Seychelles Mariculture Master Plan

Aquaculture Fact Sheet

Marine Ornamental Fishes



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by Advance Africa Management Services

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1. Background

Key marine ornamental fish species

It is estimated that 20 to 25 million marine fish, 12 million pieces of coral, and 10 million marine invertebrates are traded annually in the marine ornamental aquarium industry (Figure 1) (Domínguez and Botella, 2014). Moreover, 2 300 of the 4 000 currently known marine reef fish species are traded as ornamentals, with new species regularly being added to this growing industry (Froese and Pauly, 2014; Biondo, 2017; Rhyne *et al*., 2017).

Figure 1: Marine aquarium (Source: The Aquarium Club).

The most widely traded marine fishes in the global aquarium trade include damselfishes and clownfishes (or anemonefishes) (Pomacentridae family), angelfishes (Pomacanthidae family), surgeonfishes (Acanthuridae family), gobies (Gobiidae family) and wrasses (Labridae family) (Figure 2; Table 1) (Wabnitz *et al*., 2003). Damselfishes, clownfishes, and angelfishes together constitute over 50% of the global volume of traded marine ornamental fish species; their popularity due to their bright colours and small sizes (Bruckner, 2005; Job, 2011; Domínguez and Botella, 2014). Among the most popular aquarium species, a number are native to Seychelles and are thus permitted for aquaculture in the region (Table 1). While these species are presently traded at the highest volumes, the number of marine fish species traded in the ornamental industry is continuously growing, with a regular demand for new species (Biondo, 2017; Rhyne *et al*., 2012, 2017).

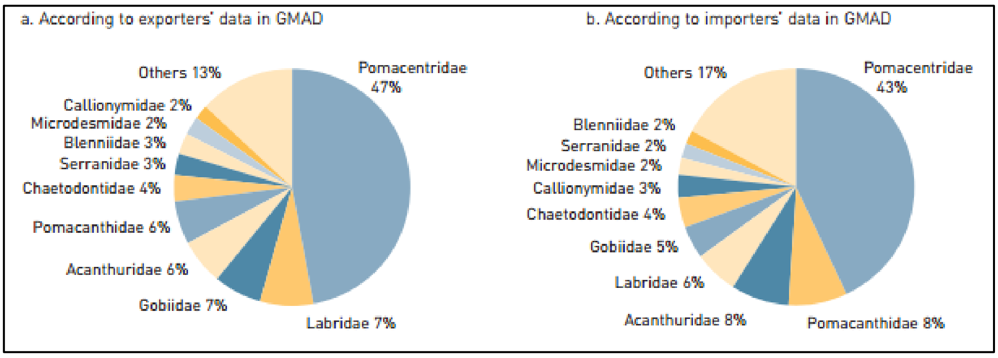


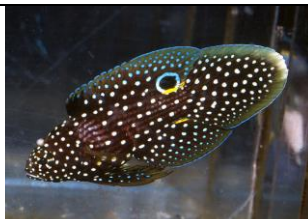
Figure 2: Marine fish families traded in global aquarium trade (Source: Wabnitz *et al*., 2003).

Table 1: Top ten traded species according to Global Marine Aquarium Database (GMAD) (Domínguez and Botella, 2014).

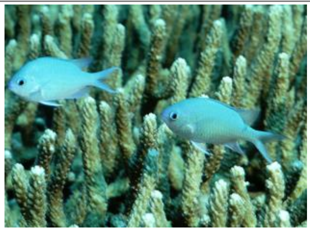
Family	Species	Common name
Pomacentridae	*Abudefduf* spp.	Seargeant majors
	Chrysiptera biocellata	Twinspot damselfish
	Chrysiptera cyanea	Blue devil
	Amphiprion bicinctus	Two-banded anemonefish
	Amphiprion ocellaris	Ocellaris clownfish
	Amphiprion sebae	Sebae clownfish
Labridae (wrasses)	*Labroides dimidiatus*	Bluestreak cleaner wrasse
Chaetodontidae (butterflyfishes)	*Heniochus acuminatus*	Longfin bannerfish
Acanthuridae (surgeonfishes)	*Paracanthurus hepatus*	Palette surgeonfish

Table 2: Common aquarium trade species native to Seychelles (Image sources: Fishbase.com).

Family	Species	Common name	Aquaculture status	Image
Acanthuridae (surgeonfishes)	*Paracanthurus hepatus*	Palette surgeonfish	1 and 2	
Apogonidae (cardinalfishes)	*Zoramia leptacantha*	Threadfin cardinalfish	3	
	Ostorhinchus cyanosoma	Yellowstriped cardinalfish	1	
	Sphaeramia orbicularis	Orbiculate cardinalfish	1	

Chaetodontidae (butterflyfishes)	*Heniochus acuminatus*	Longfin bannerfish		
Gobiidae (gobies)	*Gobiodon citrinus*	Poison goby	3	
	Nemateleotris magnifica	Fire goby		
Labridae (wrasses)	*Labroides dimidiatus*	Bluestreak cleaner wrasse	1	
Plesiopidae (longfins)	*Calloplesiops altivelis*	Comet	3	
Pomacanthidae (angelfishes)	*Centropyge acanthops*	Orangeback angelfish	1	
	Centropyge bispinosa	Twospined angelfish	1	
	Centropyge debelius	Blue Mauritius angelfish	1	
	Pomacanthus imperator	Emperor angelfish		

	Abudefduf notatus	Dusky damsel		
	Abudefduf septemfasciatus	Banded seargent		
	Abudefduf sexfasciatus	Scissortail seargent		
	Abudefduf sordidus	Blackspot seargent		
Pomacentridae (damselfishes and clownfishes)	*Abudefduf sparoides*	False-eye seargent		
	Abudefduf vaigiensis	Indo-Pacific seargent		
	Amphiprion akallopisos	Skunk clownfish	1	
	Amphiprion fuscocaudatus	Seychelles anemonefish		

	Chromis viridus	Blue green damselfish	1 and 2	
	Chrysiptera biocellata	Twinspot damselfish	1	
	Dascyllus aruanus	Whitetail dascyllus	1 and 2	
	Dascyllus trimaculatus	Threespot dascyllus	3	
Syngnathidae (seahorses and pipefishes)	*Hippocampus fuscus*	Sea pony	3	
	Hippocampus tyro	Seychelles seahorsse		

Key to aquaculture status:

1. Subject of research
2. Captive-raised, from wild captured post-larval stage
3. Commercially available

Biology and ecology of key species

Pomacentridae

The clownfishes (or anemonefishes) and damselfishes are demersal pair spawners. They form mating pairs of a male and female fish, which spawn over a solid substrate, where eggs are externally fertilised and attach to the substrate. In clownfishes, both the male and female exhibit parental care of eggs, including fanning of eggs with their fins, while in damselfishes this is done by males (Kavanagh, 2000; Domínguez and Botella, 2014; Olivotto *et al.*, 2017). These species spawn year-round in warm waters, with seasonal spawning in colder limits of their ranges (Ross, 1978;

Thresher, 1984; Domínguez and Botella, 2014). Most species of this family are protandrous hermaphrodites with a complex social hierarchy; all individuals mature as males and some will undergo sex change to become females (Domínguez and Botella, 2014).

Pomacanthidae

The marine angelfishes inhabit warm water coral reefs, generally at depths of up to 30m but can be found as deep as 100m. Angelfishes are sequential protogynous hermaphrodites; all individuals mature as females, and undergo sex change to become mature males. These species generally occur singly or in pairs, but form groups for feeding, breeding and migrating. Angelfish species are pelagic spawners (Domínguez and Botella, 2014; Olivotto *et al*., 2017).

Acanthuridae

Surgeonfishes are herbivorous coral reef fish. During the spawning season, sexual dichromatism is observed, and males become more brightly coloured. Some surgeonfish species are known to be gonochoristic, however, some species within the family may be hermaphrodites (Thresher, 1984; Claisse *et al*., 2009). They are group broadcast spawners (Domínguez and Botella, 2014).

Gobiidae

Gobies inhabit a wide range of marine, freshwater and brackish habitats, including shallow coral reefs. The goby family includes both gonochoristic and protogynous hermaphrodite species (Sadovy de Mitcheson and Liu, 2008). They are demersal pair spawners; mature fish spawn in pairs onto a substrate where they are externally fertilised, and eggs attach to the substrate with an adhesive thread. The male guards the eggs, which hatch 5 to 7 days after fertilisation (Wittenrich *et al*., 2007; Meirelles *et al*., 2009; Job, 2011).

Labridae

Species of the wrasse family are protogynous hermaphrodites. This family exhibits two different spawning strategies; some species are pelagic group spawners, while others are pair spawners that guard their eggs in nests (Job, 2011; Domínguez & Botella, 2014).

Chaetodontidae

Butterflyfishes are found mostly on reefs in shallow waters, and feed on small benthic organisms, algae and plankton. These fishes generally form shoals, but during their breeding season form pairs and move to offshore reef tidal currents to spawn. The butterflyfish family may be characterised by gonochoristic and protogynous hermaphrodite species (Fowler, 1991). The butterflyfishes are pelagic spawners and do not guard their eggs (Domínguez & Botella, 2014).

Apogonidae

Marine cardinalfish species inhabit coral reefs and lagoons. They are nocturnal fishes, and feed on plankton and small invertebrates (Job, 2011; Domínguez & Botella, 2014). The cardinalfishes are mouthbrooders, and spawn in pairs after which the fertilised eggs are incubated in one of the parents' mouths, usually the male (Domínguez & Botella, 2014).

Syngnathidae

Seahorses and pipefishes typically occur at depths of 5 to 30m in a variety of habitats, including coral reefs and seagrass beds (Lourie *et al*., 1999; Job, 2011; Domínguez & Botella, 2014). Seahorses form brooding pairs, which exhibit courtship behaviour and the female transfers eggs to the male's brood pouch, where fertilisation takes place. Eggs are incubated and hatch inside the pouch. After leaving the pouch, juveniles are well-developed and able to eat live feed, and no further parental care occurs (Foster and Vincent, 2004; Koldewey and Martin-Smith, 2010; Job *et al*., 2011).

Plesiopidae

The longfin family is represented primarily by the comet (or marine betta) in the ornamental trade. Longfins are protogynous hermaphrodites and demersal spawners, with both males and females exhibiting parental care over the egg clutch.

Fisheries

Approximately 90 to 99% of marine ornamental fishes, comprising over 2 300 species, are collected from the wild (Sadovy and Vincent, 2002; Wabnitz *et al*., 2003; Olivotto *et al*., 2011). Collection methods include the use of handnets, cast nets, fishing lines, drop nets, chemicals (cyanide and quinaldine) and dynamite (Larkin *et al*., 2000; Olivier, 2001; Moorhead & Zeung, 2010; Job, 2011).

The majority of marine ornamentals are caught in developing tropical countries. Singapore, the Philippines, Indonesia, the Solomon Islands, Sri Lanka, Australia, Fiji, the Maldives and Palau are the major suppliers; together these countries accounted for 98% of exported ornamentals from 1997 to 2002, with the USA providing the largest market (Wabnitz *et al*., 2003; Botella and Domínguez, 2014).

Wild-harvesting of coral reef species for the aquarium trade is largely unsustainable, negatively impacting populations of target species as well as directly and indirectly affecting the complex coral reef ecosystems they form a part of (Wabnitz *et al*., 2003; Domínguez and Botella, 2014). A high level of mortality of captured fish takes place before reaching the market, due to factors such as poor handling and transportation techniques and the use of chemicals which weaken fish (Wabnitz *et al*., 2003; Biondo, 2017).

The majority of species collected for this trade are overharvested, due to the increasing demand and the high levels of mortality (Balboa, 2003; Olivier, 2003; Wabnitz *et al*., 2003). Selective harvesting of smaller and more colourful individuals results in removal of juveniles that have not yet reached sexual maturity, and in species that undergo sex changes can disrupt the demographic structure, leading to population decline (Wabnitz *et al*., 2003; Domínguez and Botella, 2014). The collection methods themselves are largely destructive; in many cases collection involves damaging reef ecosystems by breaking coral to retrieve fish that hide in them (Moorhead & Zeng, 2010; Olivotto *et al*., 2011; Militz and Foale, 2016; Militz *et al*., 2017)

These factors present challenges to the sustainability of wild-caught fishes to supply the marine aquarium trade, and with the growing demand of this industry, aquaculture offers a sustainable alternative.

Aquaculture

The growing demand for coral reef fish species for the aquarium trade, and the unsustainability of wild capture fisheries for this trade, has led to increasing development of aquaculture production of various species that are popular in the trade. This is viewed as a sustainable way to increase production to meet the growing demand of this industry (Parks *et al*., 2003; Domínguez and Botella, 2014). Additionally, fishes reared in culture conditions are likely to be better suited to captivity, providing a superior product (Ogawa and Brown, 2001; Olivier, 2003).

The growing interest in the production of ornamental species, has led to advances in culture techniques and technologies and feed production (Moorhead and Zeng, 2010; Botella and Domínguez, 2014). The USA is currently the largest producer of aquaculture ornamental fish, with more than 100 fish species bred in captivity and 30 to 35 of these species commercially produced (Job, 2011). The most commonly bred species include cardinalfishes, seahorses, dottybacks, anemonefishes, damselfishes and gobies.

Many aquarium owners practice fish breeding, and therefore many marine ornamental species that are not being bred commercially have been bred on a small scale.

2. Technical approach to aquaculture production

Production cycle

Various marine ornamental fish species can be produced in land-based Recirculating Aquaculture Systems (RAS) (Figure 3). Adult fish (broodstock) are captured from the wild and held in land-based tanks, where they spawn and produce eggs. After hatching, fish remain in a land-based facility through their larval and juvenile phases, until they reach market size. These systems use water pumped ashore from the ocean which is recirculated through the system with a small amount of replacement and effluent daily. The water that is pumped ashore is filtered before entering the tanks to remove pathogens and to provide optimal water quality for the fish. Similarly, effluent water leaving the tanks is cleaned in accordance with the relevant Seychelles Aquaculture Standard and global best practice.

The technical production cycle for the various ornamental species differs between guarders, mouth brooders and broadcast spawners, and is adapted to each species environmental and habitat requirements, spawning behaviour, and larval phase.

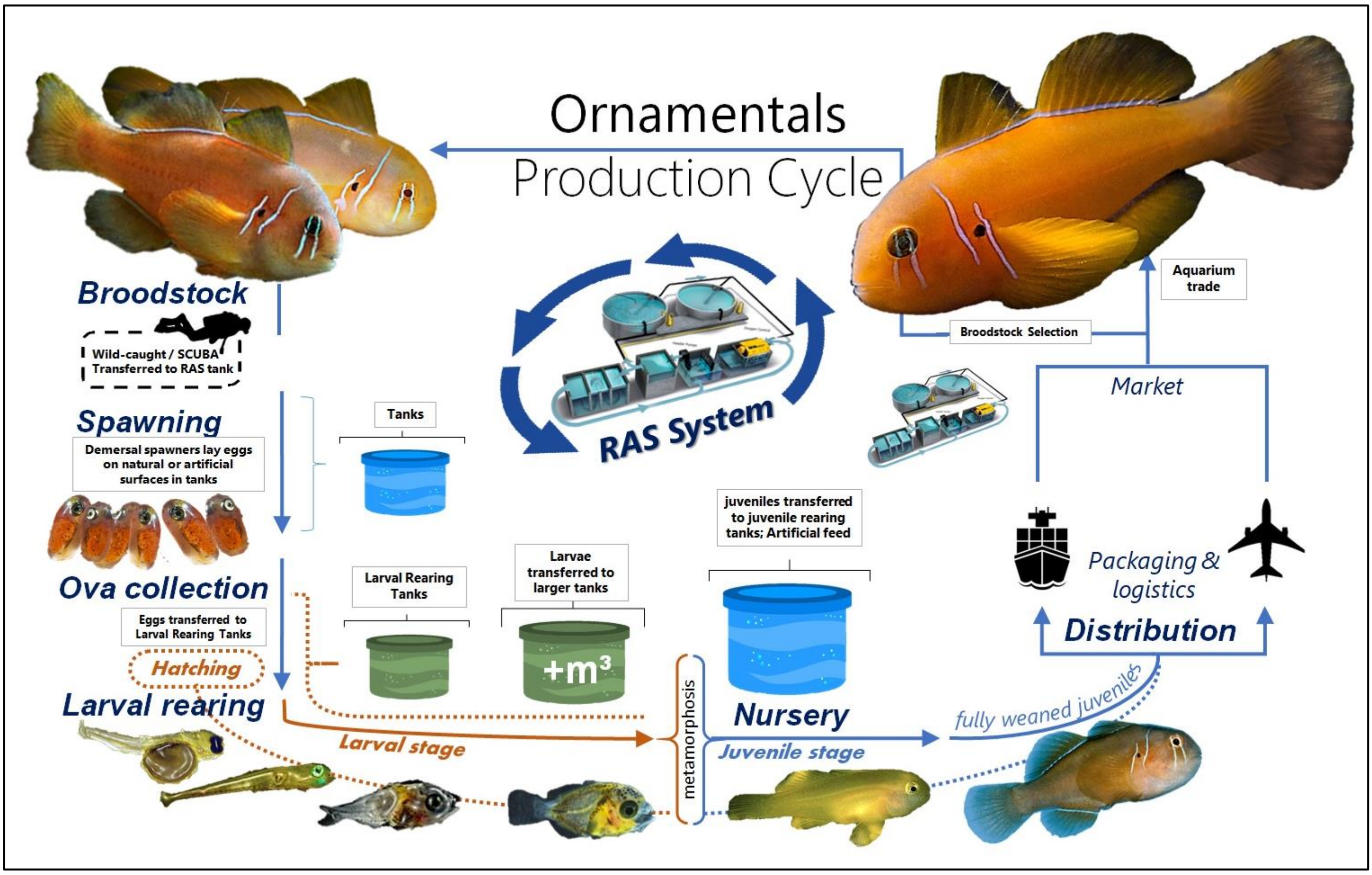


Figure 3: Production cycle for ornamental marine fish species.

Broodstock and spawning

Broodstock are captured from wild populations and transferred to land-based facilities. In order to collect mature fish, individuals are targeted by size. In species that display hermaphroditism, a wide range of size-classes should be collected to ensure the presence of both males and females. For species that breed in pairs, breeding pairs should ideally be collected, as wild-caught unpaired fish need to be induced to pair once in captivity (Oellermann, 1999).

Broodstock are placed first into quarantine tanks for one to four weeks to ensure that no disease or parasites enter the system and infect other fish. When the quarantine process is complete, broodstock are moved into broodstock holding tanks. These fish are fed a nutritious diet for successful production of high-quality eggs and healthy larvae, based on species-specific natural diets; for carnivorous species this can include mysid shrimp, artemia, fish, squid, while herbivorous species can be fed algae and seagrass (Oellermann, 1999; Job, 2011). Natural diets can be supplemented with artificially formulated pellets or flakes that can be enriched with vitamins to maintain broodstock health (Job, 2011; Domínguez and Botello, 2014).

Once broodstock are acclimated, they are transferred to spawning tanks. Tank design and fish stocking densities and sex ratios depends on the species' reproductive strategy. Pelagic spawning species require deeper tanks for spawning behaviour, while demersal spawners require a suitable substrate, such as ceramic tiles or live rock, for spawning (Baensch, 2003; Job, 2011; Chen *et al*., 2013; Domínguez and Botello, 2014). Environmental cues, such as water temperature and photoperiod, are manipulated on a species-specific basis to induce spawning (Job, 2011). Certain species additionally require hormone injections to induce spawning (Domínguez and Botello, 2014; Olivotto *et al*., 2017).

Larviculture and nursery phase

Following spawning, fertilised eggs are transferred to larval rearing tanks. In the case of pelagic spawning species, floating eggs are collected from the water surface using skimming instruments, and for demersal species, the substrate with the attached eggs is transferred (Job, 2011). For mouthbrooding species, the fish carrying the eggs (identified by a cessation in feeding) can be transferred, or eggs alone can be transferred to incubation tanks. The time to hatching following fertilisation, and the subsequent larval phase, differs among species (Table 3), and larviculture is designed accordingly (Domínguez and Botella, 2014). Early larval tanks generally have low rates of water exchange (Job, 2011)

Table 3: Differences in egg hatching among different marine fish species.

Guarders & mouth brooders	**Pelagic spawners**
• Eggs are large (2-3mm), and hatch after 3 to 10 days after fertilisation • Larvae are well-developed at hatching and begin feeding on day of hatching; live feed must be available in tank prior to hatching.	• Eggs are small (1mm) and hatch 14 to 24 hours after fertilisation. • Larvae are smaller and less developed at hatching. They begin feeding on live feed approximately two days post-hatch and live food is provided in the tank.

Larvae of most species are initially supplied with rotifers, followed by and overlapping with *Artemia* to meet nutritional requirements. Copepods and copepod nauplii can also be provided (Figure 4). These feeds can be enhanced to increase their nutritional value (Job, 2011). Towards the end of the larval phase, larvae are generally transferred to recirculating tanks and artificially formulated pellets or flakes are introduced with the live prey.

Following metamorphosis, the duration of which varies among species ranging from 10 to 60 days, juveniles are transferred to nursery tanks. During the nursery tanks, juveniles are weaned from a diet of live feed and algae to a diet of only artificial feed. Following this, juveniles are transferred to grow-out tanks at a density of one fish per litre. The majority of ornamental fish are marketed as juveniles, and are either harvested from grow out tanks for marketing within a few months (Oellermann, 1999; Job, 2011; Domínguez and Botella, 2004).

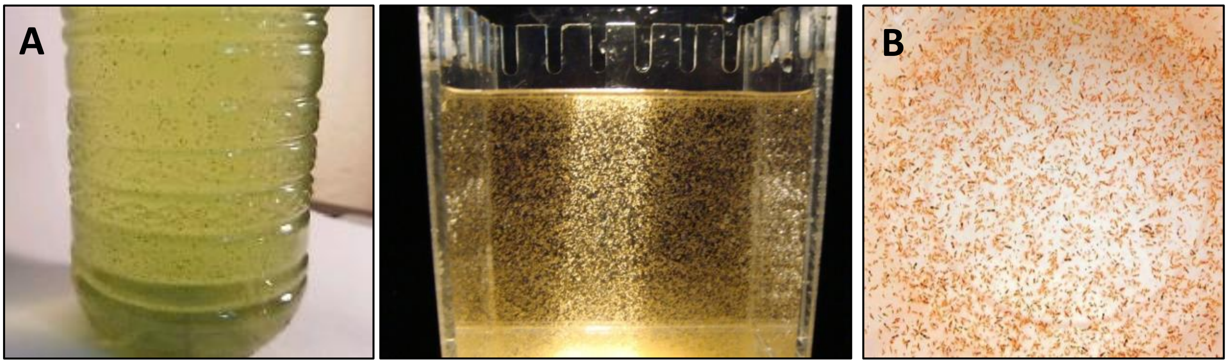


Figure 4: Live feed for larviculture rearing phase: A) Rotifers; B) Artemia nauplii; and C) Copepod nauplii (Source: Aquaculture Nursey Farms; Diapteron).

Fish health

At all stages of the production cycle, care is taken to ensure fish health and welfare. Minimising stress is key to reducing susceptibility to disease and infections, and is done by maintaining optimal production and environmental parameters including stocking densities, feeding regimens, water quality and temperatures among others (Nagasawa and Cruz-Lacierda, 2004; Sugama *et al*., 2012). A very high level of biosecurity and cleanliness is also maintained to alleviate the likelihood of disease outbreaks (Sugama *et al*., 2012; Fioravanti and Florio, 2017).

Disease in marine ornamental fish species can occur when environmental parameters, such as temperature and salinity, as well as stocking density, are not maintained at constant levels that are appropriate for the species in the culture system, as adverse conditions that result in stress make fish susceptible to infections (Monticini, 2010; Fioravanti and Florio, 2017). Parasites such as *Amyloodinium*, *Cryptocarion irritans*, *Gyrodactylus* and *Dactylogyrus* species have been recorded to infect the skin and gills of fish; these can be treated using water changes and chemical treatments such as formalin baths (Monticini, 2010; Roa *et al*., 2013). Bacterial infections, such as those caused by *Streptococcus* and *Vibrio* species, and viral diseases, such as those caused by *Betanodavirus* and *Lymphocystis* viruses, can be largely controlled by maintaining best practices and minimising stress (Monticini, 2010; Fioravanti and Florio, 2017). In the case of bacterial infection, antibiotics can be administered in controlled dosages (Roa *et al*., 2013). Viral diseases often require the infected fish to be removed from the system (Monticini, 2010).

In most culture facilities, the majority of parasites and diseases are introduced to the system from other facilities, for example by imported broodstock or fingerlings (Monticini, 2010). Obtaining broodstock from wild populations, and subjecting these fish to quarantine processes, can largely reduce the risk of diseases in cultured fish.

3. Market for tropical coral reef species

It is estimated that as many as 2 million people keep marine aquaria globally, and as these are becoming more affordable and available, the demand for marine ornamental species is increasing (Green, 2003; Livengood and Chapman, 2007; Rhyne and Tlusty, 2012). It is estimated that between 1985 and 2005, the marine ornamental trade grew by 14% annually (Bartley, 2005; Biondo, 2017), and the number of species traded in this market has also shown an increasing trend (Biondo, 2017; Rhyne *et al*., 2012, 2017).

Unlike most food fish markets, the ornamental fish market is characterised by low volumes and high value, and are considered to be the most valuable fish group by weight globally (Hardy, 2003), with a market value of between USD 245 and USD 500/kg (Wood, 2001; Wabnitz *et al*. 2003; Job, 2011). The USA is the main market for the aquarium trade, accounting for 40-50% of imports of marine ornamental fish species, followed by the UK, the EU, particularly the Netherlands, France and Germany, and to a lesser extent by Japan and Hong Kong (Wabnitz *et al*., 2003; Job, 2011; Biondo, 2017).

There is a growing market concern about the unsustainability of capture practices. There is growing awareness among consumers regarding the vulnerability of coral reef ecosystems, which has led to an increasing demand for more sustainably produced aquarium products, including cultured rather than wild-caught fish (Bell *et al*., 2009). Aquarium owners are also increasingly willing to pay higher prices for animals that are well acclimated to captive conditions, increasing the demand for aquaculture bred ornamental fish (Alencastro *et al*., 2005; McCollum, 2007; Bell *et al*. 2009)

4. Suitability for aquaculture in Seychelles

The species

A number of the most widely traded marine ornamental fish species and families are native to Seychelles, and are permitted by regulations for aquaculture production.

Access to market

Logistical considerations for marine ornamental fish are different to those for food fish. Fish need to be transported live with minimum stress, and it is recommended that travel time does not exceed 40 hours (Cole *et al*., 1999; Wabniz *et al*., 2003; Correia and Rodriques, 2017; Fioravanti and Florio, 2017).

Seychelles' level of transport infrastructure and location in the middle of the western Indian Ocean makes it well-suited to production of ornamental species for markets throughout the world. Seychelles has air links to markets in the USA, Europe, Asia and Africa.

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