RISK ASSESSMENT FOR THE IMPORTATION OF NILE TILAPIA *OREOCHROMIS NILOTICUS* AT LEONARDVILLE FISH FARM, NAMIBIA

Nile tilapia *Oreochromis niloticus* (Linnaeus 1758)

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LIST OF ABBREVIATIONS

CBD	Convention on Biological Diversity
IRA	Import Risk Assessment
LFF	Leonardville Fish Farm
MFMR	Ministry of Fisheries and Marine Resources
OIE	Office International des Epizooties / World Organisation for Animal Heath

DECLARATION

I, Matheus-Auwa Ameya, declare that this IRA is an outcome of my research views and findings.

Sources of information have been cited accordingly, and a reference list has been added. This

IRA has not previously been submitted to any other institution for the purpose of importation of Nile Tilapia.

The views expressed here are those of Matheus-Auwa Ameya and can therefore in no way be taken to reflect the positions of the Ministry of Fisheries and Marine Resources of Namibia.

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Date: October.2023

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CHAPTER 1: INTRODUCTION

1.1 Background to import risk assessment

This import risk assessment (IRA) takes into account the risks associated with *O. niloticus* to Namibia's freshwater aquatic fishes and the environment associated with the importation, as part of regulations made in terms of the Aquaculture Act 18 of 2002 section 43 (Regulations relating to Import and Export of Aquatic Organisms and Aquaculture Products).

Given the importance of farmed and wild-caught *O. niloticus*, especially as a source of protein, *O. niloticus* represents a potential source to food security in the developing world. The present report presents the risk assessment for the importation of *O. niloticus* into Namibia for aquaculture experimental purpose at Leonardville Fish Farm (LFF), in the Omaheke Region. The risk assessment is based on a rapid risk inventory. The assessment of available evidence, data and information and risk estimations of the species have been performed by Matheus-Auwa Ameya using the (Technical guidelines on rapid risk assessment for animal health threats protocols; the OIE - Guidelines for assessing the risk of non-native animals becoming invasive, and the Guidance for interpretation of CBD categories on introduction pathway (OIE, 2011; FAO, 2021; IUCN. 2017; Harrower et al., 2018).

The purpose of this work was to conduct a risk assessment of the alien *O.niloticus* which complies with the Aquaculture Act of 2002 and its regulations on the introduction and transfer of aquatic organisms in Namibia. This risk assessment concerns the likelihood of introduction, establishment, spread and potential environmental, ecological and socio-economic effects.

1.2 Objectives of the risk assessment

1. To assess the risk of *O. niloticus* introduction (entry) and escape, establishment and spread in Namibia with focus on Leonardville Fish Farm.

2. To assess the potential consequences for environmental, economic and social impacts.

1.3 Pathway identification

To classify the pathway, the definitions of the CBD classification as described by Harrower et al. (2018) were used. There are six principal pathways (Hulme et al., 2008; CBD 2014; Harrower et al. 2018): 1) release in nature, 2) escape from confinement, 3) transport-contaminant, 4) transport-stowaway,5) corridor and 6) unaided. For these main pathways, different subcategories are identified (CBD,2014).

1.4 Risk pathways

The risk pathway through which *O. niloticus* may be introduced and/or spread in a population was identified. This step facilitated the formulation of the risk questions and the collection of data. A risk pathway includes all the logical sequences by which a certain animal or human population can be exposed to a hazard, or a certain hazard can be transmitted within animal or human populations. It depicts the main mechanisms through which a hazard can, for example, be introduced into or spread throughout a new area. Elements of the risk assessment and a scenario tree as an effective way of depicting the identified risk pathway is presented in figure 1, 2 and 3.

The matrix for combining risk likelihoods was used to estimate the likelihood of entry, likelihood of exposure, and the overall likelihood of occurrence for the risk pathway, Table 1 and 2.

1.4.1 Definitions of likelihoods:

1. **Negligible**: extremely unlikely to occur

2. **Very low:** very unlikely to occur

3. **Low**: unlikely to occur

4. **Moderate**: potential to occur

5. **High**: highly likely to occur

1.5 Impact assessment

The descriptions of consequences below were used to estimate the consequence associated with entry and exposure of *O. niloticus* (i.e., catastrophic, high, moderate, low or negligible).

Catastrophic: Establishment of *O. niloticus* would be expected to cause significant economic harm at a national level and/or cause serious and irreversible harm to the environment.

High: Establishment of *O. niloticus* would have serious biological consequences (e.g., such as high mortality or morbidity) and would not be amenable to control or eradication. Such diseases could significantly harm economic performance at an industry level and/or may cause serious harm to the environment.

Moderate: Establishment of *O. niloticus* would have less pronounced biological consequences and may be amenable to control or eradication. *O. niloticus* could harm economic performance at an industry level and/or cause some environmental effects, which would not be serious or irreversible.

Low: Establishment of *O. niloticus* would have mild biological consequences and would normally be amenable to control or eradication. *O. niloticus* may harm economic performance at an industry level for a short period and/or may cause some minor environmental effects, which would not be serious or irreversible.

Negligible: Establishment of *O. niloticus* would have no significant biological consequences and would require no control or eradication. *O. niloticus* would not affect economic performance at an industry level and would cause negligible environmental effects.

1.6 Risk estimation

The results (likelihood) of the entry assessment, exposure assessment, and consequence assessment were combined to produce overall measures of the risk associated with importation of *O. niloticus*. The likelihood and consequence risk estimates were combined following a qualitative approach using a risk pre-defined combined evaluation matrix (Table 1 and 2) as recommended by OIE Framework. Risk = likelihood x consequence!

Table 1: Risk pre-defined combined evaluation matrix

		Estimated Likelihood of event 1				
		Negligible	Very Low	Low	Moderate	High
Estimated Likelihood of event 2	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Very Low	Negligible	Negligible	Very Low	Very Low	Very Low
	Low	Negligible	Very Low	Very Low	Low	Low
	Moderate	Negligible	Very Low	Low	Low	Moderate
	High	Negligible	Very Low	Low	Moderate	High

Table 2: Likelihood impact matrix

		Estimated Consequences of Entry and Exposure				
		Negligible	Low	Moderate	High	Catastrophic
Estimated overall Likelihood of occurrence	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	Very Low	Negligible	Negligible	Very Low	Low	Moderate
	Low	Negligible	Very Low	Low	Moderate	High
	Moderate	Negligible	Low	Moderate	High	Extreme
	High	Negligible	Low	Moderate	High	Extreme

CHAPETER 2. HAZARD IDENTIFICATION

2.1 Biological characteristics of the Nile Tilapia *O. niloticus*

Under optimal growth conditions, *O. niloticus* will reach sexual maturity in aquaculture ponds at an average of 3-5 months and reach a weight of 150 to 200 grams. *O. niloticus* ovulates and releases eggs many times a year, and its suitable spawning temperature is 22°C- 28 °C. It starts breeding when the male establishes a territory, excavates a crater-like spawning nest and guards the territory. The male mates with the females in the spawning nest and soon after fertilization by the male, collects the eggs into its mouth. The female incubates the eggs in its mouth and broods the fry after hatching, until the yolk sac is absorbed. The Incubating and brooding phase is accomplished in one 1-2 weeks, depending on temperature.

2.2 Physical description

Dorsal spines (total): 15 - 18; Dorsal soft rays (total): 11-13; Anal spines: 3; Anal soft rays: 9 - 11; Vertebrae: 30 - 32. Diagnosis: jaws of mature male not greatly enlarged (length of lower jaw 29-37 % of head length); genital papilla of breeding male not tessellated (Trewavas 1983). Most distinguishing characteristic is the presence of regular vertical stripes throughout depth of caudal fin (Teugels and Thys van den Audenaerde 2003; Froese and Pauly 2017).

2.3 Feeding

O. niloticus feed on a wide variety of natural food organisms, including plankton, some aquatic macrophytes, phytoplankton, planktonic and benthic aquatic invertebrates, larval fish, detritus, decomposing organic matter and even other fish and fish eggs and often filter feeders feeding on plankton (Tesfahun and Alebachew, 2023).

2.4 Oxygen, temperature and salinity requirement

Generally, the lower and upper lethal temperatures (i.e., the survival limit) for *O. niloticus* are 11-12 °C and 42 °C, respectively, while the preferred temperature ranges from 28°C to 36 °C (FAO, 2005 - 2017). Reproduction is best at water temperatures 22°C- 28 °C or higher than 27°C and does not occur below 20°C (Hossan et al., 2013; Zengeya et al. 2013; Faruk et al, 2012; FAO. 2009; Brummett, 1995). Generally, *O. niloticus* can survive dissolved oxygen (DO) concentrations of less than 3-4mg/L (Boyd 2004; El-Sayed, 2006). *O. niloticus* is the least saline tolerant of the commercially important species but grows well at salinities up to 15 ppt. *O. niloticus* reproduces at salinity levels of 10 to 15 ppt but perform better at salinities below 5 ppt. Fry numbers decline substantially at 10 ppt salinity (El-Sayed, 2006; Shipton et al. 2008).

2.5 Ammonia and pH Requirement

O. ni;oticus can survive in pH of water ranging from 5 to 9 but perform optimally in a pH range of 5 to 8 El-Sherif and El-Feky, 2009; Nobre, etal, 2014). It is recommended that ammonia levels be maintained at 0.1 mg/L (El-Sayed, 2006; Morrow J. 2009).

2.6 Utilization of *O. niloticus* by humans

O. niloticus is one of the most farmed fish globally, with a significant contribution improving local livelihoods, especially in developing countries (FAO, 2020).

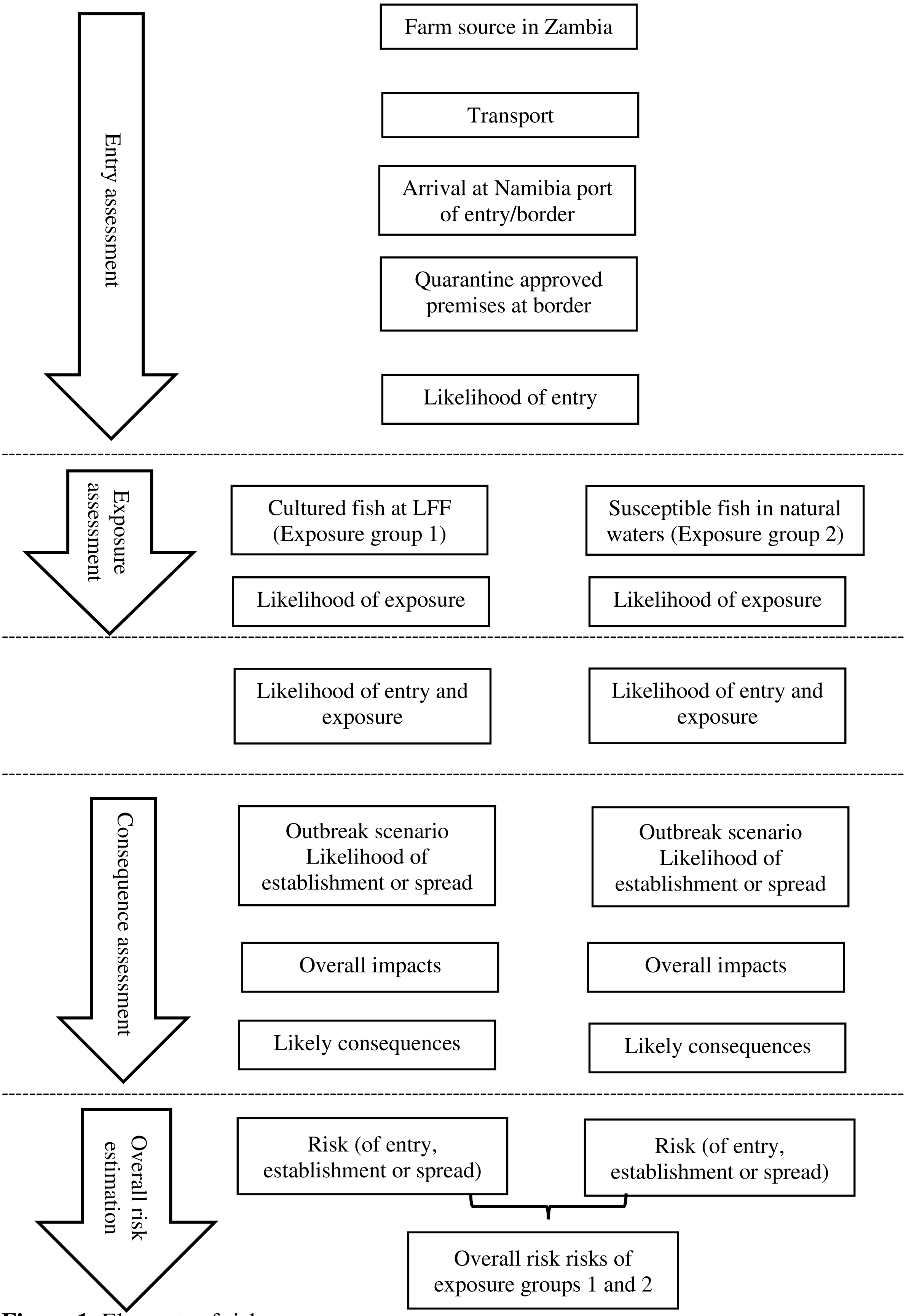


Figure 1: Elements of risk assessment

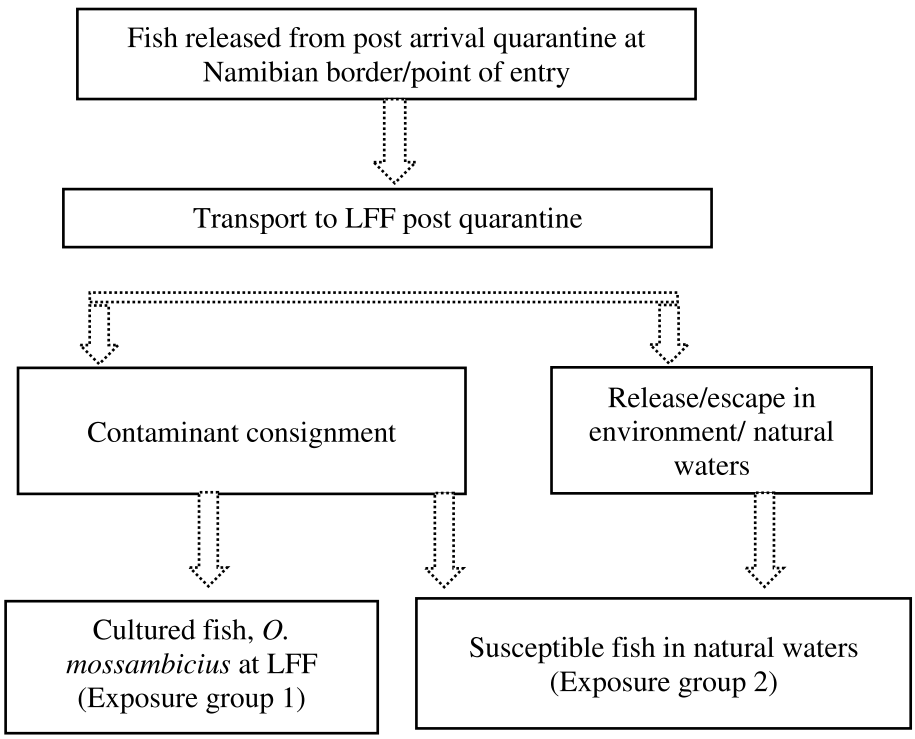


Figure 2: Potential exposure pathways

Establishment or spread pathways

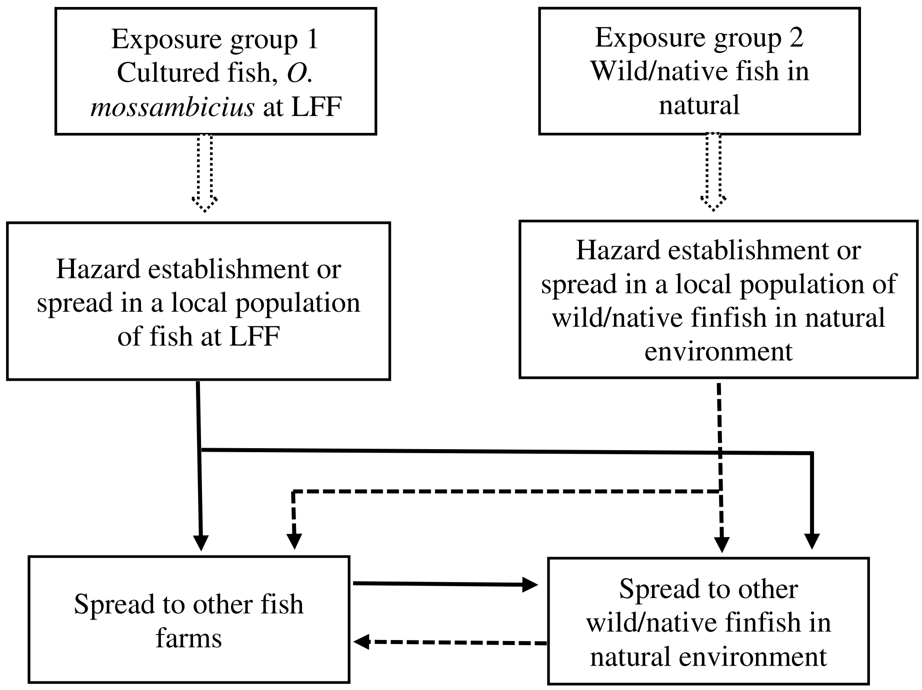


Figure 3: Identification of outbreak scenarios

SECTION A: HAZARD IDENTIFICATION, CHARACTERIZATION AND SCREENING	
Organism information	**COMMENT**
1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Domain: Eukaryota Kingdom: Metazoa Phylum: Chordata Subphylum: Vertebrata Class: Actinopterygii Order: Perciformes Family: Cichlidae Genus: Oreochromis Species: *Oreochromis niloticus* Common Name: Nile tilapia
2. Does a relevant earlier risk assessment exist?	No, this is the first full rapid risk assessment known to have been undertaken on this species in Namibia
3. Where is *O. niloticus* native?	*O. niloticus* has its native range in Africa. It native to the Nile River basin; the south-western Middle East; the Gambia, Niger, Benue, Volta and Senegal rivers and the lakes Chad, Tanganyika, Albert, George, Baringo, Turkana, Chari, Awash Rivers, Edward, Kivu, Eritea, Addagalla, Harar (Ethiopia), Baringo, Crater, Rudolf, Tana, and Buyoni Lakes, Mt Ruwenzori, Kissenyi, Kenya, Uganda and Zaire (Boyd 2004; Trewavas, 1983; Daget et al., 1991).
4. In which regions in Namibia has *O. niloticus* been recorded and where is it established?	Zambezi (recorded) Kavango (recorded) Hardap (recorded) No evidence of establishment
5. In which regions in Namibia could *O. niloticus* establish in the future under current climate and under foreseeable climate change?	Zambezi Region

6. In which SADC member states has *O. niloticus* been recorded and in which SADC member states has it established?	South Africa Mozambique Zambia Zimbabwe Tanzania Malawi Angola Botswana Comoros Democratic Republic of Congo Lesotho Madagascar Eswatini Mauritius Most of the SADC member states have been recorded to have established populations of *O. niloticus*.

6. Is *O. niloticus* known to be invasive (i.e., to threaten or adversely impact upon biodiversity and related ecosystem services) anywhere outside Namibia?	*O. niloticus* is classified as invasive in Southern Africa (Weyl 2008; Tweddle & Wise 2007; Zengeya et al. 2013) and has been listed as an invasive species recorded in many South African watercourses of (Benson et al., 2016). It is widely distributed and common in many catchments of Zambia, the middle Zambezi, Nata (Okavango), Runde-Save, Buzi and Limpopo River systems (van der Wall and Bills 1997, 2000; Tweddle and Wise 2007; Weyl 2008; Zengeya and Marshal 2008, Jere et al 2021). *O. niloticus* populations are now well established with evidence of environmental and soco-economic impacts in Zambia, Botswana, Zimbabwe, Mozambique, Angola, the Democratic Republic of Congo and Tanzania and South Africa (Picker and Griffiths, 2011; van Rensburg et al. 2011; Weyl 2008; Tweddle and Wise 2007).
7. In which region(s) in Namibia has *O. niloticus* shown signs of invasiveness?	None, no evidence

8. In which SADC member states has the species shown signs of invasiveness?	In southern Africa, established populations are documented from Zambia, Botswana, Zimbabwe, Mozambique, Angola, Malawi, the Democratic Republic of Congo and Tanzania (Picker and Griffiths 2011). In South Africa, *O. niloticus* was introduced into South Africa for aquaculture in 1955 and is thought to be confined to the Limpopo River system and small coastal river systems in the Kwa-Zulu Natal Province (van Rensburg et al. 2011; Zengeya et al. 2013). In southern Africa, *O. niloticus* is now present in multiple major drainage systems where it was historically absent, including the Pangani, Rufiji, Ruvuma, Limpopo, Zambezi and Lake Victoria basins (Genner et al., 2013; Zengeya et al., 2013; Deines et al., 2014).
9. Describe any known socio-economic benefits of the *O. niloticus*.	*O. niloticus* is used as a food source for humans and it is considered to be a popular freshwater small-scale fisheries and aquaculture fish throughout Africa. It is one of the most farmed fish globally, with a significant contribution improving local livelihoods, increasing total production, income and employment (Munguti et al 2022). *O. niloticus* has been farmed in Southern Africa for several years, including Zambia, South Africa, Zimbabwe and Mozambique), leading to the establishment of feral populations in the Limpopo and InKomati Rivers (Picker and Griffiths, 2011; Zengeya et al., 2013).

SECTION B: ENTRY ASSESSMENT - PATHWAYS

SECTION B - PATHWAYS		
LIKLIHOOD OF ENTRY		
QUESTION	**LIKLIHOOD ESTIMATE**	**JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE**
1. How many active pathways (both intentional and unintentional) are relevant to the potential entry of *O. niloticus*?	Few	*O. niloticus* is present in Namibia. It was recorded by the Directorate of Aquaculture and Inland Fisheries of the Ministry of Fisheries and Marine Resources in a market survey conducted in 2021 in the Zambezi Region (DoA unpublished data). The fish was caught by the fishermen in Lake Lyambezi. Its identity is yet to be confirmed using morphological and genetic identification methods. It is currently being farmed at a small-scale level by a farmer based in the Zambezi Region who bought the fish from fishermen at the same Lake (Mr. Sistengu, personal communication, 2023). Currently, the Eco Fish Farm in Hardap Region produces hybrid tilapia (*O. mossambicus* x *O. niloticus*). Its existence in Lake Lyambezi occurred possibly by illegal introduction. At Eco Fish Farm, *O. niloticus* introduction was intentional stocking for aquaculture. The year of stocking is not confirmed. Only the last pathway can possibly be an active pathway of introduction into Namibia. There is no

		evidence of introduction of *O. niloticus* eggs or larvae for aquaculture in Namibia.
2. List relevant pathways through which *O. niloticus* could be introduced.	**1. RELEASE OR ESCAPE FROM CONFINEMENT**	*O. niloticus* is of aquaculture interest, and it has been imported to some SADC countries (e.g., Zambia, South Africa, Zimbabwe, Mozambique…) for aquaculture. It was imported into Zambia and Zimbabwe in 1980s for aquaculture. In Zambia it escaped and appeared in the Kafue River in the 1990s after escaping from nearby fish farms (van den Audenaerde 1994, Schwanck 1995; Brummett, 2007). In Lake Kariba, it escaped from the ponds along the shoreline and cages, leading to hybridization with the local *Oreochromis mortimeri*, (Chifamba and Videler, 2014). In South Africa, it was introduced for aquaculture in 1955 and is thought to be confined to the Limpopo River system and small coastal river systems in the Kwa-Zulu Natal Province (Zengeya et al., 2013).
	2. RELEASE IN NATURE (Fishery in the wild)	In Southern Africa, *O. niloticus* has been stocked intentionally in non-native waters by voluntary stocking, possibly by angler introductions for sport fishing (Ellender et al.

		2014; Marshall, 2000). Its direct release by anglers facilitated its invasion of the Inkomati and Limpopo River systems in South Africa and Zimbabwe and Mozambique (Ellender et al. 2014; van der Waal and Bills 1997, 2000; Weyl, 2008). Intentional stocking of *O. niloticus* in Namibia is not allowed and it is regulated as it concerns an alien species (under the Namibian Regulation on the introduction and transfer of aquatic organisms, Aquaculture Act of 2002) but illegal stocking by individual fishermen would be hard to prevent. However, fishermen would first have to be able to obtain a sufficient number of *O. niloticus* specimens, transport them from areas where it has established, which would be difficult to do considering mortality rates.
MAJOR PATHWAY	**RELEASE OR ESCAPE FROM CONFINEMENT**	
Is introduction along this pathway intentional (e.g., the organism is imported for aquaculture) or unintentional (e.g., the organism finds itself accidentally attached/carried on imported goods)?	Intentional	*O. niloticus* can be imported for aquaculture for stocking. The source of *O. niloticus* at Eco Fish Farm in the Hardap Region is a result of intentional aquaculture stocking (Hadwin Dirkse, Eco Fish Farm, personal communication, 2023).

SECTION C: DETAILED ENTRY ASSESSMENT

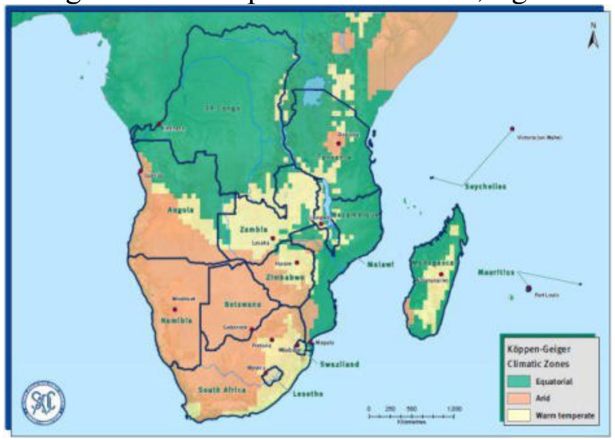
SECTION C - Detailed assessment		
LIKLIHOOD OF ENTRY	**LIKLIHOOD ESTIMATE**	**JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE**
1. What is the likelihood that large numbers of *O. niloticus* will travel along this pathway from Zambia over the course of one year?	High	Production of *O. niloticus* in SADC is limited to South Africa, Zambia, Zimbabwe Mozambique, Malawi, Angola (Picker and Griffiths, 2011; Zengeya et al., 2013). There is no evidence and information on the importation of *O. niloticus* into Namibia. Farming with *O. niloticus* hybrid in Namibia takes place at Eco Fish Farm, in the Hardap Region although not documented. Except for direct importation of *O. niloticus* for aquaculture from Zambia into Namibia, it will be difficult to obtain *O. niloticus* in large numbers to create a viable population.
2. How likely is *O. niloticus* to enter Namibia undetected?	Moderate	*O. niloticus* is a species of aquaculture significance, to find its way into an aquaculture facility in Namibia undetected is likely. Its introduction at Eco-Fish Farm is unknown. However, it could be undetected in consignments especially if the consignments are those of fry or fingerlings and illegal importation. However, it will be easy to detect through consignments imported legally and it will be easy to stop illegal stocking of this fish in fish farms in Namibia. The ministry of Fisheries and Marine Resources has fish monitoring programmes and all state, private and small-scale aquaculture fish farms are registered

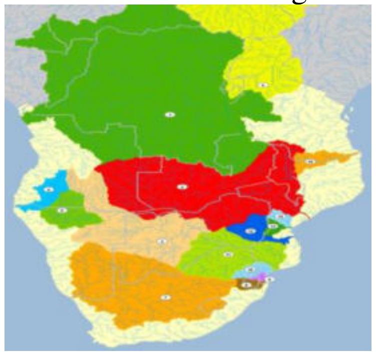
		and monitored annually. It is therefore easy to notice *O. niloticus*, during extensions services, biological surveys and information exchange with the public at the national, regional and local levels.
3. How likely is *O. niloticus* to arrive during the months of the year most appropriate for establishment?	High	Daily transports occur between Zambia and Namibia, this would cover the most appropriate time of the year for establishment. However, fish handling for aquaculture purpose and live transports of *O. niloticus* in Namibia for aquaculture would take place during summer and Autumn.
4. How likely is *O. niloticus* to be able to transfer from the pathway to a suitable habitat or host?	moderate	Incidental escape from LFF is considered moderate. LFF is not within the vicinity of a water course where circumstances suitable for *O. niloticus* exist, mainly freshwater; brackish; benthopelagic; potamodromous, slow-moving lentic sections of rivers, floodplains, pools and shoreline environments of lakes and dams, and submerged vegetation (Picker and Griffiths, 2011). The nearby Nossob River is a dry river bed about 1 kilometer away and it is non-perennial, making escape impossible. The occurrences of *O. niloticus* hybrid at the Eco Fish attest this impossibility. Although Eco Fish Farm is near a suitable habitat for the *O. niloticus* hybrid, there are no reports of escape recorded (Ameya, personnel observation, 2023).

5. How likely is *O. niloticus* to escape LFF through discharged pond waste water disposal?	Moderate	LFF is an intensive recirculation culture system in which water is recycled throughout the entire production cycle. It is unlikely for water to be discharged into the open environment.
6. How likely is *O. niloticus* to escape LFF through bird predation?	Moderate	There are no piscivorous birds observed or recorded at LFF since the start of production in 2017. Further, the fish ponds are entirely housed in a greenhouse structure. Therefore, it is unlikely.
7. How likely is *O. niloticus* to escape LFF due to flood?	Moderate	LFF is not located in a flood path and it is not within a floodplain. The fish ponds are constructed and located on higher ground.
8. How likely is *O. niloticus* to escape LFF through fomites i.e., as eggs or larvae?	Moderate	The fish processing equipment at LFF is used exclusively on the fish farm and remains on the fish farm. Vehicles and persons exiting the Fish farm are usually inspected.
Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	Low	There is no apparent link or evidence of *O. niloticus* imported from the native range or from any SADC country for the purpose aquaculture into Namibia. Importing *O. niloticus* for aquaculture purpose in Namibia is restricted, unless authorised under the Namibian Regulation on the introduction and transfer of aquatic organisms (Aquaculture Act of 2002). Thus, the likelihood of entry via this pathway is unlikely unless permitted. Therefore, importation leading to escape from confinement is unlikely.

Entry assessment likelihood = Low likelihood

SECTION D: DETAILED EXPOSURE ASSESSMENT

SECTION D - Detailed assessment		
LIKLIHOOD OF ESTABLISHMENT	**LIKLIHOOD ESTIMATE**	**JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE**
1. How likely is *O. niloticus* to establish in Namibia based on the similarity between climatic conditions within it and its current distribution or Zambia?	High	Comparison of the species' current distribution in the SADC region in terms of Köppen-Geiger climate type (Peel et. al., 2007 and Kriticos et al. 2012) suggest largely similar climatic conditions to Namibia. Therefore, climate in Namibia and Zambia does not vary enough to exceed species' tolerances, figure 4.  **Figure 4**: Köppen-Geiger Climate Classification for SADC

2. How likely is *O. niloticus* to establish in Namibia based on the similarity between other abiotic conditions within it and its current distribution or Zambia? Abiotic factors: to be considered are salinity, pH, water flow, oxygen content and disturbance levels.	High	Confirmed establishment in most SADC countries suggests high similarity. The abiotic conditions in its current distribution are similar to Namibia and there are no obvious differences between Namibia and Zambia to indicate that establishment would not be likely in Namibia.
3. How likely or widespread are habitats or species necessary for the survival and development of *O. niloticus* in Namibia?	High	*O. niloticus* occurs in freshwater, brackish and estuaries. However, it can be found in rivers, impoundments or ponds (Picker & Griffiths, 2011). Transboundary waters, which offer conditions suitable for *O. niloticus* (SADC, 2010; Matlala, 2023) are abundant throughout Namibia, suggesting a high likelihood and suitable habitat of establishment throughout Namibia, figure 5.  **Figure 5**: SADC river basins (1. Congo, 2. Zambezi, 3. Okavango/Cubango, 4. Cunene, 5. Etosha -Cuvelai, 6. Nile, 7. Orange River, 8. Maputo, 9. Umbeluzi, 10. Incomati, 11. Limpopo, 12. Save, 13. Buzi, 14. Pungwe, and 15. Ruvuma)

4. How likely is that *O. niloticus* establishment will occur despite competition from existing species in Namibia?	High	Confirmed establishment in South Africa, Zambia, Botswana, Zimbabwe and other SADC countries suggests a high likelihood. *O. niloticus* has been shown to successfully compete and out-compete other species (Tweedle and Wise 2007; Zengeya et al. 2013). Moreover, *O. niloticus* can tolerate high temperature and salinity (Zengeya et al. 2013) therefore making it easy to evade any competition by occupying different habitat niches.
5. How likely is it that establishment of *O. niloticus* will occur despite predators, parasites or pathogens already present in Namibia?	High	The potential fish predators include Catfish (*Clarias gariepinus*); tiger fish (*Hydrocynus vittatus)*; Nembwe (*Serranochromis robustus*); African pike, (*Hepsetus odoe*); Silver catfish (*Schilbe intermedius*). Other natural enemies and competitors include birds, reptiles, crabs. There is no evidence of potential evidence of pathogens present in Namibia. There is also no information to suggest that these predators would limit establishment of *O. niloticus* in Namibia.
6. How likely is *O. niloticus* to establish despite existing management practices in Namibia?	High	Confirmed establishment in most SADC countries suggests high likelihood. Given that *O. niloticus* has successfully established outside its native range, this would indicate that *O. niloticus* could establish within Namibia depending on where it will be introduced. The largemouth bass (*Micropterus Salmoides*), a non-native species that has established itself at St Von Bach Dam in Namibia attest this likelihood (Seguy, 2019; Okeyo, 2000). This would suggest that it is unlikely that current management practices would hinder the establishment of *O. niloticus*.

7. How likely are existing management practices in Namibia to facilitate establishment?	High	In case of escape, there is no information to suggest that existing management practices would affect the establishment of *O. niloticus*. Also see previous response.
8. How likely is *O. niloticus* to survive eradication measures in Namibia?	High	*O. niloticus* inhabit freshwater, brackish water and estuaries which would suggest that any eradication measure would be likely to be unsuccessful due to the ability of the species to inhabit a range of habitats. In the case were *O. niloticus* is stocked in facilities that do not discharged water into the open environment, eradication could be possible. Eradication can only be carried out in closed water bodies e.g., enclosed dams or fish farms.
9. How likely are the biological characteristics of *O. niloticus* to facilitate its establishment in Namibia?	High	Confirmed establishment in most SADC countries suggests this likelihood. *O. niloticus* is known to spawn in fresh waters in temperatures of 33°C - 24°C (Hossan et al., 2013; Faruk et al, 2012; FAO. 2009), but spawning has been shown in temperatures up to 19°C (Brummett, 1995). There is evidence that *O. niloticus* has a preference of habitat type during spawning and egg deposition, therefore selecting specific parts in the water when spawning (Gómez-Márquez et al 2003; Peña-Mendoza et al 2005). However, optimal nursery conditions for the success of *O. niloticus* have been attributed to its ability to colonize a wide range of habitats for spawning and nursery purposes (Twongo, 1995). More so, there is evidence that *O. niloticus* can occupy all available habitats within their spawning sites and even colonise a new environment by carrying

		eggs or fry in their mouth, increasing their establishment capability (Njiru et al. 2006) This suggests that the species could spawn in a wide range of regions in Namibia if it is introduced into suitable open waters.
10. How likely is the adaptability of *O. niloticus* to facilitate its establishment?	High	*O. niloticus* has a wide range of trophic and ecological adaptations, as well as its adaptive life history characteristics that enable it to occupy and adapt to many different freshwater environments, with rapid reproduction and spread (Trewavas, 1983). It has been shown that when it is introduced into a water body, it can establish if the food source and water quality are within its parameters (Njiru, 2006; Zengeya et al. 2013). Therefore, *O. niloticus* is likely to exhibit some degree of adaptability in Namibia
11. Based on the history of invasion of *O. niloticus* elsewhere in the world, how likely is it to establish in Namibia?	High	Unless introduced in an enclosed facility such as LFF or closed impoundments, Trewavas, 1983, and Zengeya et al. 2013 reported that *O. niloticus* is an excellent competitor and invader due to a variety of life history traits, suggesting that it is likely that it will establish within Namibia.
12. What is likelihood *O. niloticus* will colonize and maintain a population in Namibia?	High	Confirmed establishment and invasion in Southern Africa suggests high likelihood (Zengeya et al. 2013; Picker and Griffiths 2011).

SECTION D: EXPOSURE ASSESSMENT CONTINUE

SECTION D - Continue		
LIKELIHOOD OF SPREAD	**LIKLIHOOD ESTIMATE**	**JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE**
1. How likely is the expected spread of *O. niloticus* within Namibia by natural means?	Moderate	If *O. niloticus* is to be introduced in Namibia, then it could not spread easily through watersheds because most of the main watersheds in Namibia are not connected. The facility where the proposed experiment will be conducted is enclosed.
2. How likely is the expected spread of *O. niloticus* in Namibia by human assistance?	High	*O. niloticus* has been stocked intentionally in Namibia, at Eco Fish Farm which is currently producing *O. niloticus* hybrids. There is unconfirmed data of *O. niloticus* been illegally introduced in Lake Lyambezi (Sitengu MFMR, personal communication, 2023). Intentional importations of *O. niloticus* in Namibia such as in this case, would be regulated under the Aquaculture the Act of 2002 and its Regulations, and most likely be limited to enclosed facilities such as LFF. Once stocked at LFF; it will be unlikely to spread due to the management measures associated with the enclosed facility. Currently, *O. mossambicius* is stocked at LFF and there is no evidence of escape and spread from the fish farm. In Lake Lyambezi introduction is assumed to be illegal through human assistance. Therefore, this can attest this likelihood.

3. How likely is *O. niloticus* to spread in Namibia undetected?	High	There is no dedicated monitoring system of invasive fish species in Namibian inland waters (rivers, canals, lakes…) thus once *O. niloticus* is introduced, it would be able to spread unnoticed until captured through fishery activities.
4. How likely is *O. niloticus* to be able to transfer to a suitable habitat or host during spread?	Moderate	*O. niloticus* would be introduced from the consignment at LFF where there are no ideal circumstances for escape, establishment and spread. This suggest that spread from LFF to suitable habitat will be impossible. More so, there is no evidence of spread from Eco Fish Farm where it is currently stocked.
5. Within Namibia, how likely would it be to contain *O. niloticus* in relation to this pathway of spread?	Moderate	There are no records of *O. niloticus* escapes and spread from the existing aquaculture facility (Eco Fish Farm) in Namibia. If *O. niloticus* arrive in Namibia at LFF, it would be easy to contain because natural dispersal from LFF is impossible. There are no watersheds connected to or from LFF.

Exposure assessment likelihood: Low likelihood

Overall Likelihood of Occurrence estimate

Overall likelihood of occurrence: Likelihood of Entry x Likelihood of Exposure = **Very low likelihood**

SECTION E: IMPACT ASSESSMENT
1: ENVIRONMENTAL IMPACT

QUESTION	LIKLIHOOD ESTIMATE	JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE
1.1 What is the likelihood that the introduction of *O. niloticus* will result in environmental damage in the Namibia?	Moderate	*O. niloticus* occurs in a confined facility at Eco Fish Farm with no known evidence of impact. Suggesting that if it is stocked in an enclosed facility with management measures in place then the impact is unlikely. However, if introduced in natural water systems, the impact could be high, considering, competition for food, hybridization, spawning grounds, and out-competing native species. Possible environmental impacts could arise if the invasion has negative impacts on ecosystem services.
1.2 What is the severity of environmental impact that could be caused by *O. niloticus* in Namibia?	High	Environmental impacts will result in long term, irreversible effects at national level.
1.3 What is the impact of *O. niloticus* on biodiversity at all levels of organisation caused by the organism in its non-native range excluding Namibia?	Catastrophic	There is evidence of impacts of invasions in Southern Africa including decreased in taxonomic and functional diversity, abundance of native fish species resulting from habitat and trophic overlaps, competition for spawning sites, and hybridisation (Weyl, 2008; Ellender et al. 2014; Zengeya et al., 2015 and 2020; Jere et al., 2021).
1.4 What is the current known impact of *O. niloticus* on biodiversity at all levels of organisation (e.g., decline in native species, changes in native species communities,	Moderate	*O. niloticus* only occurs in a confined facility at Eco Fish Farm with no known evidence of impact.

hybridisation) in Namibia and the source country?		Its occurrence in Lake Lyambezi, Namibia, is unverified and there exists no evidence of impact but there exists evidence of impact in Zambia (Deines et al. 2014; Chifamba and Videler, 2014)
1.5 What is the impact of *O. niloticus* on the conservation value with regard to the National nature conservation legislation caused by *O. niloticus* currently in Namibia and the source country?	High	Based on the current information on the occurrence *O. niloticus* in Namibia, no impact that has been registered but there exists evidence of impact in Zambia (Deines et al. 2014; Chifamba and Videler, 2014).
1.6 What is the impact of *O. niloticus* on provisioning, regulating, and cultural services in its non-native range excluding Namibia?	Catastrophic	*O. niloticus* often out-compete many native fish species for food, including small insects, micro-crustaceans and smaller fish as well as competing for spawning and nursing grounds (Njiru et al. 2006; Zengeya et al. 2011; Lowe-McConnell (2000). This could have an indirect cultural impact on communities that depend on these aquatic organisms in Namibia.
1.7 What is the impact of *O. niloticus* on alteration of ecosystem function (e.g., habitat change, nutrient cycling, trophic interactions), including losses to ecosystem services, caused by *O. niloticus* currently in Namibia and the source country?	Moderate	*O. niloticus* only occurs in a confined facility at Eco Fish Farm with no known evidence of impact. Its occurrence in Lake Lyambezi, in Zambezi Region, is unverified and there exists no evidence of impact. However, in Zambia, there exists evidence of impact in Zambia (Deines et al. 2014; Chifamba and Videler, 2014)
1.8 What is the likelihood that genetic traits of *O. niloticus* could be carried to other species, modifying their genetic nature and making their economic, environmental or	High	Hybrids of *O. niloticus* and *O. mossambicus* are cultured in Namibia at Eco Fish Farm, and it is believed that the farm is producing effectively. However, *O. niloticus* is able to

social effects more serious in Namibia and the source country?		hybridise with several other Oreochromis species causing losses in genetic diversity. In Southern Africa, *O. niloticus* introductions have resulted in extensive hybridisation with native *O. mossambicus* in the Limpopo River system (Firmat et al. 2013) with *O. andersonii* and *O. macrochir* in the Kafue River in Zambia (Deines et al. 2014; Chifamba and Videler, 2014).) and in Lake Kariba they have almost replaced the native *O. mortimeri* in Lake Kariba, Zimbabwe (Tweddle 2010).
1.9 Are there any vulnerable groups (communities) in Namibia or the source country?? potentially placed at risk by the establishment of O. *niloticus*?	Moderate	No evidence exists for the establishment of *O. niloticus* in Namibia, there may be vulnerable groups, but this has yet to be identified.
1.10 What is the severity of social impact that could be caused by *O. niloticus* in Namibia?	High	Environmental impacts will result in long term irreversible effects at national level.

2: SOCIAL IMPACT

QUESTION	LIKLIHOOD ESTIMATE	JUSTIFICATION FOR THE LIKLIHOOD ESTIMATE
2.1 What is the likelihood that the introduction of *O. niloticus* will result in social impact in Namibia?	Moderate	Currently, hybrids of *O. niloticus* and *O. Mozambique* are cultured in Namibia at Eco Fish Farm. There is no evidence on social impact caused by the cultured hybrids of *O. niloticus* produced at this fish farm. More so, no direct information was found within Namibia with regard to social or human health impact as a result of *O. niloticus*, especially in Zambezi Region where this species is presumably recorded in open waters. Possible social impacts could arise if the invasion has negative impacts on fisheries and other ecosystem services. However, generally, in case of an outbreak, the small-scale fisheries and social perception of environmental quality (biodiversity) are at risk.
2.2 What is the severity of social impact that could be caused by *O. niloticus* in Namibia?	Moderate	Social impacts will result in short term reversible effects at national level.

3: ECONOMIC IMPACT

3.1 What is the likelihood that the introduction of *O. niloticus* will result in economic impact in Namibia?	Moderate	Depends on where it would be introduced, if introduced in natural waters within Namibia then recreational fisheries and small-scale fisheries could be negatively affected. If stocked in closed aquaculture facilities such as LFF, the impact could be very low. Unless the fish is allowed to spread and establish in the wild. Possible economic impacts could arise if the invasion has negative impacts on fisheries and other ecosystem services. Also see section E (1.1 and 2.1).
2. What is the severity of economic impact that could be caused by *O. niloticus* in Namibia?	Moderate	Economic impacts will result in long term reversible effects at national level.

Estimate consequence of entry and exposure: High

3. OUTCOME OF THE RISK ASSESSMENT

Estimated overall risk= Estimated overall likelihood of occurrence x Estimated consequence of entry and exposure

Overall risk: Low

CHAPTER 4: CONCLUSION AND RECOMENDATION

4.1 General conclusion and recommendations

This IRA takes into account *O. niloticus* risks to Namibia's freshwater aquatic fishes and the environment associated with the importation as part of regulations made in terms of Aquaculture Act 18 of 2002 section 43 (Regulations relating to Import and Export of Aquatic Organisms and Aquaculture Products). This report addresses the identification, assessment and impacts associated with the importation of live *O. niloticus* from Zambia to Leonardville Fish Farm, Namibia. If *O. niloticus* is deliberately introduced into LFF, the likelihood of it escaping and establishing itself into the natural environment will be low. The consequences of establishment will be high. Therefore, implementation of risk management measures is warranted.

This risk assessment concludes that the importation of live *O. niloticus* for experimental purposes should be permitted subject to risk management measures being put in place to reduce the likelihood of introduction and establishment in Namibia. These measures should additionally take into account the risks associated with the species as listed in this assessment.

4.2 Risk assessment conclusions

4.2.1 Current occurrence of *O. niloticus* in Namibia

O. niloticus is thought to exist in Namibia. Introductions and records of this species indicate its occurrence in some areas of Namibia, and recent sightings of the species have been made, for example in the Zambezi Region. Additionally, there is information about some fish farmers in Namibia keeping this species, suggesting that this species is likely being farmed.

4.2.2 Likelihood of entry

The likelihood that *O. niloticus* has been introduced into Namibia's natural waters through unintentional and deliberate human actions is currently low. To date, *O. niloticus* has been successfully cultured only at Eco Fish Farm in the Hardap Region.

4.2.3 Likelihood of establishment

The illegal introduction of *O. niloticus* in Namibia has reportedly been unsuccessful because no wild populations have been recorded. Therefore, the risk of *O. niloticus* establishment due to the proposed introduction at LFF is considered low because potential areas with suitable habitat do not exist nearby. The likelihood for *O. niloticus* to disperse naturally across Namibia as a result of introduction into the LFF is very low as there are no connected water bodies associated with the LFF.

4.2.4 Likelihood of impact

The impacts of *O. niloticus* are classified as high and these impacts are also expected to occur if *O. niloticus* escapes into suitable habitats within Namibia. If this species becomes established, it could result to predation, hybridization and competition with the native fishes, which could affect the fisheries sector.

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