<u>Biodiversity Risk and Benefit Assessment for Nile Tilapia (*Oreochromis niloticus*) in South Africa</u>

Prepared in Accordance with Section 14 of the Alien and Invasive Species Regulations, 2014 (Government Notice R 598 of 01 August 2014), promulgated in terms of the National Environmental Management: Biodiversity Act (Act No. 10 of 2004).

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SUMMARY

Internationally, alien species provide a valuable food source and an economic opportunity in both the fisheries and aquaculture sectors. In South Africa, aquaculture is composed of a blend of indigenous and non-indigenous species. However, breeding and domestication of indigenous species requires time, technological and financial resources, whilst there are already alien species with proven aquaculture potential that could be utilized for food production and job creation. There is, however, an environmental risk associated with the uncontrolled introduction and use of alien species and consideration must be given to the potential benefits and risks associated with their use. Internationally, mechanisms and management practices exist to assist with the responsible use and control of alien species in aquaculture and fisheries.

This Biodiversity Risk and Benefit Assessment (BRBA) has been conducted and documented in relation to the import, propagation and grow out of Nile Tilapia (*Oreochromis niloticus*) in South Africa.

The Department of Environment, Forestry and Fisheries (DEFF), as the lead agent for aquaculture management and development, appointed Anchor Environmental Consultants in August 2012 to conduct a Biodiversity Risk and Benefit Assessment (BRBA) for the use of Nile Tilapia in South Africa. In 2018, AquaEco has been appointed to review and update this draft risk assessment in terms of Section 14 of the Alien and Invasive Species Regulations of 2014 and the National Environmental Management: Biodiversity Act 10 of 2004.

The aim of this assessment was to consider the appropriateness (benefit) of the use of the exotic Nile Tilapia (*Oreochromis niloticus*) for aquaculture in South Africa, in relation to the potential effectiveness of management measures for ecologically sustainable development of the sector. This will assist the DEFF and other relevant competent authorities in taking informed decisions regarding the promotion and regulation of this alien and invasive species. The document not only serves as a broad high-level assessment to be applied in the context of new applications and the regulation of the

import and culture of Nile tilapia for aquaculture in South Africa, but will also contributes to the development of environmental norms and standards for the culture of the species. The assessment has been conducted in accordance with the Risk Assessment Framework stipulated for such assessments contained in Section 14 of the Alien and Invasive Species (AIS) Regulations (Government Notice R 598 of August 2014) and the National Environmental Management: Biodiversity Act 10 of 2004. The use of Nile tilapia has also been scrutinised in terms of the restricted activities for which authorisation is required, given that this species has been classified as a Category 2 Alien and Invasive Species in the AIS List (Government Notice R 864 of 29 July 2016).

The risk assessment investigated the taxonomy, key characteristics, dietary aspects and history of Nile tilapia culture, while considering its native environment originates in central tropical Africa. It was found that Nile tilapia is a highly fecund, persistent and potentially invasive species, but that these traits depend on suitable environmental conditions (especially water temperature).

A detailed methodology was followed in the identification and assessment of risks, which included the scoring of each risk pathway and resulting ecological endpoint in categories of probability, severity, scope, permanence, confidence, potential for monitoring and potential for mitigation.

The identified pathways that could facilitate risks include:

- The pathway of escape, via various potential routes that include:
    - Escape during transit of stock from a supplier;
    - Escape via the inflow water;
    - Escape via the outflow water;
    - Escape due to poor design, system malfunction or poor maintenance;
    - Escape through deliberate human actions such as theft or human error;
    - Escape through predation, where fish are preyed upon and removed as live specimens to the surrounding environment; and
    - Escape caused by natural disasters such as flooding.
- The diverse pathway related to the potential transfer of disease.

The identified risk endpoints include:

- The potential for Nile tilapia to cause physical (abiotic) damage to the aquatic environment;
- The potential for Nile tilapia to cause predator displacement in the environment;
- The potential for Nile tilapia to impact on prey species;
- The potential for Nile tilapia to compete for food, habitat niches and other resources;
- The potential for Nile tilapia to hybridise and/or cause species displacement; and
- The potential threat of new or novel diseases carried into the environment by Nile tilapia as a vector – either directly or indirectly.

During the assessment, it was found that the overall ecological risk profile for Nile tilapia was low to moderate, apart from the risk of hybridisation with Mozambique tilapia. The potential for monitoring and mitigation was found to be high, particularly as this related to the prevention of escape.

Key economic and social matters were considered in a balanced manner in conjunction with the potential ecological risks. It was found that the interest in this species across South Africa is likely to stimulate continued illicit trade. The establishment of a formal and lawful Nile tilapia aquaculture sector will contribute to the ecologically responsible use of this species. This will also be in alignment with government's objectives and policies around aquaculture development, apart from the fact that it will create employment, rare skills and local economic activity.

Several measures have been proposed for the monitoring and mitigation of the potential risks, and these could be included as conditions related to the issue of permits. Furthermore, recent initiatives to identify and map areas in which different Nile tilapia production systems can be used, are currently underway.

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1. INTRODUCTION

This Biodiversity Risk and Benefit Assessment (BRBA) pertain to the import, propagation and grow out of Nile tilapia (*Oreochromis niloticus*) in South Africa.

The BRBA has been structured according to the framework provided in Section 14 of the Alien and Invasive Species (AIS) Regulations (Government Notice R 598 of 01 August 2014), promulgated in terms of Section 97(1) of the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA).

2. PURPOSE OF THIS RISK ASSESSMENT

The purpose of this BRBA lies primarily in providing an information framework that can aid in determining the ecological risks and potential benefits of importing, propagating and growing Nile tilapia in South Africa. This framework sets out to provide information to assist decision making regarding the use and permitting of this species.

The BRBA aims to accurately depict the potential ecological risks associated with importing, propagating and growing Nile tilapia, and to evaluate these risks in determining possible justification through allowance by permitting.

Although this BRBA has been prepared to meet the requirements for risk assessments in terms of the AIS Regulations and NEMBA, it illustrates overarching generic information at a national level relevant to South Africa. The intension is to use this framework as a decision support tool for existing and future entrants into the industry sector, to which project- and site-specific information must be added when regulatory approval is sought for the import, propagation and grow out of Nile tilapia.

The main objectives of this BRBA are:

- To determine the primary risks associated with the import, propagation and grow out of Nile tilapia in South Africa.
- To determine the potential benefits associated with the import, propagation and grow out of Nile tilapia in South Africa.

- To provide key information related to the characteristics of Nile tilapia, so that this can be used to analyse risk and benefits.
- To show the pathways that facilitate risks.
- To illustrate the risks in terms of probability of occurrences, degree of severity (magnitude), extent (scale or scope), longevity (permanence), confidence of the analysis and the potential for mitigation and monitoring.
- To illustrate areas of uncertainty in the determination of risk (confidence).
- To determine whether the ecological risk profile is acceptable in terms of the environment in which these risks will occur.
- To use the determined risk factors to provide guidance around decision making and mitigation.
- To use the determined risk factors to provide guidance to monitoring, research needs and ongoing risk communication.
- To provide guidance in terms of mitigation measures.
- To indicate further site specific information required for a risk assessment.

3. THE RISK ASSESSMENT PRACTITIONER

The BRBA was originally prepared by Dr Barry Clark of Anchor Environmental. It has been reviewed, updated and recompiled by Mr. E. Hinrichsen from AquaEco (as commisioned by Aquaculture Innovations). Both authors meet the criteria for risk assessment facilitators (as per Section 15 of AIS Regulations), in that:

- They have practised as environmental assessment practitioners.
- They are independent.
- They are knowledgeable insofar as the NEMBA, the AIS Regulations and other guidelines and statutory frameworks that have relevance, are concerned.
- They are experienced in biodiversity planning in the aquaculture sector and have conducted a range of biodiversity risk assessments.
- They comply with the requirements of the Natural Scientific Professions Act 27 of 2003, and are registered as Professional Natural Scientists with the South African Council for Natural Scientific Professions (SACNASP).

4. NATURE OF THE USE OF NILE TILAPIA

Nile tilapia did not initially find its way into South Africa as an aquaculture species, but as an apparently suitable fodder fish for alien predatory species such as Largemouth Bass (*Micropterus salmoides*), and later as an angling and novelty species from Zimbabwe into the Limpopo River basin. The demand for Nile tilapia as a local candidate for aquaculture started in the late 1990's.

Today, three distinct uses and user groups can be identified for Nile tilapia in South Africa:

- Use of the species in subsistence capture fisheries. There is little doubt that Nile tilapia makes out a portion of the subsistence catch for traditional and artisanal fishermen in the Limpopo River basin and the InKomati River, where they have become established.
- A vibrant angling community that seeks new species for sport angling have become aware of Nile tilapia as a potential alternative angling target.
- The aquaculture sector in South Africa has identified Nile tilapia as a superior candidate species to the indigenous Mozambique tilapia (*Oreochromis mossambicus*), sighting better growth and yields. The rapid international expansion of farming practices with this species is mirrored in the local interests.

This global popularity of Nile tilapia has led to several important developments in culture techniques. Initially, farmed tilapia was allowed to breed freely however, farmers and scientists observed that this led to the production of small fish. In the 1960's, attempts were made to produce male monosex populations through hybridisation between different tilapia species (Hickling, 1963). This proved problematic and gradually females reappeared in the progeny (Wohlfarth, 1994). Major technological development during the 1970's allowed for the successful production of all-male populations, involving the use of sex-reversing hormones that resulted in improved returns from farming. Following this and further research into culture practices, the industry has since boomed (FAO 2012).

Globally, tilapia is often farmed with a variety of other species in the same pond; such as shrimp and milkfish. This not only optimises the financial return if space is limited, but also helps prevent the growth of harmful bacteria and serves to remove excess organic matter in the water (Troell, 2009). Genetic management of the species has also been undertaken to maximise farming efficiency. For example, the *Genetic Improvement in Farmed Tilapia* (GIFT) project in the Philippines created strains of Nile tilapia that grew up to 60% faster (Eknath & Acosta, 1998). However, in Southern Africa, the use of improved stock lines has been limited, and there is scope for improvement in this regard, either by rotational mating or the introduction of improved strains (Brummet & Ponzoni, 2009).

Depending on the nature of Nile tilapia farming (i.e. seasonal or year-round production) there are several alternative options for use as culture methods. These could be i) seasonal pond culture; ii) seasonal cage culture in lakes, rivers and dams; or iii) thermally regulated intensive bio-secure recirculation systems in tanks and raceways (Shipton *et al.,* 2008). Of these, freshwater cage culture poses the highest biosecurity risk (i.e. risk of escape and/or transfer of pathogens and disease to wild populations), while culture in raceways or ponds represent less biosecurity risk, with culture in recirculating systems the lowest biosecurity risk. Generally, the cold winters across South Africa limit systems in which temperature cannot readily be controlled (i.e. open pond culture and cage culture) to the extreme north-east of the country.

5. REASONS FOR FARMING WITH NILE TILAPIA

The FAO estimates that by 2030, fish farming will dominate global fish supplies. With aquaculture already providing more than half of the global seafood demand, it is now considered likely that marine harvesting and terrestrial rangeland farming has reached its capacity in many parts of the world. Aquaculture and intensified agriculture remains the only alternative to supplying a growing food need, fuelled by an increasing global population (Alexandratos *et al.* for the FAO, 2012).

Although the FAO State of World Fisheries and Aquaculture Report (2016) found that Africa accounted for only 2.32 percent of global aquaculture production in 2014, the FAO

State of World Fisheries and Aquaculture Report (2014) highlighted that Africa showed the fastest continental growth in average annual aquaculture production (11.7 percent in 2013).%) between 2000 and 2012. This growth will increasingly lead to the expansion of aquaculture on the African Continent, and particularly in South Africa.

The historical development of aquaculture in South Africa has been slow, and several initiatives have failed. However, South Africa is participating in this global shift that is driven by demand, market and industry globalisation, and rapidly expanding application of advanced agriculture technologies.

The National Aquaculture Policy Framework for South Africa (2013) was developed in reaction to a realization that the country is faced with rapidly diminishing marine fish stocks, an increasing demand for seafood and a developing global aquaculture sector that has become a significant agro-economic driver and food production alternative.

Nile tilapia, while alien to South Africa but indigenous to the African continent, is the second most commonly farmed fish species in the world. Globally, 4.2 million tonnes were farmed per annum in 2016 (FAO, 2018) and this species has rapidly become a universally recognised aquaculture species that efficiently yields a high quality white fish in a competitive manner.

Nile tilapia has been farmed in countries to the north of South Africa for several years (mainly Zambia, Zimbabwe and Mozambique), leading to the establishment of feral populations in the Limpopo and InKomati Rivers (Picker & Griffiths, 2011; Zengeya *et al*., 2013), and unconfirmed records in the Lower Orange River. Historic introduction of these fish to areas such as the Cape Flats and Tongaat in Kwazulu-Natal (Van Schoor, 1966 and Brink, 2002) have created feral pockets of fish of uncertain origin and genetic makeup. Systematically, these and other strains of unknown origin have made their way into legitimate and illegitimate South African aquaculture operations, together with a few advanced farming strains, imported from abroad.

The accelerated growth of tilapia aquaculture worldwide has fuelled the demand for these fish in South Africa; contributing to the increased potential for ecological risks associated with the unchecked distribution and irresponsible use thereof.

Although the locally indigenous Mozambique tilapia (*Oreochromis mossambicus*) could be considered for use in aquaculture, it has been shown (Van de Waal - unpublished data) that Nile tilapia grow approximately 30% faster and yield a larger body size. Growth to market size for Mozambique tilapia could take 10 – 14 months in comparison to 6 – 9 months for Nile tilapia, making Mozambique tilapia less economically viable as a cultured food fish. A comparative study showed that Nile tilapia is capable of yielding 11.7 kg per cubic meter as opposed to 6.5 kg for Mozambique tilapia over a typical growth season and with similar starting biomass and fish numbers (Siddiqui and Al-Harbi, 1997). In addition, the continued international development of Nile tilapia strains specific to aquaculture, make this fish species a preferred candidate for farming.

6. LEGAL CONTEXT

The Department of Environment, Forestry and Fisheries (DEFF) is the mandated authority over the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA), which sets out the framework, norms, and standards for the conservation, sustainable use, and equitable benefit-sharing of South Africa's biological resources. The AIS Regulations and the AIS List (Government Notice R 864 of 29 July 2016) have been promulgated in terms of this Act, providing enabling instruments for the Act.

These statutory frameworks recognise and categorise indigenous and alien species, some of which have the potential to become invasive when introduced into areas where they did not occur historically. A range of human activities that could potentially spurred the spread and introduction of these alien species into non-native areas, are referred to as restricted activities.

6.1. CATEGORIZATION OF ALIEN AND INVASIVE SPECIES

Collectively the NEMBA, the AIS Regulations and the AIS Lists, categorise alien and invasive species, and prescribe the approach that should be taken to each category:

- **Exempted Alien Species** mean an alien species that is not regulated in terms of this statutory framework **-** as defined in Notice 2 of the AIS List.
- **Prohibited Alien Species** mean an alien species listed by notice by the Minister, in respect of which a permit may not be issued as contemplated in section 67(1) of the Act. These species are contained in Notice 4 of the AIS List, which is referred to as the List of Prohibited Alien Species (with freshwater fish in List 7 of Notice 4).
- **Category 1a Listed Invasive Species** mean a species listed as such by notice in terms of section 70(1)(a) of the Act, as a species which must be combatted or eradicated. These species are contained in Notice 3 of the AIS List, which is referred to as the National Lists of Invasive Species (with freshwater fish in List 7 of Notice 3).
- **Category 1b Listed Invasive Species** mean species listed as such by notice in terms of section 70(1)(a) of the Act, as species which must be controlled. These species are contained in Notice 3 of the AIS List, which is referred to as the National Lists of Invasive Species (with freshwater fish in List 7 of Notice 3).
- **Category 2 Listed Invasive Species** mean species listed by notice in terms of section 70(1)(a) of the Act, as species which require a permit to carry out a restricted activity within an area specified in the Notice or an area specified in the permit, as the case may be.
- **Category 3 Listed Invasive Species** mean species listed by notice in terms of section 70(1)(a) of the Act, as species which are subject to exemptions in terms of section 71(3) and prohibitions in terms of section 71A of Act, as specified in the notice.

6.2. STATUTORY CLASSIFICATION OF NILE TILAPIA

With reference to Notice 3, List 7 (National List of Invasive Fresh-water Fish Species) in the AIS List (Government Notice R 864 of July 2016) and the categorization of alien and invasive species indicated in Section 5.1 above, Nile tilapia is categorized as follows:

- Category 1b (*compulsory control*) in National Parks, Provincial Reserves, Mountain Catchment Areas and Forestry Reserves specified in terms of the Protected Areas Act.
- Category 2 (*compulsory permitting*) for aquaculture facilities in the rest of the country.
- Category 3 (*exemptions apply*) in all other discrete catchment systems in which it occurs.

Further prohibitions and exemptions that apply to Nile tilapia, include:

- The transfer or release of a specimen of Nile tilapia from one discrete catchment system in which it occurs, to a river, wetland, natural lake or estuary, or a dam that is not an aquaculture facility, in another discrete catchment system in which it does not occur; or, from within a part of a discrete catchment system where it does occur to a river, wetland, natural lake or estuary, or a dam that is not an aquaculture facility, in another part where it does not occur as a result of a natural or artificial barrier, is prohibited.
- Release of Nile tilapia in National Parks, Provincial Reserves, Mountain Catchment Areas and Forestry Reserves declared in terms of the Protected Areas Act, is prohibited.
- Catch and release of Nile tilapia is exempted in discrete catchment systems in which it occurs.

These regulations point to Nile tilapia as being classified in Category 2 as this relates to the general import, propagation and grow out thereof for aquaculture, in areas in which it has not established a feral population.

6.3. LIST OF RESTRICTED ACTIVITIES

While Section 1 in Chapter 1 of the NEMBA defines the restricted activities in relation to alien and invasive species, these activities are expanded upon in Section 6, Chapter 3 of the AIS Regulations. These activities include:

From the NEMBA:

- Importing.
- Possessing (including physical control over any specimen).
- Growing, breeding or in any other way propagating or causing a specimen to multiply.
- Conveying, moving or otherwise translocating.
- Selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of any specimen.

From the AIS Regulations:

- Spreading or allowing the spread of any specimen.
- Releasing.
- Transferring or release of a specimen from one discrete catchment in which it occurs, to another discrete catchment in which it does not occur; or, from within a part of a discrete catchment where it does occur to another part where it does not occur as a result of a natural or artificial barrier.
- Discharging of or disposing into any waterway or the ocean, water from an aquarium, tank or other receptacle that has been used to keep a specimen or a listed invasive freshwater species.
- Catch and release of a specimen of an invasive freshwater fish or an invasive freshwater invertebrate species.
- Introducing of a specimen to off-shore islands.
- Releasing of a specimen of an invasive freshwater fish species, or of an invasive freshwater invertebrate species into a discrete catchment system in which it already occurs.

All the restricted activities above could potentially apply to the import, propagation and grow out of Nile tilapia in South Africa. However, import will be excluded where fish are obtained locally (i.e. from local producers), while intentional release generally does not apply to the use of Nile tilapia for aquaculture.

7. TARGET SPECIES: NILE TILAPIA

7.1. TAXONOMY

Common Name:	Nile tilapia
Kingdom:	*Animalia*
Subkingdom:	*Bilateria*
Infrakingdom:	*Deuterostomia*
Phylum:	*Chordata*
Subphylum:	*Vertebrata*
Infraphylum:	*Gnathostomata*
Superclass:	*Osteichthyes*
Class:	*Actinopterygii* (ray-finned fishes)
Subclass:	*Neopterygii*
Infraclass:	*Teleostei*
Order:	*Perciformes* (perch-like fishes)
Suborder:	*Labroidei*
Family:	*Cichlidae* (Cichlids)
Subfamily:	*Pseudocrenilabrinae*
Genus:	*Oreochromis* (Günther, 1889)
Species:	*niloticus niloticus* (Linnaeus, 1758)
Taxonomic Code:	1705905102

Nile tilapia (*Oreochromis niloticus niloticus*) has six sub-species:

O.n. eduardianus
O.n. filoa
O.n. baringoensis

O.n. sugui'ae
O.n. cancellatus
O.*n. vulcani*

Other Names:	Tilapia du Nil, Tilapia del Nilo, Nyl Tilapia, Nile mouthbrooder, chhnoht, chikadai, kurper, munruvare, pla pla, planil, telepia, tilapia, tilapie, trey tilapia, wass
Synonyms:	*Chromis nilotica* (Linnaeus, 1758) *Chromis guentheri* (Steindachner, 1864) *Oreochromis niloticus baringoensis* (Trewavas, 1983) *Oreochromis niloticus filoa* (Trewavas, 1983) *Oreochromis niloticus sugutae* (Trewavas, 1983) *Oreochromis niloticus tana* (Seyoum & Kornfield, 1992) *Perca nilotica* (Linnaeus, 1758) *Tilapia calciati* (Gianferrari, 1924) *Tilapia cancellata* (Nichols, 1923) *Tilapia eduardiana* (Boulenger, 1912) *Tilapia inducta* (Trewavas, 1933) *Tilapia nilotica* (Uyeno & Fujii, 1984) *Tilapia regani* (Poll, 1932) *Tilapia vulcani* (Trewavas 1933)

7.2. ORIGINATING ENVIRONMENT

Nile tilapia is native to tropical central Africa [Eritea, Addagalla, Harar (Ethiopia), Baringo, Crater, Kivu, Rudolf, Tana, Turkana and Buyoni Lakes, Mt Ruwenzori, Kissenyi, Kenya, Uganda and Zaire (Boyd 2004)]. It is a tropical freshwater and upper estuarine species preferring shallow, slow flowing or still waters such as slow-moving lentic sections of rivers, floodplains, pools and shoreline environments of lakes and dams, favouring aquatic structure and submerged vegetation (Picker & Griffiths, 2011).

7.3. KEY PHYSIOLOGICAL CHARACTERISTICS

Nile tilapia have has a deep, horizontally compressed body that is covered in cycloid scales. These fish are generally silver in colour with olive, grey and black barring, although they can flush in red, maroon and black during the breeding season (Picker & Griffiths, 2011). Other physiological characteristics include:

- The upper jaw length shows no sexual dimorphism.
- The lateral line is interrupted.
- The first gill arch has 27 to 33 gill rakers.
- The dorsal fin has 16 - 17 spines and 11 to 15 soft rays.
- Spinous and soft ray parts of the dorsal fin are continuous.
- The anal fin has 3 spines and 10 - 11 rays.
- The caudal fin is truncated.

Nile tilapia can reach a maximum length of 62 cm and a weight of 3.65 kg (at an estimated nine years of age) (FAO, 2012). Nile tilapia have however been reported to live for longer than 10 years (GISD, 2012).

Figure 1: Nile tilapia (Oreochromis niloticus).

7.4. REPRODUCTION

Under ideal conditions, Nile tilapia can reach sexual maturity at an age of 6 months and spawning commences from a temperature of 24°C and above (FAO, 2012). Male fish initiate breeding with the creation of a spawning depression, which is fiercely guarded. Sexually mature females spawn into these nesting depressions, where after males fertilise the eggs. The female collects and incubates the fertilised eggs in her mouth (i.e. mouth brooding). The eggs and the hatched fry are incubated and brooded in this manner, until the yolk sac is fully absorbed two weeks later (FAO, 2012). Small fry may remain in the female's mouth before dispersal.

The number of eggs produced is proportional to body size. This can range from 100 eggs produced by a 100 g fish to 1500 eggs spawned by a 1 kg fish. The females will not spawn while brooding, but males will fertilise the eggs of multiple females under optimal environmental conditions (FAO, 2012).

7.5. DIETARY ASPECTS

Nile tilapia are omnivorous grazers that feed on phytoplankton, periphyton, aquatic plants, small invertebrates, small fish and eggs, benthic fauna, detritus and bacterial films (FAO, 2012). Depending on the food source, they will feed either through suspension filtering or surface grazing (GISD, 2012). Nile tilapia can filter feed by entrapment of suspended particles, including phytoplankton and bacteria, on mucous excreted from the gills in the buccal cavity (Fryer & Iles, 1972), although their main source of nutrition is obtained by surface grazing on periphyton mats.

These fish, also known as phyto-planktivores, exhibit some degree of trophic plasticity or opportunism, depending on the specific habitat, available feeding niches and other species with which they coexist (Bwanika *et al.* 2007). Under certain conditions they may become piscivorous.

7.6. ENVIRONMENTAL TOLERANCES

Nile tilapia can withstand a wide range of environmental conditions, including high salinities, high temperatures, high ammonia concentrations, and low oxygen levels (less than 3 - 4 mg/L) (Boyd, 2004). Their preferred pH range is 6 – 9, while their lethal upper and lower limits are 5 and 10 respectively. For temperature, their preferred range is 31 - 36°C, while their lethal upper and lower limits are 11°C and 42°C respectively (FAO, 2012).

Optimal growth occurs between 28 - 36°C and declines with decreasing temperature (Teichert-Coddington *et al.* 1997; FAO, 2012).

7.7. NATURAL ENEMIES, PREDATORS AND COMPETITORS

As is the case with many fish species, the life history strategy of Nile tilapia is based on high fecundity to compensate for significant losses to predation. Although these fish actively avoid predation by remaining close to submerged structure and vegetation, and by shoaling, they are preyed upon by other fish, birds, reptiles (e.g. crocodiles and monitor lizards), aquatic mammals (e.g. otters) and crustaceans (e.g. crabs).

In their native range, Nile tilapia occupy an ecological niche that is highly competitive due to the presence of many *Cichlid* and other fish species. The species' natural ability to survive in such a competitive habitat results in it being well adapted to compete for food and habitat in non-native environments into which it may be introduced.

7.8. POTENTIAL TO HYBRIDISE

Nile tilapia can hybridise readily with other *Oreochromis* species. Such hybridisation can only occur with species in the same genus (*Oreochromis*) and the resultant hybrids tend to be more dominant and competitive than other *Oreochromis* species, due to fast growth, fecundity, hardiness, unspecific diet and large size. This could lead to the displacement of other *Oreochromis* species (Tweddle and Wise, 2007).

7.9. PERSISTENCE AND INVASIVENESS

The major factors limiting the distribution of Nile tilapia are food availability, salinity and temperature (Shipton *et al*., 2008; Kapetsky and Nath, 1997). Where these fish are introduced into freshwater systems within their lethal temperature range, it is likely that they will survive and become established. This persistence has led to an extended global distribution.

Nile tilapia are competitively successful due to their fast growth, large size (allowing for successful competition for nesting grounds), high fecundity, ability of juveniles to survive and avoid predation despite adverse conditions such as large temperature fluctuations, a broader-ranging and non-specific diet, and the ability to hybridise and outcompete other tilapias (Tweedle and Wise 2007).

Arguably the most undesirable trait of Nile tilapia is its ability to hybridise with other *Oreochromis* species, and to outcompete these species in their native ranges and habitats. While there are clear social and economic advantages to this species from an aquaculture perspective, this trait has resulted in ecological displacement of native *Oreochromis* species in African river systems. Examples of such displacements include:

- In Kenya, Nile tilapia has displaced almost all the native *Oreochromis* species over a 30-year period.
- In Lake Kariba (Zimbabwe) Nile tilapia has displaced Kariba Tilapia (*Oreochromis mortimeri*).
- In Lake Victoria Nile tilapia has displaced the Singida Tilapia (*Oreochromis esculentus*).

After introduction of Nile tilapia into Lake Kariba, fish were systematically moved south towards the Limpopo River, and eventually became established in a significant number of tributaries of this system. Here they have hybridised and displaced indigenous Mozambique tilapia (*Oreochromis mossambicus*) populations, while the resultant strains have been distributed further into South Africa. The increasing use of Nile tilapia in southern Mozambique has already resulted in these fish invading the InKomati River, which is likely to lead to dispersal through human actions into adjacent Swaziland and South Africa (Zengeyah *et al.* (2013). Use of these fish in Namibia has most likely caused introduction into the Lower Orange River (via the Fish River).

Globalisation has contributed to the spread of many angling and aquaculture species, with introduced species being marketed worldwide, and modern transport options allowing for the relocation of species across physical barriers (Cambray, 2003). The dispersal mechanisms for Nile tilapia are predominately through human actions in that fish are moved for aquaculture, angling and for other reasons attributed to human need and desire. An example hereof is the distribution of this species by the UN Pease Corps for small-scale aquaculture in Zambia and elsewhere in Africa during the 1980's.

Nile tilapia is one of the top ten introduced species of the world (Picker & Griffiths 2011). To date, tilapia species have been introduced into more than 90 countries across the world, with farms on every continent except Antarctica (Fitzsimmons, 2001). Nile tilapia is considered invasive in the Guangdong Province of China, Virginian Carolinian, Northern Gulf of Mexico, Northern California, Floridian and the Hawaiian Islands.

7.10. HISTORY OF TRANSLOCATION AND CULTIVATION

While tilapia farming can be traced back to ancient Egyptian times some 4000 years ago, the global interest in the culture of tilapia, mainly Mozambique tilapia, started during the 1940's. From the 1960's onwards, Nile tilapia was increasingly distributed as a preferred alternative to Mozambique tilapia, and today this species can be found on every continent except Antarctica (FAO, 2012). Nile tilapia were was introduced into China in 1978 and this country today accounts for more than half of the global aquaculture production.

Aquaculture was heralded as the perfect protein production technique for developing countries during the 1960's and 1970's. Given the apparent social and economic benefits, aid organisations (primarily in Africa), played a significant role in the distribution of Nile tilapia (Canonico *et al.* 2005).

Early unrefined farming techniques (uncontrolled spawning, inbreeding, stunted growth etc.), resulted in lower levels of initial interest in the farming of tilapia. However, from the 1970's onwards, improvements in research, the farming of monosex cultures and market development, saw this species become the second most commonly farmed fish worldwide. The Genetically Improved Farmed Tilapia (GIFT) strain developed by the WorldFish Centre, as well as other strains (e.g. GET EXCEL, GenoMar ASA and GenoMar Supreme Tilapia and others) has a significantly better growth performance than "*unaltered*" strains (Asian Development Bank, 2005).

The international production of Nile tilapia in aquaculture has increased exponentially since the 1950's and now totals 3 930 579 tonnes annually (FAO, 2015). As new first world markets increasingly became accustomed to Nile and other tilapia species, the value of the trade in Nile tilapia increased and is now valued at U$ 6.017 billion (FAO, 2015)

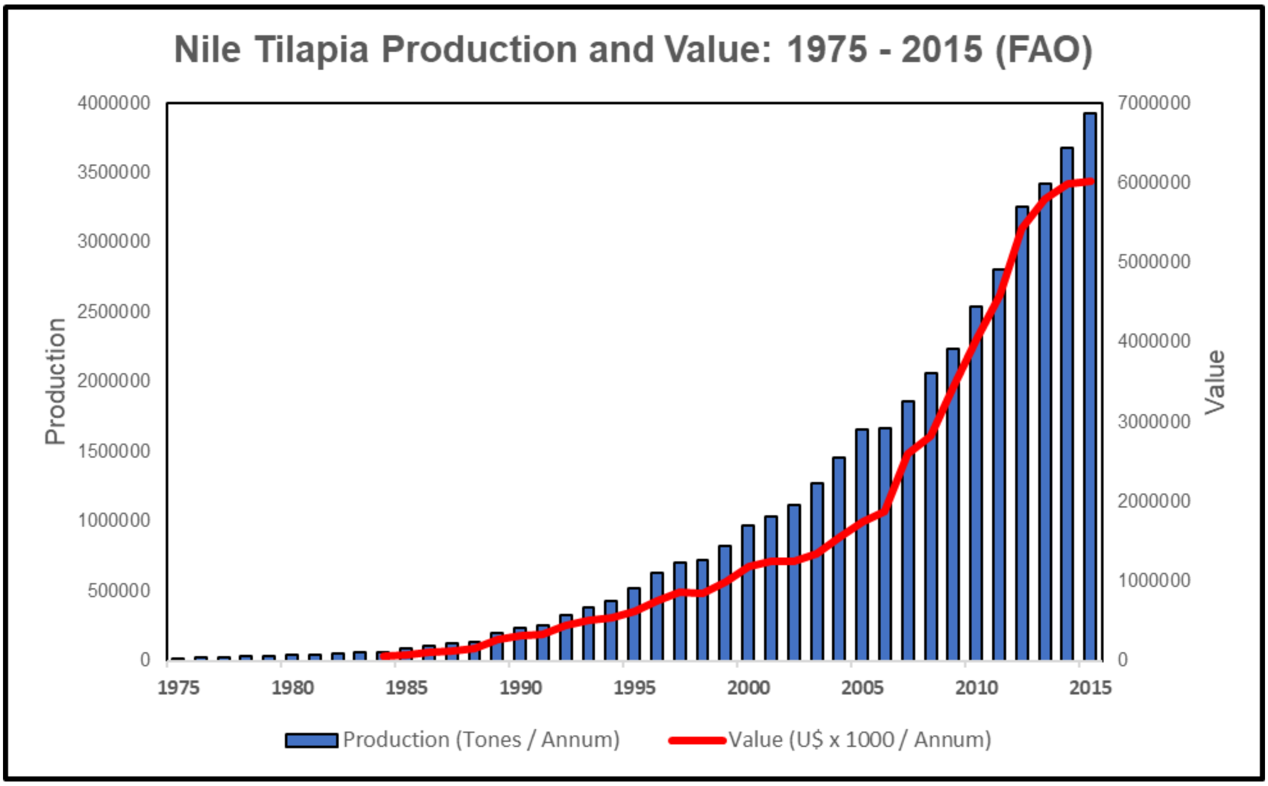

Figure 2: International production of Nile tilapia in tonnage and value between 1975 and 2015 (FAO - Fisheries and Aquaculture Information and Statistics Service).

Nile tilapia was first introduced into South Africa in 1959 (Western Cape and KwaZulu-Natal) as a fodder fish for bass (van Schoor, 1966). Since the 1980's a combination of intentional introductions by fish farmers and anglers, and the incremental introduction of fish from the north to the south of Zimbabwe, has seen the establishment of self-sustaining feral populations in the InKomati and Limpopo Rivers (Picker & Griffiths, 2011 and Zengeya *et al*., 2013). Several other locations (e.g. the Tongaat River and the Cape Flats) hold feral populations of Nile tilapia and other tilapia hybrids of unknown origin. As indicated in the previous section, systematic introduction through the south of Mozambique could result in these fish becoming established in the waterways of northern KwaZulu-Natal, and they have most probably moved down the Fish River and into the Lower Orange River, albeit that the habitat (mainly from a water temperature perspective), is not ideal.

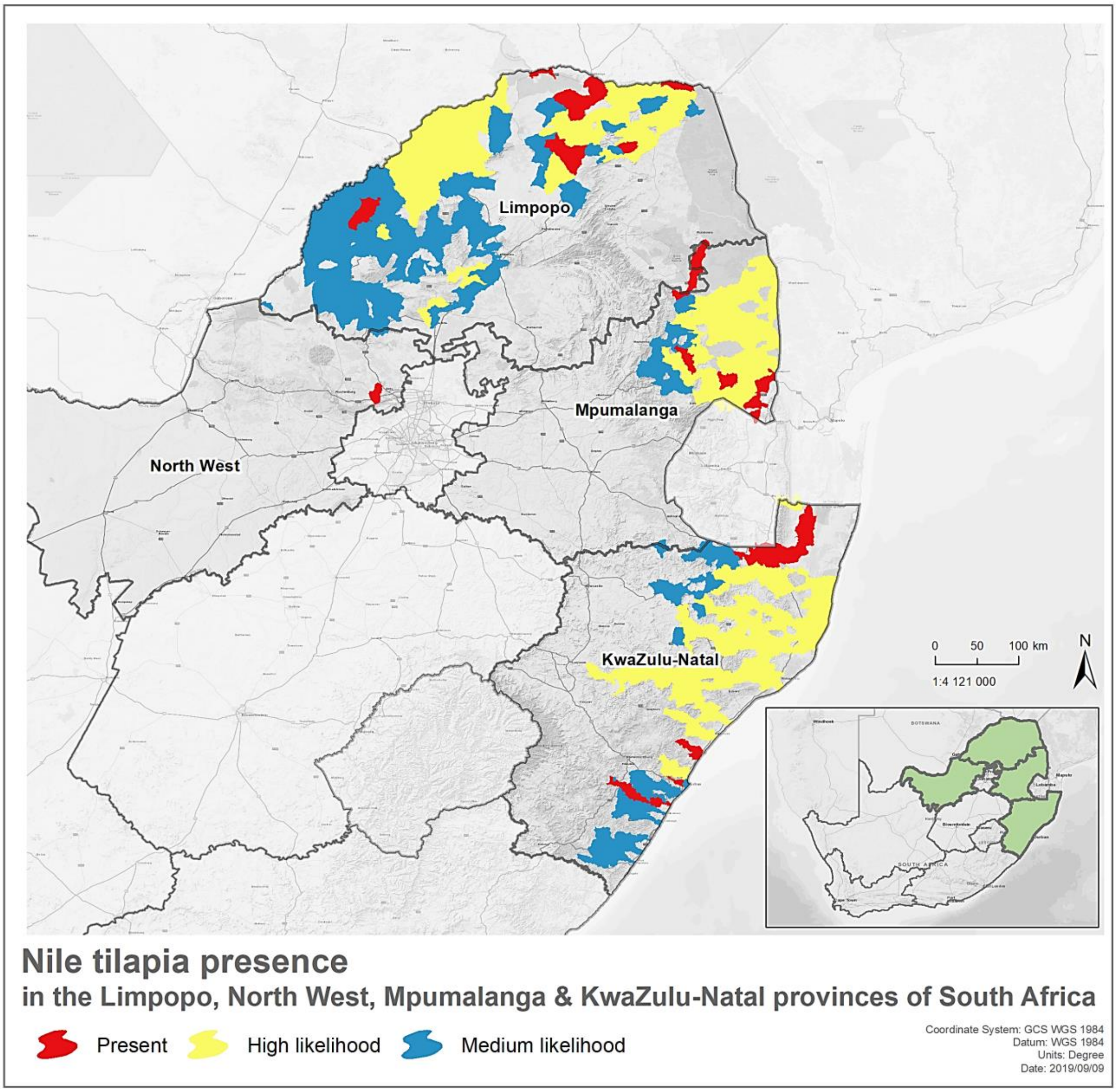

Figure 3: Nile tilapia presence indicated in the Limpopo, North West, Mpumalanga and KwaZulu-Natal provinces of South Africa (Source: SANBI, 2018).

7.11. ABILITY TO CREATE ECOSYSTEM CHANGE

Nile tilapia are only capable of bringing about ecosystem change in specific habitats that have characteristics susceptible to such change. In waters that are populated by other *Oreochromis* species they can hybridise with these and tend to become a dominant hybrid in many of the niches occupied by species in the *Cichlidae* family. This in turn can cause several ecological shifts through changes related to species displacement, competition etc. Through tropic plasticity, Nile tilapia can feed on a range of species, and even other fish under specific circumstances. Complete ecosystem dysfunction is however not possible and apart from impacts through feeding and species displacement, Nile tilapia are unlikely to impact directly on the physical or abiotic characteristics of any habitat.

7.12. PROBABILITY OF NATURALISATION

Nile tilapia have already established self-sustaining populations in the Limpopo River basin, the InKomati River and in other locations across South Africa (including an unconfirmed presence in the lower Orange River). In some countries to the north of South Africa (i.e. Botswana), fewer of these fish have been reported, but they have become well established in Zimbabwe and Mozambique.

If left unchecked, it is probable that Nile tilapia could become established in several areas in South Africa (see climate and habitat match in Section 7.1). However, given the fact that the optimal temperature for growth of Nile tilapia ranges from 28-36°C (Teichert-Coddington *et al.* 1997; FAO, 2012), and the fact that females only tend to spawn at temperatures above 24°C, it is likely that Nile tilapia will only be able to become established as self-sustaining feral populations in the tropical, north-eastern sector of the country. This is consistent with the current distribution range in the InKomati and Limpopo River basins (Picker & Griffiths, 2011).

7.13. POSSIBLE IMPACTS ON BIODIVERSITY

The possible impacts of Nile tilapia on biodiversity depend on the habitat type. These potential impacts, which can range from negligible in marginal habitats to extensive in highly suitable areas, include:

- Nile tilapia can outcompete certain species (mainly *Cichlid* species) for food and habitat, which can lead to a reduction in species related biodiversity. This is only possible in suitable habitat types, in which susceptible native species occur.
- Nile tilapia can be highly fecund, are not highly selective towards spawning habitat and conditions, and can spawn repetitively under ideal conditions. This adds to the potential for these fish to outcompete native species for food and habitat, with similar consequences to biodiversity, as indicated under the first bullet.
- Although Nile tilapia are generally omnivorous, they can elevate upwards in the trophic chain by opportunistically consuming aquatic and terrestrial invertebrates, as well as eggs and larvae of other fish species, leading to a potential decline in native biodiversity and fish species diversity.
- The introduction of Nile tilapia could cause secondary impacts to biodiversity by changing the abundance of species on which other piscivorous animals depend.
- Nile tilapia could affect biodiversity through genetic impacts. These effects can be direct through hybridisation, or indirect through declining population sizes of native species, resulting in a loss of genetic diversity.
- The potential impacts of Nile tilapia on invertebrate species are not well documented.

In this risk assessment, consideration must be given to the potential general impacts on biodiversity, through related ecological consequences and extended tropic disturbances that may occur.

7.14. POSSIBLE IMPACTS ON OTHER NATURAL RESOURCES

The possible impacts of Nile tilapia on natural resources is restricted mainly to the impacts that Nile tilapia may have on fisheries resources, by affecting the population densities and abundance of certain species. This has been recorded in some African lake systems and elsewhere, where fisheries resources are extensively used by local people.

7.15. NILE TILAPIA AS A VECTOR OF OTHER ALIEN SPECIES

The uncontrolled movement of Nile tilapia from one area to another may result in the introduction of other species, if care is not taken with regards to ensuring that other similar looking *Cichlid* species, or small fish that have few distinguishing characteristics, are excluded. This is unlikely to happen under controlled hatchery conditions where young fish of a specific species is imported from a specific source, and isolated for further use.

8. THE RECEIVING ENVIRONMENT

As a national framework document, this risk assessment cannot report on the receiving environment for specific areas, and on specific Nile tilapia projects or restricted activities. Nationally, the entire South Africa is seasonally within the lethal temperature tolerance range for Nile tilapia, meaning that this species would be able to survive in any waterway in South Africa during summer, and will persist if water quality was otherwise suitable, and food was available. Nevertheless, the winter temperatures in much of South Africa will preclude survival from year to year.

8.1. CLIMATE AND HABITAT MATCH

In South Africa, several habitat types are potentially suited to the naturalisation of Nile tilapia. As water temperature is a primary determinant for the survival and reproduction of Nile tilapia, correlations with ambient temperatures across the 31 terrestrial ecoregions of South Africa (Kleynhans *et al*. 2005) was used to determine potential areas that could be suitable to naturalisation (by comparison with known tolerance ranges of the species). It was found that Nile tilapia could theoretically survive in 12 ecoregions across South Africa, but that establishment in some of these would only be possible seasonally (i.e. in summer). With reference to the map that follows, these ecoregions are:

- Limpopo Plain (region 1)
- Soutpansberg (region 2)
- Lowveld (region 3)
- North Eastern Highlands (region 4)
- Northern Plateau (region 5)
- Lebombo Uplands (region 12)
- Natal Coastal Plain (region 13)
- North Eastern Coastal Belt (region 17)
- Western Coastal Belt (region 25)
- Orange River Gorge (region 28)
- Ghaap Plateau (region 30)
- Eastern Coastal Belt (region 31)

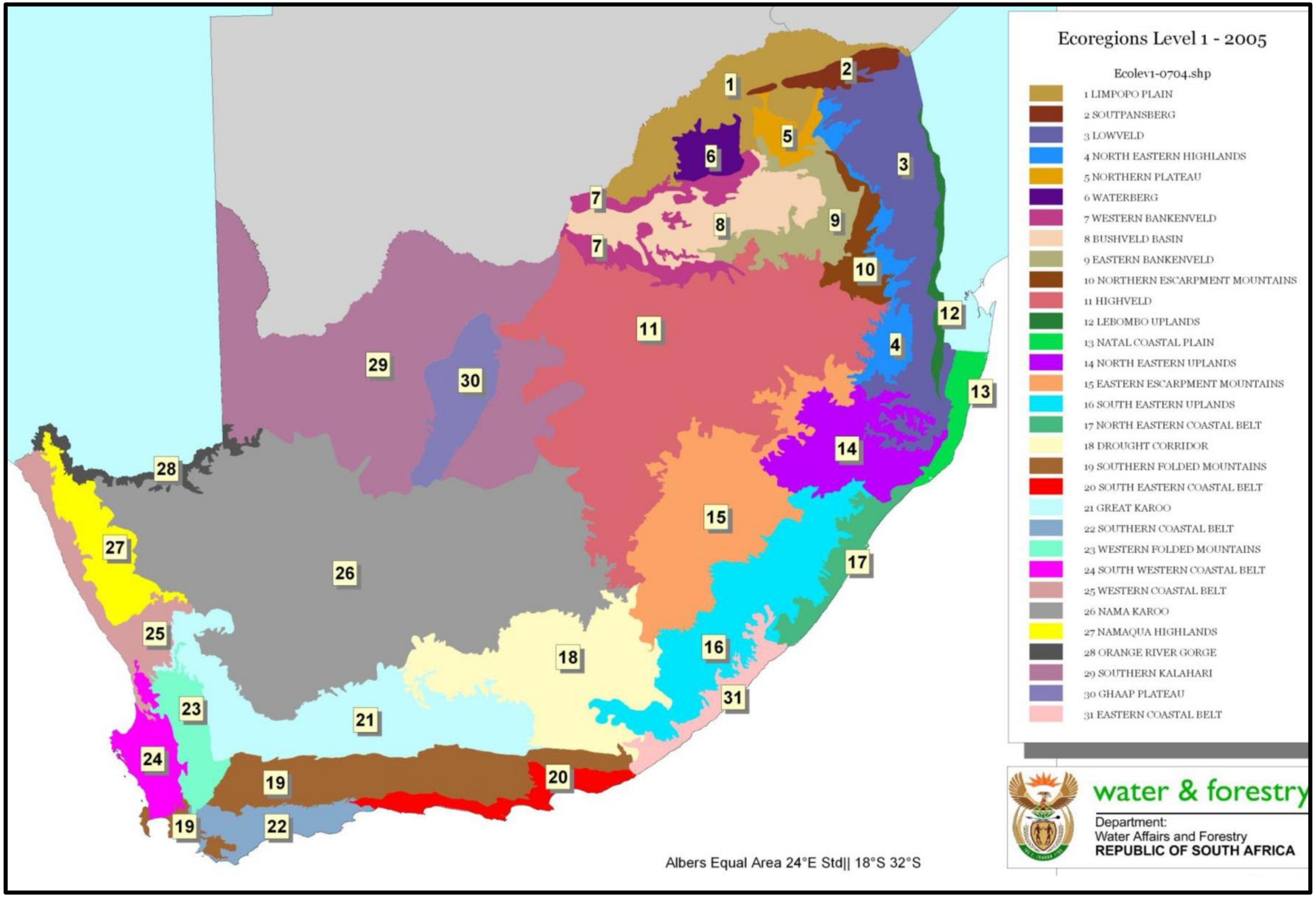

Figure 4: Ecoregions of South Africa

Noteworthy is that Nile tilapia is already confirmed as established in four of these regions [Limpopo Plain (1), Soutpansberg (2), Natal Coastal Plain (13) and North Eastern Coastal Belt (17)], while populations (perhaps seasonal) have also been reported in areas outside of these regions [Waterberg (6), Western Bakenveld (7), Bushveld Basin (8) and South-Eastern Uplands (16)] (Picker and Griffiths, 2011).

The results above reflect a coarse analysis of areas within which these fish may survive. The probability of establishment however ranges from very high in the north-eastern subtropical zones, through to low or improbable in the climatically marginal areas [such as the Western Coastal Belt (25) and the Eastern Coastal Belt (31)]. Across these large stretches of the landscape that make out each ecoregion, the potential for establishment is not evenly distributed; to the extent that large areas within marginal zones will not be suitable for the survival of self-sustaining populations of Nile tilapia.

In this risk assessment it is important to recognise that many existing and potential future Nile tilapia farms are based on indoor systems in which water temperature can be regulated. This means that Nile tilapia farming can be practised successfully in areas outside of the environmental range in which they would be able to survive in open waterbodies.

8.2. TOOLS TO IDENTIFY SENSITIVE AREAS

Many national and provincial conservation plans, biodiversity frameworks and mapped sensitive areas can be used to determine sensitive area in which Nile tilapia may pose a biodiversity impact. These include, but are not limited to:

- The National Freshwater Ecosystem Priority Areas (NFEPA), which geographically identifies sensitive freshwater environments, including environments in which certain fish species are identified as sensitive.
- A range of geographic mapping tools are published by the South African National Biodiversity Institute (SANBI), through which proclaimed conservation areas, critical biodiversity areas and other sensitive habitats can be identified.
- Apart from general information that can be accessed from the National Department of Environment, Forestry and Fisheries (DEFF), local and provision

conservation authorities, and mandated provincial biodiversity authorities can provide local information of relevance.

9. THEORY BEHIND ECOLOGICAL RISK ASSESSMENT

Ecological Risk Assessment provides an effective tool for assessing environmental effects or actions, and aids in resource based and environmental decision making. The risk assessment approach is widely recognized and much of this document is based on internationally researched risk assessment principals. To this end, the process is well suited to the establishment of the BRBA framework for the import, propagation and grow out of Nile tilapia, in that it provides a platform from which decisions can be made and from which risks can be identified for management and monitoring.

The European Union (2000) defines risk as the probability and severity of an adverse effect or event occurring to man or the environment from a risk source. The assessment methods for such risks are widely used in many environments and for many diverse purposes. Through determining the interplay between uncertainty and variability, a risk assessment evaluates the likelihood that adverse ecological effects may occur as a result of one or more stressors. This likelihood of occurrence can be further defined in terms of temporal structure (longevity or permanence), severity, scope (scale), uncertainty and the respective potential for mitigation and monitoring.

McVicar (2004) describes risk analysis as "*a structured approach used to identify and evaluate the likelihood and degree of risk associated with a known hazard*". This is done with due cognizance of information or outcome uncertainties, so that it is generally accepted that higher levels of uncertainty correspond to higher levels of risk. It is, however, important to realise that uncertainty and probability are different elements in risk assessment, and that these in themselves stand distinguished from factors such as extent (scope and scale), significance (severity) and permanence.

The risk analysis process is built around the concept that some aspects of the activity under consideration can lead to the release of a hazard, which in turn could lead to a change in the environment. In the case of importing, growing out and propagating Nile tilapia, an example would be the escape and survival of an alien species (the hazard) into the environment, potentially leading to impacts on indigenous biodiversity (the result or endpoint).

9.1. THE PRECAUTIONARY AND OTHER PRINCIPALS

The precautionary principle has emerged as a fundamental driver in risk assessment and has become a popular approach to deal with uncertainty in decision making. The United Nations 1992 Conference on Environment and Development referred to the precautionary principal as an approach in which "*the lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*".

The precautionary principle was re-stated and internationally agreed in Principle 15 of the Rio Declaration of the UN Conference on Environment and Development (UNCED):

"*In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"*.

The precautionary principal is often wrongly used as a "*trump card*" to legitimize arguments against development and environmental change. The precautionary principal is, however, a principal that removes the need for concrete scientific proof of cause and effect, and rather shifts the emphasis to responsible precaution based on logical analysis of risk and implementation of cost-effective mitigation measures.

The wide application of risk assessment also incorporates other principals, the most important of which are:

- Optimal management of risk can only occur where there is an open, transparent and inclusive process that integrates effective risk communication with hazard identification, risk assessment and risk management.

- Risk assessment is most valuable if considered together with social and economic impacts (positive and negative).
- The nature of a risk depends largely on the acceptable endpoint (acceptable level of change), which can be highly subjective.
- For risk management to be effective, acceptable endpoints should be measurable.
- Zero tolerance to environmental change is not practical in risk management.
- Specific risks should not be seen in isolation to risks associated with other activities in a common environment (risk proportionality).
- Risk assessment depends on effective and understandable communication of risk.
- Risk assessment must be consistent in the manner in which risks are determined and scaled.
- A risk does not exist if a causal pathway between the hazard and the endpoint is absent. The level of risk is however influenced by the nature of such a pathway.
- Risk assessment should lead to monitoring to improve understanding of the mechanisms leading to environmental change and the level of risk (increased or decreased).
- Risks should be identified along with the environmental change they may cause.
- Uncertainly is not a failing of risk assessment, but a characteristic which should be used in risk management.
- Cost benefit analysis should be used in risk management to logically determine the practicality, need and nature of risk mitigation measures.

9.2. METHODOLOGY IN THE RISK ASSESSMENT

In aquaculture, several risk assessment methodologies are used, each of which depict different levels of complexity and subjectivity (Burgman, 2005; Kapuscinski *et al*. 2007; Vose 2008; FAO, 2015). However, the interplay between likelihood and consequence to determine acceptability and management needs, remains at the core of most methods.

Many risk assessment methods suffer from bias and these shortcomings must be managed (Burgman 2001). Hayes *et al*. (2007) outline several ways to help maintain the scientific credibility of risk assessment (FAO, 2015).

Risk assessment is primarily made up of three phases, consisting of problem formulation, problem analysis and risk characterisation. The problem analysis phase can be further sub-divided into two distinct sections: characterization of exposure and characterisation of effect.

Risk analysis provides an objective, repeatable, and documented assessment of risks posed by a particular course of actions or hazards. This BRBA framework depicts two methods to assess risk:

1. A step-by-step process expanded and modified from the aquaculture risk assessment work by Fletcher *et al*. (2002 and 2003), in which an inventory of potential risks is characterized and scored for probability, severity, scope, permanence, confidence, monitoring and mitigation; and
2. The European Non-Native Species Risk Analysis Scheme (ENSARS) (Copp *et al.,* 2008) developed by CEFAS (UK Centre for Environment, Fisheries & Aquaculture Science). ENSARS provides a structured framework (Crown Copyright 2007-2008) for evaluating the risks of escape and introduction to, and establishment in open waters, of any non-native aquatic organism. For each species, 49 questions are answered, providing a confidence level and justification (with source listed) for each answer. The questions and results of the assessment on Nile tilapia can be found in Appendix 1.

The following steps constitute the method that has been expanded and modified from the work by Fletcher et al. (2002 and 2003):

- Identification of risks and determination of endpoints (consequences). This is also referred to as problem formulation in risk assessment and determines what is at risk.
- Determination of the endpoints and the acceptability in endpoint levels (the level of acceptable change if a risk or stressor were to occur).

- Modelling of the risk pathway from hazard to endpoint (also called logical modeling).
- Assessing the risk by means of any information resources and experience. This can be divided into two distinct sections: the exposure assessment (nature of the risk / stressor) and effects assessment (nature of the endpoint or effect on the environment).
- Determination whether the risk has the potential to increase the probability of the endpoint occurring. If there is no such potential, such a risk can be eliminated from analysis.
- Describing the probability, intensity (severity) and scale (scope) of the risk to the environment (also called risk characterisation).
- Determining the level of uncertainty (confidence) in risk characterisation.
- Tabulating the findings according to intensity (severity or degree) of change, the geographical extent of the change (scope), and the duration or permanence of the change.
- Approximating the probability and the uncertainty.
- Addressing areas of weakness where the collated information appears incomplete or inadequate.
- Assessing the acceptability of the proposed activity through reference to the tabled analysis.
- Assessing the opportunity for risk mitigation and monitoring, and the need for additional research to reduce uncertainty.
- Effectively communicating risk in an on-going manner to all relevant stakeholders.

9.3. THE RISK PATHWAY

Before any risk can be characterised, the link between the hazard and the endpoint must be established. For any specific ecological risk to come to fruition and create an impact, a risk pathway is required. For example, in the case Nile tilapia, the ecological risk or hazard that these fish could pose to the environment through hybridisation with other species (example of an endpoint or impact) is directly linked to the pathway of escape from the facilities in which it is used or kept, into the surrounding water resources. The ecological endpoint is therefore facilitated and dependent on the physical pathway of escape. For this reason, each identified risk must be evaluated from its potential occurrence (the hazard), through the pathway and the resultant effects (the endpoint) thereof, as well as the mitigation measures that can be implemented to reduce the risk from occurring, or minimising any negative effects.

In aquaculture of Nile tilapia, only two pathways exist through which a risk can influence or impact on an endpoint. These are the pathway of escape of the fish and the pathway that facilitates the introduction or spread of a potential disease. It is therefore logical that the potential manifestation of species related ecological impacts or endpoint of the identified risks is eliminated if the potential for escape is eliminated (apart from disease).

Some confusion is caused by the fact that both the pathway (escape in the case of aquaculture with Nile tilapia) and the endpoint can be characterised and scored for probability, severity, scope, permanence, confidence, monitoring and mitigation. It is important that characterisation of the pathway be determined and presented separately, with due regard that a zero risk in occurrence of a pathway will render the risk of an endpoint invalid. However, a low risk in the pathway does not necessarily correlate with a low risk in the endpoint.

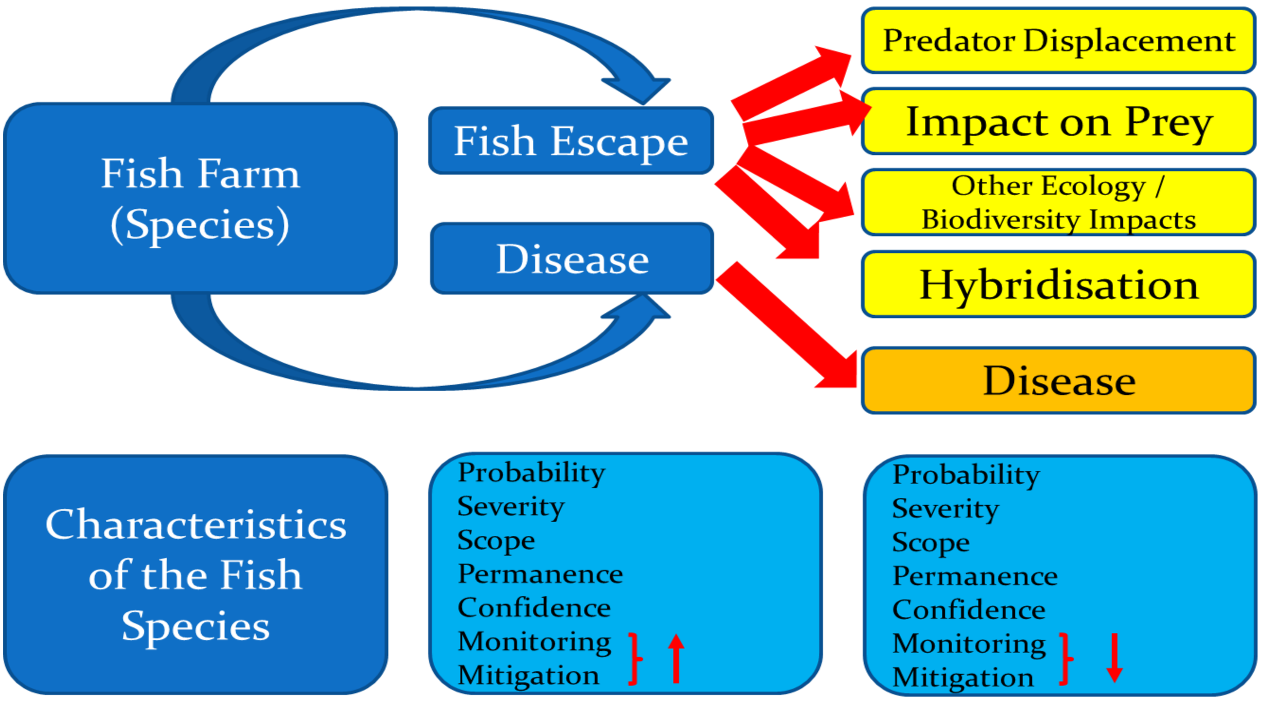

Figure 5: Schematic illustration of the risk assessment process and the dependency of endpoint risk on the pathway.

9.4. SCALES AND CATEGORISATION OF RISK

Several scaling methods are used to determine risk and the factors that contribute to risk. These scales are largely subjective, but depend on professional judgement where technical experts determine a suitable scaling, bootstrapping where previous or historical examples are used, and formal analyses where theory-based procedures for modeling are used to set scales. For this risk assessment, the following scaling or categorization has been determined by using a combination of professional judgement and referencing to several international methodologies.

Table 1: Categories of risk probability: Probability of a risk or stressor occurring.

Scale	Explanation and Comments
High	The risk is very likely to occur.
Moderate	The risk is quite likely to be expressed.
Low	In most cases, the risk will not be expressed.
Extremely Low	The risk is likely to be expressed only rarely.
Negligible	The probability of the risk being expressed is so small that it can be ignored in practical terms.

Table 2: Categories of risk severity: Severity of the effects of the stressor on the endpoint.

Scale	Explanation and Comments
Catastrophic	Irreversible change to ecosystem performance or the extinction of a species or rare habitat.
High	High mortality or depletion of an affected species, or significant changes in the function of an ecosystem, to the extent that changes would not be amenable to mitigation.
Moderate	Changes in ecosystem performance or species performance at a subpopulation level, but they would not be expected to affect whole ecosystems and changes would be reversible and responsive to high levels of mitigation.
Low	Changes are expected to have a negligible effect at the regional or ecosystem level and changes would be amenable to some mitigation.
Negligible	Effects would leave all ecosystem functions in tacked without the need for mitigation.

Table 3: Categories of risk scope or scale: Scope or scale of the effects of the stressor on the endpoint (i.e. geographic extent).

Scale	Explanation and Comments
Extensive	Effects are far reaching over multiple ecosystems (or biomes) incorporating various habitat types.
Regional	The effects are manifested over a measurable distance, usually limited to one or two ecosystems.
Local	The effects are limited to a distance covering a portion of an ecosystem, such as a single water body or coastal bay.
Project Based	The effects are limited to the boundaries of the project or within a distance that can be influenced directly by remediation, without affecting other users of a common resource.
Negligible	Effects are so limited in scale that the scope is insignificant.

Table 4: Categories of permanence or longevity: Permanence or longevity of the effects of the stressor on the endpoint.

Scale	Explanation and Comments
Permanent	Change to the endpoint caused by the stressor will last for more than one century, regardless of the mitigation measures.
Long lasting	Change to the endpoint caused by the stressor will outlast the expected lifespan of the activity or project.
Moderate	Effects can be measured in years, but it is within the expected lifespan of the activity or project and where effects are measured on organisms, it is usually within the organism's expected lifespan.
Temporary	Effects are usually inside of one year in duration.
Short term	Effects can usually be measured in days.
Periodic	Effects occur more than once within the temporary or short-term classification of permanence.

Table 5: Categories of uncertainty (or certainty and confidence): Uncertainty in the analysis of risks, stressors and endpoints and the interrelationships between these.

Scale	Explanation and Comments
Doubtful	When confidence in the analysis is so low that the outcome can be near random.
Low	When confidence in the analysis is such that an alternative outcome will occur regularly, but that such an alternative in probability, severity, scope and permanence will regularly constitute a change by more than one position in the respective scales.
Moderate	When confidence in the analysis is such that an alternative outcome will occur regularly, but that such an alternative in probability, severity, scope and permanence will rarely constitute a change by more than one position in the respective scales.

High	When variability in an analysis is accurately predictable and an alternative outcome occurs only occasionally.
Very High	When confidence in the analysis is at a level at which an alternative outcome is virtually impossible, and occurs rarely.

Table 6: Categories of monitoring: Monitoring of the effects of the stressor on the endpoint within reasonable time and cost.

Scale	Explanation and Comments
Zero	Where no monitoring is possible.
Low	Where limited indicators can be collected and reported about either severity, scope or the temporal nature of the effect or impact of a stressor, and where inferred changes in ecosystem functionally, habitat and species loss is mostly used.
Moderate	Where only certain indicators can be collected and reported about the severity, scope and temporal nature of the effect or impact of a stressor, and where inferred changes in ecosystem functionally, habitat and species loss is used.
High	Where sufficient information (key indicators) can be collected and reported about the severity, scope and temporal nature of the effect or impact of a stressor, to identify major changes in ecosystem functionally, habitat and species loss.
Very High	Where the full severity, scope and temporal nature of the effect or impact of a stressor may be monitored with confidence and reported within the resources of a project.

Table 7: Categories of mitigation: Mitigation of the effects of the stressor on the endpoint within reasonable time and cost.

Scale	Explanation and Comments
Irreversible	When no degree of mitigation can prevent the alteration of ecosystem functionally, habitat or species loss.
Low	When the effects of a stressor or risk can be mitigated, but where such mitigation requires additional resources and where the outcome of mitigation is doubtful, and where some ecosystem functionally, habitat or species loss may occur.
Moderate	When the effects of a stressor or risk can be mitigated, but where such mitigation requires additional resources and where the outcome of mitigation may lead to altered ecosystem functionally but not ecosystem, habitat or species loss.
High	When the effects of a stressor or risk can be mitigated within the resources of a project and when the outcome of mitigation can return the environment to a condition in which ecosystem changes and functions do not cause multi-tropic disturbances.
Very High	When the effects of a stressor or risk can be mitigated within the resources of a project and when the outcome of mitigation can return the environment to a condition near to that prior to the establishment of the activity, within a reasonable timeframe.

Using the scales above the following example of an assessment matrix for a risk and endpoint can be illustrated. This matrix has been used as the format for this risk assessment of the import, propagation and grow out of Nile tilapia in South Africa.

Table 8: Example of a matrix indicating all categories and scales of risk.

Risk / Stressor	As example: the escape of Nile tilapia				
Endpoint	As example: hybridization with indigenous species				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary (Periodic)*	Short term (Periodic)*
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

* *The addition (or submission) of "periodic" under permanence can be used to add additional information with regards to the temporal nature of the effects on the endpoints.*

One important aspect, which is not directly addressed in this multi-criteria scaling is the nature of the receiving environment. The severity of the effect is scaled, but this is only indirectly related to the nature of the receiving environment. As an example, if an activity was proposed or developed in a degraded environment, it will be necessary to adjust the severity of the impact, as opposed to the severity when the same activity was to be undertaken in a pristine environment.

It is important to continuously be mindful of the fact that the analysis, and particularly the management of risk, depends on financial, human, intellectual and other resources. The scaling of risk, and particularly the potential for monitoring and mitigation, should therefore take cognisance of the availability and practical application of financial and human resources.

The identified risks and the scaling of probability, severity, scope, permanence, confidence, mitigation and monitoring must be considered collectively, to arrive at a risk profile. As an example, if an effect on the environment has a "*high*" probability, but with "*low*" severity and "*temporary*" permanence, then the resultant risk can be seen to be acceptable.

9.5. PERCEPTION OF RISK

The nature and perception of risk differs significantly from environment to environment for the same stressors. This difference is caused by factors such as the nature of the endpoint and the surrounding environment, but also significantly by the different manner in which people perceive risk. Risk perception involves people's beliefs, education, attitudes, judgements and feelings, as well as the wider social or cultural values that people adopt towards different risks and their consequences. Factors such as income level, ethnic background, political outlook, public values, historical land use, zoning, life style and psychological condition, inevitably drive the acceptance and perception of varying levels of risk, and the manner in which risk is managed.

In this case, it is important that the perception of risk remains in context to the use of Nile tilapia, the environment in which the use will occur, the use or development scale, the potential for mitigation and other factors.

9.6. RISK COMMUNICATION

A comprehensive an accurate assessment of risk is worthless if risk is not correctly communicated to planners, managers, industry experts, environmental agencies and stakeholders. In this framework assessment, the communication of risk is not being fully investigated. Yet, the following notes on communication of risk are important:

- Risk assessment is the first step in an on-going process in which risks must be monitored, mitigated and correctly communicated through tools such as assessments, plans, audits, meetings and more.

- The communication of risk must take cognisance of the nature of the parties to which information is given. This should incorporate consideration of factors such as education, manner in which they are being affected by the risk, socio and economic character and more.
- Risk communication must be used to improve the understanding and confidence of initial risk assessment.
- Risk communication must always be clear, transparent, timely and unbiased.
- The communication of risk is the means through which information can be provided to decision making authorities to evaluate the granting of rights (authorisations, permits, concessions etc.) in terms of statutory provisions.

10. SPECIFIC FRAMEWORK ASSESSMENT FOR NILE TILAPIA

The methodology above meets the requirements for risk assessment as per Section 14 of the AIS Regulations (GN R 598 of August 2014). However, this BRBA is a framework document that users need to pullulate with specific and detailed information pertaining to the receiving environment and the nature of their own proposed import, propagation and grow out of Nile tilapia.

10.1. INVENTORY OF POTENTIAL PATHWAYS AND RISKS

The ecological risks associated with the import, propagation and grow out of Nile tilapia, have been determined and generically evaluated for the entire South Africa. This information should be used as a starting point towards compiling a project specific risk assessment.

The following pathways between risks or stressors and the endpoint (i.e. the environment) have been identified:

- Escape, which could take on many forms (discussed below).
- The diverse pathway related to the movement of disease.

The following risk endpoints have been identified and make up the risk inventory for assessment:

- The potential for physical (abiotic) damage to the environment.
- The potential for predator displacement.
- The potential for competition - for food, habitat niches and other resources.
- The potential for hybridisation and displacement.
- The potential for impacts on prey species.
- The potential threat of new or novel diseases.

As indicated, the primary ecological risks in the inventory above are linked to the pathway of escape, and further, with the ability of Nile tilapia to establish a feral and self-propagating population, were it to escape. This ability is determined by the nature of the facilities in which the fish are kept and the life history characterises of Nile tilapia as described in Section 6.

10.2. DISCUSSION OF RISK PATHWAYS

Using the risk inventory above, further information is provided for the respective risks in the sections below. It should be noted that the manifestation of any risk is directly related to the degree of mitigation, and that the severity of all risks is directly dependant on the level of mitigation.

10.2.1. THE PATHWAY OF ESCAPE

The potential for escape of all life stages must be evaluated from the proposed holding or production facilities. In this regard, consideration must be given to the following potential pathways of escape, which are discussed hereafter:

- Escape during transportation / shipment of fry to an aquaculture facility
- Escape through the incoming water resources
- Escape by means of outflow water
- Escape caused by poor design, system malfunction or poor maintenance
- Escape by means of deliberate or accidental human actions such as theft or human error, including inadvertent actions that cause escape during grading, handling or harvesting.

- Escape through predation, where fish are preyed upon and removed as live specimens to the surrounding environment in the process
- Escape due to natural disasters such as flooding

Escape during transportation / shipment

During this process, there is a risk that the containers or packaging materials could be breached, and that fry or fish could be released to the environment. It is generally concluded that although a low probability of escape exists, the chances of any such event leading to the establishment of a feral population is negligible, given that escape during transport is not likely to lead to the fish landing in an aquatic environment in which they will survive. The risk of an escape event occurring during the shipment process is thus negligibly low, with a high potential for monitoring and mitigation.

Escape through the incoming water resources

In general, escape of Nile tilapia through incoming water resources is not possible, given that water is typically supplied to aquaculture facilities through directional flow in a pipeline (often from a borehole or via a high velocity pump). From this perspective, the risk of escape through the incoming water can be ignored.

The exception to the above would be in cases where water is supplied to an aquaculture facility through passive flow with a low velocity and no other barrier to prevent fish from migrating out of a production facility and into a suitable habitat. The production of Nile tilapia in cage culture systems poses a likely risk of escape.

Escape through outflow water

Nile tilapia will move with water from a production facility and colonise the surrounding environment if:

- The physical (e.g. velocity, pressure, temperature) and chemical properties of the water through which the fish move is suitable.
- There are no physical barriers such as screens, filters, soakaway systems etc.

- The receiving environment can support survival.

In fully recirculating systems, the outflow can generally be controlled, and water can be released via a range of barriers, which could include the release of water into an environment that is not likely to support survival (such as irrigation to crops). However, in flow through systems and in cage culture it is probable that a pathway for escape exists.

It is important that containment for all life stages (ova, fry, fingerlings, growers and brood stock) be investigated, and the potential for escape established. In certain instances, the potential for escape for adult fish may be absent, while ova may be transferred freely to the surrounding environment (e.g. in cage culture and in flow through systems).

Escape through poor design, system malfunction or poor maintenance

A pathway for escape (and disease) can be facilitated by poor design, system malfunction and poor maintenance. The design of any system (even fully recirculating systems) should pay attention to the prevention of pathways that could lead to the escape of fish. Likewise, regular maintenance is required to prevent malfunction and the development of situations that could lead to escape.

The most common design and maintenance issues relate to the failure of key components such as tanks, pipes, filters etc. It is important that these critical points be identified and that the consequences of failure be anticipated through predicting a pathway of escape in the event of system failure or malfunction. Doing this will allow an opportunity for the creation of a contingency barrier against the escape of fish (such as an overflow sump or soakaway trench along the anticipated pathway of flow).

Escape by means of deliberate human actions such as theft or human error, including inadvertent actions that cause escape during grading, handling or harvesting.

Theft is a human characteristic that depends on a combination of socio and economic factors. Escape through theft of live fish is generally improbable, given that the incentive for theft is mostly around fish as a means to a meal. However, measures such as security systems and access controls should be implemented to prevent theft.

Illegitimately giving or selling fish to third parties, potentially creates a greater risk than theft.

Human error is an unavoidable characteristic of all human endeavour and can be directly linked to factors such as level of training, experience, awareness, employment conditions and the nature of the production facility. As with design and maintenance aspects, it is important that critical points and causes of human errors be identified and that the consequences thereof be anticipated through predicting a pathway of escape. Doing this will allow an opportunity for the creation of a contingency barrier against the escape of fish (such as an overflow sump or soakaway trench along the anticipated pathway caused by the human error).

Escape through predation

For fish to escape through predation, a predator must gain access to the fish and prey in such a manner that allows for specimens to be transferred to an escape pathway or into the surrounding environment in a viable state. This is generally uncommon in closed or contained production systems, but can be common in cage culture, where predatory animals (e.g. crocodiles, predatory fish and predatory birds can cause structural damage that potentially leads to escape).

Escape due to natural disasters such as flooding

Natural disasters such as flooding and storms can lead to inundation or structural damage that facilitates the escape of fish. This risk is a function of the sighting of facilities, the design of such facilities and the prevalence of natural disasters. Aquaculture facilities should not be sighted in low lying areas that are prone to flooding i.e. where there is a risk of flooding, no development is to take place below the 1:100 flood line, or nearer than 32 meters from the watercourse.

As with the matters above, it is important that potential weaknesses or risk prone aspects, insofar as natural disasters are concerned, be identified and that the consequences thereof be anticipated through predicting a pathway of escape. Doing this will allow an opportunity for the creation of a contingency barrier against the escape of fish (such as an overflow sump or soakaway trench along the anticipated pathway caused by the natural disaster).

10.2.2. THE PATHWAY OF DISEASE

Concomitant with all species introductions, there is potential for the introduction of novel diseases (bacterial, viral pathogens and parasites) into the recipient environment, and these could affect indigenous species and the ecology. These diseases can either originate from the introduced fish, or as a result of contaminated transport water or packaging materials.

The introduction of disease does not necessarily depend on the pathways that may exist for the escape of fish. Disease causing organisms can move from a fish farm into the surrounding environment through the transfer of water (with or without fish), but also through the disposal of dead fish, through the moving of fish farming equipment, on the hands and shoes of people that move through a fish farm and in a myriad of other ways.

The potential for the movement of disease from a fully contained recirculatory system, in which access control and biosecurity measures are strictly adhered to is low, while the potential for the movement of disease from cage farming systems is high. In all instances, the most effective means of control is to prevent the introduction of disease causing organisms. The import of fish into South Africa is subject to veterinary clearance from the Directorate of Animal Health in the Department of Agriculture, Forestry and Fisheries (DAFF). In addition to this, the disease protocols and screening for certain notifiable diseases, in terms of the protocols of the World Organisation for Animal Health (OIE), is mandatory and should be applied.

10.3. DISCUSSION OF RISK ENDPOINTS

10.3.1. PHYSICAL ABIOTIC DAMAGE TO THE ENVIRONMENT

The risk of Nile tilapia causing any physical damage to the environment is highly improbable. Albeit that the male of the species can create a small depression in the environment (substrate) for nesting, their foraging, reproduction and other life history patterns does not cause physical damage to the aquatic environments in which they occur. Accordingly, this risk has been eliminated from further assessment.

10.3.2. PREDATOR DISPLACEMENT

Although Nile tilapia is is capable of feeding over a wide trophic range, they are not apex predators. Their feeding habits and the environmental conditions support the notion that they will not cause any predator displacement. However, their trophic plasticity could lead to predation on the eggs and the young of a range of fish species, which could affect predatory synergies.

10.3.3. COMPETITION - FOOD, HABITAT & OTHER RESOURCES

The establishment of a viable feral population of Nile tilapia can occur wherever the biotic and abiotic requirements of the species are met. In South Africa, the primary limiting factor to the survival of a viable population of Nile tilapia in any water resource is water temperature. Where Nile tilapia escapes into an environment in which the water temperature is within the lethal limits for the species, they will generally survive and become invasive.

Consideration has been given in the risk assessment to the potential general impacts on biodiversity through related ecological consequences, and extended tropic disturbances that are built off competition for food, habitat and other resources. Escapees from aquaculture facilities are inevitable and occur worldwide, unless appropriate mitigatory methods are applied. Due to their ability to adapt to new environments (with rapid reproduction and spread), Nile tilapia have the potential to threaten native biodiversity.

Apart from the risks of hybridisation that is discussed separately hereafter, a potential impact of Nile tilapia relates to comparative tropic competition for food and suitable habitat. Although several indigenous *Tilapia* and *Oreochromis* species, as well as other fish species, could be impacted upon by Nile tilapia, the species most at risk would be the Mozambique Tilapia. In suitable habitat, Nile tilapia will outcompete Mozambique tilapia and other *Cichlid* species through direct competition and possible displacement. A study by Zengeyah *et al.* (2011) investigated the stomach contents of *tilapiine* species in the Limpopo River Basin to determine the impacts of the alien Nile tilapia on the native Mozambique tilapia and Redbreast tilapia (*Tilapia rendalli)*. Nile tilapia and Mozambique tilapia have high diet overlap whereas Redbreast tilapia exhibits low diet overlap with Nile tilapia. This could result ultimately in the displacement of Mozambique tilapia, as Nile tilapia can be an aggressive competitor.

10.3.4. HYBRIDIZATION

The only species with which Nile tilapia can hybridise in South Africa is the Mozambique tilapia. The consequence of such hybridisation has been referenced in various sections of this risk assessment, and since hybrids between these species will generally dominate pure strain Mozambique tilapia, this will lead to marginalisation and eventual displacement.

As a result of hybridisation, Mozambique tilapia could lose genetic material (and thus adaptive value) which distinguishes it from Nile tilapia. This includes its drought resistance, tolerance of low temperatures and the ability to survive in high salinity environments (D'Amato *et al.,* 2007). Hybrids of Nile tilapia and Mozambique tilapia are widely cultured in South Africa, however it should be recognised that these do not share the same traits as GIFT and other internationally improved strains, although they may be morphologically indistinguishable (N. James, Rivendell Hatchery, pers. comm.).

This potential impact of hybridisation is of concern given that Mozambique tilapia is classified as 'Near-Threatened' by the IUCN.

10.3.5. IMPACT ON PREY SPECIES

As indicated above, Nile tilapia can feed across a wide trophic range, which could include the eggs and young of other fish, other aquatic vertebrates such as amphibians and a wide range of aquatic invertebrates. Little research has been done to quantify the potential impact of Nile tilapia on other aquatic organisms on which it may prey.

10.3.6. EFFECTS OF DISEASE

Assemblage of new stock and high stocking densities commonly found in aquaculture, can lead to disease related issues. The potential impacts of novel diseases introduced into an area through aquaculture can be wide-ranging and severe. Nevertheless, Nile tilapia stock that is currently used in South Africa has not been reported as carrying diseases of concern; albeit that the national capacity and systems related to health management and monitoring for disease is virtually absent. It is therefore of critical importance that specific national disease management protocols be devised and implemented.

Some of the parasites which affect tilapia may also affect other freshwater finfish. If unknown diseases are introduced, indigenous species may not have an adequate immune response to cope. A summary of the symptoms of diseases and/or parasites which have been found internationally to infect Nile tilapia is provided in the table below. To date, none of these diseases have been found in South African tilapia (DAFF 2012b), albeit that Epizootic Ulcerative Syndrome has been described in other fish species.

Table 9: Symptoms of the diseases/parasites which commonly infect Nile Tilapia (Modified from FAO, 2012).

Name of disease or parasite	Explanation and Comments
Motile Aeromonas Septicaemia (MAS)	Loss of equilibrium; lethargic swimming; gasping at surface; haemorrhaged or inflamed fins & skin; bulging eyes; opaque corneas; swollen abdomen containing cloudy or bloody fluid; chronic with low daily mortality.
Vibriosis	Same as MAS.
Columnaris	Frayed fins &/or irregular whitish to grey patches on skin &/or fins; pale, necrotic lesions on gills.
Edwardsiellosis	Few external symptoms; bloody fluid in body cavity; pale, mottled liver; swollen, dark red spleen; swollen, soft kidney.

Streptococcosis	Lethargic, erratic swimming; dark skin pigmentation; exophthalmia with opacity & haemorrhage in eye; abdominal distension; diffused haemorrhaging in operculum, around mouth, anus & base of fins; enlarged, nearly black spleen; high mortality.
Saprolegniosis	Lethargic swimming; white, grey or brown colonies that resemble tufts of cotton; open lesions in muscle.
Ciliates	Occurs on gills or skin.
Monogenetic trematodes	Occurs on body surface, fins or gills.
Epizootic Ulcerative Syndrome	Occurs as lesions on the skin which can range from small pinpoint red spots, haemorrhagic spots, localised swelling, localised raised areas on the body surface, protruding scales, scale loss, skin erosion, reddened areas of the skin under the scales, exposure of underlying musculature, and ulceration. Ulcers can be found over a broad area with the centre of the lesions being necrotic. Lesions are observed most often in the lateral surface but can also occur on any part of the body.
Viral Encephalopathy Retinopathy	There are no external signs on the body surface and gills of affected fish except a progressive change in pigmentation. Erratic swimming behaviour, such as spiralling, whirling or belly up at rest, or lying down at the bottom of the tank or swimming rapidly in circles or straight ahead.

It is important to consider the ecological risk of disease against the background of historical and current fish import practices for the aquarium and ornamental trade in South Africa. Very few health checks are done for the import of many fish species.

10.4. ASSESSMENT SCORING OF RISK LEVELS

With reference to the pathways and risk inventory in Section 9.1, the flowing sections illustrate the outcome of the assessment of risk levels. As a national risk framework, it is impossible to accurately determine the risk levels for each instance in which Nile tilapia is used, or in which it is being proposed for use in aquaculture or introduction. Moreover, it is impossible to determine the precise levels of risk based on the design of an individual aquaculture project, and the level of mitigation that will applied. For these reasons, the scoring that follows must be used as a point of departure to provide a generic framework, which will require further detailed assessment for individual projects.

10.4.1. RISK PATHWAYS

The relationship between a risk pathway and the endpoint has been illustrated in Section 8.3. It should be noted that the probably of a pathway such as escape refers specifically to the probability (chance) of escape, and not to the probability of the escape event leading to an impact or endpoint. Likewise, the severity refers to the severity (quantity) of escape, the scope to the distribution of escapees and permanence to the survival and propagation of the escapees. These aspects should not be confused with the characterisation of the endpoints or impacts.

The risks associated with the respective pathways differ greatly between the respective production systems use in aquaculture (i.e. ponds, raceways, cages, recirculatory systems etc.) For this reason, the tables hereafter depict an aggregate score for South Africa in general.

a. The risk of Nile tilapia escaping during transit between hatcheries and from suppliers to farmers.

Table 10: Risk pathway characterisation related to escape during transport and transit.

Risk	Escape				
Pathway	Escape during transport or transit				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

b. The risk of Nile tilapia escaping through inflow water.

Table 11: Risk pathway characterisation related to escape through the inflow water.

Risk	Escape				
Pathway	Escape through inflow water				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

c. The risk of Nile tilapia escaping through outflow water.

Table 12: Risk pathway characterisation related to escape through the outflow water.

Risk	Escape				
Pathway	Escape through outflow water				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

d. The risk of Nile tilapia escaping through poor design, system malfunction and/or poor maintenance to aquaculture facilities.

Table 13: Risk pathway characterisation related to escape through poor design, system malfunction and/or poor maintenance.

Risk	Escape				
Pathway	Escape due to poor design, system malfunction and/or poor maintenance				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

e. The risk of Nile tilapia escaping through deliberate human actions such as theft or human error.

Table 14: Risk pathway characterisation related to escape through theft or human error.

Risk	Escape				
Pathway	Escape due to human actions such as theft or human error				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

f. The risk of Nile tilapia escaping through predation, where fish are preyed upon and removed as live specimens to the surrounding environment.

Table 15: Risk pathway characterisation related to escape through predation.

Risk	Escape				
Pathway	Escape due to predation				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

g. The risk of Nile tilapia escaping through natural disasters such as flooding.

Table 16: Risk pathway characterisation related to escape through natural disasters.

Risk	Escape				
Pathway	Escape due to natural disasters				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

h. The risk of Nile tilapia serving as vector for the introduction of novel diseases and pathogens (including parasites).

Table 17: Risk pathway characterisation related to spread of novel diseases.

Risk	Spread of disease				
Pathway	Various disease pathways - water, air or direct contact				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

10.4.2. RISK ENDPOINTS/IMPACTS

It should be noted that the probably of an endpoint or an impact such as predator displacement refers specifically to the probability (chance) of impact, and not to the probability of the pathway that led to the impact or endpoint. Likewise, the severity refers to the severity (quantity) of the impact, the scope to the distribution of the impact and the permanence to the duration of the impact. These aspects should not be confused with the characterisation of the pathway.

a. The risk of Nile tilapia causing physical (abiotic) damage to the environment.

Table 18: Risk endpoint characterisation related to physical damage to the environment.

Risk	Life history characteristics of Nile Tilapia				
Endpoint / Impact	Physical (abiotic) damage to the environment				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

b. The risk of Nile tilapia competing with and/or displacing other predatory species.

Table 19: Risk endpoint characterisation related to predator competition and displacement.

Risk	Life history characteristics of Nile Tilapia				
Endpoint / Impact	Competition and displacement of predatory species				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

c. The risk of Nile tilapia causing impacts related to competition for food, habitat niches and other resources.

Table 20: Risk endpoint characterisation related to competition for food, habitat and other resources.

Risk	Life history characteristics of Nile Tilapia				
Endpoint / Impact	Competition for food, habitat niches and other resources				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

d. The risk of Nile tilapia hybridising with other species and/or genetic displacement.

Table 21: Risk endpoint characterisation related to hybridisation.

e. The risk of Nile tilapia impacting on potential prey species.

Table 22: Risk endpoint characterisation related to impacts on prey species.

f. The risk of Nile tilapia acting as a vector for the introduction of disease and pathogens.

Table 23: Risk endpoint characterisation related to disease and pathogens.

Risk	Life history characteristics of pathogen				
Endpoint / Impact	Multiple disease related impacts				
Probability	High	Moderate	Low	Extremely low	Negligible
Severity	Catastrophic	High	Moderate	Low	Negligible
Scope	Extensive	Regional	Local	Project based	Negligible
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
Confidence	Doubtful	Low	Moderate	High	Very high
Monitoring	Zero	Low	Moderate	High	Very high
Mitigation	Irreversible	Low	Moderate	High	Very high

10.5. SUMMARY OF RISK PROFILE

The pathway and endpoints of the risks that have been set to analysis above can be summarized to arrive at an overall risk profile. The following table summarises the characterisation of pathways and endpoints (aggregate for all production systems and environments):

Table 24: Risk profile characterised by risk pathways and risk endpoints.

	Risk Pathways								**Risk End Point or Impacts**					
Risk	Transit	Inflow water	Outflow water	Design, malfunction or maintenance	Theft or human error	Predation	Natural disasters	Disease pathways	Physical damage	Compete or displace predators	Competition food, niches & resources	Hybridization	Impact prey species	Disease impacts
Probability	E Low	E Low	Mod	Mod	Mod	Low	Low	Low	Neg	Neg	Mod	High	Low	Low
Severity	Low	Mod	Mod	Mod	Mod	Mod	Mod	Low	Neg	Neg	Mod	Mod	Low	Mod
Scope	Local	Local	Reg	Reg	Reg	Reg	Reg	Reg	Local	Local	Reg	Reg	Local	Local
Permanence	Mod	Mod	Long L	Long L	Long L	Long L	Long L	Long L	Short T	Temp	Long L	Perm	Mod	Mod
Confidence	High	Mod	Mod	Mod	Mod	Mod	Mod	Mod	High	High	High	High	Low	Mod
Monitoring	Mod	Mod	Mod	Low	Low	Low	Low	Mod	High	Mod	Mod	Mod	Low	Mod
Mitigation	V High	High	High	High	Mod	High	High	High	Low	Low	Low	Low	Low	Mod

Neg=Negligible, Mod=Moderate, Reg=Regional, Perm=Permanent, E Low=Extremely Low, Proj B=Project Based, Ext=Extensive, Long L=Long Lasting, Short T=Short Term, Temp=Temporary, V High=Very High, Irrev=Irreversible

Using the table above, a numeric scoring can be used to weigh and prioritise the potential risks of greatest concern. Various mathematical methods have been used for risk scoring to prioritise the importance or interrelatedness between the numerical weighting of either probability, severity, scope and/or permanence. In the methodology that has been applied to this BRBA, a selection of 4 consecutive numbers (weights) have been given to each of the five categories under probability and severity; spanning from 1 (high) to 20 (low), to correspond with high to negligible probabilities and very high to negligible severities, respectively. Similarly, a selection of 3 consecutive numbers, spanning from 1 (high) to 15 (low), has been used for scope and permanence, to achieve the greater relevance (weight) to probability and severity, which is sometimes achieved by applying multiplication of the scores in these categories. Given that confidence, monitoring and mitigation are based largely on judgements of value, and not on the actual nature of the impact or risk to the environment, 2 consecutive numbers, spanning from 1 (low) to 10 (high) has been used or these categories.

To illustrate this, the following numeric values are given to the respective scales:

Table 25: Numeric values associated with risk characterisation.

Probability	High	Moderate	Low	Extremely low	Negligible
	1 2 3 4	5 6 7 8	9 10 11 12	13 14 15 16	17 18 19 20
Severity	Very high	High	Moderate	Low	Negligible
	1 2 3 4	5 6 7 8	9 10 11 12	13 14 15 16	17 18 19 20
Scope	Extensive	Regional	Local	Project based	Negligible
	1 2 3	4 5 6	7 8 9	10 11 12	13 14 15
Permanence	Permanent	Long-lasting	Moderate	Temporary	Short term
	1 2 3	4 5 6	7 8 9	10 11 12	13 14 15
Confidence	Doubtful	Low	Moderate	High	Very high
	1 2	3 4	5 6	7 8	9 10
Monitoring	Zero	Low	Moderate	High	Very high
	1 2	3 4	5 6	7 8	9 10
Mitigation	Irreversible	Low	Moderate	High	Very high
	1 2	3 4	5 6	7 8	9 10

Using this method, an impact or risk that is very probable, that has severe effects, a broad scope, long permanence and that is predicted with little confidence, and that is difficult to monitor and mitigate can score a theoretical low overall value/weight of 7. Alternatively, a negligible impact or risk that is unlikely to occur, with limited scope, a short lifespan and which can be predicted with confidence and that can be monitored and mitigated, can score a theoretical high overall value of 100. Using this numeric allocation to illustrate risk is convenient in that low scoring risks pose a threat to the environment, while high scoring risks are acceptable.

The scoring of evaluated pathways and risk endpoints for Nile tilapia is shown in Table 28.

Table 28: Score allocation to the risk profile before mitigation.

	Risk Pathways								**Risk End Point or Impacts**					
Risk	Transit	Inflow water	Outflow water	Design, malfunction or maintenance	Theft or human error	Predation	Natural disasters	Disease pathways	Physical damage	Compete or displace predators	Competition food, niches & resources	Hybridization	Impact prey species	Disease impacts
Probability	16	16	6	5	5	12	12	11	19	18	7	3	11	11
Severity	14	12	11	11	11	12	12	14	19	18	11	10	13	11
Scope	8	8	6	6	5	5	5	5	9	9	5	5	8	8
Permanence	7	7	6	6	6	6	6	5	14	10	5	2	7	8
Confidence	8	6	6	6	6	6	6	6	8	7	8	8	4	5
Monitoring	6	5	5	4	4	4	4	6	7	5	5	5	4	6
Mitigation	10	8	8	8	6	8	8	8	3	3	3	3	3	5
Total Score	69	62	48	46	43	53	53	55	79	70	44	36	50	54

Notwithstanding all factors considered, as a general rule, scores above 50 denote acceptable levels of risk and those below 50, unacceptable. The score allocation, although subjective and debatable, has been done based on information in this BRBA.

When considering the pathways for the manifestation of risks, the scores for escape through theft or human error, poor design and malfunction or a lack of maintenance, and escape through outflow water, poses the greatest threats. However, these aspects show a high potential for monitoring and mitigation, meaning that effective risk pathway management could see a lowering of the potential impact to endpoints.

With due consideration to the pathways above, the scores for the ecological endpoints or impacts related to hybridisation and competition for food, habitat niches and resources, are most relevant. Of all the ecological endpoints, the risk of hybridisation and genetic displacement of Mozambique Tilapia is of greatest concern. The absolute prevention of escape is the only effective means of mitigation against this risk.

Note that this scoring methodology has been used to grade the potential negative risks and impacts only. The potential positive impacts of establishing a compliant Nile tilapia aquaculture sector in South Africa have not been considered (see Section 10 below). Reports abound across South Africa of unlawful distribution of Nile tilapia by unscrupulous anglers, farmers and non-abiding aquaculture facilities. It is for this very reason that the establishment of compliant aquaculture sector is important towards curbing the illegal distribution of these fish.

11. KEY ECONOMIC, SOCIAL AND SOCIETAL CONSIDERATIONS

The risk profile above is based on the potential negative environmental or ecological consequences related to the use and introduction of Nile tilapia. These risks, must be considered in a balanced manner in conjunction with potential economic, social and societal considerations.

Globally, the demands and markets for Nile tilapia have expanded rapidly. In response to this, the interest in this species as a candidate for farming has spread across many countries, including South Africa. This interest in South Africa has resulted in much illicit distribution of these fish from the Limpopo River and from countries such as Zimbabwe and Mozambique. There is little doubt that this illicit distribution and sale will continue, leading not only to ecological risks, but also to the distribution of hybridised fish, the use of fish that are not well adapted or selected for optimal performance in aquaculture and the potential spread of fish disease and other fish species. The establishment of a formal and lawful Nile tilapia based aquaculture sector, in specific areas and in which the risks are known and mitigated, is the most prudent response hereto. This will also contribute to the furtherance and success of aquaculture in South Africa, which is a clear objective of the current policies and strategies adopted by the South African Government, particularly the Department of Environment, Forestry and Fisheries (DEFF). Success in Nile tilapia aquaculture will have several socioeconomic advantages, which include:

- The creation of rare skills and the application of new technologies.
- The beneficial use of natural resources.
- The creation of economic opportunities in the broader South African contexts. This is especially relevant considering that these opportunities will be created in primary production.
- Direct and indirect food security.

Although Nile tilapia show a better growth rate in aquaculture over the indigenous Mozambique Tilapia, the use of Nile tilapia should only be permitted in areas where the potential invasion of the species is either limited by water temperature, the absence of Mozambique Tilapia, or where invasion has already occurred.

It is important to consider the potential socio-economic consequences that may result from the manifestation of any of the ecological impacts. Were Nile tilapia to become established across the climatic range in which it will survive in South Africa, the socio-economic consequences are limited. Tilapia do not support a commercial freshwater fishery in South Africa, (B. Clark, Anchor Environmental, pers. comm.). If Nile tilapia were to displace Mozambique tilapia, subsistence fishermen may benefit from the presence of a faster growing species, while recreational fisheries are likely to be affected only by the presence of an alternative but similar species. The establishment of Nile tilapia (regardless of the probability thereof), holds no direct threat to humans or any human livelihoods.

12. BALANCED COST OF ERADICATION

There are few examples of Nile tilapia having been eradicated successfully. The island state of Palau used Rotenone to successfully eradicate tilapia from five invaded locations on the island (GISD, 2012).

A balanced view must be taken to the potential ecological cost of Nile tilapia invasion and the potential cost of eradicating the fish. This cannot be approached as an actual cost as an expense of this nature must be weighed up against the ecological costs and the net gain of benefits that would result from an eradication effort. Given the limited ecological costs (as determined by the limited risk and impact that the establishment of this species could have), the potentially impacted species, the nature of the receiving environment and the insignificant effects that could manifest towards human beings and their livelihoods, it is suggested that the cost of eradicating any fish would be unwarranted. The climatic and other habitat associated control mechanisms outweigh any benefits that may accrue from the actual expenses associated with eradication.

Despite the balanced view above, the "*polluter pays*" principle in Section 28 of the National Environmental Management Act 107 of 1998 may apply, in terms of which the onus to cover the costs associated with environmental degradation, lies with the developer or proponent, which in this case will be the party responsible for release of Nile tilapia into an environment in which it may cause invasion.

13. RISK MONITORING

The potential for monitoring of the respective pathways and risks have been analysed as part of the assessment. Monitoring is a key aspect towards bolstering the acceptability of risk as it provides a mechanism for tracking risks through a project cycle, and it increases confidence in future assessments. Other important reasons for monitoring relate to environmental protection, research, traceability, market requirements and self-assessment of performance.

Threshold limits should be identified before allowing for the use of Nile tilapia in any specific area. The full extent of the monitoring programme should be documented in a monitoring plan so that there is clarity on what will be monitored, how, for how long and the manner in which it should be recorded and reported. Monitoring must take account of practicality, and especially the cost effectiveness in relation to the levels of identified risks.

The following preliminary monitoring requirements could be considered for inclusion in a monitoring programme for associated with the use of Nile tilapia in aquaculture. It is further recommended that the monitoring regime be subjected to an external verification by an independent specialist.

- Monitoring regime for all transit and receipt of new batches of fish to determine origin, numbers, quarantine procedures and disease status.
- Ongoing monitoring for fish health and disease.
- A monthly inspection of the sumps, screens, filters and other discharge systems through which outflow water flows.
- A monthly inspection of all maintenance, as well as integrity, functioning and contingency planning for the operation of production facilities.
- A three-monthly review of the training levels and ability of personnel, to minimise the risk of human error.
- A six-monthly review of security to prevent theft.
- A six-monthly review of fish stock records.

14. RISK CONTROL MEASURES AND MITIGATION

Controlling the spread of an invasive species through prevention is thought to be the most cost-effective means (Leung *et al.* 2002). It was illustrated in the analysis of pathways and risks that mitigation could lead to lowered levels of severity, scope, longevity etc. Such mitigation measures should be recorded, implemented, audited and reported; both internally and, if required, externally by an independent specialist.

The following preliminary mitigation measures could be considered for inclusion as conditions related to the issuing of permits for the use of Nile tilapia in aquaculture:
The prevention of escape through transit:

- Obtain broodstock and fish from a single, reputable and permitted supplier.
- Use best packaging materials and techniques, as well as reputable transit agencies.
- Keep accurate dispatch and receipt fish stock records of fish stocks.
- Encourage facilities to operate both a hatchery and grow out of fish on site in order to limit or prevent the transport of live fish to and from the facility, except for import of new broodstock.

The prevention of escape through inflow and outflow water:

- Limit the construction of hatcheries in highly sensitive ecosystems.
- Implementation of mechanisms to prevent facilities from flooding due to overfilling or tank/pipe failure.
- The implementation of a dedicated maintenance schedule and the appointment of human resources dedicated to system maintenance.
- Use and maintenance of screens over outlet pipes. The creation of physical barriers around the facility can also be effective in preventing escape (Novinger & Rahel, 2003).
- All outlet and inlet pipes should have mesh screens which will prevent the escape of eggs from the hatchery and fry from the grow-out facilities. Gravel beds through which outflow water can flow can be more practical in certain instances as they do not block as quickly.
- The prevention of outflow water reaching any surrounding waterways through locating farms well away from natural waterways and use of irrigation and soak-away systems for water discharge.

The prevention of escape cause by design, malfunction or maintenance issues:

- The use of best technology and management to prevent poor design and malfunction, including the implementation of backup systems and contingency plans in case of system failure.

The prevention of theft of fish:

- Ensure that access is strictly controlled and that facilities remain locked when personnel are not in attendance.
- Educate personnel in their responsibility towards the maintenance of security.
- Maintain and review an accurate stock record.

For the prevention of human errors:

- The training of personnel to reduce the possibility of human error.
- The appointment of suitably qualified personnel.
- The implementation of adequate supervision systems.

The prevention of escape cause by predation:

- Keep facilities locked when personnel are not in attendance.
- Ensure that predators such as otters and birds cannot access the facilities.

Precautions against escape cause by natural disasters:

- All facilities must remain outside of the flood line. New land-based aquaculture facilities should be sited outside of the 1:100-year flood line, with infrastructure built to resist the impacts of floods.
- Maintenance of facilities to prevent structural failure in storms and wind.

The prevention of risks associated with foreign disease and pathogens:

- Fish may only be bought from certified disease-free suppliers and such imports should meet all further requirements that may be determined by the State Veterinarian.
- Upon receipt, all fish should be subjected to quarantine.
- Packaging materials for every shipment must be new, and destroyed after shipping.
- Water in which fish were transported must be released into the quarantine facilities.
- Limit access to the production facilities.
- Prevent use of equipment from other fish farming facilities.

- Once in the production system, a fish health monitoring program must be applied, cooperatively with a registered South African veterinarian, and (if need be) the closest State Veterinarian. Animal health experts from the Department of Environment, Forestry and Fisheries (DEFF) may also be approached [South African Aquaculture Fish Monitoring and Control Programme (DAFF, 2015)].

15. BENEFIT / RISK TRADE-OFF

In all development, the use of benefit versus risk tradeoffs is common. Most such tradeoffs are done rapidly and without detailed analysis and many involve financial risks and tradeoff between potential gains in profits against the factors that may cause financial losses. In the ecological and environmental context, the tradeoff is between viability of an aquaculture development against levels of acceptable environmental risk. This encompasses the process of precautionary decision making.

It is not possible for a proposed aquaculture activity to have no risk or impact and there is usually a trade-off between acceptable environmental risk and socio-economic benefits. This trade-off is normally defined as acceptable limits of effects.

Benefit and risk tradeoff can become a highly-complicated exercise when assigning objective and comparable values to these. Although this tradeoff is not being pursued in this report, considering the risk profile indicated above in conjunction with the advantages and potential benefits from the use of Nile tilapia for aquaculture, one can arrive at an acceptable risk tradeoff in which the use of this species should be permitted in areas where it will not be able to cause invasion and in areas where invasion has already taken place.

16. RECOMMENDATIONS

Risk assessment techniques have been applied to all the major risk components related to the use of Nile tilapia for aquaculture in South Africa. Although this risk assessment should only serve as a framework around which the risk of any individual project and/or location can be investigated. The focus should remain on preventing the spread or deliberate introduction on Nile tilapia into new areas or river systems. Ongoing deliberations (2017) between conservations authorities (DEFF and provincial authorities), representatives of the tilapia farming sector and scientists have resulted in the following decisions and recommendations:

a. In the areas that have been fully invaded by Nile tilapia (to be determined by mapping out affected quaternary catchments), all types of aquaculture production systems should be permitted for Nile tilapia. This includes areas in Mpumalanga, Limpopo, North-West and KwaZulu-Natal. An exception would apply to small and isolated (point-source type) catchments in which eradication may be viable (e.g. the Tongati River in KwaZulu-Natal), or areas in which invasion has been isolated by specific barriers, in which case the farming of Nile tilapia should only be allowed in closed Recirculating Aquaculture Systems (RAS), outside of the 1:100-year flood line with no connection to any waterway, and subject to Risk Assessment.
b. In all provinces in which Nile tilapia does not pose a risk of invasion due to climatic conditions, all types of aquaculture production systems should be permitted (except for sensitive areas as mapped). These provinces are the Orange Free State, Gauteng and Northern Cape (excluding the lower Orange River, in which Nile tilapia should only be allowed in closed Recirculating Aquaculture Systems (RAS), outside of the 1:100-year flood line with no connection to any waterway, and subject to Risk Assessment).
c. In the Western Cape, Nile tilapia may hybridise with Mozambique tilapia even though Mozambique tilapia is not indigenous to the province. Only Recirculating Aquaculture Systems (RAS) are permitted in the Western Cape. Open water culture systems could be considered in areas of low sensitivity as mapped in the SEA, provided that reasonable measures are taken to prevent escape. However, it is unlikely that these production systems will be viable given the generally cold climatic conditions characteristic of the Western Cape.
d. In Mpumalanga, Limpopo, North-West, KwaZulu-Natal and the Eastern Cape where Nile tilapia do not already occur, aquaculture with Nile tilapia may only be allowed in highly secure closed Recirculating Aquaculture Systems (RAS), outside of the 1:100-year flood line with no connection to any waterway, and subject to Risk Assessment, which may be subject to rejection by the competent

authority (national or provincial). The absence of Nile tilapia in these provinces are subject to scientific ground-truthing and confirmed mapping.

e. In Mpumalanga, Limpopo, North-West, KwaZulu-Natal and the Eastern Cape where the presence of Nile tilapia is uncertain, these areas require field sampling and/or genetic investigation to establish and confirm the presence of Nile tilapia. If found to be present, the provisions under (i) apply. If found to be absent, the provisions under (v) apply.

17. CONCLUSION

This BRBA has illustrated that the primary risk related to the use of Nile tilapia in aquaculture in South Africa is its potential for hybridisation with, and displacement of Mozambique tilapia, after it has escaped or been intentionally introduced.

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APPENDIX 1. Risk scoring methodology for *O. niloticus* and guidance supplied by the F-ISK toolkit (Copp *et al.* 2008)

	Risk query:			
Question	**Biogeography/historical**	**Reply**	**Comments & References**	**Certainty**
1	**Is the species highly domesticated or cultivated for commercial, angling or ornamental purposes?** *Guidance*: This taxon must have been grown deliberately and subjected to substantial human selection for at least 20 generations, or is known to be easily reared in captivity (e.g. fish farms, aquaria or garden ponds).	Y	Tilapia is the second most important group of farmed fish after carps, and the most widely grown of any farmed fish. FAO 2012	4
2	**Has the species become naturalised where introduced?** *Guidance*: The taxon must be known to have successfully established self-sustaining populations in at least one habitat other than its usual habitat (e.g. Lotic vs lentic) and persisted for at least 50 years (response modifies the effect of Q1).	Y	O. niloticus is one of the top ten introduced species of the world. Picker & Griffiths 2011	4
3	**Does the species have invasive races/varieties/sub-species?** *Guidance*: This question emphasizes the invasiveness of domesticated, in particular ornamental, species (modifies the effect of Q1).	Y	Genetically Improved Farmed Tilapia (GIFT tilapia) is a selective breeding project that aims to increase the efficiencyefficiency of tilapia aquaculture efforts. GIFT tilapias reproduce at an extremely high rate, can withstand crowded conditions and can thrive in a variety of brackish, fresh and saltwater conditions (Canonico et al. 2005).	4
4	**Is species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-intermediate, 3-high)?)?** *Guidance*: Climate matching is based on an approved system such as GARP or Climatch. If not available, then assign the maximum score (2).	1	Could be seasonally	3
5	**What is the quality of the climate match data (1-low; 2-intermediate; 3-high)?** *Guidance*: The quality is an estimate of how complete are the data used to generate the climate analysis. If not available, then the minimum score (0) should be assigned.	2	Compatibility of this species to local environmental conditions was evaluated by comparing the ambient annual temperature ranges of the 31 terrestrial ecoregions of South Africa Kleynhans et al. 2005	3
6	**Does the species have broad climate suitability (environmental versatility)?** *Guidance*: Output from climate matching can help answer this, combined with the known versatility of the taxon as regards climate region distribution. Otherwise the response should be based on natural	N	Their hardiness and adaptability to a wide range of culture systems has led to the commercialization of tilapia production in more than 100 countries. FAO 2012; The wide tolerance of tilapias to variation in environmental	3

	occurrence in 3 or more distinct climate categories, as defined by Koppen or Walter (or based on knowledge of existing presence in areas of similar climate).		conditions, their amazing capacity to reproduce, and their great ability to compete with other species s a major concern when they are introduced outside of their native range. Boyd 2004	
7	**Is the species native to, or naturalised in, regions with equable climates to the risk assessment area?** *Guidance*: Output from climate matching help answer this, but in absence of this, the known climate distribution (e.g. a tropical, semi-tropical, south temperate, north temperate) of the taxons native range and the 'risk are' (e.g. country/region/area for which the FISK is being run) can be used as a surrogate means of estimating.	N	Since the 1980s, introductions in other parts of Southern Africa has led to fish escaping into rivers (a phenomenon that has been compounded by intentional introductions by anglers) and as a result, the Nile tilapia has established self-sustaining wild populations in the InKomati and Limpopo Rivers Picker & Griffiths 2011	3
8	**Does the species have a history of introductions outside its natural range?** *Guidance*: Should be relatively well documented, with evidence of translocation and introduction.	Y	Tilapia have become the second most common aquaculture species and they have been introduced into at least 90 countries on all continents except Antarctica Fitzsimmons 2001	4
9	**Has the species naturalised (established viable populations) beyond its native range?** *Guidance*: If the native range is not well defined (i.e. uncertainty about it exists), or the current distribution of the organism is poorly documented, then the answer is "Don't know".	Y	Equally, it should be noted that this species is potentially able to establish naturalised populations in all twelve of these regions Picker & Griffiths 2011	4
10	**In the species' naturalised range, are there impacts to wild stocks of angling or commercial species?** *Guidance:* Where possible, this should be assessed using documented evidence of real impacts (i.e. decline of native species, disease introduction or transmission), not just circumstantial or opinion-based judgments.	Y	This, and a low catch per unit effort, may indicate a degree of overharvesting of angling species. Measures proposed to prevent further overexploitation include a ban on draw netting as well as restocking the river with tilapia. Van der Waal 2000	4
11	**In the species' naturalised range, are there impacts to aquacultural, aquarium or ornamental species?** *Guidance*: Aquaculture incurs a cost from control of the species or productivity losses. This carries more weight than Q10. If the types of species is uncertain, then the yes response should be placed here for more major species, particularly if the distribution is widespread.	?	No record of this	2
12	**In the species' naturalised range, are there impacts to rivers, lakes or amenity values?** *Guidance*: documented evidence that the species has altered the structure or function of natural ecosystems.	Y	Consequently, controlling tilapia abundance to reduce the internal nutrient loading of lakes should receive special attention to manage tropical and subtropical eutrophic lakes and reservoirs Starling et al. 2002	4

13	**Does the species have invasive congeners?** *Guidance*: One or more species within the genus are known to be serious pests.	Y	Eutrophic water conditions frequently are a result of intensive O. niloticus production. O. niloticus' selective feeding regime can also unbalance algal constituents of the water column GISD 2012	4
14	**Is the species poisonous, or poses other risks to human health?** *Guidance*: Applicable if the taxon's presence is known, for any reason, to cause discomfort or pain to animals.	N	No reference	4
15	**Does the species out-compete with native species?** *Guidance:* known to suppress the growth of native species, or displace from the microhabitat, of native species.	Y	However, the lungfish decline may reflect the interaction of overexploitation by the fishery and a low level of Nile perch predation that restricts lungfish to wetland refugia Goudswaard et al. 2002; The introduction of invasive Nile tilapia (*Oreochromis niloticus*), and the rapacious predator Nile perch (*Lates niloticus*), into Lake Victoria resulted in a decline in population sizes, genetic diversity and even extirpation of native species which were previously the mainstay of local fisheries. Angienda et al. 2011	4
16	**Is the species parasitic of other species?** *Guidance*: Needs at least some documentation of being a parasite of other species (e.g. scale or fin nipping such as known for topmouth, gudgeon, blood-sucking such as some lampreys)	N	No reference	4
17	**Is the species unpalatable to, or lacking, natural predators?** *Guidance*: this should be considered with respect to where the taxon is likely to be present and with respect to the likely level of ambient natural or human predation, if any.	N	No reference	4
18	**Does species prey on a native species (e.g. previously subjected to low (or no) predation)?** *Guidance*: There should be some evidence that the taxon is likely to establish in a hydro-system that is normally devoid of predatory fish (e.g. amphibian ponds) or in river catchments in which predatory fish have never been present.	N	No record of this	3
19	**Does the species host, and/or is it a vector, for recognized pests and pathogens, especially non-native?** *Guidance*: The main concerns are non-native pathogens and parasites, with the host being the original introduction	Y	Ciliates and Monongeneticv trematodes are protozoan parasites which tilapia are hosts for. FAO 2012	4

	vector of the disease or as a host of the disease brought in by another taxon.			
20	**Does the species achieve a large ultimate body size (i.e. > 10 cm FL) (more likely to be abandoned)?** *Guidance*: Although small-bodied fish may be abandoned, large-bodied fish are the major concern, as they soon outgrow their aquarium or garden pond.	Y	The relatively energy-rich omnivorous diet of Nile tilapia in Lake Nabugabo may confer an energetic advantage for increased growth compared to the relatively energy-poor phytoplanktivorous diet of Nile tilapia in Lake Wamala Bwanika et al. 2004	4
21	**Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle?** Guidance: Presence in low salinity water bodies (e.g. Baltic Sea) does not constitute euryhaline, so minimum salinity level should be about 15%o.	N	No record of this	4
22	**Is the species desiccation tolerant at some stage of its life cycle?** *Guidance*: Should be able to withstand being out of water for extended periods (e.g. minimum of one or more hours).	N	No reference	4
23	**Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use)?** *Guidance*: Species that are known to persist in a wide variety of habitats, including areas of standing and flowing waters (over a wide range of Velocities: 0 to 0.7 m per sec).	Y	This suggests that lower feeding level (1% BW/day), lower stocking density (3 female m^2) and lower waterflow rate (0.06± 0.00 L/s) could be adopted as a management strategy to improve current tilapia hatchery seed production, although, optimum water flow-related stocking density needs further investigation Tsadik & Bart 2007	3
24	**Does feeding or other behaviors of the species reduce habitat quality for native species?** *Guidance*: There should be evidence that the foraging results in an increase in suspended solids, reducing water clarity (e.g. as demonstrated for common carp).	Y	However, the lungfish decline may reflectreflect the interaction of overexploitation by the fishery and a low level of Nile perch predation that restricts lungfishlungfish to wetland refugia. Goudswaard et al. 2002; The introduction of invasive Nile tilapia (*Oreochromis niloticus*), and the rapacious predator Nile perch (*Lates niloticus*), into Lake Victoria resulted in a decline in population sizes, genetic diversity and even extirpation of native species which were previously the mainstay of local fisheries. Angienda et al. 2011	4
25	**Does the species require minimum population size to maintain a viable population?** *Guidance*: If evidence of a population crash or extirpation due to low numbers (e.g. overexploitation, pollution, etc.), then response should be 'yes'.	Y	Need certain number to prevent inbreeding (no ref)	3

26	**Is the species a piscivorous or voracious predator (e.g. of native species not adapted to a top predator)?** *Guidance*: Obligate piscivores are most likely to score here, but some facultative species may become voracious when confronted with naïve prey.	N	Can be omnivorous (Bwanika et al. 2007	3
27	**Is the species omnivorous?** *Guidance*: Evidence exists of foraging on a wide range of prey items, including incidental piscivory.	Y	Nile tilapia were found to have a more varied omnivorous diet in lakes where it co-exists with the introduced Nile perch (lakes Nabugabo and Victoria), and a primarily herbivorous diet in lakes without Nile perch (lakes Wamala, Mburo, Nyamusingiri, and Kyasanduka) Bwanika et al. 2007	4
28	**Is the species planktivorous?** *Guidance*: Should be an obligate planktivore to score here.	Y	It is an omnivorous grazer that feeds on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus and bacterial films associated with detritus. FAO 2012; Differences in the patterns of growth in Nile tilapia between lakes may reflect, at least in part, the relatively energy-rich omnivorous diet of Nile tilapia in Lake Nabugabo versus a phytoplanktivorous diet in Lake Wamala. Bwanika et al. 2007	4
29	**Is the species benthivorous?** *Guidance*: Should be an obligate benthivore to score here.	Y	It is an omnivorous grazer that feeds on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus and bacterial films associated with detritus. FAO 2012	4
30	**Does it exhibit parental care and/or is it known to reduce age-at-maturity in response to environment?** *Guidance*: Needs at least some documentation of expressing parental care.	Y	Mouth brooding (FAO 2012	4
31	**Does the species produce viable gametes?** *Guidance*: If the taxon is a sub-species, then it must be indisputably sterile.	Y	No reference	4
32	**Does the species hybridize naturally with native species (or uses males of native species to activate eggs)?** *Guidance:* Documented evidence exists of interspecific hybrids occurring, without assistance under natural conditions.	Y	Hybrids of *O. niloticus* and the native *O. mossambicus* were discovered in dry pools beside the Limpopo River, alongside pure strains of each species Moralee et al. 2000	4
33	**Is the species hermaphroditic?** *Guidance:* Needs at least some documentation of hermaphroditism.	N	No reference	4

34	**Is the species dependent on presence of another species (or specific habitat features) to complete its life cycle?** Guidance: Some species may require specialist incubators (e.g. unionid mussels used by bitterling) or specific habitat features (e.g. fast flowing water, particular species of plant or types of substrata) in order to reproduce successfully.	N	No reference	4
35	**Is the species highly fecund (>10,000 eggs/kg), iteropatric or have an extended spawning season?** Guidance: Normally observed in medium-to-longer lived species.	N	A 100g female will produce about 100 eggs per spawn, while a female weighing 600-1 000 g can produce 1 000 to 1 500 eggs. If there is no cold period, during which spawning is suppressed, the female may spawn continuously FAO 2012	4
36	**What is the species' known minimum generation time (in years)?** *Guidance*: Time from hatching to full maturity (i.e. active reproduction, not just presence of gonads). Please specify the number of years.	1	Can breed after 5/6 months FAO 2012	4
37	**Are life stages likely to be dispersed unintentionally?** *Guidance*: Unintentional dispersal resulting from human activity.	Y	Eggs are removed from female mouth brooders and incubated Boyd 2004	4
38	**Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant nearby)?** *Guidance*: the taxon has properties that make it attractive or desirable (e.g. as an angling amenity, for ornament or unusual appearance).	N	No record of this	3
39	**Are life stages likely to be dispersed as a contaminant of commodities?** *Guidance*: Taxon is associated with organisms likely to be sold commercially.	N	Depends on management practices	3
40	**Does natural dispersal occur as a function of egg dispersal?** *Guidance*: there should be documented evidence that eggs are taken by water currents or displaced by other organisms either intentionally or not.	N	FAO 2012	4
41	**Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping stone' habitats)?** *Guidance*: There should be documented evidence that larvae enter, or are taken by, water currents, or can move between water bodies via connections	N	FAO 2012	4
42	**Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?** *Guidance*: There should be documented evidence of migratory behavior, even at a	N	No reference	4

	small scale (tens or hundreds of meters).			
43	**Are eggs of the species known to be dispersed by other animals (externally)?** *Guidance*: For example, are they moved by birds accidentally when the water fowl move from one water body to another?	?	No record of this	2
44	**Is dispersal of the species density dependent?** *Guidance*: There should be documented evidence of the taxon spreading out or dispersing when its population density increases.	?	No record of this	2
45	**Any life stages likely to survive out of water transport?** *Guidance:* There should be documented evidence of the taxon being able to survive for an extended period (e.g. an hour or more) out of water. PLEASE NOTE THAT THIS IS SIMILAR TO QUESTION 22. THIS IS AN ERROR WITH THE FISK TOOLKIT AND THE CREATORS WILL BE ALERTED. FOR THE PURPOSES OF THIS STUDY, THE ANSWER HAS BEEN REPEATED.	N	No reference	3
46	**Does the species tolerate a wide range of water quality conditions, especially oxygen depletion & high temperature?** *Guidance:* This is to identify taxa that can persist in cases of low oxygen and elevated levels of naturally occurring chemicals (e.g. ammonia).	Y	They are relatively resistant to poor water quality and disease. FAO 2012, They resist disease well, and they can tolerate low dissolved oxygen concentration, high ammonia concentration, and impaired water quality in general. Boyd 2004	4
47	**Is the species susceptible to piscicides?** *Guidance*: There should be documented evidence of susceptibility of the taxon to chemical control agents.	Y	Botanical pesticides can be used as a control which is effective but less toxic Caguan et al. 2004	4
48	**Does the species tolerate or benefit from environmental disturbance?** *Guidance:* The growth and spread of some taxa may be enhanced by disruptions or unusual events (floods, spates, desiccation), especially human impacts.	Y	Tilapia thrive in disturbed habitats, they reproduce and spread rapidly, they are carnivorous on the eggs and young of other species, and are strong competitors with other species for food and other resources. Boyd 2004	4
49	**Are there effective natural enemies of the species present in the risk assessment area?** *Guidance:* A known effective natural enemy of the taxon may or may not be present in the Risk Assessment area. The answer is 'Don't know' unless a specific enemy/enemy is known.	?	No record of this	2