Impacts of Fish Introduction on Aquatic Environment: a Study with Special Reference to Common Carp/ *Cyprinus Carpio, (Linnaeus, 1758)*

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Abstract: *Fish introduction was practiced for years in the world for economical, social, biological and ecological purposes without consideration of the deleterious impacts on the aquatic environment. The most important environmental impacts caused by fish introduction were competition for resources, predation, disease and parasites, genetic impacts, fish community alternation, physiological changes, impact on other aquatic fauna, habitat alternation and socioeconomic impacts. The impacts of fish introduction were evaluated on the following criteria: species suited to the physico-chemical properties of the intended water body; attractiveness and profitability of the fish to the fishers; fish with good flesh quality for the consumers; and fish that fill a vacant niche to establish balanced community. Fish introduction in Ethiopia started during the Italian invasion and then the practice expanded in many natural and man-made waters. Information on management, status and impact on the aquatic environment were not well documented. The literature review, focus group discussion and field observation indicated that ill-conceived and poorly monitored fish introduction was practiced. As the rule of thumb, well-organized and adequate knowledge on fish introduction management is essential in 'Resource Management Challenged Environments' and for 'Meeting the needs of the society, and keeping the balance of aquatic environment.*

Keywords: Anthropogenic, biodiversity, ecology, exotics, information, management

1. Introduction

Over the past 70 years, large-scale movements of fish, including a total of 1354 introductions of 237 species into 140 countries, have occurred (Cowx, 1994). It has been identified at least 134 fish species had been introduced or relocated within 29 European countries, especially Central and Eastern Europe. Holcik (1991) indicated that poor success was recorded for most as well as measurable ill-effects on native fish and their habitats.

The reasons for introduction of fish are many and varied. European Inland Fisheries Advisory Commission put the reasons into three main categories which are related to the status of the wild stocks, the impact of anthropogenic activities and the ease with which factors limiting natural

production can be removed or ameliorated. Based on these reasons and identified objectives, introduction was carried out for mitigation, enhancement, restoration and creation of new fisheries. A number of transplantation and introductions of exotic species for culture have been made and many of them have established the new environments with very little adverse effects providing important sources of food or recreation.

Indiscriminate introductions that may lead to environmental problems are discouraged and many governments have imposed restrictions on imports. The most important ecological effects of an introduction or transplantation of a species to new environment is its influence on the local plants and animal life /fish species/, transmission of diseases, genetic dilution from exotics, interbreeding with wild fish and altering the genetic make-up of the native fish (Pillay, 1992). Any intended water body for fish introduction should be studied and the scientific information of the fish on economical, biological, ecological, social and environmental values should be considered (Stephanou, 1990). It is now widely accepted in different parts of the world that in the establishment and management of fish productions by introduction requires appropriate studies to determine the need and the desirability (Pillay, 1990).

Introduction programs must share the objectives of effective aquatic ecosystem management in order to provide benefits on a sustainable basis (Dogde and Mark, 1994). The introduction density in terms of the carrying capacity of the ecosystem in consideration of the existing stock biomass and allowances for migration/dispersal, predation and predicted survival of the stocked fish in order to avoid over introduction is the most important issue to be accounted.

There is evidence from experience in several instances that adequately planned release of spawner of hatchery-raised young in sufficient numbers for required periods of time has resulted in remarkable increases in commercial catches. Generally, introduction in rivers and lakes is done to enhance economically important ones or to occupy ecological niches in the fauna. Therefore, these water body systems need appropriate studies to determine the need and desirability for introduction (Pillay, 1990).

Fishes have often been moved from lake to lake, sometimes with the laudable goal of increasing the yield of human food. Except in lakes and man-made reservoirs without fish, such efforts have failed to achieve the desired objectives and sometimes the results have been disastrous. When large lakes whose fisheries are immensely important as sources of human food are involved, especially in areas where other animal protein is scarce, much is at stake. A major scientific objection to such introductions is that the outcome is often unpredictable and irreversible. An additional danger, not considered here, is that introductions may lead to introgression of new genes. This can hamper taxonomic and evolutionary studies and hinder progress in aquaculture, as it is happening among the economically important tilapiine cichlid fishes of Africa (Barel *et al*, 1985).

The Chinese cultured common carp *(Cyprinus carpio*) and goldfish (*Cyprinus .crassus*) for food and ornamentation before the present era (BP) (MacCrimmon, 1968; Balon, 1974). During the past 400 years, carp has been intensively cultured in Europe and introduced into many countries around the world (Balon, 1974). Evidence suggests that the Romans first cultured carp collected from Danube River and expanded it in monasteries throughout the Middle Ages. Although little evidence is available showing that these and others species were purposely introduced into wild environments, there is no doubt that ponds and waterways failed as frequently then as they do in modern times so that cultured fish were released to new environments to start new population (Dogde and Mark, 1994).

Historical, zoogeographical, morphological and physiological information was used in explaining the origins and history of domestication of the *C. carpio*. C. *carpio* are an introduced species throughout most of the world and are generally considered a nuisance and potential pest (Chumchal, 2002). They are important food fish throughout most of the world except in Australia and North America where the fish is considered unpalatable (MacCrimmon, 1968; Balon, 1974)

In Africa, the primary purpose of introductions of fish species was to maintain or increase yields and harvests, sport fish and control of vectors (e.g. malaria). Some introductions met this purpose but others may have compromised long-term sustainable harvests, in part by altering the aquatic

environment and competing with native species. The short-term benefits have been increased fish protein supply in these countries. But more research and assessment are necessary to understand how introductions serve reaching long-term objectives (Oguto Ohwayo *et al*, 1991).

Many fish introductions have been practiced in natural and man- made waters in different parts of Ethiopia including the Amhara National Regional State (Yared, 2010; Shibru and Fisseha, 1981). Specific information of the introduced fish species, management strategies of, status assessment and the impacts of introduced fish species on the aquatic environment are not well-documented in an accessible way for further evaluation. Fish introduction programs have been frequently carried out without much prior thought and planning and with poor knowledge of the biology of the introduced species or of the local fauna (Abebe and Stiassny, 1998). The objectives of this survey were (1) to collect integrated baseline information on current and projected future activities in fish introduction, and (2) to recommend an intervention mechanism in fish introduction to sustain the well-being of the biodiversity and the aquatic ecosystem.

2. Materials and Methods

Relevant literature review, field data, focus group discussion and personal experience (1986- to the present on fisheries management as expert and researcher) to overview exotic fish introduction and indigenous fish translocation to different aquatic ecosystems were employed. Besides, impacts of introduction on the aquatic ecosystems and fish biodiversity with special reference to *cyprinus carpio* (L.1758) were considered. Occasional field work was carried out on Lakes Lego (2013 & 2014), and Maibar (2005 &2006) in South Wollo, Geray reservoir (2012 &2013) in West Gojjam and Lake Zengena (2004 and 2006) in Awi zone. The Focus group discussion (2013) was organized with people in Lake Lego bordering kebeles (05, 12, 15) engaged in fishing activities. Each focus group consisted of eight members selected based on educational status (from illiterate to grade 10 complete), age (19 to 43 years) and fishing experience (1 to 20 years). The focus group discussion was carried out separately in each kebele on the current fisheries problems of Lake Lego. Descriptive statistics was used to analyze the data.

3. Results and Discussion

The surveyed water bodies were introduced with exotic and indigenous fish species (Table 1).

The abundance of introduced fish species in the surveyed water bodies varied spatially. *C.carpio* dominated in the surveyed water bodies followed by *O.niloticus* and *T.zilli*. The proportion of *C. carpio's* dominance on the surveyed water bodies except Geray reservoir was observed (Table 2). The focus groups' discussion carried out on the Lego fisheries problem emphasized that deterioration of the fishing activities was worsened after unintentional introduction of *C. carpio* from Lake Ardibo's irrigation canal through Ankerkeha River. The focus groups' discussion also expressed that there were various problems on the Lego ecosystem such as wetlands degradation, monofilament gillnets use with very small mesh size up to four centimeter against the allowed lowest, ten centimeter mesh size, open access fishery activities that created 'Too many boats chasing too few fish'" situation that resulted the deterioration of the Lego fishery from time to time.

Table 1. Surveyed water bodies and fish species abundance

Water bodies	year	Fish species	caught in number	Total species caught	% Species caught
Lake Lego	2013 & 2014	O. niloticus	6	61	9.84
		C. garipinus	4		6.56
		C. carpio	51		83.60
Maibar	2005 & 2006	O.niloticus	109	432	25.2
		C.carpio	323		74.8
Zengena	2004 & 2006	T. zilli	1	26	3.85
		C. carpio	25		96.15
Geray	2012 & 2013	O. niloticus	86	144	59.72
		C. carpio	58		40.28

Ethiopia has 172 freshwater fish species (Froese, R. and D. Pauly, 2014). The freshwater fish species comprises of 39 endemic and 11 introduced (Table 2). Fish introduction activities started in the Ethiopian aquatic ecosystems during the Italian invasion. The introduction of Eastern mosquito fish /*Gambusia holbrooki* in Lake Tana for control of malaria and northern pike /*Esox lucius*/ for fishery enhancement is a typical example practiced during the Italian invasion. Exotic fish introduction and translocation of indigenous fish species for enhancing fisheries in lakes, reservoirs and small water bodies have been practiced broadly since 1975 through the Sebeta Fish Breeding and Research Centre, now a research wing of the Ethiopian Institute of Agricultural Research.

Table 2. Introduced fish species in Amhara Region

Water body	Introduced species

	native	exotic
Lake Lego	*O.niloticus & T.zilli*	*C. carpio*
Ardibo	*O.niloticus & T.zilli*	*C. carpio*
Golbo	*O.niloticus & T.zilli*	*C. carpio*
Maibar	*O.niloticus & T.zilli*	*C. carpio*
Tirba	*O.niloticus & T.zilli*	
Bahir Giorgis	*O.niloticus & T.zilli*	*C. carpio*
Zengana	*O.niloticus & T.zilli*	*C. carpio*
Lai Bahir	*O.niloticus & T.zilli*	*C. caprio*
Tach Bahir	*O.niloticus & T.zilli*	*C. carpio*
Geray reservoir	*O.niloticus & T.zilli*	*C. carpio*
W asha reservoir	*O.niloticus & T.zilli*	*C. carpio and C.carassius*
Ango-Mesk reservoir	*O.niloticus & T.zilli*	*C. caprio*

Source: Yared Tigabu Ecohydrology and Hydrobiology 2010

The different water bodies found in different regional states of Ethiopia were introduced with different exotic and native fish species (Yared, 2010). Common carp /*Cyprinus carpio*/ is most dominantly introduced exotic fish species in many parts of Ethiopia (Yared Tigabu 2010). Even though C. carpio was widely introduced in Ethiopia, little was known about its reproductive biology (Mathewos,u 2013). Adequate information on introduced fish species, strategies of management, assessment of current status and the impacts of introduced fish species on the aquatic environment is not well-documented in an accessible way for further evaluation and monitoring (Abebe and Stiassny, 1998).

The Fisheries Legislation Proclamation No. 315/ 2003 of Federal Democratic Republic of Ethiopia and Fisheries Legislation Proclamation No. 92/2003 of the Amhara National Regional State were declared to manage fisheries resources. The two proclamations by the same token share common objectives: conservation of fish biodiversity and environment, making use of fisheries' resources with appropriate fishing gear and preventing as well as controlling of overexploitation of the fisheries resources. They also create enabling environment for fisheries' development to have proper contribution to speed economic growth through the expansion of aquaculture development in natural and man-made water bodies. Besides, they increase the supply of safe and good quality fish and ensure a sustainable food security. They also create conducive environment to get economic benefit and job opportunities.

In reality, these Fishery Legislation Proclamations (No. 315/ 2003& No. 92/2003) were not implemented to alleviate the fisheries problems that have been observed for years. The conservation of freshwater biodiversity and the freshwater aquatic environment are managed in a 'Business –as- usual' context. There are numerous ways in which fish introduction activities can harm the native fish stocks in particular and the aquatic ecosystem in general. Based on a review of relevant scientific literature, the more common impacts of fish introduction in general and *C. carpio* introduction in particular have been identified and summarized as follows.

1. Competition for Resources: Aquatic macrophytes are integral to ecosystem functioning through their provision of habitat for phytophilic zooplankton and refuge for planktonic species from fish predation (Perrow et al., 1999). *C. carpio* indirectly reduce abundance of other fishes through reductions in spawning and nursery habitats. They disturb the benthic sediments of freshwater lakes and slow-flowing rivers during feeding, disrupting the production of aquatic invertebrates and damaging aquatic macrophytes, especially the delicate species (Cahn 1929; Crivelli 1983; Fletcher et al. 1985; Pinto et al. 2005).

2. Predation: Introduced species can reduce or eliminate native species through predation at any life stage of the native fishes (He and Kitchell, 1990; Arthington, 1991). Based on a review of several inland lakes in Québec, Chapleau *et al* (1997) suggested that piscivory by introduced fishes was probably responsible for the local extinction of many small-bodied fishes. Conversely, predation by indigenous fishes can be important in suppressing an introduced or invading species (Christie *et al*., 1972). *Cyprinus carpio* is regarded as a serious pest because of its disturbance of the habitat, its ability to occupy a wide variety of habitats, and its predation on the eggs of other fishes. Carp also reduces zooplankton and macro invertebrate populations by predation and by eliminating macrophytes that provide cover.

3. Diseases and Parasites: Fish introductions have been associated with the transfer of diseases and parasites to new aquatic ecosystems in different regions (Arthington, 1991; Fernando, 1991; Holcik, 1991). The potential consequences of introducing disease or parasites include direct mortality, establishment of a reservoir of infection, reduced performance and increased

sensitivity to stressors (Goede, 1986). Introduction of exotic species could have catastrophic socioeconomic consequences if it involves negative impacts, and particularly the occurrence of new disease or the genetic deterioration of cultured brood stocks.

4. Genetic Impacts: Introgression, the transfer of genetic information from one species to another through hybridization and repeated backcrossing, is a common phenomenon. Hybridization reduces the effective population size of the native species thereby increasing the incidence of inbreeding leading to the potential for eliminating unique genomes or producing undesirable changes in allelic frequencies. Interspecific hybridization can result in infertile hybrids having intermediate characteristics of the parents (Arthington, 1991; Ferguson, 1990; Verspoor and Hammar, 1991).

In Australia, hybridization between two or possibly more imported varieties of the European carp, Cyprinus carpio, has given rise to the vigorous and aggressive "Boolara" strain which spread explosively in the 1960s and 1970s, becoming far more widespread and problematic than the other originally introduced stocks which remained confined to their original sites of introduction. The tendency to cause a general decay in water quality and the high fecundity of carp has caused them to be generally regarded as a nuisance (McCrimmon, 1968).

5. Physiological Changes: Maturing at small size with large number of oocytes is one of the physiological advantages of the traits of the carp which appear to have provided their population with resilience to the exploitation by providing rapid growth to maturity and the opportunity for early life reproduction prior to their capture. The establishment and year round reproduction of C.carpio in a tropical environment with high fecundity has shown that introducing the species to other natural lakes with prior indigenous fish can threaten their ecology (Mathewos, 2013).

6. Fish Community Alteration: The introduction of a new species can upset the natural balance of the fish community and create ecological instability. A typical example of the disastrous effects of introducing species is available from Lake Victoria, the world's largest tropical lake. In the 1970s, there were over 300 endemic cichlid species, representing 99 per cent of the lake's fish species. The physical and biological properties of the lake changed considerably since the

introduction of the exotic fish, Nile Perch (*Lates niloticus*). The majority of cichlids endemic to the lake became extinct and now the group represents only one per cent of the lake's fish diversity. This can be manifested in terms of altered growth and survival of indigenous fishes, and decline in the yields of fisheries which are sought (Ogutu-Ohwayo & Hecky, 1991; Stiassny, 1996).

C. carpio are distributed worldwide and considered one of the most wide-spread, detrimental invasive species (Lowe *et al*, 2004) because of their ability to attain extreme densities (up to 1000 kg/ha) (Panek, 1987; Koehn, 2004) and alter freshwater ecosystems (Weber & Brown, 2009). Introduction of the notorious *C. carpio* into the waters of the United States has caused great ecological damage to the environment and population of desirable native fishes (Stroud, 1975). Centrarchids can experience reductions in growth and survival in the presence of *C. carpio* (Wolfe *et al*, 2009), and inverse relations between *C. carpio* and some fishes have been documented (Jackson et al. 2010).

7. Impacts on other Aquatic Fauna: There is also evidence to indicate that some fish introductions have had a pronounced impact on other aquatic fauna by reducing or eliminating the numbers of large-bodied epibenthic-limnetic taxa including amphibians and invertebrates (Bradford *et al*., 1998). *C. carpio* reduce macrophyte biomass in three ways: 1) Bioturbation- Carp often uproot aquatic macrophytes when feeding, 2) Direct Consumption- Carp have been known to feed on tubers and young shoots, 3) Indirectly by increasing turbidity which in turn limits the available sunlight (Fletcher *et al*., 1985; Lougheed *et al*. 1998).

8. Habitat Alteration: Exotic fish introductions can also produce more subtle changes to the ecosystem, including habitat conditions, which can impact on native species. *C. carpio* is one of the more obvious nuisance species with respect to habitat modification and increase of turbidity (Welcomme, 1988). In the United States, Europe, India, South Africa and Australia, carp has acquired a reputation for causing the degradation of aquatic habitats and water quality (Crivelli, 1983; Fletcher *et al.*, 1985; Welcomme, 1988; Khan *et al.*, 2003).

The behavior of carp is believed to increase turbidity levels by re-suspending sediments and the fish excrete nutrients contribute to accelerated eutrophication (McClaren, 1980; Williams *et al.*, 2002; Miller & Crowl, 2006). Carp act as "nutrient pumps" when they consume the nutrient rich benthic sediments and then excrete those nutrients back into the water column in a form that is available to other organisms (Hestand & Carter, 1978; Welcomme, 1984).

9. Socio-economic Impact: Impacts of exotic fish introduction do not only concern biological and ecological parameters, but also directly or indirectly affect socio-economical factors. In Lake Victoria, fishery was based on the use of small mesh gill nets before introduction of *Lates niloticus*, as most of the captured fishes were small cichlids. When these native species declined and got replaced by Nile perch, eight million people in Kenya, Uganda and Tanzania who depended on this lake for food were affected and induced a shift from subsistence fisheries to commercial operations for export leaving many in vain (Stiassny, 1996). Sociological impact is not an easily quantifiable parameter. In the present context, the introductions have resulted in a significant contribution to the protein supply to the poorer people and a significant number of job opportunities have been created or lost as a result of the introduction.

C. carpio has been the keystone of many aquaculture development projects and has been introduced into different regions from several sources on several occasions. The introduction of fish in many African countries has positive impacts on food supply and protein supply. Carp are an important food fish throughout most of the world except in Australia and North America where the fish is considered unpalatable (McCrimmon, 1968). The fishery has benefited from the presence of carp (*Cyprinus carpio*) apart from the increase in fish biomass. Carp are considerably large, easier, to catch and preferred species to the native fish in most areas, especially in the highlands (Coates *et al.*, 1995).

4. Conclusion and Recommendation

Knowledge-driven exotic fish introduction and indigenous fish translocation should be considered to decide the trade-offs of fish introduction activities. Prior studies are very essential to generate and to have clear understanding of the future fish introduction and translocation management for various purposes. Scientific interventions to reduce spread of disease and

parasites, genetic dilution, habitat alternation, resource competition, biodiversity conservation, sustenance of livelihoods and sustainable aquatic resource management for the present and the next generations is critical. Ogutu-Ohwayo *et al* (1991) emphasized exotic fish introduction needs regulation and guidelines. As a result of the dangers and risks caused by introductions, many European countries have introduced measures to control them (Holcik, 1991).

Fish introduction practices in Ethiopia have been frequently carried out without much prior thought and planning and with inadequate scientific knowledge of the biology of the exotic fish species, the native fish, and the local fauna in the aquatic system and the possible impacts that emerge after introduction. The attempts to evaluate the success or failure of fish introduction practices in Ethiopia are handicapped by poor statistics and inadequate information. Unplanned and inadequately monitored exotic fish introduction and indigenous fish translocation should be regulated by the Fisheries Legislation Proclamations No. 315/ 2003 and No. 92/2003. The fish introduction going on 'Businessas- usual' should be based on appropriate precautions and research directed.

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