertensii* in their natural habitats (Fautin & Allen, 1992). Due to the symbiotic relationship between the clownfish and sea anemone, several studies on these two animals have been conducted worldwide (Ghosh et al., 2011, Martinez, 2021, Nguyen et al., 2019). However, studies of this clownfish in Malaysia are still limited (Khoo et al., 2018). Since fish growth can be considered a fitness indicator (Nguyen et al., 2019), our research looked at the fitness of *A. ocellaris* in relation to its host sea anemone using growth as an indicator.

MATERIALS AND METHODS

This study was carried out at the nursery of Akuarium Tunku Abdul Rahman (AkuaTAR), Pulau Pinang, for eight months, from January to August 2021. A total of eight pairs of 4 months old clown anemonefish, born in captivity, were used in this experiment. Two sets of 150 L rectangular glass tanks were prepared, one with sea anemone (*Radianthus magnifica*) and the second one without the sea anemone. Only one pair (1 male and 1 female) of clownfish was placed in each tank (Figure 1). A total of four replicate tanks were prepared for each set. All fish were fed till satiation with marine pellets twice a day: morning (9 am) and afternoon (4 pm). Uneaten food was siphoned out and up to 25% water change were conducted daily. Temperature was maintained at between 28°- 30°C and light intensity followed the natural condition of day and night. Initial total length (TL, cm) and wet weight (W, g) for each fish were taken before the fish were placed in the tanks and then their TL and W were measured every month until the end of the study period.

Statistical analyses were performed using SPSS version 21 software. A two-way ANOVA and an independent two samples t-test were used to analyze the clownfish growth data and to determine if there were significant differences between sex and period of rearing.

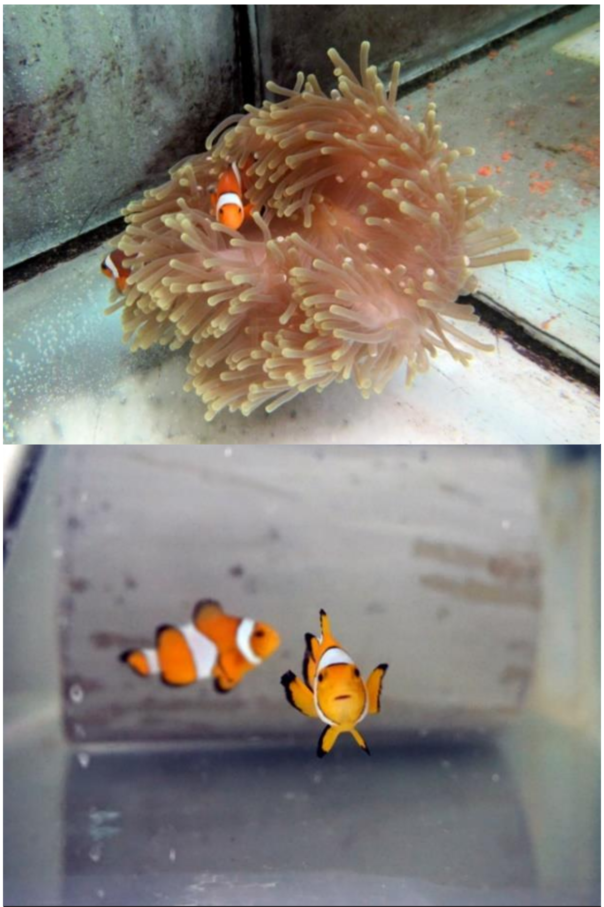

Figure 1: Clown anemonefish with sea anemone (left) and without sea anemone (right) in one of the experimental tanks.

RESULTS AND DISCUSSION

In this experiment, we looked at the possible effect of the sea anemone (*Radianthus magnifica*) on the fitness of *A. ocelllaris*. Four pairs of clown anemonefish were placed in four tanks with sea anemones (T1), while another four pairs were placed in tanks without sea anemones (T2). We measured their growth in length and weight for eight months. The result showed that the growth of female fish in all experiment tanks was greater than the male fish in those tanks (Figures 2 and 3). No fish mortality was observed over the entire period of study. There were significant differences in sizes (length and weight) between sex and month of study in T1 ($P<0.05$) (Table 1). However, there was no significant difference in T2 ($P>0.05$). T-tests were then carried out to see if there were differences in fitness between fish in T1 and T2. The results showed that the length and weight of anemone fish in T1 (42.89 ± 5.13 cm; 1.99 ± 0.84 g) were significantly higher than T2 (38.53 ± 5.6 cm; 1.35 ± 0.42 g), ($t(124) = 4.4799$, $P<0.05$) and ($t(124) = 5.4073$, $P<0.05$), respectively.

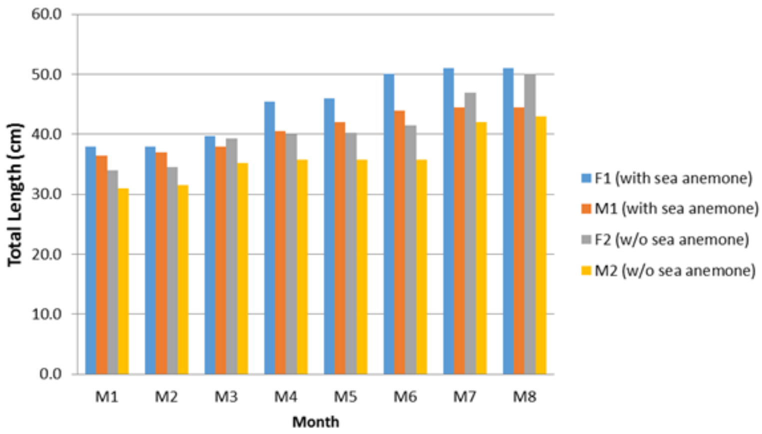

Figure 2: Mean total length of anemonefish with and without sea anemones.

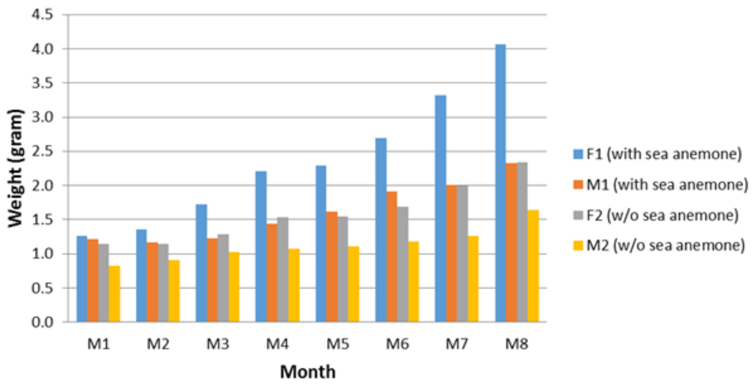

Figure 3: Mean wet weight of anemonefish with and without sea anemones

Table 1: Multi-level ANOVA showing the statistical difference in growth of *A. ocelllaris* between sex and month of study.

Tank	F value	Length (L)	Weight (W)
T1 - With anemone	$F_{7,48}$ = 2.448 (L); 6.937 (W)	P = 0.0313	P = 0.0001
T2 - Without anemone	$F_{7,48}$ = 0.535 (L); 2.180 (W)	P = 0.8040	P = 0.0527

The significant growth of clownfish in the presence of sea anemones is supported by previous study by Martinez (2021), who analyzed the influence of *Entacmaea quadricolor* bubbletip anemone on clownfish. This result was also in accordance to Nguyen et al. (2019), who studied the growth of two different stages (12 days old and 60-92 days old) of *A. ocellaris* associated with six different host sea anemones, and reported that post-settlement juveniles (60-92 days old) of *A. ocellaris* living with natural host species grew faster than those living with unnatural hosts or without anemone contact. While Ghosh et al. (2011), who studied the spawning frequency of *A. ocellaris* with two different sea anemones, *Radianthus magnifica* and *Stichodactyla mertensii*, concluded that the successful spawning of *A. ocellaris* was facilitated by the presence of hosts.

In its natural habitat, clownfish obtain protection from predators, deworming, additional nutrients, and fitness from the sea anemones (Nguyen et al., 2019). In addition, anemones offer protection for the nests and assist in the viability of clownfish eggs and larvae (Fautin & Allen, 1992). These suggest that the fitness of *A. ocellaris* in captivity will be optimized by keeping them with their natural anemone host species. This study, thus, acknowledges the importance of sea anemones on the growth of the clown anemonefish, *A. ocellaris.*

CONCLUSION

The effects of sea anemone host on the fitness of the clownfish were interesting and suggest that the importance of this relationship be looked into in more detail. Other aspects of the relationship that can be explored are the biology of the host anemone, and its impact on the reproductive behaviour of the clownfish. In the short term, these early findings can be useful for aquaculturists and fisheries managers in developing management plans for the aquaculture of clownfish in Malaysia.

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THE CLOWNFISH MATING PROCEDURES ESTABLISHED AT AKUARIUM TUNKU ABDUL RAHMAN (AkuaTAR), PENANG

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Clownfish or Nemo, well known from the movie "Finding Nemo", is a very popular marine ornamental fish. Clown fish are distinguished by their bright orange colour and three white lines on the head, centre of the body, and base of the tail, and having a size of about 10-18 cm in length. Clownfish share a symbiotic relationship with sea anemones and coexist together to seek protection from predators and feed on food that is trapped in anemones. Conversely, clown fish guard anemones from predators such as butterfly fish, clean them from dirt or parasites, and its excrement serves as food for anemones (Hartanto, 2004).

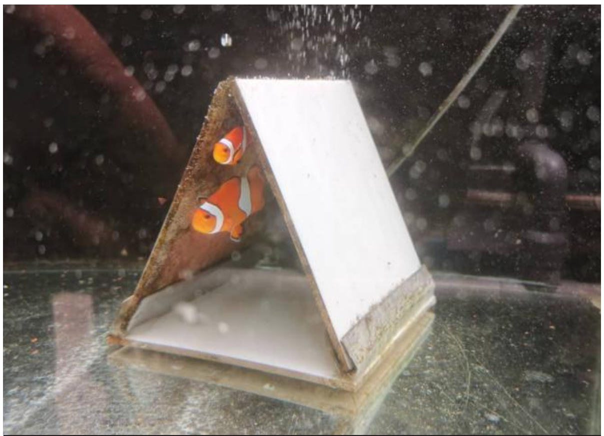
Clownfishes are hermaphrodite fish which possess both male and female reproductive organs. They release eggs throughout the season, with time intervals of roughly ten days or three times a month for productive broodstock. Clownfish lays its eggs on the substrate near an anemone or its home and incubates them until they hatch. The eggs will hatch in 5 to 9 days, depending on the species, egg quality, and environmental conditions. Usually, the eggs will hatch at night, which is about 2 hours after sunset (Marjorie et al., 2022). All clownfish juveniles are male throughout the larval stage, i.e, the first stage of clownfish development. A young fish in the same group will develop and dominate an area until it reaches its maturity level. This fish will then mature into a female. The dominating males will be the second biggest young fish. While the other fish in the group will remain as non-dominant males with no role in the reproductive process. Based on these criteria, the Akuarium Abdul Rahman (AkuaTAR) has established two primary procedures for selecting the broodstock to be bred.


1st pairing method on broodstock selection

This first mating procedure was done by placing 5 - 6 clownfish that have reached the age of 12 months and above in a fibreglass tank (104 x 26 x 26 cm) with a sea anemone. After a while, two clown fishes will dominate the sea anemone and drive away the other fishes. This indicates that the clownfish have found their mates. This pair is then transferred to the breeding tank for breeding preparation. The process was repeated in other tanks until most of the fish are in pairs.

The second pairing procedures was carried out by placing two clownfish, as young as 10 months old with significant size difference in a glass tank (60 x 40 x 40 cm). After a few days, if the pair of fish begins to move or swim together, they can be transferred to the broodstock tank for breading preparation. If the matched pair is found or observed to be unsuitable, where the larger fish are seen to attack their partner, then the replacement of another pair should be made.

In conclusion, both methods are basic and easy to perform. The first method requires a sea anemone while the second method uses mosaic or PVC pipe as a place for fish to shelter and breed. The second mating method was found to have several advantages which is, the breeder can choose the clownfish that have beautiful colour and pattern stripes to be paired. The mating period is also short and this method can be used for a large quantity of fish at one time.


A pair of clownfish in mosaic rectangular


A pair of clownfish with sea anemone

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MACROBRACHIUM LANCHESTERII (UDANG GANTUNG): A POTENTIAL ORNAMENTAL SPECIES

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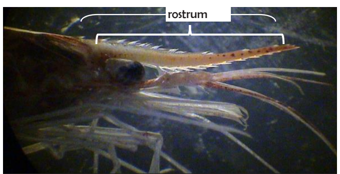
Macrobrachium lanchesterii (De Man, 1911) is a freshwater shrimp and is widely distributed worldwide. Its common name is Asian glass shrimp or *udang gantung* in Malay and is also known as riceland prawn. They are omnivorous and will feed on various food types, including algae, detritus, and small pieces of meat. Glass shrimp can be a valuable source of protein in the aquaculture industry as feed for various aquatic species. Glass shrimp has been used as an ornamental species (Aquadiction, 2023) and as live feed, especially for carnivorous fish such as marble goby and arowana. Glass shrimp are a popular choice for aquarium enthusiasts as they are relatively easy to care for and have an interesting appearance. In order to create a condusive environment for glass shrimp to live and reproduce, a well-filtered aquarium with plenty of hiding places and vegetation is required. It is also essential to regularly monitor water parameters to ensure optimal conditions for the shrimp (Grave & Fransen, 2011). In addition, glass shrimp were consumed by the Kelantanese as its meat is tender and sweet. Glass shrimp also contain high levels of chitin, a compound with potential applications in the pharmaceutical and cosmetic industries such as wound dressings, dietary supplements, and skincare products (Lee et al., 2008).

Glass shrimp are typically small in size, with a maximum length of 8 cm, and have a semi-transparent exoskeleton that allows them to blend into their surroundings (Aquadiction, 2023). Glass shrimp have a distinctive morphology that sets them apart from other shrimp species. They have a flattened rostrum (a protruding structure on the head), which is rounded at the tip and lacks teeth or spines. They also have a pair of long antennae, a pair of short antennae, five pairs of walking legs, and three pairs of swimming legs (Santos & Anger, 1994). Glass shrimp are known for their unique reproductive system. Female glass shrimp carry their eggs on their pleopods (swimming legs) until they hatch, releasing the larvae into the water column (Ruppert & Barnes, 1994). They are easy to breed in captivity and their high reproductive rates make them a sustainable source of food for aquaculture (Schaus, 2003). Female glass shrimp berried 50 - 200 eggs which are relatively small and greenish in colour, and the larvae are release as free floating after 4 - 6 weeks from the pleopods (Garnelio, 2023).

Conflict arise when unethical seed supplier of giant freshwater prawn mix their post larvae (PL) with adult glass shrimp when they sell the seeds to aquaculturists. The giant freshwater prawn or locally known as "udang galah", is highly valued for its sweet and succulent meat and is a popular food item that is widely cultivated in Malaysia. The average body weight of giant freshwater prawn can reached up to 20 g to 40 g after six months of culture. However, the maximum weight of adult glass shrimp is only 5 g. The morphological characteristics of giant freshwater prawn PL is not well distinguished from the adult glass shrimp without thorough observation. Failure to identify the seed at the initial stage of the culture will result in harvesting small size or stunted prawn even after several months. Thus, to prevent unwanted losses due to misidentification of prawn during seed stage, the morphological differences between these two species (*M. rosenbergii and M. lanchesterii*) through naked eyes are presented as below.

GIANT FRESHWATER PRAWN (*M. rosenbergii*)

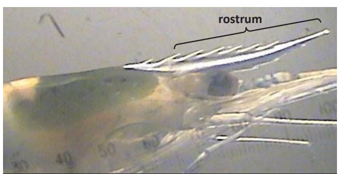


Giant freshwater prawn larvae (30 - 45 day post-hatching)

Rostrum with tip bends upwards and 11 - 13 teeth

The reproductive organs of female and adult male prawns can be clearly seen at the base of the third and fifth walking legs (pereiopods). No stretching was found on the swimming legs (pleopods) of prawns (1 - 5 cm in length). At this size, it is difficult to distinguish between male and female prawns.

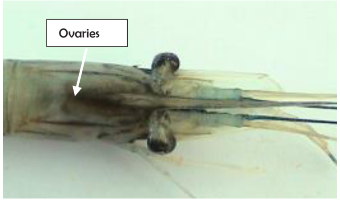
GLASS SHRIMP (*M. lanchesterii*)



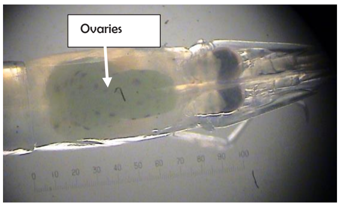
Adult glass shrimp

More horizontal rostrum with 7 - 8 teeth on the spear

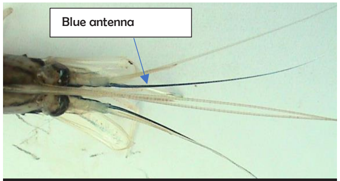
The female glass shrimp can be distinguished by the extension of her swimming legs (pereiopods) and they will only form if this shrimp has ever released eggs. Produces green eggs in the lower part of its body. There is no stretch on the swimming legs of adult male shrimp.



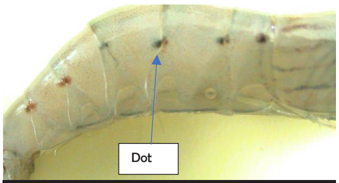
Orange-colored ovaries fill the dorsal (top) and lateral (side) spaces of the head (cephalothorax) when the prawn is ready to lay eggs. Under normal conditions, the colour is blackish-gray.



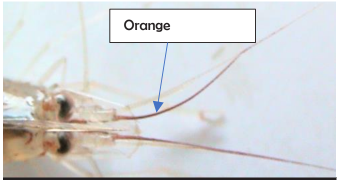
Ovaries located in the head (cephalothorax) will be green when it is ready to lay eggs. In normal conditions, it is slightly brownish in color. The skin on the head is more transparent.



Posses e a pair of blue antenna



Dot between body segment



Posses a pair of orange antenna

No dot between the body segment

In conclusion, glass shrimp has great potential for the aquaculture and aquarium industries. They are adaptable to a wide range environmental conditions, fast grower, and relatively easy to culture. Furthermore, their high nutritional value makes them an ideal feed for aquatic species and their aesthetic qualities make them a popular choice for aquarium enthusiasts and further R&D on this species needs to be carried out.

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R&D ON SEAHORSES IN MALAYSIA

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Seahorses (*Hippocampus sp.*) are an outstanding marine species with unique horse shaped head, large eyes, curvaceous trunk, and prehensile tail. It also possesses unique features including male pregnancy, lengthy parental care, small brood sizes, and strict monogamy in most species. Seahorses have commercial value as traditional medicine, curio objects, and pets in the aquarium industry. There are 48 valid species, 27 of which are represented in the international aquarium trade (Koning & Hoeksema, 2021). Many species of seahorses are threatened by intensive exploitation, overfishing, as well as widespread degradation of their natural habitats. Over-harvesting has been the primary cause of coastal ecosystem collapse and remains the most significant threat to marine populations. Due to this, seahorses were included both in the IUCN Red List of Threatened Species and in the Appendix II of CITES, as well as in some regional and national lists of threatened species (Vincent et al., 2011). Owing to all these scenarios, aquarium trade and R&D on seahorses have increased in the last years.

Aquaculture has been proposed as a solution to address unsustainable trade for traditional medicine, aquarium fishes, and curios. Several attempts have been made to cultivate seahorses in Malaysia. The outcome is promising but much remains to be done, mainly economising the farming system and raising healthy stocks to harvestable size for the market (Ann et al., 2021).

SEAHORSE AQUACULTURE

Seahorse culture began in 1957 in China, where *Hippocampus trimaculatus* was first bred in captivity at the Shantou Mariculture Experimental Farm in Guangdong Province (Fan, 2005). However, serious efforts to breed seahorse on a commercial scale only started in the 70's and has advanced over the years with the closure of the life cycle of several species (Vincent et al., 2011). The majority of aquaculture operations was still in small-scale operations with relatively few personnel to cater the domestic aquarium market (Koldewey & Martin-Smith, 2010). There are at least 13 species in commercial culture or under research for their culture potential (Vincent et al., 2011).

Although our understanding of seahorse biology has improved greatly since the early 1990's, there are still large gaps in knowledge for many species. There was still scarce information available on the biology, species identification, behaviour, and life cycle of seahorse, and this certainly had an impact on the success of seahorse aquaculture.

STUDIES AND REPORTS ON SEAHORSES IN MALAYSIA

Table 1 lists most of literatures on seahorse's diversity, distribution, prevalence, growth, and culture from Malaysia. In general, it could be concluded that studies on this aquatic species are not really extensive.

Table 1: Studies and reports on seahorses in Malaysia

Research	Author
Disease of seahorses *Hippocampus barbouri* (Jordan & Richarson, 1908) in aquaculture	Marjorie et al. (unpublished data)
Distribution of seahorse species in Malaysia, harvesting trends and conservation concerns - A review	Ann et al. (2021)
Growth of four generations of zebra-snout seahorse, *Hippocampus barbouri* (Jordan & Richardson, 1908) in captivity	Ismail et al. (2020)

Effect of cultured *Artemia* on growth and survival of juvenile *Hippocampus barbouri*	Wung et al. (2020)
A first record of seahorses and their habitats in Penang National Park, Penang, Malaysia	Quek et al. (2020)
Observational developments of the culture of big-belly seahorse, *Hippocampus abdominalis* (Lesson, 1827): A conservation effort for the future	Ismail & Yap (2019)
Success of breeding and rearing of seahorse (*Hippocampus spp.*) in captivity	Ismail (2017)
Reproductive performance of seahorse, *Hippocampus barbouri* (Jordan and Richardson 1908) in control condition	Nur et al. (2016)
Breeding and rearing of the spotted seahorse (*Hippocampus kuda*) in captivity	Ismail & Haron (2015)
Species and size composition of seahorse (Genus *Hippocampus*, Family Syngnathidae) in the coastal waters and local market of Kota Kinabalu, Sabah, Malaysia	Shapawi et al. (2015)
Food and feeding habits of the seahorses *Hippocampus spinosissimus* and *Hippocampus trimaculatus* (Malaysia)	Yip et al. (2014)
Diversity, habitats and conservation threats of syngnathid (Syngnathidae) fishes in Malaysia	Lim et al. (2011)
Fisheries, large-scale trade, and conservation of seahorses in Malaysia and Thailand	Perry et al. (2010)
Exploitation and trade in seahorses in the Peninsular Malaysia	Choo & Liew (2005)
A record of seahorse species (family Syngnathidae) in East Malaysia, with notes on their conservation	Choo & Liew (2004)
Spatial distribution, substrate assemblages and size composition of sea horses (Family Syngnathidae) in the coastal waters of Peninsular Malaysia	Choo & Liew (2003)

At the Fisheries Research Institute, Penang, several studies were initiated about ten years ago. The first study was on the breeding and rearing of *Hippopocampus kuda* in captivity for 180 days (Ismail & Haron, 2015). Later, Ismail (2017) reported on the in-house nursery technique for breeding and rearing of *H. kuda, H. barbouri*, and *H. abdominalis* in captivity. The growth and survival rates of H. abdominalis from birth to adulthood were documented by Ismail & Yap (2019). For the record, this is the first successful life cycle completion in captivity and production of the next generation of *H. abdominalis* in Malaysia. Subsequently, study on the growth of four generations of *H. barbouri* in order to determine the effect of different generations on the size of *H. barbouri* in captivity was reported (Ismail et al., 2020).

R&D on seahorses was continued with the current focus on the disease. In 2022, a preliminary study was conducted to determine the diseases and pathogens that affected seahorse in captivity. The seahorses were analysed using H&E staining, Giemsa staining, and wet mount sampling. The initial results demonstrated the presence of gas bubble disease (GBD) and tail rot in seahorse. The study will be continued in 2023 with examination of more pathogens associated with seahorses particularly infections of *Cryptocaryon irritants.*

CONCLUSION

Seahorse aquaculture is a potential pathway in reducing pressure on exhausted wild populations. However, diseases and feeding technique remain the most pressing concerns in seahorse aquaculture. The best way to manage disease is through prevention and routine quarantining of new animals arriving at the culture facility. The provision of optimal environmental parameters and a good diet will also reduce health problems. It is clear that the lack of information on the treatment of the common diseases experienced in seahorse culture is a major constraint to the viability of seahorse culture and more research is required.

Healthy seahorse | Sick seahorse

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TAKING FRI'S CORAL FRAME TECHNOLOGY INTO CORAL CONSERVATION

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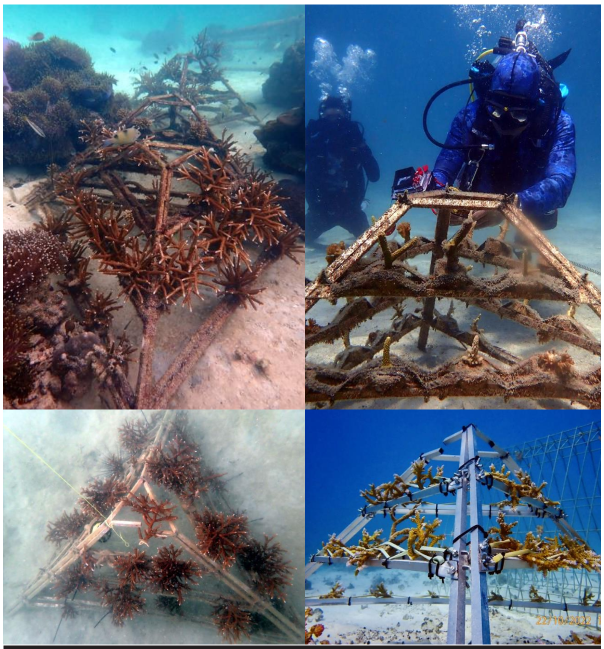
Coral reefs are declining throughout the world. It is expected that by 2050 about half of the present reefs will disappear, due to climate change and human effect. In Malaysia, coral reefs are more frequently threatened by natural phenomena and the rapid development of coastal areas, making the need to raise corals for restoration and rehabilitation purposes a critical tool for conservation of this valuable ecosystem. Fortunately, we can conserve corals through coral restoration and rehabilitation utilising the *in situ* (located in the sea) and *ex situ* (located on land) coral nursery or coral gardening concepts. Various methods to assist in the conservation and restoration of corals have been developed all over the globe. While the benefits to natural reefs are clear, the information on the methodology required for coral nurseries to effectively house and propagate corals, especially in Malaysia, remains insufficient. Moreover, some of these methods are complicated, utilise bulky devices, expensive, and not environment and user-friendly. Thus, there is a critical need to develop a suitable range of coral propagation methodologies and technology specific to Malaysian conditions, as advanced technology will be required for increased reef restoration and coral farming in the future. Paralleling the biological developments, there is also a need for effective and inexpensive coral cultivation apparatus, which addresses the problems related to setup and portability of a coral restoration and farming projects.

Researchers at the Fisheries Research Institute (FRI), Penang has successfully developed a simple, inexpensive, practical, and environmental-friendly coral frame, named My Coral Tripod, that is suitable for *in situ* coral farming and coral conservation concept in Malaysia. This light weight and portable coral frame help in mitigating silt and sedimentation issues inherently present in coral restoration, while taking advantage of its design to accelerate coral growth. Coral fragments or nubbins can either be fixed inside the cement pots or directly strapped onto the coral frame using provided rubber bands as parts of the accessories. These small fragments can be successfully cultured in the sea in mid-water or benthic nurseries until large enough to survive well. Since 2019, this aluminium-based coral frame has been placed at some of the Marine Park Islands in the Malaysia and Pulau Layang Layang, Sabah. This ongoing project aimed to examine the feasibility of using this patented My Coral Tripod in establishing new coral populations in their natural habitat. Results showed that constant improvement of the coral frame has increased coral survivorship from 50% in 2019 up to 80% in 2022. It is our ultimate goal that the usage of My Coral Tripod will assist in restoring reef ecosystem by returning coral cover at target reef sites to a self-sustaining level.



My Coral Tripod at Pulau Payar, Kedah (top left); Pulau Perhentian, Terengganu (top right); Pulau Tinggi, Johor (bottom left); and Pulau Layang Layang, Sabah (bottom right)

IDENTIFICATION AND MAPPING OF COMMERCIALLY VIABLE AQUATIC PLANT SPECIES

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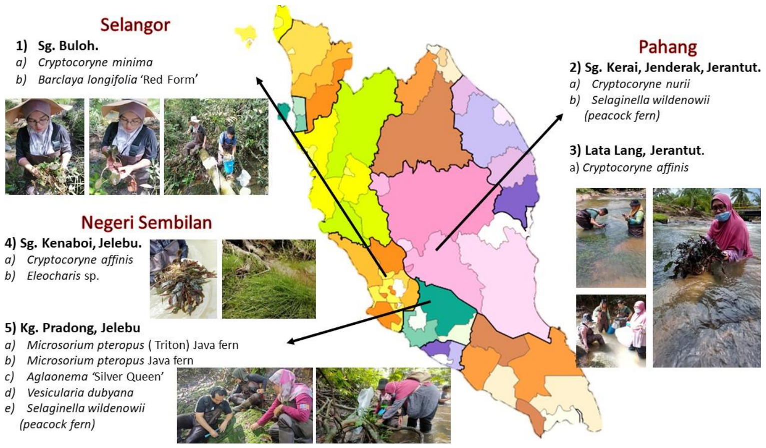
Aquatic plants tend to be overlooked although it is part of the ornamental fish industry. Globally, the industry is worth about USD 1.4 billion in 2021 and demand is expected to grow in the coming years (Dataintelo, 2022). In the wild, aquatic plants play many roles to support the aquatic animal species that lives alongside it. It is utilised as food and shelter, an oxygen producer, and even as a place to lay eggs for some species (Bolpagni et al., 2018). In short, aquatic plants are an essential piece of the aquatic ecosystem for it to thrive and uphold its biodiversity.

Although aquatic plants can survive or thrive in less-than-ideal conditions, some have very narrow tolerance, thus making them a good indicator species for the water quality of a certain area (Lacoul & Freedman, 2006). At present, wild aquatic plants in Malaysia are being threatened with various factors including habitat loss, run off and pollution, and climate change. Besides that, uncontrolled harvesting of wild species also leads to significant losses because some of the plants are endemic to that particular area. The exclusivity of some aquatic plants such as *Cryptocorene nurii var. raubensis*, makes it more desirable and holds higher aesthetic value, thus making them unscrupulously exploited.

In the determination to preserve these hidden gems, FRI Glami Lemi's (FRIGL) Aquatic Plant Unit has taken an initiative to identify and map commercially viable aquatic plant with the aims to ascertain endemic species that could be turn into high value commodity, establish the optimum culture method, map the original habitat, monitor the areas, and recommend ways to preserve the biodiversity and survival in the specific location. All the information will be cross reference with weather data, land development in the area, and other factors that could adversely affect the plants and whether replanting is necessary for the area. Ultimately, FRIGL targets to develop genebank for endemic and high value aquatic plant in driving the growth of aquatic plant industry and preservation effort. The genebank will act as a base to develop new varieties of the local cultivar and distribute to national and international cultivators. At the same time, public awareness on the importance of aquatic plants to the biodiversity and stability of the ecosystem will also be heightened to stop over harvesting and polluting the area.



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SEARCHING FOR THE ANCIENT DRAGON (THE DRAGONFISH) USING THE MODERN TOOL OF ENVIRONMENTAL DNA

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The Dragonfish or Asian Arowana, *Scleropages formosus*, a freshwater fish species from the Osteoglossidae family, is known as the king of aquariums. It is one of the most popular and expensive ornamental fish in the trade. Their spectacular swimming movement mimicking a dancing dragon, resembles an ancient dragon with an elongated body, large shining scales, and a pair of front barbels has fascinated the eyes of many people, especially the hobbyists. Arowana inhabits an acidic environment of blackwater rivers with a slow-moving stream through forested swamps and wetlands. Over-harvesting and destroying natural habitats have accelerated the depletion of the wild population, which derives from the rapidly increasing trade demand over the past 30 years.

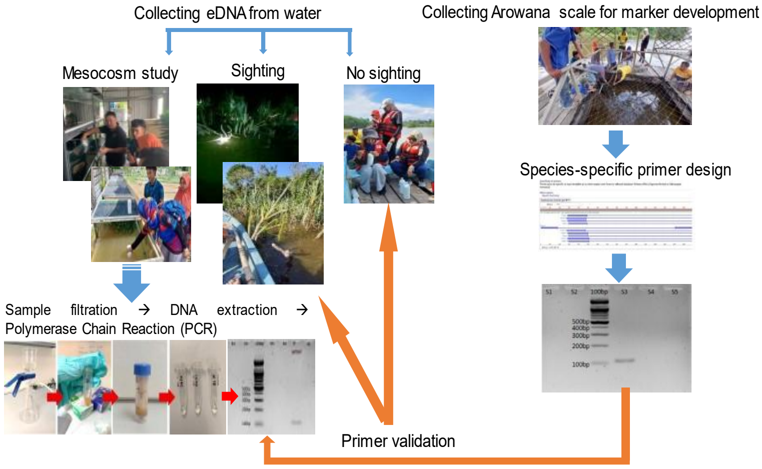
S. formosus can be found throughout Southeast Asia (Pouyaud et al., 2016), with several colour varieties in their natural habitats (Chang, 2009; Mohd-Shamsudin et al., 2011). The most common is the green variety distributed in Indonesia (Kalimantan & Sumatra), Vietnam, Myanmar, Cambodia, Thailand, and Malaysia. The red-tailed golden variety can be found in northern Sumatra, while the other red varieties (commercially known as super red, blood red or chilli red) originated from upstream of the Kapuas River and surrounding lakes in western Borneo, Indonesia. Nevertheless, the most expensive one is the Golden Variety or Blue-based Malayan Arowana which is endemic to the Bukit Merah Lake area and tributaries in Perak, Malaysia and Kerian River Basin (Mohamad-Zaini, 2015).

Due to over-exploitation and declining wild population, *S. formosus* has been listed as endangered by IUCN (International Union for Conservation of Nature) (Larson & Vidthayanon, 2019) as well as Appendix 1 of CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora), whereby no wild trade is allowed and import and export permits are required for international trading, with only captive-bred populations. The declaration of Bukit Merah Lake as Arowana Sanctuary in 2009 is a good move to revive the wild population, but ironically the real wild population status is not properly documented and well-studied. The information on the wild status is currently insufficient to make a definite management decision, which hinders further export to some countries that require proper CITES regulations on conservation strategies and monitoring of the wild population. At the moment, there are no specific regulations to prohibit or control wild catch, except for the routine monitoring of the fishermen's catch (Anon., 2009).

Conservation of wild stocks requires multiple efforts including strengthening the regulations and enforcement. Restocking using some captive-bred individuals is necessary for *in situ* conservation. The release of captive-bred must be genetically similar to the original stocks (Lucas et al., 2019). Monitoring programs using conventional sampling methods require substantial labour, cost, and logistic planning. Traditional tools may also be time-consuming, inefficient, and in some cases, lethal to the targeted organisms. As the population is small and it is almost impossible to do routine sampling for this endangered species, an emerging modern tool of environmental DNA (eDNA) offers a sensitive and non-invasive method for this objective.

eDNA is DNA that has been released by an organism into the environment (Taberlet et al., 2012). The DNA can be extracted from environmental samples such as soil, water or feces without having to isolate the target organism, allowing the detection of species at any life stage and from both sexes (Herder et al., 2014). This technique has been successfully used to detect threatened species (Balasingham et al., 2018; Weltz et al., 2017) without the need for lethal sampling (Lim & Then, 2022). Hence, the detection of wild and endangered *S. formosus* is possible through the application of eDNA. Subsequently, this tool can be used to develop a proper management program for conservation purposes.

Dragonfish is the resemblance to the ancient dragon myth (Mohamad-Zaini, 2015)



Workflow of eDNA in Dragonfish Monitoring

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Picture by Mr Koo Heng Soon

MOINA AS POTENTIAL LIVE FEED FOR FRESHWATER ORNAMENTAL LARVICULTURE

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Artemia is commonly used as live feed for freshwater fish fry. Due to strong demand and limited resources, the price of *Artemia* has continuously increased and greatly affected nursery operators. To make it worse, production of *Artemia* was increasingly restricted and unsustainable (Litvinenko et al., 2015). Hence, there is a crucial need to find an alternative for *Artemia* and *Moina*, fit this purpose.

Moina is a freshwater crustacean that is increasingly used in aquaculture as live feed. Among the species used were *M. dubia*, *M. micrura*, and *M. macropa*. *Moina* is small in size, easy to culture, hardy, and adaptable to a wide range of water conditions, making it an ideal food for fry, juveniles and young fish. *Moina* culture could be implemented in small-scale operations using basic and simple equipment and fed with various diets (algae, yeast, and commercial dry feeds). They reproduce quickly, allowing for a continuous supply of food in the hatchery.

Moina is also a popular live feed for ornamental fish, especially for smaller fish like tetras, killifish, and bettas (De Silva et al., 2011). *Moina* provides essential nutrients like protein, fats, and vitamins. Ornamental fish tend to be more active and interested in live food, as opposed to dried or frozen food.

Moina is often obtained from unhygienic and contaminated sources such as sewage ponds or drainage systems. This practice is not proper as there are associated risks of transferring of pathogens to fish fry production system. Furthermore, current production of *Moina* is characterized with low output, restricted, and unpredictable quality, not fit as a reliable source for hatcheries and ornamental fish industry. There are also no guidelines or protocol on the production of *Moina* sp. as live feed. Since the use of *Moina* is getting much attention, there is an apparent need to establish a guideline for hygienic production of *Moina*.

In view of this, the Fisheries Research Institute of Glami Lemi (FRIGL), Negeri Sembilan, has developed a practical, cost effective, and hygienic technology of mass culturing *Moina* sp. (Hanan et al., 2019). This technology solved the issue of obtaining *Moina* sp. from contaminated sources and the problem of the low, limited, and inconsistent *Moina* sp. production. The technique was transferred to DOF Aquaculture Extension Centre in Enggor, Perak, and managed to increase the production of good quality and healthy fish seeds up to 43% by totally using hygienic *Moina* sp. (Mohd-Yusof et al., 2022). In addition, this technique was able to reduce the operating cost of feeding by 60%.

Table 1: Several studies on the usage of *Moina* sp. as early diets for ornamental fish.

Ornamental Fish Species	Life Stage	Moina Species	Duration (days)	Reference
Angelfish, *Pterophyllum scalare* - Schultze, 1823)	fry (5 days post hatch)	*Moina* sp.	20	Eiras et al. (2022)
Severum, *Heros severus* - Heckel,1840	fry (5 days post hatch)	*Moina* sp.	20	Eiras et al. (2022)
Fighting fish, *Betta splendens*	fry (5 days post hatch)	*Moina* sp.	30	Srikrishnan et al. (2017)
Guppy, *Poecilia reticulata*	fry	*Moina* sp.	21	De Silva et al. (2011)
Fighting fish, *Betta splendens*	juvenile	*Moina* micrura	30	Rasdi et al. (2020)
Red fin barb, *Pethia reval*	fry	*Moina* sp.	4 months	Rathnayake et al. (2016)
Fighting fish, *Betta splendens*	fry	*Moina* sp.	16	Kwon et al. (2013)

In conclusion, *Moina* could be exploited as live feed for ornamental fish in Malaysia. So far, more than thirty local aquaculturists have benefitted from the TOT carried out by the FRI Glami Lemi. Currently, the culture system is being further improved by integrating IOT to monitor water quality parameters during Moina production.

Moina sp.

Moina sp. cultivation-open culture system

Moina sp. cultivation-open culture system

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ANTIMICROBIAL USAGE AND ANTIMICROBIAL RESISTANCE IN ORNAMENTAL FISH

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Misuse and overuse of antimicrobials in animal farming (including fish) is driving antimicrobial resistance (AMR) which is one of the top 10 global public health threats facing humanity (WHO 2021). AMR occurs when bacteria, viruses, fungi, and parasites change over time and no longer respond to medicines; therefore, making infections harder to treat and increasing the risk of disease spread, severe illness, and death (WHO, 2021). The cost of AMR to national economies and the health systems is significant as it affects productivity of patients or their caretakers through prolonged hospital stays and the need for a more expensive and intensive care. This article aims to present the overview of the AMR situation in ornamental fish industry.

Besides food fish, ornamental fish may also contribute to significant dissemination of AMR bacteria. The ornamental fish industry is a multibillion-dollar industry today with a USD 5.4 billion market size in 2021 and anticipated to expand at a compound annual growth rate of 8.5% from 2022 to 2030 (Grand View Research, 2021). The growing interest in attractive and unique fish for aquariums as part of a luxury lifestyle, hobby, source of entertainment, and also psychological benefits are the major factors driving the consistent growth in ornamental fish industry.

Antimicrobial used in fish culture is more detrimental to the ecosystem health because of wider environmental exposure pathway for drug distribution through water. The antibiotic movement pathways of ornamental fish are very complex and dynamic as ornamental fish shipments travel thousands of miles from production sites and countries of origin via holding and transhipment facilities, wholesalers, and retailers for eventual display in public aquariums or hobbyists' homes around the world (Livengood & Chapman, 2011). Transportation of live ornamental fish is a real challenge. Priority and care are given to maintain the health, behaviour of fish, and reduce stress (Vanderzwalmen et al., 2021). Antibiotics are frequently added to the transport water as a prophylactic measure to prevent the occurrence of disease. Numerous public health concerns have been linked with this industry, including zoonotic pathogens, antimicrobial use (AMU) practices, and antimicrobial resistance (AMR).

Oxytetracycline, sulphonamides, and quinolones are some of the most common antibiotic and chemotherapeutic agents used worldwide in food fish (Hemalini et al., 2022) and in ornamental fish farming as well. This may pose a hazard for humans who have direct skin contact with live fish and transport water including professionals in all segments of the ornamental fish business (aquaculture and fisheries) and inspections, and to a lesser extent, people keeping aquariums at home. The risk for humans may be direct, as the antibiotic may enter the body of humans via skin or ingestion when fish trade professionals do not wear protective clothing. The bacteria in humans may become multi resistant when exposed to these antibiotics. Moreover, the fish trade professionals may be directly exposed to bacteria which are already multi resistant against antibiotics, and this imposes a risk for transferring of resistance to other bacteria, which, in case of causing disease in humans cannot be treated anymore with the antibiotic (WHO, 2020). Another risk for humans is the fact, that tropical freshwater fish may be carriers or be clinically infected by potential zoonotic bacteria, which may be harmful to humans via direct contact (Lehane & Rawlin, 2000; Haenen et al., 2013).

Various studies have demonstrated the prevalence of multi-drug resistant bacterial pathogens and associated resistance genes in ornamental fish (Verner-Jeffreys et al., (2009); Gerzova et al., (2014)). Several recent studies are listed in the Table below. In Malaysia, reports on AMR surveillance of ornamental fish pathogens are still limited. Musa et al. (2008) reported that all *A. hydrophilia* isolates from ornamental fish collected from an aquarium shop in Kuala Terengganu, Malaysia, were resistant towards sulfamethoxazole, 13 isolates were resistant to oxytetracycline, and eight to nalidixic acid.

Table 1: Several latest findings on antimicrobial resistant in bacterial isolates obtained from ornamental fish and transport water.

Country	Ornamental Fish	Findings	Reference
India	Koi and goldfish	Significant resistance pattern in *Acinetobacter, Comamonas, Klebsiella, Enterobacter, Edwardsiella, Aeromonas and Lactococcus*, with MAR indexes (>0·3),	Preena et al. (2019)
Sri Lanka	Not mentioned	68.3% of *Aeromonas* sp. isolates had MAR indexes (> 0.2),	Dhanapala et al. (2021)
India	Guppy and Molly	Elevated resistance pattern for *A. veronii, E. faecalis, K. aerogenes, B. subtilis, E. faecalis, C. testosteroni* with MAR indexes (>0.33),	Hemamalini et al. (2022)
Netherlands	Not mentioned	• *Aeromonas* spp. (n = 59) showed resistance to oxytetracycline (85%), flumequine (53%), trimethoprim-sulphamethoxazole (30%), neomycin (34%), florfenicol (9%), and nitrofurantoin (17%). • 11 suspected ESBL (extended-spectrum beta-lactamase) *E. coli* isolates were found in 2 of 50 freshwater ornamental fish and 9 of 50 transport water samples. • OXA-48-like carbapenemase gene variants of limited public health risk were frequently found in *Shewanella* spp.	Haenen et al. (2020)
Italy	134 imported ornamental fish mostly freshwater species (Poeciliidae family)	The most frequently isolated bacterium was *Aeromonas sobria* (37%) and showed resistance against lincomycin, ampicillin, oxytetracycline, and tetracycline.	Sicuro et al. (2020)

Note: MAR-Multiple Antibiotic Resistant. MAR index is calculated as the ratio between the number of antibiotics that an isolate is resistant to and the total number of antibiotics the organism is exposed to. A MAR greater than 0.2 means that the high-risk source of contamination is where antibiotics are frequently used.

CONCLUSION

The ornamental fish industry has been demonstrated to have contributed significantly to AMR. However, the data on AMR and particularly antimicrobial usage (AMU) in ornamental fish and transport water is still scarce. More studies are needed to evaluate the types and quantities of antimicrobials used in ornamental fish industry in Malaysia and the AMR surveillance of the main ornamental fish pathogens. Since the ornamental fish bring such pleasure and significant benefit to the people and country, we could adopt better management and mitigation in antimicrobial use. The regulations of the World Trade Organization (WTO) about the production, sale, and distribution of antimicrobials can be useful to control the use of prohibited antimicrobials for treating bacterial infections in ornamental fish. Better husbandry and good hygiene could be adopted throughout the global ornamental fish transport chain. Furthermore, only approved antimicrobials should be used after consultation with veterinarians or aquatic animal health professionals.

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PROSPECTIVE OF THE FIGHTING FISH FAMILY (OSPHRONEMIDAE) AS ORNAMENTAL FISH

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Malaysia is blessed with diverse freshwater fishes that are striking and unique. Some of them are endemic and endangered which made them rare and very much pursued. There are many native fishes with great potential as aquarium fish, but not being fully exploited. This includes genus from Osphronemidae family such as Betta, *Parosphromenus*, and *Trichopodus* (Figure 1). The swelling interest in these species has spear head the demand with some of them have already been marketed locally and internationally.

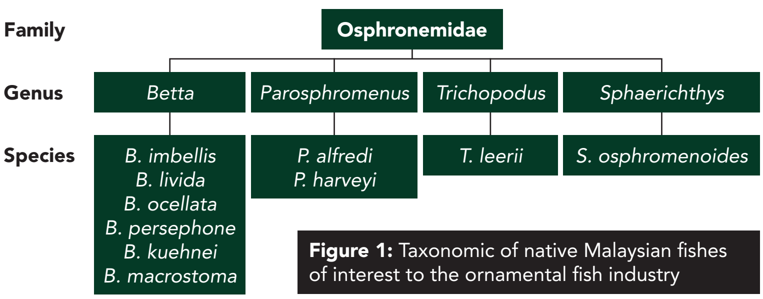

Figure 1: Taxonomic of native Malaysian fishes of interest to the ornamental fish industry

Osphronemidae family inhabits freshwaters and is uniquely adapted to stagnant waters. They live in peat swamps, rushing streams, large river backwaters, creeks, and paddy fields. Members of the Osphronemidae have an additional respiratory organ, the labyrinth, which consists of a complex bony structure lined with thin, highly vascularised respiratory epithelium that allows the fish to breathe air from the water surface (Tate et al., 2017). The purpose of this organ is to adapt to habitats with low oxygen water, such as peat bogs with murky, black water. They are highly adaptable in captivity and moderately easy to care for. Besides that, these fish have good acceptance of artificial food, hardy with eye-catching appearance, and non-aggressive nature that allows co-existence with other species (Ng, 2016).

Betta is among the most sought-after species with economic and ecological importance (Department of Fisheries, 2018). *Betta imbellis, B. livida, B. ocellata, B. persephone, B. kuehnei*, and *B. macrostoma* are among the common species in the local ornamental fish market. Many native *Betta* are endemic and site specific. For example, *B. livida* is found only in Sepang, Selangor and Tanjong Malim, Perak. *B. ocellata* in Sabah, *B. persephone* in Johor, *B. kuehnei* in Kelantan and southern Thailand, and *B. macrostoma* in Sarawak and Brunei (Schindler & Schmidt, 2009; Tan & Ng, 2005). In view of this speciality, these species could be made state icon. Each *Betta* species has its own unique appearances that fascinate *Betta* fish lovers. The exclusivity of *B. livida* for example, lies in its red coloured body and metallic green spots. *B. kuehnei* on the other hand, has striking iridescent bluish-green shading on the sides of the head and opercula. To date, native *Betta* have grown very popular and could fetch hundreds of ringgits per pair (Abd Rahman & Matthew, 2021).

Parosphromenus spp., also called licorice gourami, are found in peat swamp areas. A total of seven species have been recorded in Malaysia. All species in this genus are now threatened with extinction (IUCN, 2022). *Parosphromenus* has a beautiful and unique body and fin colour such as *P. alfredi* and *P. harveyi*. However, *Parosphromenus* are timid and sluggish swimmers. Therefore, *Parosphromenus* spp. is more appropriate in aquariums with plants in them and not in community tank with fast swimming fish species. As for *Trichopodus*, pearl gourami (*Trichopodus leerii*) and chocolate gourami (*Sphaerichthys osphromenoides*) are two most probable contenders in ornamental trading. The pearl gourami has pearl-like spots on its body. At present, the chances of catching wild pearl gourami is very low and most specimens in the market come from captive breeding. The chocolate gourami has an attractive chocolate brown colour and is timid. This fish is better to be kept in community aquarium with peaceful fish to avoid intimidation.

The trouble in obtaining wild fish is a hurdle in trading. Furthermore, some of the potential species are faced with extinction as registered in the IUCN Red List (2022) (Table 1). Destruction of forest, especially peat swamp for development, agriculture, and oil palm plantations are destroying the original habitat of these native fish. The over-manipulation of these fish in their natural habitat further exacerbates the situation. Traders and enthusiasts of native ornamental fishes play an important role in the conservation of native species (King, 2019; Ng, 2016).

The development of ornamental fish hatcheries is essential in fulfilling the demand from the industry and for conservation purpose (Raja et al., 2014). Developing best practises for captive breeding, care, and rearing may help in reducing reliance on wild stocks and increase production of potential fish species. With this goal in mind, the Fisheries Research Institute Glami Lemi in collaboration with the State Fisheries Offices, has taken the initiative to map, breed, and restock native fish species particularly *Betta* and *Parosphromenus*. The conservation effort in local native ornamental fish will require a concerted effort by the government, hobbyists, breeders, and the public to ensure the continued existence of these species in the trade and the preservation of Malaysia's natural treasure. Restocking of fish in their natural habitats is an important task and essential to maintain the biodiversity of the area, protect the genetic pool of the population, and avoid negative impacts on the existing population in the habitat (IUCN/SSC, 2013).

Table 1: IUCN Red List Status and Distribution of Native Malaysian Fishes of the family Osphronemidae of interest to the Ornamental Fish Industry

Potential Species	Common Name	IUCN Status	Distribution
B. imbellis	Crescent betta	LC	Peninsular Malaysia
B. livida	Selangor red betta	EN	Selangor and Perak
B. persephone	None	EN	Johor
B. ocellata	None	LC	Sabah
B. kuehnei	None	DD	Kelantan
B. macrostoma	Brunei beauty	VU	Sarawak
P. alfredi	Licorice gourami	CR	Johor and Pahang
P. harveyi	Licorice gourami	EN	Selangor and Perak
T. leerii	Pearl gourami	NT	Peninsular Malaysia
S.osphromenoides	Chocolate gourami	DD	Peninsular Malaysia (Johor, Negeri Sembilan, Pahang, Selangor, Perak) and Sarawak

*DD: data deficient; LC: least concern; NT: near threatened; VU: vulnerable; EN: endangered; CR: critically endangered


Betta ocellata


B. kuehnei


B. persephone


B. livida


P. harveyi


Parosphromenus alfredi


Trichopodus leerii (Siering, 2005)


Sphaerichthys osphromenoides (Tsunamicarlos, 2006)


Bluish-green iridescent on the sides of the head and opercula of *B. kuehnei*

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ORNAMENTAL FISH INVASIVE ALIEN SPECIES (IAS) IN MALAYSIAN WATERS

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The Department of Fisheries (DOF), Malaysia, reported a total of 242 million ornamental fish, worth around RM534 million, was traded in 2021 (DOF, 2021). Besides aquaculture, the ornamental fish trade could also indirectly put pressure on our local water bodies with intentional and unintentional introduction of fish. Intentional or unintentional alien ornamental species introduction could occur as a result of floods, natural disasters, or hobbyist release of unwanted fish. Numerous issues may develop after the introduction of a new species, according to global experiences. These include: alteration of the receiving environment, predation and interspecific competition, crowding and stunting, genetic degradation, introduction of parasites and disease, and extinction of numerous native species (Zaret & Paine, 1973; Taylor et al., 1984; Johnson et al., 2006; Gaygusuz et al., 2007; ; Amundsen et al., 2009).

Alien fish have long been introduced into Malaysia starting with the migration of the Chinese in the early 20th century. The primary means of introduction are through aquaculture, recreational fisheries, and ornamental industries (Figure 1). The routes of unintended foreign fish introductions in wetlands, lakes, and rivers include escaping from fish farms or releasing them, using them as fish bait, and getting rid of surplus aquarium fish.

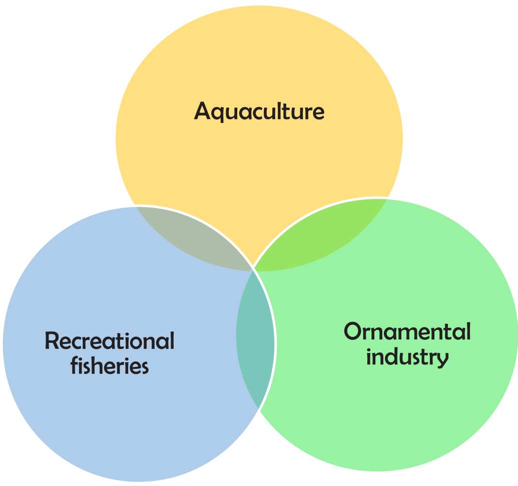

Figure 1: History of alien fish introduction in Malaysia (Khairul Adha et al., 2013)

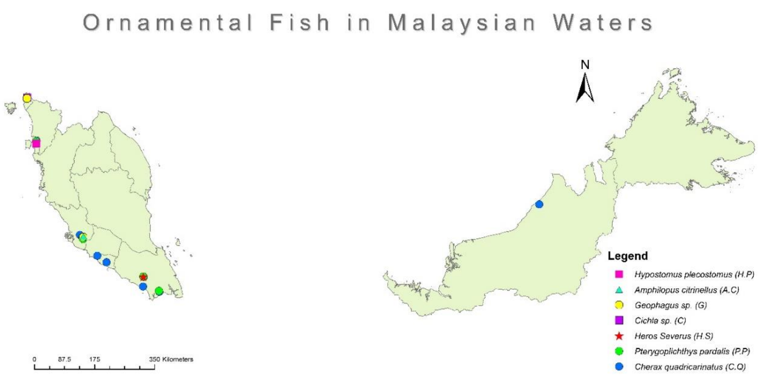

Figure 2: Types of ornamental fish reported in Malaysian waters

Table 1: Localities of ornamental fish reported in Malaysian waters

Family	Species	Location	State
Cichlidae	*Amphilopus citrinellus*	Seberang Perai Tengah	Pulau Pinang
		Seberang Perai Utara	
		Putrajaya Lake	Putrajaya
Parastacidae	*Cherax quadricarinatus*	Seberang Perai Utara	Pulau Pinang
		Machap Dam	Johor
		Skudai River	
		Suai	Sarawak
		Benut River	Johor
		Timun River	Negeri Sembilan
		Puchong Perdana	Selangor
		Ayer Keroh Lake	Melaka
Cichlidae	*Cichla sp.*	Timah Tasoh Dam	Perlis
Cichlidae	*Geophagus sp.*	Timah Tasoh Dam	Perlis
		Putrajaya Lake	Putrajaya
Cichlidae	*Heros severus*	Machap Dam	Johor
Loricariidae	*Hypostomus plecostomus*	Seberang Perai Tengah	Pulau Pinang
Loricariidae	*Pterygoplichthys pardalis*	Seberang Perai Utara	Pulau Pinang
		Machap Dam	Johor
		Putrajaya Lake	Putrajaya
		Langat River	Selangor
		Skudai River	Johor

Most ornamental IAS were found in Perlis, Penang, Selangor, Negeri Sembilan, Melaka, Johor, and Sarawak particularly at 12 locations, i.e., seven rivers and five lakes/reservoirs. The most commonly found species was *Cherax quadricarinatus*, found in six states (Table 1). A total of eight species were recorded (five belong to the family Cichlidae, two Loricariidae, and one Parastacidae) (Aqmal-Naser & Amiruddin 2018; 2019).

Figure 3: Ornamental Fish IAS in Malaysia.

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LIVE FEED FOR MARINE ORNAMENTAL FISH

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One important aspect of keeping fish healthy and happy in captivity is providing them with a diet that mimics their natural diet as closely as possible. Live feed is one way to do this, as it can provide fish with a more natural and varied diet than dry or frozen food. Ornamental fish requires a balanced diet to stay healthy and thrive in captivity. One important aspect of their diet is the use of live feed.

Live feed can provide a more natural diet for the fish, as well as help to keep their digestive systems healthy. In marine aquariums, live feed is often used to supplement the diet of fish, as it is considered to be a more natural and nutritious option. Each type of live feed has its own nutritional benefits, and it is important to research the specific dietary needs of the fish species in the aquarium before providing live feed.

Additionally, live feed can provide beneficial bacteria that can help to balance the fish's gut microbiome. Some common live feeds for marine aquarium fish include:

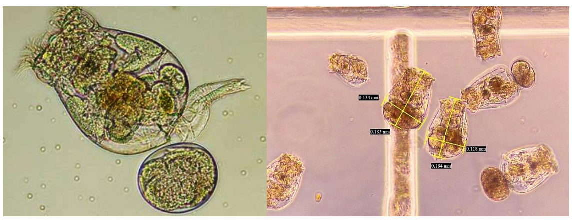
- Brine shrimp: These small crustaceans are a popular live feed for a variety of marine fish, as they are rich in protein and other nutrients. They are easy to culture and can be purchased in various life stages, from eggs to adults. They are a great source of protein, as well as rich in vitamins and minerals. They are also small in size, making them easy for most ornamental fish to consume. Brine shrimp can also be enriched with other nutrients such as nanochloropsis, which is a good source of carotenoids, vitamins, and minerals.

- Copepods: These tiny crustaceans are a natural part of the diet of many marine ornamental fish and invertebrates. They are rich in fatty acids and other nutrients, and can be purchased live or in a frozen form.

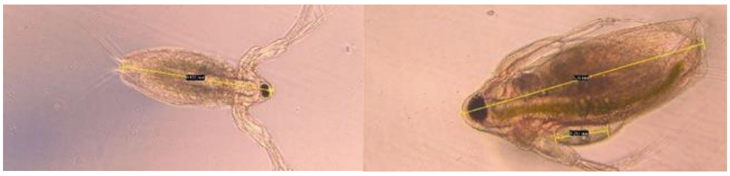
- Mysis shrimp: These small shrimp-like crustaceans are a popular live feed for marine ornamental fish, as they are high in protein and other nutrients. They can be purchased live or in a frozen form.

- Black worms: These worms are a good live feed option for marine ornamental fish that are carnivorous, they are high in protein and other nutrients. They are also high in fat, which can be beneficial for fish that need to build up their energy reserves.

- Rotifers: These small aquatic animals are a good food source for small fish fry and invertebrates.



- Diaphanosoma: These small aquatic animals are a good food source for small fish fry and invertebrates.



When using live feed for marine ornamental fish, it is important to properly quarantine the live feed before introducing it to the aquarium. This can help to prevent the spread of disease, as well as ensure that the live feed is safe for the fish to consume. It is also important to monitor the amount of live feed provided to the fish, as overfeeding can lead to water pollution and other problems. Fish should only be fed as much as they can consume within a few minutes, and any uneaten food should be removed from the aquarium.

However, it is important to research the specific dietary needs of the fish species in the aquarium before providing live feed. Some fish may not be able to properly digest certain types of live food, and providing the wrong type of live food can lead to health problems. For example, some species of fish are not able to digest worms and will not eat them, while others will thrive on the worms.

In conclusion, using live feed for aquarium fish can provide a more natural diet for the fish, as well as help to keep their digestive systems healthy. It is important to research the specific dietary needs of the fish species in the aquarium before providing live feed, and to properly quarantine live feed before introducing them to the aquarium. Additionally, it is also important to monitor the amount of live feed provided to the fish, as overfeeding can lead to water pollution and other problems. With the right live feed and the right feeding schedule, you can keep your fish healthy and happy.

COMMON DISEASES IN ORNAMENTAL FISHES: CONTROL AND PREVENTION MEASURES

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Ornamental fish production is ever expanding due to the vast interest of hobbyists, aquarium industry, and as a source of foreign income and employment (Anjur et al. 2021). A total of 287 million pieces of ornamental fish, worth about RM506 million were produced in Malaysia in 2019 with *Xiphophorus hellerii* (green swordtail), *Xiphophorus maculatus* (moonfish), *Poecilia sphenops* (guppy), and *Trichopodus trichopterus* (three-spot gourami) servingas the important species (Department of Fisheries Malaysia, 2019). With the rapid growth of the industry, there is also a surge in infectious diseases which contributes to significant losses.

Virus and bacteria are the most common disease vectors infecting ornamental fish. One of the most significant is Koi Herpesvirus diseases (KHVD), caused by Cyprinid Herpes Virus-3 (CyHV-3) or known as Koi Herpesvirus (KHV). It was first reported in Israel in 1998, causing massive mortalities of koi. At present, KHV infection is common and listed as one of the reportable diseases by the World Organization for Animal Health (WOAH). KHV infection route is through the skin, which then passess through the bloodstream to the kidney, spleen, and liver. KHV has a broad infection range and could infect other fish including carp (Michel et al., 2010), goldfish (Bergmann et al., 2010), Russian sturgeon (*Acipenser gueldenstaedtii*), and Atlantic sturgeon (*A. oxyrinchus*) (Bergmann et al., 2009). The Clinical signs of KHVD include gathering and gasping near the water surface and/or near aerated area, excessive mucus from the gills and skin, changes in skin condition, ulcers, haemorrhages, erratic swimming, sunken eyes (enophthalmos), lethargy, and anorexia (McDermott & Palmeiro, 2020).

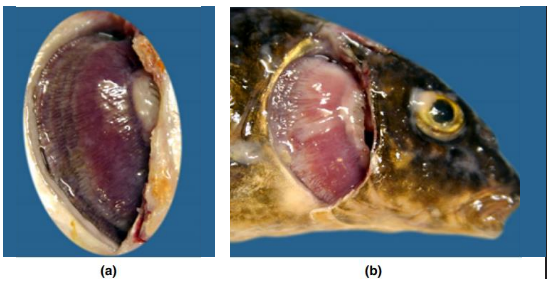

Figure 1: Image of clinical symptoms of KHV infected fish. (a) severe gills necrosis (b) excessive mucus production from the gills and enophthalmos. Source: Bergmann et al., (2010).

Another vital disease is koi sleepy disease which is instigated by poxvirus or Carp edema virus (CEV). This disease was demonstrated to cause high morbidity and mortality in koi and common carp (*C. carpio*) (Hasemi et al., 2018; Stevens et al., 2018) with clinical signs of severe lethargy, cutaneous lesions, or haemorrhages of the skin with edema signs of hypoxia, enophthalmos, and pale swollen gills (Haenen et al., 2004; Hasemi et al., 2018; Stevens et al., 2018). CEV infection was reported in various water temperature ranges: 15-25°C in Japan, 6-9°C in UK and 7-15°C in Austria (Way & Stone, 2013).

To date, there are not many treatments for KHV (McDermott & Palmeiro, 2020). Table 1 lists the possible treatments for KHV.

Table 1: Possible treatments and mitigation measures for KHV and CEV

Possible Treatment		References
1.	Cyanobacterium (*Arthrospira platensis*) exopolysaccharides applied in water and fish feed	Richert et al. (2017)
2.	Depopulation and disinfection as post-infected fish	McDermott & Palmeiro (2020)
3.	Increasing water temperature above 29°C as clinical manifestation and mortality of KHV infection was in the range of 21-27°C	Hartman et al. (2019)
4.	Reducing osmotic stresses via prolonged salt bath immersion at 0.1-0.3% for KHV and 0.3-0.5% for CEV	McDermott & Palmeiro, (2020); Seno et al. (2003); Hesami et al. (2018); Stevens et al. (2018)
Mitigation measures		
1.	Observe good hygiene practices, up-to-date biosecurity system, and vaccination	McDermott & Palmeiro (2020)

2.	The use of disinfectant such as chlorine (200mg/L), iodophores, benzalkonium chloride, and ethyl alcohol is are recommended to disinfect the whole system and equipment	Walster (2008); Hartmann et al. (2019)
3.	Ensure ponds and equipments are completely dried for a minimum period of 2 weeks before use	McDermott & Palmeiro (2020)
4.	Vaccination (attenuated, live vaccine, DNA, and oral vaccine containing liposome-entrapped kill KHV antigens, autogenous inactivated vaccines)	Ronen et al. (2003); Lusiastuti et al. (2021)

Other the other hand, the most prevalent bacterial infection in ornamental fish is caused by *Aeromonas, Shewanella, Citrobacter, Plesiomonas, Edwardsiella*, and *Pseudomonas species* (Anjur et al., 2021). Musa et al. (2008) isolated 26 bacterial strains from 50 diseased ornamental fish in an aquarium shop in Terengganu and 15 of them were *Aeromonas hydrophila. A. hydrophila* is the most common bacteria which affects aquaculture industry leading to great economic losses (Liu et al., 2020). *A. hydrophila* can infect various fish species whether cultured or wild, food fish, or ornamental (Anjur et al., 2021) causing various diseases particularly Motile *Aeromonas Septicemia* (MAS) (Hossain et al., 2019), with mortality approximately at 80% (Le et al., 2018). The clinical signs MAS consist of ulcerations, haemorrhages, abscesses, ascites, and anaemia (Anjur et al., 2021). Even though there are plenty of antibiotics available in the market, *A. hydrophila* was reported to be resistant to at least 5 classes of antibiotics (Preena et al., 2019). The potential use of bacteriophages for therapeutic purpose was promising with the recent application of bacteriophages from the family Myoviridae and Podoviridae to control *A. hydrophila* growth (Liu et al., 2020).

Due to the importance of ornamental trade in bringing income to the country, control and prevention of ornamental fish diseases should be given emphasise. Most disease may be circumvented by applying best management practices in all aspects of production, transportation, and trade. Hobbyists should be aware of the dos and don'ts in keeping the pet-fish especially the disposal method to ensure any disease vectors are not transferred to local stream. In conclusion, good husbandry, biosecurity practices, and know-how are the key for disease control and prevention in ornamental fish culture and commercialisation.

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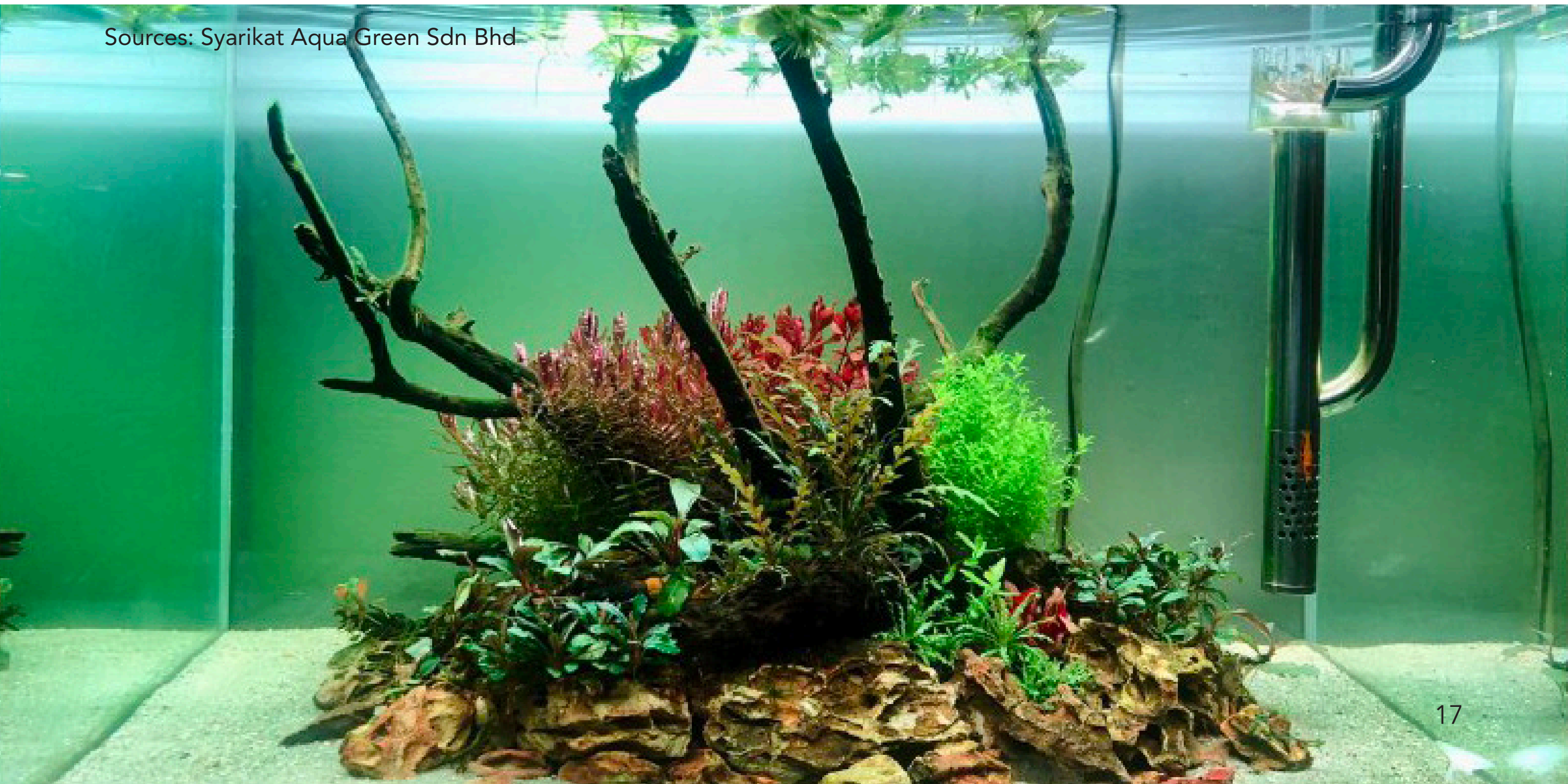
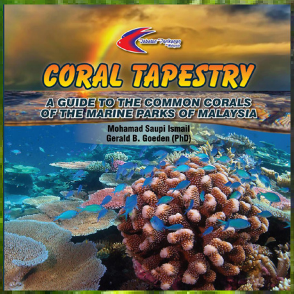
Sources: Syarikat Aqua Green Sdn Bhd

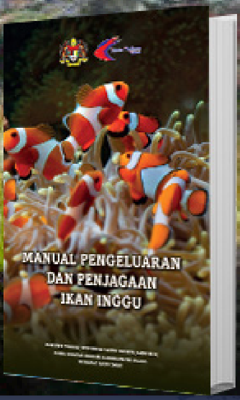


Documentations on ornamental fish and aquatic plants by the Department of Fisheries Malaysia

Books



Manuals



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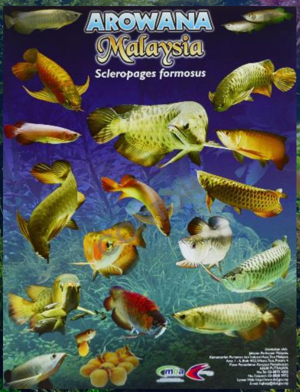

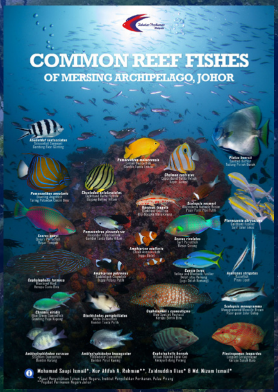

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