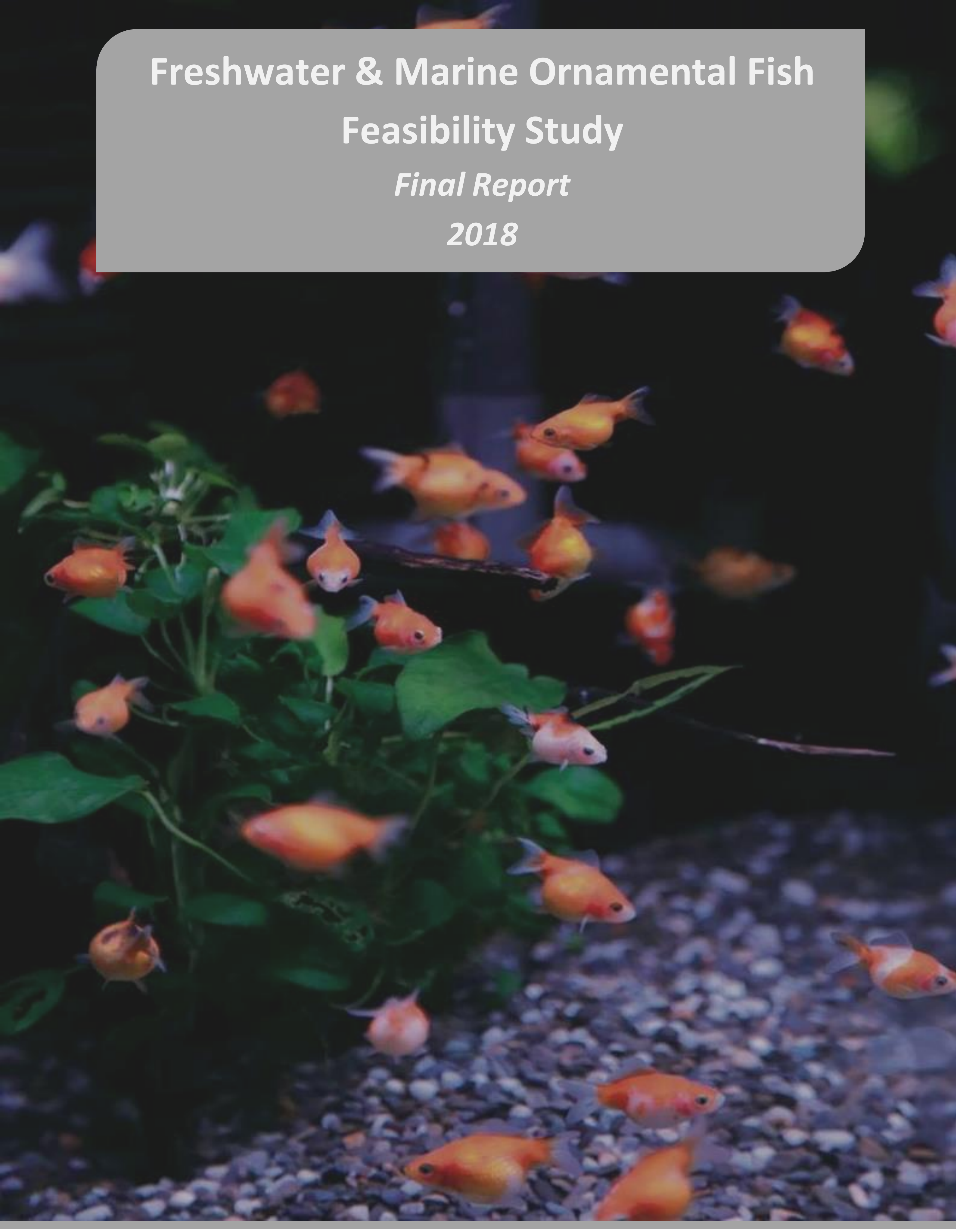
Freshwater & Marine Ornamental Fish Feasibility Study

Final Report

2018



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Executive Summary

The Department of Agriculture, Forestry and Fisheries (DAFF) Chief Directorate: Aquaculture and Economic Development aims to "*develop a sustainable and competitive sector that will contribute meaningfully to job creation, economic development, sustainable livelihoods, food security, rural development and transformation"* in South Africa. In line with this mandate, research and development has been done on several freshwater and marine species which are important and valuable species to the South African aquaculture sector.

Aquarium fish keeping is an increasingly popular hobby, that over recent years has experienced a growing interest that has resulted in ornamental fish being traded in more than 125 countries across the globe. The majority of ornamental fish are sourced from developing countries, typically located in tropical and sub-tropical regions. It is estimated that over 2500 species form part of the global ornamental fish industry, of which 60% of these species are freshwater ornamental fish. Marine ornamental fish make-up almost 15% of the ornamental fish market by value, with an estimated 98% of these fish being wild-caught fish (Dey, 2016).

The South African ornamental industry is still in its infant stages, with very low local production volumes. As a result of the limited production, the local market is reliant on imported ornamental fish. The production of ornamental fish is challenging in South Africa specifically due to the climate extremes and low winter temperatures, as well as the need for advanced technology, infrastructure, and highly skilled and knowledgeable industry experts. Currently, there are no documented marine ornamental producers in South Africa, which indicates a gap in the market. Freshwater ornamental fish production is currently underway in South Africa; however, the supply of fish is limited and relies on local markets and retailers in Gauteng and KwaZulu Natal.

The generic economic models were developed for both marine and freshwater ornamental fish. The following species listed in the table below can be considered for commercial ornamental fish production in South Africa.

Table 1-1: Marine and Freshwater Ornamental Fish Species Overview

Marine Ornamental Fish	Freshwater Ornamental Fish
Live bearers	
	Guppies, Swordtails, Platies and Mollies
Substrate Spawners	
Clown fish and Dotty backs	Angel Fish, Ancistrus Catfish, Tanganyikan Cichlids, South American Cichlids and Corydoras Catfish
Egg Scatterers	
Yellow Tang and Angel fish	Goldfish, Koi, Tetras, Barbs & Danios and Gourami's
Mouth Brooders	
	Malawi Cichlids

Based on the generic economic model results for **marine ornamental fish,** the only feasible production system identified was the recirculating aquaculture system (RAS). A major factor identified in the economic model is the high prices and production volumes required for producers to be profitable in South Africa.

Production areas are limited to the Western Cape, Eastern Cape, Northern Cape and KwaZulu Natal provinces, however, due to the warm conditions along the Northern KwaZulu-Natal coastline, this is considered to be a prime area for marine ornamental fish production. The table below provides **a financial overview** for substrate spawners (clownfish and Dottybacks) in a RAS.

Table 1-2: Financial Overview - Substrate Spawners in a RAS

Production Scale	Min 15 000 fish	Max 45 000 fish
SUBSTRATE SPAWNERS – DOTTYBACKS AND CLOWNFISH		
Selling Price	R 26/fish	R 23/fish
Total Capital Expenditure	R 1 065 409.13	R 2 493 050.74
Loan Amount – Working Capital	R 107 272.18	R 242 435.89
Loan Amount - Infrastructure	R 958 136.95	R 2 250 614.85
Profitability Index (PI)	1.24	1.58
Internal Rate Return (IRR)	10%	14%
Net Present Value over 10 years	R 1 321 650.21	R 3 930 334.64

From the table above, it can be seen that a total capital amount of R 1 065 409 is required to produce 15 000 fish per annum, while R 2 493 050 is required to produce 45 000 fish per annum. At the average identified selling price of R 26/fish, an IRR of 10% can be achieved when selling 15 000 fish per annum, while an IRR of 14% can be achieved when producing 45 000 fish per annum and selling at the lowest feasible price of R 23/fish.

The generic economic model for **freshwater ornamental fish** identified the RAS, as the most feasible and profitable production system in South Africa. The RAS can be used to produce several species such as guppies, tetras, and cichlids, to name a few. The pond culture method should only be considered for Koi and Goldfish as these species are not suited to being cultured in a RAS. The table below provides **a financial overview** for egg scatterers in a pond culture system in Gauteng (i.e. Koi or Goldfish).

Table 1-3: Egg Scatterers in a Pond System

Production Scale	15 000 fish/annum	45 000 fish/annum
Selling Price	R 23/fish	R 18/fish
Total Capital Expenditure	R 1 834 125.10	R 3 310 717.20
Loan Amount – Working Capital	R 90 725.50	R 212 768.00
Loan Amount - Infrastructure	R 1 743 399.60	R 3 097 949.20
Profitability Index (PI)	1.19	1.36
Internal Rate Return (IRR)	10%	12%
Net Present Value over 10 years	R 2 173 540.86	R 4 504 281.58

A total capital investment of R 1 834 125 required to produce 15 000 fish per annum, and R 3 310 717 required to produce 45 000 fish per annum. Production is profitable at both production volumes identified with an IRR of 10% achieved when selling at the price of R 23/fish identified, and an IRR of 12% when selling 45 000 fish per annum at the price of R 18/fish. Freshwater ornamental fish can be produced anywhere in South Africa; however, the most suitable provinces would offer warm conditions such as Mpumalanga, KwaZulu-Natal, Gauteng and select regions of the Eastern and Western Cape. These provinces also have a distinct advantage due to the presence of large urban centres which are key markets for freshwater ornamental fish.

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1. Introduction

1.1. Project Background

In South Africa, aquaculture has been identified as a key economic sector and employment cluster. Various policies, programmes and initiatives have been developed and implemented to assist with the development of the aquaculture sector. In support of aquaculture development, key initiatives such as the National Aquaculture Strategic Framework (NASF), the Aquaculture Development and Enhancement Programme (ADEP), and Operation Phakisa were established. The primary goal of the various policies, programmes and initiatives is to accelerate the growth of the aquaculture industry in order to assume a critical role of supplying fish products both locally and internationally; improving job creation, and contributing to the national economy, among other aspects. The sector has also been identified as a key industry that can impact the development and reindustrialisation of the rural communities and townships in South Africa.

Aquaculture is one of the fastest growing food sectors in the world, yet in South Africa, the sector remains small and underdeveloped despite the high-growth potential offered by the sector. In recent years, South Africa has seen improved access to aquaculture technology, increasing amounts of research and development, as well as support from various government departments. The freshwater and marine ornamental fish industry is currently underdeveloped with low production volumes being produced, which is attributed to the high volume of imported fish found in South Africa. The ornamental fish industry has the potential to grow and develop in South Africa, specifically with the production of freshwater ornamental fish. Ornamental fish production is labour intensive and will provide several employment and skills development opportunities.

Through continued research and development, value chain development, education and skills development and continued support, the South African ornamental fish industry could be further developed and expanded over time.

This report focuses specifically on freshwater and marine ornamental fish production in South Africa, and considers the following potential production systems:

I. RAS, and
II. Pond culture.

1.2. Purpose of the Feasibility Study

The feasibility study aims to provide guidelines and background information on the production of freshwater and marine ornamental fish in South Africa. The study covers the following aspects:

I. Freshwater and marine ornamental fish background,
II. Geographical distribution of ornamental fish in South Africa,
III. Detailed market assessment at a global, regional, and local level,
IV. Potential barriers to entry,
V. SWOT Analysis and mitigation measures,
VI. Financial analysis, and
VII. Conclusions and recommendations.

As there are a vast number of species that fall under the freshwater and marine ornamental fish category, the feasibility will be divided into breeding technique categories, with specific species identified under each category. The following species are covered in the feasibility study.

Table 1-1: Marine and Freshwater Ornamental Fish Species Overview

Marine Ornamental Fish	Freshwater Ornamental Fish
Live bearers	
	Guppies, Swordtails, Platies and Mollies
Substrate Spawners	
Clown fish and Dotty backs	Angel Fish, Ancistrus Catfish, Tanganyikan Cichlids, South American Cichlids and Corydoras Catfish
Egg Scatterers	
Yellow Tang and Angel fish	Goldfish, Koi, Tetras, Barbs & Danios and Gourami's
Mouth Brooders	
	Malawi Cichlids

As seen in the table above, the number of freshwater ornamental fish considered is much higher than the marine ornamental fish species, this can be attributed to the lack of research and data on marine ornamental species, specifically for aquaculture purposes.

In addition to the feasibility study conducted, generic economic models were developed for freshwater and marine ornamental fish. The generic economic models are aimed at assisting DAFF, industry stakeholders, role-players, and new entrants to the ornamental fish industry to determine the financial viability of ornamental fish projects in South Africa.

1.3. Feasibility Study Overview

The feasibility study is made up of ten (10) sections. Each section is discussed in more detail below to provide an overview of the report.

- **Section 1:** This section provides a project background and provides the main aspects that are will covered within the feasibility study.
- **Section 2 and 3:** These sections focuses on freshwater and marine ornamental fish by identifying key fish species under the relevant breeding category and highlighting key biological and physical characteristics for each of the species.
- **Section 4:** A detailed explanation of the potential production systems that can be used for ornamental fish in South Africa is provided. These production systems are included in the generic economic model to determine the financial viability of each system.
- **Section 5:** This section looks at the geographical distribution of freshwater and marine ornamental fish in South Africa, and provides a high-level suitability assessment, and identifies key requirements for profitability.
- **Section 6:** This section provides a detailed global, regional, and local market analysis for ornamental fish. Marketing, pricing, demand and supply, and the barriers to entry are key factors to be considered before implementing an aquaculture operation.

- **Section 7:** A SWOT Analysis shows a high-level overview of the freshwater and marine ornamental fish industry in South Africa. Mitigation measures are discussed to address key weaknesses and threats identified.

- **Section 8 and 9:** This section provides a financial analysis for the potential production systems based on the results obtained from the generic economic model for both freshwater and marine ornamental fish. A high-level cost-benefit analysis is discussed to compare the feasibility of the potential production systems.

- **Section 10:** The last section provides the conclusion on the feasibility study and provides recommendations for the growth and development of the freshwater and marine ornamental fish industry in South Africa.

Disclaimer: *Production information and assumptions in this report may be subject to change over time as certain production variables can be expected to fluctuate. Technical assumptions were utilised from various industry experts and stakeholders. Due to the sensitive nature of information shared by stakeholders, personal details of stakeholders will not be included in the report. Stakeholders will be referenced as "Personal Communication" in the document, and reference list.*

2. Marine Ornamental Fish

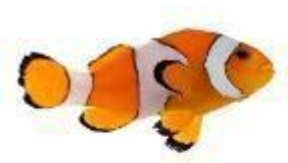
Marine ornamental fish are separated into two main categories for this report. Namely Substrate Spawners and Egg Scatterers. The data presented below, and technical information was used to develop the assumptions for the generic economic model, specifically tank requirements, temperature ranges and breeding behaviour.

2.1. Substrate Spawners

Substrate spawners typically deposit their eggs on a substrate within the tank (tank glass, wood, rocks, plants etc.). In comparison to egg-scattering fish, the substrate spawners produce fewer eggs, however the eggs are generally larger in size. Substrate Spawners can be divided into two groups, namely those that care for their eggs and those that don't. Further to this, spawners can be classified as either cavity spawners, who lay their eggs in a cave/shelter, or alternatively open spawners who lay their eggs on an open surface (Butler, 2015).

2.1.1. Clownfish

Ocellaris family, commonly known as the Clownfish are one of the most popular marine tropical fish. Currently cultured ornamental fish production has had some success in producing clownfish in captivity.



Clownfish Overview

Size	6 – 10 cm
Recommended Water Temperature	26-30˚C
Salinity	32 -35 ppt
Dissolved Oxygen	4.8 -6.5 ppm
pH	8.0 -8.4
Hardness	29 -35 dH
Ammonia & Nitrites	Ammonia should be 0 Nitrites and Nitrates less than 0.2 ppm
Lifespan	3 – 6 years
Diet	Omnivorous
Minimum Aquarium Size	114 litre tanks

Adapted from (FishLore.com, 2018)

Feeding: Clownfish can eat a wide variety of food. Flakes or pellets for omnivorous fish, as well as a mix between frozen and live foods is ideal to maintain a balanced diet. It is recommended that clownfish are fed once a day, depending on the size of the tank, and the number of fish/species within the tank. As feed plays an important role in growth, it is important to have a good feeding plan in place. Clownfish are generally fed until they reach satiation, this can be tested by seeing what they eat in a two to three-minute period (Ocellaris Clownfish, 2018).

The breeding & production of Clownfish: Available information indicates that clownfish are monogamous, and pair for life. However, there is a possibility this species may be polygamous. When breeding pairs are selected, it is advisable to buy sub-adult/juveniles to ensure they can adjust to being kept in captivity and mature in the available water conditions. According to Gopakumar (2006), it is best to purchase three to four sub-adults (2.5 to 5 cm in size) and place them in a tank with no other fish. Clownfish can change their sex, and in a tank environment the clownfish may form pairs and experience sex reversals to ensure they can pair up. Identifying the male and female in the pair may be challenging until they are sexually mature, however careful monitoring of the pairing process is required to ensure successful spawning can take place. Generally, from larvae, to sexual maturity and finally to spawning takes approximately 9 to 15 months depending on the species of clownfish (Gopakumar, 2006).

Larval rearing is the most critical and time-consuming phase of producing marine ornamental fish. Key aspects such as providing a stable environment and water conditions, adequate food on a consistent basis and strict daily monitoring and maintenance practices must be in place. When feeding the larvae, it is estimated that 300 -600 rotifers are required per larvae per day for a period of five to ten days. The production and maintenance associated with rotifers is a whole production process. The larvae which reach a size of 13 mm in approximately 30 days, can then be transferred to grow out tanks. Clownfish generally reach a marketable size of 38 mm over a four-month period; however, growth and development of the clownfish is highly dependent on water and food quality, amount of food fed and tank environment conditions.

Compatibility: The clownfish are peaceful species, and can be paired with several species, provided the tank environment is suitable for all species considered for the tank/aquarium environment.

2.1.2. Dotty Backs

Dottybacks (*Pseudochromis* family) are a family of small saltwater fish made up of over a 100 species. It is thought to be an intelligent, hardy, and vibrantly coloured fish, making it popular in marine aquariums (Pet Guide, 2013).

Dottyback Overview

Size	5- 10 cm
Water Temperature	22 -28°C
pH	8.1 – 8.4
Hardness	8 -12 dH
Lifespan	5 – 7 years
Diet	Primarily carnivore, can tolerate a variety of foods
Aquarium Size	Approx. 114 litres minimum

Adapted from (FishLore.com, 2018)

Feeding: Dottybacks are easy feeders and can be fed a variety of frozen food including some shrimp varieties. This species can also be fed pellets or granules, provided the feed meets the nutritional requirements of the fish.

Breeding: Certain varieties of the Dottybacks are being successfully bred in captivity, one of the most common is the Orchid Dottybacks. According to Schulz III (2008), all dottybacks are hermaphrodites, as fish can adopt either male or female sexual organs, and when adding two like species to a tank it should result in the formation of a breeding pair. Males will typically perform a mating dance outside his “cave” to attract the females attention. Once the female enters the cave, she can lay up to 1000 or more eggs, followed by the fertilization of the eggs by the male. The male dottyback then guards and protects the eggs. After three to six days, transparent fry will hatch, and will be larval for up to 30 days. Raising the fry to adult size is possible, however it is very involved, technical and risky (Schulz III, 2008). Orchid Dottybacks normally reach a marketable size of 3 cm after one and half months, however other varieties of Dottybacks have slighter longer growing periods. Aspects such as growing conditions, feed, and water conditions play a major role on the growth rate and quality of the fish produced (Vossen, 2017).

Compatibility: In general, Dottybacks can be aggressive and territorial making them incompatible with most aquarium species. The calmest, and as a result most popular Dottyback is the Orchid Dottyback, which can do well in tanks with other fish species. It is important to ensure the tank is large enough for the fish, as well as provide hiding places, caves, and vegetation (Schulz III, 2008).

2.2. Egg Scatterers

Egg scatterers breed either by spawning in pairs, or in some cases groups. The breeding process involves the simultaneous release of eggs by the females and sperm by the males. The fertilised eggs are then broadcast or spread into plankton, float away or sink to the bottom of the tank. Egg scattering fish species don't care for their eggs, thus large amounts of eggs are produced. A key disadvantage of this reproduction method is the low survival rate from larvae to adult stage. The survival rate for individual eggs is very low, so fish produce millions of eggs (Lende & Khileri, 2018).

2.2.1. Yellow Tang

The Yellow Tang (*Zebrasoma flavescens)* are popular in saltwater aquariums, particularly because of their bright colouring, and behavioural traits, which are suited to tank environments. It is thought that most of the Yellow Tangs traded on the ornamental market are harvested off the coast of Hawaii, with the nutrient rich waters of the Pacific Ocean providing the perfect breeding and growing environment for the Yellow Tang.

Yellow Tang Overview

Size	Up to 20 cm
Water Temperature	24 -27°C
pH	8 -8.4
Hardness	8-12 dH
Lifespan	Up to 10 years in captivity
Diet	Herbivore
Aquarium Size	Minimum size 283 litres

Adapted from (FishLore.com, 2018)

Feeding: In their natural habitat, tangs form large shoals and graze on algae as they move along the coral reefs. In tank environments, it is recommended that tangs are fed a large amount of algae-based foods such as Nori, although tangs will accept most food once they have acclimated to the tank environment.

Breeding: According to Fishlore.com (2018), the Yellow Tang is being bred at the Oceanic Institute in Hawaii as of December 2015. According to the Oceanic Institute, in December 2017 the first successfully bred yellow tangs were released to the Maui Ocean Centre. The breeding of tangs has been complex and a lengthy process, however the positive results are an encouraging sign for marine ornamental breeding and aquaculture. It has taken approximately ten years to successfully breed the Yellow Tangs in captivity.

Compatibility: Yellow Tangs typically are only aggressive towards their own species, or Tangs in general. It is recommended that one tang is stocked per system, unless multiple Yellow tangs are introduced into a system simultaneously (LiveAquaria.com, 2018).

2.2.2. Marine Angelfish

Marine Angelfish belong to the *Pomacanthidae* family which contains seven genera and an estimated 86 species in total. For this study, the *Pomacanthus* genus, which is made up of 13 species will be the primary focus. These 13 species include the Arabian Angelfish, Blue Ring Angelfish, Blue faced Angelfish, Emperor Angelfish (pictured), French Angelfish, Koran Angelfish, Red Sea Angelfish, and the Blue girdled angelfish (Animal World, 2015). While angelfish are popular in saltwater aquarium environments, they are sensitive to water conditions and water quality making them susceptible to disease.

Marine Angelfish Overview

Size	10 to 60 cm
Water Temperature	22 to 27.8˚C
pH	8.1 -8.4
Salinity	½ cup salt for every 4 litres of water
Lifespan	Up to 15 years
Diet	Omnivore
Breeding ratio	Pairs or harems (1 male to 3 females)
Aquarium Size	370 – 1000 litres

Adapted from (FishLore.com, 2018)

Feeding: Angelfish are grazers and will constantly look for food. In a tank environment it is recommended that angelfish are introduced into an established tank environment with good algae growth. It is also beneficial for the angelfish to have live rock, and small crustaceans in the tank. As angelfish eat sponge and tunicates naturally, it can be challenging to get angelfish to acclimate to tank life if they are wild caught.

Breeding: Saltwater angelfish start off as females and become males if they are dominant in the tank environment, thus making it hard to distinguish if they are male or female as they adapt according to the situation. Some angelfish species find a mate and pair with them, while others display harem behaviour with one male having several female fish. Angelfish become very territorial, thus it is recommended that breeding pairs or harems are not kept in a normal aquarium environment (Fish Keeping Advice, 2015).

While the breeding of angelfish has been reported in captivity to date it has only been successfully achieved by oceanic research institute in Hawaii. The angelfish spawn easily in captivity however difficulties arise when managing, feeding, and protecting the larvae. There is limited data available on the feeding patterns and behaviours of marine ornamental larva, making the breeding process highly complex and risky.

Compatibility: Angelfish tend to become territorial as they mature, thus it is recommended that only a single specimen is kept in a tank. It is not recommended that different angelfish species are kept together, however other aggressive species such as tangs, eels, groupers, and triggerfish could be suitable tank mates for angelfish (Animal World, 2015).

2.3. Legislative Requirements in South Africa for Marine Ornamental Fish

National government is responsible for the management of marine living resources, who has delegated some of these responsibilities to provincial authorities and statutory boards. The Marine Living Resources Act (MRLA) of 1998 is the primary legislation governing the conservation and sustainable long-term utilisation of marine living resources in South Africa.

I. **Short term recreational fishing permit:** Valid for a period of four weeks (one month) to undertake recreational fishing for marine aquarium fish. The permit costs approximately R 50.

II. A maximum of five fish per species, which have been collected on a recreational fishing permit may be held in captivity.

III. The following species may not be caught or harvested:
- Hard Corals (Order *Scleractinia),*
- Sea Fans (Order *Gorgonacea),*
- Sea Pens (Order *Pennatulacea),*
- Sand Dollars (*Enchinodiscus spp.),*
- Giant Clams (*Tridacna spp.),*
- Abalone (*Haliotis spp.),*
- Rock Lobsters (Family *Palinuridae),*
- Seahorses and Pipefish (Family *Syngnathidae),*
- Coelacanth (*Latimeria chalumnae),*
- Seventy-four (*Polysteganus undulosus),*
- Brindle Bass (*Promicrops lanceolatus),*
- Potato Bass (*Epinephelus tukula),*
- Natal Wrasse (*Anchichoerops natalensis),*
- Great White Shark (*Charcarodon carcharias), and*
- Marine Mammals (Class *Mammalia).*

Marine aquaculture is regulated by the Marine Living Resources Act (MRLA) of 1998 under Chapter 6 of the Act. The marine aquaculture sector is practiced both on a hobbyist and commercial scale. Currently the sector is sub-divided into three components, namely the small scale hobbyist breeding marine ornamentals for recreational purposes; a marine ornamental supplier importing for sale to local pet stores and the commercial marine ornamental operation producing marine ornamentals for sale on the local and international market. A marine aquaculture import permit is required by the Department of Agriculture, Forestry and Fisheries (DAFF) for the import of marine ornamentals, regulated in terms of the MLRA. A permitting framework will be in place in the near future, with the development of new legislation (i.e. Aquaculture Bill) for the regulation of commercial breeders and ornamental hobbyists.

3. Freshwater Ornamental Fish

Freshwater ornamental fish are separated into four main categories for this report. Namely Live Bearers, Substrate Spawners, Egg Scatterers and Mouth Brooders. The data presented below, and technical information was used to develop the assumptions for the generic economic model, specifically tank requirements, temperature ranges and breeding behaviour.

3.1. Live Bearing Fish

Live bearers included species such as Guppies, Mollies, Platys, and Swordtails, which are some of the most popular freshwater aquarium fish today. Live bearers give birth to live fry which can be considered an advantage over egg laying species as specialised hatchery facilities are not required. Guppies, Mollies, Platys and Swordtails all form part of the *Poeciliidae* family, more commonly known as the toothed carp, due to the teeth in their upper and lower jaw. Generally, live bearers are hardy fish, that are highly adaptable and can be kept in a variety of environments and conditions.

3.1.1. Guppies

Guppies (*Poecilia Reticulata)* are the most popular, and well-known freshwater aquarium fish globally. This species is highly adaptable and can be kept in a range of water and climatic conditions. This tropical fish can be found in the rivers and lakes of South America. The guppy is omnivorous and feeds on a wide range of organic matter that is available in the water.

Guppy Overview

Size	6 cm
Water Temperature	17 – 28°C
pH	7 – 8.5
Hardness	143 – 536 dH
Lifespan	1 – 3 years
Diet	Omnivorous
Breeding ratio	1 male to 2 females
Aquarium Size	45 x 30 x 30 cm

Adapted from (FishLore.com, 2018)

Feeding: Guppies are omnivorous, however in a tank or aquarium environment it is preferable to feed them freeze dried feed options to avoid the risk of disease from live food. Typically, fish flakes are recommended for guppies, however pellets can also be used. Guppies should be fed small amounts of food twice a day to avoid over feeding (Guppyfish Care, 2018).

Compatibility: In a tank environment, guppies are generally peaceful, and should not be kept with fin nipping species such as barbs, tetras etc. It does well in a quiet community tank with other live bearers, corydoras, rasboras and small loricariids (Seriously Fish, 2018)

Breeding: Densely planted tanks assist with the survival of the fry. A single female can produce between 5 – 100 young, and gestation period is approximately 4 to 6 weeks. Once fry have been born, it is recommended the fry are removed from the tank as the larger fish may eat them. Guppies are prolific breeders and should be monitored to ensure limited breeding. The ideal tank conditions for breeding should be between 25 -26 °C, with access to feed and good water conditions. It is important to select guppies for breeding to ensure the fry are of good quality, and possess the required traits based on the market being supplied or personal preference (Guppyfish Care, 2018).

3.1.2. Swordtails

Swordtails (*Xiphophorus Hellerii)*, like guppies are a very popular aquarium fish due to their ease of care and peaceful nature. Swordtails can be found in a variety of colours, with different fin types. Typically, males are slightly smaller than females, and can be up to 13 cm in size.

Swordtail Overview

Size	Up to 13 cm
Water Temperature	22 – 28°C
pH	7 – 8.4
Hardness	12 – 30 dH
Dissolved Oxygen	> 2.0 ppm
Lifespan	3 -5 years
Diet	Omnivorous
Breeding ratio	3 Females: 1 Male
Tank Size	114 litres

Adapted from Aquarium Guide (2018)

Feeding: Swordtail fish can tolerate a wide range of foods, from freeze dried flakes to live food such as bloodworms, brine shrimp, mosquito larvae or fruit flies. In their natural habitat they have been known to eat algae, and other vegetation so it is important to ensure the fish receive herbivorous food options, combined with some protein to provide a balanced diet. As with guppies, the risk of disease by feeding live foods is higher, however there is an opportunity for tank owners or freshwater producers to produce their own live food (The Aquarium Guide, 2018).

Compatibility: Swordfish are peaceful, and active in a tank/aquarium environment. They are best kept with other swordtails or passive species such as platies, mollies, or angelfish. Peaceful corydoras types can also be a good match for swordtails. Male swordtails are aggressive to one another, and the number of males in a tank should be based on the tank size, and number of females (The Aquarium Guide, 2018).

Breeding- Like guppies, Swordtails are prolific breeders, and can reproduce every 28 days. It is recommended that the male to female ratio be maintained at one male to three or four females to ensure the males don't harass the females. As they are live bearers, the fry come out swimming, but should be removed from the tank or separated from the adult fish to ensure their survival.

3.1.3. Platy's

The Southern Platy (*Xiphophorus Macultus)* are brightly coloured, well known aquarium species. They can be found in almost every colour except for purple. Platies are members of the *Xiphophorus* genus, and includes two species, namely the Southern Platy (*Xiphophorus Macultus),* the Variatus Platy (*Xiphophorus Variatus),* both of which are closely related to the Swordtail (*Xiphophorus Hellerii).* Platies are generally short and stocky fish, which can be found in an estimated 24 varieties, of different colours, sizes, and shapes.

Platy Overview

Size	Males (5 cm) Females (7.5 cm)
Water Temperature	20 – 26°C
pH	7 – 8.5
Hardness	10- 30 dH
Dissolved Oxygen	> 2.0 ppm
Lifespan	2 – 3 years
Diet	Omnivores
Breeding ratio	1 male to 3 females
Minimum Tank Size	45 litres

Adapted from (Seymour, 2014)

Feeding: Platies are omnivores in the wild, and eat plants, algae, small crustaceans, and insects. In a tank or aquarium environment, the natural feeding habitats should be replicated as closely as possible by using high quality flakes, as well as live and frozen foods. Fish flakes should be of high quality, and ideally high in protein, alternatively live foods such as blood worm and shrimp can also be used. Live food can be a challenge to source, thus frozen foods (blood worm etc.) can also be used (Seymour, 2014).

Compatibility: Platies are peaceful fish by nature, and are compatible with other live bearer species, as well as angelfish, gourami's, and tetras.

Breeding: Platies are easy to breed and follow a similar pattern to other live bearers. It is recommended a higher female to male ratio is maintained to ensure the males don't harass the female fish. Gestation is typically 4 to 6 weeks, and broods of up to 80 fry are common. The platy fry can generally able to accept powdered flakes, and live food from birth as they are generally well developed in comparison with other fish species fry. Fry should be removed from the parents until they are around 1 cm in size or larger to avoid cannibalism within the tank (Seymour, 2014).

3.1.4. Mollies

Like Platys, there are several varieties of mollies that cab found, specifically in the aquarium trade. For this study, two key varieties, the Shortfin Molly (*Poecilia sphenops)* and the Sailfin Molly (*Poecilia latipinna)* will be focused on.

Shortfin Molly (*Poecilia sphenops):* The Shortfin Molly is a well-known aquarium species and can be found in many different colours and patterns. They originate from Central and South America, and due to their adaptability and ability to live in brackish, fresh, and marine waters it has been classified as an invasive species in various countries. Selective breeding and the introduction of hybrids (*Poecilia sphenops x Poecilia latipinna*) has resulted in variety of colours, fin, and body shapes, in contrast to the silverfish, almost colourless mollies found in the wild. Most mollies reach sizes of between 8 cm (males) and 12 cm (females). While mollies are considered as popular aquarium fish, there seems to be a high mortality rate of mollies due to tank and/or aquarium setups that are unsuitable.

Sailfin Molly (Poecilia latipinna)

Sailfin Mollies can be found in various colours and are quite large fish in terms of aquarium fish, often reaching between 10 to 15 cm in tanks. As with the shortfin molly, it should be maintained in medium to hard water with basic pH to reduce the risk of disease and mortality. Breeding of mollies is relatively easy, fish should be at a ratio of two females to one male. Gestation is typically two months long, with up to 50 fry being produced at a time.

Mollies Overview

Size	Males (8 cm) Females (12-15 cm)
Water Temperature	20 – 26°C
pH	7 – 8.5
Hardness	15 - 35 dH
Dissolved Oxygen	> 2.0 ppm
Lifespan	3 -5 years
Diet	Omnivore & herbivorous (Sailfin)
Breeding ratio	2 females to one male
Minimum Tank Size	75 litres

Adapted from (FishLore.com, 2018)

Feeding: Mollies are naturally omnivorous, and feed on small invertebrates, algae, and plant matter. In a tank or aquarium, mollies should be fed high quality flaked food, which can be supplemented by a variety of vegetables. In place of vegetables, which may rot in the tank if not eaten by the fish, spirulina-based pellet or flakes which can form part of the required plant matter for their diet (Seymour, 2018)

Compatibility: Mollies generally do well in groups made up of a few males, and several females. In terms of tank mates, mollies can compatible with swordtails, platies, angel fish, the corydoras catfish and some of the larger tetra varieties (AquariumFish.net, 2018)

Key criteria for successfully raising mollies in an aquarium environment

- **Tank size:** As these fish can be up to 15 cm in size, large tanks are required, at least 90 cm or bigger in size.
- **Water quality:** While mollies can tolerate variable conditions, mollies cannot tolerate soft, acidic water, and instead require hard water with a pH of 7 or more.
- **Salt:** The use of salt is debated, as mollies have been known to thrive in brackish and saltwater conditions.

3.2. Substrate Spawners

Substrate spawners include species such as Cichlids, Angels, Gobies, Damsels and Clownfish. Substrate spawners typically deposit their eggs on a substrate within the tank (tank glass, wood, rocks, plants etc.). In comparison to egg-scattering fish, the substrate spawners produce less eggs, however the eggs are generally larger in size. Spawners can be divided into two groups, namely those that care for their eggs and those that don't. Further to this, spawners can be classified as either cavity spawners, who lay their eggs in a cave/shelter, or alternatively open spawners who lay their eggs on an open surface (Butler, 2015).

3.2.1. Angelfish

The Freshwater Angelfish (*Pterophyllum scalare)* forms part of the Cichlidae family and is one of the most kept of the cichlid family. It is also known as the Silver Angelfish or the Common Angelfish. Through captive breeding over time, angelfish are now mostly all captive bred, and have been developed to have various colours and fin varieties available. Apart from the common Angelfish, the Altum angelfish and Leopold Angelfish fall under the same *Pterophyllum* genera. Of the three angelfish, the common Angelfish has proved to be the hardiest and easiest to breed in captivity in comparison with the other two varieties.

Angelfish Overview

Size	Up to 15 cm
Water Temperature	23 – 28°C
pH	6.5 to 6.9 – acidic
Hardness	2 -10 dH
Dissolved Oxygen	> 5.0 ppm
Lifespan	Up to 15 years
Diet	Omnivorous
Breeding ratio	Fish pair up naturally
Minimum Tank Size	+/- 115 litres For breeding pair, a 210-litre tank is recommended

In tank environments, a 15-20% water change is required weekly for angelfish, however water replacement should be monitored as angelfish are very sensitive to changes in water conditions, specifically regarding the hardness and pH (Animal World, 2015). As they are substrate spawners, sand/gravel mix is required to facilitate breeding, while tank sizes between 114 litres and 210 for a pair.

Feeding: Angelfish are omnivores, and will eat live, fresh, or flaked foods, however it is recommended their diet is high in protein. A combination of both fresh and processed foods is favourable for angelfish, with careful portion control as overeating could potentially be fatal to the fish (Animal World, 2015). Angelfish have been known to go on 'hunger strikes' if the water quality deteriorates to a certain point. If angelfish do not eat, it is an indication that the water quality and conditions need to be tested, and possible water replacement is required (Aquatic Community, 2006).

Compatibility: According to technical experts, it is recommended that angelfish can or could be successfully kept together with the Cory and Ancistrus Catfish.

Breeding angelfish requires special attention, specifically regarding the tank size, water conditions and quality, as well as water temperature. For breeding the water should more slightly warmer, more acidic, and softer than normal. The female typically lays 1000 eggs at a time, followed by the male who fertilizes the eggs. A key challenge with angelfish is their tendency to eat the eggs rather than care for the eggs. Generally, the eggs hatch within a few days, and fry should be free swimming within a week (Animal World, 2015).

3.2.2. Ancistrus Catfish

The Antricus Catfish (*Antricus Temminickii),* is commonly known as the bristlenose catfish due to the soft tentacles on its snout. Although quite common in the aquarium trade, it is confused with the *Antricus Cirrhosus*. The difference between these two, is the absence (*A. Temminickii)* vs presence (*A. Cirrhosus)* of a dark spot at the base of the dorsal fin. Over time, the *Antricus Cirrhosus* has dominated the aquarium industry, and are more commonly found.

Antricus Catfish Overview

Size	8-15 cm
Water Temperature	21 – 24°C
pH	6.5 -7
Hardness	4 -10 dH
Lifespan	5 years or more
Diet	Mainly vegetarian
Breeding ratio	One female to one male or one male to two females
Minimum Tank Size	+/- 115 litres

Feeding: Fed mainly vegetarian foods. Prepared foods can include algae wafers, and spirulina based sinking food. Vegetables such as cucumber and courgette can be added to the diet, in addition to more meaty foods.

Compatibility: Not aggressive to other species, however male catfish may fight over territory if the tank is too small (Plantetcatfish, 2018).

Breeding: Antricus have been bred successfully in aquariums tanks of approximately 115 litres. For spawning, tunnels or a cave like structure should be placed in the tank for the eggs to be laid in. Once the eggs are laid, the male generally fans and guards the eggs.

3.2.3. Tanganyikan Cichlids

Lake Tanganyika is one of two great rift lakes in Eastern Africa, along with Lake Malawi. It is the second deepest lake in the world, and with its depth of 1470 m, it has very stable and oxygen rich water conditions. It has been referred to as an "island sea" because of its abundant life and volume of water.

Lake Tanganyika is thought to be home to a huge diversity of cichlid species, with approximately 250 cichlid species being identified, with a range of body shapes, colours, sizes, and behaviours. In the lake, cichlids inhabit various regions of the lake, from rocky areas, to sandy and midwater areas or a combination of the two. Over time, the cichlids have developed unique feeding habits to take advantage of the various regions in the lake (Animal World, 2015).

3.2.3.1. Lamprologus

Lamprologus comprises of more than 20 varieties of fish, which are commonly known as “shell fish”. These fish are the smallest fish in the cichlid family, reaching sizes of 5 to 8 cm. In their natural habitat, these fish are known for seeking refuge from predators, and establishing ‘homes’ in snail shells within Lake Tanganyikan.

Lamprologus Overview

Size	Ranges from 4 to 8 cm
Water Temperature	23 – 26°C
pH	7.8 – 9 (very alkaline)
Hardness	15 -25 dH
Lifespan	8 -10 years
Diet	Omnivore. Some varieties are carnivorous
Breeding ratio	One male to two or more females. In some cases, fish will pair up.
Minimum Tank Size	189 litres

Adapted from (Magaziner, 2014)

In a tank or aquarium environment, it is important to mimic the natural conditions of Lake Tanganyikan, specifically if the cichlids have been wild caught. The fish like to dig and burrow in sand in the lake, thus sand substrate of approximately 5-6 cm deep is recommended. In addition to sand substrate, shells should be provided for the fish in the tank, however it should be noted that these fish are very territorial, and shells should be strategically placed approximately 15 cm or more apart, with enough shells for each fish. By ensuring each fish has its own territory and shell, this will allow for a happy and functioning social group of shell fish. As it may be challenging to source the exact shells found in the natural habitat of the fish, aquarium hobbyists have had success in using cleaned, escargot shells in their tanks, provided the shells cater for the size of the fish (Seriously Fish, 2018).

Feeding: These fish will accept live and frozen feed; however, it is advisable that a varied diet is provided to maintain optimal health of the fish. Dried, processed feed will be accepted in tanks, although generally the fish prefer live and/or frozen food.

Compatibility: These fish are territorial, specifically over its shell, and small territory it maintains. It is recommended that it is paired with species that won’t challenge its shell territory, such as rock dwellers or open water species.

Breeding: These fish are harem breeders and should be kept in groups with two to three females for each male. If there are too many males, they will be excluded from the group, and will need to eventually be removed from the tank as he will not be part of the harem. It is not recommended that one male and one female are bought and paired together, as there is no guarantee that they will naturally pair up or breed (Seriously Fish, 2018).

3.2.3.2. Julidochromis

This is a small group of cichlids found naturally in Lake Tanganyika, with approximately five species falling under this genus, and several variants or sub-species that have emerged over time. These are small to medium size fish, which are generally found in deeper waters, and rocky areas of Lake Tanganyika.

Julidochromis Overview

Size	12 – 13 cm
Water Temperature	22.2 – 26.7°C
pH	7.8 – 9.5 (very alkaline)
Hardness	10 -13 dH
Lifespan	5-8 years
Diet	Omnivore
Breeding ratio	One male to two or more females. In some cases, fish will pair up.
Minimum Tank Size	75 litres (for a pair)

Adapted from (Animal World, 2015)

It is important to mimic the natural conditions of Lake Tanganyikan. The lake is rich in oxygen, thus tanks should be equipped with bubblers to maintain oxygen levels, as well as have good water movement and strong, efficient filtration in place. Maintaining a pH of above 7 is key for fish health, as the natural pH of the lake is very hard. These cichlids are adaptable for aquarium/tank conditions if efforts are made to make them as close to the natural conditions as possible. They are substrate spawners, however they tend to spawn in caves.

Feeding: These fish will accept live and frozen feed; however, it is advisable that a varied diet is provided to maintain optimal health of the fish. Dried, processed feed will be accepted in tanks, although generally the fish prefer live and/or frozen food. Meaty food should make up at least half of their diets.

Compatibility: *Julidochromis* can do well in community cichlid tanks, and can also be kept as single fish, or in groups of several breeding pairs. Other Tanganyika cichlids of similar sizes are recommended tank mates; however, it should be noted that they will not tolerate their own offspring when they reach adulthood. As they are substrate spawners, it is not recommended that Plecostomus are stocked in the tank, as they will eat the fry at night (Animal World, 2015).

Breeding: *Julidochromis* are egg layers that form monogamous pairs, and nuclear families. They are sheltered substrate spawners and prefer laying eggs in caves. It is advisable that juveniles are bought together in groups of six to ten fish and allowed to pair off naturally. Once they are paired up, the male will establish a territory in the tank around a specific cave or crevice, care should be taken to remove other cichlids if the tank is not large enough for each pair to have a territory. *Julidochromis* fry are slow growers and will reach approximately 2 cm in size over a two-month period. Generally, *Julidochromis* are easy breeding fish, and fry survival rates can be increased if fry are removed from the main tank and raised with careful monitoring and maintenance of water and tank conditions (Animal World, 2015).

3.2.4. South American Cichlids

South American Cichlids are also known as “New World” cichlids and include the central American and American dwarf cichlids. It is estimated that South and Central American cichlids can be divided into 570 species. These fish are attractive and come in various sizes and colours, making them popular in freshwater aquariums. South American Cichlids can be divided into three categories, namely:

1. **Large South American Cichlids:** The are ideal for large show tank aquariums because of their temperaments, sizes, and personalities. Tank sizes of 260 litres or more are recommended.
2. **South American Dwarf Cichlids:** These fish are small cichlids that reach 10 cm or less in size. They generally have attractive colours and patterns and can be placed in tanks of 75 litres. These fish are somewhat shy and delicate in comparison to other cichlids; thus, they are not recommended to beginner cichlid keepers.
3. **Unique South American Cichlids:** These cichlids include fish such as Discus, and Angelfish as well as Blood Parrot and Flowerhorn Cichlid, which are very unique cichlid hybrids.

Oscar Cichlid (*Astronotus ocellatus)* is a large, boldly coloured cichlid, which have become well known in freshwater aquariums. While Oscars can be bred commercially, the wild caught Oscars are still popular, and widely available on international markets. These fish should not be kept with other fish species, as they are predatory, and will eat other fish in the tank (Animal World, 2015).

Oscar Cichlid Overview

Size	Up to 35 cm
Water Temperature	22 – 25°C
pH	6.5 to 7.2
Hardness	5 – 10 dH
Lifespan	10 years or more
Diet	Omnivore
Breeding ratio	Usually pairs
Minimum Tank Size	400 litres or large (depending on number of fish)

Adapted from (Animal World, 2015)

Ram Cichlid (*Mikrogeophagus ramirezi)* is a small, peaceful cichlid variety. The Ram cichlid can be found in in several colour variations, and through selective breeding the variety has evolved to include other cichlids such as Electric Blue Ram, Gold German Ram, and Blue Ram to name a few. Although breeding has been beneficial for aquarium owners, over time it has led to smaller fish, with weaker colour displays as well as complications with the fry, which makes sourcing good quality Ram Cichlids somewhat challenging.

Ram Cichlid Overview

Size	5 – 7 cm
Water Temperature	25.6 – 29.4°C
pH	6.0 to 7.5
Hardness	6 – 14 dH
Lifespan	Up to 4 years
Diet	Omnivore
Breeding ratio	Usually pairs
Minimum Tank Size	38 litres

Adapted from (Animal World, 2015)

Golden Severum Cichlid (*Heros Severus)* is a relatively small cichlid, that closely resembles the larger Discus cichlids. Naturally the fish is greenish in colour, however through captive breeding the fish is now mostly found with yellow colouring. Apart from the golden Severum, several colour varieties can be found in the freshwater ornamental industry. Like other cichlids, the most important aspect is water quality and management, as poor water quality can result in increased risk of disease, shorter lifespans and generally an unhappy tank environment (Animal World, 2015).

Golden Severum Cichlid Overview

Size	Up to 19 cm
Water Temperature	23.3 – 28.9 °C
pH	6.0 to 6.5
Hardness	4 – 6 dH
Lifespan	Up to 10 years
Diet	Omnivore
Breeding ratio	Usually pairs
Minimum Tank Size	170 litres

Adapted from (Animal World, 2015)

3.2.5. Corydoras Catfish

Corydoras Catfish (*Corydoras spp)* are popular and hardy fish in freshwater aquariums. There are several Cory catfish types, including Bronze Cory Catfish, Bandit Cory, and the Julii Cory to name a few. The Bronze Cory is one of the more well recognised corys in the aquarium industry. As Cory catfish are bottom dwellers, tanks should have adequate gravel or substrate (approximately 6 cm deep) on the tank bottom. While Cory Catfish are low maintenance fish, they require very stable environmental conditions, specifically for breeding to occur successfully (Aquatic Community, 2006).

Corydoras Catfish Overview

Size	5 to 7 cm
Water Temperature	22 – 26°C
pH	6.5 to 7
Hardness	5 – 10 dH
Salinity	Not tolerant of salinity
Lifespan	5 years
Diet	Mainly vegetarian
Breeding ratio	2 females to 1 male
Minimum Tank Size	+/- 115 litres

3.3. Egg Scattering Fish

Egg scatterers breed either by spawning in pairs, or in some cases groups. Males and females will release sperm, and spermatic fluid of the male and the eggs at the same time. These mix together, and the eggs will be fertilised. The fertilised eggs are then broadcast or spread into plankton, float away or sink to the bottom. Egg scattering fish species don't care for their eggs, thus large amounts of eggs are produced. A key disadvantage of this reproduction method is the low survival rate from larvae to adult stage (Lende & Khileri, 2018).

3.3.1. Common Goldfish

Goldfish (*Carassius auratus)* are one of the most commonly kept freshwater ornamental species globally. The goldfish is a member of the carp family and is native to East Asia. The original goldfish is a green to olive colour; however, through years of cross breeding, producers have been able achieve the gold or more yellow colour of the carp. Although the goldfish is one of the most commonly kept pets in South Africa, approximately 85% of the fish are imported from the Far East and Israel.

Goldfish Overview

Size	10 cm in tanks. Larger ponds/tanks can reach 30 cm
Water Temperature	18.3 – 22°C
pH	6 -8
Hardness	5 -19 dH
Dissolved Oxygen	5 – 7 ppm
Lifespan	5 -10 years
Diet	Omnivore
Breeding ratio	1 male to 2 females
Minimum Tank Size	57 litres

Adapted from (Animal World, 2015)

Feeding: Goldfish are omnivores, and will accept fresh, frozen or flake foods. To ensure they receive a balanced diet, it is recommended that high-quality foods are used, specifically flakes.

Breeding: Common goldfish are egg layers, that spawn readily in optimal conditions. Goldfish typically reach sexual maturity when they are 10 to 12 months old. Breeding tanks should be established to mimic natural conditions, and provision for solid surfaces, oxygenating plants and vegetation should be made. The water temperature should be dropped to 11°C, and then slowly increased at a rate of 2°C per day until the goldfish spawn. Spawning lasts up to three hours, and females can produce 10000 eggs at a time. Parents should be removed from the breeding tank as they can have tendencies to eat the eggs, thus posing a risk to the eggs. Eggs hatch in four to seven days depending on the tank conditions and water temperature (Animal World, 2015).

Compatibility: Unlike cichlids, common goldfish can be kept with other goldfish varieties, and Koi. Goldfish generally produce more waste than other fish, thus water changes and water quality must be monitored, especially if other tank mates are sensitive to water changes (Animal World, 2015).

3.3.2. Koi

Koi is a variety of carp that has been selectively bred for its colouring and markings, and more specifically the aquarium trade. While Koi are similar to Goldfish, as they are from the same family, Koi require much larger water volumes, and due to selective breeding and specific colourings, can fetch much higher prices than goldfish. Koi originate from Japan, and are native to Asia and Central Europe, and are classed as ornamental or decorative fish. Koi are kept in large ponds, as they require large volumes of water and space due to their size and growth. The ponds should provide clean, well oxygenated water that supports the growth and development of the fish. The larger the volume of water, the more stable the water conditions will be, specifically with regards to water temperatures in outdoor ponds (Koi Ponds Care, 2018).

Koi Overview

Size	92 cm or larger
Water Temperature	15-25°C
pH	6.5 – 7.5
Hardness	5-15 dH
Dissolved Oxygen	7 – 9 ppm
Lifespan	20 years or more
Diet	Omnivore
Breeding ratio	One male to two females
Minimum Tank Size	Adult Koi - +/- 3785 litres

Adapted from (Fishlore, 2018)

Feeding: Koi are omnivores and require a high quality and varied diet for optimum growth and development of colours. Care should be taken if feeding live feed as it can increase the risk of bacteria and parasitic infections in koi ponds (Fishlore, 2018).

Breeding: Breeding Koi in pond setups can be challenging as they are known to eat their eggs. Suitable spawning sites must be setup in the ponds, and the fish should receive a high-quality diet which will assist them with spawning. Over a period of a few weeks, the fish should slowly receive increasing amounts of protein. Koi typically reach sexual maturity at two years of age. If younger Koi are used for breeding, the fry are typically weaker, and have been known to be of lower quality, and more at risk of being affected by diseases.

Compatibility: Koi due to their size are generally not kept with other fish. In breeding season, the koi become more aggressive, and in some cases males and females may be separated.

3.3.3. Tetras

There are over 700 known species of tetras, ranging in sizes from super small to super large. The smaller tetras are well known in the aquarium industry and are popular additions to freshwater tanks. For this study, the Neon Tetra was looked at in more detail, however the information will be applicable to most of the other tetra varieties.

Neon Tetra Overview

Size	4 cm
Water Temperature	20 - 25°C
pH	5 - 8
Hardness	3 -25 dH
Lifespan	5-8 years
Diet	Omnivore
Breeding ratio	School of fish with minimum of 5 fish. 2 females for every male
Minimum Tank Size	38 litres

Adapted from (Animal World, 2015)

Feeding: As omnivorous fish, neon tetra will eat small or finely ground foods, both live, fresh and flakes. Shrimp or blood worm can be fed to tetras on occasion. Tetras can be fed several times a day, however they should only receive small amounts of food, typically what they consume in three minutes or less at each feeding.

Breeding: Neon tetras have been bred in captivity, however they are not considered an easy species to breed. Tank conditions are essential for tetras to breed, as soft, acidic water is required, and breeding tanks should be sterilised, as well as all equipment and tank decorations. The tetras typically spawn in the morning, and females will lay up to 130 eggs at a time. Once the eggs have been laid, the parents will eat them, thus it is best they are removed from the breeding tank. Both eggs and fry are light sensitive, and eggs are prone to fungus, thus low light is required for tetra eggs and fry development. Eggs will hatch within 24 hours, and the fry will be free swimming in approximately four days. Tetra are often unwilling to breed in home aquariums which makes commercial production challenging (Animal World, 2015).

Compatibility: Tetras are ideal for community tanks as they are peaceful fish. They should be kept with larger or aggressive fish such as angel fish. Good tank mates include corydoras catfish, peaceful barbs and small rasboras (Animal World, 2015).

3.3.4. Barbs & danios

Barbs and Danios form part of the largest order of fresh-water species the *Cyprinidae* family, with over 2000 species. Barbs and Danios are popular schooling fish for aquariums and community tanks. The goldfish (discussed above) also belongs to this large family of species. Barbs and Danios are typically recognised by the small barbels found in the corner of their mouths, only very few of the species do not have these barbs.

Barbs

Barbs are small, hardy freshwater aquarium favourites. They are very social fish, and don't have very particular feeding or water requirements. Barbs can be found in several varieties and colours; however, their production requirements are very similar. The overview below is a general species overview; however, each species may have slightly different temperature and pH requirements which should be considered.

Barb Overview

Size	5 cm
Water Temperature	22.8- 26.1°C
pH	6.5 – 7.0
Hardness	2 – 18 dH
Dissolved oxygen	6 ppm
Lifespan	4 -7 years
Diet	Omnivore
Breeding ratio	One male to two females
Minimum Tank Size	38 litres

Adapted from (Fishlore, 2018)

Danios

There are several Danio variations that have been selectively bred for the aquarium trade, with varieties that suit every hobbyist needs. Some of these varieties include the Zebra Danio, and colour morphs such as the Golden and Albino Zebra danio, Longfin Blue Danio and Sandy Zebrafish. Recently, a Zebrafish has made its way on to the market. This variation is a genetically modified fish available in fluorescent colours of red, blue, green, orange – yellow and purple.

Danio Overview

Size	5 - 6 cm
Water Temperature	17.3- 23.9°C
pH	6.0 – 8.0
Hardness	2 – 20 dH
Dissolved oxygen	6 ppm
Lifespan	3.5 -5 years
Diet	Omnivore
Breeding ratio	One male to two females
Minimum Tank Size	38 litres

Adapted from (Animal World, 2015)

Feeding: As omnivores Barbs and Danios, feed can be live, fresh or flakes, however high-quality feed is of importance to ensure optimal growth and condition of the fish. Barbs can be fed several times a day, however they should only receive small amounts of food, typically what they consume in three minutes or less at each feeding.

Breeding: Barbs and Danios are egg laying fish, and will typically spawn in areas with dense vegetation, where they can deposit their eggs. Barbs and Danios are considered fairly easy to breed, and the fry do not present many challenges during their life cycles. Barb females typically lay up to 300 eggs at a time. Barbs do not care for their eggs and should be removed from the breeding tank as they will eat their eggs. Danios typically form breeding pairs that are lifelong. Sexual maturity of Danios is reached when the fish are approximately 10 to 12 weeks old, and typically when tetras are 9 months old.

3.3.5. Gourami's

Gourami's can be classified as Labyrinth fish, along with other species such as Betta (Siamese Fighters) and Paradise Fish. These fish have an additional respiratory organ known as the "labyrinth organ" which gives them the ability to breath oxygen.

Gouramis are split into three main groups, namely the Gourami family (*Osphronemidae),* Climbing Gouramis (*Anabantidae)* and Kissing Gouramis (*Helostomatidae)* (Animal World, 2015). As there is a huge variety of gourami fish, the Blue Gourami will be used to give an overview of the species, however each species may have slightly different production requirements and conditions (Animal World, 2015).

Blue Gourami's Overview

Size	15 cm
Water Temperature	22.8-27.8°C
pH	6 – 8.8
Hardness	5 – 35 dH
Dissolved oxygen	6 – 7 ppm
Lifespan	4-6 years
Diet	Omnivore
Breeding ratio	Usually pairs
Minimum Tank Size	132 litres

Adapted from (Animal World, 2015)

Feeding: Gouramis are omnivores, and in the wild feed on insect larvae, crustaceans, and zooplankton. In aquarium setups, these fish will accept live, fresh and flake foods, however the quality of the food is of key importance. Supplementation can include blood worm, brine shrimp or other suitable substitutes (Animal World, 2015)

Breeding: Blue Gouramis are bubble nest builders like most other fish in this family, which typically means the male fish will build a large bubble nest, where the female will then deposit her eggs in. Blue Gouramis typically reach sexual maturity when they reach 4 to 8 months of age, which can differ according to the environmental or tank conditions. Female Gouramis can produce 700 – 800 eggs at a time. Tanks must be correctly setup with vegetation, a good size surface area, and must be at optimal water and temperature conditions for breeding. With Gouramis, the male usually tends the nest and guards the eggs, and as a result, the female should be removed from the breeding tank so not to be attacked by the male. After the eggs have hatched, and the fry are swimming, the male should also be removed from the tank as he may eat the fry (Animal World, 2015).

Compatibility: Blue Gourami are good community fish when they are small, however as they get older, they have been known to attack smaller fish. All gourami fish react differently in tank situations, as some are peaceful and shy, while others are aggressive. (Animal World, 2015).

3.4. Mouth Brooder Fish

Mouthbrooder fish can be thought of as being highly advanced from an evolutionary perspective. These fish, unlike other species protect their young during the vulnerable development stages by brooding them in their mouths. Typically, once the male has fertilised the eggs, the female will pick up the eggs and incubate them in her mouth for 21 to 36 days depending on the water temperature, and fish species. Once the egg yolk sac has disappeared and the fry are free swimming, the female will release them out her mouth. In some cases, select species such as the African cichlid continue to care for the fry, and keep them safe in their mouth should danger present itself when the fry are able to swim freely (Elieson, 2018).

3.4.1. Malawi Cichlids

Lake Malawi is known to be home to some of the most colourful cichlids. Lake Malawi has far less diversity than Lake Tanganyika, with two main groups being identified as the *Haplochromines* and the *Tilapiines.* The *Haplochromines* group contains almost 99% of the Malawi cichlids, and can be further divided into three groups, namely *Mbuna, Haplochromis* and *Astatotilapia.* For this report, the Mbuna and Haplochromis group, specifically peacock cichlids will be covered (Animal World, 2015).

3.4.1.1. Mbuna Cichlids

Mbuna cichlids, or more commonly known as Zebra cichlids are endemic to Lake Malawi. These fish are very active and aggressive and are well known in the freshwater ornamental fish industry. “Mbuna” refers to “rockfish” as these cichlids are found along the rocky shores of Lake Malawi. Mbuna cichlids live among the rocks, and feed on algae, insects and crustaceans found on the rocks. The group consist of approximately 12 genera, with Zebra Cichlids being some of the most popular rock-dwelling Mbuna fish (Animal World, 2015). Zebra cichlids are amongst the most popular Mbuna group, with some key zebra cichlids being the Kenyi Cichlid, Red Zebra, Blue Daktari, and Demanson’s Cichlid to name a few.

Mbuna Cichlid Overview

Size	10 -13 cm
Water Temperature	22.8 – 27.8°C
pH	7.7 -8.6
Hardness	6 -10 dH
Dissolved oxygen	6 ppm
Lifespan	Up to 10 years
Diet	Omnivores
Breeding ratio	One male to several females
Minimum Tank Size	180 litres

Adapted from (Animal World, 2015)

Feeding: As an omnivore, these fish feed primarily on algae, as well as plankton, crustaceans and invertebrates found in the rocks they live in. In captivity, these fish will accept frozen or live protein sources (shrimp etc.), as well as flakes, pellets, and spirulina. Other feed options include blood worm or live feeder guppies.

Breeding: Typically, each Mbuna ‘family’ will be made up of a male and several females. Breeding males will establish a small territory in the tank and protect it fiercely. The females require enough room in the tank to evade the breeding males and move out of their territory as the males typically continue to breed even when the female is ready to lay eggs (Animal World, 2015).

Compatibility: Mbuna cichlids are not considered to be community fish as they are aggressive. They should be kept in groups of one male to several females in a large tank. Species specific tanks should be maintained, specifically if breeding Malawi cichlids.

3.4.1.2. Peacock Cichlid

Peacock cichlids from Lake Malawi are known for their brilliant colouring, and more amicable nature in comparison to other cichlids. There are an estimated 28 species, with several subspecies. The Haplochromis group is made up of an estimated 213 species, of which Peacock cichlids (*Aulonocara* genus) has approximately 23 species (Animal World, 2015).[1]

Peacock Cichlid Overview

Size	10 -23 cm
Water Temperature	22.8 – 27.8°C
pH	7.7 -8.6
Hardness	6 -10 dH
Dissolved oxygen	6 ppm
Lifespan	8 - 10 years
Diet	Omnivores
Breeding ratio	One male to four to six females
Minimum Tank Size	208 litres

Adapted from (Animal World, 2015)

Feeding: Peacock cichlids are primarily carnivorous, and will feed on plankton, larvae, and crustaceans in their natural environment. In captivity they are easily adapted to a flake or pellet diet that should be supplemented with some meaty items. Pelleted, frozen or live food such as daphnia, bloodworm and shrimp are recommended as meaty sources for the cichlids (Animal World, 2015).

Breeding: Peacock cichlids have been successfully bred in captivity and are easy breeding fish. These fish generally tend to their young, making the breeding process somewhat less complicated than other species of fish discussed above. It is recommended that breeding groups are kept in their own tank to avoid aggression between fish guarding their fry and other fish in the tank. Peacock cichlids generally spawn in caves or shelters in the tank, thus limited data or research is available on their actual spawning processes. As mouth brooders, the female will carry the eggs in her mouth until they hatch, and the fry are large enough to feed on their own (Animal World, 2015).

Compatibility: Peacock cichlids although more peaceful than other cichlids, should either be kept singly in tanks of 208 litres or more, or as a group of one male and several females in a tank larger than 283 litres. These fish are peaceful with the same species, provided there is only one male, or large enough tank to support two males with their own territories (Animal World, 2015).

[1] *The latest NEMBA AIS classification list Peacock cichlids as potential category 2 species, thus permits would be required for production if the classifications are finalised. As of March 2018, the document was out for public comment.*

4. Potential Culture Systems for Marine and Freshwater Ornamental Fish

The following section looks at potential culture systems that could be considered for marine and freshwater ornamental fish production in South Africa. The potential production systems identified are considered in the generic economic model to determine the financial feasibility of each system from an economic perspective. Each production system is unique in terms of the infrastructure requirements and operational costs. The potential culture systems that could be used to culture ornamental fish in South Africa include the following:

4.1. Recirculating Aquaculture System

The Recirculating aquaculture system (RAS) offers a dual objective of sustainable aquaculture, (i.e. to produce food while sustaining natural resources) which is achieved through the minimum impact the system has on its surrounding environment and the eco-system in general. The RAS system, is sometimes referred to as indoor or urban aquaculture, reflecting its independency of surface water to produce fish. Water recirculating methods of aquaculture production is ideally suitable for areas with scarce water resources. The capital investment for farm construction is normally much higher for RAS systems, when compared to that of conventional aquaculture systems. As such, the system should be designed and constructed in a way that it would be managed at less running costs, to compensate for the initial capital investment. The RAS is classified as an intensive farming method and can be used to produce ornamental fish in tanks. This production system is considered to be suitable for both freshwater and marine ornamental fish as it allows for several species to be produced simultaneously. Fish can either be in the same tank (polyculture) or more commonly in different tanks (monoculture). The RAS offers producers the opportunity to establish ornamental production activities on a small, medium, or large scale depending on the aim of the producer and allows producers to produce fish that would not be suitable for more extensive production methods.

By making use of the RAS for ornamental fish production, producers can control the production of fish and be able to supply ornamental fish throughout the year, as well as have different size fish available at various times throughout the year. As the climate in South Africa varies throughout the year, a RAS is typically established indoors (shed, warehouse etc.) or under greenhouse tunnels which assists with temperature control and operating expenses (Helfrich & Libey, 2013). Typically, with ornamental fish, various tanks will be required for each stage of the fish life cycle (i.e. breeding/egg laying, larval rearing, fry and grow-out), as the phase from egg to fry is high risk, and requires special attention, as well as separation from the parents, who in most cases will eat the eggs and/or the fry. Tank sizes should be tailored to meet the requirements of the fish, depending on the size of the fish, the volume of water best suited for the fish and the stocking density that must be achieved (Upfold, 2018).

From technical assessment received, out of the nineteen-species discussed above, the following species can be cultured in a RAS:

- **Freshwater Ornamental Fish:** Tetras, Barbs & Danios, Gouramis, Angels, Catfish (Antricus and Corydoras), Cichlids (South American, Tanganyikan, Malawi), Guppies, Platys, Swordtails and Mollies.
- **Marine Ornamental Fish:** Clownfish, Dotty backs, Angel fish and Yellow Tangs.

Advantages of using the recirculating aquaculture systems

I. RAS generally requires less area and water than other conventional aquaculture systems,
II. Offers producers polyculture or monoculture options depending on species being produced,
III. Offers year-round production when done under tunnel systems in South Africa,
IV. The system allows for intensive aquaculture production to be undertaken on a smaller footprint,
V. RAS provides opportunities to reduce water usage, improve waste management and increase nutrient recycling,
VI. RAS allows for better hygiene, disease management, biological pollution control and reduction of visual impact of the farm, and
VII. Allows for good biosecurity control and management.

Disadvantages of using the recirculating aquaculture systems

I. The operation of the system requires some level of skills and expertise,
II. Not suited for all species - Koi and Goldfish are not suited for RAS,
III. There are many different bio filtration systems involved in operating the systems. Filtration needs must match species requirements,
IV. Large capital investment is required for building and starting up facilities,
V. Managing disease outbreaks may pose specific challenges in RAS, in which a healthy microbial community contributes to water purification and water quality, and
VI. Minerals, drug residues, hazardous feed compounds and metabolites may accumulate in the system and affect the health, quality, and safety of the fish.

4.2. Flow Through Systems

Within a flow-through system, grow-out tanks are continuously refreshed with large quantities of new water, usually gravity-fed from nearby streams, rivers or directly from the sea. The most essential features of flow-through aquaculture systems are therefore the rapid removal of wastes, the continuous replenishment of the system with highly oxygenated water, as well as a sloping topography. Flow-through aquaculture systems require water exchange to maintain suitable water quality for fish production and rely on water flow for the collection and removal of metabolic wastes.

Water for flow-through facilities is usually diverted from the ocean, streams, springs, or artesian wells to flow through the farm by gravity. Water pumped from wells or other sources is more expensive and are seldom used. However, water diverted from springs or surface sources for flow-through aquaculture might require an application for water rights as well as compliance with certain regulations. The discharge of a high-volume, dilute effluent from flow-through aquaculture facilities greatly limits the treatment options available to producers from both technological and economic perspectives. Concrete raceways are the most common in flow-through systems. Circular rearing tanks are also used in flow-through systems, most commonly for brood stock production.

Flow- systems for ornamental production are currently being utilised in South Africa. On a large scale this can be seen in practice at the Two Oceans Aquarium in Cape Town, and to a certain extent at uShaka Marine World in Durban, who make use of semi-closed RAS, which incorporates some aspects of flow-through into a standard RAS to account for water exchange (Upfold, 2018).

Advantages of using the flow through system

I. Allows for improved water quality – constant movement of waste and oxygen through the system,
II. Offers degree of control over the system,
III. Marine ornamental systems can be land based if system has access to seawater,
IV. Systems can be designed according to species & farm conditions (round/rectangular etc.), and
V. Systems can be adapted for various farming scales (small/medium/large).

Disadvantages of using the flow through system

I. The success of operating a flow-through system depends on natural conditions and environmental events,
II. The system water source can get easily polluted or contaminated,
III. The diluted waste from the system can also have an inadvertent influence on the downstream habitat,
IV. The system is high-tech driven, thus requires a lot of energy which is not cost effective,
V. Water discharged from flow-through tank systems may pollute receiving waters with nutrients and organic matter, and
VI. The discharge of effluent water may require a permit from the Department of Water Services (DWS) for freshwater ornamental fish or from the Department of Environmetal Affairs (DEA) for marine ornanamentals, with required periodic testing and oversight.

4.3. Raceway Systems

Raceways for fish culture are series of tanks (rearing units) which are relatively shallow and continuously supplied with high-water flow (usually along the long axis), to sustain aquatic life. A typical raceway culture system consists of a long and narrow canal of concrete with a water inlet and outlet to maintain a continuous flow of fresh or salt water. With water continuously flowing through the canal, the water quality should be of a high quality, and allow for fish to be cultured at high densities. In an ideal raceway system, water flow is at an almost approximately uniform velocity across the tank cross section. However, friction losses at the tank-water and air-water boundary layers causes water velocities to vary across the width and depth of the raceway. Circular rearing units are more thoroughly mixed and have relatively uniform environmental conditions throughout the tank. The basic structure of raceways should be designed in a way that none of the parts of culture waters are stagnant in the tanks, otherwise debris or faeces would be accumulated in locations, thereby deteriorating water quality, or causing outbreaks of disease in the system. As such, the primary factor to be considered in raceway construction is the water sources available. When water sources available are sufficient to support all the system, the raceways can be located across the water current.

Throughout Israel, raceway culturing is widely used for ornamental production, typically small raceways of up to six metres in length are used. From technical assessments and stakeholder consultations, it was identified that raceways have been successfully used in South Africa in the past, however challenges related to water availability and access, as well as identifying suitable sites is a major challenge. Currently there is very limited data available on the use of raceway systems.

Further investigation and research should be conducted to understand how Israel has made a success of the industry using raceway systems.

Advantages of using the raceway system

I. Stocking densities for raceways are usually higher than for other culture systems,
II. The labour cost associated with cleaning, grading, moving and harvesting is significantly lower,
III. Raceways offer a much greater ability to observe the fish. This can make feeding more efficient,
IV. Disease problems are easier to detect and at earlier stages in raceway systems . Also, disease treatments in raceways are easier to apply and require fewer chemicals than a similar number of fish in a pond (due to the higher density in the raceway),
V. Raceways also allow closer monitoring of growth and mortality and better inventory estimates than ponds,and
VI. Management inputs such as size grading are much more practicable in raceways when compared to other culture systems like ponds, and harvesting is also easier.

Disadvantages of using the raceway system

I. The required hydrological conditions for the construction of raceways limit the number of sites where a farm could be constructed,
II. The need for large constant flows of consistent, high-quality water can pose a challenge in water scarce areas or during a drought period,
III. Locating and securing a proper water supply is a major consideration,
IV. Commercial viability often requires that the water gravity flows through a series of raceways before it is released. This adds a requirement for an elevation of the water source and suitable topography for the gravity flow between raceways,
V. The release of large volume of effluent with low retention times is another major limitation of raceways, and
VI. Raceway aquaculture is generally high-tech and high risk as problems can develop rapidly if the system fails.

4.4. Pond Culture Systems

When considering pond culture for ornamental production, it is important to note that out of the fifteen freshwater ornamental and four marine ornamental species presented in Sections Two and Three, only Koi, Gourami's and Goldfish are suited for pond culturing. Pond culturing is not recommended for freshwater ornamental fish, aside from Koi and Goldfish, as pond culturing diminishes the genetic and breeding control producers have, and as a result over time the strain being cultured can be lost.

As discussed in the species overviews, each fish has unique temperature and water condition requirements, which can be challenging to manage and stabilise in pond environments. Other challenges with pond culture including harvesting and sorting, specifically of smaller species such as Tetra. Species such as cichlids are not suited for pond culturing, as they are very territorial and if there is limited to no control in the pond environment this could lead to cannibalism and high levels of stress within the fish (Upfold, 2018).

Koi, Goldfish and Gouramis are well suited to pond culture due to their need for space, specifically for Koi, as well as their ability to withstand fluctuating water temperatures, and water conditions to a certain degree. Goldfish can be stocked at a density of approximately 50 fish/m^3, Gouramis at 75 fish/m^3 and Koi at 25 fish/m^3. Although these three species are suited for pond culturing, it is not recommended they are stocked in the same pond. Koi and Goldfish can be compatible when juveniles, however once the Koi outsize the goldfish, they have been known to eat the goldfish (Upfold, 2018).During stakeholder consultations , it was identified that on some occasions Guppies are added to goldfish and koi ponds, however the guppies are often eaten by the larger fish, which would be problematic if trying to produce guppies on a large scale in the same pond system.

Marine ornamental fish are not suited for pond culture as the quantity of seawater required is unsustainable in pond environments. Most marine fish species are not euryhaline, and thus the use of estuary water is not suitable for pond production (Urban-Econ, 2018).

Advantages of using pond systems

- Koi and goldfish are more suited to pond culturing -space for growth & water conditions,
- Ponds can be specifically designed to shape, size and depth depending on space avalibaility,
- Low technology requirements – reduced operational and capital expenditure,
- Non-productive land can be utilised for fish ponds,
- Fish can grow in 'natural' conditions, and
- Ponds can be designed depending on scale of production (small-scale/commercial etc.).

Disadvantages of using pond systems

- Breeding and genetic control is limited,
- Females and males may need to be seperated to ensure females are not stressed or harassed by the males, specifically with koi production,
- Control of water conditions (temperature, pH,hardness and oxygen) can be challenging,
- Disease control is challenging in ponds, as one fish or use of live feed can infect all stock within the pond,
- Harvesting of fish can be challenging,
- Pond preparation is lengthy and costly,
- Fish montoring and management is more difficult in pond systems,
- Water quality must be well maintained as feed and waste can accumluate and affect pond conditions,
- Draining and cleaning ponds can be problematic if ponds are incorrectly designed, and
- Cannabilism can be a problem if different size fish are kept in the same pond (Upfold, 2018).

4.5. Culture System Summary

Having presented the advantages and disadvantages of various culture systems for ornamental production in South Africa, Table 4-1 below provides a summary for each production system based on the literature discussed. An indication of whether the system is viable or non-viable for ornamental production in South Africa is provided. Based on the system status, the generic economic model was developed to provide additional insight into the financial viability of the potential systems, which is discussed in the Financial Analysis.

Table 4-1: Ornamental Fish Production Systems Summary

System	System Overview	System Status
Pond Culture	I. Not suited for marine ornamental fish II. Only suited for few freshwater ornamental fish species III. Provides ideal culture environment for goldfish and koi IV. Minimal technology & infrastructure required	Viable for Koi, Goldfish and Gourami's
Cages	I. Not data/information on this system being tested in South Africa II. Size of ornamental fish may pose a challenging when designing cages for culturing III. Ornamental fish are harvested and sorted at different sizes this would be difficult if using cage culture IV. Less control of environmental conditions V. Ideal locations for cage culture is limited in South Africa	N/A
Aquaponics	I. Not suited for marine or freshwater ornamental fish II. Freshwater ornamental fish– nutrient output of fish is too low for plant production III. Marine ornamental fish – Salt water systems not suitable	Non-viable
RAS	I. Tested and utilised in South Africa II. Offers poly or mono culture options III. Great aspects of control – water conditions, temperature, breeding and harvesting IV. Good biosecurity control and management V. Disease can be issue – loss of all fish stocks has occurred in RAS	Viable
Flow-through systems	I. Limited literature avaliable on flow-through systems II. South African aquariums use a combination of Flow-through & RAS – semi open flow-through system III. Requires high volumes of water & well designed systems IV. System allows for good quality water to be mainatained as waste is rapidly removed	Viable
Raceways	I. Tested and utilised in Israel II. Current not ideal for smaller fish species III. Maintaining water temperature & conditions challenging with water exchange in raceways IV. Water access and site selection make use of this system challenging in South Africa	Potentially viable
Ranching	I. No data/information on this system being tested locally or globally II. High risk for mortality and loss of stocks	N/A

There is limited information avaliable on ornamental fish production in South Africa, thus it is difficult to assess which systems may be the most viable options to implement. In recent years, the marine aquaculture industry has seen growth, and success in the production of marine fin fish species which although differ significantly from ornamental fish, could provide valuable information into potential systems and techniques that can be adapated and applied to ornamental production, specifically for marine ornamental fish.

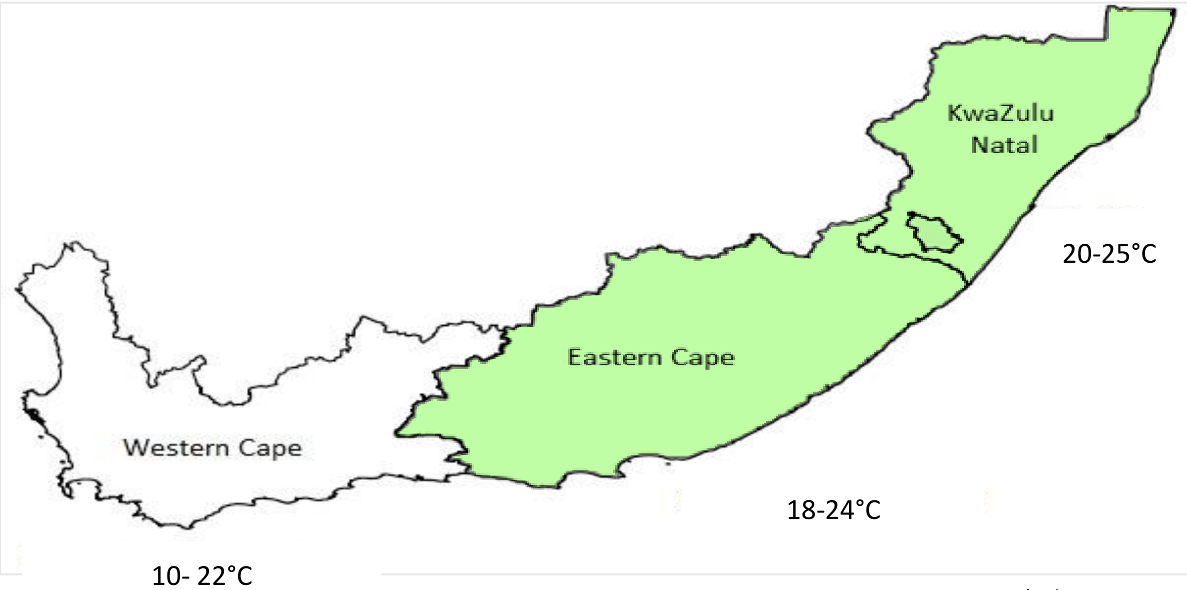
5. Geographical Distribution of Ornamental Fish in South Africa

As the climatic and geographic conditions vary across South Africa, it is important to understand where both freshwater and marine ornamental fish could be successfully produced based specifically on temperature requirements. When considering the geographic distribution of ornamental fish, temperature was the primary consideration however, aspects such as slope, water volumes and quality, soil conditions etc. need to be observed at a site-specific level. Temperature and location plays a major role in determing the profitability of an aquaculture opeartion, thus the economic model takes into consideration location at a provincial level, and makes provision for temperature variations which impact on the electricity and water consumption costs.

5.1. Marine Ornamental Fish

When considering the distribution, and potential for marine ornamental fish production in South Africa, a key factor is the proximity of the operation to the coastline, as well as water and air temperature conditions. The South Africa coastline experiences temperatures ranging from an average of 10˚C to 25°C as seen in Figure 5-1. Seasonal fluctuations may occur, however unlike air temperature, the variations within the ocean are much smaller.

Figure 5-1: Average Ocean Temperatures for the South African Coastline



Source: (Urban-Econ,2018)

When considering the four marine ornamental fish species discussed in Section Two, it is assumed that marine ornamental fish are ideally suited to the KwaZulu Natal and Eastern Cape Coastline regions as they offer warmer air and water temperatures as seen in Figure 5-1 above. Warmer water conditions provide optimal production conditions for marine ornamental fish. Although some marine ornamental species can tolerate cooler water temperatures found along the Western Cape coastline, the costs of heating water, as well as temperature fluctuations in winter months could have an impact on growth rates and survival rates. While the Eastern Cape and KwaZulu Natal do offer more favourable conditions, the Western Cape can still be considered for ornamental fish production, provided the production systems selected account for the heating of water, as well as can cope with higher operational expenditure than the warmer coastal areas.

As most marine ornamental fish are kept and raised by hobbyists, it is difficult to determine specific locations that are optimally suited for marine ornamental fish production, as this would be dependent on the species selected and the type of production systems being used. Currently there are no marine ornamental producers that can be used as a benchmark to identify the optimal production areas in South Africa.

5.2. Freshwater Ornamental Fish

When considering the freshwater ornamental fish species, they can be distributed across South Africa in terms of their temperature requirements.Table 5-1 below highlights the optimal temperature ranges.

Table 5-1: Freshwater Ornamental Fish optimal temperature range

Species	Temperature Range (˚C)	Species	Temperature Range (˚C)
1. Guppy	17 – 28	**2. Antricus Catfish**	21 – 24
3. Swordtail	22 – 28	**4. Tanganyikan Cichlid**	22 – 27
5. Platy	20 – 26	**6. South American Cichlids**	22 – 30
7. Molly	20 – 26	**8. Cory Catfish**	22 – 26
9. Angelfish	23 - 28	**10. Goldfish**	18 -22
11. Koi	15 – 25	**12. Tetra**	20 – 25
13. Barb	23 – 26	**14. Danio**	17 – 24
15. Gourami	23 – 28	**16. Malawi Cichlid**	23 - 28

Based on the table above, the following eco-regions illustrated in Table 5-2 and Figure 5-2 below may be suitable for freshwater ornamental production.

Table 5-2: Ecoregion suitability for Freshwater Ornamental Fish

Ecoregion	Temp Range (˚C)	Mean Annual Temp (˚C)	Freshwater Ornamental Species Suitability (Table 5-1)
1. Limpopo Plain	2 -32	18 - >22	All species
2. Soutpansberg	4 – 32	16 - > 22	All species
3. Lowveld	4 – 32	16 - > 22	All species
4. North Eastern Highlands	2 - 32	16 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
5. Northern Plateau	2 - 30	16 -20	1,5,7,10,11,14. *Seasonal*
6. Waterberg	2 - 32	14 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
7. Western Bankenveld	0 - 32	14 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
8. Bushveld Basin	0 - 32	14 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
9. Eastern Bankenveld	0 - 30	10 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
10. North Escarpment Mountains	0 – 30	10 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
11. Highveld	-2 - 32	12 - 20	1,5,7,10,11,14. *Seasonal*
12. Lebombo Uplands	6 -32	18 - >22	All species
13. Natal Coastal Plain	8 – 32	20 - >22	All species
14. North Eastern Uplands	0 – 30	14 - >22	All species. *Seasonal*
15. E. Escarpment Mountains	<-2 – 28	<8 - 18	1,10,11,14. *Seasonal*
16. South Eastern Uplands	0 – 30	10 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
17. North Eastern Coastal Belt	4 – 30	16 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
18. Drought Corridor	-2 – 30	10 - 20	1,5,7,10,11,14. *Seasonal*
19. Southern Folded Mountains	0 – 32	10 - 20	1,5,7,10,11,14. *Seasonal*
20. South Eastern Coastal Belt	2 – 30	12 - 20	1,5,7,10,11,14. *Seasonal*
21. Great Karoo	0 - >32	10 - 20	1,5,7,10,11,14. *Seasonal*
22. Southern Coastal belt	4 – 30	10 - 20	1,5,7,10,11,14. *Seasonal*

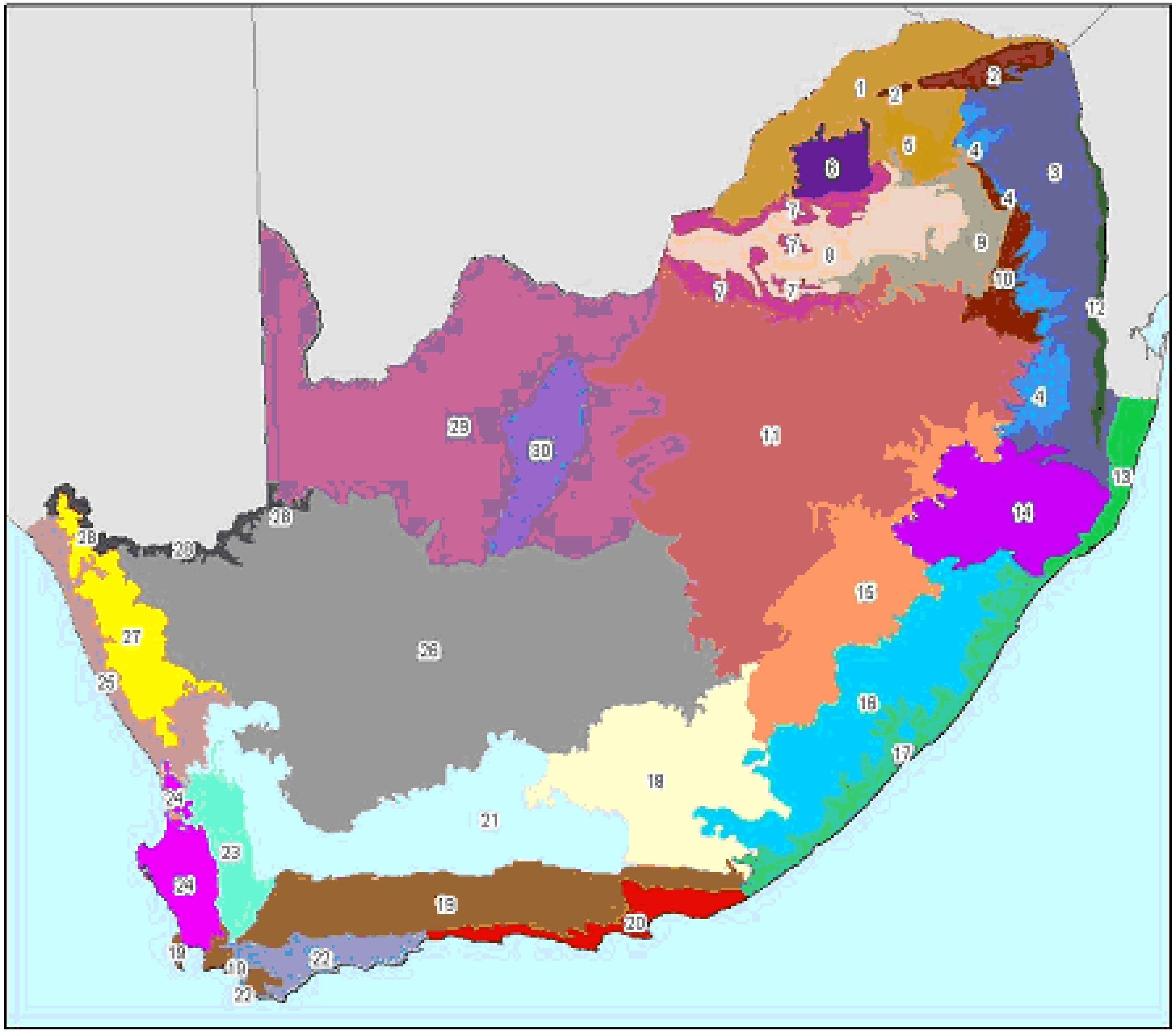
Ecoregion	Temp Range (˚C)	Mean Annual Temp (˚C)	Freshwater Ornamental Species Suitability (Table 5-1)
23. Western Folded Mountains	0 - >32	10 - 20	1,5,7,10,11,14. *Seasonal*
24. South Western Coastal Belt	4 – 32	10 - 20	1,5,7,10,11,14. *Seasonal*
25. Western Coastal Belt	2 - >32	16 - 20	1,5,7,10,11,14. *Seasonal*
26. Nama Karoo	0 - >32	12 -20	1,5,7,10,11,14. *Seasonal*
27. Namaqua Highlands	2 - 32	12 - 20	1,5,7,10,11,14. *Seasonal*
28. Orange River Gorge	2 - >32	16 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
29. Southern Kalahari	-2 - 32	14 - 22	1 ,3,5,7,10,11,12,14. *Seasonal*
30. Ghaap Plateau	0 - 32	16 -20	1,5,7,10,11,14. *Seasonal*
31. Eastern Coastal Belt	4 – 28	16 -20	1,5,7,10,11,14. *Seasonal*

Based on Table 5-1 and Table 5-2 above as well as Figure 5-2 below, it can be seen that some of the warm water freshwater species such as the various Cichlids, Catfish and Angelfish would not be able to exist naturally in South Africa based on the ecoregion temperature ranges[2]. However, through aquaculture, the temperature range can be controlled, thus water can be heated to meet the needs of all the species discussed. It is important to note that temperature variations between summer and winter are huge, thus some freshwater ornamental species may exist naturally in South Africa, however it may be seasonal within some eco-regions.

Due to the fragmented and limited data on ornamental fish production in South Africa, it is difficult to determine the most suitable regions for production, however the temperature ranges provide a good starting point. As with any aquaculture operation, care must be taken to ensure the species are not released, or cannot escape into natural water bodies, as if the conditions are well suited it could mean the ornamental fish may affect biodiversity and breed naturally within water systems.

[2] *It should be noted these temperature ranges are based on air temperature, and not water temperature conditions*

Figure 5-2: South African Temperature Based Ecoregions



Ecoregions of South Africa: Level 1

Legend

1 LIMPOPO PLAIN
2 SOUTPANSBERG
3 LOWVELD
4 NORTH EASTERN HIGHLANDS
5 NORTHERN PLATEAU
6 WATERBERG
7 WESTERN BANKENVELD
8 BUSHVELD BASIN
9 EASTERN BANKENVELD
10 NORTHERN ESCARPMENT MOUNTAIN
11 HIGHVELD
12 LEBOMBO UPLANDS
13 NATAL COASTAL PLAIN
14 NORTHERN EASTERN UPLANDS
15 EASTERN ESCARPMENT MOUNTAINS
16 SOUTH EASTERN UPLANDS
17 EASTERN COASTAL BELT
18 DROUGHT CORRIDOR
19 SOUTHERN FOLDED MOUNTAINS
20 SOUTH EASTERN COASTAL BELT
21 GREAT KAROO
22 SOUTHERN COASTAL BELT
23 WESTERN FOLDED MOUNTAINS
24 NAMA KAROO
25 WESTERN COASTAL BELT
26 NAMA KAROO
27 NAMAQUA HIGHLANDS
28 ORANGE RIVER GORGE
29 SOUTHERN KALAHARI
30 GHAAP PLATEAU

Version 2, September 2003
Contact person
MoolmanJ@dwaf.gov.za
Albers equal area projection
Central meridian 24
Standard parallels •18, •32
Cape datum

5.3. Key Location and Site Requirements

Based on the table below, the following location and site requirements should be considered for freshwater and marine ornamental fish.

Table 5-3: Ornamental Fish Location & Site Requirements

Marine Ornamental Fish	Freshwater Ornamental Fish
1. Coastal areas – access to seawater, 2. Warmer conditions as marine fish generally are tropical species, 3. Reasonable energy costs, 4. Waste management plan or system, 5. Access to markets – travel time for fish is important to consider, 6. Access to inputs (feed) & materials (buildings etc.), 7. Site should be secure to reduce theft & access, and 8. Surrounding land uses should be considered - factories, farming, mining etc. can affect water sources.	1. Slope – level ground, 2. Access to good quality water, 3. Adequate water supply, 4. Reasonable energy costs, 5. Site should be protected from extreme wind, 6. Access to markets – travel time for fish is important to consider, 7. Access to inputs (feed) & materials (buildings etc.), 8. Waste management plan or system, 9. Site should be secure to reduce theft & access, and 10. Surrounding land uses should be considered - factories, farming, mining etc. can affect water sources.

5.4. Key requirements for profitability

Listed below are some key factors, that in addition to the results obtained from the generic economic model could affect the profitability of marine and freshwater ornamental fish production in South Africa. These factors include:

I. Site selection,
II. System selection and design,
III. Correct species selection (suited to system and skill level),
IV. Specialised breeding for rare or unique species if possible,
V. Market access and travel time for the fish,
VI. Economies of scale,
VII. Ability to produce year-round,
VIII. Temperature,
IX. Water quality & avaliability,
X. Technical skills and knowledge,
XI. Disease management and control, and
XII. Good farm management practices.

6. Freshwater and Marine Ornamental Fish Market assessment

The ornamental industry origin can be tracked as far as 2000 BC, and even earlier records exist in China and Egypt. Ornamental fish were captive freshwater fish used for decorative purposes and were likely considered to be status symbols (Palmtag, 2017). In more recent times, aquarium exhibitions were noted in mid-19th century in the United Kingdom. Goldfish and other freshwater ornamental species started becoming popular with aquarium hobbyists in American households imported mostly from South Asia and South America (Palmtag, 2017). However, it was only during the early 20th century that the industry experienced significant international trade due to the development of air travel and airport infrastructure.

With the increased interest in the industry from the late 1960's, specifically in the evolvement and development of the ornamental fish industry (both in keeping and transporting fishes), the marine ornamental fish industry was also established (Palmtag, 2017). Today, the ornamental fish industry can be divided into two main market outlets: the freshwater which is dominated by cultured species (over 90%) and the marine ornamental fish industry, that in contrast to the freshwater ornamental fish industry is dominated by captured wild species. On a global scale, it has been reported that between 95% to 99% of all marine ornamental fish are wild caught, with a very limited number of marine species being commercially produced.

The following market analysis will cover both markets (freshwater and marine ornamental fish), with the intention to define the global scale of production, supply chain, demand, and trade patterns. This will then be followed by a closer look at the South African market dynamic and highlighting some possible market opportunities in the industry. Aquarium plants and corals were not considered for this study or included in the generic economic models.

6.1. Freshwater and Marine Ornamental Fish Production

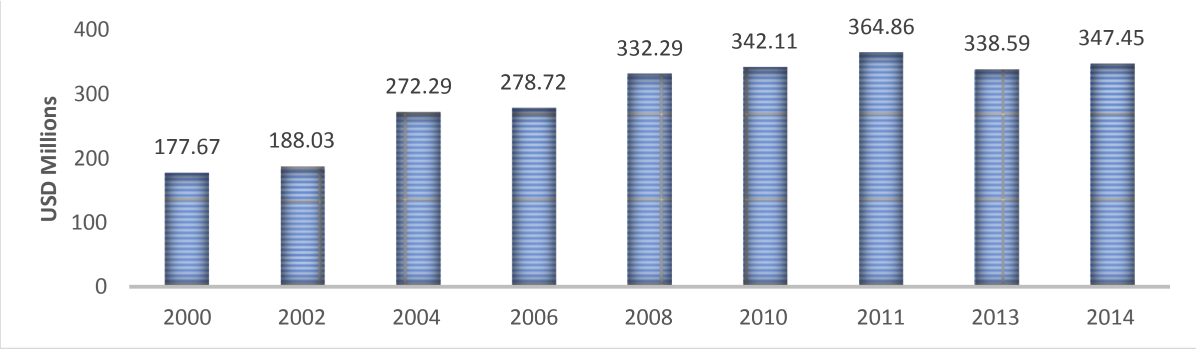
This sub-section will discuss the production and demand patterns for marine and freshwater ornamental fish at a global, regional, and local scale.

6.1.1. Global Supply Analysis

International trade in ornamental fish has become a billion-dollar industry, with total retail value estimated at approximately USD 3 billion, and of which about 55% of the market supply is originated from Asia (InfoFish, 2017). Over 2 500 species are involved in the global ornamental fish industry, of which over 60% are of freshwater origin. Of the total traded species more than 1800 are fish, over 700 are invertebrate species, and the remainder includes cnidarians, molluscs, arthropods, echinoderms, annelids, and poriferans (Dey, 2016).

Globally, the supply patterns of the ornamental industry indicate that the aquarium fish trade moves more than two billion live fish worldwide per year. For fresh water ornamental fish, more than 90% of them are captive bred, but over 90% of commercial marine organisms are wild-caught, which comes mainly from coral reefs and adjacent areas (Dominguez & Botella, 2014; Dey, 2016; Davenport, 2016). Overall, the global supply (of freshwater and marine) has shown a steady growth from approximately USD 177 million to more than double in 2014, recorded at USD 347 million. This steady growth can be seen in Figure 6-1 below (Dey, 2016).

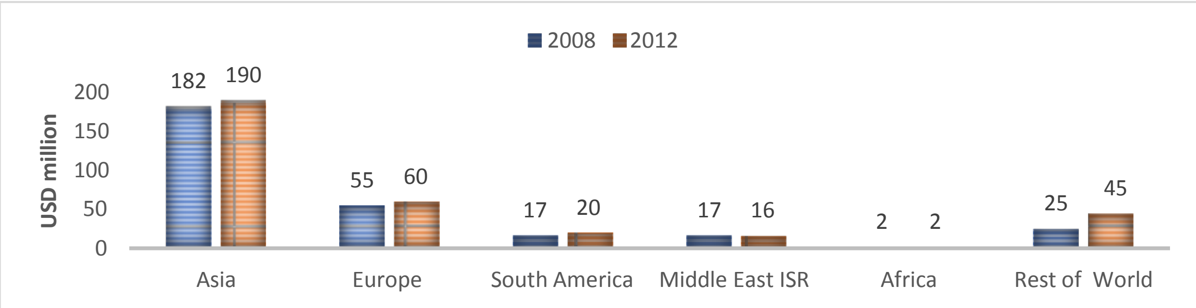
Figure 6-1: Total global trade value (in millions USD) of ornamental fish (2000 - 2014)



Source: (Dey, 2016)

Figure 6-2 depicts the key regions and their respective exports in USD millions between the years 2008 and 2012.

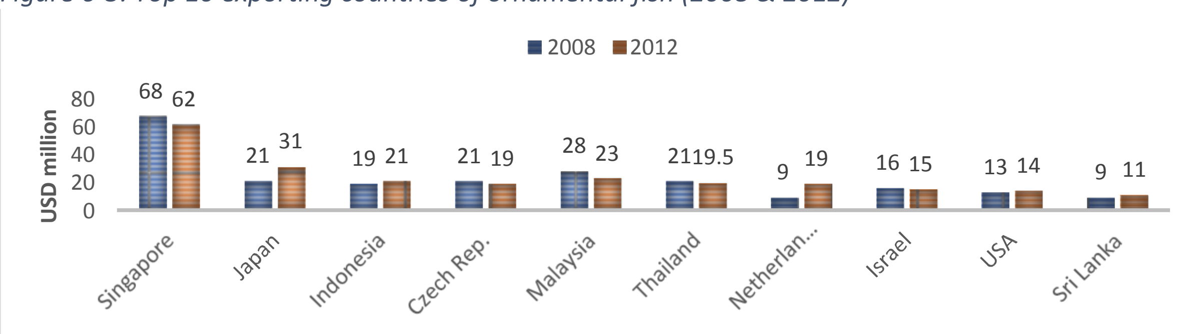
Figure 6-2: Fish exports in USD million by key regions (2008 & 2012)



Source: (OFI, 2015)

As illustrated in the figure above, Asia has retained its leading global position in terms of production and export with over USD 180 million value of ornamental trade recorded in 2012. (OFI, 2015). South America and the Middle East followed Asia closely regarding the value of fish exports. The Asian region supplied 78.6% of the total export market in 2014, which accounted for USD 197.7 million. Similarly, an increase in supply was noticed in Europe during 2014, which was reported to be valued at USD 95.8 million (27.6% of the total global exports of ornamental fish) (Dey, 2016). This was followed by African countries with USD 7.6 million (2.2%), Oceania (USD 4.9 million) and the Middle East (USD 1.76 million) for the year 2014. (Dey, 2016). Figure 6-3 below illustrates the Top 10 exporting countries for ornamental fish between the years 2008 and 2012.

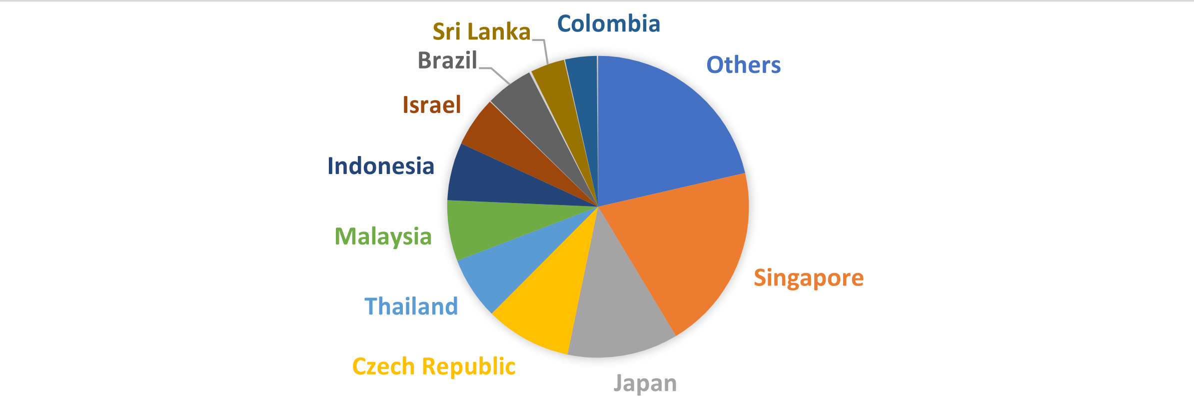
Figure 6-3: Top 10 exporting countries of ornamental fish (2008 & 2012)



Source: (OFI, 2015)

As shown in the figure above, Singapore dominated the ornamental industry from 2008 as the lead supplier with close to USD 60 million value of trade during 2012 (OFI, 2015). It is also worth noting that counties such as Singapore, the Czech Republic, Malaysia, Thailand, and Israel have experienced a decline in ornamental fish exports. In contrast, Japan, Indonesia, Sri Lanka, and the Netherlands have experienced an increase in exports. Figure 6-4 demonstrates the percentage share of the top suppliers of marine and fresh water ornamental fish by value for the year 2014. Singapore is the leading, global ornamental fish exporter, recording a value of USD 69.32 million, which contributed close to 20% of the total supply (Dey, 2016). However, recent data shows that even though Singapore retained its global position, it did so with a lower trade value of about USD 40 million (FactFish, 2016). Japan held its share as second place in the market (with a trade value of USD 41.34 million) due to its growing niche market for Koi carp (Dey, 2016). In third position, the Czech Republic supplied ornamental fish worth USD 32.0 million (and taking over more traditional suppliers such as Malaysia), followed by Thailand (USD 23.31 million), Malaysia (USD 22.62 million), Indonesia (USD 21.54 million), Israel (USD 19.04 million), Brazil (USD 18.52 million), Sri Lanka (USD 13.1 million), and Colombia (USD 12.3 million) (Dey, 2016).

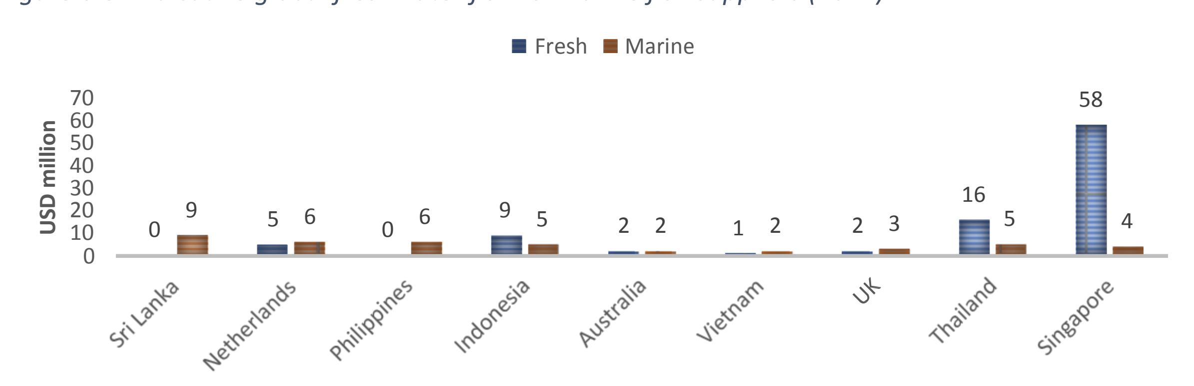
Figure 6-4: Top suppliers of marine & freshwater ornamental fish by value (USD million) 2014



Source: (Dey, 2016)

Regarding freshwater and marine ornamental supply by countries, limited and fragmented information is available. Indicative data from 2011 shows (Figure 6-5 below) that freshwater ornamental supply was dominated by Singapore, Thailand, and Indonesia, while marine ornamental fish are mainly supplied from Sri Lanka, Philippines, and Indonesia (OFI, 2015;Palmtag, 2017).

Figure 6-5: Indicative global freshwater fish vs. marine fish suppliers (2011)



Source: (OFI, 2015)

6.1.1.1. Freshwater Ornamental Fish

The freshwater ornamental fish industry is a fairly well-established industry due to the success of captive-bred production, as well as the available knowledge and skills capacity within the industry (Dey, 2016). Traditionally, freshwater ornamental fish are produced primarily in outdoor and earthen ponds with dominant production taking place in Asian countries such as Singapore, Thailand, and Indonesia. However, over time the use of technology has included the use of RAS and Flow-through systems (OFI, 2015). The countries that traditionally specialise in the breeding and propagation of freshwater ornamental fish include Thailand, Indonesia, Singapore, China, Malaysia, and Japan. However, more recently the culture of ornamental fish can now be found in countries such as the Czech Republic, Spain, Israel, Belgium, and Holland. Transportation and logistics costs are being reduced since the production of fish is done closer to consumer centres, resulting in more profits (Vas, 2012).The common freshwater ornamental farmed fish species include:

- **Livebearers** – platies, guppies, swordtails, mollies, etc., and
- **Egg-layers** – gourami's, danios, barbs, tetras, and cichlids.

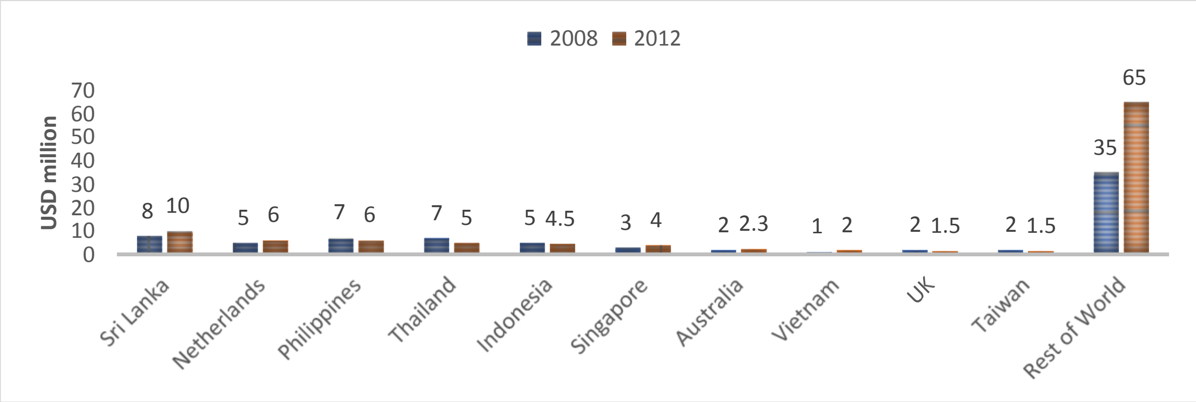
Furthermore, different types of Koi and goldfish are also in high demand in key international markets such as the US market and Japan (Treece, 2017). Malaysia, China, Israel, Europe, and the United States are considered key producers and suppliers of Koi-Carp (Pawlak, 2016). The top 20 most popular freshwater ornamental fish in the international markets (EU Markets) include the following:

1. Goldfish – colour variations
2. Guppy
3. Cardinal Tetras
4. Neon Tetras
5. Corydoras Catfish
6. Rummy nose tetra
7. Platy
8. Fantail/Oranda
9. Mollies
10. Antricus Catfish
11. Colisa
12. Swordtail
13. Plecostomus
14. Otocinclus
15. Clown loach
16. Butterfly loach
17. Ramirezi dwarf cichlid
18. Killifish/ Normans Lampeye
19. Chinese Algae Eater
20. Bettas (OFI , 2015).

6.1.1.2. Marine Ornamental Fish

Marine aquarium keeping is one of the world's most popular hobbies. Over 46 million organisms representing 2500 species (both fish and plants) are traded annually with a value exceeding USD 300 million. In addition to a wide range of fish species, approximately 500 species of invertebrates other than corals are (roughly ten million individuals) are traded each year. These include molluscs (gastropods, bivalves, and cephalopods), echinoderms (starfish, urchins, and sea cucumbers), actinarians (sea anemones), crustaceans (shrimp, crabs, and lobsters), polychaetes (feather dusters and Christmas tree worms) and poriferans (sponges) (Palmtag, 2017). The Philippines, Sri Lanka, Thailand, and Indonesia supply most of the marine ornamental fish, with most specimens being procured by the USA, Europe, and Japan (Palmtag, 2017; OFI, 2015). This relationship of supply and procurement is depicted in the Figure 6-6 below.

Figure 6-6: Marine ornamental fish exports – top 10 countries (2008 vs. 2012)



Source: (OFI, 2015)

From the figure above, it is evident that the marine ornamental fish industry is growing in size whereby production overall has grown (refer to the "rest of world"). However, most of the supply is from wild-caught sources (95%) and much less is being farmed (5%). The following section will provide more detail on the supply chain.

The most popular marine ornamental fish species that are traded on these international markets include:

1. Acanthuridae (Surgeon fish)
2. Apogonidae (cardinal fish)
3. Ballistidae (trigger fish)
4. Blenniidae (blennies)
5. Callionymidae (dragonets)
6. Chaetodontidae (butterfly fish)
7. Gobiidae (gobies)
8. Grammatidae (basslets)
9. Labridae (wrasses)
10. Microdesmidae (dart fish)
11. Pomacanthidae (angel fish)
12. Pomacentridae (damsels)
13. Pseudochromidae (Dottybacks)
14. Scorpaenidae (scorpion fish
15. Serranidae (groupers) and
16. Pomacentridae (Clown fish) (Palmtag, 2017).

Wild-caught marine ornamental fish

As previously mentioned, the supply of marine ornamental fish is predominantly from wild-caught sources, with very few fish being produced in captivity. The wild-caught supplies include fish, corals, and invertebrates from over 50 countries over five continents (some of which are small pacific islands) (Davenport, 2016).

There are hundreds of species which are only available as wild-caught specimens, either because no one has found a way to breed or produce them successfully in captivity, or economics prohibit production (Watson & Shireman, 2002). Except for very few species, all marine ornamental fish are caught from the world's tropical oceans (Watson & Shireman, 2002). The journey of a marine ornamental, from when it is caught (in its native habitats) to the home aquarium, requires the services of a variety of players aligned in a complex supply chain (Palmtag, 2017). The supply chain of wild-caught ornamental fish is presented in Figure 6-7 and discussed in the following stages (Davenport, 2016):

- **Stage 1 Catching the fish** - Fish are typically caught by hand or net, then bagged or put into containers and taken to shore. Catching wild fish is done in several ways including: chase and net, hand-picked, traps, active netting, and diving.

- **Stage 2 On Shore** - The fish either get sent directly to the exporters or are stored for agents to collect.

- **Stage 3 Good Husbandry** - The fish are rested & acclimatised in special tanks, and prepared for overseas export, ensuring they have the right permits and licences.

- **Stage 4 Ready for Export** - government officials first examine the fish, doubled-bagged, placed into specialised air cargo containers, then boxed and clearly labelled with packing dates & advisory notes before leaving the country.

- **Stage 5 On Arrival** - On arrival in the receiving country, the fish and their paperwork are inspected by customs and border inspection officers, including vets, and the Animal & Plant Health Agency. When cleared, the import companies take them straight to their facilities.

- **Stage 6 Acclimatisation-** The fish must be rested and acclimatised by wholesalers and/or retailers before being put on sale.

- **Stage 7 Ready to Sell** - Retailers ensure care information is given to customers and the fish are suitably packed for their journey to their new home.

Figure 6-7: Generic supply-chain of wild-caught fish from their natural habitat to an aquarium

Source: (Davenport, 2016)

There are some environmental concerns regarding the way wild-caught aquarium reef fish are exploited, including:

- The methods for collection and transportation can be wasteful (due to current capture, transport, and shipping practices), about 80% of all marine fish die even before they are sold to hobbyists. As much as 90% of all ornamental marine fish that are sold die within thefirst year. (Yan, 2016),
- The impact on the natural habitat of these fishes require effective conservation efforts to ensure sustainable exploitation,
- Need to ensure that benefits of the trade are equitably shared (specifically with the local communities who are typically highly depended on this as a source of income), and
- Concerns about the introduction of exotic species in receiving countries (Vas, 2012;Davenport, 2016).

The production of marine ornamental fish through aquaculture is a leading solution that could address some of the above issues and reduce habitat destruction by decreasing the need for wild livestock and providing an alternative profession for collectors (Palmtag, 2017).

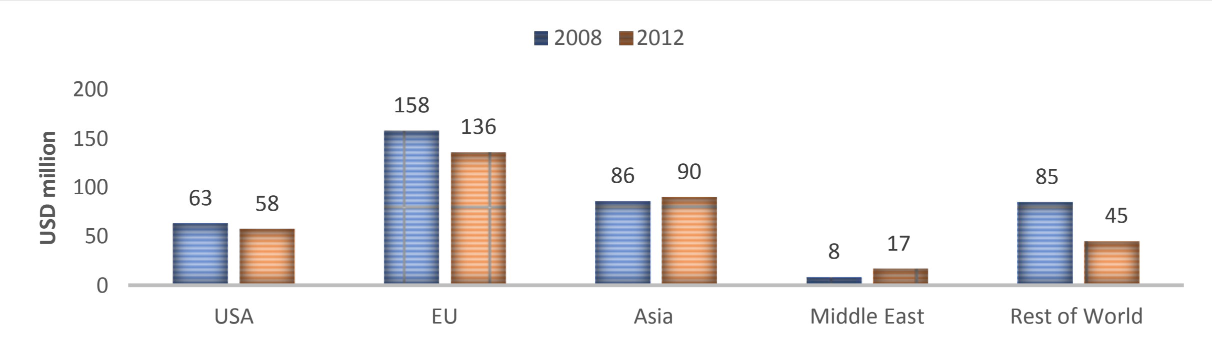
Farmed marine ornamental fish

It is estimated that approximately 25 species of 8,000 marine fish are farmed (i.e.: the rest are wild-caught). This highlights the need for research to constantly develop production practices, the "know-how" to breed and domesticate many of the high value marine species (Vas, 2012). The farming technology of marine ornamental is highly advanced and is typically done in a RAS environment. Unfortunately, it is known today to only a few countries including: EU, USA, Israel, and Asia.

6.1.2. Global Freshwater and Marine Ornamental Fish Demand Analysis

The demand for ornamental fish is often directly linked to the state of country's national economy (Dey, 2016). Hence, it is of no surprise that the overall demand for freshwater and marine ornamental fish is high in key international market places such as the EU, USA, and Asia as seen in Figure 6-8 below. There is a noticeable decrease in the imports value between 2008 and 2012 in the USA and EU markets, which is likely attached to the global economic fluctuations and recession that was experienced. Contrary to that, the Asian market has demonstrated some growth during the same period, which is likely due to the overall growth of the Chinese middle-class.

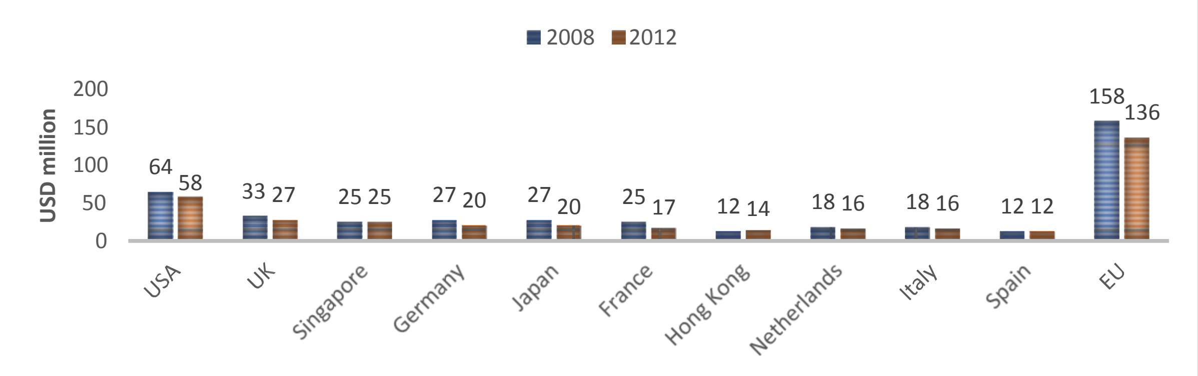
Figure 6-8: Ornamental fish imports by main regions (2008 vs 2012)



(OFI, 2015)

At a country level, the world's largest single market for ornamental fish is the USA, where keeping fish in aquaria is thought to be the second most popular hobby in the country (Dey, 2016). Following the USA is the UK and other key Europeans countries such as Germany, France, Netherlands, Italy, and Spain. Within Asia, countries such as Singapore, Japan, and Hong-Kong have also reported a significant importation of ornamental fish (OFI, 2015). However, it is only Singapore and Hong-Kong that indicate some market growth between 2008 and 2012 as seen in Figure 6-9 below.

Figure 6-9: Ornamental fish imports to 10 countries (2008 vs 2012)



(OFI, 2015)

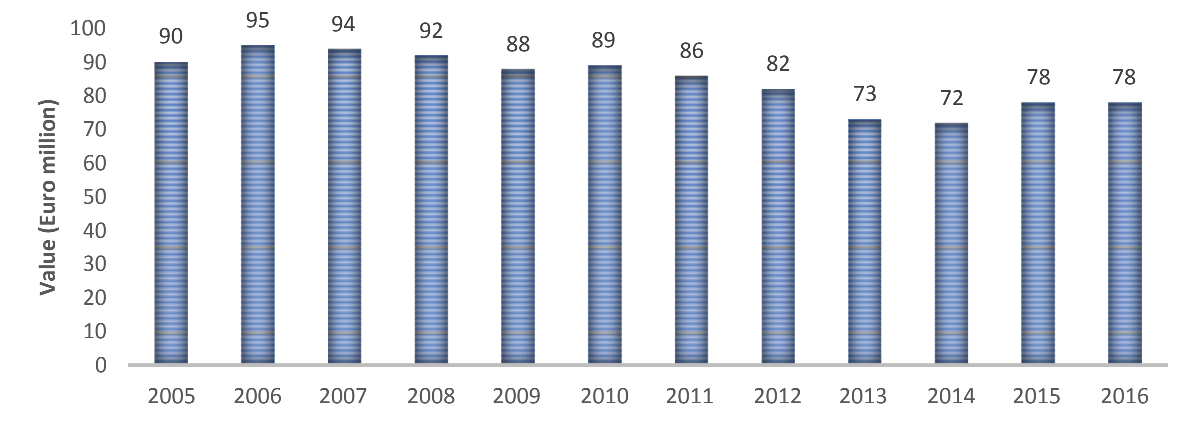
6.2. Marine and Freshwater Ornamental Fish Market Channels

This section provides an overview of the key global, regional, and local trade channels of ornamental fish, as well as specific details such as changes in trade over time and the value of the ornamental fish trade. The generic economic models take both local and international markets into consideration and offers flexible pricing options which are dependent on the size of the fish being produced and the target market identified. The pricing of the fish, and the target market impact on the financial results obtained when using the generic economic model, as these two factors play a key role in determining the profitability of an operation. Understanding the markets, pricing and preferred products for the market is essential.

6.2.1. European Ornamental Market

The EU market as indicated earlier is the largest region in terms of ornamental fish imports. Information obtained from the EU Border Inspection Posts (BIPs) for both freshwater and marine ornamental fish indicate that since 2009 there have been a steady decrease in importation value (from non-EU members) until 2014, followed by a recovery period during 2015 and 2016, with trade values reaching USD 70 million, as seen in Figure 6-10 below (OATA, 2017).

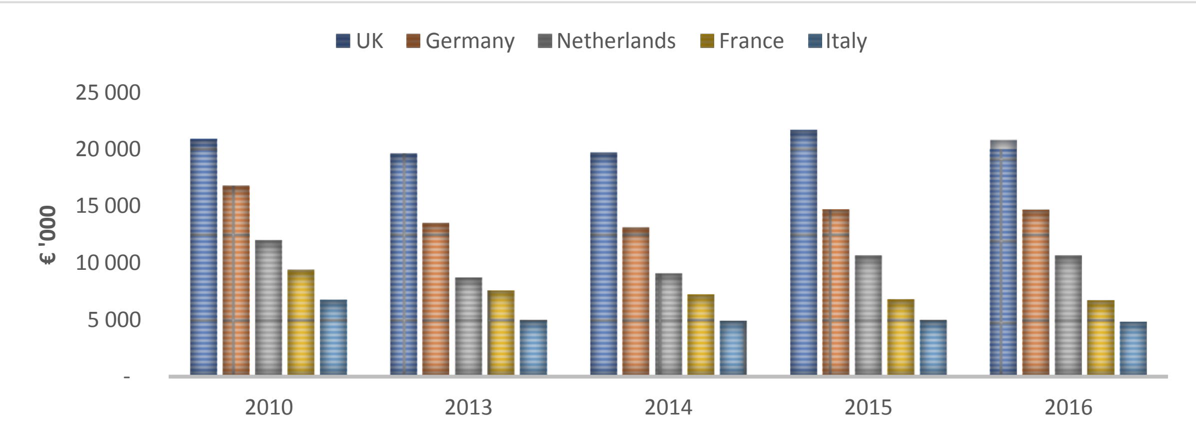
Figure 6-10: Total value of freshwater and marine ornamental fish imports into EU (2005-2016)



Source: (OATA, 2017)

From the data, it can be deduced that there are five (5) dominant countries with regard to the trade of ornamental fish in the EU (some of which are acting as hub of trade and re-exporting goods into other EU members).These leading countries are: the UK, Germany, Netherlands, France, and Italy as seen in Figure 6-11 below (OATA, 2017). The results show that the EU market importation is not expanding by much (possibly a reflection of the EU economy status).

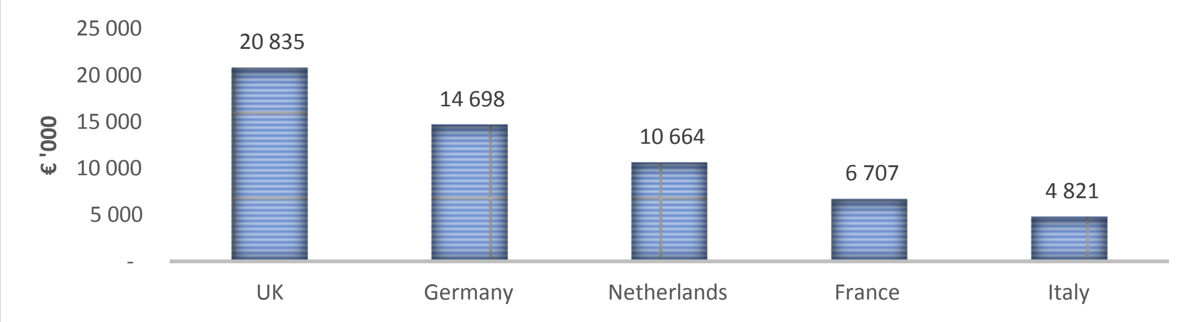
Figure 6-11: The top 5 EU ornamental fish import countries from 2010-2016 in €' 000



Source: (OATA, 2017)

Figure 6-12 below shows that the top five (5) importing counties jointly import about 75% of total import into the EU in the following split: UK 27% (€ 20.835 million), Germany 19% (€14.698 million), Netherlands 14% (€10.664 million), France 9% (€6.707 million), and Italy 6% (€4.821 million) (OATA, 2017).

Figure 6-12: Top 5 EU Ornamental Importers from non-EU member during 2016 (in € '000)



Source: (OATA, 2017)

In terms of EU sources of importation, the top exporting country was Singapore, accounting for just over 21.2% (€16.6 million by value) of all ornamental fish entering the EU market. After Singapore, Israel is considered to be the second biggest exporter into the EU market with 14.9 % of the EU market share (€11.69 million). Japan is also a major contributor to the EU market in value during 2016 and is position as the third exporter into the EU market with 13.6% and €10.6 million. Other contributors to the EU market include Indonesia with 12.5% (€9.79 million), and Thailand with 6.3% (€4.97 million) (OATA, 2017).

When comparing the imports between freshwater and marine, the following trends were identified (OATA, 2017; Dey, 2016):

1. EU imports of freshwater ornamental fish between 2010-2014 show a decline (from €75 million to €60 million) with limited recovery during 2015 and 2016 to about €65 million,

2. EU imports of marine ornamental fish between 2010-2016 show some growth from just over €12 million (2010) to over €14 million (specifically from 2014 to 2015),

3. Singapore, Israel, Japan, Thailand, and Indonesia were the main exporters of freshwater ornamental fish into EU markets,
4. Indonesia, USA, the Philippines, Sri Lanka, and Maldives are the main suppliers of marine ornamental fish into EU markets,

5. It was noticeable that during 2016 the USA and Kenya were active exporters of marine ornamental fish into the EU market, with 16.9% of total EU marine import (€ 2.39 million) and 8.5% (€1.12 million), respectively,

6. Other suppliers of freshwater fish include Hong Kong, Brazil, Peru, USA, Taiwan, Nigeria, Tanzania, India, Burundi, and the Democratic Republic of Congo, and

7. In terms of proximity to the EU market, the Czech Republic is the most important European supplier to the regional markets,

Finally, the EU imports are sourced globally for both marine and freshwater ornamental fish as demonstrated in Figure 6-13 below. In that regard, it is concluded that a few African countries are exporting into the EU market, with mainly freshwater ornamental fish being traded.

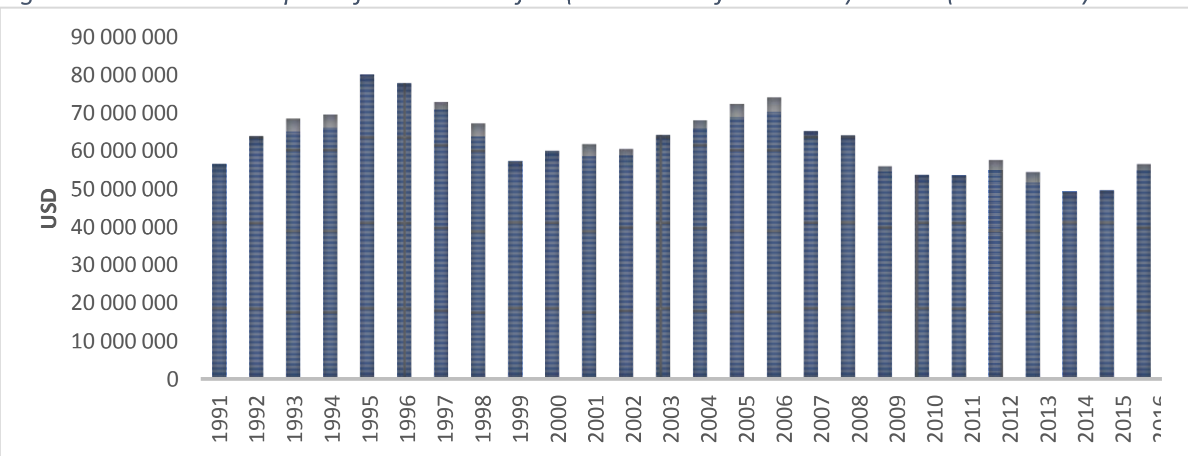
Figure 6-13: Countries of origin (non-EU) for ornamental fish imports into the EU market (2016)

Source: (OATA, 2017)

6.2.1.1. USA Ornamental Fish Marketing Channels

Paying attention to the USA market in particular, it is depicted that since 2009 (Figure 6-14 below) the USA imports of ornamental fish has fluctuated between the values of USD 50 to 60 million, which could be linked to the economic status of the country.

Figure 6-14: The USA import of ornamental fish (marine and freshwater) in USD (1991-2016)



Source: (FactFish, 2016)

Almost 45 countries were found to export marine ornamental fish into the USA during 2008, 2009 and 2011 (Rhyne, et al., 2017). Of these 45 countries the key suppliers of ornamental fish into the US market included Singapore, Indonesia, Thailand, Hong Kong, and the Philippines, as well as other important Asian suppliers such as Malaysia and Japan. Additional significant suppliers of ornamental fish into the USA market include Colombia, Peru, and Brazil (Dey, 2016).

The USA imports and global trade channels for ornamental fish can be seen Figure 6-15 below.

Figure 6-15: The USA imports & global trade channels in % (2008, 2009 & 2011)

Source: (Rhyne, et al., 2017)

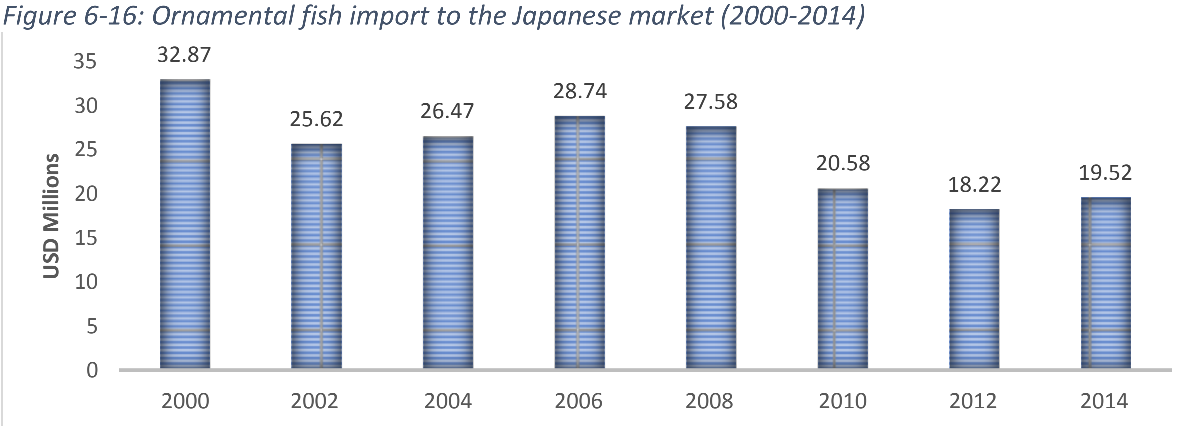
In summary the USA marine ornamental fish imports channels are from four main regions

1. The Southern Asia region – this is the main region includes key suppliers such as the Philippines and Indonesia (56% and 28% of total USA imports of marine ornamental fish),
2. The Pacific Ocean islands,
3. The Central and Southern American, and
4. The East and Western Africa (Rhyne, et al., 2017).

6.2.1.2. Japan ornamental fish market channels

The total import value of ornamental fish (freshwater and marine) into Japan showed a decline from USD 32.9 million in 2000 to 2003 (USD 25.62 million). A gradual increase between 2005 and 2008 can be seen, followed by further decline until 2012 and a slow recovery until 2014, where the market reached a value of USD 19.52 million as seen in Figure 6-16 below (Dey, 2016). The decline in imports was mainly due to the recession that the country was experiencing during that period, which ultimately resulted in Japan losing its market position as the single biggest global market for the first time since 2003.

Figure 6-16: Ornamental fish import to the Japanese market (2000-2014)



Source: (Dey, 2016)

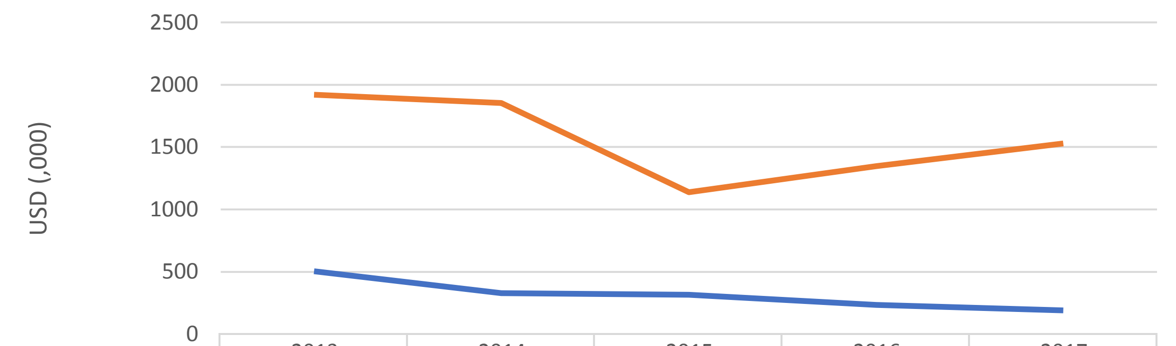
In 2014, the top ten suppliers to the Japanese market of ornamental fish (freshwater and marine) were Indonesia, Singapore, Brazil, Philippines, Colombia, Peru, USA, Thailand, Hong Kong, and Sri Lanka whereas China and Malaysia were the main suppliers of goldfish (Dey, 2016). Japan has implemented changes to regulations that restrict keeping pets such as cats and dogs in high rise apartments, which resulted in both freshwater and marine aquariums becoming an important feature of home décor. To date, the most popular ornamental fish species in Japan are guppies, which constitute more than 28% of the market. Other preferred ornamental fish species include tetras, tiger barb, discus, angelfish, gourami, platy, swordtail, zebra danio etc. (Dey, 2016)

6.2.2. South African Freshwater and Marine Ornamental Fish Trade

There is limited and fragmented data on the local South African demand and trade patterns for ornamental fish. The main local market is based in the metropolitan and large cities (e.g.: Johannesburg, Cape Town, Durban etc). Some historical data from late 2000's revealed that the total local market for Koi and ornamental fish was estimated to be valued at about R11.5 million during 2008 (Britz, et al., 2009).

Further to that, based on the assumption that local production of freshwater and marine ornamental fish is very low, the local market size dynamic can be represented by the import data avaliable. Making use of the South African Revenue Services (SARS) data, it is evident that freshwater and marine ornamental markets have been decreasing in size since 2013, with the exception of the marine ornamental market recovery which can be seen from 2015, which can be seen in Figure 6-17 below (TradeMap, 2017).

Figure 6-17: South African Freshwater and Marine Ornamental Imports in Value (USD) 2013-2017



	2013	2014	2015	2016	2017
Fresh water	507	331	318	237	194
Marine	1920	1852	1140	1347	1530

Source: (TradeMap,2017)

Additional data from 2015 indicates that South Africa imported approximately 39 tons of freshwater ornamental fish with an estimated value of R 3.4 million (DAFF, 2017). The ornamental fish were sourced from various countries, such as Malaysia (which contributed more than 40% to the total quantity of imports), Indonesia with 19%, Thailand with 17%, and China with 2.5%. (DAFF, 2017).Table 6-1 below highlights the ornamental fish imports to South Africa.

Table 6-1: South Africa's ornamental fish imports during 2015

Exporter	Quantity Imported (tons)	Value (R millions FOB)	Average price/kg (Rands)
China	1,085	0,141634	138,03
Colombia	0,396	0,033874	85,76
Germany	0,018	0,005431	301,72
India	0,702	0,065806	93,89
Indonesia	7,517	0,596718	83,97
Israel	0,85	0,051259	280,95
Kenya	0,638	0,033853	51,99
Malawi	0,2	0,033799	168,995
Malaysia	16,786	1,685949	97,53
Netherlands	0,056	0,051381	917,52
Nigeria	0,85	0,072237	85,42
Singapore	1	0,133726	131,83
Sri Lanka	1,107	0,060784	54,07
Taiwan	1	0	80
Thailand	6,779	0,34307	52,64
UK	0,03	0,083716	2790,53

Source: (DAFF, 2017)

Data shows that South Africa also exported 49.64 tons of freshwater ornamental fish with an estimated value of R 1.3 million. The volumes of ornamental fish exports increased significantly by 353.75% as compared to 2014 data. Ornamental fish were mostly destined for Taiwan (over R 200 000), Japan (R 192 000), USA (R 168 000), and Mauritius (R 108 000), and are likely to be mainly Koi-carp fish (considering no aquarium fish are known to be exported from South Africa). Other significant destinations in term of volume included: Hong Kong, Gabon, France, and Botswana (DAFF, 2017). It should be noted was that not all the ornamental fish exported were farmed within South Africa, as species were imported from other countries, and redistributed from South Africa (DAFF, 2017).

Table 6-2: South Africa's ornamental fish exports during 2015

Importers	Quantity (tons)	Value (R millions FOB)	Average price/kg (Rands)
Angola	0,065	0,013179	202,75
Botswana	2,803	0,037874	28,13
Burkina Faso	0,060	0,000200	3,33
DRC	0,050	0,000575	11,5
France	7,8	0,020318	2,60
Gabon	8,95	0,002613	2,90
Hong Kong	24	0,058998	2,46
Japan	3,77	0,192069	50,95
Mali	0,360	0,000763	2,12
Mauritius	0,446	0,108398	243,04
Mozambique	0,210	0,019176	82,86
Namibia	0,579	0,095177	164,38
Senegal	0,120	0,000400	3,33
Spain	0,002	0,000500	250

Importers	Quantity (tons)	Value (R millions FOB)	Average price/kg (Rands)
Swaziland	0,172	0,011170	63,55
Taiwan	0,212	0,607953	2867,70
UK	0,001	0,000120	120
USA	0,040	0,168619	3,40

Source: (DAFF, 2017)

The ornamental fish industry in South Africa is in its infant stages, specifically from a production point of view. The local production is made up of mainly aquarium freshwater ornamental fish and the Koi-carp fish. Based on published information of data collected in 2015, there are an estimated 12 local ornamental farms (all of which are freshwater farms) that are operating in the country, however there are no existing records of current species being produced as well as the production volumes of these farms. These farms are distributed by province as follows Free State – 1 farm, Gauteng – 4 farms, KZN – 3 farms, Limpopo – 1 farm, and Western Cape – 3 farms (DAFF, 2017).

Most of the farms can be associated with the production of Koi-carp fish in earthen ponds and are aimed at supplying the local and international markets whereas the ornamental aquarium fish farms only focus on the local market. The local koi market seems to be small, and based on a report from 2010, was already saturated with supply (Nel, 2010). Only one large-scale commercial freshwater ornamental farm was noted in KwaZulu Natal. The farm supplies to local markets only (i.e.: no export is noted), with the following market engagements

- Generally, fish are harvested three times a week in various quantities,
- Number of fish being sold per week varies and dependant on the demand from off-takers,
- Once the fish are harvested, they are supplied to wholesalers or pet stores directly with focus on the KwaZulu Natal and Gauteng markets,
- The fish are packed in plastic bags with water and transported in boxes. KZN is primary market as it is easier to supply to, while the Gauteng markets require the fish to be transported by air,
- No records of quantities fish being sold from the farm were available at the time of compiling this report, and
- The farm faces major competition from Asian imports. This is particularly due to the prices, diversity and quality of fish being imported (some fish are hybrid and genetically modified which enhance colour variations and fish attractiveness) (Upfold, 2018).

6.3. Marine and Freshwater Ornamental Fish Market Requirements

The overall global ornamental market preferences are defined typically by the end-consumers, which are the generally home aquarists or hobbyists. These end-consumers are a diverse group with respect to the species and assemblages of organisms that they desire to display. There are several possible groups of preferences in the ornamental aquarist space, including:

- A small fish display setup, such as clownfish or damselfish (family *Pomacentridae*) in a smaller tank (e.g.: 40 litres),
- Large predatory fish, such as sharks or moray eels, in very large home aquarium (e.g., 4000 L),
- A "fish only tank", which is typically made of a community of fish and decorative rocks,

- A "specialty tank", with aquarist who cares for an individual or group of organisms that require special conditions, such as seahorses or jellyfish, and
- The most popular version of the marine home aquarium is the "reef tank". The "reef tank" simulates a natural reef environment, typically a tropical coral reef, and features a diverse assemblage of invertebrates as well as fish (Palmtag, 2017).

Consumer requirements for both marine and freshwater ornamental fish are similar in the sense that price is related to quality of fish, and specifically to: colour, species, variety, age, and size. Variation in prices based on fish size is a major factor in the industry. As seen in Table 6-3 below, the prices range from R 1.50 to R 45 depending on the species and size of the fish (Kaiser EDP, Enviro-Fish Africa, 2011).

Table 6-3: Ornamental fish wholesale prices in South Africa (2011)

Species	Size Range (mm)	Wholesale Price (R)
1. **Goldfish**	40 -120	3.75 – 17.50
2. **Koi**	40 – 60	1.50 – 6.50
3. **African fish**	80	15
4. **Sharks**	50 – 70	7 -18
5. **Scats**	30	28
6. **Loaches**	50 – 60	5 -55
7. **Eels**	120	20
8. **Knifefish**	100	45
9. **Puffer fish**	20	11
10. **Angelfish**	25 – 35	10 – 15
11. **Tetras**	20 – 40	2.50-18
12. **Gouramis**	40 -80	6 -25
13. **Danios & Minnows**	25 -30	2 -2.50
14. **Guppy**	35-40	1.50-7.50
15. **Molly**	40 – 60	4 -22.50
16. **Platys**	35	5.75
17. **Catfish**	25-120	5.50-27
18. **Siamese Fighters**	Large	8-13
19. **Malawi Cichlids**	30 -100	5-18
20. **Cichlids**	30 -60	5 -45

Source: (Kaiser EDP, Enviro-Fish Africa, 2011)

The local South African market seems to be affected by the seasons, as more freshwater pond fish are sold more in summer (e.g.: Koi etc.), while tropical fish that require aquariums are sold more in winter (Kaiser EDP, Enviro-Fish Africa, 2011). Some of the most popular species on the South African market include; tetras, guppies, and clown fish but diversity is important for suppliers. (Kaiser EDP, Enviro-Fish Africa, 2011). Overall, the local market (as with other international markets) has a very strong preference for continued reliable supply with consistent quality of fish (Kaiser EDP, Enviro-Fish Africa, 2011;Upfold, 2018).

6.4. Barriers to entry and limitations of the market

Barriers to entry, and market limitations are an important consideration when looking at the feasibility of a product. Various aspects such as market saturation, trade barriers, market competition and potential market restrictions are important for this market assessment.

6.4.1. Market Saturation

The international markets for freshwater ornamental fish are large and very competitive, dominated by producers in Singapore, Thailand, and Indonesia. The key markets are countries within the EU block, the USA and Asia (with key players like Japan), most of which are thought to have reached some level of overall saturation in the early 2000's. The key international markets have shown some fluctuations in demand which has been linked to global economic downfall over the past 20 years. Developed markets could present potential growth opportunities for both freshwater and marine ornamental such as China (due to the growth of their middle class). Potential urban markets in some African countries could present additional opportunities (mainly for freshwater ornamental fish).

6.4.2. Competition

The industry is very competitive with regards to farmed freshwater fish as tropical countries (such as Singapore, Thailand, and Indonesia) enjoy ideal climate conditions allowing them to produce at a low cost and whereby in South Africa, production is faced with cold winter and possible high costs due to heating requirements. Farmed marine ornamental fish on the other hand, offer the advantage of being environmentally friendly (and can be marketed differently to the wild-caught ones). Yet, price wise farmed fish could experience some competition from wild-caught if the supply increases into the market. If South Africa producers were able to compete with international producers and the prices of imported fish, the transformation of the industry would require an effective marketing approach. Possible marketing strategies to assist with developing the local industry could include "Pay per Click" (PPC), specifically on Google and social media platforms. Digital marketing campaigns can target specific market niches based on regions or specific target audiences that can be identified by interest/hobbies or demographics (Ashkenazy, 2018).

6.4.3. Logistics Challenges

Logistic is a key challenge for the local industry mostly because of the costs. This has a major impact since distribution of live fish is a complex logistical issue as in most cases the fish need to be sent by air, in boxes that contain bags of sufficient water to sustain the fish during the transition to the market. Costs of freight in South Africa could therefore reach in the range of 50%-150% of the cost of the fish, which reduces the ability of local producers to export fish (Kaiser EDP, Enviro-Fish Africa, 2011).

6.4.4. Trade and Business Restrictions

International trade regulations for key markets is highly demanding such as the EU that requires producers to align with the International Air Transport Association (IATA) Live Animal Regulations (Kaiser EDP, Enviro-Fish Africa, 2011). Streamlining of relevant permits (such as with other aquaculture operations) should be coordinated by Department of Agriculture and Fisheries (DAFF) and Department of Environmental Affairs (DEA) as required (Britz, et al., 2009).

Other issues such as introduction of disease has already had a major impact on the Koi industry with the spread of the Koi Herpes virus (KHV) during 1998 following its global spread by infected ornamental fish (DAFF, 2017). The environmental conditions for the virus persisted in natural freshwater bodies in South Africa for a significant part of the year, and hence facilitating the spread of the virus to wild or feral common carp populations where contact is made with natural water bodies.

6.4.5. Market immaturity

The South African market for both freshwater and marine ornamental fish indicates a decline in consumption/demand, with some indication of the marine ornamental market recovering in 2015 (TradeMap, 2017). The total value of the freshwater ornamental industry in 2017 was estimated at USD 194000 (R 2.2 million). This industry could be capitalised on in the future by local producers, however local producers would need to be more competitive to establish themselves despite the well-developed ornamental import market.

With regards to the marine ornamental fish market, the estimated trade value for 2017 was recorded at USD 1 530 000 (R 17.8 million). This industry presents several opportunities for the South African industry, provided local producers can successfully produce marine ornamental fish on a commercial scale. Interventions to address the lack of local producers and the available “know-how” could be to support joint venture operations between well-established international operations and local producers and stakeholders. Government funding, support and incentives could assist with this intervention to encourage the participation of international operations.

South Africa has an established local demand for ornamental fish. Despite that, there are major concerns by the producers that the market is shrinking in size due to change of habit (young consumers have changed their preferences to digital hobbies and aquariums are no longer that popular) (James, 2017). Further to that, competition from international suppliers (i.e.: Asian and South American) is extremely challenging to sustain local production (Personal Communication, 2018; Kaiser EDP, Enviro-Fish Africa, 2011).

7. SWOT analysis and Mitigation Measures

This section provides a SWOT Analysis for the freshwater and marine ornamental fish industry in South Africa and provides high-level mitigation options to address the threats and weaknesses identified.

7.1. SWOT Analysis

Table 7-1 below presents the strength, weaknesses, opportunities, and the threats faced by the freshwater and marine ornamental fish industry in South Africa.

Table 7-1: Freshwater and Marine Ornamental Fish Swot Analysis

Strengths	Weaknesses
• High-value industry • Aquariums are popular amongst hobbyists • Market available for freshwater & marine ornamental fish • Huge variety of fish species and varieties • Improved technology – better understanding and ability to breed marine ornamental fish	• Limited/no production data in South Africa • Technical expertise and knowledge is limited • Knowledge on production systems is minimal • Market is erratic, and fluctuates based on consumer demand & economic conditions • Limited research and development focused on marine ornamental fish • Complex and costly production • Each species has unique characteristics & requirements; thus, mass production is challenging
Opportunities	**Threats**
• Opportunity to reduce wild harvests of marine ornamental fish • Investigate use of marine fin fish technology to produce marine ornamental fish • Investigate hybridisation of species to compete with Asian imports • Opportunity to expand the industry	• High mortality rates of fish (specifically marine fish) • Unsustainable harvesting practices are threatening wild marine ornamental fish stocks • Disease outbreak – limited knowledge on diseases, specifically in ornamental fish • Imports from more established markets

The generic economic model considered some key weaknesses and threats that would impact on profitability. The model assists with developing a risk profile for producers which is used to determine interest rates and loan repayments based on education levels and skills, and access to land, infrastructure, and facilities. Factors such as specific production needs and requirements were incorporated into the model to provide an accurate financial analysis for the various species.

7.2. Mitigation Measures

The mitigation measures identified in the table below aim to address the threats and weaknesses identified in the SWOT analysis discussed above. It is essential for ornamental fish producers to take note of the potential risks and weaknesses identified to ensure they can implement mitigation measures and understand the challenges they may face.

Table 7-2: Freshwater and Marine Ornamental Fish Mitigation Measures

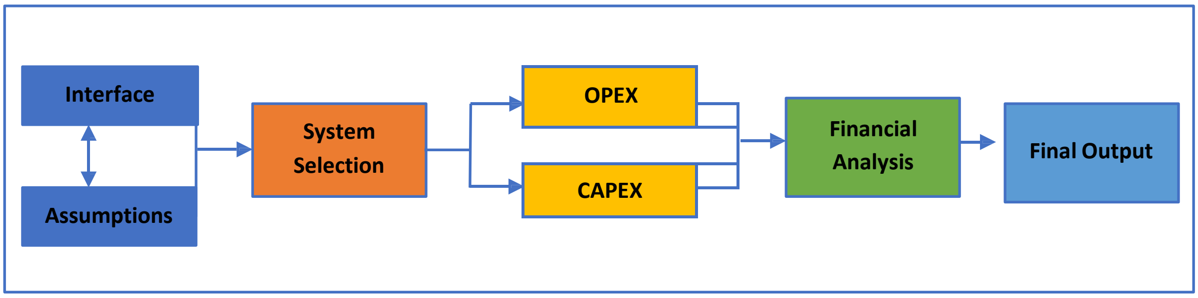
Risks Identified	Mitigation Measures
1. Limited/no production data	• Identify ornamental fish producers in South Africa • Encourage annual reporting of production data focusing on volumes and species being produced
2. Limited knowledge & expertise	• Identify experts in the ornamental fish industry • Encourage workshops or training opportunities between experts and new entrants to the industry
3. Production system information	• Promote and encourage research and development on production systems for ornamental fish, specifically for marine fish • Partner with research institutions to work on this challenge
4. Research and development challenges	• Focus on funding, promoting, and supporting research and development for the ornamental fish industry in South Africa
5. Costs of production	• Investigate what can be done to reduce production costs • Identify how the ornamental fish industry value chain can be developed
6. Mass production challenges	• Through research & development, identify best way to increase volumes of production • Research and development is required to look at potential production systems that can be used for marine ornamental fish • Trial or pilot projects would provide useful insight into developing the marine ornamental fish industry in South Africa • Investigate use of marine fin-fish production techniques for marine ornamental production (i.e. dusty kob) • Research and development is required to better understand unique characteristics of each species to better develop optimal production conditions/environments
7. High mortality rates	• Can be addressed through research and development within the industry • Educating and skills development to better understand ornamental production, specifically for new entrants or small-scale producers
8. Disease outbreak	• Implement biosecurity guidelines for ornamental fish producers • Focus research & development on identifying specific diseases predominantly in marine ornamental fish sector • Early warning systems for producers
9. Importation challenges	• Identify local market opportunities • Assist producers to align with international standards to allow for export to USA and EU markets • Develop ornamental regulations and standards to ensure quality of fish, and production methods meet international standards • Identify potential trade tariff to reduce import volumes and protect local producers

8. Marine Ornamental Fish Financial Analysis

8.1. Introduction

The generic economic model provides users with the opportunity to individual producer data, proposed production volumes and scales and financial data. Through the model, the users will receive financial outputs which include capital and operational costs and financial indicators which will guide the user in determining whether the proposed aquaculture project is feasible, and a viable investment opportunity. A high-level overview of the model process can be seen in the figure below.

Figure 8-1: Generic Economic Model Overview



Source: Urban-Econ,2018

The generic economic model can be customised to provide results for individual producers based on selections made with regard to the location of the aquaculture operation (at a provincial level), type of operation (start-up or existing), the scale of operation, type of production system, size and pricing of the ornamental fish, education level and type of financing that could be used to fund the proposed aquaculture project.

8.2. Key Economic Model Assumptions

The generic economic models for marine ornamental fish was developed using data from various information sources, consultations with various stakeholders and industry experts.

8.2.1. Production Assumptions

To develop the generic economic model, specific production assumptions for marine ornamental fish were identified and utilised. Some key assumptions used can be seen in Table 8-1 below.

Table 8-1: Marine Ornamental Fish Model Assumptions

Breeding Stock	• R 100 per fish
Maximum production cycle length	• 6 months
Survival Rate (6 months)	• 5%
Mortality Rate (6 months)	• 95%
Average Feed price	• R 30/kg
Stocking Density	• **Breeding tanks:** 1 pair (2 fish) per tank

Producers should be encouraged to establish relationships with suppliers to benefit from bulk prices, specifically at larger tonnages. The feed price utilised for the results presented below were based on a price of R 30/kilogram, the cost of feed has negative impact on the profitability of an operation, as well as the minimum tonnages and selling price required to achieve a profit.

8.2.2. Capital Expenditure

The capital expenditure costs for marine ornamental fish production focused on the establishment of a RAS. The capital expenditure is determined by the scale of production, and the selected production cycle length. Some of the key factors to note include the following:

a. **Pre-development costs** for construction phase, concept design, specialist consultations, town planning alignment (zoning, rezoning etc.), and development of bulk infrastructure (roads, installation of electricity to the site, bulk water services etc.) were excluded from the model as this is site specific and not suitable to model at a provincial level,
b. **Land costs** were included should an individual/business not have an existing farm. Based on average farm prices for 2017/2018, a per hectare (ha) rate of R 246 346 was used,
c. **Services** such as the costs of water and electricity were included in the model, and vary between the provinces,
d. **Buildings** such as storerooms, offices, hatchery, packing room and a feed room were considered,
e. **Aquaculture system** costs focused on the development of infrastructure for the systems, and additional equipment required.
f. **Infrastructure costs** are calculated as a once-off, lump sum amount to be spent in year one, however a producer can choose to phase in production which would split the costs up depending on how the production is phased in.

8.2.3. Operational Expenditure

Operational expenditure, or working capital was determined by looking at the variable costs of production, and fixed costs. Costs can be divided into fixed and variable costs. **Variable costs** include fingerlings, feed, transport, and water costs. It should be noted that it is was assumed that aquaculture producers in South Africa are currently not charged for water unless using municipal water sources (DAFF,2018). **Fixed Costs** include costs such as salaries, insurance, electricity, legal/licensing costs, veterinary services, and general expenses (telephone, electricity, health and safety apparel, stationery etc.). Reserve and unforeseen costs have also been included (calculated at 2% of the variable cost total).

8.2.4. Scale of Production

From the generic economic model, two production volumes were identified, firstly the minimum production volume indicates at what tonnage a producer would be profitable from when selling at the average selling price identified in the model, and secondly, the optimal production tonnage was identified, which indicates where the optimal return on investment and profitability is achieved when selling at the lowest feasible selling price.

8.2.5. Marine Ornamental fish production in South Africa

When considering marine ornamental fish production in South Africa, there is limited data available on potential production systems, commercial operators, and technical information on the commercial production of marine ornamental fish. Out of the potential production systems identified, marine ornamental fish are limited to recirculating aquaculture systems (RAS) or alternatively a combination of the RAS and flow-through systems.

When considering the financial aspect of producing marine ornamental fish, several factors impact on the prices and income stream of an operation as well as the operational expenditure. Some key challenges identified include:

1. Production of marine ornamental fish is limited to provinces located along the coastline
2. Low wholesale selling price of fish (R 18 – R 50 per fish)
3. Unless producing on a large scale, only small numbers of fish will be available to sell every month
4. Markets are dependent on size, colour, and type of fish
5. Operational costs involved with pumping seawater and developing suitable infrastructure is exceptionally high
6. Limited data on breeding and grow-out success of marine ornamental fish, thus it is a high-risk operation
7. Fish are sold at a per fish price, not at per kg/per group price
8. Marine ornamental fish market in South Africa is dominated by the import market.

The generic economic model for marine ornamental fish was developed using data from various information sources and consultations with various stakeholders and industry experts. The model provides insight into the financial viability of each system, the capital expenditure required to establish a production system, and the recommended selling prices for various fish species. The model will allow producers to determine what size fish should be produced and what the required minimum tonnage is for ornamental fish producers to be profitable in South Africa.

8.3. Production System Financial Analysis

Based on the potential production systems identified, a financial analysis was conducted by making use of the generic economic model.Table 8-2 below highlights some of the key assumptions used to obtain the results presented.

Table 8-2: Marine Ornamental Fish Production and Financial Assumptions

	Overview
Province	KwaZulu Natal
Market	Local
Operational Status	Start-up farmer with an existing farm, but no facilities, or infrastructure
Skills Level	Formal education (certificate/diploma)
Financing Option	Debt/Equity at 20%
Production Cycle length	6 months
Additional Information	• The models include the costs for infrastructure development • The production cycle excludes the construction and development phase and only considers from when production starts. • Fingerlings/juveniles can either be bought in and grown out on site, alternatively a hatchery can be used to breed and grow juveniles.

Based on the assumptions above, the results obtained from the generic economic models are presented below for marine ornamental fish.

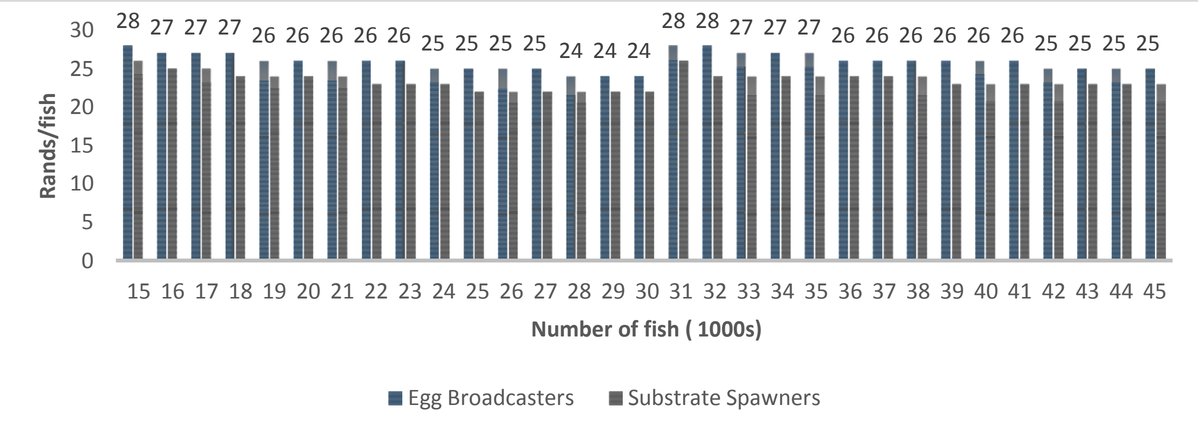
8.3.1. Recirculating Aquaculture Systems

Based on the assumptions presented in Table 8-2 above, the following results were obtained from the generic economic model. Table 8-5 below represents the financial indicators obtained when producing marine ornamental fish in a RAS.

8.3.1.1. Price Sensitivity Analysis

The generic economic model clearly identifies the key impact pricing of the fish (Rands/fish) plays in determining the minimum and maximum profitable scales of production. The average for marine ornamental fish is anywhere from R 10 per fish up to R 900 per fish depending on the rarity, breeding, size, and quality of the fish. Figure 8-2 below identifies the minimum selling price at the various production volumes, ranging from 15 000 fish to 45 000 fish per annum.

Figure 8-2: Marine Ornamental Fish Price Sensitivity Analysis



Based on the image above, it can be seen that the selling price for substrate spawners can range from R 23 per fish (45 000 fish/annum) to R 26/fish when producing 15 000 fish per annum. In comparison, the egg broadcaster prices from R 25/fish to R 28/fish indicating a R 2 difference between the groups; this can be attributed to different mortality rates. From the graph, it can be identified that when producing between 25 000 fish/annuum and 30 000 fish/annum, produces can sell for R 22/fish – this pricing difference can be attributed to increasing infrastructure costs which are influenced by the production scale. For example, at over 30 000 fish per annum, and additional greenhouse tunnels and ponds are required.

*The average selling price for **substrate spawners is R 23/fish** and **R 26/fish for egg broadcasters.***

8.3.1.2. Infrastructure Expenditure

The table below provides a summary of the infrastructure and built environment costs required to establish a RAS for marine ornamental fish production. The prices used for the analysis correlate to the graph above.

Table 8-3: Infrastructure Costs for a RAS (Substrate Spawners)

Production Scale	Min 15 000 fish	Max 45 000 fish
Infrastructure (Buildings)	R 282 600	R 531 650
Purchase Land	R 369 519	R 812 941

Production Scale	Min 15 000 fish	Max 45 000 fish
RAS System	R 291 128	R 687 866
Additional equipment	R 14 889	R 218 156
Total Capital Expenditure	**R 958 136**	**R 2 250 614**

8.3.1.3. Operational Expenditure

The table below provides a summary of the operational costs required for marine ornamental fish production. The operational expenditure is shown for the first year of operation.

Table 8-4 :Operational Expenditure for a RAS (Year 1) – Substrate Spawners

Production Scale	Min. 15 000 fish	Max 45 000 fish
Variable costs	**R 143 000**	**R 416 000**
Feed	*R 32 400*	*R 97 200*
Consumables – water quality	*R 6 000*	*R 18 000*
Freight Costs	*R 54 000*	*R 159 000*
Packaging	*R 42 000*	*R 126 000*
Chemicals	*R 3 600*	*R 10 800*
Fixed Costs	**R 129 200**	**R 262 766**
Total Operational Costs	**R 272 200**	**R 678 766**

Very little information is available on the captive breeding of marine ornamental fish, thus feeding programmes and requirements are based on assumptions. Prices are based on 2017/2018 estimates and are subject to change over time.

8.3.1.4. RAS Financial Overview

The table below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size and the estimated number of employees required in the first year of production.

Table 8-5: Marine Ornamental Fish Financial Analysis for a RAS

Production Scale	Min 15 000 fish	Max 45 000 fish
EGG BROADCASTERS – YELLOW TANGS & ANGELFISH		
Selling Price	R 28/fish	R 25/fish
Total Capital Expenditure	R 1 197 552.24	R 2 961 391.98
Loan Amount – Working Capital	R 132 742.15	R 294 356.81
Loam Amount - Infrastructure	R 1 064 810.39	R 2 667 035.16
Profitability Index (PI)	1.18	1.36
Internal Rate Return (IRR)	10%	12%
Net Present Value over 10 years	R 1 413 134.30	R 4 017 098.68
Production Assumptions		
Farm Sized Required	1.5 hectares	3.3 hectares
No. employees required (year 1)	1 (excluding the owner)	4 (excluding owner)
SUBSTRATE SPAWNERS – DOTTYBACKS AND CLOWNFISH		
Selling Price	R 26/fish	R 23/fish
Total Capital Expenditure	R 1 065 409.13	R 2 493 050.74
Loan Amount – Working Capital	R 107 272.18	R 242 435.89

Production Scale	Min 15 000 fish	Max 45 000 fish
Loam Amount - Infrastructure	R 958 136.95	R 2 250 614.85
Profitability Index (PI)	1.24	1.58
Internal Rate Return (IRR)	10%	14%
Net Present Value over 10 years	R 1 321 650.21	R 3 930 334.64
Production Assumptions		
Farm Sized Required	1.5 hectares	3.3 hectares
No. employees required (year 1)	1 (excluding the owner)	4 (excluding owner)

From the table above, it can be seen that substrate spawners and egg broadcasters showed very similar results when using the generic economic model to comparing the two categories. When looking at the substrate spawners (Clownfish and Dottybacks), it can be seen that a total capital amount of R 1 065 409 is required to produce 15 000 fish per annum, while R 2 493 050 is required to produce 45 000 fish per annum. An IRR of 10% is achieved when producing 15 000 fish per annum and selling them at R 23/fish.

It should be noted that while an operation could be profitable, producers must take note of the high risks and complex nature of commercial marine ornamental production.

8.4. Marine Ornamental Fish Cost Benefit Analysis

Table 8-6 below shows a high-level cost benefit analysis for marine ornamental fish, based on the profitability index (PI) which is used as the cost benefit ratio. The analysis considers the potential production systems, at the minimum profitable scale, and the optimal production scale when selling the fish at the average price identified from the economic model.

Table 8-6: Marine Ornamental Fish Cost Benefit Analysis

	Substrate Spawners	Egg Broadcasters
Selling price	R 26/fish	R 28/fish
Minimum Profitable Scale	*15 000*	*15 000*
Internal Rate of Return (IRR)	10%	10%
Selling price	R 23/fish	R 25/fish
Maximum Scale	45 000	45 000
Internal Rate of Return (IRR)	14%	12%

From the table above, it can be seen that the minimum scale of production requires 15 000 fish per annum to be sold, which equates to 1 250 fish per month, when selling the fish at the average price identified in the model of R 26/ fish (substrate spawners). Depending on the market being supplied, these prices may be higher or lower than estimated price used. The maximum scale accommodated in the model looks at producing 45 000 fish per annum, where a price of R 23/fish can be achieved.

Captive breeding of marine ornamental fish species is challenging and risky, specifically for the egg broadcaster species. As mentioned in the species overview, it has taken research institutes 10 years to successfully breed Yellow Tangs in captivity. The model accounts for a 95% mortality from egg to fry stage, as well as 3% monthly mortality thereafter.

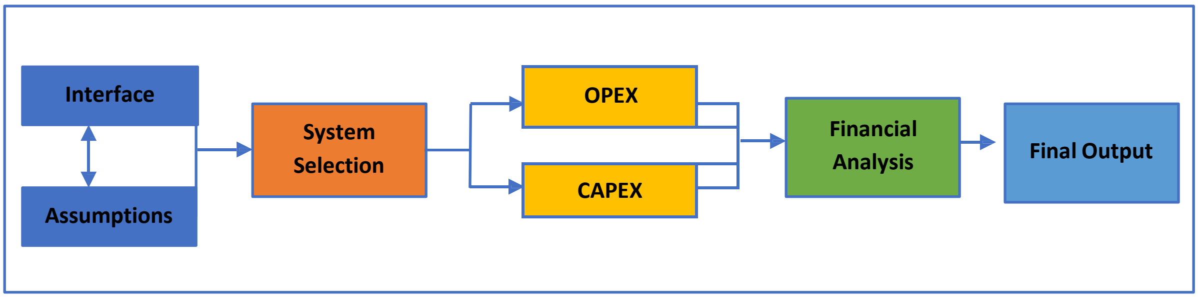
It is evident that marine ornamental fish production in South Africa is underdeveloped and limited to the RAS production system, thus impacting on potential feasibility of the industry. The South African market is dominated by imported marine ornamental fish, thus South African producers would face several challenges, specifically when looking at the pricing and marketing of fish. Production areas are limited to coastal regions in the Western Cape, Eastern Cape, Northern Cape and KwaZulu Natal. KwaZulu Natal, the Eastern Cape and Western Cape are expected to offer the “best-case” in terms of investment opportunities, economic return, access to markets and more suitable climatic regions along the coast.

9. Freshwater Ornamental Fish Financial Analysis

9.1. Introduction

The generic economic model provides users with the opportunity to individual producer data, proposed production volumes and scales and financial data. Through the model, the users will receive financial outputs which include capital and operational costs and financial indicators which will guide the user in determining whether the proposed aquaculture project is feasible, and a viable investment opportunity. A high-level overview of the model process can be seen in the figure below.

Figure 9-1: Generic Economic Model Overview



Source: Urban-Econ,2018

The generic economic model can be customised to provide results for individual producers based on selections made with regard to the location of the aquaculture operation (at a provincial level), type of operation (start-up or existing), the scale of operation, type of production system, size and pricing of the ornamental fish, education level and type of financing that could be used to fund the proposed aquaculture project.

9.2. Key Economic Model Assumptions

The generic economic models for freshwater ornamental fish was developed using data from various information sources, consultations with various stakeholders and industry experts.

9.2.1. Production Assumptions

To develop the generic economic model, specific production assumptions for freshwater ornamental fish were identified and utilised. Some key assumptions used can be seen in Table 9-1 below.

Table 9-1: Freshwater Ornamental Fish Model Assumptions

Breeding Stock	• R 100 per fish
Maximum production cycle length	• Varies per species – 3 to 6 months
Survival Rate (10 months)	• 86%
Mortality Rate (10 months)	• 14%
Average Feed price	• R 30/kg
Stocking Density	• **Breeding tanks:** 1 pair (2 fish) per tank

The feed price utilised for the results presented below were based on a price of R 30/kilogram, the cost of feed has negative impact on the profitability of an operation, as well as the minimum tonnages and selling price required to achieve a profit.

9.2.2. Capital Expenditure

The capital expenditure costs for freshwater ornamental fish production focused on the establishment of a RAS and pond culture system depending on the type of fish selected. The capital expenditure is determined by the scale of production, and the selected production cycle length. Some of the key factors to note include the following:

g. **Pre-development costs** for construction phase, concept design, specialist consultations, town planning alignment (zoning, rezoning etc.), and development of bulk infrastructure (roads, installation of electricity to the site, bulk water services etc.) were excluded from the model as this is site specific and not suitable to model at a provincial level,
h. **Land costs** were included should an individual/business not have an existing farm. Based on average farm prices for 2017/2018, a per hectare (ha) rate of R 246 346 was used,
i. **Services** such as the costs of water and electricity were included in the model, and vary between the provinces,
j. **Buildings** such as storerooms, offices, hatchery, packing room and a feed room were considered,
k. **Aquaculture system** costs focused on the development of infrastructure for the systems, and additional equipment required.
l. **Infrastructure costs** are calculated as a once-off, lump sum amount to be spent in year one, however a producer can choose to phase in production which would split the costs up depending on how the production is phased in.

9.2.3. Operational Expenditure

Operational expenditure, or working capital was determined by looking at the variable costs of production, and fixed costs. Costs can be divided into fixed and variable costs. **Variable costs** include fingerlings, feed, transport, and water costs. It should be noted that it is was assumed that aquaculture producers in South Africa are currently not charged for water unless using municipal water sources (DAFF,2018). **Fixed Costs** include costs such as salaries, insurance, electricity, legal/licensing costs, veterinary services, and general expenses (telephone, electricity, health and safety apparel, stationery etc.). Reserve and unforeseen costs have also been included (calculated at 2% of the variable cost total).

9.2.4. Scale of Production

From the generic economic model, two production volumes were identified, firstly the minimum production volume indicates at what tonnage a producer would be profitable from when selling at the average selling price identified in the model, and secondly, the optimal production tonnage was identified, which indicates where the optimal return on investment and profitability is achieved when selling at the lowest feasible selling price.

9.3. Production System Financial Analysis

Based on the potential production systems identified, a financial analysis was conducted by making use of the generic economic model.Table 9-2 below highlights some of the key assumptions used to obtain the results presented.

Table 9-2: Freshwater Ornamental fish: Financial and Production Assumptions

Province	Gauteng
Market	Local
Operational Status	Start-up farmer with an existing farm, but no facilities, or infrastructure
Skills Level	Formal education (certificate/diploma)
Financing Option	Debt/Equity (20% debt)
Additional Information	• The models include the costs for infrastructure development • The production cycle excludes the construction and development phase and only considers from when production starts.

9.3.1. Recirculating Aquaculture System

The RAS is the most viable system in South Africa based on the generic economic model. The design of the system allows for careful monitoring and control of the conditions for the fish, thus allowing for optimal production conditions.

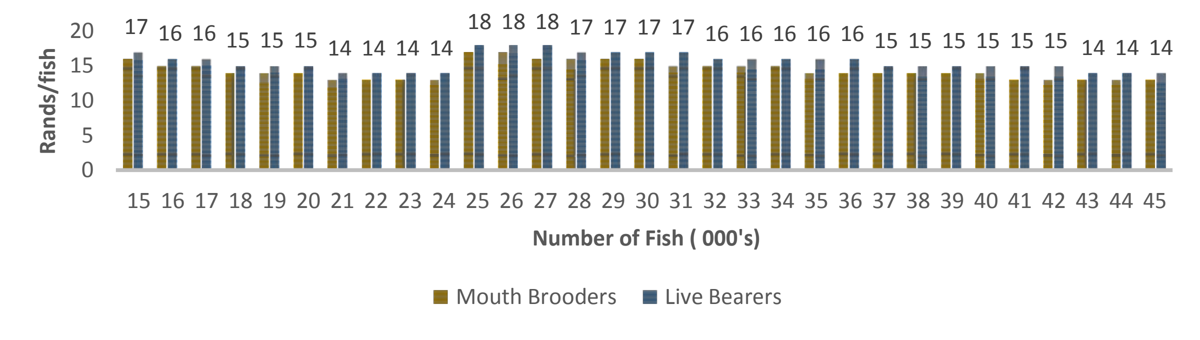
9.3.1.1. Mouthbrooders and Live Bearer Fish Analysis

Mouth brooders and live bearer fish differ slightly to other freshwater ornamental fish, as their unique breeding behaviour reduces the need for a hatchery. Mouth brooders include species such as the Malawi Cichlid, while live bearers include species such as guppies, mollies, and platys.

9.3.1.1.1. Price Sensitivity Analysis

The generic economic model clearly identifies the key impact pricing of the fish (Rands/fish) plays in determining the minimum and maximum profitable scales of production. The average price for live bearers and mouth brooder fish is anywhere from R 6 per fish up to R 30 per fish depending on the rarity, breeding, size, and quality of the fish. Figure 9-2 below identifies the minimum selling price at the various production volumes, ranging from 1000 fish to 100 000 fish per annum.

Figure 9-2: Live Bearers & Mouth Brooders Price Sensitivity Analysis



The selling price for **live bearer's** ranges from R 14 per fish (45 000 fish/annum) to R 17/fish when producing 15 000 fish per annum. **Mouth brooders** prices range from R 13/fish to R 16/fish indicating a R 1 difference between the groups. From the graph, it can be identified that when producing between 21 000 fish/annuum and 25 000 fish/annum, produces can sell for R 14/fish – this pricing difference can be attributed to increasing infrastructure costs which are influenced by the production scale. For example, at over 24 000 fish per annum, and additional greenhouse tunnels and ponds are required.

*The average selling price for **live bearers is R 15/fish** and **R 14/fish for mouth brooders.***

9.3.1.1.2. Infrastructure Expenditure

The table below provides a summary of the infrastructure and built environment costs required to establish a RAS for the production of live bearers.

Table 9-3: Infrastructure Costs for a RAS (Live Bearers)

Production Scale	15 000 fish/annum	45 000 fish/annum
Infrastructure (Buildings)	R 225 000	R 365 250
Purchase Land	R 431 105	R 800 624
RAS System	R 191 298	R 438 896
Additional equipment	R 45 489	R 246 027
Total Capital Expenditure	**R 919 993 45**	**R 1 897 698**

9.3.1.1.3. Operational Expenditure

The table below provides a summary of the operational costs required for live bearers. The operational expenditure is shown for the first year of operation.

Table 9-4 :Operational Expenditure for a RAS (Year 1) – Live Bearers

Production Scale	15 000 fish/annum	45 000 fish/annum
Variable costs	**R 94 230**	**R 241 490**
Feed	*R 38 880*	*R 116 640*
Consumables	*R 6 000*	*R 12 000*
Freight Costs	*R 26 450*	*R 79 350*
Packaging	*R 3 500*	*R 10 500*
Chemicals	*R 3 600*	*R 7 200*
Fixed Costs	**R 115 418**	**R 272 673**
Total Operational Costs	**R 209 648**	**R 514 613**

Limited information on is available on the commercial production of freshwater ornamental fish, thus feeding programmes and requirements are based on assumptions. Prices are based on 2017/2018 estimates and are subject to change over time.

9.3.1.1.4. Financial Overview

Table 9-5 below provides a financial analysis of mouth brooder and live bearer fish production

Table 9-5: Mouthbrooders and Live-bearer fish Financial Overview

Production Scale	15 000 fish/annum	45 000 fish/annum
	Live bearers (Production Cycle = 6 months)	
Selling Price	R 17 /fish	R 14/fish
Total Capital Expenditure	R 1 018 109.73	R 2 123 659.62
Loan Amount – Working Capital	R 98 116.28	R 225 961.55
Loan Amount - Infrastructure	R 919 993.45	R 1 897 698.07
Profitability Index (PI)	1.41	1.27
Internal Rate Return (IRR)	12%	11%
Net Present Value over 10 years	R 1 325 827.40	R 2 693 864.03
	Additional Information	
Farm Size Required	1.8 hectares	3.3 hectares
No. employees required Year 1	1 (excluding owner)	2 (excluding owner)

Production Scale	15 000 fish/annum	45 000 fish/annum
Mouth brooders (Production Cycle = 5 months)		
Selling Price	R 16/fish	R 13/fish
Total Capital Expenditure	R 920 282.10	R 1 737 979.39
Loan Amount – Working Capital	R 78 461.90	R 172 201.07
Loan Amount - Infrastructure	R 841 820.20	R 1 565 778.32
Profitability Index (PI)	1.54	1.58
Internal Rate Return (IRR)	14%	14%
Net Present Value over 10 years	R 1 413 045.14	R 2 741 618.50
Additional Information		
Farm Size Required	1.8 hectares	3.3 hectares
No. employees required Year 1	1 (excluding owner)	2 (excluding owner)

Live bearers require a slightly higher capital expenditure than **mouth brooders** with a total capital investment of R 1 018 109 required to produce 15 000 fish per annum, and R 2 123 659 required to produce 45 000 fish per annum. Live bearers are profitable at both production volumes identified with an IRR of 11% achieved when selling 15 000 fish per annum at the average price of R 17/fish identified from the model, and an IRR of 11% when selling 45 000 fish per annum at the lowest feasible price identified of R 14/fish.

Mouth brooders require a total capital investment of R 920 282 required to produce 15 000 fish per annum, and R 1 737 979 required to produce 45 000 fish per annum. Mouth brooders are profitable at both production volumes identified with an IRR of 14% achieved at both production scales. This indicates that while at higher volumes more fish will be sold, the higher capital expenditure required at higher production volumes impacts on the profitability of an operation.

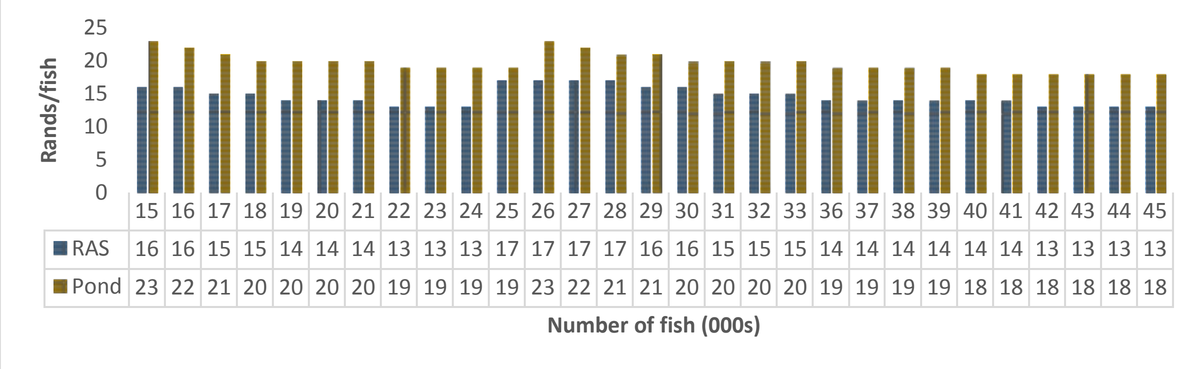
9.3.1.2. Egg Scatterers & RAS

The generic economic model presents five (5) fish varieties that are classified as egg scatterers. When looking at the use of RAS for egg scatterers (tetras, barbs & danios and gouramis) and ponds (koi and goldfish).

9.3.1.2.1. Price Sensitivity Analysis

Pricing plays a key role in determining the minimum and maximum profitable scales of production. The average price for egg scatterers can range from R 10 per fish up to R 90 per fish in commercial pet shops, this is depending on the rarity, breeding, size, market, and quality of the fish. Figure 9-3 below identifies the price range for egg scatterers in a pond and RAS based on the generic economic model.

Figure 9-3: Egg Scatterers - Price Sensitivity Analysis



	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	36	37	38	39	40	41	42	43	44	45
RAS	16	16	15	15	14	14	14	13	13	13	17	17	17	17	16	16	15	15	15	14	14	14	14	14	14	13	13	13	13
Pond	23	22	21	20	20	20	20	19	19	19	19	23	22	21	21	20	20	20	20	19	19	19	19	18	18	18	18	18	18

The selling price for **egg scatterers in a RAS** ranges from R 13 per fish (45 000 fish/annum) to R 16/fish when producing 15 000 fish per annum. In comparison, the **egg scatterers produced in a pond** have a price range from R 18/fish to R 23/fish.

From the graph, it can be identified that when producing between 19 000 fish/annuum and 24 000 fish/annum, produces can sell for R 13 to R14/fish – this pricing difference can be attributed to increasing infrastructure costs which are influenced by the production scale. For example, at over 24 000 fish per annum, and additional greenhouse tunnels and ponds are required. Pond culture system are slightly costlier to establish; thus, the higher selling price is required to compensate for the higher capital expenditure.

*The average selling price for **egg scatterers in a RAS is R 15/fish** and **R 20/fish for egg scatterers in a pond system.***

9.3.1.2.1. Infrastructure Expenditure

The table below provides a summary of the infrastructure and built environment costs required to establish a RAS for egg scatterers.

Table 9-6: Infrastructure Costs for a RAS (Egg Scatterers)

Production Scale	15 000 fish/annum	45 000 fish/annum
Infrastructure (Buildings)	R 282 600	R 371 650
Purchase Land	R 431 105	R 800 624
RAS System	R 180 443	R 209 929
Additional equipment	R 45 489	R 246 027
Total Capital Expenditure	**R 966 737**	**R 1 660 131**

9.3.1.2.2. Operational Expenditure

The table below provides a summary of the operational costs required to produce egg scatterers in a RAS. The operational expenditure is shown for the first year of operation.

Table 9-7 :Operational Expenditure for a RAS (Egg Scatterers) – Year 1

Production Scale	15 000 fish/annum	45 000 fish/annum
Variable costs	**R 99 865**	**R 248 795**
Feed	*R 41 404*	*R 123 120*

Production Scale	15 000 fish/annum	45 000 fish/annum
Consumables	*R 6 000*	*R 6 000*
Freight Costs	*R 29 425*	*R 88 275*
Packaging	*R 4 000*	*R 12 000*
Chemicals	*R 3 600*	*R 3 600*
Fixed Costs	**R 96 995**	**R 217 211**
Total Operational Costs	**R 196 860**	**R 466 006**

Limited information on is available on the commercial production of tetras, thus feeding programmes and requirements are based on assumptions. Prices are based on 2017/2018 estimates and are subject to change over time.

9.3.1.2.3. Financial overview

Table 9-8 below looks at the production of egg scatterers in a RAS

Table 9-8: Egg Scattering Fish in a RAS –Financial Overview

Production Scale	15 000 fish/annum	45 000 fish/annum
Selling Price	R 16/fish	R 13/fish
Total Capital Expenditure	R 1 045 093.83	R 1 832 014.56
Loan Amount – Working Capital	R 78 356.00	R 171 883.37
Loan Amount - Infrastructure	R 966 737.83	R 1 660 131.20
Profitability Index (PI)	1.28	1.48
Internal Rate Return (IRR)	11%	13%
Net Present Value over 10 years	R 1 333 724.39	R 2 703 336.78
Additional Information		
Farm Size Required	1.8 hectares	3.3 hectares
No. employees required Year 1	1 (excluding owner)	2 (excluding owner)

From the table above, it can be seen that a total capital investment of R 1 045 093 required to produce 15 000 fish per annum, and R 1 832 014 required to produce 45 000 fish per annum. Egg scatterers are profitable at both production volumes identified with an IRR of 11% achieved when selling 15 000 fish per annum at the average price of R 16/fish identified from the model, and an IRR of 13% when selling 45 000 fish per annum at the lowest feasible price of R 13/fish.

9.3.2. Egg Scatterers & Pond Culture

Pond culture can be used to produce a select few fish species, namely Goldfish, Koi, and Blue Gouramis. Pond culture, as discussed previously is not suited for all ornamental fish, specifically due to maintaining water quality, temperature, and physical requirements such as oxygen availability, pH, and ammonia levels.

9.3.2.1.1. Infrastructure Expenditure

The table below provides a summary of the infrastructure and built environment costs required to establish a pond system.

Table 9-9: Infrastructure Costs for a Pond System

Production Scale	15 000 fish/annum	45 000 fish/annum
Infrastructure (Buildings)	R 625 360	R 685 790
Purchase Land	R 514 961	R 1 133 191
Pond System	R 407 800	R 907 800
Additional equipment	R 70 978	R 271 467
Total Capital Expenditure	**R 1 743 399**	**R 3 097 949**

9.3.2.1.2. Operational Expenditure

The table below provides a summary of the operational costs required for egg scatterers produced in a pond system. The operational expenditure is shown for the first year of operation.

Table 9-10 :Operational Expenditure for a Pond Year 1

Production Scale	15 000 fish/annum	45 000 fish/annum
Variable costs	**R 57 110**	**R 143 310**
Feed	*R 12 960*	*R 34 560*
Consumables	*R 6 000*	*R 6000*
Freight Costs	*R 28 800*	*R 86 400*
Packaging	*R 3 500*	*R 10 500*
Chemicals	*R 3 600*	*R 3 600*
Fixed Costs	**R 190 891**	**R 446 617**
Total Operational Costs	**R 248 001**	**R 589 928**

Limited information on is available on the commercial production of egg scatterers in pond systems thus feeding programmes and requirements are based on assumptions. Prices are based on 2017/2018 estimates and are subject to change over time.

9.3.2.2. Financial Overview

Table 9-11 below looks at the production of egg scatterers in a pond system.

Table 9-11: Egg Scatterers in a Pond System

Production Scale	15 000 fish/annum	45 000 fish/annum
Selling Price	R 23/fish	R 18/fish
Total Capital Expenditure	R 1 834 125.10	R 3 310 717.20
Loan Amount – Working Capital	R 90 725.50	R 212 768.00
Loan Amount - Infrastructure	R 1 743 399.60	R 3 097 949.20
Profitability Index (PI)	1.19	1.36
Internal Rate Return (IRR)	10%	12%
Net Present Value over 10 years	R 2 173 540.86	R 4 504 281.58
Additional Information		
Farm Size Required	2.2 hectares	4.6 hectares
No. employees required Year 1	1 (excluding owner)	2 (excluding owner)

A total capital investment of R 1 834 125 required to produce 15 000 fish per annum, and R 3 310 717 required to produce 45 000 fish per annum. The egg scatterers can be profitable at both production volumes identified with an IRR of 10% achieved when selling 15 000 fish per annum at the average price of R 23/fish identified from the model, and an IRR of 12% when selling 45 000 fish per annum at the lowest feasible price of R 18/fish. The initial capital costs associated with establishing the ponds, and the minimum of six (6) tunnels required for continuous production affect the overall pricing of these fish. Should producers have existing ponds and tunnels, profitable selling prices will be much lower.

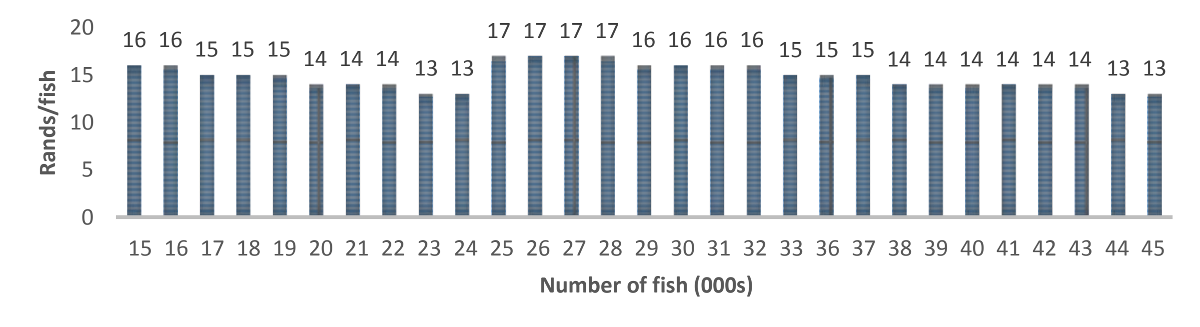
9.3.2.3. Substrate Spawners

The generic economic model looks at five (5) species that fall under the substrate spawner category, including Angelfish, Cory catfish, Ancistrus catfish, Tanganyikan Cichlids and South American Cichlids.

9.3.2.3.1. Price Sensitivity Analysis

As previously mentioned, pricing plays a key role (Rands/fish) plays in determining the minimum and maximum profitable scales of production. The average price for substrate spawners ranges from R 10 per fish up to R 45 per fish depending on the rarity, breeding, size, market, and quality of the fish. Figure 9-4 below identifies the minimum selling price at the various production volumes, ranging from 15 000 fish to 45 000 fish per annum.

Figure 9-4: Substrate Spawners –Price Sensitivity Analysis



The selling price for substrate spawners ranges from R 13 per fish (45 000 fish/annum) to R 16/fish when producing 15 000 fish per annum (based on the generic economic model). It can be seen that when producing between 23 000 fish/annuum and 24 000 fish/annum, fish can sell for R 13/fish – this pricing difference can be attributed to increasing infrastructure costs which are influenced by the production scale. For example, at over 24 000 fish per annum, and additional greenhouse tunnels and ponds are required. Pond culture system are slightly costlier to establish; thus, the higher selling price is required to compensate for the higher capital expenditure.

The average selling price for ***substrate spawners is R15/fish.***

9.3.2.3.2. Infrastructure Expenditure

The table below provides a summary of the infrastructure and built environment costs required to establish a RAS for South American Cichlid production.

Table 9-12: Infrastructure Costs for a RAS (Substrate Spawners)

Production Scale	15 000 fish/annum	45 000 fish/annum
Infrastructure (Buildings)	R 282 600	R 371 650
Purchase Land	R 431 105	R 800 624
RAS System	R 213 298	R 308 496
Additional equipment	R 45 489	R 246 027

Production Scale	15 000 fish/annum	45 000 fish/annum
Total Capital Expenditure	**R 999 593**	**R 1 758 698**

9.3.2.3.3. Operational Expenditure

The table below provides a summary of the operational costs required for the production of substrate spawners. The operational expenditure is shown for the first year of operation.

Table 9-13 :Operational Expenditure for a RAS (Substrate Spawners) – Year 1

Production Scale	15 000 fish/annum	45 000 fish/annum
Variable costs	**R 97 705**	**R 242 315**
Feed	*R 38 880*	*R 116 640*
Consumables	*R 6 000*	*R 6 000*
Freight Costs	*R 29 425*	*R 88 275*
Packaging	*R 4 000*	*R 12 000*
Chemicals	*R 3 600*	*R 3 600*
Fixed Costs	**R 102 563**	**R 233 916**
Total Operational Costs	**R 200 268**	**R 476 231**

Limited information on is available on the commercial production of substrate spawners, thus feeding programmes and requirements are based on assumptions. Prices are based on 2017/2018 estimates and are subject to change over time.

9.3.2.3.4. Financial Overview

Table 9-14 below provides a financial overview for substrate spawners in a RAS system. The overview provides a summary of the total capital investment required, financial indicators achieved and labour requirements for year one (1).

Table 9-14: Substrate Spawners Financial Overview

Production Scale	15 000 fish/annum	45 000 fish/annum
Selling price	R 16/fish	R 13/fish
Total Capital Expenditure	R 1 079 369.50	R 1 934 841.59
Loan Amount – Working Capital	R 79 776.05	R 176 143.52
Loan Amount - Infrastructure	R 999 593.45	R 1 756 698.07
Profitability Index (PI)	1.10	1.16
Internal Rate Return (IRR)	8%	9%
Net Present Value over 10 years	R 1 182 526.28	R 2 249 325.57
Additional Information		
Farm Size Required	1.8 hectares	3.3 hectares
No. employees required Year 1	1 (excluding owner)	2 (excluding owner)

From the table above, to produce 15 000 fish per annum, a total capital investment of R 1 079 369 is required, and R 1 934 841 required to produce 45 000 fish per annum. These fish can be profitable at both production volumes identified with an IRR of 8% achieved when selling 15 000 fish per annum at the average price of R16/fish identified from the model, and an IRR of 9% when selling 45 000 fish per annum at the lowest feasible price of R 13/fish. Substrate spawners require a hatchery thus the capital expenditure may be slightly higher than other RAS systems considered above.

9.4. Freshwater Ornamental Fish Cost Benefit Analysis

The tables below show a high-level cost benefit analysis for freshwater ornamental fish in Gauteng, based on the profitability index (PI) which is used as the cost benefit ratio.

Table 9-15 below provides the cost benefit analysis for Live bearer fish, which covers species such as guppies, swordtails, platys, and mollies. Based on the findings presented previously, RAS is the only viable system considered for live bearers. The maximum production cycle length considered is 6 months, although if producers have a market the fish can be sold when smaller, however this will affect the prices received.

Table 9-15: Live bearers Cost Benefit Analysis

	Live Bearers
Selling Price	R 17/fish
Minimum Profitable Scale	15 000 fish/annum
Profitability Index	1.41
Internal Rate of Return (IRR)	12%
Selling Price	R 14/fish
Optimal production scale	45 000 fish/annum
Profitability Index	1.27
Internal Rate of Return (IRR)	11%

Table 9-16 below looks at the cost benefit analysis for Mouth brooder fish.

Table 9-16: Mouth Brooder Fish Cost Benefit Analysis

	Mouth Brooders
Selling Price	R 16/fish
Minimum Profitable Scale	15 000 fish/annum
Profitability Index	1.54
Internal Rate of Return (IRR)	14%
Minimum feasible price	R 13/fish
Optimal production scale	45 000 fish/annum
Profitability Index	1.58
Internal Rate of Return (IRR)	14%

Table 9-17 below looks at Substrate Spawners, which includes species such as Angel fish, Cory and Ancistrus Catfish, South American Cichlids, and Tanganyikan Cichlids.

Table 9-17: Substrate Spawners Overview

	Substrate Spawners
Selling Price	R 16/fish
Minimum Production Scale	15 000 fish/annum
Profitability Index	1.10
Internal Rate of Return (IRR)	8%
Selling Price	R 13/fish

	Substrate Spawners
Maximum Production Scale	45 000 fish/annum
Profitability Index	1.16
Internal Rate of Return (IRR)	9%

Table 9-18 below deals with egg scattering fish, which include species such as tetra's, goldfish, koi, blue gouramis, barbs and danios. The different species have unique production requirements, thus goldfish and koi can only be produced in ponds, while tetras, barbs and danios rely on RAS, and lastly blue gouramis can be produced in either RAS or Pond systems.

Table 9-18: Egg Scatterer Fish Overview

	Goldfish/Koi (Pond)	Tetras/Barbs/Danios (RAS)
Selling Price	R 23/fish	R 16/fish
Minimum Production Scale	15 000 fish/ annum	15 000 fish/ annum
Profitability Index	1.19	1.28
Internal Rate of Return (IRR)	10%	11%
Selling Price	R 18/fish	R 13/fish
Maximum Production Scale	45 000 fish/annum	45 000 fish/annum
Profitability Index	1.36	1.48
Internal Rate of Return (IRR)	12%	13%

9.5. Freshwater Ornamental Fish Financial Analysis Summary

The table below provides a summary of the financial analysis results conducted for live bearers, mouth brooders, egg scatterers and substrate spawners are all produced in a RAS. An analysis for egg scatterers in a pond system covers potential species such as goldfish and koi.

Table 9-19: Freshwater Ornamental Fish: Financial Analysis Summary

	Live Bearers	Mouth Brooders	Egg Scatterers (RAS)	Substrate Spawners	Egg Scatterers (Pond)
Min no fish/annum	15 000	15 000	15 000	15 000	15 000
Selling Price	R 17/fish	R 16/fish	R 16/fish	R 16/fish	R 23/fish
Capital Expenditure	R 1 018 109	R 920 282	R 1 045 093	R 1 079 369	R 1 834 125
IRR	12%	14%	11%	8%	10%

The production of freshwater ornamental fish is profitable in both a RAS and pond culture system. Out of the five (5) species/categories considered above, mouth brooders and live bearers are the most profitable, this can be linked to the fact that no hatchery is required thus the capital expenditure is slightly lower. Substrate spawners offer the lowest return on investment. The analysis above is based on ideal market conditions, and producers must ensure they establish and secure off-take markets that pay premium prices to ensure the producer can develop a successful and profitable operation. It is recommended producers focus on producing special or rare fish that are of a high quality to ensure premium prices will be received.

10. Conclusion and recommendations

This section provides conclusions and recommendations based specifically on the production of marine and freshwater ornamental fish and the market assessment. In addition, recommendations are also provided to address the challenges identified throughout the study.

10.1. Conclusion

The freshwater and marine ornamental fish industry in South Africa is underdeveloped, and currently very small with regards to the current production volumes as well as the limited number of producers involved in the industry. As the South African industry is primarily based at a recreational or hobbyist level, it is a major challenge to identify suitable production systems, scales, and methods for commercial production as it is not a popular practice locally. The ornamental fish industry (both marine and freshwater) possess some opportunities for South Africa but does require improved coordination between the private and government sectors. The local South African market contributes an estimated R 3-4 million of trade of ornamental fish (which is currently imported into the country. For producers to meet globally standards, and increase production, the ornamental value and supply-chain must be well designed to optimise operation and financial margins.

Models such as farming cooperatives with satellite producers and central distribution channels should be developed (and copied from other international regions which have applied them successfully like in Asia). Improved support could be provided to protect the local industry from importation using tariff tools. Additional efforts could also be put into aligning South Africa to the International Air Transport Association (IATA) and Live Animal Regulations, which would enable producers to supply the EU markets. Lastly, investment in farmed marine ornamental fish industry and involvement of industry experts could assist with positive growth and development. Possible incentives should be proposed to local-international partnership with proven track-records of “know-how” to establish ornamental fish parks in locations such as Special Economic Zones (SEZ).

As mentioned, marine ornamental fish are recommended for production along the KwaZulu Natal coastline and selected regions along the Western Cape and Eastern Cape coastlines to ensure constant access to seawater, however, the most suitable province for production will be dependent on the species selected, and the optimal water temperatures required. Generally marine ornamental fish are tropical fish thus KwaZulu-Natal offers producers warmer water conditions which would reduce heating and electricity costs All the marine ornamental fish species identified offer good investment opportunities, however, it should be noted that while marine ornamental fish are profitable based on the generic economic model, careful research and development of systems and breeding methods is required due to the high mortality rates experienced.

Freshwater ornamental fish can be produced anywhere in South Africa; however, the most suitable provinces would offer warm conditions such as Mpumalanga, KwaZulu-Natal, Gauteng and select regions of the Eastern and Western Cape. These provinces also have a distinct advantage due to the presence of large urban centres which are key markets for freshwater ornamental fish

10.2. Recommendations

From the study conducted, the following recommendations have been made:

I. Research and development is required to better understand how commercial production of ornamental fish can be done, specifically looking at breeding, feeding and production systems,
II. Strategic guidelines should be developed for marine and freshwater ornamental fish production in South Africa. These guidelines should include information on production systems, legislative and regulatory information, and environmental considerations for ornamental fish production,
III. The freshwater and marine ornamental fish models should be updated annually to ensure the data is relevant and accurate,
IV. Clear classifications or definitions of what an ornamental fish producer is versus an ornamental hobbyist are required,
V. Ornamental fish producers in South Africa should be identified and recorded. These producers should be encouraged to participate in the aquaculture industry by providing data and information to DAFF,
VI. In terms of permits, ornamental fish producers are not likely to produce on a large scale, thus exceptions could be made for registered producers to not require permits, or to implement permits for small-scale producers that are more affordable,
VII. Research into marine ornamental fish production is essential to reduce the pressure and risk of exploiting natural marine fish stocks, as well as damaging the ocean reef environment,
VIII. Support research into the use of marine fin fish breeding and production technology for marine ornamental fish production,
IX. The value chain should be studied, and supported to assist existing producers, and encourage new entrants into the ornamental fish industry,
X. Implement testing, regulation, and production standards for ornamental fish producers to align with to ensure export markets such as the USA and EU can be targeted,
XI. Implement pilot projects to test systems and species combinations in South Africa. Specifically looking at marine ornamental fish, and
XII. Encourage ornamental producers to produce fish in the already identified Aquaculture development zones (ADZ) to maximise on the infrastructure and support available.

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