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Item Type	Report
Authors	Mboya, D.O.; Manyala, J.O.; Ngugi, C.C.
Publisher	Fisheries Department
Download date	28/05/2021 05:43:29
Link to Item	http://hdl.handle.net/1834/7351

Fish introductions and their impact on the biodiversity and the fisheries of Lake Victoria.

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Abstract

Recent fish introductions in Lake Victoria have had both positive and adverse implications on its biodiversity and fisheries. This paper reviews the impact of six introductions in Lake Victoria basin with emphasis on areas where the introduced species have put more risks or benefits to the host environments. There have been six introductions of fish species (*Lates niloticus, Oreochromis niloticus, Cyprinus carpio, O. melanopleura, O. leucostictus* and *Tilapia zillii*) in Lake Victoria in a span of 20years. A significant ecological imbalance has been created through the depression of haplochromiine cichlids, changes in food webs and food chains, and alterations of water quality. There is evidence for example, that the introduced *O. melanopleura* has crossbred with *T. zillii* while *O. niloticus* has crossbred with *O. variabilis* with apparent dominance of the introduced species in these hybrids. The native species *(Labeo victorianus, Barbus spp, Haplochromis spp., Protopterus aethiopicus, Bagrus docmac, Clarias spp, Alestes spp, Synodontis spp* and the native tilapia species) have declined considerably in the commercial catches in the last few decades. On the other hand, it has been a great boost to the riparian communities, and Kenya as a whole from the increased commercial fish landings from less than 20,000 m.tons in the 1970's to over 193,000 m. tons in the 1990's. Presently, the introduced *L. niloticus* and *O. niloticus* compose over 70% of the total landings by weight. Fish protein food supply has increased significantly; number of fishermen now is over 36,000 (up from 11,000 in the 1971) with the export sector directly employing over 500,000. Given the dependants as well as those engaged in the auxiliary activities in this sector, the fishing industry currently supports over 1 million people. On the other hand, a significant nutritional loss has also been noted as a result in the decline in the local's favourite fish species (endemic species) in the catch. With the market expansion, the local community have been reduced to low-grade fish, which do not meet the export requirement and fish skeletons. The only native species landed in large quantity is the *Rastrineobola argentea*, which has gained popularity for its use as animal feed. There is urgent need to document all fish introductions in this country with appropriate evaluation of each case from time to time. This evaluation report will contribute to the development of guidelines to introduction programs in future. The need for research in order to better anticipate with confidence the cost of any introductions before such programs are implemented cannot be overemphasised.

Key words: Introductions, Alien species, Endemic species

Introduction

Fisheries' managers all over the world often use stocking, transfer and introduction of fish as management techniques. Types of fish introduction range from stocking with resident species through to release of exotic species. The term "introduced species refer to any species intentionally or accidentally transported and released into an environment outside its present range. In this paper however, one reservation is made with respect to this definition in that a species is considered to have been introduced to a country once it has

crossed national boundaries as adopted by Welcomme (1988). It however excludes the many more introductions made between river basins within national territories.

A total of 1354 introductions of 237 species into 140 countries have been documented world-wide (Hickley, 1994; Pitcher, 1995). Africa has experienced 147 introductions of 50 fish species, 23 of these from outside Africa. In Kenya's freshwater lakes about 14 introductions have received due documentation with 6 introduced species in Lake Victoria, 7 in Lake Naivasha and 1 in Lake Baringo. It is worth noting at this point that this list is far in-exhaustive. The major reasons for the introductions in Kenya's freshwater lakes are:
(i) Enhancement and /or supplement stocks in order to improve the fisheries.
(ii) Recreation (aquarium /ornamental fisheries)
(iii) To provide sport fish to attract tourism
(iv) To fill an apparently vacant niche
(v) Control weeds and disease vectors; mosquitoes and snails.
(vi) Accidental together with other fish or as escapees from fishponds.
(vii) Create a commercial fishery

Introduction of fish species in Lake Victoria basin, like elsewhere in the world, has had both positive and negative implications. On the adverse side they have been accused of eliminating the native species through competition and /or hybridisation as well as altering their gene pools. Farther, they have been reported to cause or initiate ecological imbalance (LVEMP, 1999; Ochumba *et al*., 1994). Without denying the importance of the concern about the adverse effects, a great deal of benefits has been realised due to the introductions and associated developments. It has seen a big boost to the total quantity of fish landed from these lakes and other benefits associated with this have been evident. However, it has been observed that the significance of, and risk associated with, fish introductions depend very much upon the relationship of the candidate species, the type of fishery and fish community into which it is being placed.

Objective: This paper was aimed at reviewing the status of knowledge regarding introductions of fish species in Lake Victoria basin.
Method: Method used in collection of this information include reviews of existing publications, field reports and Frame Survey 2000 report in the department of Fisheries, Ministry of Agriculture and Rural Development.

Fish introductions in Lake Victoria basin

Six exotic species have so far been introduced into the Lake Victoria basin. These are *Lates niloticus, Cyprinus carpio, Tilapia zillii, Oreochromis niloticus, O. leucostictus* and *O. melanopleura* (Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991; Welcomme, 1988). According to Reynolds *et al*. (1995), *L. niloticus* (Nile perch) was introduced in Lake Victoria by officials of the Uganda Game and Fisheries department between 1954 and 1957. This first placement seemed to have been carried out surreptitiously and other two official introductions were made in 1962 and 1963. The Nile perch later found its way through the Nyanza Gulf and by 1982 had colonised the whole lake (Witte &

Dansen, 1995). Okemwa and Ogari (1994), Ochumba *et al*. (1994) and Ogutu-Ohwayo & Hecky (1991) gave an account for the introduction of the tilapiine species as follows. *T. zillii* was introduced to fill an apparently vacant niche of a macrophytophage, whereas *O. niloticus* and *O. leucostictus* were introduced to supplement stocks of the native tilapiines, which had declined due to overfishing. *O. melanopleura* was introduced accidentally from fishponds.

A number of writers, e.g., Okeyo-Owuor, 1999; Abila, 1998; Pitcher & Bundy, 1995; Reynolds *et al*., 1995; Ochumba *et al*., 1994; Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991) have given an account of the introduction of the *L. niloticus* into the waters of Lake Victoria. The main reasons noted are to provide sport fish to attract tourism and improve the fisheries. The perch was introduced supposedly, to feed on the smaller sized haplochromiine cichlids that were at that time abundant but of lesser economic value, so as to convert their biomass into larger table sized fish. Where-as *L. niloticus* and *O. niloticus* have overly established in the lake, *C. carpio* and *O. melanopleura* have not appeared in the catch.

Biological implications of fish introductions

The impact of introduction in Africa has perhaps received a high public profile on account of the concern about the effects of Nile perch on endemic fishes in Lake Victoria. According to Manyala (1999), the early fishery of Lake Victoria (in the 1920s) was dominated by haplochromine cichlids and the endemic tilapiines, the lungfish, catfishes and several cyprinids. Upto the early 1970's, these endemic speci es constituted over 83% (about 564,000 metric tons) of the total demersal ichthyomass in the lake, with an estimated annual potential yield of 200,000 metric tons. Okemwa and Ogari (1994) noted that as the catch rates for the indigenous tilapia i.e., *O. esculentus* and *O. variabilis*, declined in the 1970's due to overfishing, attention was directed to the large quantities of the relatively un-exploited haplochromines. Although never adequately exploited as a fishery, the flock of haplochromine species in L. Victoria was one of the world richest comprising more than 300 endemic species. Ogutu-Ohwayo and Hecky (1991) reported that this diverse group of fishes had undergone adaptive radiation and occupied many trophic levels. It contributed to the understanding of the process of evolution by adaptive radiation and its decimation is a great loss to evolutionary science.

The most prominent biological effects of fishes introduced can be divided in three categories. The first include species that have directly through predation and indirectly through competition depleted or even eliminated resident species. The second include genetically and ecologically related species, which have eliminated others through competition and /or hybridisation. The third includes species that have caused or initiated environmental degradation.

Predation and competition or competitive interactions

Introduced piscivorous fish almost always decimate or even eliminate many of the resident species in their new habitats (Kodhongania & Chitamwebwa, 1995; Ochumba *et al*., 1994; Okemwa & Ogari, 1994; Ogutu-Ohwayo & Hecky, 1991). Nile perch

introduction in Lake Victoria provides a spectacular example of the effects of introducing a large predator into a lake. As the population of Nile perch increased, many native species declined and some completely disappeared. Although the decline may have been initiated by human exploitation, Ogutu-Ohwayo and Hecky (1991) noted that predation by Nile perch certainly contributed to the final elimination of many of the native species**.** Soon after its introduction into Lake Victoria, it was observed that most sizes fed almost exclusively on haplochromine cichlids and a rapid decline of the latter was reported. It was further noted that the landings of other native inshore genera such as *Tilapia*, *Protopterus*, and *Clarias* also declined. By 1980's, the endemic fishes, espcecially the anadromous cyprinids and mormyrids were too scarce to support a significant fishery (Ochumba *et al*., 1994). Manyala (1999) indicated that out of the 300 haplochromine cichlid species which existed in Lake Victoria before the introduction of Nile perch, 200 are thought to be extinct. Arthington (1991) and Fausch (1988) however observed that resource competition for food, and space perhaps mediated by interference and aggression, seems to be one of the most probable mechanisms of the impact of introduced species other than just predation. Currently, the lake has been reduced to a three species fishery of *L. niloticus*, *O. niloticus* and *R. argentea* the with the two species forming over 70% of the total fish landings by weight.

Hybridisation and competition

It has been noted that the tilapiine species form hybrids, and upon introduction, introgressive hybridisation may lead to genetic changes in the surviving species. Such has been reported as a consequence of some introductions followed by other forms of reproductive isolation such as infertility (Krueger & May, 1991). Kudhongania & Chitamwebwa (1995) reported that the establishments of the four exotic tilapiines in Lake Victoria introduced intra-specific competition with the indigenous species and enhanced the likelihood of genetic dilution through hybridisation. Studies on the life history of the indigenous tilapiines in Lake Victoria indicated that availability of suitable spawning sites was the most important factor limiting populations. The native tilapiines were spatially segregated, with the smaller *O. variabilis* being more inshore than *O. esculetus*. When *T. zillii* and *O. leucostictus* became established, they occupied the same habitat as *O. variabilis*. Such competition was also observed for nursery grounds (Ogutu-Ohwayo & Hecky, 1991). Although competition for food among indigenous tilapiines was thought to be insignificant*, O. esculentus* feeding only on planktonic diatoms was at a competitive disadvantage *to O. niloticus*.

Kudhongania and Chitamwebwa (1995) and Ogutu-Ohwayo and Hecky (1991) noted that hybridisation must have led to the restructuring of the tilapiine communities in Lake Victoria. Hybrids between *O. niloticus* and *O. variabilis*, and between *T. zillii* and *O. melanopleura* were identified in Lake Victoria with apparent dominance of *O. niloticus* in the crosses. Similar scenario was observed in Lake Naivasha where mixing of tilapiine *spp*. as a result of introductions appear to have resulted in elimination of some species through hybridisation and /or competition. Hybridisation between *O. leucostictus* and *O. spirulus* was followed by the disappearance, first of *O. spirulus* then the hybrids from this lake. On these grounds it is also suspected that the disappearance of *O. esculentus* and *O.*

variabilis of Lake Victoria could be due to hybridisation and /or competition with the introduced tilapiines especially *O. niloticus* and *T. zillii*. *O. niloticus* was however reported as a superior competitor with its wide food spectrum, high fecundity, faster growth rate longer life span and growth to larger sizes than the endemic *Oreochromis spp*.

Allendorf (1991) observed that the genetic effects of introductions constitute a threat to the long-term existence of many wild populations and species but are often more difficult to detect and monitor than demographic or ecological effects. Separating contributions of hybridisation, competition, and predation and over-fishing to the demise of the endemic *Oreochromis spp*. in the case of Lake Victoria is difficult to ascertain. This is because these processes may happen concurrently.

Ecological alteration

Trophic cascade theory predicts that increased piscivory that may result from introductions, should lead to a reduced phytoplankton and water clarity through a cascade of interactions. A similar cascade effect could be initiated by increasing the abundance of zooplanktivores (Ogutu-Ohwayo & Hecky, 1991). The haplochromines are grazers and feed on the dominant and /or bloom forming blue-green algae and detritus. It has been observed that their absence could partly be responsible for the enhanced algal blooms and detritus accumulation in the deep waters (Manyala, 1999; Ochumba, 1995). Okemwa & Ogari, (1994) also noted this could be a cause of increased de-oxygenation observed in the deep layers. Fish introductions have modified the phytoplankton, zooplankton and fish assemblages in the lake with resultant impact on the water quality. Owing to these, many writers (see LVEMP, 1999; Muli, 1996; Ochumba, 1995; Ochumba *et al.,* 1994) have reported that Lake Victoria fishes are under threat.

Socio-economic impacts of fish introductions

Despite the ecological and genetic outcomes of fish introductions, increases in production have been of much benefit to the people of various parts of Africa. Malnutrition is a concern in many countries. In the vicinity of lakes and rivers, people depend on fish as their cheapest source of animal protein. Nile perch and the Nile tilapia that were introduced into Lake Victoria have so far resulted in tremendous increases in the quantities of fish landed (Reynolds *et al*., 1995; Ogutu-Ohwayo & Hecky, 1991). Some decades have now passed since the original introductions of Nile perch into Lake Victoria waters, and the attendant controversy, far from diminishing, seems to have proliferated almost as rapidly as the fish itself. Sometimes assuming quite sensational, strident and bitter expression, spilling over from professional fisheries' circles into the popular literature and press (Reynolds *et al*., 1995).

Without denying the importance of the concern about ecological and other disruptions to the lacustrine system and dependent human populations, a great deal of development has been realised due to the introductions and associated changes, and that more may be forth coming. Ogutu-Ohwayo and Hecky (1991) reported that the total quantity of fish landed from Lake Victoria has increased between two and six folds following establishment of

Nile perch and the Nile tilapia. In the Kenyan part of the lake, the annual commercial catches increased from 20,000 metric tons in 1977 to 192,740 metric tons in 2000 hitting a peak of over 193,652 metric tons in 1994. The socio-economic benefits can be seen in three basic categories; nutritional benefits, employment benefits and, market expansion and export earnings.

Nutritional benefits

Special emphasis is given to the nutritional welfare benefits that have accrued under the new regime of introduced species of Lakes Victoria for riparian and regional populations. This lake has always served as an important source of fish for those living within the immediate area but its importance to markets across the wide East African region has until recently been relatively minor. With the introductions in Lake Victoria and the conditions developed under the post-Nile perch regime, this situation was transformed**.** This lake now serves as fish supplier not only to broad sections of East African region, but also to overseas markets (Fisheries Department, 1999; Jansen *et al*., 1999; Okeyo-Owuor, 1999; Pitcher & Bundy, 1995). Also to be taken into account is the considerable volume of sun-dried, smoked and salted fish products. These move to remote markets within the three riparian states and as exports to Sudan, Zaire, Rwanda and Burundi.

Pre-Nile perch regimes saw the Lake Victoria fishery shift towards *R. argentea* and the haplochromiines that could not withstand heavy commercial exploitation. With the enhancement of fish stock through introductions, there is no doubt that many new consumers gained tremendously from the changes having effected the rich Lake Victoria fisheries. During the 1980's, high amounts of fish were made available, from this Lake Victoria, at more affordable prices throughout the large portion of the three East African countries (Jansen *et al*., 1999). Abila (1998) observed that the major objectives of introducing the perch into Lake Victoria have been met and perhaps even beyond expectations.

Employment benefits

With the rich Nile perch fishery, opportunities were created for employment and thereby increased participation in the harvesting sector (Jansen *et al.,* 1999). At the production level, Frame Survey 2000 for Lake Victoria indicated that the fishery of Lake Victoria is supporting more operators. Records on the Kenya' s part of Lake Victoria show an increment in the number of fishermen in the harvesting sector from 11,000 in 1971 to 36,159 in march 2000 (Fisheries Department, 2000). The number of canoes has increased to more than double (to 11,515 canoes) over the same period. The effect is multiplied when landing-site activities such as portage, net making and mending, canoe construction and repair, and fish processing and marketing are taken into account.

Market expansion and export earnings

Interests in possibilities for large-scale commercial processing and overseas export of Nile perch fillet first grew in Kenya from around 1985. This country still acts as a host to 12 industrial plant activities linked to the lake. In 1997, about 5.3 mil. tons of Nile perch products valued at over Kshs 863 mil. were exported by fish processing factories based in

Kisumu Municipality alone, with over 57% of the exports going to markets bound by the European Union (Fisheries Department, 1997).

Socio-economic displacement

Increased competition for fresh fish at major landing sites has frequently been noted. This has had the effect of driving up ex-vessel prices and these increases are eventually passed on to the consumer. This tendency is distressing for low-income people, as fish has been in the past been very attractive to buy in comparison with other forms of protein. One outcome of the situation is a move by consumers to seek a low-grade or cheaper fish. These come in the form of undersized or immature Nile perch /tilapia or by-products (skeleton and off-cuts) of the former from fish filleting factories. Competition for the fresh fish gives more fear for stock over-exploitation.

Other impacts

Other kinds of impacts (alleged, or real, likely or remote) have been associated with developments in the post Nile perch regime relates to culture, beliefs and superstitions. Some potential consumers developed real or imagined allergy to the fish flesh. For other different reasons; - medical, taboos, odour, taste, cultural factors and bad believes about Nile perch, some riparian folk resent it to date. In this point of view, they consider its introduction to Lake Victoria an overwhelming loss of the mouth-watering dishes (Osienala 1996).

Assessment of success/ failures of introductions

It is difficult to assess the success for a variety of reasons. The primary problem stated by Allendorf (1991) is that fish introductions are often made without appropriate mechanisms to evaluate if the desired objective(s) is achieved. The evaluations that have been done often ignore possible effects of the introductions on other taxa such as native fishes, amphibians and invertebrates. Exaggerated and undocumented claims of success often made by those responsible for the introductions have been observed to compound the problems.

Geographical and temporal scales of comparison have been used to evaluate successes, but have been observed to present several problems. For example, in many cases, introductions have increased the number of species existing within a particular geographical or political area. Viewed on this narrow scale, introductions may appear to increase biodiversity. However, such introductions also have caused extinction of many species. Thus on a global scale, such introductions reduce biodiversity. The temporal scale is also very important to consider Allendorf (1991). Any beneficial effects of introductions usually occur immediately while the harmful effects are often delayed. Thus, we are always faced with political and economic pressure to embrace short-term benefits at the cost of the long-term well being of an ecosystem.

Another difficulty of scale in evaluating introductions is the units with which we measure success or failure. The desire benefits of introductions are usually some short-term aspects of human well-being (for example food or recreation) or profit. The overall effect

of such introductions often involves these two measures balanced against a loss in biodiversity. This is difficult balance to evaluate, for example how much money is a species of fish worth? How about an endemic invertebrate species? A review of the history of fish introductions all over the world indicates that most purposeful introductions have not achieved their objectives. Most important, any benefits of introductions have come at considerable costs.

General recommendations

From the foregoing, the need to fully understand and minimise threats of introductions before such programs are implemented cannot be overemphasised. The introductions should only be objective driven and appropriate mechanisms of evaluation and monitoring of the desired objectives should be an integral part of this effort. Allendorf (1991) recommended education, co-operation, regulation and research as the key issues when dealing with species introductions. Many passed and current arguments in favour of introductions have been based upon perceived societal demands. The society must realise that such introductions involve a "*cost*" and we do not understand natural systems sufficiently to know what the *cost* will be. There is a need to increase effort to educate the public and management agencies on the limitations and dangers of fish introductions.

Co-operation among management agencies is essential. Unfortunately, management objectives and responsibilities usually are defined upon political rather than the geographical or biological boundaries. Management agencies must consider the potential long-term effects of introductions inside and outside their areas of geographical and taxonomic responsibilities. Management decisions as regards to fish introductions should be done by umbrella management agencies rather than individual states being let to pursue their own agenda. Regulations and policies should be developed and enforced that recognise and encourage co-operation among responsible agencies to protect natural ecosystems. Researches being critical, there is need to be able to better anticipate the effects of proposed introductions. In this context, Waples' rule of introduction of " ***first, do no harm***" has become universally accepted (Allendorf, 1991).

Acknowledgement

To Lake Victoria Environmental Management Programme under whose scholarship this work was done.

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