Biodiversity Risk and Benefit Assessment for African sharptooth catfish (*Clarias gariepinus*) in South Africa

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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Prepared For	Directorate: Sustainable Aquaculture Management Department of Environment, Forestry and Fisheries (DEFF) Private Bag X2 Roggebaai, 8001 www.daff.gov.za/daffweb3/Branches/Fisheries-Management/Aquaculture-and-Economic-Development
Originally Prepared By (2012)	Dr B. Clark Anchor Environmental Consultants
Reviewed, Updated and Recompiled By (2019)	Mr. E. Hinrichsen AquaEco as commisioned by Aquaculture Innovations

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EXECUTIVE SUMMARY

Internationally, alien species provide a valuable food source and an economic opportunity in both the fisheries and aquaculture sectors (Bartley 2006). 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 use of African sharptooth catfish: *Clarias gariepinus* in South Africa. This species is native to large parts of South Africa but has become invasive and established in non-native areas in the Eastern and Western Cape.

The Department of Environment, Forestry and Fisheries (DEFF), as the lead agent for aquaculture management and development, appointed Anchor Environmental in August 2012 to conduct a BRBA for the use of African sharptooth catfish in South Africa. In 2018, AquaEco was appointed to review and update this 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 African sharptooth catfish (*Clarias gariepinus*) 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 species. The document not only serves as a broad high-level assessment to be applied in the context of new applications and regulation of the import and culture of African

sharptooth catfish in South Africa, but 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 for such assessments contained in 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 risk assessment investigated the taxonomy, key characteristics, dietary aspects and history of African sharptooth catfish culture, while considering that it is native to most of Africa and large parts of South Africa. It was found that African sharptooth catfish is a highly fecund, persistent and potentially invasive species, but that this would only be possible outside of its native range in South Africa. Much of the Eastern and Western Cape that fall outside of the native range for this species has already been invaded.

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

During the assessment, it was found that the overall ecological risk profile for African sharptooth catfish was moderate to high, especially in the areas of competition, the displacement of other aquatic predators and impacts on prey species. These risks however depend on a facilitative pathway, which shows a high likelihood given their ability to escape from aquaculture production systems. However, these risks should not be considered in environments where these fish occur naturally, and consideration should be given to the fact that most large rivers in their non-native range in South Africa have been fully invaded.

Key economic and social matters were considered in a balanced manner in conjunction with the potential ecological risks. It was found that the continued interest in this species across South Africa is likely to lead to a continued desire to use it for aquaculture purposes. The establishment of a formal and lawful African sharptooth catfish 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.

It is recommended in this BRBA that African sharptooth catfish farming should be allowed in all areas where they occur naturally, as well as in areas linked to fully invaded river systems. Further risk assessment methods and application for permits should be applied in areas where these fish do not yet occur. 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.

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1. INTRODUCTION

This Biodiversity Risk and Benefit Assessment (BRBA) pertains to the import, propagation and grow out of African sharptooth catfish (*Clarias gariepinus*) in South Africa.

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

At date of publication, this BRBA will be recognised as a national reference work related to the ecological risks and potential benefits of importing, propagating and growing African sharptooth catfish in South Africa. In this regard it replaces all preceding risk assessment documents and frameworks for the species.

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 African sharptooth catfish 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 African sharptooth catfish, and to evaluate these risks in determining possible justification through allowance by permitting.

[1] *Note that at the time of publication revised draft regulations had been circulated for public comment and will be promulgated in due course. This BRBA will require review and update in terms of these revised regulations.*

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

The main objectives of this BRBA are:

- To determine the primary risks associated with the import, propagation and grow out of African sharptooth catfish in South Africa.
- To determine the potential benefits associated with the import, propagation and grow out of African sharptooth catfish in South Africa.
- To provide key information related to the characteristics of African sharptooth catfish for risk and benefit analysis.
- 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.

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 commissioned 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 AFRICAN SHARPTOOTH CATFISH

African sharptooth catfish, although highly capable of being invasive in new habitats, is recognized as indigenous to South Africa, albeit that it does not occur naturally across the entire country. The natural distribution of these fish in South Africa is north of the Orange River system in the west and northwards of the Umtamvuna River in the east (Jubb 1967).

Distribution of African sharptooth catfish has been extended through inter-basin transfer schemes, anglers and aquaculture facilities (Cambray 2003a). These fish reached the Eastern Cape from the Orange-Vaal system via the Orange-Fish River tunnel in 1975 (Cambray & Jubb 1977), eventually inhabiting the Sunday's River and spreading further west. They were found in the Kei system in the 1980's (de Moor & Bruton 1988) and in the Tyume River in the Keiskamma system in 1985 (Mayekiso 1986). Today, most of the main rivers in the Eastern Cape have populations of African sharptooth catfish (Cambray 2003a, Weyl & Booth 2008, Booth *et al*. 2010).

In the Western Cape, these fish reportedly escaped from the Jonkershoek Hatchery into the Eerste River in the 1970's (Gaigher *et al.* 1980). It was deliberately introduced by conservation authorities into the Cape Flats for angling (Cambray 2003b). A range of other illicit translocations has resulted in naturalized populations in the Cape Flats, Kuils, Berg, Breede, Clanwilliam and Olifants rivers (Cambray 2003b).

Today, at least three user groups can be identified for African sharptooth catfish in South Africa:

- A small, informal and sometimes opportunistic fishery exists for African sharptooth catfish. Although many communities do not eat catfish for religious and cultural regions, there are people in certain areas that make use of these fish as a source of food.
- A fraternity exists around the use of African sharptooth catfish as a recreational angling species.
- A relatively small aquaculture sector currently exists for African sharptooth catfish. This fish is an ideal candidate species for aquaculture, given its hardiness and the high densities at which it can be farmed. It has, however, suffered from poor market acceptance in the past.

In the remainder of Africa, especially in western African countries such as Nigeria, African sharptooth catfish farming dominates local fish supplies. Today, this species has a global farming footprint and they are produced in a variety of systems, including ponds, tanks, raceways and cage systems. More recent advances are seeing these fish also being farmed in thermally regulated intensive bio-secure recirculation systems where water quality parameters are controlled. Of these, cage culture and open-ended ponds pose the highest biosecurity risk (i.e. risk of escape and/or transfer of pathogens and disease to wild populations), while culture in closed-end recirculating systems pose the lowest biosecurity risk.

5. REASONS FOR THE FARMING OF AFRICAN SHARPTOOTH CATFISH

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 remain 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 % 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 %) 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.

Britz *et al*. 2009 reports only two African sharptooth catfish farms in South Africa in 2008, with a production value of around ZAR 3.6 million. Annual production remained at around 180 ton per annum from 2006 to 2011. However, the DAFF Aquaculture Yearbook of 2016 reports on the existence of 13 farms in 2015, but production of zero tons per annum since 2012, sighting the sector was concentrating on the production of fingerlings. These numbers do not reflect that at least one large-scale commercial farm exists in the Eastern Cape, and that a range of informal and small-scale operations produce small amounts of fish for own and localised consumption.

Recognised in the FAO Statistical Database (2016) as North African catfish, global production is reported to be in the region of 231 091 tons per annum in 2016 (FAO, 2016). Considering underreporting in a range of African countries, this is likely an underestimate.

Water transfer schemes, the attempted use of African sharptooth catfish in aquaculture and stocking as an alternative angling species has seen the establishment of extralimital populations in non-native parts of the Eastern and Western Cape Provinces. Today, it can be said that African sharptooth catfish occur across South Africa with the probable exception of some smaller cold-water stream systems along the Eastern Escarpment and some smaller and isolated rivers in the Eastern Cape and northern regions of the Western Cape.

Albeit that production levels of African sharptooth catfish in South Africa remain low, the species is a strong candidate for aquaculture development given its hardy nature, wide climatic tolerance, fecundity, non-specific diet, fast growth and tolerance for high stocking densities. For this reason, there is every possibility that interest in the farming of these fish will persist. Negative market perception remains a major limiting factor to growth in the farming of this species.

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)[2] 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

[2] *Note that at the time of publication revised draft regulations had been circulated for public comment and will be promulgated in due course. This BRBA will require review and update in terms of these revised regulations.*

they did not occur historically. A range of human activities that could potentially cause 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 for 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. CLASSIFICATION OF AFRICAN SHARPTOOTH CATFISH

African sharptooth catfish has not been included in Notice 3, List 7 (National List of Invasive Fresh-water Fish Species), nor in Notice 4, List 7 (Prohibited Freshwater Fish) in the AIS List (Government Notice R 864 of July 2016). Whether included in further revisions of the AIS List or not, this species can be regarded as indigenous and should be free to use in aquaculture across South Africa, with the requirement for risk assessment and permitting only in areas where it has not yet invaded (certain remote streams of the Eastern Cape and smaller tributaries of mainstream rivers of the northern sections of the Western Cape Province). Precautionary principles should be applied as this relates to the import of stock that may be genetically divergent from the indigenous strains in South Africa.

It must be noted that most Provinces have specific Provincial Ordinances that govern the movement and keeping of fish species such as African sharptooth catfish. The National Government have confirmed that all provinces should regulate the import, propagation and grow out of fish in terms of the forthcoming National Regulations, but the repeal of Provincial Ordinances (and compliance thereto) remains a matter under the jurisdiction of each Province.

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:

<u>From the NEMBA:</u>

- 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 African sharptooth catfish in South Africa. However, import will be excluded where fish are obtained locally (i.e. from local producers). Moreover, the use of African sharptooth catfish is not restricted by the AIS Regulations in that it is not listed as an Alien and Invasive Species.

7. TARGET SPECIES: AFRICAN SHARPTOOTH CATFISH

7.1. TAXONOMY

<u>Common Name</u>:	African sharptooth catfish / African catfish
Kingdom:	*Animalia*
Subkingdom:	*Bilateria*
Infrakingdom:	*Deuterostomia*
Phylum:	*Chordata*
Subphylum:	*Vertebrata*
Infraphylum:	*Gnathostomata*
Superclass:	*Osteichthyes*
Class:	*Actinopterygii* (ray-finned fishes)
Subclass:	*Neopterygii*
Infraclass:	*Teleostei*
Order:	*Siluriformes*
Family:	*Clariidae*
Subfamily:	*Clariinae*
Genus:	*Clarias*
Species:	*Clarias gariepinus*

Taxonomic Code: 1411803003

No subspecies have been reported for African sharptooth catfish, albeit that a range of genetically unique populations may exist across Africa.

Other Names: Barbel, Mudfish, North African Catfish, Mulonge, Bombe, Skerptand- barber.

Synonyms: *Silurus gariepinus Burchell, 1822*
Macropteronotus charmuth Lacepède, 1803

Clarias capensis Valenciennes, 1840

Clarias lazera Valenciennes, 1840

Clarias syriacus Valenciennes, 1840

Clarias mossambicus Peters, 1852

Clarias macracanthus Günther, 1864

Clarias orontis Günther, 1864

Clarias xenodon Günther, 1864

Clarias robecchii Vinciguerra, 1893

Clarias muelleri Pietsmann, 1939

Clarias microphthalmus Pfeffer, 1896

Clarias guentheri Pfeffer, 1896

Clarias longiceps Boulenger, 1899

Clarias longiceps Boulenger, 1899

Clarias moorii Boulenger, 1901

Clarias tsanensis Boulenger, 1902

Clarias vinciguerrae Boulenger, 1902

Clarias malaris Nichols & Griscom, 1917

Clarias notozygurus Lönnberg & Rendahl, 1922

Clarias depressus Myers, 1925

Clarias muelleri Pietschmann, 1939

7.2. ORIGINATING ENVIRONMENT

African sharptooth catfish are the most widely distributed fish in Africa. Their native range covers most of the continent, except for Maghreb, Upper and Lower Guinea, and the Cape provinces of South Africa (Picker & Griffiths, 2011), which have subsequently been invaded. They are equally present in Jordan, Lebanon, Israel and Turkey, and have been introduced in Europe, Asia and South America.

The natural distribution of these fish in South Africa is northwards of the Orange River system in the west and northwards of the Umtamvuna River in the east (Jubb, 1967).

African sharptooth catfish is a freshwater species, but is widely tolerant of many different habitats, even the upper reaches of estuaries. It can tolerate waters high in turbidity and low in dissolved oxygen and is often the last or only fish species found in remnant pools of drying rivers (Safriel & Bruton 1984, Van der Waal 1998). It favours floodplains, slow flowing rivers, lakes and dams (Skelton, 2001) and may undertake regional upstream migrations for spawning.

7.3. KEY PHYSIOLOGICAL CHARACTERISTICS

African sharptooth catfish is a typical air-breathing catfish and are readily recognized by their cylindrical body, smooth skin without scales, flattened bony head, small eyes, elongated spineless dorsal fin and four pairs of barbels around a broad mouth. The upper surface of the head can be coarsely granulated in adult fish, but smooth in young fish (Van Oijen, 1995). Their colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey while the underside is a pale cream to white (Skelton 2001). Other physiological features include:

- The mouth is terminal with four pairs of barbels.
- The first gill arch has 24 to 110 gill rakers.
- Only the pectoral fins have spines.
- The cleithrum is pointed.
- These fish have an air-breathing labyrinthic organ arising from the gill arches.

African sharptooth catfish can attain a maximum length of 170 cm and weigh up to 60 kg (FAO, 2018).

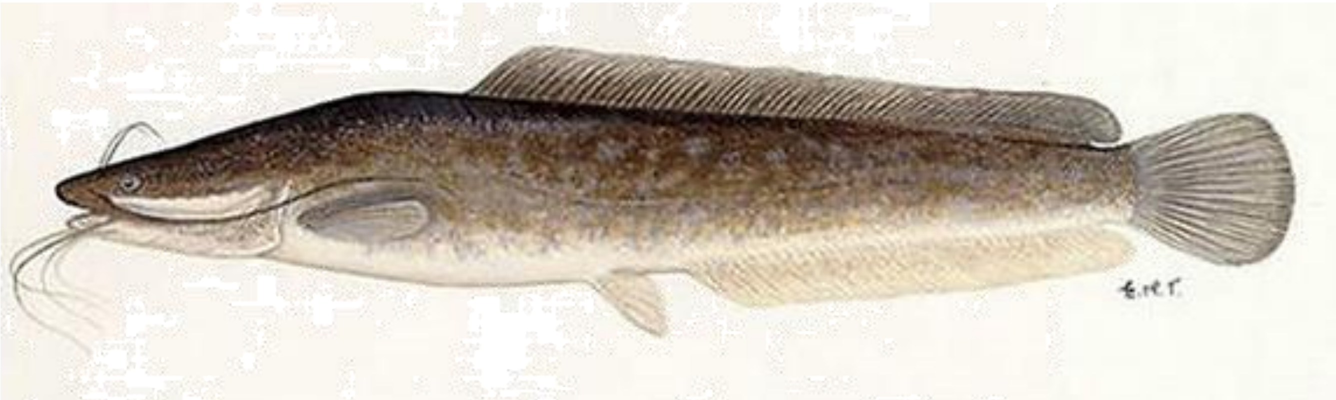

Figure 1: African sharptooth catfish (Clarias gariepinus).

7.4. REPRODUCTION

Under ideal environmental conditions, these fish can reach sexual maturity at an age of eight months, when they are 180 - 200 grams in weight and 26 - 30 cm long (Kurbanov & Kamilov, 2017). African sharptooth catfish are known to breed in summer after commencement of good rains, and usually at night. In certain areas these fish may migrate to the flooded shallows of rivers and lakes (Skeleton, 1993) to commence with spawning.

These fecund fish produce an average of approximately 45 000 eggs for a 2 kg female (Burton, 1979b). Gaigher, 1977, reported over 1 million eggs being released from large females.

The females release their eggs, which are externally fertilised by a congregation of male fish. These eggs usually adhere to submerged vegetation, where they may hatch within 20 to 60 hours depending on temperature (Bruton, 1979b). There is no parental care of the young, and the fry begin to swim freely at approximately 35 hours after fertilization, with feeding commencing within 80 hours (Hecht et al, 1988). Larvae can reach 3 to 7 grams in 30 days.

7.5. DIETARY ASPECTS

Displaying both scavenging and predatory behaviour African sharptooth catfish are considered omnivorous (Burton, 1979a). These fish are known to have an extremely varied diet consisting of fruit and seeds, all types of aquatic invertebrates and small vertebrates, small mammals and even plankton. Although inactive foods are preferred, these fish are capable of hunting for prey (Bruton 1979a, Skelton 2001). Solitary feeding, social hunting and coordinated pack-hunting foraging behaviour, and even feeding migrations have been observed (Bruton 1979a, Merron 1993).

7.6. ENVIRONMENTAL TOLERANCES

African sharptooth catfish can tolerate a wide range of water quality extremes and are highly adaptable to extreme climatic and environmental conditions (Skelton, 2001). These fish can survive outside of water for extended periods of time, given a high tolerance against the build-up of ammonia in cells and tissues under such conditions (Yuen *et al*, 2005). This facilitates short overland migration during wet and damp periods (Welman 1948, Johnels 1957). During dry periods African sharptooth catfish can secrete mucus to keep the skin moist or dig holes or crude burrows beneath the mud to survive (Burton, 1979c; Van der Waal, 1998).

Hecht *et al,* 1988, reports on a range of environmental tolerances, including:

- Survivable water temperature at 8 - 35°C, with spawning requiring temperatures above 18°C and egg hatching from 17 - 32°C (Teugels, 1986).
- Salinity at 0 to 12 ppt.
- Dissolved oxygen at 0 to 100% saturation, given their ability to utilise atmospheric oxygen as an obligate air breather using the epibranchial organ.
- pH at 6.5 – 8.0.

7.7. NATURAL ENEMIES, PREDATORS AND COMPETITORS

As is the case with many fish species, the life history strategy of African sharptooth catfish is based on high fecundity to compensate for significant losses to predation. Although these fish actively avoid predation, they are preyed upon by other fish, birds, reptiles (e.g. monitor lizards), aquatic mammals (e.g. otters) and crustaceans (e.g. crabs). Due to the abundance of African sharptooth catfish across Africa it is preyed upon widely by African Fish Eagle, Marabou Stork and Nile crocodile.

7.8. POTENTIAL TO HYBRIDISE

Under artificial conditions African sharptooth catfish has been hybridised with Vundu (*Heterobranchus longifilis*), which occur in the Zambezi basin, to produce viable offspring (Hecht & Lublinkhof, 1985). However, African sharptooth catfish occur naturally across the range of Vundu and that of at least another six species of the family *Clariidae*, in southern Africa. No natural hybridisation has been recorded in this instance, and hybridisation is not regarded as a biodiversity risk in South Africa. Hybridisation has however been recorded between African sharptooth catfish and other species of the family *Clariidae* in Asia (Senanan et al 2004).

Some generic trait selection has been undertaken for African sharptooth catfish in Europe. As these fish display improved growth and other traits conducive to aquaculture, the import of these strains into South Africa may become relevant, in which case further investigation may be required into the potential risk of genetic change in naturally occurring populations with which they breed.

7.9. PERSISTENCE AND INVASIVENESS

African sharptooth catfish display physiological, morphological and life history characteristics of a successful invasive species in that they are highly fecund, hardy and have a wide environmental tolerance. Together with rapid growth and a wide array of habitat preferences, these fish can survive extreme water conditions and have a highly variable and non-specific diet, which means they can outcompete other species, occupy niche habitats and potentially impact on indigenous fish and aquatic invertebrate populations in areas not previously inhabited (Bruton, 1986). Added to these traits is the ability of African sharptooth catfish to move and survive overland and to escape from confined enclosures such as ponds, dams, raceways and other aquaculture systems (Cambray, 2003a).

Where water temperatures remain between 8 - 35°C, African sharptooth catfish is a persistent survivor and will readily spawn and invade new habitats. African sharptooth catfish have been introduced globally and have shown varying levels of invasiveness. In many Asian countries their continued spread and biodiversity impacts have been recorded widely (Invasive Species Compendium, 2017), while in countries such as Brazil (Weyl *et al.*, 2016) and India (Kumar *et al.,* 2011), these fish have become highly invasive. Today these fish can be found in a range of countries across Asia, Europe and South America, including in a range of island nations (FAO, 2018).

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 African sharptooth catfish is predominately through human actions in that fish are moved for aquaculture, angling and for other reasons such as via water transfer schemes.

In this BRBA, the invasive potential of African sharptooth catfish should be considered against the fact that these fish are indigenous to a large portion of South Africa and have fully invaded large river systems outside of their nature range; including the Fish, Sundays, Gouritz, Berg, Breede and Olifants Rivers. The prospects of removing these extralimital fish from these systems is virtually zero.

7.10. HISTORY OF TRANSLOCATION AND CULTIVATION

Although African sharptooth catfish has been farmed across Africa in varying degrees of sophistication for centuries, experimental farming thereof began in South Africa during the 1940's (Hey, 1941). By the 1950's researchers such as Greenwood stimulated further interest in the species for farming purposes, and by the 1970's this species was widely farmed across Africa (Hecht *et al.,* 1988). Farming in South Africa was however always hampered by poor market acceptance of the product.

Aquaculture has been sighted to be the primary reason for the spread of African sharptooth catfish around the world (Cambray, 2005) although water transfer schemes, indiscriminate anglers and provincial conservation authorities also played a role. Fast growth rates and excellent feed conversion ratios have made this species popular in the global aquaculture industry (Hecht *et al.,* 1988; Na-Nakorn & Brummett, 2009).

Advances in the artificial spawning, aquaculture diet formulation and husbandry techniques worldwide, has seen the development of a strong global aquaculture sector for this species, employing a range of farming techniques and production systems, including:

- Tanks and ponds of various materials;
- Raceways;
- Cage culture systems in existing waterbodies; and
- High density recirculatory systems.

Farmed globally, the production of African sharptooth catfish (or North African catfish as it is recorded by the FAO) now totals 231 091 tonnes annually (FAO, 2016). The trade in African sharptooth catfish is now valued at U$ 664 million per annum (FAO, 2016). In South Africa the production was recorded to be as high as 1150 tons in 1991, but no production has been reported to the FAO for 2016, albeit that at least one commercial farm has been actively producing fish in the Eastern Cape.

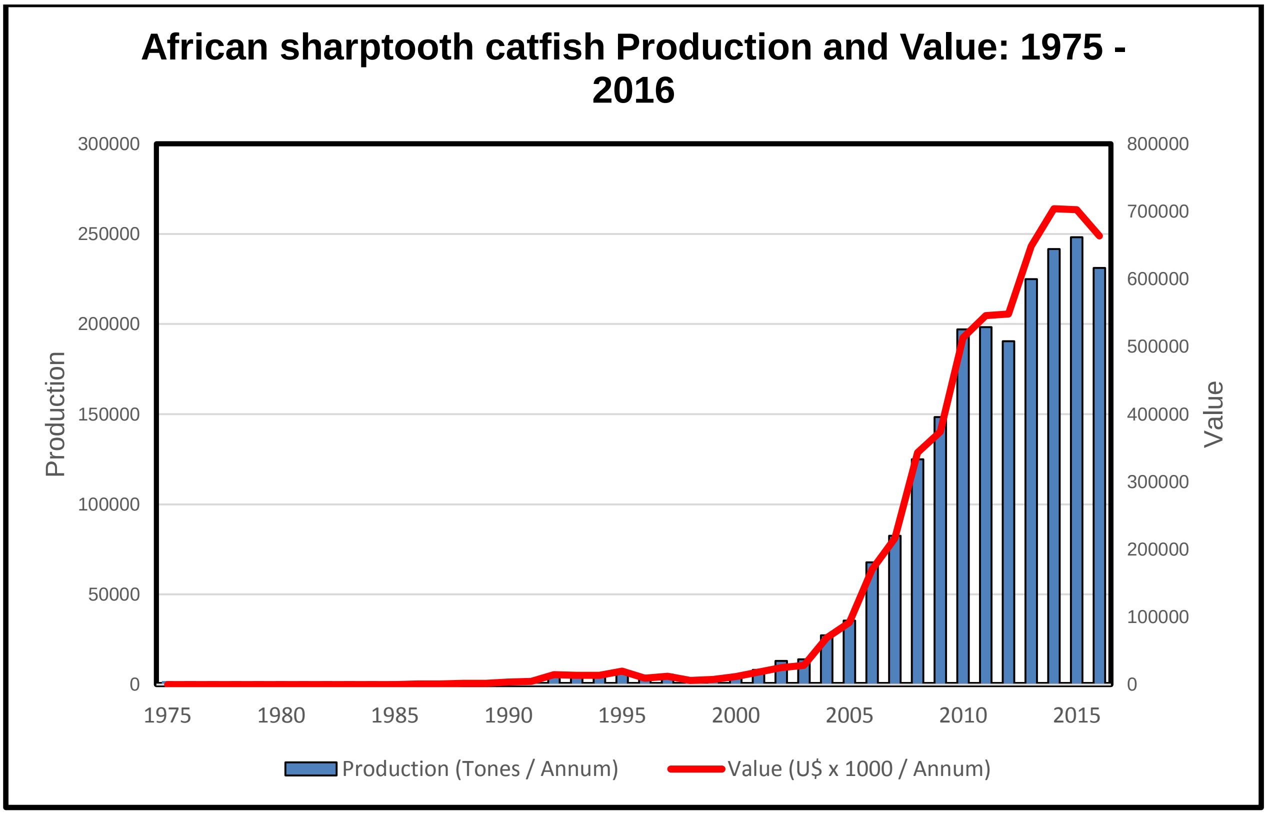

Figure 2: *International production of African sharptooth catfish in tonnage and value between 1975 and 2016 (FAO - Fisheries and Aquaculture Information and Statistics Service).*

7.11. ABILITY TO CREATE ECOSYSTEM CHANGE

As African sharptooth catfish can feed as generalists and predators in an introduced environment, these fish are able to create ecosystem change through predation on, and displacement of, other aquatic organisms (Hecht, 1985). Competition and predation on aquatic fauna such as fish, fish eggs, amphibians and a range of aquatic invertebrates can cause a loss in biodiversity and can have tropic consequences in areas where they have not occurred naturally (Schmidt *et al.,* 2009). An example of this is the presence of African sharptooth catfish in the southern Cape, threatening a range of indigenous fish species through predation and competition (De Moor & Burton, 1988). More recently, the same threat has been recorded in a range of Western Cape streams (Impson, pers. comm.).

The ability to create ecosystem change is directly dependant on the presence of organisms that can be predated upon by African sharptooth catfish in areas outside of their native range. In South Africa, no ecosystem change is possible through hybridisation or other direct physical (abiotic) changes to the environment. Although this can cause several ecological shifts, complete ecosystem dysfunction is not possible.

7.12. PROBABILITY OF NATURALISATION

In South Africa, African sharptooth catfish have established self-sustaining populations in a range on non-native areas in the Eastern and Western Cape. Naturalised populations of African sharptooth catfish are already known to have established in the Cape Flats, Kuils, Berg, Breede, Clanwilliam and Olifants rivers (Cambray 2003b). In the Eastern Cape most of the main rivers also now have populations of these fish (Cambray, 2003a; Weyl & Booth, 2008; Booth *et al*., 2010).

There fish have become naturalised occurs their introduced range, and there is little prospect of eradication, other than possibly from small and barricaded streams in which a dedicated program is implemented. It is only in selected smaller Eastern and Western Cape streams where these fish have not yet become invasive, while they are climatically excluded from some cooler escarpment streams in the Eastern Cape, KwaZulu Natal and Mpumalanga.

Through the action of humans (through water transfer schemes, fish farmers and anglers), these fish have an effective means of dispersal, consistent with international findings related to the facilitated spread of alien species (Courtenay *et al.,* 1992).

It can be concluded that African sharptooth catfish have dramatically increased their range in South Africa, and there is a high probability of invasion and naturalisation in the remaining few climatically suitable areas of the Eastern and Western Cape where they do not already occur.

7.13. POSSIBLE IMPACTS ON BIODIVERSITY

The possible impacts of African sharptooth catfish on biodiversity depend on the habitat type and presence of species that can suffer from competition and predation. These potential impacts, which can range from negligible to extensive, may include:

- African sharptooth catfish can outcompete certain species for food and habitat, which can lead to a reduction in species related abundance and biodiversity.
- African sharptooth catfish can be highly fecund. 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 African sharptooth catfish 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 and amphibians, leading to a potential decline in native biodiversity and fish species diversity.
- The introduction of African sharptooth catfish could cause secondary impacts to biodiversity by changing the abundance of species on which other piscivorous animals depend.
- African sharptooth catfish could indirectly affect biodiversity through genetic impacts. These effects would be related to declining population sizes of native species, resulting in a loss of genetic diversity.

African sharptooth catfish are reported as being a threat to a range of South African fish species in the Red Data Book, some of which are highly endemic to the Western Cape regions. The species affected through African sharptooth catfish predation belong mainly to the genus *Barbus* and *Pseudobarbus* (minnows), but a range of other indigenous fish species suffer from competitive pressure and the decimation of eggs and larvae (Garrow, 2012).

In 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 potential impacts of African sharptooth catfish have been illustrated in the preceding sections and have been shown to be directly linked to their predatory and competitive behaviour towards other species. The potential impact on other natural resources is largely limited given that African sharptooth catfish do not feed on other aquatic resources such as macrophytes and do not cause physical and structural damage to the environment through their habits.

7.15. CATFISH AS A VECTOR OF OTHER ALIEN SPECIES

The uncontrolled movement of African sharptooth catfish one area to another may result in the introduction of other species, if care is not taken with regards to ensuring that other 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 are spawned and reared.

Twenty parasites have been recorded in or on this catfish including *Argulus japonicas*, which is alien to South Africa (Van As & Basson, 1984; de Moor & Bruton, 1988). The uncontrolled movement of African sharptooth catfish can facilitate the spread of these parasites and could lead to impacts on indigenous fish species due to their lack of resistance to such new parasites.

8. THE RECEIVING ENVIRONMENT

As a national framework document, this risk assessment cannot report on the receiving environment for specific areas, and on specific African sharptooth catfish projects or restricted activities. Nationally, the entire South Africa is seasonally within the lethal temperature tolerance range for African sharptooth catfish, 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. Only a few cooler streams and rivers on the southern and eastern escarpment are cold enough during winter to preclude these fish seasonally.

8.1. CLIMATE AND HABITAT MATCH

As water temperature is a primary determinant for the survival and reproduction of African sharptooth catfish, correlations with ambient temperatures across the 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 African sharptooth catfish is native to 18 of the 31 ecoregions and have been introduced into most of the remaining ecoregions, with the possible exception of the Namaqua Highlands (27). Moreover, it was found that African sharptooth catfish could survive in all South African ecoregions, albeit that survival would be seasonal (i.e. in summer) in selected areas within these regions. From a seasonal water temperature perspective, establishment would be most unlikely in the Eastern Escarpment Mountains (15), albeit that rivers in this region would be habitable in summer, and African sharptooth catfish occur in some major rivers that have their upper tributaries in this region (e.g. Caledon, Orange and Kraai Rivers).

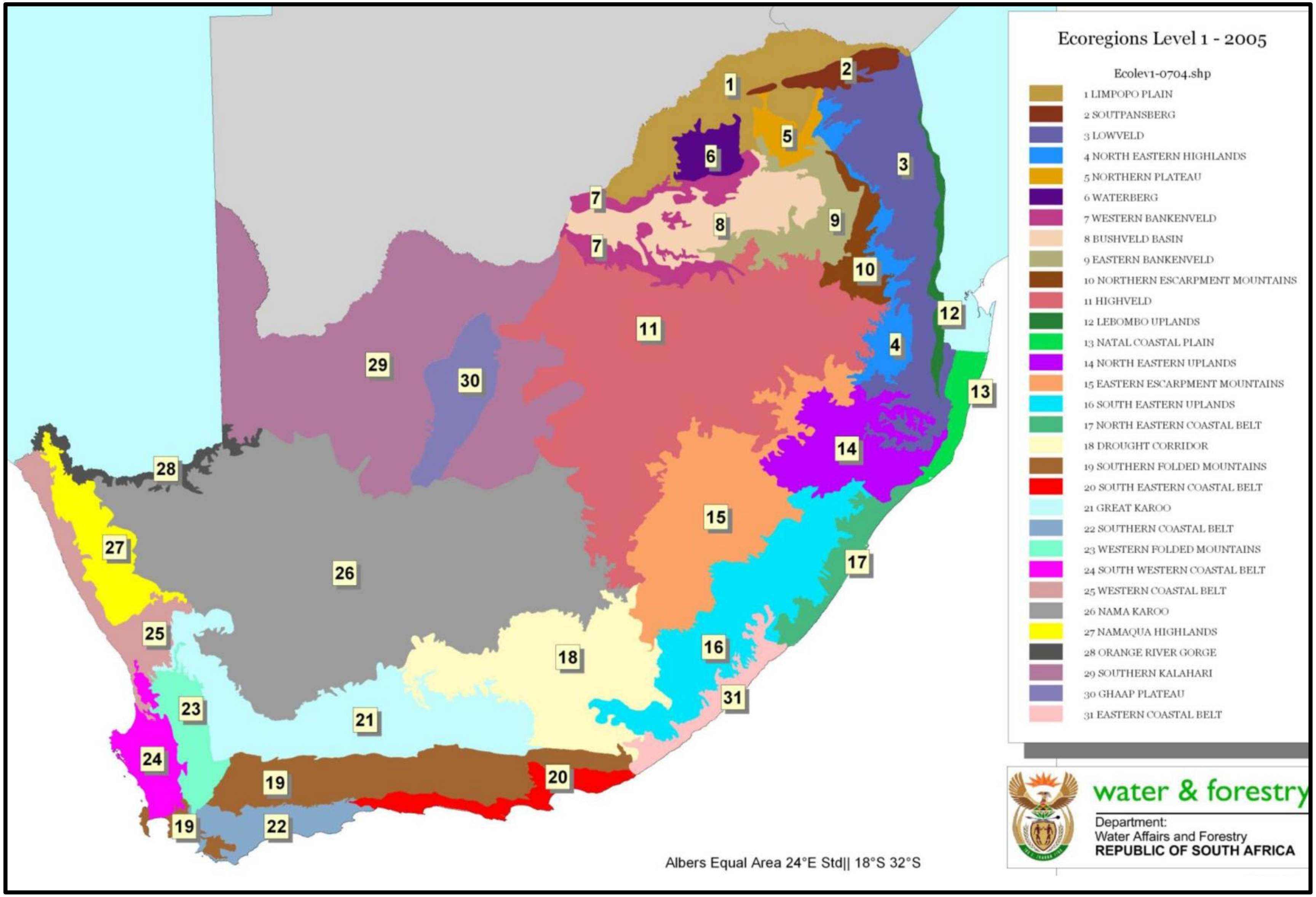

Figure 3: *Ecoregions of South Africa*

The results above reflect a coarse analysis of areas within which these fish may survive. The probability of establishment however ranges from very high across most of South Africa, through to low in the cooler streams of rivers of the high altitude and eastern escarpments, which are climatically marginal.

In this BRBA is it important to recognise that future African sharptooth catfish farms may increasingly be based on systems in which water temperature can be regulated. This means that African sharptooth catfish farming may 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 areas in which African sharptooth catfish may pose a biodiversity impact. These include, but are not limited to:

- The National Freshwater Ecosystem Priority Areas (NFEPA) and its implementation manual (Driver *et al*., 2011), 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 (see also Swartz 2012).
- 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 (see also Kleynhans 1999, 2005 and 2007).

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 (Anderson *et al.,* 2004, Covello *et al*., 1993, EPA 1998, Landis 2004.). To this end, the process is well suited to the establishment of the BRBA framework for grow out and propagation of African sharptooth catfish, 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 realize 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 grow out and propagation of African sharptooth catfish, 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 (EU Commission 2000). 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, Nash *et al*., 2005, Kapuscinski *et al*., 2007; Vose 2008, MacLeod *et al*., 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 characterization. The problem analysis phase can be further sub-divided into two distinct sections: characterization of exposure and characterization 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*. (different authors in 2003, 2005 and 2015), 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 African sharptooth catfish 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*. (different authors in 2003, 2005 and 2015):

- 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 characterization).
- Determining the level of uncertainty (confidence) in risk characterization.
- 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 African sharptooth catfish, the ecological risk or hazard that these fish could pose to the environment through predation on 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 African sharptooth catfish, 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 endpoints of the identified risks are 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 African sharptooth catfish) and the endpoint can be characterised and scored for probability, severity, scope, permanence, confidence, monitoring and mitigation. It is important that characterization 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.

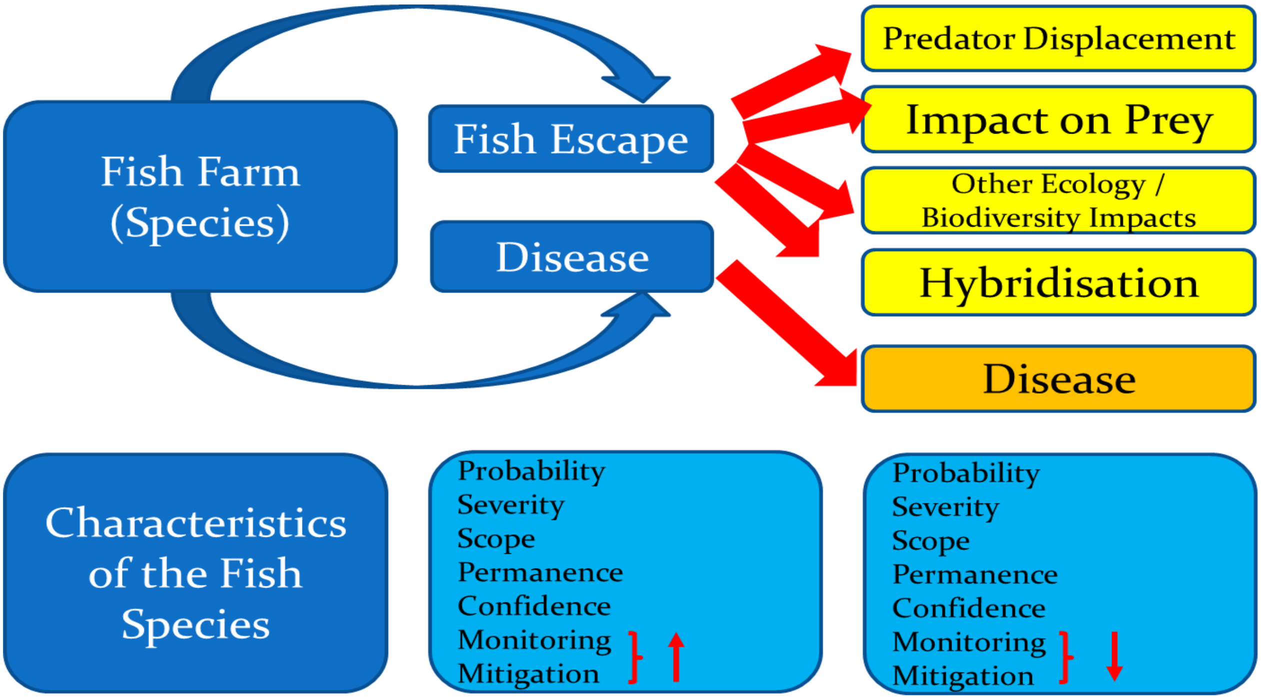

Figure 4: Schematic illustration of the risk assessment process and the dependency of endpoint risk on the pathway.

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 grow out and propagation of African sharptooth catfish in South Africa.

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

Risk / Stressor	As example: the escape of African sharptooth catfish				
Endpoint	As example: predation on indigenous fish 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 African sharptooth catfish, 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 AFRICAN SHARPTOOTH CATFISH

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 grow out and propagation of African sharptooth catfish.

10.1. INVENTORY OF POTENTIAL PATHWAYS AND RISKS

The ecological risks associated with the import, grow out and propagation of African sharptooth catfish, 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.
- 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 African sharptooth catfish 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 African sharptooth catfish as described in Section 7.

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

<u>Escape during transportation / shipment</u>

During transport and shipment, there is a risk that the containers or packaging materials could be breached, and that fry or fish could be released to the environment. Although it can be generally concluded that there is only a low probability of escape, African sharptooth catfish are hardy survivors, even when being exposed outside of water. This means that any fish escaping from a transport activity, near to any waterbody in South Africa, could survive and lead to the establishment of a feral population. The risk of an escape event occurring during the shipment process however remains low, with a high potential for monitoring and mitigation.

Escape through the incoming water resources

In tank-based aquaculture that is supplied with water through directional flow in a pipeline, the risk of escape through the incoming water can be ignored. However, in systems where passive and low velocity flow is used, with no other barrier, such as in some pond systems, African sharptooth catfish will be able to escape via inflow water sources, given their ability to migrate upstream. These fish are adept at migration between waterbodies.

Where African sharptooth catfish are farmed in cage culture systems, some level of escape is highly probably.

Escape through outflow water

African sharptooth catfish 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 volume of 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).

African sharptooth catfish are adept at migration between waterbodies, including an ability to move overland from one waterbody to another. Under cool and damp conditions, often under the cover of darkness, these fish will actively seek new waterbodies to colonise by moving in this manner. This means that any opportunity provided for escape from an aquaculture facility, will be exploited and could lead to the escape of these fish into a new habitat. In this manner these fish will move from pond systems and from tanks in which the water level is sufficiently high to allow escape over the sidewalls.

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 are 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).

It should be noted that African sharptooth catfish have the ability to escape out of most aquaculture production systems (cages, ponds, raceways and tanks), and can generally only be contained with absolute security in vertically walled tank systems in which the water depth is kept at least 30 cm below the edge, and in which additional screening measures are used to prevent escape though outflow systems and filters. As these fish can escape through small openings and can survive overland crossing, absolute containment is challenging.

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 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).

Open ponds and open raceways systems for African sharptooth catfish can also pose risks around predator assisted escape, where animals such as otters are known to prey on fish.

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 sited in low laying areas that are prone to flooding.

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 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, or through open ponds or raceway systems, is high. In all instances, the most effective means of control is to prevent the introduction of disease-causing organisms.

Given that African sharptooth catfish are indigenous to large parts of South Africa, attempts at farming the species largely depend of the use of locally collected or spawned progeny. This eliminates the risk of importing new disease and parasites from other countries. However, were fish to be imported this will be subject to veterinary clearance from the Directorate of Animal Health in the Department of Environment, Forestry and Fisheries (DEFF). 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.

High stocking densities commonly found in hatcheries can lead to outbreaks of parasites and diseases, if the hatchery design and management is not well maintained. Some of the parasites which affect African sharptooth catfish may also affect other freshwater finfish. If unknown diseases are introduced, indigenous species may not have an adequate immune system to cope with them, and as a result it can lead to their demise. Some diseases-causing organisms that may affect African sharptooth catfish, occur widely in all water bodies and generally do not become pathogenic under natural conditions outside of the fish farming environment. As these disease-causing organisms are already present in the environment, the farming of African sharptooth catfish is generally not regarded as an additional source. Nevertheless, fish farms could harbour other diseases that are novel to the surrounding environment and act as a source of infection to the environment.

10.3. DISCUSSION OF RISK ENDPOINTS

10.3.1. PHYSICAL ABIOTIC DAMAGE TO THE ENVIRONMENT

The risk of African sharptooth catfish causing any physical damage to the environment is highly improbable. Their nesting, 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

African sharptooth catfish are omnivorous, feed over a wide trophic range, and can act as apex predators in certain instances. Their feeding habit is such that they may impact heavily on populations of prey items in non-native habitats and they have the ability to outcompete indigenous predatory fish. This supports the notion that African sharptooth catfish can cause predator displacement in aquatic systems where other indigenous predatory fish. Their trophic plasticity can also lead to predation on the eggs and the young of a range of indigenous fish species, which could affect predatory synergies.

10.3.3. COMPETITION - FOOD, HABITAT & OTHER RESOURCES

The establishment of a viable feral population of African sharptooth catfish can occur wherever the biotic and abiotic requirements of the species are met. Although some marginal habitats exist, they are seasonally able to survive across most of South Africa. Where African sharptooth catfish escape, it is probable that they will survive and could become invasive if this happens outside of their native range.

African sharptooth catfish can outcompete other aquatic predators (fish, birds, crustaceans etc.), especially in non-native aquatic systems in which other indigenous predators are not as flexible in their dietary preferences, and in which the wide variety of hunting strategies of the African sharptooth catfish create new prey opportunities.

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 feeding plasticity, African sharptooth catfish can threaten native biodiversity in areas where do not / did not occur previously.

10.3.4. HYBRIDIZATION

Although hybridisation has been recorded between Sharptooth and other catfish species in other part of the world, there are no records of hybridisation of this species with other nature South African fish species. Given this finding, this risk endpoint has been eliminated from further assessment.

10.3.5. IMPACT ON PREY SPECIES

As indicated above, African sharptooth catfish can feed across a wide trophic range, which could include fish, the eggs and young of other fish, aquatic crustaceans, molluscs and a range of aquatic invertebrates and vertebrates such as amphibians. Little research has been done to quantify the potential impact of African sharptooth catfish on other aquatic organisms in areas into which they have been introduced.

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. Nevertheless, African sharptooth catfish 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 poor. It is therefore of critical importance that specific national disease management protocols be devised and implemented.

Although extensive research is lacking, at least two exotic parasites have been reported from African sharptooth catfish in South Africa; these being *Argulus japonicus* and *Dactylogyrus extensus* (Smit *et a.l,* 2017). These and other parasites, which affect African sharptooth catfish, 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 to infect African sharptooth catfish internationally is provided in the table below.

Name of disease or parasite	Explanation and Comments
Broken head disease	Skeletal deformities (lardosis and scoliosis), fish suddenly stop feeding, become lethargic and die with swollen weak tissues on both sides of the head. Usually observed in fish >10 cm. Dead fish exhibit thick and curved skulls showing a lateral crack.
Ruptured intestine syndrome	Lethargic behaviour, swollen abdomen, discoloured abdominal skin, reddish anal area, rupture of the abdominal wall at the final stage.
Ulcerative syndrome	Skin ulceration, sluggish behaviour, red or white necrotic skin ulcers on the mandible and maxilla and on the caudal peduncle, with ulcers also possible on other parts of the body.
White spot (*Myxobacteria*)	Fish remain at water surface in vertical position and swim sluggishly. White spots on skin around the mouth and gills.
Aeromonas septicaemia	Fraying and reddening of the fins, de-pigmentation and ulcers.
Motile *Aeromonad* septicaemia	Exophthalmia and distended abdomen. Deep dermal ulcers with haemorrhages and inflammation.
Water mould (*Saprolegnia spp*.)	Grey/white patches on skin, fins, gills and eyes resembling cotton-wool. Normally small, focal infections spreading rapidly over body or gills. Eggs also develop mould.
Protozoan parasites (*Costia spp*., *Chilodonella, Trichodina*)	Fish remain at the water surface in a vertical position, or nervously scratch the head and side on tank bottom. Skin covered with a thin whitish grey mucus and mortalities can be severe.
Trematode parasites (*Gactylogyru ssp. Gyrodactilu ssp*.)	Fish remain at the water surface in a vertical position, or nervously scratch the head and side on tank bottom. Skin covered with a thin whitish grey mucus and mortalities can be severe.
Protozoan parasites (*Henneguya spp*.)	In fingerlings causes white spots on skin and gills.
Nematode parasites	*Nematode* worms perforate muscle and viscera, but fish not severely affected.

(*Cysticerca spp*.)	
Protozoan gill and/or external parasites (*Trichodina maritinkae*)	Small white spots on skin or gills, causing irritation, instability, lethargy, weakness, loss of appetite and decreased activity. Gills can be pale and very swollen.

Table 9: Symptoms of the diseases/parasites which may infect African sharptooth catfish globally (Modified from FAO, 2018).

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 10.1, 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 African sharptooth catfish 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 9.3. 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish 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 African sharptooth catfish causing physical (abiotic) damage to the environment.

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

Risk	Life history characteristics of Sharptooth Catfish				
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 African sharptooth catfish competing with and/or displacing other predatory species.

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

Risk	Life history characteristics of Sharptooth Catfish				
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 African sharptooth catfish 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 Sharptooth Catfish				
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 African sharptooth catfish impacting on potential prey species.

Table 21: Risk endpoint characterisation related to impacts on prey species.

Risk	Life history characteristics of Sharptooth Catfish				
Endpoint / Impact	Impacts on prey 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

e) The risk of African sharptooth catfish acting as a vector for the introduction of disease and pathogens.

Table 22: 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):

	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	Impact prey species	Disease impacts
Probability	E Low	Low	Mod	Mod	Mod	E Low	Low	Low	Neg	Mod	Mod	High	Low
Severity	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Low	Neg	Mod	Mod	High	Low
Scope	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local
Permanence	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Short T	Long L	Long L	Long L	Mod
Confidence	High	Mod	Mod	Mod	Mod	High	Mod	Mod	V High	High	High	High	Mod
Monitoring	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	High	Mod	Mod	Mod	Mod
Mitigation	V High	High	Mod	V High	High	High	High	High	Low	Low	Low	Low	High

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

Table 23: Risk profile characterised by risk pathways and risk endpoints.

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:

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

Table 24: Numeric values associated with risk characterisation.

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 African sharptooth catfish is as follows (table next page):

	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	Impact prey species	Disease impacts
Probability	16	10	6	7	8	14	12	9	20	8	7	4	12
Severity	12	11	11	11	11	11	12	15	20	10	9	6	16
Scope	7	7	7	7	7	7	7	8	9	9	9	8	8
Permanence	7	7	7	7	7	7	7	8	15	6	6	6	7
Confidence	8	6	6	6	6	8	6	6	9	7	7	8	6
Monitoring	6	5	5	5	6	6	6	6	8	6	6	6	6
Mitigation	10	7	6	9	8	8	8	7	3	3	3	3	8
Total Score	66	53	48	52	53	61	58	59	84	49	47	41	63

Table 25: Score allocation to the risk profile.

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 score for escape through outflow water poses the greatest threat, given the ability of these fish to escape from production systems in general. Also, this threat should be seen against the fact that these fish are native to large parts of South Africa, essentially nullifying the risk. Moreover, the risk of escape varies significantly between different production systems for African sharptooth catfish. Effective risk pathway management could see a lowering of the potential impact to endpoints.

With due consideration to the pathway of escape above, the score for the ecological endpoint related to impacts on prey species, competition for food, habitat niches and resources, and displacement of predator species, is of highest relevance. Here also, this must be seen against the fact that these fish are native to large parts of South Africa, essentially nullifying these risks.

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 African sharptooth catfish 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 African sharptooth catfish. These risks must be considered in a balanced manner in conjunction with potential economic, social and societal considerations (Wise *et al*., 2007).

In Africa, the demands and markets for African sharptooth catfish have expanded. In response to this, the interest in this species as a candidate for farming has spread across many countries, including South Africa. This interest has resulted in a desire to farm with these fish in certain parts of South Africa, which may fall outside of their native range, which could pose ecological and disease risks to aquatic systems.

The establishment of a formal and lawful African sharptooth catfish 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 African sharptooth catfish 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.

Ultimately, the use of African sharptooth catfish should only be permitted in areas where they are native, or in areas where invasion has already occurred and in which further introduction will not pose a risk to invitation in new areas.

It is important to consider the potential socio-economic consequences that may result from the manifestation of any of the ecological impacts. Were African sharptooth catfish to become established across South Africa, the socio-economic consequences are a loss of biodiversity caused by predation – primality of susceptible fish species, none of which support any commercial fisheries. The establishment of African sharptooth catfish (regardless of the probability thereof), holds no direct threat to humans or any human livelihoods.

12. BALANCED COST OF ERADICATION

A balanced view must be taken to the potential ecological cost of African sharptooth catfish 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 ecological costs, the potentially impacted species, the nature of the receiving environment, the net gains from a African sharptooth catfish farming industry and the limited risk towards human beings, it is suggested that the cost of actively eradicating African sharptooth catfish would be unwarranted in most instances. The actual expenses associated with active eradication will be high and absolute success in not certain. Management trough exclusion of African sharptooth catfish from areas in which they have not yet invaded, and the granting of permits in areas where African sharptooth catfish have become established, would constitute a more practical approach.

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 African sharptooth catfish 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 African sharptooth catfish 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 associated with the use of African sharptooth catfish 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 six-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 African sharptooth catfish in aquaculture (see also O'Sullivan 1992, Pillay 1992, Garrett *et al*., 1997, Midlen *et al*., 1998, Fernandes *et al*., 2002, Hinrichsen 2007 & 2013, AU-IBAR 2016).

The prevention of escape through transit:

- Obtain 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 records of fish stocks.

The prevention of escape through inflow and outflow water:

- 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.
- All outlet and inlet pipes should have appropriately sized mesh screens which will prevent the escape of eggs from the hatchery and fry from the grow-out facilities.

The prevention of escape caused 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 caused 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:

- Facilities must remain outside of the flood line where possible. Infrastructure should be 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:

- Fry and 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 African sharptooth catfish for aquaculture, one can arrive at an acceptable risk tradeoff in which the use of this species should be permitted in areas where it is native and in areas where it has already invaded fully.

16. RECOMMENDATIONS

Risk assessment techniques have been applied to all the major risk components related to the use of African sharptooth catfish for aquaculture in South Africa. 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 African sharptooth catfish into new areas or river systems where they do not occur. Ongoing deliberations between conservations authorities (DEFF and provincial authorities), representatives of the African sharptooth catfish farming sector and scientists should formulate an approach for new projects based on the following position taken from the results of this risk assessment:

a. In areas where African sharptooth catfish are native, or in areas where catchments have historically been invaded by these fish, the establishment of new production facilities should be permitted.
b. In areas where African sharptooth catfish are not present, the establishment of new production facilities should not be permitted, regardless. This is due to the ability of these fish to escape from production facilities, which will lead to ecological impacts in aquatic environments in which these fish have not invaded.

17. CONCLUSION

This BRBA has illustrated that the primary risk related to the use of African sharptooth catfish in aquaculture in South Africa is its potential for invasion, predation on other aquatic species, and ecological disruption in areas outside of its native range, after it has escaped or been intentionally introduced.

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APPENDIX 1. Risk Scoring Methodology for African sharptooth catfish 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	Hecht et al. 1988	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	Cambray 2010	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	de Moor & Bruton1988, Cambray 2010	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).	2	Safriel & Bruton 1984	4
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	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 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).	Y	Skelton 2001	4
7	**Is the species native to, or naturalised in, regions with equable climates to the risk assessment area?** *Guidance*: Output from climate matching will help answer this, but in absence of this, the known climate distribution (e.g. a tropical, semi-tropical, south temperate, north temperate) of the taxon's native range and the 'risk area' (country/region/area for which the FISK is being run) can be used as a surrogate means of estimating.	Y	Jubb 1967, Picker & Griffiths 2011	4
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	Cambray 2005, FAO 2012	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	Cambray 2005, 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.	?	No record of this	3
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	3
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.	?	No record of this	2
13	**Does the species have invasive congeners?** *Guidance*: One or more species within the genus are known to be serious pests.	Y	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	de Moor & Bruton 1988, Cambray 2003	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	Skelton 2001	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 hydrosystem that is normally devoid of predatory fish (e.g. amphibian ponds) or in river catchments in which predatory fish have never been present.	Y	de Moor & Bruton 1988	4
19	**Does the species host, and/or is it a vector, for recognised pests and pathogens, especially non-native?** *Guidance*: The main concerns are non-native pathogens and parasites, with the host being the original introduction vector of the disease or as a host of the disease brought in by another taxon.	Y	Barson & Avenant-Oldewage 2006	4
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	Y	Robbins et al. 1991	4

	concern, as they soon outgrow their aquarium or garden pond.			
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%.	N	Safriel & Bruton 1984	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).	Y	Hecht et al. 1988	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	Skelton 2001	4
24	**Does feeding or other behaviours 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	de Moor & Bruton 1988	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	4
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.	Y	Hecht 1985	4
27	**Is the species omnivorous?** *Guidance*: Evidence exists of foraging on a wide range of prey items, including incidental piscivory.	Y	Bruton 1979	4
28	**Is the species planktivorous?** *Guidance*: Should be an obligate planktivore to score here.	Y	Skelton 2001	4
29	**Is the species benthivorous?** *Guidance*: Should be an obligate benthivore to score here.	Y	Skelton 2001	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.	N	Hecht et al. 1988	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.	N	Hecht & Lublinkhof 1985	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?**	N		4

	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.		No reference	
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.	Y	Bruton 1979a	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	Skelton 2001	4
37	**Are life stages likely to be dispersed unintentionally?** *Guidance*: Unintentional dispersal resulting from human activity.	Y	Cambray & Jubb 1977	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).	Y	Cambray 2010	4
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	No record of this	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	Skelton 2001	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	Skelton 2001	3
42	**Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?** *Guidance*: There should be documented evidence of migratory behaviour, even at a small scale (tens or hundreds of meters).	Y	Skelton 2001	4
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.	N	FAO 2012	4
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. *(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*).	Y	Hecht et al. 1988	4
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	Skelton 2001	4

47	**Is the species susceptible to piscicides?** *Guidance*: There should be documented evidence of susceptibility of the taxon to chemical control agents.	Y	Omitoyin et al. 2006	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, dessication), especially human impacts.	Y	FAO 2012	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/enemies is known.	Y	Hecht et al. 1988	4