Impact of Introduced Nile tilapia (*Oreochromis niloticus*) on Non-native Aquatic Ecosystems

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Abstract: The global invasion of non-native aquatic ecosystems by Nile tilapia (*Oreochromis niloticus*) is well documented and coincides with their increased use as an aquaculture species. Aquaculture can be defined as the farming of fish or other aquatic organisms and it varies considerably in terms of production practices. Generally, freshwater finfish, such as Nile tilapia, are reared in inland ponds (closed systems). However, in several countries, floating cages are increasingly used to rear Nile tilapia in open water bodies. In such systems, escape is inevitable. The Nile tilapia is considered an omnivorous species and it ingests zooplankton, phytoplankton, or debris present in rivers. As a consequence, the release of Nile tilapia into non-native aquatic ecosystems may result in competition for food and space, thereby damaging native species. The wide environmental tolerance and high reproductive rate of Nile tilapia facilitate its use for aquaculture, but also render the species highly invasive. Here, we review the high frequency of Nile tilapia in non-native biodiversity and indicate the existence of the species under feral conditions in every country in which it has been introduced through farming systems.

Key words: Aquaculture, fish, biodiversity, exotic, freshwater

INTRODUCTION

Rapid human population growth has necessitated increased food production from agriculture, livestock and aquaculture (Vicente *et al.*, 2011a) However, the expansion of land for crop production results in many environmental problems, making enhanced productivity the key means of increasing food production. In particular, there is considerable emphasis on breeding programs (Fonseca-Alves *et al.*, 2011).

Introductions of non-native fish species can reduce biodiversity and modify local community dynamics in freshwater systems. Exotic species have been identified as the third leading cause of extinction of vertebrate species in aquatic environments (Groombridge, 1992). Introductions of exotic species generally threaten the stability of ecosystems, resulting in extinction through long-term predation and competition and leading to replacement of native species by exotic species. Other documented effects are hybridization with native species, disruption of the food chain and environmental degradation (Williamson, 1996; Cox, 1997).

The *Nile tilapia*, *Oreochromis niloticus* (Linnaeus 1757), is responsible for reducing local biodiversity, through competition with other aquatic species for available food resources. Lack of predation and adaptation to changing environmental conditions increase the impact of Nile tilapia on the ichthyological composition (Leveque, 2002; Vicente *et al.*, 2011a).

The Nile tilapia is an omnivorous species indigenous to Africa and it is found mainly in the basins of the Nile, Niger and Chad and in lakes of the Middle East (Leveque, 2002). In North and South America, introductions of Nile tilapia stem from aquaculture facilities and also from historical introductions for recreational angling. The Nile tilapia has been introduced in more than 100 tropical and subtropical countries, to improve fishing productivity and facilitate the development of aquaculture (Coward and Bromage, 2000; Leveque, 2002).

The ease of reproduction of the Nile tilapia encourages farmers to acquire the species and populate their tanks at a low investment cost. Furthermore, the Nile tilapia constitutes a rough species, which occurs in a wide range of environmental variations, tolerating extreme limits of temperature and oxygen, as well as the presence of various pollutants (Beyruth *et al.*, 2004).

FEEDING BEHAVIOUR AND REPRODUCTIVE TRAITS OF NILE TILAPIA

Adult Nile tilapia feed predominantly on phytoplankton. If phytoplankton is not abundant, the adults feed first on zooplankton and thereafter on debris.
Seasonal variations also influence the type of diet. During the rainy season, debris is predominantly consumed, whereas, in dry seasons, consumption of phytoplankton prevails (Beveridge and Baird, 2000). Food is ingested by filtration and retained by the gill rakers, which are characteristic of microphagous species and are located in the arches. Within the pharyngeal cavity, food can be ingested or rejected (Beveridge et al., 1993). The accepted material is broken into smaller fragments by pharyngeal bones and forwarded to the oesophagus (Beveridge and Baird, 2000).

The reproductive behaviour of Nile tilapia is highly influenced by the mode of reproduction. In the genus Oreochromis, for example, males build nests for spawning and develop secondary sexual structures (Turner and Robinson, 2000).

Yamamoto (1969) revealed that steroid hormones may be used to modify the phenotypic sex of Nile tilapia. Androgen hormones have been widely used to produce all-male populations of several tilapia species (Macintosh and Little, 1995; Green et al., 1997). Various techniques have been used in an attempt to curb overpopulation. Such methods include stock manipulation, utilization of tilapia fish predator cultures and monosex creation (Phelps and Popma, 2000). Of these, monosex creation is most frequently used. The production of single-sex male tilapia, by adding the hormone androgen 17α-methyltestosterone to the larval diet, is considered to provide optimal sex reversal of tilapia (Turner and Robinson, 2000).

**USE OF NILE TILAPIA IN AQUACULTURE**

The Nile tilapia is feral in every country in which it has been cultured or introduced and where local conditions allow the species to establish (Courtenay, 1977; Costa-Pierce, 2003). Nile tilapia comprise 83% of the global production of tilapia (FAO, 2002) and are responsible for the dramatic expansion of tilapia in recent decades (Bentsen et al., 1998; Gupta and Acosta, 2004). The large size at the first reproduction, rapid growth rate and versatile feeding habits with a basal position in the food chain (Costa-Pierce, 2003) justify the predominance of the Nile tilapia in tilapia production (Gupta and Acosta, 2004). As a consequence of its considerable potential for aquaculture, the species has undergone several breeding programs, which have generated different lineages.

The rearing of tilapia in cages, especially in small volumes, has increased considerably in recent decades and may become the most important aquaculture system in many countries. According to Beveridge (2004), the technique has several advantages over traditional farming, including low initial investment, utilization of available aquatic resources, enhanced production control, elimination of problems associated with excessive reproduction and ease of handling (Shinohara et al., 2012). Tilapia have several favourable characteristics for aquaculture, including rapid growth rates (Hassanien et al., 2004), especially in males (Toguyeni et al., 2002), high feed conversion rates (Kubitza, 2000) and disease resistance (Ardjosoeiro and Rammarine, 2002) at high densities (Gall and Bakar, 1999) and low concentrations of dissolved oxygen (El-Sayed and Kawanna, 2004). Roughness (Yi et al., 1996), ease of obtaining fingerlings (Coward and Bromage, 2000) and high market acceptability (Wille et al., 2002) are additional desirable features of the species for aquaculture.

**IMPACT OF NILE TILAPIA INTRODUCTIONS ON ECOSYSTEMS**

The terms introduced species, exotic species, alien species, non-native species, non-indigenous species and allochthonous species have the same biological significance and according to the European Inland Fisheries Advisory Commission (EIPAC) and correspond to any species transported and released by humans outside of their natural range, intentionally or accidentally (Vitule, 2009; Fonseca-Alves et al., 2011). Another important concept and distinct from the above is that of invasive species. The International Union for Conservation of Nature (IUCN), for example, defines invasive species as any organism introduced by humans in places outside their native range that was established and dispersed, causing a negative impact on other species or ecosystem (ISSG, 2011).

The introduction of exotic species and extinction of native species, coupled with environmental changes, influence the loss of biodiversity, through increasing genetic similarity and taxonomic and functional biota, on a global and regional scale. This phenomenon affects evolutionary and ecological factors (Olden et al., 2004) and is known as biotic homogenization (McKinney and Lockwood, 1999). The construction of canals, international trade, recreation and aquaculture (Naylor et al., 2001) are the main reasons for the mixing of allopatric groups. Olden and Poff (2003) describe many possible scenarios for increasing similarity quenching and biotic introduction of species. In fish, the pattern is related to the degree of disturbance caused by human activities, such as human settlements and usage of land and water resources (Mendoca et al., 2012). For example, the construction of dams fragments rivers, thereby
changing the processes and dynamics of flow and threatening limnological biodiversity (Power et al., 1996). The same characteristics that increase the ability of the Nile tilapia to become a potentially invasive pest in various environments are responsible for the economic importance of the species in aquaculture (Peterson et al., 2005). Rapid growth rate, high prolificacy, varied food habit, high resistance disease and year-round spawning, in addition to excellent flavour, make tilapia fish farming increasingly important in Neotropical regions (Melo et al., 2006).

Canonicco et al. (2005) reviewed the potential impacts of tilapia on ecosystems into which they are introduced. These include local extinction of native species, predation of eggs and young of other fish species (Goudswaard et al., 2002), alteration of the dynamics of nutrients and eutrophication (Starling et al., 2002), destruction of vegetation from the lake bottom and introduction of parasites (McCray et al., 2001). According to Casal (2006), the Nile tilapia has been introduced in 85 countries, with establishment reported in 58% of these countries and adverse ecological effects in 14%. Based on the considerable capacity of the species for colonization and its potential environmental impact, the protection and management of aquatic environments is crucial when introducing tilapia into ecosystems (Esselman, 2009).

Organic residues produced as a result of microbial action provide essential nutrients for the development of plankton and macrophytes. When present in excess, these residues cause eutrophication of the environment and changes in the composition and abundance of many aquatic organisms (Vicente et al., 2011b). Kestemont (1995) collated information about the negative effects of aquaculture on the biological environment and highlighted the following: changing values of water temperature; increased chemical biochemical oxygen demand; elevated levels of phosphorus and suspended solids; decreased concentrations of dissolved oxygen; chemical contamination; accumulation of sediment rich in organic matter, pollution, erosion and increased risk of disease spread.

When a new species is introduced into an ecosystem, there is always the risk of it being able to escape and settle in the natural environment, resulting in possible adverse effects to native species or even the functioning of the ecosystem (Gozlan et al., 2010). The effects resulting from introductions can be devastating, causing biological invasions are considered a major cause of biodiversity loss (Vitule, 2009; McGeoch et al., 2010).

Fish are among the group of aquatic animals over introduced worldwide (624 species) and 91% of the sources of introductions are related to farmed fish (Gozlan, 2008). Nile tilapias are used for aquaculture because they are extremely hardy, physiologically tolerant and characterized by multiple spawning and parental care (Agostinho et al. 2007). The negative effect of the Nile tilapia on the native fauna of worldwide has been extensively reported. The Nile tilapia changes native community structure, reduces abundance of planktonic microcrustaceans, lowers water transparency and increases the abundance of microalgae (Attayde et al., 2007).

Many non-native freshwater fish are invading Latin America and others parts of world (Vitule, 2009) and the characteristics of successful invaders and their impacts on native species have been increasingly known (Espinola et al., 2010; Dos Santos et al., 2011). However, controlling the non-native fishes is difficult, mainly because physical or chemical removal of the invaders is, in addition to its potential adverse impacts on local species, overall ineffective in large ecosystems or for species with high reproductive rates (Garcia-Berthou, 2007; Sato et al., 2010).

Gozlan (2008) evaluated the threats posed by introduced freshwater fishes on non-native aquatic ecosystems. Through his analysis of datasets from the FishBase and from Food and Agriculture Organization (FAO), he concluded that the majority of intentional non-native fish introductions associated with aquaculture and its societal benefits, have not been reported as having an impact on aquatic ecosystems. Consequently, Gozlan (2008) advocated the protection of introductions that have beneficial outcomes and a more systematic ban of species freshwater fish presenting a higher risk.

**CONCLUSION**

As a consequence of its wide environmental tolerance, high reproductive rate, rapid population growth and ease of cultivation, the Nile tilapia has become a model of livestock farming in several countries. However, the same characteristics that make the species attractive for aquaculture render it highly invasive, with considerable potential for becoming a pest in aquatic environments where it is introduced. The risks of tilapia introductions must therefore be rigorously evaluated and weighed against the potential socio-economic benefits.

**REFERENCES**


