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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 Tchad 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.

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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 (Ardjosoediro and Ramnarine, 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 (EIFAC) 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 (Mendonca *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).

Canonico *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 (McCrary *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 becoming 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 on 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

Agostinho, A.A., L.C. Gomes and F.M. Pelicice, 2007. Ecologia e Manejo de Recursos Pesqueiros em Reservatorios do Brasil [Ecology and Management of Fishery Resources in Reservoirs of Brazil]. Eduem Publisher, Maringa, Brazil, Pages: 501 (In Brazilian).

Ardjosoediro, I. and I.W. Ramnarine, 2002. The influence of turbidity on growth, feed conversion and survivorship of the Jamaica red tilapia strain. Aquaculture, 212: 159-165.

Attayde, J.L., N. Okun, J. Brasil, R. Menezes and P. Mesquita, 2007. Impactos da introducao da tilapia do Nilo, Oreochromis niloticus, sobre a estrutura trofica dos ecossistemas aquaticos do Bioma Caatinga [Impacts of the Nile tilapia (Oreochromis Niloticus) Introduction on the trophic structure of the aquatic ecosystems of the caatinga biome.]. Oecologia Brasiliensis, 11: 450-461.

Bentsen, H.B., A.E. Eknath, M.S. Palada-deVera, J.C. Danting and H.L. Bolivar *et al*., 1998. Genetic improvement of farmed tilapias: Growth performance in a complete diallel cross experiment with eight strains of *Oreochromis niloticus*. Aquaculture, 160: 145-173.

Beveridge, M.C.M., D.J. Baird, S.M. Rahmatullah, L.A. Lawton, K.A. Beattie and G.A. Codd, 1993. Grazing rates on toxic and non-toxic strains of cyanobacteria by *Hypophthalmichthys molitrix* and *Oreochromis niloticus*. J. Fish Biol., 43: 901-907.

Beveridge, M.C.M. and D.J. Baird, 2000. Diet, Feeding and Digestive Physiology. In: Tilapias: Biology and Exploitation, Beveridge, M.C.M. and B.J. McAndrew (Eds.). Kluwer Academic Publ., New York, USA., ISBN-13: 9780412800900, pp: 59-87.

Beveridge, M.C.M., 2004. Cage Aquaculture. 3rd Edn., Blackwell Publishing Company, New York, USA., Pages: 376.

Beyruth, Z., C.S.R. Mainardes-Pinto, S.M. Fusco, F.C. Faria and A.L. Silva, 2004. Utilizacao de alimentos naturais por *Oreochromis niloticus* em tanques de terra com arracoamento [Use of natural food by *Oreochromis niloticus* in earthen ponds with feeding]. Bull. Inst. Fish., 30: 9-24 (In Brazilian).

Canonico, G.C., A. Arthington, J.K. McCrary and M.L. Thieme, 2005. The effects of introduced tilapias on native biodiversity. Aquat. Conserv.: Mar. Freshwater Ecosyst., 15: 463-483.

Casal, C.M.V., 2006. Global documentation of fish introductions: The growing crisis and recommendations for action. Biol. Invasions, 8: 3-11.

Costa-Pierce, B.A., 2003. Rapid evolution of an established feral tilapia (*Oreochromis* spp.): The need to incorporate invasion science into regulatory structures. Biol. Invasions, 5: 71-84.

Courtenay, W.R., 1977. Tilapias as Non-Indigenous Species in the Americas: Environmental, Regulatory and Legal Issues. In: Tilapia Aquaculture in the Americas, Costa-Pierce, B.A. and J.E. Rakocy (Eds.). World Aquaculture Society, Baton Rouge, LA., USA., pp: 18-33.

Coward, K. and N.R. Bromage, 2000. Reproductive physiology of female tilapia broodstock. Rev. Fish Biol. Fish., 10: 1-25.

Cox, G.W., 1997. Conservation Biology: Concepts and Applications. In: 2nd Edn., Wm. C. Brown Publ., Dubuque, USA., ISBN-13: 9780697218148, Pages: 362.

Dos Santos, A.F.G.N., L.N. dos Santos and F.G. Araujo, 2011. Feeding morphology of the Neotropical piscivorous fish *Cichla kelberi* (Perciformes: Cichlidae) introduced into an oligotrophic Brazilian reservoir. Rev. Biol. Trop., 59: 1245-1255.

El-Sayed, A.M. and M. Kawanna, 2004. Effects of photoperiod on the performance of farmed Nile tilapia *Oreochromis niloticus*: I. Growth, feed utilization efficiency and survival of fry and fingerlings. Aquaculture, 231: 393-402.

Espinola, L.A., C.V. Minte-Vera and H.F. Julio Jr., 2010. Invasibility of reservoirs in the Parana Basin, Brazil, to *Cichla kelberi* Kullander and Ferreira, 2006. Biol. Invasions, 12: 1873-1888.

Esselman, P.C., 2009. Fish Communities and Conservation of Aquatic Landscapes in Northeastern Mesoamerica. ProQuest Publisher, USA., ISBN-13: 9781109114737, Pages: 120.

FAO, 2002. FAO Yearbook: Fishery Statistics; Aquaculture Production. Vol. 90/2, Food and Agriculture Organisation of the United Nations, Rome Italy, ISBN-13: 9789250047720, Pages: 178.

Fonseca-Alves, C.E., S.C.M.C. Carneiro and V.T. Vidotto, 2011. Reintroduction in nature of giant anteater (*Myrmecophaga tridactyla*) after osteosynthesis of radio and ulna. Biol. Stud., 33: 39-43.

Gall, G.A.E. and Y. Bakar, 1999. Stocking density and tank size in the design of breed improvement programs for body size of tilapia. Aquaculture, 173: 197-205.

Garcia-Berthou, E., 2007. The characteristics of invasive fishes: What has been learned so far? J. Fish Biol., 71: 33-55.

Goudswaard, P.C., F. Witte and E.F.B. Katunzi, 2002. The tilapiine fish stock of Lake Victoria before and after the Nile perch upsurge. J. Fish Biol., 60: 838-856.

Gozlan, R.E., 2008. Introduction of non-native freshwater fish: Is it all bad? Fish Fish., 9: 106-115.

Gozlan, R.E., J.R. Britton, I. Cowx and G.H. Copp, 2010. Current knowledge on non-native freshwater fish introductions. J. Fish Biol., 76: 751-786.

Green, B.W., K.L. Verrica and M.S. Fitzpatrick, 1997. Fry and Fingerling Production. In: Dynamics of Pond Aquaculture, Egna, H.S. and C.E. Boyd (Eds.). CRC Press, Boca Raton, FL., USA., pp: 215-243.

Groombridge, B., 1992. Global Biodiversity: Status of the Earth's Living Resources. Chapman and Hall, London, UK., Pages: 614.

Gupta, M.V. and B.O. Acosta, 2004. From drawing board to dining table: The success story of the GIFT project. NAGA Worldfish Centre Q., 27: 4-14.

Hassanien, H.A., M. Elnady, A. Obeida and H. Itriby, 2004. Genetic diversity of Nile tilapia populations revealed by randomly amplified polymorphic DNA (RAPD). Aquacult. Res., 35: 587-593.

ISSG, 2011. Aliens: The invasive specie bulletin. NewsLetter of the IUCN/SSC Invasive Specie Specialist Group, No. 32. pp: 1-47. http://www.issg.org/pdf/aliens_newsletters/A32.pdf

Kestemont, P., 1995. Different systems of carp production and their impacts on the environment. Aquaculture, 129: 347-372.

Kubitza, F., 2000. Tilapia: Tecnologia e Planejamento na Producao Comercial [Tilapia: Technology Planning and in Commercial Production]. Degaspari Publisher, Jundiai, Sao Paulo, Brazil, ISBN-13: 9788590101772, Pages: 285 (In Brazilian).

Leveque, C., 2002. Out of Africa: The success story of tilapias. Environ. Biol. Fish., 64: 461-464.

Macintosh, D.J. and D.C. Little, 1995. Nile Tilapia (*Oreochromis niloticus*). In: Broodstock Management and Egg and Larval Quality, Bromage, N.R. and R.J. Roberts (Eds.). Chapter 12., Blacwell Scientific Ltd., USA., pp: 277-320.

McCrary, J.K., E.P. Vandenberghe, K.R. McKaye and L.J. Lopez-Perez, 2001. Tilapia cultivation: A threat to native fish species in Nicaragua. Encuentro, 58: 9-19.

McGeoch, M.A., S.H.M. Butchart, D. Spear, E. Marais and E.J. Kleynhans *et al*., 2010. Global indicators of biological invasion: Species numbers, biodiversity impact and policy responses. Diversity Distrib., 16: 95-108.

McKinney, M.L. and J.L. Lockwood, 1999. Biotic homogenization: A few winners replacing many losers in the next mass extinction. Trends Ecol. Evol., 14: 450-453.

Melo, D.C., D.A.A. Oliveira, L.P. Ribeiro, C.S. Teixeira and A.B. Souza *et al*., 2006. Caracterizacao genetica de seis planteis comerciais de tilapia (*Oreochromis*) utilizando marcadores microssatelites [Genetic characterization of six commercial stocks of tilapia (*Oreochromis* sp.) using microsatellite markers]. Braz. Arch. Vet. Med., 58: 87-93 (In Brazilian).

Mendonca, B.S., B.P. Ribas, A.J. Shinohara, I.S.T. Vicente, R.M. Botelho, L.W. Genovez and L.E. Pezzato, 2012. The soy protein as food for tropical fish grown. Proceedings of the 9th Meeting of Animal Science, September 26-27, 2012, Sao Paulo State University, pp: 20-24.

Naylor, R.L., S.L. Williams and D.R. Strong, 2001. Aquaculture: A gateway for exotic species. Science, 294: 1655-1656.

Olden J.D., N.L. Poff, M.R. Douglas, M.E. Douglas and K.D. Fausch, 2004. Ecological and evolutionary consequences of biotic homogenization. Trends Ecol. Evol., 19: 18-24.

Olden, J.D. and N.L. Poff, 2003. Toward a mechanistic understanding and prediction of biotic homogenization. Am. Nat., 162: 442-460.

Peterson, M.S., W.T. Slack and C.M. Woodley, 2005. The occurrence of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus) in coastal Mississippi, USA: Ties to aquaculture and thermal effluent. Wetlands, 25: 112-121.

Phelps, R.P. and T.J. Popma, 2000. Sex Reversal of Tilapia. In: Tilapia Aquaculture in the Americas, Costa-Pierce, B.A. and J.E. Rakocy (Eds.). World Aquaculture Society, USA., pp: 34-59.

Power, M.E., W.E. Dietrich and J.C. Finlay, 1996. Dams and downstream aquatic biodiversity: Potential food web consequences of hydrologic and geomorphic change. Environ. Manage., 20: 887-895.

Sato, M., Y. Kawaguchi, J. Nakajima, T. Mukai, Y. Shimatani and N. Onikura, 2010. A review of the research on introduced freshwater fishes: New perspectives, the need for research and management implications. Landscape Ecol. Eng., 6: 99-108.

Shinohara, A.J., R.M. Botelho, B.S. Mendonca, I.S.T. Vicente, B.P. Ribas, P.L.P.F. Carvalho and L.W. Genovez, 2012. Phytase in diets for Nile tilapia (Oreochromis nilotic). Proceedings of the 9th Meeting of Animal Science, September 26-27, 2012, Sao Paulo State University.

Starling, F., X. Lazzaro, C. Cavalcanti and R. Moreira, 2002. Contribution of omnivorous tilapia to eutrophication of a shallow tropical reservoir: Evidence from a fish kill. Freshwater Biol., 47: 2443-2452.

Toguyeni, A., B. Fauconneau, A. Fostier, J. Abucay, G. Mair and J.F. Baroiller, 2002. Influence of sexual phenotype and genotype and sex ratio on growth performances in tilapia, *Oreochromis niloticus*. Aquaculture, 207: 249-261.

Turner, G.F. and R.L. Robinson, 2000. Reproductive Biology, Mating Systems and Parental Care. In: Tilapias: Biology and Exploitation, Beveridge, M.C.M. and B.J. McAndrew (Eds.). Kluwer Academic Publ., New York, USA., ISBN-13: 9780412800900, pp: 33-58.

Vicente, I.S.T., M.K.H.R. Rocha, B.S. Mendonca and L.R. Faria *et al*., 2011a. Computed tomography in the evaluation of fish nutrition. Proceedings of the 4th International Symposium on Fish Nutrition and Health, September 26-27, 2012, Sao Paulo State University, pp: 20-24.

Vicente, I.S.T., M.K.H.R. Rocha, B.S. Mendon'a, A.J. Shinohara and E. Portilho *et al*., 2011b. Available phosphorus and bone mineralization of Nile Tilapia. Proceedings of the 4th International Symposium on Fish Nutrition and Health, September 26-27, 2012, Sao Paulo State University, pp: 12-15.

Vitule, J.R.S., 2009. Introducao de peixes em ecossistemas continentais brasileiros: Revisao, comentarios e sugestoes de acoes contra o inimigo quase invisivel (Introduction of fish in Brazilian continental ecosystems: Review, comments and suggestions for actions against the enemy almost invisible). Neotrop. Biol. Conserv., 4: 111-122.

Wille, K., E. McLean, J.S. Goddard and J.C. Byatt, 2002 2002. Dietary lipid level and growth hormone alter growth and body conformation of blue tilapia, *Oreochromis aureus*. Aquaculture, 209: 219-232.

Williamson, M., 1996. Biological Invasions. Chapman Hall, London, pp: 244.

Yamamoto, T., 1969. Sex Differentiation. In: Fish Physiology, Hoar, W.S. and D.J. Randall (Eds.). Academic Press, New York, USA., pp: 117-175.

Yi, Y., C.K. Lin and J.S. Dian, 1996. Influence of Nile tilapia (*Oreochromis niloticus*) stocking density in cages on their growth and yield in cages and in ponds containing the cages. Aquaculture, 146: 205-215.