Universal Journal of Environmental Research and Technology
 eISSN 2249 0256
Available Online at: www.environmentaljournal.org
Volume1, Issue 2: 115-123

Open Access Review Article

A Review on Translocation and Management of Genetic Resources of Commercially Important Aquaculture Finfishes

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Abstract:
Carps, Salmonids, Nile tilapia and Clariids constitute about 90 % of total finfish aquaculture production and cultured in different territorial regions around the world. Even though some of the new introductions haven't been successful, aquaculture production of these species stretched beyond their native territories and resulted in many folds due to sheer new introduction. In Europe, genetic resources of newly introduced species are being relatively well managed in comparison with African and Asian countries. Though, Access and Benefit Sharing system (ABS) clearly guides new translocations and resolve the issue of benefit sharing between various stakeholders, these guidelines are often found to be ignored. Introduction of alien species to any environment poses threat to the integrity of ecology, biodiversity and genetic intrusion with wild stock. Giving adequate importance to proper management of genetic resources is one of the sustainable approaches to restore the ecological equilibrium.

Keywords: Biodiversity, Exchange of genetic material, Finfishes, Genetic resource management.

1.0 Introduction:
Introduction of alien species to new environment is in practice since centuries. The primary aim of such exchanges is to achieve higher productivity through acclimatization of new species which may be profitable than the native one. Such exchanges significantly encouraged modification of genetic resources through hybridization and other genetic engineering processes like polyploidy techniques. Thus, ever growing demand for increased production has always put pressure on diversity of population. Hence, it is important to conserve and judicious utilization of genetic diversity for the benefit of all stakeholders which could be possible only through systematic and sophisticated genetic resource management. Considering the importance of global biodiversity that to be protected and improvement of sustainable food production, the international community (Commission of Genetic Resources for Food and Agriculture) has emphasized the issues of genetic resources in animals (CGRFA 2007a), terrestrial crops (CGRFA 2009) and now it is the right time to consider and concentrate on the aquatic farming animals due to high demand (CGRFA 2010 and CGRFA 2007b).

The effort has begun from United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, in 1992 which resulted in establishment of the Convention on Biological Diversity (CBD). Three major objectives with which CBD came into picture were, to promote the conservation of biodiversity, the sustainable use of its components and equitable sharing of benefits coming from the utilization of genetic resources through the Access and Benefit Sharing (ABS) system. 'Bonn Guidelines' of Convention on Biological Diversity 2002 adopted to implement ABS system that include rules of access and benefit-sharing process, with a clear emphasis on the compulsion of users to seek the prior consent of the providers. It also explains other issues like incentives, accountability, varification, dispute settlement, material transfer agreements, monetary and non-monetary benefits. Considering the mandate of the Johannesburg World Summit on Sustainable Development (2002), the Conference of the Parties decided to form an international framework on ABS which formally initiated from 2005.

Table 1: World Aquaculture Production by Species Groups in 2008 (Source: FAO Yearbook 2008)

Species	Quantity (Tons)	Value (USD 1000)
Carps, barbels and other cyprinids	20, 593, 403	26, 694, 905
Tilapias and other cichlids	2, 797, 819	4, 021, 164
Clariids and other miscellaneous freshwater fishes	5, 359, 290	9, 799, 669
Salmons, trouts, smelts	2, 295, 523	10, 669, 95
Sturgeons, paddlefishes	25, 683	105, 339

Carps, salmonids, tilapia and catfishes contribute more than 90% of total finfish aquaculture production in the world and which is worth of approximately US$ 50,000,000,000 in 2008 (Table.1). The present review throws light on major historical exchanges of genetic resources of these species across different territories and their management patterns. Effect of translocation on genetics and biodiversity, its conservation, access and benefit sharing of genetic resources among different stake holders and impact of new introduction on ecology are also briefly discussed.

2.0 Common carp *(Cyprinus carpio L.)*

Common carp (Fig.1) is one of the oldest domesticated fish species for food in the world (Balon, 2006). It is naturally distributed over a large part of Asia and Europe and also has been introduced in other parts of the world. At present, the species is being produced in more than 80 countries and total world production reached 2.9 million ton in 2009 (FAO 2009a) contributing to 9.9% of total global freshwater aquaculture. The common carp was introduced to Indonesia from China in the 18th century. Subsequently introduction of common carp strains (Galician, French and German strains) took place from Taiwan and Europe. By early 1900s, majority of introduced strains were well adopted and widespread throughout Indonesia. Successive hybridization of these strains to improve production traits resulted in several local Indonesian common carps such as Maalaya, Punten, Sinyonya, Cangkringan, Rajadanu, Wildan and Szarvas (Emmawati *et al*., 2005).

The first introduction of common carp in Thailand took place 80-100 years ago and now it is one of the very well established species for culture (Pongthana, 2005). Similarly in India, Prussian strain (1937) and Bangkok strain (1957) were introduced to utilize pond bottom food resources in polyculture and at present the strain is an integral part of Indian freshwater aquaculture (Reddy 2005). Amur common carp from Hungary introduced in late 1990s has gained wide acceptance among farming community for its desirable traits like late maturity and high compatibility with other carps in composite culture (Basavaraju *et al*., 2003). The three introduced varieties of common carp in Vietnam are the Hungarian scaled, Hungarian mirror and Indonesian yellow varieties which are now commonly cultured throughout country (Dan *et al*., 2005). Introduction of alien fish species (Chinese common carp) in Bangladesh has started in 1960. Later in 1995, a new strain of common carp from Vietnam was introduced with an objective of higher fish production (Hussain and Mazid, 2005).

Fig. 1: Common Carp

Japanese succeeded in producing many new varieties through inter-specific hybridization. In 1960, the mirror carp introduced from Germany and hybridized with Koi carp had lead to creation of a new variety. Till date, Japanese have bred approximately 100 varieties. The koi carp originated from Chinese red common carp was introduced to Japan as early as 19^{th} century. In 1973, the Japanese koi carp was translocated back to China and now China is produces Koi carp on a very large scale (Lou, 2001). European strains of common carp are wild origin and have undergone continuous genetic improvement programmes. Wide range of Carp genetic resources are available like pure breeds, unselected and selected strains, hybrids, and genetically altered forms (e.g. triploids, gynogenetic, androgenetic, all-male progenies, all-female progenies and XX neomales). Extensive exchange of pure breeds and crossbreeds is evident within European countries as well as outside the Europe (Jeney and Jian, 2009). The Database on troductions of Aquatic Species (DIAS) lists more than 120 common carp introductions (FAO 2009b).

2.1 Management of Carp Genetic Resource Exchange:

International exchange of genetic resources is regulated by International law (Bartley *et al*., 2007). From the technological point of view, there are no major technological limitations/ constraints to the genetic material transfer of common carp. However, epidemiological and ecological concerns are the major issues against the transfer among different countries and continents. In Europe, the principle of zoning or water catchment area is imposed to monitor the transfer/movement of carps among countries Infestation of Koi Herpes Virus in Europe and in some parts of Asia is an alarming illustration of uncontrolled exchange of carp genetic resources. In addition, contamination of natural water bodies caused by the deliberate introduction of common carp in Australia is an example for the ecological impact of introduction of non-indigenous species. Therefore, good genetic resource management needs to be promoted to avoid negative impacts on biodiversity and environment. In addition to this, developing strategies for the conservation and utilization of genetic resources of common carp in Asian countries is the need of the hour. The development of a uniform methodology and approach for characterization of common carp genetic resources is a fundamental need for the exchange of genetic resources (Jeney and Jian, 2009).

3.0 Salmonids

Salmonid genetic resources are extensively translocated and well documented. Among the salmonids, Atlantic salmon *(Salmo salar)*, Rainbow trout *(O. mykiss),* Coho salmon *(O. kisutch)*, and Pink salmon *(Oncorhynchus gorbuscha)* are translocated extensively due to their food, sport and economical importance. Rainbow trout (*Fig.3*) is the most widely and successfully translocated species among salmonids (Froese and Pauly 2009). Fish Base (www.fishbase.org) lists that among 125 translocations, 81 are considered as 'established'. *O. mykiss* is listed as 'one hundred of the world's worst invasive alien species' due to the negative impact of introductions on native species (Lowe *et al*., 2000).

Fig.2: Atlantic Salmon

Fig.3: Rainbow Trout

Fig.4: Coho Salmon

Similarly, coho salmon (*Fig.4.*) is one of the most widely and successfully translocated species of the genus *Oncorhynchus* in the world. First translocation of coho salmon into the Great Lakes occurred as early as 1870s. Further efforts around 1960s were very successful (Sandercock, 1991). However during 1970s, transplantations of coho salmon from the State of Washington into rivers of South Korea and to several rivers in Hokkaido, Japan were not successful. Although, 1.3 million eyed eggs were transplanted between 1968 and 1971 into Chile, no success was reported (Basulto, 2003). In spite of that, since 1990s onwards, several transplants have taken place for both ranching and aquaculture purposes (Soto *et al*. 2001).

Atlantic salmon (*Fig.2.*) was transferred at the beginning of the twentieth century from the east coast of Canada to USA and the Canadian Pacific coast (McKinnell *et al*., 1995). Transplants to New Zealand and Australia from UK, USA and Germany between 1864 and 1910 have been successful (Welcomme, 1988). *Salmo salar* was also translocated in the mid-1960s to Tasmania, Australia. Importantly, introduction of Atlantic salmon from Norway and Ireland into Chile has been very successful as Chile has become one of the leading producers of Salmon. Similarly, pertaining to translocations of other species such as Sockeye salmon, Chinook salmon are also well established (Emery 1985 and Crawford, 2001). Transplantation of pink salmon has been a limited success due to unfavorable environmental conditions and predation during freshwater and oceanic migration phases (Withler, 1982). Transplantation of chum salmon started in 1932, during which stocks from Russia to Finland and Norway were introduced (Holcik, 1991). Meanwhile, decades of overfishing has threatened the population of chum, coho, chinook, sockey salmon and stealhead trout (FWS 2009). Conservation efforts such as decrease in harvest of both abundant and threatened species and permitting increased spawning escapement of some stocks has prompted the recovery of the population.

3.1 Management of Salmonid Genetic Resource Exchange:

Distribution of salmonid genetic resources has been expanded beyond their natural territories within northern and also into the southern hemisphere. That is why Chile, Australia and New Zealand are practicing salmonid aquaculture (Solar, 2009). Among the salmon producing countries, Norway and Chile have a large share of their economy associated with salmon fisheries. The trade of salmon and trout among fisheries commodities has 11% increased since 2000. It is anticipated that the demand for farmed salmon increases steadily in the coming years since developing countries are turning out to be the potential markets (FAO 2008).

Since salmonid exhibit strong homing instinct, they are particularly vulnerable to habitat destruction in freshwater and the intense fisheries at sea. As a result, genetic resources of salmonids are depleting. Wide range of stakeholders concerned about salmonid genetic resources include local aboriginal communities, major industrial fishing companies, international farming companies and biotechnological/pharmaceuticals corporations. Among them, corporates are highly concerned over the possible loss of access to salmonid genetic material and benefit sharing with other stake holders. Several examples or case studies on the access, use and conservation of salmon genetic resources are discussed (Greer and Harvey, 2004, Rosendal *et al*., 2006 and Olesen *et al*., 2007). They discussed the underlying principle behind the access to wild and improved breeding material, patent legislation aimed to protect biotechnological innovations of improved genetic material through expensive research and development. Olesen (2007) stresses the importance of common systematic legislation for access to aquatic genetic resources. Otherwise the genetic resources developed will be used by others in different ways and protection and control of access might become difficult. Thus, the original owners or developers of the resource may be denied deserved benifits.

4.0 Nile Tilapia

Natural distribution of genetic resources of Nile tilapia (*Fig.5*) is the river Nile and its tributaries. The other aqutic systems of Nile tilapia distribution include lakes, sub-Sahelian watersheds of west Africa, rivers like Niger, Volta, Gambia and Senegal (Trewavas, 1983). Within Africa, tilapia was introduced in various regions for promoting aquaculture and to develop new fisheries (Philippart and Ruwet, 1982).

Global transfer of Nile tilapia (*Oreochromis mossambicus*) for aquaculture into Asia is dated back to the late 1940s (Smith & Pullin., 1984). Even though many tilapia species have been introduced into Asia and South America over the years, only *O. niloticus* became the most dominant species. A founder stock from Egypt in 1962 was transferred to Japan and the descendents are transferred to Thailand in 1965 and from there to the Philippines in 1972. This 'strain' is still in use by the tilapia farmers in Thailand and Philippines (Eknath *et al*., 2009). Similarly, a shipment containing 60 individuals of unknown parentage have been introduced to Brazil in 1971 which became founder population.

Fig.5: Nile Tilapia

Fig.6: Gift Tilapia

4.1 Management of Tilapia Genetic Resource Exchange:

Many natural populations of tilapia in Africa are under severe threat of irreversible change due to habitat disturbance, overfishing, neglected and irresponsible fish transfers. The stocks introduced were of unknown origin and almost invariably derived from the introduction of small numbers of fish stock. This has resulted in genetic deterioration due to inbreeding and introgression of genes (Pullin, 1988; Pullin and Capili, 1988; Dey and Eknath, 1997). In 1988, in order to uplift the genetic quality of tilapia, the Genetic Improvement of Farmed Tilapia (GIFT) project was implemented by the International Center for Living Aquatic Resources Management (ICLARM) (now the WorldFish Center). Contribution of GIFT project in improving the genetic quality of tilapia has been tremendous (*Fig.6*). The genetic gain achieved per generation across five generations of selection for growth performance was approximately 12-17%. The accumulated genetic gain in relation to the base population was 85% (Eknath and Acosta, 1998; Eknath *et al*., 1998). ICLARM conducted a meeting in 1992 to draw the strategies for better management of genetic resources which include advanced breeding approaches that will benefit small-scale and poor fish farmers. To mention other relevant recommendations (i) continuation of collection of wild tilapia genetic resources in Africa to include them in the ongoing breeding programmes, (ii) compensation to the African contribution of tilapia germplasm to the GIFT, (iii) developing a genetic resource database which could be informative to all stakeholders (Table. 2). Cataloguing has been initiated through a database called 'fishbase', which also incorporates a tilapia strain registry (Eknath and Hulata, 2009).

5.0 Clariids:

Catfishes are major aquaculture species which are reported in more than 30 countries with a total production of over 3,00,000 t worth nearly US$400 million in 2009. Most production involves the African catfish *Clarias gariepinus* and three Asian species; *Clarias batrachus, Clarias macrocephalus* and *Clarias fuscus* (Na-Nakorn and Brummett, 2009). Since Clariids are air-breathing fishes, translocation was easy task and took place with high frequency especially within African countries. The most widely introduced clariid is *C. gariepinus* throughout Africa, Asia and to a lesser extent in Europe and Latin America. In Asia, *C. batrachus* and *C. macrocephalus* have been introduced from Thailand to many countries such as China (Ma *et al*., 2003), the Philippines, Taiwan, USA and Hong Kong (FishBase). However, it has been reported that introduction has negatively impacted by causing loss of endemic cyprinids in Lake Lanao, Mindanao and for the displacement of native *C. macrocephalus* in Luzon. *Clarias fuscus* from China was introduced to Hawaii during the 1800s and now it became commercially important species as there is high demand for live fishes sold on the banks of the pond (Szyper *et al*., 2001).

5.1 Management of Clariids Genetic Exchange:

Usually, translocations within countries take place without documentation. Only anecdotal reports, if available, are the main source of information regarding such translocations within countries. Unscientific introduction of *Clarias gariepinus* in India is a real threat to the native species in inland water bodies (personal communication). Although it is illegal in many countries to free movement of stocks among water bodies or to introduce them to areas where they are non-indigenous, such regulations are often ignored with respect to clariids (Na-Nakorn and Brummett, 2009).

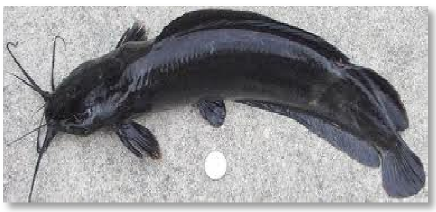

Fig. 7: ***Clarius batrachus***

Fig. 8: ***Clarius gariepinus***

Table.2: Summary of Worldfish GIFT Multiplication and Distribution by Country (Ponzani *et al.*, 2010)

Country (Organization or Institute)	No. of hatcheries that received GIFT	Percentage of market that are GIFT	Percentage of market that are GIFT
Bangladesh (BFRI)	48	150-160 million (monosex)	95 (approx.)
Bangladesh (BRAC)	No information (supplied to own hatcheries)	No information	15 million (approx.; no percentage)
Brazil (Universidade Estadual de Maringa)	54 private; 24 public	78,000 (approx.)	15 (approx.)
China (FFRI)	11	300 million	80
Malaysia (DoF)	36	111,300	10
Philippines (GIFT Foundation)	None after 2002	None after 2002	3
Philippines (TGA Farm)	3 (under TGA)	5 million per month	40
Sri Lanka (NAQDA)	No information	No information	90
Thailand (Pathumthani Fisheries Test and Research Center)	292	14,773,947	75
Vietnam (RIA 1)	100	200,000,000	Northern Vietnam - more than 80% Southern Vietnam - less than 30%
Vietnam (RIA 2)	1	500,000	No information

6.0 The Impact:

Common carp, Salmonids, Tilapia and Clariids altogether contributes substantially to aquaculture production and hence add majorly to the GDPs of the respective nations, particularly in developing countries. Many folds of growth in aquaculture production of the world within the time frame of two or three decades, would never have been achieved without the exchange of genetic resources. Exchange of genetic resources will be best achieved through appropriate coordination of consortia of countries that own the resources. It is evident that translocations in aquaculture have been beneficial from food production and livelihood point of view with only few exceptions (Crivelli, 1995 and Gozlan, 2008).

6.1 Consequences of Translocation on Genetics and Biodiversity:

Translocation of new species raises much concern due to its potential threats on both native biota and environment. Translocation of non-native species may pose problems such as spread of diseases, competition with indigenous species and genetic contamination. Consequences may appear where genetic introgression can compromise reproduction of the pure species and lead to species extinction (Allendorf and Luikart, 2007). To illustrate, a decline in overall fecundity of *Clarius* and subsequent reduction in wild stocks has been observed (Na-Nakorn and Brummett, 2009). Hybrid variety resulted after translocation may also be compromised in terms of fitness and immunity (Euzet and Pariselle, 1996). Introgression of gene pools of introduced species into local species due to interbreeding will risks the wild genetic material for future fisheries and aquaculture ventures. However, benefits of translocation are vividly visible in terms of enhanced production and livelihood security in many countries (Crivelli, 1995; Gozlan, 2008).

The biodiversity is not only threatened by these interspecific and intergeneric hybrids, but also through the escape of cultured populations to nature affecting the conspecific wild populations. The consequences have been literally brutal in case of escape of culture stocks of salmonids to the wild populations in Europe (Hutchinson, 2006). Escape of genetically modified (GM) Atlantic salmon in wild exhibiting violent and competitive nature, had severely threatened existence of wild population (Nayer *et al.*, 2005). Even if hybrids between escapees from aquaculture and wild fish exhibit higher than average fitness in the local environment, a genetic variability can be attributed to slight loss of less well-adapted genes from the wild population (Hartl, 1980; Stearns, 1992). It is also important to note that, threat to the existence of wild biodiversity depends largely on the stability of the ecosystem in which the species or population inhabits (Stearns, 1992). The translocation and introduction of non-native species in aquaculture are controversial and have attracted much attention (Moyle and Leidy, 1992; Gopal, 2005; De Silva *et al.*, 2006). The Access and Benefit Sharing (ABS) system which regulates the utilization and other types of access to genetic resources systematically guides both providers and users of genetic resources. This system emphasizes the obligation of users to seek prior consent of the providers. The guidelines also address the elements, such as incentives, accountability; means of varification, dispute settlement and an indicative list of both monetary and non-monetary benefits (Nguyen *et al*., 2009).

7.0 Conclusions:

Genetic resources of many fish species are untouched and less harnessed for aquaculture. Besides, genetic resources of several species are under extinction due to poor management, unregulated and careless exploitation. Management of aquatic genetic resources plays an important role in enhancing production and conservation of biodiversity. Better management involves several steps; cataloguing of genetic resources; characterization to determine the genetic structure or distinctness, evaluation to estimate their economic potential, evaluation of probable impact on eco-balance upon translocation and carrying out sustainable genetic improvement programmes. Sustainable management of any genetic resources is possible only through interest and active participation by a wide range of stakeholders including fish farmers, fisheries scientists, public policy makers, NGOs and other associated professionals like processors, wholesalers and retailers. Threatened species can be safeguarded through ranching activities, standardizing captive breeding and seed rearing technology to minimize dependency on wild seed, selective breeding aiming multiple traits improvement, efficient breeding plans, in which selection is based on advanced genetic technologies, periodic genetic evaluation, training for aquaculture geneticists and educating fish farmers regarding importance of genetic management of endangered species, international collaboration for advanced need based research to protect genetic resources. Cooperative learning from previous research oversights has to be encouraged, instead of competitive secrecy, which aids future research economically and technologically.

Primarily, all subspecies and populations have to be taxonomically distinguished using modern genetic technologies. Since in situ conservation measures are still in infancy stage in aquatic species, establishing a standardized set of neutral molecular markers, gene banking and cryopreservation warrants urgent consideration. In addition, systematic identification and documentation systems to regulate national or international access to stored material or to determine ownership is also need of the hour. Similar to GIFT tilapia efforts, research and extensional works to be extended to other aquatic organisms to improve them genetically and to harness the potential benefits; while greater understanding regarding eco-sensitivity is necessary. Translocations of genetic materials across the trans-boundaries can be best achieved through consortia of countries. These networking may facilitate exchange of natural germplasm resources and genetic improvement through proper mechanisms and strategies that encourage the sustainable use of genetic resources to improve aquaculture, food security and rural livelihoods.

8.0 Acknowledgement:

I sincerely thank Dr. K. N. Prabhudeva, Director of Extension, KVAFSU, Bidar and Mr. K. B. Rajanna, Assistant Professor, FRIC, Hebbal for their valuable inputs in preparing this paper.

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