Species Risk Assessment

Introduction of the Nile Tilapia (*Oreochromis niloticus*) into the Eastern Cape

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For:

The Eastern Cape Development Corporation

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Executive Summary

This risk assessment has been commissioned by the Eastern Cape Development Corporation (ECDC). The purpose of the assessment is to determine the biodiversity risk associated with the introduction of the Nile Tilapia (*Oreochromis niloticus*) for use in the aquaculture industry in the Eastern Cape. According to the legislative framework, a permit for its introduction may only be issued once a risk assessment has been undertaken.

An analysis of the historical record describing the introduction of the species into African freshwater systems suggests that in those catchments that can support reproductive populations of Nile tilapia, an apparently inevitable result of its introduction is the complete elimination of indigenous species of the same genus (*Oreochromis*). The competitive success of Nile tilapia in comparison with other *Oreochromis* spp. is a result of a combination of fast growth rates, large size resulting in success in competition for nesting grounds, high fecundity as a result of large size, the ability of juveniles to survive and avoid predation in extreme shallows despite adverse conditions such as large temperature fluctuations, a much broader-ranging diet than other species in the genus, and the ability to hybridise with other tilapias, followed by the subsequent extinction of these hybrids, leaving the pure strain. Furthermore, the success of Nile tilapia as an invasive species indicates that there are few, if any, successful competitors in the ecological niche occupied by this species.

Wherever it has been introduced throughout the world the Nile tilapia has thrived, and there are no recorded instances of its extirpation once established in a system. Wherever the climate is suitable, the species has clearly demonstrated a propensity to thrive on introduction, and there are few limiting factors to its establishment in a range of aquatic habitats - the exception being torrential river systems. It is evident that the major limiting factors to its distribution in freshwater systems are salinity and temperature.

In order to determine the potential for the species to become established in the Eastern Cape, an analysis of a representative sample of water temperature data from 20 river and dam systems across the Province's catchments was undertaken. The analysis revealed that the rivers at low altitudes, e.g. the Buffalo, Nahoon and Keiskamma, have mean temperatures above 15°-18°C in all months of the year, and if the Nile tilapia become established in these rivers, they are likely to continue feeding and growing for most of the year, albeit very slowly, if at all, in winter. Minimum temperatures recorded in these rivers are 8° to 10°C. These temperatures, if continuous over several days, may result in mortalities, but it is likely that during low temperature events, the fish will seek out deeper holes where temperature fluctuations are less extreme.

All but one river in the Eastern Cape flows directly to the Indian Ocean, the exception being the River Kraai, which is a tributary of the Orange River. Available temperature records for the Kraai River are from Aliwal North, very close to the Orange River confluence. Temperatures in the Kraai are only suitable for Nile tilapia from October to April. From May to September, temperatures drop below 10°C, and in June and July the mean temperature is below 10°C, thus Nile tilapia will be unlikely to be able to establish themselves in this river, even if escaping to the river initially in warmer months. The proximity of the Kraai confluence to the large Orange River impoundments of Gariep and Vanderkloof, however, gives cause for concern as minimum temperatures in these reservoirs do not drop below 10°C in winter. Thus summer escapees into the Kraai could find their way down the Orange River and survive, eventually colonising the whole river.

The nature of the introduction, and hence the biodiversity risk, associated with developing *O. niloticus* aquaculture in the Eastern Cape is dependent upon the type of culture technology that will be applied. The following three potential culture technologies that could be introduced to the Province were assessed:

1. Semi-intensive seasonal pond culture
2. Semi-intensive seasonal cage culture in lakes, rivers and dams
3. Thermally regulated intensive bio-secure recirculation systems in tanks and raceways

Due to the inherent problems associated with maintaining bio-security in pond and cage based systems, combined with the high likelihood that escapees would establish feral populations, it is recommended that neither system be used for the culture of the species in the Eastern Cape. With respect to thermally regulated intensive bio-secure recirculation systems in tanks and raceways, it is evident that while it would be theoretically feasible to develop a bio-secure culture environment in which the fish were unable to escape, bio-security can only be ensured if all protocols are strictly adhered to and rigorously enforced. In this regard, consideration needs to be taken of the fact that once the species has been introduced into the region, it would be a simple procedure to move it - be it accidentally or with intent - from site to site, and by doing so seriously increase the chances of the fish escaping into the wild, where there is a high probability that it will establish a feral population. In this regard, the permitting authority should seriously consider the likelihood of permit compliance, and indeed, its ability to enforce permit regulations.

The dominance of Nile tilapia and it's hybrids as the preferred tilapia species for commercial production is generally attributed to it's high growth rate and yields in culture systems. Most notably, in regions such as the Eastern Cape where culture temperatures are sub-optimal, and production is likely to be limited to intensive thermally regulated indoor systems, the choice of culture species becomes of paramount economic importance, and provides the underlying rationale for farmers wanting to introduce the species into the province. Indeed, while it is beyond the scope of this report to determine the economic efficiency of tilapia production in the Eastern Cape, it is likely that should the sector prove profitable, economic efficiency would likely be significantly enhanced by the culture of *O. niloticus* or one of its hybrids.

1 Introduction

This risk assessment has been commissioned by the Eastern Cape Development Corporation (ECDC). The purpose of the assessment is to determine the biodiversity risk associated with the introduction of the Nile Tilapia (*Oreochromis niloticus*) for use in the aquaculture industry in the Eastern Cape. The Government Gazette N°. 30293 classifies the Nile Tilapia as an "invasive Species", and as such it's introduction to South Africa is controlled under the National Environmental Management: Biodiversity Act (NEMBA, Act 10 of 2004). According to the legislative framework, a permit for its introduction may only be issued once a risk assessment has been undertaken. The protocol for the risk assessment is outlined in Chapter 4, Sections 13 and 14 of the Government Gazette n°. 30293. This risk assessment will follow the Government Gazette n°. 30293 guidelines.

2 Risk Assessment

2.1 Species Information

2.1.1 Taxonomy

Species: *Oreochromis niloticus niloticus* (Linnaeus, 1758)
Family: Cichlidae (Cichlids),
Subfamily: Pseudocrenilabrinae
Order: Perciformes (perch-like fishes)
Class: Actinopterygii (ray-finned fishes)
Taxonomic Code: 1705905102

Oreochromis niloticus has seven sub-species, the most widely distributed of which is *O. niloticus niloticus*. Other sub-species are *O.n. eduardianus, O.n. filoa, O.n. baringoensis, O.n. sugutae, O.n. cancellatus and O.n. vulcani* (Trewavas, 1983).

Common names: Nile tilapia, Tilapia du Nil, Tilapia del Nilo.

2.1.2 Natural geographic range

The Nile tilapia is distributed in tropical and subtropical Africa but not into the Jordan Valley of the Middle East; several subspecies are recognised. It is widely distributed in West Africa, in the Volta, Gambia, Senegal, and Niger River basins, but is absent from Sierra Leone, Liberia, Zaire, and much of the Ivory Coast and Cameroon (Trewavas, 1983; Lim and Webster, 2006). It is present throughout the Nile River basin and is native to the Lake Chad basin and to lakes Tanganyika, Albert, Edward, and Kivu (Trewavas, 1983; Lim and Webster, 2006).

2.1.3 Persistence attributes and invasive tendencies

In those catchments that can support reproductive populations of Nile tilapia, an apparently inevitable result of its introduction to any river system or lake in Africa is the complete elimination of indigenous species in the same genus (*Oreochromis*). The competitive success of Nile tilapia in comparison with other *Oreochromis* spp. is a result of a combination of faster growth, larger size resulting in success in competition for nesting grounds, high fecundity as a result of large size, the ability of juveniles to survive and avoid predation in extreme shallows despite adverse conditions such as large temperature fluctuations, a much broader-ranging diet, and the ability to hybridise with other tilapias, and the subsequent disappearance of these hybrids (Tweddle & Wise, 2007).

As an example, in Kenya, almost all native *Oreochromis* species were replaced within 30 years of the introduction of Nile tilapia outside its natural range. Outside Africa, tilapias have had major impacts on ecosystems in Australia, in the Americas, and in Asia. In Lake Victoria, in addition to the loss of the native *Oreochromis* spp., it is possible that *O. niloticus* was responsible for the disappearance or demise of several endemic Cichlidae (Tweddle & Wise, 2007).

Nile tilapia, despite its widespread distribution has not yet been introduced to all freshwater ecosystems in tropical and sub-tropical Africa. This suggests that these systems are at risk of invasion, and Lake Malawi, which hosts at least four endemic *Oreochromis* species, collectively known as chambo, represents a particularly vulnerable system (Tweddle & Wise, 2007). Experience with other *Oreochromis* species in Africa suggests that chambo will be eliminated if placed in direct competition with *O. niloticus*. In addition to chambo, Lake Malawi is home to up to 1,000 other endemic haplochromine cichlid fish species which would be at risk if Nile tilapia was introduced (Tweddle & Wise, 2007). Other river systems throughout tropical and sub-tropical Africa are also vulnerable to invasion by Nile tilapia. These include the Cunene and other west flowing rivers in Angola, where in future, there is likely to be increased pressure to promote aquaculture development (Tweddle & Wise, 2007).

Historical data suggests that the introduction of Nile tilapia into freshwater ecosystems results in localised species extinctions among indigenous fishes. If the species enters river or lake systems in Africa, and provided the water temperature doesn't fall below 12°C, it displaces any indigenous *Oreochromis* and many haplochromine cichlid species (Tweddle & Wise, 2007). The time scale leading to the displacement of the indigenous species depends on the size of the system, the number and size of each introduction of the fish, and the existence of obstacles to free movement. Examples, described in more detail below, include the extinction of *O. esculentus* in Lake Victoria, which took 30 years, and the replacement of *O. mortimeri* which took only 10 years in the smaller Lake Kariba. The impacts of Nile tilapia, as reported in the literature, are summarised in Table 1 (Tweddle & Wise, 2007):

In those systems that have become invaded by Nile tilapia, the invasions have had a considerable impact on fish production (Wise *et al.*, 2007). The replacement of indigenous species with Nile tilapia changes the quality of the fish caught - Nile tilapias are often regarded as being of inferior quality to the species they replace and therefore command lower market prices (Wise *et al.*, 2007). While the success of tilapias in aquaculture has many benefits in terms of both food production and revenue generation, it has resulted in severe ecological perturbation, particularly to the populations of indigenous tilapiine species in African river systems. Examples are provided below.

Table 1. A summary of the impacts on the Nile tilapia on fisheries and the environment as reported in the literature and from expert observations (from Wise *et al.*, 2007)

LAND-USE TYPE	IMPACT	COUNTRY
Fisheries		
Fish catch	50% decline in total biomass catch	Nicaragua
	Increases tilapiine and cichlid catch by between 15 and 25%	Lake Victoria, Kenya
	Effect of O. *niloticus* on catch is difficult to assess due to presence of Nile perch[1]	Entire Lake Victoria
	The catch increased but represents a return to the catch levels before the Nile tilapia invasion and prior over-harvesting	Tanzania
Environment		
Endangerment and extinction of species in freshwater systems	Decline of endangered Moapa dace (*Moapa coriacea*) and Moapa white river springfish (*Crenichthys baileyi moapae*)	Nevada & Arizona, USA
	31% of native fishes are considered at risk or already extinct	Mexico
	80% decline in native cich5ds[2]	Nicaragua
	Drastic decline of native fish [3]	in Madagascar
	Aust. lungfish *Neoceratodus fosteri*, recently declared 'vulnerable'[4]	Australia
	O. esculentus extinct	Lake Victoria (entirety)
	O. esculentus & O. variabilis extinct	Lake Victoria, Tanzania

[1] *There has been a change in catch from O. esculentus & O. variabilis (2 endemic tilapiines) and a species flock of several hundred haplochromine cichlid species to Nile perch, Nile tilapia, and a small pelagic cyprinid (Rastrineobola argentea).*

[2] *Caused by three tilapiine species: O. aureus, O. mossambicus and O. niloticus*

[3] *Caused by three tilapiine species: O. macrochir, O. niloticus and O. mossambicus*

[4] *Caused by a single tilapiine species O. mossambicus*

Lake Kariba and the Zambezi

As result of the proven success of Nile tilapia in aquaculture, in 1982, it was imported into Zambia and introduced into two fish farms. From these farms, it subsequently escaped into the Kafue River, where it first appeared in catches in 1992. Subsequent introductions occurred further southwards near Lake Kariba (van der Waal, 2007) and into cages in the lake itself, from which it inevitably escaped. The complete replacement of the indigenous *O. mortimeri* in Lake Kariba by *O. niloticus* took over a decade to complete (from 1993 to 2004, Figure 1; Tweddle and Wise, 2007). Karenge & Kolding (1995) reported on inshore fish populations in Lake Kariba (up to 1992), and made no mention of Nile tilapia. The available data suggest that there was no change in the overall catch of tilapiines from the lake. Nevertheless, as the data are presented as the number of fish per net and not as weight, it is likely that the overall annual catch by weight is now greater - as *O. niloticus* grows to a larger size than *O. mortimeri*.

It should be noted that the Peace Corps have actively promoted the use of Nile tilapia for small-scale aquaculture in the Zambezi system in Zambia, and as a result of escapees from ponds, the species in now well established in the Kafue system where it has become an important component of catches in the artisanal fishery.

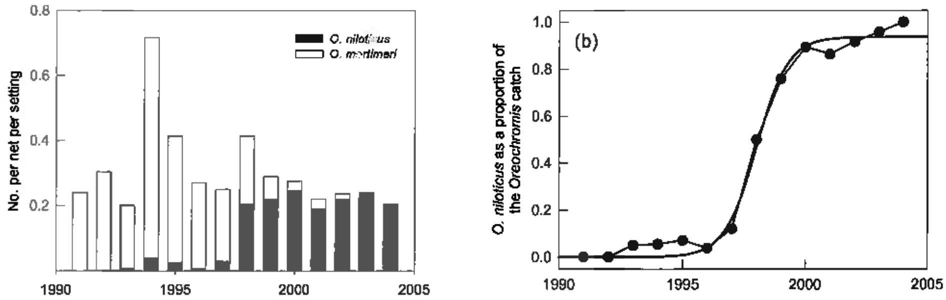


Figure 1. The replacement of *O. mortimeri* by *O. niloticus* in gillnet catches in Lake Kariba (graphs by Ms P. Chifumba, data supplied by Dr B. Marshall to D. Tweddle).

<u>*Limpopo River and other southern catchments*</u>

Nile tilapia was introduced into Southern Zimbabwe from Lake Kariba, and can now be found in dams, in all catchments, in addition to the Limpopo, the Zambezi, Runde and Nata (i.e. Makgadikgadi/Okavango) systems (Tweddle and Wise, 2007). It was distributed in the nineties to fish farms south of Lake Kariba and also to dams for angling. Subsequent to the initial introductions, anglers and fish farmers have distributed it to dams around Bulawayo, Zimbabwe, and in addition, some fish were placed into the tributaries leading into the Limpopo River. To date, it is known from no less than twelve different dams connected to Zimbabwean tributaries of the Limpopo River (van der Waal, 2007). A typical example of the consequences of introducing Nile tilapia to waters originally inhabited by Mozambique tilapia, *O. mossambicus,* is presented in Box 1 (from Tweddle and Wise (2007).

Box 1

History of impacts of Nile Tilapia in the Zhovhe Dam, Umzingwane River (B.C.W. van der Waal, pers. comm. to Tweddle and Wise, 2007)

1. Dam built ca. 1995.
2. Request for advice on invasion by alien aquatic weeds (*Azolla filiculoides*). Sampled *O. mossambicus*, *Labeo* spp., and *Clarias gariepinus*, but no *O niloticus*
3. 1997/8. *O. niloticus* were caught by previous owner in dam. Believed to be escapees from other dams higher up in the catchment.
4. 2000. Dr van der Waal caught a few *O niloticus*.
5. 2002/3. Dr van der Waal caught many *O niloticus*, also *O mossambicus* and a few hybrids.
6. 2005. Dr van der Waal caught 80 fish - nearly all *O. niloticus* with a few hybrids, but no *O. mossambicus*. 88 fish caught by gillnet – none were *O. mossambicus*. A fishery with many kilometres of nets existed from 2002-2005.
7. 2005-6. Campfire conservancy charges for recreational fishing.
8. 2006. All fish seen caught have been *O. niloticus*.

It is evident that once in the system, the replacement of *O. mossambicus* by *O. niloticus* took less than a decade to complete. Although hybrids occurred initially, it appears that they have subsequently also died out.

<u>*Lake Victoria*</u>

In Lake Victoria, the introduction of Nile tilapia in the late 1950s resulted in the extinction of the highly-prized *O. esculentus*, and probably *O. variabilis* by the late 1980s. Tweddle & Wise (2007) described the change in detail. The introduction of Nile tilapia to Lake Victoria increased the overall fish catch from the lake. However, despite increased catches, landed fish were of a lower quality (Wise *et al.*, 2007). In this regard, in Lake Victoria, lower value Nile tilapia is able to withstand fishing pressure better than the higher value *O. esculentus*, which it eliminated from the lake.

<u>*Lake Chicamba*</u>

In Lake Chicamba in Mozambique on the Revue River system, the invasion by Nile tilapia added to the catch per unit effort of the gillnet fishery. The initial invasion into Lake Chicamba most likely came via the Zonue River from a farm dam located on the river of the Zimbabwe / Mozambique border (Weyl, 2007).

<u>*Madagascar*</u>

The decline of native species in Lake Itasy, Madagascar, was correlated with the introduction of exotics and the decline of *Ptychochromoides betsileanus* is attributed to the progressive introduction of different tilapiines (Canonico *et al.*, 2005; Tweddle and Wise, 2007). In Lake Alaotra, the progressive introduction of different species including *O. niloticus* (1961) influenced a severe decline of native fish (Canonico et al., 2005; Tweddle and Wise, 2007).

2.1.5 History of domestic propagation and the extent of naturalisation

At present, Nile tilapia's distribution in South Africa is restricted to the Limpopo catchment (van der Waal, 2007), and their presence in the system makes it possible for them to enter and migrate into the lower ranges of the Levuvhu, Olifants, Nzhelele, Nwanedi, Sand, Magalakwin, Mogol, Matlabas, Crocodile, and Marico rivers. While their migration into the upper reaches of the catchment will be restricted by dam walls and weir systems, there is the possibility that recreational anglers may transfer the fish into the dam systems in the higher reaches of the catchment. It is highly probable that the movement of the fish into these dams will result in their successful colonisation, the hybridisation with the indigenous fauna, and further upstream migrations (van der Waal, 2007). Furthermore, in the absence of appropriate compliance mechanisms, it is probable that anglers and/or fish farmers will in time distribute the Nile tilapia to other river systems south of the Limpopo. Such movements will afford the species the opportunity to invade those river systems where Mozambique tilapia is found. Currently, temporary safe refuge areas for the Mozambique tilapia are the smaller east-flowing rivers of KwaZulu/Natal and the Eastern Cape that have their own catchments and are not connected to larger rivers (van der Waal, 2007).

2.1.6 Nutritional and dietary requirements

Nile tilapia is primarily described as a phytoplanktivorous species that feeds on suspended matter or bottom deposits, of which diatoms supply the major dietary component (Witte, F. & de Winter, W., 1995). Despite the general characterisation as a phytoplanktivore, there appears to be considerable plasticity in the feeding behaviour of the species, and in many respects, it could best be described as an opportunistic omnivore. For example in the Malagarasi swamps, Lowe McConnell (1958) demonstrated detrital feeding behaviour in which the species fed on soft, flocculent bottom deposits, which comprised finely divided plant fragments, including semi-digested material ejected by *Alestes macrophthalmus* and *Distichodus* sp. In contrast, in Lake Edward, Worthington (1932) described carnivorous feeding behaviour in which shoals of *O. niloticus* were observed to suck at the water surface, apparently feeding on dead lakeflies that were thickly scattered on the water surface.

More recently, Bwanika *et al.* (2007) further demonstrated the plasticity in the trophic level at which the fish can feed - in Ugandan lakes in which it co-exists with the introduced Nile perch (lakes Nabugabo and Victoria), the species is best described as having a varied omnivorous diet. In contrast, in those lake in which it does not co-exist with Nile perch (lakes Wamala, Mburo, Nyamusingiri, and Kyasanduka), it is best described as having a herbivorous diet. A shift from a primarily herbivorous diet to an omnivorous diet that includes macro-invertebrates observed for *O. niloticus* in Lake Nabugabo (Bwanika *et al.*, 2006) may offer an energetic advantage that promotes elevated growth, and facilitates its persistence with Nile perch (Bwanika *et al.,* 2007). Importantly, Balirwa (1998) suggested that the flexible feeding habits of *O. niloticus* could account for flexibility in growth, maturation and variations in fecundity and condition among lakes.

2.2 Restricted Activity

2.2.1 Nature of the restricted activity

The nature of the introduction, and hence the biodiversity risk, associated with developing *O. niloticus* culture in the Eastern Cape is dependent upon the type of culture technology that will be applied. As this report is designed to provide an assessment of the risk associated with the species introduction for use in aquaculture, it is appropriate to include all likely culture technologies that could be applied. As temperature is arguably the major factor that affects the growth rate and economic efficiency of a production system, the ambient temperature in the region can be used as a guide as to the likely culture technologies that would be applied.

Concomitant with all polikotherms (cold blooded animals), tilapia growth is temperature dependent. In general tilapia production is optimised at 28-30ºC, while *O. niloticus* is reported to have optimal growth at 25-28ºC (Charo-Karisa, 2006). As water temperatures falls, reduced metabolic activity results in a rapid decline in growth rates, and *O. niloticus* is reported to cease feeding at between 13-18ºC (Atwood *et al.*, 2003) or at 20ºC (Charo-Karisa, 2006). Reduced growth rates result in longer grow-out periods, lower levels of farm production, and reduced economic efficiencies. It is for this reason that many tilapia farms are located in tropical regions where the high ambient temperatures promote optimal year-round production. In temperate regions such as the Eastern Cape, tilapia farming would either be restricted to seasonal production (during the warmer summer months), or alternatively, it could be undertaken under thermally controlled conditions in highly intensive production systems (partial or full recirculation systems) that allow year round production. This being the case, the following culture systems will be assessed:

1. Semi-intensive seasonal pond culture
2. Semi-intensive seasonal cage culture in lakes, rivers and dams
3. Thermally regulated intensive bio-secure recirculation systems in tanks and raceways

2.2.2 Reason for the restricted activity

Aquaculture is an economic activity in which successful participants maximise their profits by optimising their farming activities. With respect to culture species, the inherent differential growth and culture characteristics between species makes the decision as to which species to farm one of the fundamental determinates to economic success. Of particular import to the economic efficiency of a farming operation is a species' growth rate. In a comparative study that investigated the differential growth rates of *O. mossambicus* and *O. niloticus* in pond culture systems in Limpopo province, Van de Waal (unpublished data) demonstrated that over a six month period, juvenile *O. niloticus* (±30g) grew approximalty 30% faster than *O. mossambicus*. Likewise, the development of the Genetically Improved Farmed Tilapia Programme (GIFT) based in the Philippians has further enhanced the desirability of selecting *O. niloticus* as a culture species. Using selective breeding programmes, the GIFT programme has developed stains of *O. niloticus* that grow between 40-60% faster than their unselected counterparts (Mazid *et al*., 1995); Indeed, *O. niloticus* or one of its hybrids now dominates global tropical freshwater tilapia culture, and in most Asian countries, producers have changed from farming *O. mossambicus / O. hornorum* hybrids to *O. niloticus*, or the more cold temperature tolerant *O. aureus* (Penman and McAndrew, 2000). In addition to the improved growth rates observed with *O. niloticus*, under optimal culture conditions, the species attains a larger size than *O. mossambicus*, which, depending upon the market and marketing strategy, can be linked to higher revenues. With the improved growth characteristics associated with *O. niloticus*, many farmers show a preference to culture the exotic *O. niloticus* over the indigenous *O. mossambicus*.

2.2.3 Location of the restricted activity

Any area within the Eastern Cape.

2.3 The Receiving Environment

2.3.1 Climate

With respect to climate, the geographic distribution of fish fauna across the province will primarily be determined by the water temperatures of the river and dam systems. Thus, an analysis of the climatic factors affecting the potential distribution of *O. niloticus* throughout the province should be restricted to an analysis of the monthly water temperatures in the Provinces' various catchments. In order to provide a representative sample of the water temperatures that could be anticipated across the catchments of the Eastern Cape, a series of 20 river and dam systems have been selected. Their selection was according to their geographic location along the coast, their elevation and the availability of historical temperature data (Figure 2). The mean monthly temperature profiles of the selected rivers and dam systems are presented in Figure 3. The temperature data, collected between 1974 and 2007, are derived from the DWAF - Hydrological Services Department Database, and, while much of the dataset is incomplete, it provides the most comprehensive historical record of water temperatures that is available.

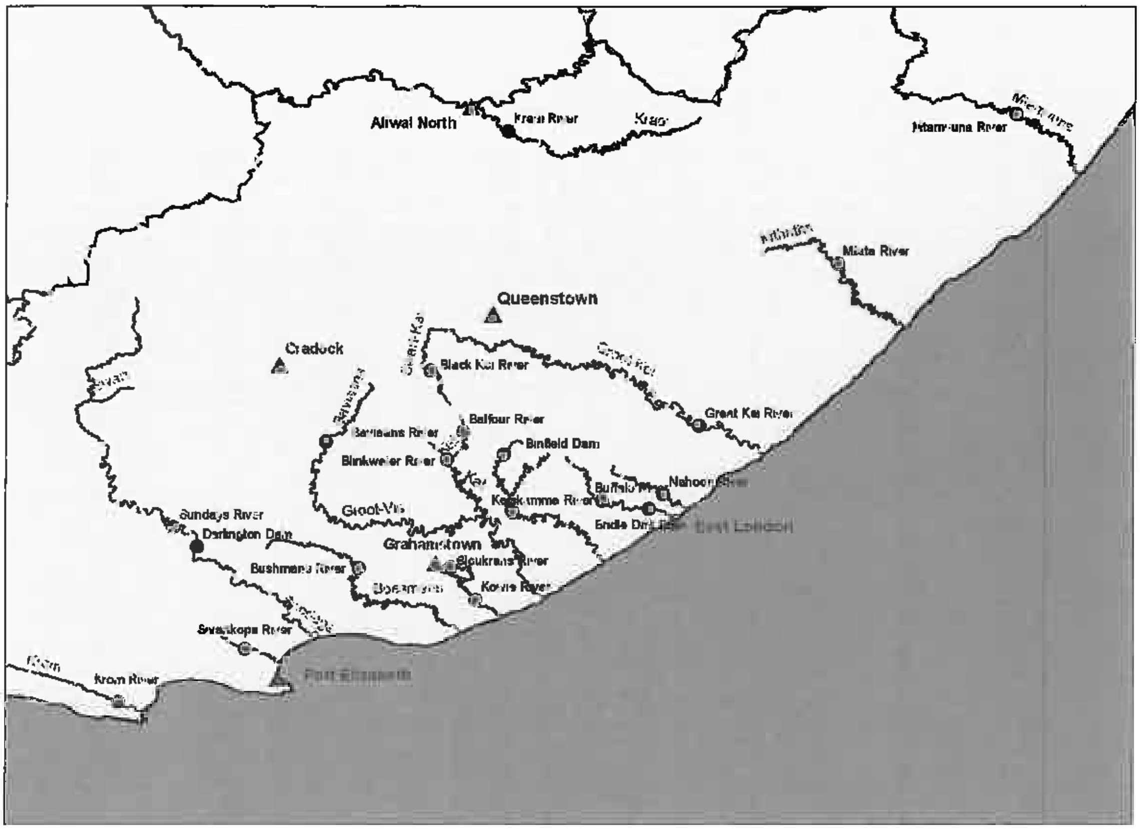
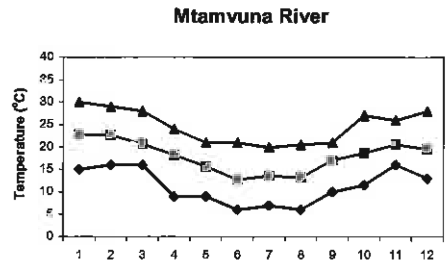
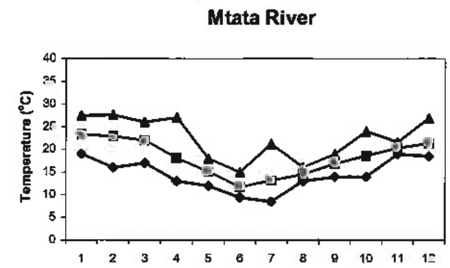


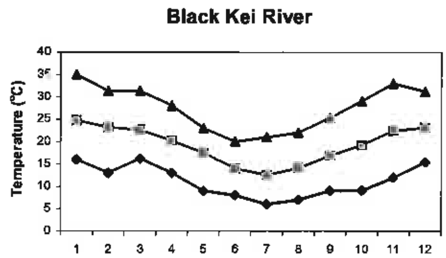
Figure 2. Localities for water temperature sampling sites in the Eastern Cape used for the production of annual temperature graphs in Figure 3.

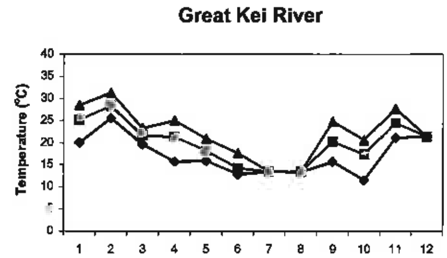
In general, mean water temperatures in the Eastern Cape are only above 20°C from November to March – below 20°C Nile tilapia feeding ceases. Mean monthly temperatures over 25°C were achieved in only two of the 20 waters analysed, in February in the Great Kei River and in January in the Kromme River - 25°C represents the lower limit for optimal growth of Nile tilapia. Over the 20 sites, highest mean monthly temperatures ranged from 20°C in the Blinkwater to 27°C in the Kromme River. Lowest mean monthly temperatures in Winter ranged from 8°C in the Kraai River, a tributary of the Orange River, in June, to 18°C in the Nahoon River in July.

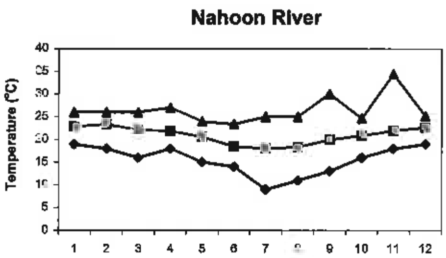
A review of the monthly mean water temperatures that have been recorded suggests that temperatures fluctuate considerably, and most rivers have recorded temperatures that are below the minimum tolerance levels for Nile tilapia. The data do not indicate whether these temperature lows are prolonged or whether they extend throughout the water column in deeper pools. Of note is a small dataset for Nahoon Dam that shows a maximum daily fluctuation from 15-23°C. While the depth of sampling was not recorded, it was probable that at or near the surface the fluctuations would be greatest. Of particular import in this regard is that in comparison with rivers systems, the depth of water in a reservoir has a moderating effect on temperature extremes. Such damping of extreme temperatures is evidenced by the comparatively narrow temperature range that has been recorded in the Darlington Dam, with those upstream in the Sundays River (Figure 3).

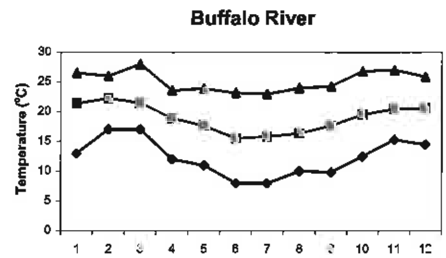

Mtamvuna River
Temperature (°C)

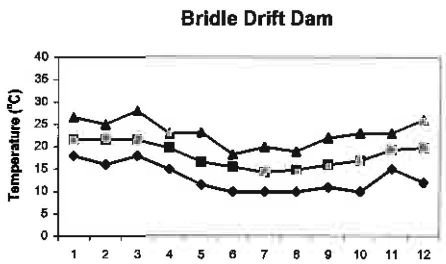

Mtata River
Temperature (°C)

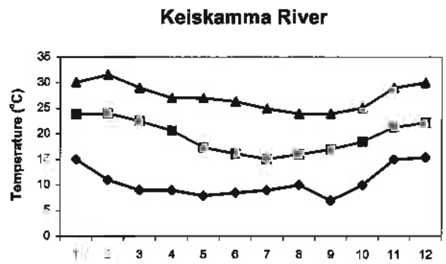

Black Kei River
Temperature (°C)

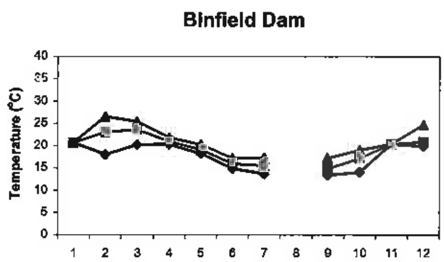

Great Kei River
Temperature (°C)

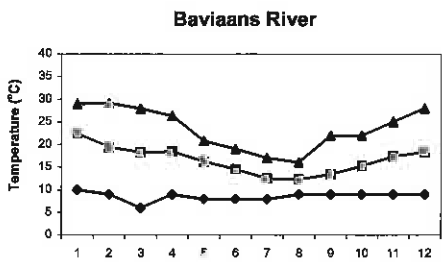

Nahoon River
Temperature (°C)

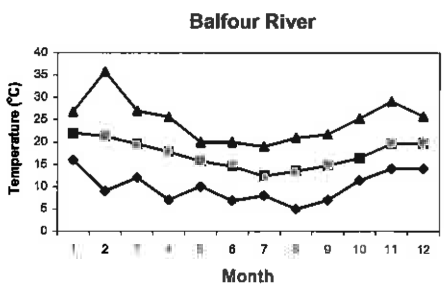

Buffalo River
Temperature (°C)

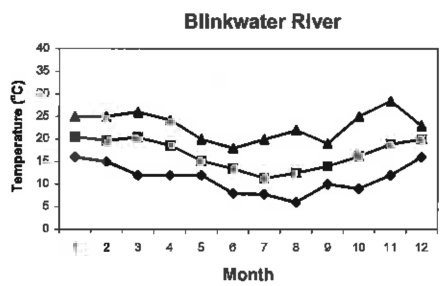

Bridle Drift Dam
Temperature (°C)


Keiskamma River
Temperature (°C)


Binfield Dam
Temperature (°C)


Baviaans River
Temperature (°C)


Balfour River
Temperature (°C)
Month


Blinkwater River
Temperature (°C)
Month

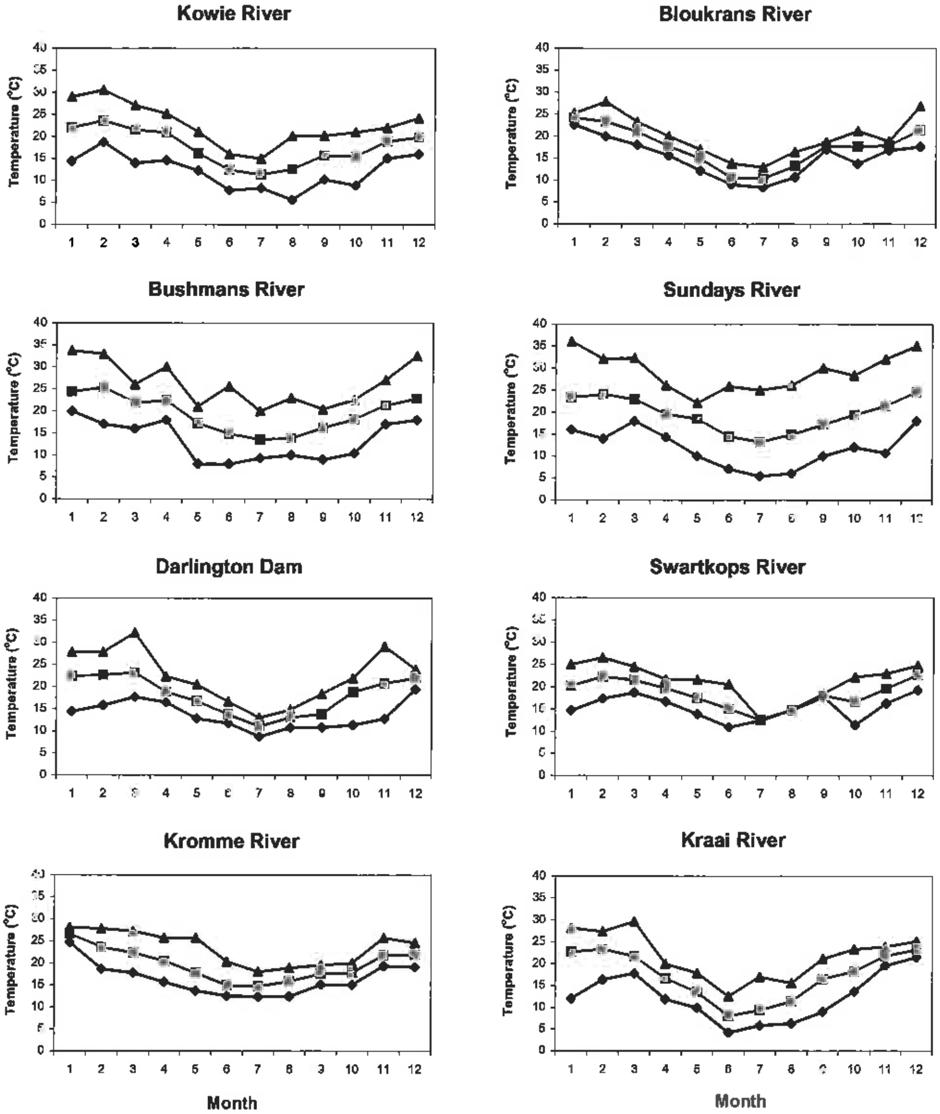


Figure 3. Temperature profiles for 20 selected water bodies in the Eastern Cape, derived from the DWAF - Hydrological Services Department Database for 1974 to 2007. The graphs show the monthly temperatures, as means of all data (■), maximum recorded (▲), and minimum recorded (♦).

2.3.1 Habitat

In general, tilapias live in a range of ecosystems from slow-moving lentic sections of rivers, floodplains and pools, to shallow and deep water lakes and dams. The group evolved as a riverine species inhabiting marginal waters and floodplain pools, colonising lakes and dams as they formed (Lowe-McCommell (2000). *O. niloticus* is no exception, and has been recorded in all of these systems. The species is found in shallow freshwater systems, and in Lake Victoria, they are primarily concentrated at depths of 1-2m, with few occurring at depths above 12m (Goudswaard *et al.*, 2002). In the deep rift valley lakes such as Lake Turkana, the fish are restricted to the estuaries, deltas and lagoons and are absent from the open waters (Poll, 1946). Balirwa (1998) noted that in Lake Victoria, the species remains close to shore in the vegetative zone, with the larger adults moving into the deeper littoral zone to feed. Notwithstanding climatic conditions, it is reasonable to suggest that many of the river, lake and dam systems in the Eastern Cape would provide some suitable habitat for the species, and perhaps of more significance to the establishment of *O. niloticus* populations in the Eastern Cape, are the prevailing climatic conditions.

2.3.2 Natural enemies, predators and competitors

In its natural habitat, adults of the species have few natural predators, and while large Nile perch, *Lates niloticus*, and the catfish *Bagrus docmak* are capable of predating medium sized specimens, large specimens coexist in open waters with these predators. As juveniles are able to tolerate large temperature fluctuations, they can occur in very shallow water where they are able to avoid predation by Nile perch. Typically, juveniles remain in the cover of vegetation until they are large enough to be relatively safe in open water. In rivers to the south of its natural range, there are few large fish predators, and it is evident that the ability of the species to evade predation by fish at the various stages of its life cycle is one of the reasons for its success as an alien invasive species.

The success of Nile tilapia as an invasive species indicates that there are few, if any, successful competitors in the ecological niche occupied by this species.

Although there is limited natural predation and competition by fishes, otters and birds pose a considerable threat to fish farming in the Eastern Cape. The Cape clawless otter, *Aonyx capensis*, is common in the province and in the absence of control mechanisms could prove a problem for fish farming, particularly for fishes grown in cages in dams and ponds. White breasted and reed cormorants, darters, and several kingfishers will prey on juvenile tilapias, which will be particularly vulnerable because of their preponderance for very shallow water.

2.3.3 Reproductive compatible species

In general, tilapia species readily hybridise with other closely related species, and indeed, the widespread movement and mixing of tilapia species in Africa has resulted in hybridization between species in many lake and river systems (Penman and McAndrew, 2000). For example, in Lake Victoria and its outpost lakes, hybridisation has been reported between the alien *O. niloticus* and the indigenous *O. esculentus* and *O. variabilis* (Tweddle and Wise, 2007), and while there is evidence of introgression between the species in these lakes, the Lake Victoria population now appears to be virtually pure *O. niloticus* (Tweddle and Wise, 2007). More recent genetic studies have revealed introgression between *O. niloticus* and *O. esculentus* in many satellite lakes around Lake Victoria, with few populations of pure strains of the species (Tweddle and Wise, 2007). Likewise, in the Limpopo catchment, hybridisation has been reported with *O. mossambicus* in dams where the species initially became intermingled. However, there is evidence that the hybrids eventually disappear, leaving only *O. niloticus*, and while further genetic studies are required, it appears that in general, *O. niloticus* eliminates the indigenous tilapia genes (Tweddle and Wise, 2007).

In Sri Lanka Reservoirs, Amarasinghe and De Silva (1996) demonstrated that *Oreochromis mossambicus* and *O. niloticus* readily interbreed and introgressive hybridisation of the two species occur. The reproductive biology of *O. mossambicus*, *O. niloticus* and their hybrids in three reservoirs was evaluated, and it was observed that there was an imbalance in sex ratio with males becoming the dominant gender. The estimated fecundity for 20-cm fish (using fecundity-total length relationships for various populations) indicated that there was a decline in fecundity in hybrid forms, and it was hypothesised that the long-term effect of cross-hybridisation between the two species could lead to a decline in fish yields.

2.4 Risk Profile

2.4.1 Probability of naturalisation in the Eastern Cape

Wherever it has been introduced throughout the world the Nile tilapia has thrived, and there are no recorded instances of its extirpation once established in a system. Wherever the climate is suitable, the species has clearly demonstrated a propensity to thrive on introduction, and there are few limiting factors to its establishment in a range of aquatic habitats - the exception being torrential river systems. It is evident that the major limiting factors are salinity and temperature.

Philippart and Ruwet (1982) (cited in Tweddle and Wise, 2007) summarised aspects of the ecology of tilapias, including geographic distribution, physical and chemical factors that influence this, and aspects of their behavioural ecology. They showed a figure of temperature tolerance for *O. niloticus*, with a range from 14°C to 33°C. The data suggested that the species' extreme tolerance in some natural habitats and in culture ponds was 7°C to 39°C, and in laboratory tests, the upper lethal temperature limit was 42°C. Atwood *et al.* (2003) conducted experiments on the temperature tolerance of *O. niloticus* comparing the effects of environmental and dietary factors. Under any treatment, all fish stopped feeding when temperatures decreased to between 18°C and 13°C (which is less than the 20°C stated by Charo-Karisa, 2006). First mortality occurred at 10.6°C and all fish succumbed by 6.8°C. These results are in fairly close agreement with the findings of Philippart and Ruwet (1982). Although there was little difference between treatments generally, the effect of salinity on mortality was found to be significant. Fish in saline waters succumbed at higher or equal temperatures than in other treatments. This contrasts with *O. mossambicus*, which is more tolerant of low temperatures at high salinity (Allanson *et al.*, 1971). This has important implications for survival and conservation of *O. mossambicus* in southern Africa.

Rivers to the east of the province at low altitudes, e.g. the Buffalo, Nahoon and Keiskamma, have mean temperatures above 15°-18°C in all months of the year and if the Nile tilapia become established in these rivers, they are likely to continue feeding and growing for most of the year, albeit very slowly, if at all, in winter. Minimum temperatures recorded in these rivers are 8° to 10°C. These temperatures, if continuous over several days, may result in mortalities, but it is likely that during low temperature events the fish will seek out deeper holes where temperature fluctuations are less extreme. In the Nahoon River, only one reading of less than 10°C, the temperature at which first mortalities were recorded by Philippart and Ruwet (1982), was recorded in 300 measurements.

All but one river in the Eastern Cape flow directly to the Indian Ocean, the exception being the River Kraai, which is a tributary of the Orange River. Available temperature records for the Kraai River are from Aliwal North, very close to the Orange River confluence. Temperatures in the Kraai are only suitable for Nile tilapia from October to April (Figure 3). From May to September, temperatures drop below 10°C, and in June and July the mean temperature is below 10°C, thus Nile tilapia will be unlikely to establish themselves in this river, even if escaping to the river initially in warmer months. The proximity of the Kraai confluence to the large Orange River impoundments of Gariep and Vanderkloof, however, gives cause for concern as minimum temperatures in these reservoirs do not drop below 10°C in winter. Thus summer escapees into the Kraai could find their way down the Orange River and survive, eventually colonising the whole river downstream.

A similar problem exists with upland tributaries of the other Eastern Cape rivers. In the Black Kei River, for example, minimum temperatures of below 6°C occur and the minimum temperature drops below 10°C for six months of the year. Nile tilapia, therefore, are unable to colonise this tributary. Downstream, however, the Great Kei River is apparently a suitable habitat for Nile tilapia throughout the year (although there are few data points in winter) and escapees upstream in summer are likely to invade the lower reaches.

In the west of the province conditions are more borderline for Nile tilapia survival, with for example, minimum recorded temperatures dropping below 10°C from June to August in the Sundays River. Such low temperature events are likely to result in fish mortalities. Nevertheless, mean temperatures in these months are greater than 14°C, and may promote the survival of some fish in deeper holes. In contrast, in Darlington Dam on the Sundays River, the large size of the dam moderates water temperature fluctuations, and the minimum temperatures recorded dipped below 10°C only in July. This being the case, the species is likely to survive throughout the year with few temperature-induced mortalities.

2.4.2 Probable impact on biodiversity and the use of natural resources

2.4.2.1 Threats to Eastern Cape fish fauna.

The Mozambique tilapia (*Oreochromis mossambicus*), is most at risk from the potential invasion of Nile tilapia. To the south of the Limpopo system, *O. mossambicus* extends along the entire coast to the Eastern Cape. At the extremes of its natural distribution it is temperature limited. Nevertheless, low temperature survival is linked to salinity tolerance, and thus at the geographical extremes of its range, populations survive in estuaries (Allanson *et al.,* 1971). While Nile tilapia tolerates fairly high salinity, it does not have lower temperature tolerance in saline water (Atwood *et al*., 2003). Thus, while *O. mossambicus* is threatened through most of its freshwater range by *O. niloticus*, it is likely to continue to survive in estuarine refugia. In freshwaters, however, *O. niloticus* is likely to eliminate *O. mossambicus*.

The endangered Eastern Cape rocky, *Sandelia bainsii*, occurs in a limited number of streams in the province, i.e. the Kat, Kowie, and at least two small coastal streams in the East London area. The ability of this species to coexist with Nile tilapia is unknown and thus, given the rocky's endangered status, the precautionary principle to species conservation should be applied, and thus no alien species should be allowed into those catchments in which it occurs. In addition, two other endemic species occur in the province, *Barbus trevelyani* and *Barbus amatolicus*. These species occur at altitude where temperatures are cooler, and are thus unlikely to be impacted by Nile tilapia invasion.

2.5 Risk Management Measures

As outlined in Sections 2.1, *O. niloticus* exhibits a number of biological characteristics that enable it to establish satellite populations outside of it's natural geographic range, and indeed, many introductions into regions where it is not endemic have resulted in the establishment of feral populations. In this regard, the introduction of the species as an aquaculture candidate has undoubtedly promoted the spread of the species (Tweddle and Wise, 2007; Weyl, 2007). The introduction of farmed aquatic species to regions in which they are not endemic, and the resultant affects on biodiversity is a major issue that Government, NGO and Industry Associations have addressed through the development of Best Management Practices (BMP). Of particular relevance is the Code of Conduct for Responsible Fisheries (FAO, 1995), and the associated Technical Guidelines – Precautionary Approach to Capture Fisheries and Species Introductions (FAO, 1996). Specifically, the codes of conduct indicate that States should conserve their genetic diversity and maintain ecosystem functioning, use the precautionary approach when deciding whether to permit introductions; and in the case of aquaculture, view the movement of aquatic animals into areas that are beyond their natural range as introductions to the wild - this due to the inherent difficulty in maintaining aquatic animals in bio-secure environments, and that over time, it is inevitable that escapes will occur (Box 2).

Box 2

FAO Code of Conduct for the development of responsible fisheries (1995)

Section 9.3.1 : States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of Origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks.

Technical Guidelines – Precautionary Approach to capture fisheries and Species Introductions (FAO, 1996)

Section 104 : .... Recognising the difficulties with introductions, the objectives of the precautionary approach to species introductions in relation to capture fisheries should be to reduce the risk of adverse impacts of introductions on capture fisheries, to establish corrective or mitigating procedures (as in a contingency plan) in advance of actual adverse affects, and to minimise unintended introductions to wild ecosystems and associated capture fisheries.

Section 105 : In relation to aquaculture, experience has shown that animals will usually escape the confines of a facility. As a consequence, the introduction of aquatic organisms should be considered as a purposeful introduction into the wild, even though the quarantine/hatchery may be a closed system.

Taking into consideration the precautionary principle of species introduction outlined by the FAO (Box 2), and taking cognisance of the likelihood of *O. niloticus* establishing viable populations in the Eastern Cape (Section 2.4.1), and the probable impacts that the introduction will have on the aquatic biodiversity (Section 2.4.2.1), the following risk assessment is designed to quantify those aquaculture activities that pose the highest risk to the Province's aquatic biodiversity, and where possible develop mitigation measures. In order to undertake this assessment the four likely aquaculture development scenarios that are likely to be proposed (Section 2.2.1) are discussed in detail.

2.5.1 Development Scenario 1: Semi-intensive seasonal pond culture

Semi-intensive and intensive pond culture techniques using waters drawn from rivers, lakes, or dams could be considered throughout the province. Depending upon the location, the ambient water temperatures that are found throughout the province would likely curtail the growing season to 4-6 months, and thus in comparison with areas that experience higher ambient temperatures, the operation is likely to be marginal. Depending upon the site, pond culture systems are difficult to secure in terms of bio-security and the prevention of escapees. In order to reduce pumping costs, ponds are often located on or near to flood plains, and during flood events, ponds often become inundated. The resulting fish escapes are extremely difficult to control.

Description of impact

The release of Nile tilapia into river systems, and concomitant changes to ecosystem function.

Assessment of impact before mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Highly Probable
Degree of confidence:	Medium

Mitigation and risk management

In order to reduce the risk of escapees entering the river systems, it would be appropriate to install a series of mechanical screens on the grow-out and hatchery effluent streams. For example, in the grow-out facility, a series of mesh screens from 3 cm – 0.5cm could be used to prevent fish and fingerlings from moving out of the facility. In contrast in the hatchery, the loss of ova would need to be considered, and here it would be appropriate to install a drum filter (±40-60µm) to filter the effluent waters. In addition, to reduce the risk of flooding, ponds could be sited above the 100 year flood-line.

Assessment of impact after mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Probable
Degree of confidence:	Medium

Recommendation

If poorly managed and maintained, mechanical barriers (e.g mesh screens) are prone to clogging and failure – particularly during times of high flow rates. Failure of the screens could easily result in fish escapes and the establishment of feral populations. Further, it should be noted that in order to maximise the length of the growing season, pond culture operations would likely be proposed for the warmer, low altitude areas, where the establishment of feral populations are most likely to occur. Due to the problems associated with maintaining bio-security in pond based systems, it is recommended that pond culture systems are not considered appropriate culture technology.

2.5.2 Development Scenario 2: Semi-intensive seasonal cage culture in lakes, rivers and dams

Cage culture represents an *in situ* culture technology in which fish are maintained in holding pens in lake, river or dam systems. Cage culture operations have the inherent risk that structural failures in the cage system will enable fish to enter the water bodies in which they are placed. Physical damage to cages can be the result of many factors, such as adverse weather events resulting in the destruction of the cage system, the physical tearing of the nets from poor management, or predators trying to access the fish. Poor maintenance and management procedures can also result in accidental fish releases to the receiving waters.

Description of impact

The release of Nile tilapia into river systems, and concomitant changes to ecosystem function.

Assessment of impact before mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Highly Probable
Degree of confidence:	Medium

Mitigation and risk management

It is extremely difficult to mitigate against cage failure. Mooring systems can be over-engineered to provide security against failure, and individual cages can be fitted with double nets to provide a barrier to escapees – if the inner nets tears, the fish remain confined by the second net.

Assessment of impact after mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Highly Probable
Degree of confidence:	Medium

Recommendation

Due to the inherent and highly probable nature of the risk associated with cage culture, it is recommended that cage culture is not considered appropriate culture technology.

2.5.3 Development Scenario 3: Thermally regulated intensive bio-secure recirculation systems in tanks and raceways

Thermally regulated intensive bio-secure recirculation systems represent a relatively new culture technology for tilapia. Fish are cultured at high density in tanks or raceways under controlled environmental conditions. In marginal areas such as the Eastern Cape, temperature would be need to be controlled by placing the system in green houses, and during cold weather events, would most probably require supplemental heating to maintain optimal culture temperatures. The culture systems employ biofiltration systems in which water is filtrated and re-used, and in comparison with alternative culture technologies, this significantly reduces that amount of water that is required to culture a given volume of fish. Under normal operating conditions, between 15-20% of the system waters would be replaced daily. Under a standard development scenario, water would be extracted from a river or dam system, used in the system, filtered and returned to the water body.

Description of impact

The release of Nile tilapia into river systems, and concomitant changes to ecosystem function.

Assessment of impact before mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Highly Probable
Degree of confidence:	Medium

Mitigation and risk management

The bio-security afforded to these systems can be enhanced by incorporating design criteria and management practices into the production model; and critically, the probability that escapees will enter the river catchments can be significantly, but not entirely reduced. With respect to design criteria, it would be appropriate to consider the following:

1. Water inflow and outflow streams. Consideration should be given to the water requirements of the system, and the possibility of isolating the system from the catchment. Isolation from the catchment could be achieved by substituting river or dam water with borehole water, and restricting effluent waters to man made evaporation dams that are isolated from the catchment. Ideally fish / ova should not be allowed to enter the evaporation dam, as depending on the location, a failure in the dam system could conceivably result in fish entering the larger catchment. To mitigate the risk of fish, fry or ova entering the evaporation dam, effluent waters from both the grow-out and hatchery operations should be mechanically screened (using a 40 or 60ɥm drum filter) to prevent fish and ova entering the dam system. As a further precaution, and in

the event of a failure of the screening system, the dam could be treated with a piscicide such as rotenone to kill any fish that entered the dam.

2. In order to prevent fish being removed from the facility, an electrified security fence should be placed around the property. Access to the site, and in particular the operational systems should be restricted at all times.

3. All systems should be covered.

4. The movement of fish should be restricted, and no live fish should be allowed to leave the facility. Primary processing will therefore have to be undertaken on site.

Assessment of impact after mitigation

Extent:	Catchment wide
Duration:	Permanent
Intensity:	Medium
Significance:	High
Status of impact:	Negative
Probability:	Improbable [a]
Degree of confidence:	Medium

[a] The classification of the post-mitigation probability of escapes occurring as "improbable" relates to the physical barriers that can applied to prevent escape events. However, it should be noted that the potential for human error to result in escape events remains relatively high, and as such, if human error is taken into consideration, the probability of an escape event should be viewed as "probable".

Recommendation

While it would be theoretically feasible to develop a bio-secure culture environment in which the fish were unable to escape, bio-security can only be ensured if all protocols are strictly adhered to and rigorously enforced. In this regard, consideration needs to be taken of the fact that once the species has been introduced into the region, it would be a simple procedure to move it - be it accidentally or with intent - from site to site, and by doing so seriously increase the chances of the fish escaping into the wild, where there is a high probability that it will establish a feral population. In this regard, the permitting authority should seriously consider the likelihood of permit compliance, and indeed, its ability to enforce permit regulations. In this regard, cognisance should be taken of Section 105 of the FAO Technical Guidelines on the Precautionary Approach to Capture Fisheries and Species Introduction (Box 3).

Technical Guidelines
Precautionary Approach to capture fisheries and Species Introductions (FAO, 1996)

Section 105: In relation to aquaculture, experience has shown that animals will usually escape the confines of a facility. As a consequence, the introduction of aquatic organisms should be considered as a purposeful introduction into the wild, even though the quarantine/hatchery may be a closed system.

2.5.3 Potential costs associated with control and eradication

Under the "polluter pays" principle, the onus is on the farmer to cover the costs associated with the eradication of the fish were it to escape into the environment. The eradication of introductions into the smaller rivers may be achieved by the selective use of piscicide such as rotenone, under tightly controlled conditions. However, prior to the use of piscicides, it is likely that an Environmental Impact Assessment – although not legislated for - may be required. The costs associated with such an eradication programme are likely to be substantial, and will depend upon the size and nature of the river system that has been affected. Crucially, eradication is likely to be impractical in the larger rivers and dams where any introduction would effectively be irreversible.

2.6 Market Analysis

Over the past 15 years, the emergence of tilapia as an internationally traded commodity has stimulated producers to invest in the species. In addition to the existing markets in the traditional tilapia growing countries (principally South East Asia, Latin America and Africa), significant new markets have been established in the USA and to a much smaller extent the EU. In the USA, tilapia markets (across all product classes) have grown from less than 4,000 tons in 1992 to 170,000 tons in 2007 - representing 400,000 tons of whole fish (Globefish, 2008a). In contrast, while market penetration in Europe remains fairly limited, it has expanded rapidly from 1,917 tons in 1996 to 10 - 15,000 tons in 2007 (Globefish, 2007a, 2007c).

Global tilapia production is likely to reach 4 million tonnes in the near future, and will likely exceed that of salmon. Nevertheless, the quantity of tilapia traded worldwide is still relatively small, and only about 10% of production is exported from producer countries – the majority of which is destined for the USA markets. After China, the USA remains the main world market. However, the US market for tilapia is expected to grow during the coming months and years. The EU market is also growing, with products increasingly being sourced from Asia, mainly China, Thailand and Indonesia. (Globefish, 2007c)

Traditional tilapia markets have been dominated by three product types, *viz.* frozen whole, frozen fillets and fresh fillets. In recent years, the fillet markets have remained buoyant, and in many markets have increased their market share at the expense of frozen whole fish. New value added product lines (e.g breaded, spiced) originating from China have dramatically changed the marketing landscape. Indeed in 2006, more than half of all the tilapia product originating from China was classified as value added.

An analysis of the global markets for tilapia reveals that Chinese production dominates world supply, particularly in the frozen whole and frozen filleted sectors of the markets. Indeed in 2007, China exported 143,500 tons of frozen product to the USA (Globefish, 2008b). With whole frozen tilapia fillets selling at a unit prices as low as US$0.81 / kg, it represents one of the lowest cost white fish materials, and as such, the remarkable growth in imports is due to the fact that the product provides an excellent cheap raw material to develop into value added white fish products. Interestingly, the advent of cheap Chinese frozen product has forced the traditional Latin American tilapia suppliers to move away from frozen tilapia products and move into the higher value fresh fillet sector, where current (Globefish 2008a) wholesale prices are approximalty US$1.45 / kg – this allows them to take competitive advantage of their geographic location that enables them to move higher value fresh product cheaply into the North American markets. It is interesting to note that while tilapia imports and production have increased significantly in recent years, prices has fallen markedly. In 2003, the average wholesale price of fresh fillets on the US market was US$5.72 kg (Globefish 2004), which in comparison with current prices (US$1.45 / kg) represents an approximate four fold decrease in prices between 2003 to 2008.

With respect to the EU, in 2006, China supplied 3,400 tons representing 34% of tilapia imports (Globefish 2007b). However, it is important to note that while imports to the EU are relatively low, they are expanding very rapidly with a fivefold increase in imports between 2005 and 2006. Taking into consideration the strength of the Chinese production, economies of scale and low production costs, it is highly likely that the anticipated growth within the EU for frozen tilapia products will be dominated by supplies from China.

While the UK is considered the major European outlet for tilapia, it is also marketed in France, Belgium, Germany, the Netherlands, and in smaller quantities in Austria, Italy, Switzerland, Denmark and Sweden. Tilapia consumption follows the conventional regional distribution pattern of fish consumption - the Northern Europeans prefer fillets, while their Southern counterparts generally prefer whole fish.

With respect to the production of Nile tilapia, it is unfortunate that the FAO report tilapia production under the general statistical category of 'tilapias nei', which includes all species, and there are no definitive global records for Nile tilapia production. Nevertheless from the records that do exist, it is evident that in 2003, China produced nearly 806 000 t and Egypt reported a production of nearly 200 000 t of Nile tilapia, while the Philippines, Thailand and Indonesia produced 111 000 t, 97 000 t and 72 000 t respectively. The other significant Nile tilapia producers were the Lao People's Republic, Costa Rica, Ecuador, Colombia and Honduras. Brazil and Taiwan Province of China are also major producers of Nile tilapia and many others, such as Cuba, Israel, Malaysia, the USA, Vietnam and Zimbabwe produce significant quantities annually (FAO, 2005). It is important to note that many of the reports for Nile Tilapia production are unlikely be attributed to pure strains, but are more likely attributable to their hybrids. For example, in Saudi Arabia, the culture industry is primarily based on the culture of *O.niloticus x O. aureus* hybrids (Siddiqui and Al Najada, 1992), which result in single sex populations that in terms of yield, perform better under culture conditions than their pure strain counterparts.

The dominance of Nile tilapia and it's hybrids as the preferred tilapia species for commercial production is generally attributed to it's high growth rate and yields in culture systems. Siddiqui and Al-Harbi (1995) undertook a comparative study of the growth characteristics of *O. mossambicus*, *O. niloticus* and *O. niloticus x O. aureus* hybrids under tank culture conditions. It was demonstrated that over a single growth cycle, the yields (kg m^{-3}) attributable to the culture of *O. mossambicus* was 6.5 kg m^{-3}. In contrast, the yields attributable to *O. niloticus* and the *O. niloticus x O. aureus* hybrid were 11.7 kg m^{-3} and 13 kg m^{-3} respectively. Clearly, the significantly higher yields attributable to the culture of O. niloticus and it's hybrid provides the economic rationale for farmers to favour the culture of the species. Most notably, in regions such as the Eastern Cape where culture temperatures are sub-optimal, and production is likely to be limited to intensive thermally regulated indoor systems, the choice of culture species becomes of paramount economic importance, and provides the underlying rationale for farmers wanting to introduce the species into the province. **Indeed, while it is beyond the scope of this report to determine the economic efficiency of tilapia production in the Eastern Cape, it is likely that should the sector prove profitable, economic efficiency would likely be significantly enhanced by the culture of *O. niloticus* or one of its hybrids.**

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