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Inland fisheries resource enhancement and conservation in Asia

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN ASIA

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FOREWORD

Inland capture fisheries provide an important source of food and livelihoods for many people in rural areas. In 2008, inland capture fisheries provided 10.2 million tonnes of fish worldwide (FAO, 2010), which was largely used for direct human consumption. Asia has overwhelmingly contributed to the world's inland capture fisheries production with a reported total production of 6.8 million tonnes in 2008 (FAO, 2010). The actual contribution of inland capture fisheries, however, is far higher than what is reflected in the above official data. Because of the difficulties involved in collecting data from large numbers of small-scale, scattered and often unregistered fishers, official figures for fish catches tend to be vastly underestimated.

Inland fisheries resources provide not only the material basis for maintaining capture fisheries production, but also serve as a reservoir of aquatic biodiversity. However, over the past few decades inland fisheries resources have come under increasing pressure from overfishing, use of destructive fishing gear/methodologies, water engineering projects, pollution and environment changes and have shown a clear declining trend. This has been well demonstrated by the disappearance of some traditionally important fish species and a general reduction in the catch of high valued species.

Fisheries resource enhancement and conservation measures have long been adopted in many Asian countries for sustaining capture fish production, conserving aquatic biodiversity, rescuing endangered species, improving environmental conditions and upgrading recreational fisheries by offsetting the adverse impacts of human activities on inland fisheries resources. The contribution of inland fisheries resource enhancement and conservation to sustained inland capture fisheries and conservation of aquatic biodiversity as well as to nutritional security and improved rural livelihoods has been commonly recognized. On the other hand, external interventions to the aquatic ecosystem from fisheries resource enhancement and conservation activities may have had adverse impacts on the ecosystem and wild fish community, especially when such activities are carried out without a strong scientific basis or adequate evaluation and monitoring mechanisms. There is a general lack of comprehensive understanding as to the effectiveness and impacts of current enhancement and conservation activities in the region.

This publication is the product of a regional review study on inland fisheries resource enhancement and conservation conducted during 2009-2010. It includes ten country review papers and one regional synthesis report generated from a regional expert workshop. The publication provides the most up-to-date, comprehensive information on inland fisheries resources enhancement and conservation in the region, covering practices, methodologies, operational modalities, impacts, constraints and recommendations for the way forward. The synthesis report provides a regional perspective on inland fisheries resources enhancement and conservation practices in Asia, with special focus on identifying common issues and problems, and recommends actions on improved practices for maximizing benefits to the region.

This publication can serve as an important reference for people working in inland fisheries resources management. More importantly, it provides a starting point for anticipated thrusts in promoting better practices of inland fisheries resource enhancement and conservation.

Hiroyuki Konuma
Assistant Director-General and
Regional Representative for Asia and the Pacific

PREPARATION OF THE DOCUMENT

This regional review study is an effort to promote improved inland fisheries management under the Code of Conduct for Responsible Fisheries. It covers ten Asian countries with significant inland capture fisheries, namely Bangladesh, China, India, Indonesia, the Republic of Korea, Myanmar, Nepal, Sri Lanka, Thailand and Viet Nam. The review study was conducted in collaboration with the Network of Aquaculture Centre in Asia-Pacific (NACA). Experts from the ten participating countries prepared a comprehensive review paper for each country during November 2009 to February 2010 following the guidelines jointly developed by the FAO Regional Office for Asia and the Pacific and NACA.

A regional expert workshop on inland fisheries resource enhancement and conservation in Asia was subsequently convened by the FAO Regional Office for Asia and the Pacific and NACA from 8 to 11 February 2010 in Pattaya, Thailand. The FAO Regional Office for Asia and the Pacific, NACA, the International Institute for Sustainable Development (IISD) as well as the ten experts from the ten countries who participated in the review study attended. The workshop participants shared experiences and lessons on inland fisheries enhancement and conservation practices across the region, discussed the impacts of inland fisheries resource enhancement and conservation practices, identified the constraints and related problems from a regional perspective and recommended regional collaborative activities to promote improved practices of inland fisheries resource enhancement and conservation. A regional synthesis report was produced as the major output of the workshop.

All the country review papers were presented, commented on and reviewed by a panel of experts during the workshop. The authors revised their manuscripts following the suggestions made by the review panel. The regional synthesis report was drafted by Sena De Silva (Director General, Network of Aquaculture Centers in Asia-Pacific, Bangkok, Thailand) based on the workshop discussions and further reviewed. The revised country papers were then reviewed and technically edited by an editorial team, which consisted of Miao Weimin (Aquaculture Officer, FAO Regional Officer for Asia and the Pacific, Bangkok, Thailand), Sena De Silva and Brian Davy (Senior Fellow, International Institute for Sustainable Development, Ottawa, Canada) before the authors finalized their manuscripts. The manuscripts were then reedited by the FAO Regional Office staff for final printing after receiving the final confirmed version from the authors.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN BANGLADESH

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ABSTRACT

Bangladesh is endowed with a vast inland waters in the form of rivers, canals, natural and man-made lakes, freshwater marshes, estuaries, brackish water impoundments and floodplains. The potential fish resources resulting from these waters are among the richest in the world. This aquatic diversity is attributed to the habitats created by the Bengal Delta wetlands and the confluence of the Brahmaputra, Ganges and Jamuna rivers that flow from the Himalayan Mountains into the Bay of Bengal.

There are, however, serious concerns surrounding the slow decline in the condition of open water fish stocks which have been negatively impacted through a series of natural and anthropogenic changes. These include disturbances resulting from the large scale water abstraction for irrigation and the construction of water barrages and dams, over-exploitation of stocks, unplanned introduction of exotic species and pollution from industry. Also, natural phenomena, regular flooding etc. cause rivers to continually change course creating complications of soil erosion or over siltation of waterways.

In order to reverse the trend and ensure sustainability of inland fisheries resources, various measures for resource enhancement, conservation and management have been adopted from time to time. A number of resource enhancement projects have been undertaken and the focal point of all these initiatives are: restriction on size at capture for certain periods, on the use of gear and mesh size, and catch of species for specific periods, introduction of closed seasons, restriction of fishing by dewatering or any other destructive method.

The needs of Bangladesh's poor fisher community to eat what they catch and lack of a legal legislative framework means this situation can only worsen. Hope, however, is offered through several new conservation initiatives including habitat restoration, enhancement of depleting fish stocks in rivers and floodplains, transferring fishing rights to true fishers and establishment of fish sanctuaries at strategic points in rivers and floodplains. This paper reviews the progress of the enhancement and conservation approaches, and attempts to identify the problems and constraints then provides some recommendations in the context of overall developments of inland fisheries of Bangladesh.

Key words: Fisheries, fishers, resource enhancement, biodiversity, conservation, Floodplain, rivers, constraints, Bangladesh

1. INTRODUCTION

1.1 Inland fisheries resources of Bangladesh

Bangladesh (20^o 34' to 26^o 38' ^{o}North; 88^o 01' and 92^o 41' ^{o}East) is divisible into three broad physiographic regions. The floodplains, terraces and hills occupy about 80, 8 and 12 percent respectively of the land area. The inland open water fisheries of Bangladesh are highly diversed and unique and are based on extensive networks of floodplains, large and small rivers, *beels* (relatively large surface, static water bodies that accumulate surface run-off through internal drainage channels), *haors* (back swamps or bowl-shaped depressions between the natural levees of rivers) and *baors* (oxbow lakes created due to meandering rivers which changed course, and cut-off from the main course), all offering wide scope and potential for fish production. Bangladesh has also large impounded water areas in the form of man-made ponds, ditches, borrow pits, lakes and enclosures (DOF, 2005). Moreover, it is a country dominated by wetlands having more than 50 percent of its territory under freshwater marshes, swamps, rivers estuaries and the world's largest contiguous mangrove forest – the Sundarbans. The inland open water fishery resources (Table 1) have been playing a significant role in the economy, culture, tradition and food habits of the people.

Fish have been an integral part of life of the people of Bangladesh from time immemorial. Fisheries, second only to agriculture in the overall economy of Bangladesh, contribute nearly 5 percent to the gross domestic product (GDP), 23 percent of gross agriculture products and 5.71 percent to the total export earnings (DOF, 2008). It accounts for about 63 percent of animal protein intake in the diet of the people of Bangladesh (DOF, 2005). The people of Bangladesh largely depend on fish to meet their protein needs in both the rural and urban areas. The total fish production from different water areas is given in Table 1.

Table 1. The inland water resource types and the proportionate contribution of each to total fish production in Bangladesh (2007-2008)

Resource type	Water area (ha x '000)	Production (t x '000)	Contribution (%)
A. Inland Fisheries			
(i) Capture			
1. Rivers & Estuaries	853.86	136.81	
2. *Beel*	114.16	77.52	
3. Floodplain & *Haors*	2 832.79	819.45	
4. *Kaptai* lake	68.80	8.25	
5. *Sundarbans*	177.7	18.15	
Capture Total	**4 047.32**	**1 060.18**	**41.36**
(ii) Culture			
1. Ponds & ditches	305.03	866.05	
2. *Baors*	5.49	4.78	
3. Coastal shrimp farms	217.88	134.72	
Culture Total	**528.39**	**1 005.55**	**39.32**
A. Inland total	**4 575.71**	**2 065.72**	**80.59**
B. Marine fisheries	**–**	**497.57**	**19.41**
Country Total (A + B)	–	2 563.30	100.00

FRSS, 2009

1.2 Aquatic Fauna

Bangladesh is endowed with a very rich aquatic flora and fauna because of its geographical settings and climatic characteristics (Table 2). Bangladesh's water bodies are known to be the habitat of 267 freshwater fishes under 52 families and 156 genera, 475 marine fishes, 23 exotic fishes, 372 molluscs and a number of other vertebrates and invertebrates.

The major fish groups found in the country's inland waters are major carps, large catfishes, minor carps, small catfishes, river shads, snakeheads, freshwater eels, feather backs, perches, loaches, anchovies, gobies, glass fishes, mullets, minnows, barbs and flounders. The total inland capture fishery production of Bangladesh in the year of 2007-2008 (July-June) was 1.06 million tonnes. The catch was dominated by major carps (30 percent) followed by exotic carps (16.4 percent) and snakeheads (5.8 percent).

Table 2. Diversity of aquatic animals in Bangladesh water

Animal group	Number of Species	
	Freshwater	Marine
Finfish	267	475
Shrimp	–	41
Prawn	20	–
Mollusc	26	336
Crab	4	11
Lobster	–	6
Frog	10	
Turtle & tortoise	24	7
Crocodiles	2	1
Snakes	18	6
Otters	3	–
Dolphin	1	8
Whale	–	3
Total	375	894

Source: Ahmed and Ali, 1996; Ali, 1997 and Banglapedia, 2004

1.3 Status of inland fisheries resources in Bangladesh

Until 1970s, there was an abundance of fish in the natural waters of the country to satisfy the demand. In recent years, however, the availability of several fish species has declined, and many are thought to be critically endangered.

The annual flooding of approximately 2-3 million ha of floodplain has been either controlled or prevented altogether by means of sluice gates or pumps positioned along earth embankments or levees (ESCAP, 1998). This reduction in area is believed to be one of the major reasons for declining floodplain fisheries in Bangladesh (FAP 17, 1994). Siltation has threatened the existence of most of the river and many are gradually being turned in to small canals. The *Beel* fishery is deteriorating day by day due to over-fishing, uncontrolled use of chemicals, fertilizers and insecticides, destruction of natural breeding and feeding grounds, harvesting of wild brood fishes (Azher *et al.,* 2007). Clearing riparian vegetation and unplanned crop cultivation resulting from myopic leasing practices and lack of land-use policies coupled with pollution from industrial effluents and agro-chemicals continue to impact on the ecological balance, reduce aquatic diversity and diminish fish production. Both *Haors* and *Baors* are now under heavy fishing pressure. The construction of dams and other flood control structures have reduced the natural recruitment and contributed to stock depletion in *baors*. Pond culture fisheries have always been considered as being crucial for the livelihoods of the most vulnerable communities of the country. Selective aquaculture, however, could be detrimental for fish biodiversity as the culture technologies advice farmers to remove all small indigenous fishes from the ponds before releasing the fry of target fish.

The threat to inland open water biodiversity is country-wide and more than 15 percent of the inland open water fishes appear to have disappeared. Only one or two individuals of a further 20 percent of species have been found in the last ten years. The percentage of critically endangered fish described by the IUCN (2000) increased almost five times in recent years (Hossain and Wahab, 2010).

1.4 Enhancement and conservation practices

The government and a number of non-government organizations (NGOs) have taken a number of regulatory and development interventions for sustainable management of the inland fisheries. In order to reverse the negative trends and ensure sustainability of fish biodiversity and production from inland open waters, various measures for protection, conservation and management of fisheries resources have been adopted from time to time. These measures comprise the implementation of different acts and related rules including new fisheries management policy (licensing the fishing rights directly to the true fishers), community based fisheries management (CBFM), establishment of fish sanctuaries at strategic points of the rivers and floodplains, fish stock enhancement through releasing fish seed in seasonal floodplains, and fish habitat improvements through excavation of link canals (between rivers and floodplains) and *beels.*

1.4.1 History of resource enhancement and conservation – the Acts and Policies

A number of legal instruments have been introduced over the years, some of the latter ones specifically intended to boost inland fish production and habitat conservation are given in Table 3.

Table 3. A list of legal instruments and policies in relation to inland fisheries development and conservation that have been introduced over the years

Act	Applicable area	Scope
Indian Fisheries Act (1887)	British India	–
Conservation and Protection of Fish Act (1950)	East Pakistan	To reverse the declining trends in fisheries
National Environment Policy (1995)	Bangladesh	Restoration of water bodies for fisheries production
National Fisheries Policy (1998)	Bangladesh	Overall fisheries development; establishment of fish sanctuaries and other conservation measures
National Water Policy (1999)	Bangladesh	Requires fishery aspects need to be taken into account in water management developments
National Land Use Policy (2001)	Bangladesh	Emphasis on maintaining and protecting the decaying inland water bodies

Over time, the main focus has drawn towards community participatory management, or co-management. The government has developed a series of strategies for the implementation of the National Fisheries Policy, one of which covers inland capture fisheries and emphasizes access control rather than revenue generation and community participation, along with setting up of fish sanctuaries, as a key management measure (DOF, 2005).

1.4.2 Inland resource enhancement and conservation projects

In the early 1990s, the government through Department of Fisheries (DOF) re-stocked some open waters with fingerlings produced in government and private hatcheries in order to replenish lost species, particularly indigenous carps. After some initial restocking from the government's own resources, two major donor funded projects were undertaken (Ali, 1997). The Second Aquaculture Development Project funded by ADB undertaken by the DOF included a component for replenishing indigenous major carp stocks by stock enhancing *beels* in the northeastern Bangladesh with carp hatchlings. The project failed due to faulty design and erroneous implementation. In addition, there was no reliable production monitoring system that time. The Third Fisheries Project (TFP) was undertaken by the DOF funded by the World Bank, ODA and UNDP. The project carried out a major stock enhancement program in the floodplain of the western part of the country between 1991 and 1996. In contrast to the Second Aquaculture Project, the TFP identified suitable floodplains and stocked the selected floodplains with large fingerlings at the beginning of the monsoon in June-July. The TFP also established an intensive fish catch monitoring program in the selected floodplains. Due to TFP activities fish production in floodplains increased substantially. Nevertheless the approach used was too top-down, did not involve the fisher communities and mostly lacked the support of the local people.

The largest fisheries project of the government – the Fourth Fisheries Project (FFP 1999-2006) funded by the World Bank, DFID and the Global Environmental Facility (GEF) aimed to support sustainable growth in fish production for domestic consumption and export, and equitable distribution of the benefits generated from the activities. It also intended to contribute to poverty alleviation in Bangladesh by improving the livelihoods of the poor people dependent on fisheries resources. The Community Based Fisheries Management (CBFM) Project

1995-1997 was carried out with the partnership of Department of Fisheries (DOF) and five major NGOs. The project was designed to execute a number of action researches to evaluate the feasibility and efficacy of alternative local fishery management arrangements that might achieve greater equity and sustainability. The Management of Aquatic Ecosystem through Community Husbandry (MAECH) project, funded by USAID, started in October 1998 and completed its second phase in 2006. The project realized that a reduction in fishing was the critical part of reviving the wetland fisheries and identified alternative income generating opportunities for fisher households and others directly dependent on wetland resources.

In addition to the major projects a number of smaller projects have also been conducted. One such project funded by Danida and IFAD worked on the *baor* (oxbow lakes).The small projects emphasized the participation of fisher communities (bottom-up approach) and focused more on social development and conservation of fish stocks for sustainable catches rather than just on stocking.

1.4.3 Scale of operations

Some of the projects were site-specific but the large projects mostly were executed country-wide. The major projects so far carried out are Third Fisheries Project, CBFM Project, Fourth Fisheries Project and MAECH project. Table 4 summarizes the scale and scope of those projects that have had an impact on stock enhancement of inland fisheries in Bangladesh.

Table 4. Summaries of the scope and scale of various projects that have had an impact on stock enhancement in inland fisheries in Bangladesh

Project	Scope
Third Fisheries Project (1990-1997)	Stocking 100 000 ha of floodplains
CBFM Project	Alternative local fishery management arrangements for enhancing fisheries in 10 rivers (partly), 7 *beels* and two *baor* sites in east, north, south and central Bangladesh
Fourth Fisheries Project (FFP)	Stocking of water bodies with fingerlings, setting up of fish sanctuaries, habitat restoration through re-excavation of canals and beels, and construction of fish passes and fish-friendly regulators to ease river-floodplain migration of fish in 49 sites covering 33 of the 64 districts in Bangladesh
MAECH project	The Hail *Haor* in northeast Bangladesh, the Turag-Bangshi site in the central part of the country – the north of Dhaka and the Kangsha-Malijhi site in the north-central part of Bangladesh

1.4.4 Major target species

In stock enhancement programs, in most cases, three Indian major carps – rohu – *Labeo rohita*, catla – *Catla catla* and mrigal – *Cirrhinus mrigala*, and common carp – *Cyprinus carpio* were the target species. In addition, every year the Ministry of Fisheries and Livestock (MOFL) through Department of Fisheries (DOF) observe Fish Fortnight/ Week and when fingerlings of Indian major carps, common carp, silver carp, grass carp and some minor carps are released at upazilla (sub-district) level. In recent years, the Upazilla Fisheries Officers and Farm Managers under Department of Fisheries (DOF) are instructed to produce fingerlings not only of large carps but also some medium-size minor carps and catfishes. One of the components of fourth fisheries project (1999-2006) was developing a socially feasible and ecologically sound management plan for the conservation of hilsa, *Tenualosa ilisha* fisheries. Other management interventions included the re-excavation of link canals between rivers and floodplains and setting up of sanctuaries targeting the indigenous fish and other aquatic organisms.

2. TECHNICAL DESCRIPTION OF MAJOR INTERVENTIONS

2.1 Rational and purpose of the interventions

Implementation of the acts/regulation has always been very difficult in the inland waters of Bangladesh because of its complexity due to multi-species and multi-gear, widely scattered fisheries in diversified water bodies – river, canals, floodplain, *Beels, Haor, Baor,* lakes etc. involving the poor and the ultra-poor fishers. Inland water bodies are owned by the State except seasonal floodplain which are mostly privately owned rice fields in the lean season. For administrative convenience, a river is divided into several sections, each section being called a *jalmohal* (fishery). An individual *beel* or a group of *beels*, an oxbow lake and a state owned pond are also called a *jalmohal*. However, the flowing rivers have been declared as open and free access for fishing since 1995 without any control over-fishing effort and as such rivers are over exploited. The *jalmohal* measuring up to three acres are managed by local government (the Union Council) and up to 20 acres by the Ministry of Youth and Sports who leases them to unemployed youths for fish production while those above 20 acres are controlled by Ministry of Land (MOL) for revenue collection. The MOFL through DOF is responsible for managing fisheries resources for sustainable production. Again the revenue oriented short term competitive leasing system of *jalmohal* without consideration of aspects of biological management of fisheries, indulges in destructive fishing leading to depletion of fish stocks. Primary responsibility of implementing the acts/regulations is with DOF, but due to lack of sufficient manpower and in the absence of logistic supports, the laws have never been enforced properly.

In order to ensure sustainable production in inland waters, various regulatory and development interventions were undertaken by the Government. These include the regulatory interventions of the promulgation of Fish Protection and Conservation Act 1950 and the related rules and implementation of different development and management programs/projects, which includes New Fisheries Management Policy (licensing the fishing rights directly to the fishers), community based co-management of fisheries, establishment of fish sanctuaries, enhancing fisheries through stocking of fish fry in seasonal floodplains, fisheries village approach of extension of fisheries, community based floodplain aquaculture and fish habitat improvement through excavation of link canals and *beels*. Some of the interventions have been proven to be successful and effective for enhancing fish biodiversity and production as well as improving the socio-economic condition of the fishing community.

2.2 The operations

2.2.1 Fingerling stocking in the rivers and floodplain

Stocking generally commences in June-July or even earlier if there is sufficient water depth and continues up to August at a rate of not more than 10 kg/ha, using major carp fingerlings of 9-14 cm in length. The species composition used mostly was rohu (40 percent), mrigal (20 percent), and catla (40 percent). In some instances the fingerlings of exotic common carp are also released. Fingerlings release take place at a point determined by community consensus. In most cases, stock enhancement is being done on a partnership (cost-sharing) basis by the community and the project under the following arrangements. In the first year, the project contribute 90 percent towards the cost fingerlings stocked and the remainder by the community. In the second year, the project contribute 60 percent and the community 40 percent. In the third year, the project contribute 30 percent and the community pay the rest. From the fourth year up, the community is responsible for stocking. The stockings are done in both small and large floodplains and in the part of the rivers. The Fisheries Community Based Organizations (FCBOs) raise money from the fishers for the lease of the water body and the cost of fingerlings. Sometimes they borrow money from banks. Release of fingerlings are followed by a fishing ban, though considering the daily need of subsistence fishers, use of small traps are allowed. FCBOs control the use of gear specially the monofilament gill nets and undersized stocked fish are released after capture.

The large scale fingerling stocking took place during the implementation of forth fisheries project (1999-2006). In recent times, every year MOFL through DOF observe Fish Fortnight/Week during May-June and along with other programs like rally, seminar, fish fair, technology fair, exhibition, boat race, folk music, signboard on engine boat, wall writing, group discussion, T-shirt and cap distribution, use of posters etc., fish fingerlings are released in the rivers and floodplains.

2.2.2 Habitat restoration

Silted up *beels, baors* (oxbow lakes) and link canals have been made through re-excavations by the Local Government Engineering Department (LGED) using the food for work approach at various times, under the Fourth Fisheries Project. Habitat restoration was implemented through active participation of fishers and FCBOs. By 2000 a total of about 8 300 ha water area of ponds, borrow pits, oxbow lakes, dead rivers, canals and *beels* had been excavated under this program (DOF, 2005). The main objective of habitat restoration was to reopen river-floodplain connections by de-silting natural drainage channels. It also included, in a few cases, planting water tolerant trees and other rehabilitation interventions. In addition, local communities and FCBOs under different projects were made aware and motivated to undertake activities to restore fish habitats on their own.

2.2.3 Fish passes and fish friendly regulators

For the past twenty years between 1970 and 1990, over two million ha of floodplain became unavailable for inland fisheries production because of the construction of levees (Siddiqui, 1990). To control water entering the floodplains, 7 000 regulators have been constructed in Bangladesh to allow the smooth movement of adult fishes (local migrants) and drifting larvae. These fish passes and fish friendly regulators were built, under the Fourth Fisheries Project, to facilitate and maintain natural fish migration, reduce larval mortality rates significantly, maintain smooth connectivity between the river and floodplains, reduce turbulence, provide enough flow and depth to attract fish to and fro between river and floodplain and provide an exit and entrance velocity within the swimming speed of fish. There are four examples of such installations in Bangladesh.

Figure 1. Sariakandi Fish Pass in Bangladesh (http://www.bdfish.info/en/2009/11/sariakandi-fishpass/)

Sariakandi fish pass is located at the western part of the Bolai canal under Sariakandi Upazila, Bogra. Among all the fish passes Sariakandi fish pass is the largest and newest fish pass in Bangladesh allowing fish movement between the Jamuna and Bangali River. Kasimpur regulator and fish pass is on the Manu River, at the western end of Korakadi canal, located between Kushiyara River and Kawadighi Haor at Moulovibazer and Jugini regulator and fish pass is at the east bank of the river Jamuna at Tangail, located on the Lohajong River in Jugni village. Moricherdana fish pass is at the confluence with the Mohanonda River, Chapai-Nawabganj district.

2.2.4 Fish sanctuaries

Among all measures, fish sanctuaries have been found to be most effective for fish biodiversity conservation, whereas other measures were difficult to implement in the present administrative and social contexts. The government established fish sanctuaries under different development projects following a number of management approaches since 1960 and more intensively in last decade. Many NGOs have also been involved in fish stock development by establishing traditional sanctuaries in *beels* and rivers of Bangladesh.

Most of the fish sanctuaries in recent times focus on the need of the involvement of the fisher community and local government in the management system, long tenure of lease periods and also strong monitoring and supervision. Moreover, to safeguard fisher interests, the government policy now is to establish sanctuary in part of the floodplain and the remaining part is open for fishing by the locals. Based on this idea, the government has established a number of sanctuaries involving the fisher communities with support of NGOs. In a government declared fish sanctuary, catching/killing of fish is prohibited and the order of the competent authority at all times in the future or for a specified period mainly with objective of protecting/conserving the fish.

A total of 464 permanent fish sanctuaries covering an area of 1 746 ha have been established in 98 455 ha water bodies by 2007 (Table 5). A number of the sanctuaries have been closed after the projects ended. Management has deteriorated in many sanctuaries due to the conflict of interests among the stakeholders, lack of funding and lack of coordination among the organizations.

Table 5. Fish sanctuaries established in Bangladesh by 2007

Project/Program	Water body ha	Sanctuary ha	No. of Sanctuary
FFP	12 233	1 022	63
CBFM-2	9 602	93	182
MAECH	785	76	65
NFMP	1 698	77	21
FDMP in *Beel* and Chharas	1 294	18	29
ADP-Faridpur	454	11	14
PBAEP	307	26	19
FHRP	3 890	73	45
FDP in *Jabai Beel*	75	4	4
SEMP-17	50	17	12
CBWM-4	17	4	7
Kaptai Lake	68 000	324	2
BFRF – The *Matshyarani*	50	1	1
Total	98 455	1 746	464

Modified from Ali e*t al.,* 2009

2.2.4.1 Technical aspects of fish sanctuaries

The effectiveness of sanctuaries depends on several key factors such as identification of the type of sanctuary, selection of the water body based on technical and social issues, appropriateness and compliance of the community with the rules Depending on the purpose, the sanctuary may be seasonal/temporary or permanent.

The required sanctuary area will depend on many factors – present state of fish stocks (abundance by species), reproductive capacity (fecundity) of individual species, age at first maturity, longevity, fishing (catches) and natural mortality (spawn to maturity), productivity of the water body (carrying capacity), etc. To ensure the breeding stock required to sustain the fishery at about “maximum sustainable yield” level in an ecosystem (taking into consideration these factors) is the central theme of technical fisheries management. Mathematical models could give estimates of such areas required based on the above criteria. However this type of study and model has yet to be developed for complex multi-species inland fisheries in diversified and changing habitats. An individual sanctuary should not be too small as it will not be self sustaining because most larvae (fish and other organisms) produced in it could be transported elsewhere, while a large reserve will retain too much of reserve's productivity releasing too little at the edges to effectively enhance the fishery in surrounding areas. Therefore medium-size sanctuaries could be recommended for enhancing fisheries most effectively.

Fish sanctuaries in Bangladesh are usually constructed when water begins to recede but of reasonable depth, with branches of bushy trees like hizole (*Barringtonia acutangula*), gamboling (*Diospyros pererina*), babla (*Acacia* sp.), shewra (*Sterbulus* sp.), black berry (*Syzygium cumini*), jarul (*Lagerstroemia speciosa*), gab (*Diospyros peregrine*) and tamarind (*Tamarindus indica*). The whole sanctuary is supported by large number of bamboo poles fixed around it to prevent downstream drifting of tree branches by water current. Water hyacinth (*Eichhornia crassipes*) and sometimes Helencha, *Enhydra fluctuans* are used to cover the part of the sanctuary surface.

Figure 2. A typical fish sanctuary constructed with bamboo poles and water hyacinth. The fish habitats are created at the bottom with bushy tree branches (inset photo).
Photo credit- Dr Mostafa A R Hossain

2.2.5 Aquaculture/enhancement efforts

As more fish species of Bangladesh become threatened, there is tremendous need to preserve the disappearing genetic material as well as to conserve the existing gene pools. The ideal strategy for conservation of threatened and endangered fish species is through restoration of the native habitat of the species (*in situ* approach). Unfortunately, most habitat damages are irrevocable and where remediation is possible it is costly and requires a great deal of time, as the restoration process is slow. One alternative is to maintain *ex situ* conservation (outside the natural environment) as live populations or in a cryopreserved sperm bank (Pullin *et al.,* 1991).

Domestication of wild fishes in most cases benefits both the farmer and the environment. Investments in domestication have to pay off; therefore, researches should take into account the biodiversity and production scenario and overall socio-economic and environmental outcome at a broader scale. In Bangladesh, to date about 20 fish species have been domesticated and their breeding and rearing protocols have been developed. Around 50 percent of the domesticated fishes are cypriniforms and now under nation-wide aquaculture. Though there is high possibility of working with reduced gene pool, it is optimistically believed that the biodiversity of the domesticated fish are well-preserved.

Fish sperm cryopreservation assists conservation of fish biodiversity through gene banks of endangered species, and assists aquaculture by providing flexibility in spawning of females and selective breeding through synchronizing artificial reproduction, efficient utilization of semen, and maintaining the genetic variability of broodstocks (Lahnsteiner, 2004). In Bangladesh, research on fish sperm cryopreservation started in early 2004. The studies have focused on aquacultured or commercial species and so far none of the threatened species have been considered (Table 6).

Table 6. Cryopreservation of sperm of some fish species in Bangladesh

Fish group	Fish
Indigenous – carp	*Catla catla*
	Cirrhinus mrigala
	Labeo rohita
	Labeo calbasu
	Puntius sarana
Indigenous – catfish, eel	*Ompok bimaculatus*
	Mastacembelus armatus
	Channa striatus
	Rita rita
Exotic fishes	*Cyprinus carpio*
	Hypophthalmichthys molitrix
	Hypophthalmichthys nobilis
	Barbonymus gonionotus
	Oreochromis niloticus

Source: Hossain and Wahab, 2010

2.3 Social aspects and impact assessment

The impact assessment surveys carried out by different government organizations (GOs) and NGOs in most cases were short sighted and site specific and often overlooked the wider impact area and associated social dimensions. Mostly the organizations that carried out the enhancement programs also undertook impact assessments which led to a bias towards highlighting the positive impacts. The lack of coordination among the organization also made the outcomes of the impact assessment programs frailer.

The consultation jointly organized by FAO and the DFID-UK (Petr, 1998) focused on a broad range of topics including technical, social, economic and administrative aspects of Third Fisheries Project, ADB Second Aquaculture Project and the Oxbow Lake Project. Among others, MAECH project conducted survey in its three projects site – Hail Haor, Turag-Bangshi, and Kangsha-Malijhee and found that both fish production and number of species gradually increased when compared with the base year (MAECH, 2006). Several authors, individually or under different projects carried out surveys to study the impact of aquatic resource enhancement and conservation (Thompson *et al.,* 1999; Ahmed and Ahmed, 2002; Thompson, 2003; Sultana and Thompson, 2007; Ali *et al.,* 2009)

Floodplains in Bangladesh comprise different types of wetland habitat: river, canal, *beel* and *haors, baors* etc. In the surveys conducted, fish catches were monitored by fisheries biologists in specific locations selected to include representative areas of different floodplain habitats in different sites. To assess direct impacts of resource enhancement on livelihoods of poor and middle class people's fish consumption, a number of studies monitored a panel of households. To assess changes in fish consumption, local men and women were trained as monitors and visited sample households at regular intervals to weigh by species the fish being prepared for cooking and home consumption.

2.4 Impacts of major enhancement and conservation activities

2.4.1 Impact on natural population and biodiversity

Impact studies carried out by different projects found that many fish species benefited from the enhancement programs. The biodiversity and production of major carps, small and large catfishes, barbs, minnows, eel and several perches increased in and around the intervention sites (Thompson, 2003; Haque *et al.,* 2007; Ahmed *et al.,* 2007). Although not targeted, the biodiversity of many non-fish aquatic animals and plants – phytoplankton, zooplankton, mesogastrapods, polychaetes, tubificids, bivalves, oligochaetes and nematodes increased significantly in the water bodies after setting up the sanctuaries (Azhar *et al.,* 2007).

MAECH project reported that both fish production and number of species gradually increased when compared with the base year (MAECH, 2006). Compared with the baseline years the survey found substantial increases in total fish catch and in catch per hectare in all three sites. In the final year of the survey (2004), catch per person day was higher in all three sites than in the baseline year suggesting that fishing was more sustainable than before the intervention started.

Fish sanctuaries in Bangladesh were proved to be one of the most important and efficient tools for management in protection and conservation of fishes and other aquatic organisms (Ali *et al.,* 2009). Since mid 80s, the concept of the involvement/participation of the local fisher communities in setting up and managing sanctuaries has been the government policy. Surveys carried out in most of the sites in which fish sanctuaries were established, found a gradual increase in the species numbers compared with the base year with 2-3 fold increase in fish production. Many rare fish species were repopulated in the *beels* and rivers with sanctuaries (Haque *et al.,* 2007; Ali *et al.,* 2009).

2.4.2 Socio-economic benefits

The most obvious impacts of the resource enhancement are that fishery management has improved in almost all the sites. Institutional development resulted from enhancement activities did result in greater empowerment of the participating communities which strengthened their access to resources and their facility to make decisions, and would definitely result in more sustainable fisheries in the future (Sultana and Thompson, 2007). In general, significant changes in indicators of empowerment (participation and influence) and institutional efficiency (ease of decision making) were reported in the *beels* (both closed and open), but the pattern of changes was less clear for rivers. Sustainability (wellbeing) was perceived to have improved mainly in the stocked closed *beels* probably due to stocking. Based on the case studies in six closed beels/baors, three open *beels* and 10 river parts, the impact assessment indicated that there were benefits from CBFM in all the open *beels,* and in closed *beels* (Thompson *et al.,* 1999). In the rivers some material benefits for fishers have been observed and in two the fishery appeared to be better managed, but in other rivers, open access and conflicts were found to be dominant.

In the intervention sites, fish consumption among landless, marginal and middle class households increased significantly compared to baseline years and the benefits of intervention were shared widely across both poor and better off households. Per capita daily fish consumption of the beneficiaries in the area increased. A comparison between participating and non-participating groups conclusively established that resource enhancement activities contributed to women empowerment as well. (MAECH, 2006)

3. CONSTRAINTS AND PROBLEMS

3.1 Operational constraints

Conflicting policies and lack of coordination among Departments: One of the major problems in the inland fisheries resource enhancement and conservation in public water bodies in Bangladesh is the policy conflict among the government ministries. The Ministry of Land is the custodian of the water bodies and is responsible for collecting the maximum revenue by leasing those water bodies. On the other hand, the Ministry of Fisheries and Livestock is mandated to ensure that all of the country's fisheries including major floodplains are managed to ensure the maximum sustainable yield of fish. The Ministry of Environment and Forests (MOEF) aims to protect natural habitats, maintain biodiversity and ensure an acceptable quality of water. Myopic government policies and acute lack of coordination and a reluctance to support local communities establishing rights over open water fisheries, are some of the serious constraints. Lack of coordination among the target communities and government and/ or concerned NGOs was primarily responsible for the failure of many enhancement and conservation projects.

Lack of proper guidelines: Although the national fisheries policy envisages establishing fish sanctuaries, there is no clear guideline for establishment and management of these. In the last few years, many fish sanctuaries have been established in different waters of different shapes and sizes using different materials. There has been no set rule as to the size and design of the sanctuaries.

Lack of incentives and alternative sources of income: Most of the participating fishers often lack incentives and past experience of cooperation. Stocking of fingerlings, gear bans, and seasonal bans on all or some fishing gears were effective to conserve and enhance resources, but led to the exclusion and suffering of poor fishers. The absence of alternative sources of income during the ban period (seasonal closure) impacted on poor fishers.

Targeting the wrong people: In many cases the Fisheries Management Committees (FMCs) did not represent fishers, nor did the management plans further the interests of fishers. At some sites, rights were not transferred at all or transferred to the wrong people. In executing FFP, too much power was given automatically to the FMCs, often making the village level fisheries sub-committees largely irrelevant. Dominance by the elite in water body management and in the institutions was a persistent problem in many of the sites.

Excessive bureaucratic regulation: The procedure of transferring *jalmohals* from MOL to MOFL for biological management or for resource enhancement is still a lengthy and a difficult job. After long negotiations and struggle, water bodies could be physically transferred to projects and community management may come into being be only in the middle or close to the end of the project life and only after the project had paid the full revenue due to the government. However, when the project period is over, lease fees cannot be paid from the normal budget of DOF for shortage of funds, and if the community organization can not continue to do this or there is no community organization, then the water bodies are taken back by MOL and are leased to others for same old revenue collection leading to destructive fishing. When this happens, all the effort of fisheries resource enhancement along with its conservation approach would have gone in vain.

Poor database: Documented baseline information on floodplains and rivers in general is scanty. For example, water area, depth, siltation, CPUE, daily catches, fish production, species number and richness, presence fish feed, trends in fish catches by species and gear type, number of different gears and fishers, daily gear operating hours, gear operating days, fisher's income, numbers of households and their dependence on a fishery, household consumption, supply of species-wise fishes in the fish market and landing center. This gap in documentation hinders enhancement and conservation planning and assessment of management impacts.

3.2 Technical constraints

Unplanned stocking: In the FFP, stocking with carp fingerlings in many water bodies was mostly a failure in terms of returns to fishers, issues of control and access, and sustainability. Stocking was undertaken too early in the establishment of community management, and well before fisher communities could take decisions on what management tools are appropriate for them.

Quality of fingerlings: The quality of the fingerlings and the growth rate of different species is a major problem. The growth rate of the fingerlings released is low for major carp because of inbreeding or other problems. Fingerlings came from poor strains or from hatcheries that do not replace or renew their bloodstocks for years.

Alien stocking: Unplanned stocking of exotic carp fry in different *beels* coupled with inundation of many culture ponds led to an increasing abundance of exotic fishes in floodplains. In a stocking program, loss of fish biodiversity is a matter of concern. When water bodies are stocked for 3-4 successive years, the percentage of native species was reported to gradually decline in the water bodies, which then functions like a large pond.

Effectiveness of fish sanctuary: The performance of different sanctuary materials and their relative size are largely unknown. It has been found that many small-size sanctuaries have been established, which are not sufficient in protecting fish. On the other hand, management and maintaining of very large sanctuaries is difficult in terms of financial involvement and acceptance by local communities. No attempt has been made to study the effectiveness of different sanctuary materials to attract selective fishes. It was also notable that with the increase in production of large catfishes, production of other small indigenous species of fish (SIS) including prawn decreased due to the predatory nature of large catfishes particularly via intensive predation on the egg, spawn and larval stages. This is a major problem of survival of small fishes in brush parks and sanctuaries. Poaching (illegal fishing) is also one of the biggest and country-wide problems in the fish sanctuaries. As fish become more abundant in a sanctuary, they also become more vulnerable to poachers. Water pollution is another threat to the fishes of the sanctuaries. Pumping out of water from the *beel* sanctuary for agriculture or extreme drought, reduce the water area and depth in the sanctuary, resulting in heavy degradation of water quality, disease outbreaks and even mass mortality of fish and other aquatic animals.

Faulty design of fish friendly regulators: The present mode of operation and management of fish passes and fish friendly structures is inequitable in terms of distribution of benefits and costs. Decisions to open or close gates are often influenced by powerful groups, and poor fishers are discriminated against. In most cases, no fisher representative was included on the management committee of these regulators. The landless and women are altogether ignored. Management committees lack democratic practices. Ongoing destructive fishing practices both up and downstream very close to the fish friendly structure hinder safe migration of fish and fish hatchlings.

3.3 Distribution of social benefits

Inequitable distribution of benefits: Though CBFM is a widely accepted institutional framework for sustainable development of fisheries sector, benefits generated from its activities are, however, not equally distributed among people of the target communities.

Women's participation: The participation of women in the enhancement activities is not encouraging. The reasons behind non-participation of women in CBFM activities were – unwillingness, husband's attitudes, family disliking, religious bindings, society's view, education, time constraints, child caring responsibilities and unawareness.

4. RECOMMENDATIONS

Although much of the damage to the habitat and biodiversity of the inland waters of Bangladesh over recent decades is likely to be irreversible, there is still time to act. The Bangladesh government, the NGOs and national and international bodies should foster a social and technical environment in which the enormous richness of the fisheries resources can stabilize and eventually rebuild so as to continue to feed people of today and tomorrow.

4.1 Technological needs

- *Stock enhancement:* In stock enhancement program, management measures should be site-specific and identified through participatory rural planning. Traditional knowledge on fish biology, ecology, migration timing and route, breeding etc. should be taken into account. In any stock enhancement program, therefore, large fingerlings should be stocked at low densities than small fingerlings at high densities.
- *Encouraging more sanctuaries:* In most open water bodies, there are less risky options than stock enhancement through hatchery reared fingerling release. User communities are more prepared to invest in, notably fish sanctuaries and different forms of fishing bans. Interventions that were relatively low-cost, easily do-able, especially sanctuaries, which usually cause little or no social conflict, were found to be more effective and equitable in implementation.
- *Effectiveness of sanctuaries:* To make fish sanctuaries more effective, the following stages should be adopted-mitigation of all the conflicts among the stakeholders involved, formulation of clear guidelines

of sanctuary management, selecting the strategic place and size of the sanctuary, proper awareness building among the stakeholders, ensuring proper community organization and full participation and continuous monitoring and impact assessment.

- *Fish friendly regulators:* Fish passes and other fish friendly structures will also need effective management and operation in ways that maximize migration of important fish species in and out of compartments. Participatory and stakeholder based management of these structures is needed to make them more effective.
- *Fishing ban and Alternative income generating activities (AIGAs):* To attain a sustainable yield, the resource users should follow the fishing ban strictly both gear-wise and season-wise at all the sites all over the country. Project partners should consider the suffering of the fisher households while the ban is in force and provide alternative livelihood options for fishers such as credit with low interest and other sustainable means. The NGO partners should make the local communities understand about the future threat to fisheries resources and inspire them to be involved in AIGAs through rigorous training.

4.2 Improvements in operations and impacts assessments

- *Awareness about conservation and incentives to fishers:* Creating public awareness of the importance of maintenance of fish diversity in Bangladesh is necessary and should be the first priority for a lasting change. Sustenance of fish diversity can only be achieved with public support. A key step in building fisheries co-management and fish biodiversity conservation with community participation is to bring all the various stakeholders to a common front with a view to sharing resources and knowledge, creating an environment for meaningful discussion on cross-cutting themes and valuing each other
- *Revising policy:* There is a positive potential for co-management in the country, but this will only be successful under the right conditions executed by the right bodies. In this regard, it is essential to develop a dynamic partnership between local communities and interest groups on the one hand and the government on the other to support a greater participatory approach, using the capacities and interests of the former complemented by the ability of the latter to offer enabling legislation and administrative.
- *Minimizing conflict:* Future efforts should overcome mistrust between local DOF and NGO staff by building understanding and trust as development partners. To sustain the community organizations and to ensure their improved management, forging of links between FCBOs, the local government (*Union Parishad and Upazila Parishad*) and the local administration (*Upazila*) should be encouraged. Projects should avoid sites plagued with community conflicts or court cases. Where a conflict exists between different *groups or factions*, time and concerted efforts are needed to resolve the conflicts and arrive at a consensus.
- *Baseline surveys and impact assessment:* Regular monitoring and evaluation on water bodies, aquatic animals and plants, gear used, CPUE, socio-economic data on fishers and other *resource users should be carried out* on a regular basis. The methods used by different organizations for M&E, the outcomes, reliability and relative costs should be thoroughly reviewed to fine-tune future projects and feedbacks should be provided to resource users and technical staff.

5. CONCLUSIONS

A renewable resource like fish, when under intense exploitation, needs a management regime as it is not inexhaustible. Therefore, management measures should be applied in such a way that young fish are protected to grow before capture and enough are left as breeding stock for future generations. The management measures should include – regulation of fishing intensity at sustainable level, control gear selectivity, gear type and size of fish harvested, closed season, prohibition of destructive fishing, closed fish sanctuaries, and allocation of resources to different types of fisheries.

For sustainable and well-protected fish diversity for the present and the future, the country should: –

- Rational use of inorganic fertilizers and pesticides, and proper management of industrial effluents,
- Maintenance of minimum water depth (at least 1 m) during water extractions from critical water bodies,
- Regulation of selective fishing gears, mesh sizes, and fishing by dewatering,
- Establishment of more fish sanctuaries and natural *beel* nurseries in strategic points,
- Coordinated country-wide stock enhancement programs,
- Establishment of community-based organizations (CBO) among the fishers,
- Zero tolerance to new exotic fish introduction, and
- Strict application of existing fisheries rules and regulations.

This is the high time to care for the biodiversity of the rivers, floodplains, indigenous fishes and other aquatic animals and plants – the heritage and livelihood of Bangladesh, before they are lost forever. The researchers, policy makers, GOs and NGOs and national and international bodies should come forward to enhance and conserve the resource – both ecosystem and species using both *in situ* and *ex situ* approaches.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN CHINA

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Abstract

The inland aquatic ecosystems in China have been largely influenced by the large-scale economic activities and over-exploitation of aquatic resources. Fisheries resource enhancement and conservation activities such as artificial fish nest, artificial fish releasing, forbidden fishing and establishment of natural reserves were carried out throughout China. The purpose of these activities was to restore the quantity of inland fisheries resource, guarantee sustainable development of fishery, maintain biological diversity and preserve ecological balance. These activities with multiple ways, abundant species, large water areas and large scale practice have played an active role to resource enhancement and conservation. Through this practice, the ecological environment of inland waters improved, the biological diversity is raised, the fish catch is increased, and the social, ecological and economic benefits have been improved totally. However, several problems such as poor technology, nonstandard operation affected the fisheries resource enhancement and conservation and ecological stability. This paper will review the history, and practice and analyze the problems and insufficient in inland fisheries resource enhancement and conservation in China and finally recommends some suggestions on technology and operation in order to sustain inland fisheries resource.

Key words: Inland water, fisheries resource, enhancement, conservation, China

1. INTRODUCTION

The extent of inland water resources in China is about 18.38 million ha. Besides 1.48 million ha ponds, there are 16.90 million ha natural waters, including 7.65 million ha rivers, 7.14 million ha lakes and 2.11 million ha reservoirs (Bing *et al.,* 2005). These inland waters support rich aquatic life. There are more than 20 000 kinds of aquatic organisms in China at present, including about 3 000 species of fish, 240 kinds of migratory fish, more than 300 kinds of shrimp, 600 kinds of crabs, 90 kinds of cephalopods, about 300 species of amphibians and reptiles, 40 species of aquatic mammals and 600 kinds of aquatic plants (Shen, 2008). The fisheries resource enhancement and conservation in China recorded that the fry of grass carp, black carp, silver carp and bighead carp were released to ponds and lakes during the Tang Dynasty (Team of Fishery Resource Investigation in the Yangtze River, 1990). Nevertheless, the real history of fishery resources enhancement commenced in the 1950s, with the success of artificial breeding of the four famous Chinese carps. In addition to releasing of fish seeds, several natural reserves were also established for fisheries enhancement since 1982. By the end of 2009, 200 natural reserves and 160 national aquatic germplasm resources protected areas have been established, which has effectively improved the environmental quality for protecting biological diversity and improving the aquatic environment (Hong, 2009). This paper tries to review activities of enhancement and conservation of inland fisheries resources in China. Hopefully, the experience of enhancement and conservation of inland fisheries resources in China could be useful to other Asian countries.

2. GENERAL OVERVIEW OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION PRACTICES

2.1 History of inland fisheries resource enhancement and conservation in China

The extent of inland water resources in China is about 18.38 million ha. Besides 1.48 million ha of ponds, there are 16.90 million ha of natural waters, including 7.65 million ha of rivers, 7.14 million ha of lakes and 2.11 million ha of reservoir (Bing *et al.,* 2005). These inland waters support rich aquatic life. There are more than 20 000 kinds of aquatic organisms in China at present, including about 3 000 species of fish, 240 kinds of migratory fish, more than 300 kinds of shrimp, 600 kinds of crabs, 90 kinds of cephalopods, about 300 species of amphibians and reptiles, 40 species of aquatic mammals and 600 kinds of aquatic plants (Shen, 2008). Among those, Chinese sturgeon, White sturgeon, Chinese sucker, dolphin, Chinese alligator, and giant salamander etc. have a high economic and academic value.

The captive breeding and releasing fish seed to inland waters had a long history in China. It has been recorded that the fry of grass carp, black carp, silver carp and bighead carp were released to ponds and lakes during the Tang Dynasty Yonghui 2 year (Team of Fishery Resource Investigation in the Yangtze River, 1990). Nevertheless, the real history of fishery resources enhancement commenced in the 1950s, with the success of artificial breeding of the four famous Chinese carps (Shen, 2008). Many fish species including the four famous Chinese carps, common carp, bream, crabs, salmon, eel, sturgeon, whitebait, mullet etc. were released into freshwaters. According to incomplete statistics, from 2004 to 2006, over US$75.91 million were spent for fisheries resource enhancement. About 45 billion of aquatic organisms belonging to over 90 species were released into inland waters for enhancement (Yin and Zang, 2008).

In addition to releasing of fish seeds, several natural reserves were also established for fisheries enhancement since 1982. By the end of 2009, 200 natural reserves and 160 national aquatic germplasm resources protected areas were established (Hong 2009). China has established a national, provincial and municipal protected area network, which has effectively improved the environmental quality for protecting biological diversity and improving the aquatic environment. Especially in recent years, the central and local governments have further increased enhancement and protection of fishery resources, through which good economic and social benefits have been achieved.

2.2 Major practices of inland fisheries resource enhancement and conservation in China

2.2.1 Approaches

Presently the approach of enhancement and conservation in China are mainly artificial releasing programs and protective measures. A national program to hatchery release is being implemented since 2006. The protective measures consisted of closed fishing in spring, designation of protected areas, artificial fish nests, restriction on use of harmful gears and issuance of fishing quota (Table 1).

Table 1. Approaches for enhancement and conservation in China

Water type	Approaches					
	Artificial releasing	Artificial fish nest	Protected area	Closed seasons for fishing	Restriction harmful gears	Fishing quota
River	✓		✓	✓	✓	
Lakes	✓	✓	✓	✓	✓	✓
Reservoir	✓	✓	✓	✓	✓	✓

2.2.2 Species

The species for enhancement practices varies in different inland water areas in China. The species used for enhancement included not only *Piceus, Idellus, Molitrix, Mobilis, Cyprinus carpio, Carassius auratus, Parabramis pekinensis, Megalobrama skolkovii* and others which have economic value and are widely distributed, but also included some rare or endangered species with higher economic value or academic value, such as *Acipenser dabryanus, Acipenserschrenckii, Brachymystax lenok tsinlingensis, Trachidermus fasciatus, Acipenser sinensis, Myxocyprinus asiaticus, Tanichthys albonubes* (Table 2).

Table 2. Species used for enhancement and conservation in China

		Name of aquatic species
Fish	Major economic species	*Mylopharyngodon piccus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys mobilis, Cyprinus carpio Linnaeus, Carassius auratus auratus, Culterinae, Parabramis pekinensis, Hemisalanx prognathus Regan, Paramisgurnus dabryanus, Megalobrama terminalis, Megalobrama skolkovii, Squaliobarbus curriculus, Hemibarbus labeo, Hemibarbus maculates , Pelteobagrus fulvidraco , Pelteobagrus vachelli , Pseudobagrus ussuriensis, Silurus asotus, Siniperca spp, Ophicephalus argus, Schizothoracinae, Oncorhynchus keta, Cirrhinus molitorella, Silurus lanzhouensis Chen, Silurusmeridionalis, Hypomesus olidus, Acipenser ruthenus, Spinlbarbus denticulatus, Leuciscus leuciscus, Coregonus peled, Coilia ectenes, Gymnocypris przewalskii, Leiocassis longirostris, Plagiognathops microlepis, Varicorhinus simus, Spinibarbus sinensis, Procypris rabaudi*
	Rare and endemic species	*Procypris rabaudi, Megalobrama pellegrini, Esox lucius, Lota lota, Thymallus arcticus grubei Dybowski, Hucho taimen, Botia (Sinibotia) superciliaris Gunther, Schizothorax(Schizothorax)sinensis, Leuciscus waleckii*
	Wildlife Species	*Acipenser dabryanus, Acipenserschrenckii, Brachymystax lenok tsinlingensis, Trachidermus fasciatus, Acipenser sinensis, Myxocyprinus asiaticus, Tanichthys albonubes*
Crustacean	Major economic species	*Eriocheir sinensis, Hyriopsiscumingii, Trionyx Sinensis*
	Rare and endemic species	*Trionyx sinensis*
	Wildlife Species	*Palea steindachner*
Mammals	Wildlife Species	*Neophocaena phocaenoides, Lipotes vexillifer*
Amphibians	Wildlife Species	*Andrias davidianus*

2.2.3 Water areas

In China, there are 50 000 rivers with catchment area of over 100 km^2 of which 104 rivers are over 300 km and 22 rivers with more than 1 000 km in length including the Yangtze River, Yellow River, Heilongjiang River, Pearl River, Huaihe River. China is also one of the countries which have many lakes in the world. There are more than 2 800 natural lakes with water area above 1 km^2 including Poyang Lake, Dongting Lake, Taihu Lake, Hongze Lake, Qinghai Lake. In addition to rivers and lakes, there are reservoirs such as the Three Gorges Reservoir, Xiaolangdi Reservoir, Liujiaxia Reservoir. The enhancement and conservation activities are implemented in these inland waters (Table 3).

Table 3. Water area for enhancement and conservation in China

Inland	Water type	Protected water area
Northeast of China	River	Heilongjiang River, Ussuri River, Songhua River, Nen River, Mudanjiang River, Yalu River, Liao River, Dalinghe River.
	Lakes	Xingkai Lake, Chagan Lake, Jingpo Lake, Huaao Lake.
	Reservoir	Shuifeng Reservoir, Nierji Reservoir, Dading-mountain Reservoir, Lianhua Reservoir.
North China	River	Yellow River, Fen River, Luo River, Qin River, Huaihe River, Weihe River, Luanhe River.
	Lakes	Nansi Lake, Dongping Lake, Baiyang Lake.
	Reservoir	Danjiangkou Reservoir, Xiaolangdi Reservoir, Dagang Reservoir, Miyun Reservoir, Sanmenxia Reservoir.
The middle and lower reaches of Yangtze River	River	Yangtze River, Hanjiang River, Wanhe River, Huaihe River, Ganjiang River, Xiuhe River, Xiang River, Zijiang River, Yuan River, Lishui River.
	Lakes	Poyang Lake, Dongting Lake, Taihu Lake, Hongze Lake, Chaohu Lake, Honghu Lake, Liangzi Lake.
	Reservoir	The Three Gorges Reservoir, Danjiangkou Reservoir, Zhelin Reservoir, Wanan Reservoir, Zhanghe Reservoirs.
Southern China	River	Xinjiang River, Beijing River, Dongjiang River, Pearl River estuary, Qiantang River, Minjiang River.
	Lakes	Thousand Islands Lake.
	Reservoir	Longtan Reservoir, Xinfengjiang Reservoir, Tianshengqiao Reservoirs.
Southwest of China	River	The Yangtze River, Jinshajiang River, Yalong River, Jialing River, Wujiang River, Chishui River, Minjiang River, Tuojiang River, Nanpan River, Beipan River, Lantsang River, the Yellow River, Yarlung Zangbo River, etc.
	Lakes	Dianchi Lake, Erhai Lake, Fuxian Lake, Lugu Lake.
	Reservoir	The Three Gorges Reservoir, Wanfeng Reservoir, Ertan Reservoir.
Northwest of China	River	The Yellow River, Weihe River, Jinghe River, Tarim River, Ili River, and Black River.
	Lakes	Qinghai Lake, Hulun Lake, Bosten Lake, Ulungur Lake, Bell Lake.
	Reservoir	Nierji Reservoir, Liujiaxia Reservoir, Hongshan Reservoir.

2.2.4 Scale of operation

At present, all provinces, autonomous regions and municipalities carry out fisheries enhancement activities except in the Tibet autonomous region. Every year, large-scale fish stocking activities are carried out in China (Table 4).

Table 4. Large-scale fishery enhancement and releasing activities in China from 2003 to 2009

Time	Ceremonial Site	Theme	Organization involved	Species and amount
10-10-2009	Xinjiang Heaven Pool	Protecting lake around snow mountain	Ministry of Agriculture, Water Resources Department, Xinjiang People's Government	*Aspiorhynchus laticeps, Esox lucius linnaeus, Lucioperca lucioperca, Lota lota, Coregonus peled,* etc. Total: 40 million ind.
06-06-2009	Beijing City	Living aquatic resources enhancement action, emission reduction and Promoting ecological civilization.	Ministry of Agriculture, Beijing Municipal Government	*Acipenser sinensis, Acipenser dabryanus, Myxocyprinus asiaticus, Hyriopsis cumingii and Schizothorax Heckel, etc.* Total: 25 million ind.

Table 4. *(continued)*

Time	Ceremonial Site	Theme	Organization involved	Species and amount
22-04-2009	Wanzhou City	Conserve aquatic resources and building ecological civilization of Yangtze River	Ministry of Agriculture, Chongqing Municipal Government	*Hypophthalmichthys moritrix, Aristichthys nobilis, Ctenopharyndogon idellus, Procypris rabaudi, Onychostoma sima, Spinibarbus sinensis, Myxocyprinus asiaticus,* etc. Total: 5 million ind.
25-09-2008	Yibin City	Protection of aquatic animals; construction of the ecological civilization	Ministry of Agriculture, Three Gorges Project Construction Commission of the State Council, Water Resources and bureau of aquatic products of Sichuan province, People's Government and the Municipal Water Conservancy Bureau of Yibin.	*Acipenser dabryanus*, *Myxocyprinus asiaticus,* Four famous Chinese carps etc. Total: 1.43 million ind.
22-04-2007	Jingzhou City	Saving the rare aquatic organisms, building harmonious home of Yangtze River	Ministry of Agriculture, Three Gorges Project Construction Commission of the State Council	*Acipenser sinensis, Acipenser dabryanus, Myxocyprinus asiaticus, Hyriopsis cumingii* and *Schizothorax Heckel,* etc. Total: 1.59 million ind.
13-07-2006	Fuyuan County	Multiplication and releasing	Ministry of Agriculture, Heilongjiang government, Russia's Amur fishery Bureau and Bureau of the Jewish State Fishery	*Aclpenser schrenckii, Huso dauricus Georgi,* etc. Total: 1.21 millions ind.
19-09-2005	Shanghai City	Love national treasure, create urban ecology	Ministry of Agriculture, Municipal Government, Three Gorges Project Construction Commission of the State Council	*Acipenser sinensis,* etc. Total: 0.59 millions ind.
22-04-2004	Wuhan City	Protect rare aquatic animal of Yangtze River	Ministry of Agriculture, Hubei Provincial Government, Wuhan Municipal	*Acipenser sinensis,* four famous Chinese craps, etc. Total: 0.39 million
29-09-2003	Guangzhou City	Protect rare aquatic animal of Pear River	Ministry of Agriculture, Guangzhou City	*Acipenser sinensis, Trionyx sinensis, Mylopharyngodon piceus Richardson, Ctenopharyndogon idellus, Hypophthalmichthys moritrix, Aristichthys nobilis, Cirrhinus molitorella, Megalobrama hoffmanni,* etc. Total: 0.35 million ind.

3. DETAILED DESCRIPTION AND ANALYSIS OF CURRENT PRACTICES OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION

3.1 Major enhancement and conservation practices

3.1.1 Stocking fish fry

Artificial releasing of fish fry is used in China for restoration of depleted fish stocks. Here, the fries are produced through artificial or natural breeding methods and are then released to natural waters. According to reported statistics, 24.4 billion of aquatic organisms had been released to the ocean, rivers, lakes and other natural waters from 1999 to 2003. The estimated average recaptured rate is ranging from three percent for Chinese sturgeon in the Yangtze River to fifteen percent for the four famous Chinese carps in Xinganjiang Reservoir (Chen, 2002).

3.1.2 Building fish nests

By creating favorable conditions for natural reproduction of fish, the fisheries resources can be enhanced. For this purpose, artificial fish nests are established. Here, spawning substrates are artificially created to provide a suitable environment for million spawners to lay eggs. As this strategy increases the spawning area, improve the rate of fish spawning as well as the hatching and survival of young, it is an effective means of enhancement of inland fisheries resources. Guangxi province placed 1 000 m^2 of artificial fish nests consisting of 5 500 bundles of grass in the West River in March 2009 (Li, 2005). By the end of March 2009, a large number of fish assembled around the nests. The eggs of common carps and Crucian carps were observed in these nests in April 2009. The eggs were found in more than 60 percent of the grass with an average of more than 100 eggs per bundle. The fertilization rate was high and eggs were hatched into fry after 2 to 4 days. About two months later, there were 30 to 50 million eggs in the artificial fish nests. This is equivalent to artificial release of 2 550 000-4 250 000 fish fry with 85 percent natural hatching rates (Wu and Wang, 2009).

3.1.3 Establishing natural reserves

In China, natural reserves have been established for conservation and protection of endangered fish species and economically important fish germplasm resources for the sustainable use of resources. By the end of 2009, 200 natural reserves and 160 national aquatic germplasm resources protected areas have been established which has effectively improved the environmental quality for protecting biological diversity and improving the aquatic environment (Hong, 2009). The natural reserves and conservation areas have played an active role for protecting biological diversity and improving the aquatic environment.

3.1.4 Managing fishing activity

The management of fishing activity mainly includes formulating the minimum captured sizes of kinds of fish, eliminating harmful fishing gear and methods, delimiting the fishing forbidden areas and closed fishing seasons, confining the fishing quantity (Zhu and Zhen, 2009). All of the above can directly protect the fish resources.

Fishing in forbidden areas were established in the Yangtze River involving 10 provinces (autonomous regions and municipalities) which is more than 8 100 km of river length. The fishing is forbidden in main streams from Deqin country in Yunnan province to Yangtze Delta, including some branch rivers in the Poyang Lake region and Dongting Lake region. The forbidden fishing period in the river basin in upper Gezhou Dam is from February 1 to April 30, and below the Gezhou Dam is from April 1 to June 30 (Chen, 2002).

Fishing quota system is an effective measure to protect the Yangtze fishery resources. Fisheries administrative departments set the upper limit on fish catches, and issue fishing permits. Management based on fishing quota had been carried out at the downstream of the Yangtze River on Poecilia and Coilia ectenes, and achieved good results (Shi *et al.,* 2009).

3.2 Operation of fisheries resource enhancement and conservation

3.2.1 Policy making, planning and organization

China began to pay attention to the protection of aquatic resources since the 1970s. In 1986, the implementation of Fisheries Law brought the exploration and utilization, enhancement and conservation, monitoring and management of fishery resource into the legal system. In 2003, in order to promote and regulate the fishery resource enhancement activities, the Agriculture Ministry of China issued the Notification of Intensifying Fishery Resource Enhancement Activities. In 2006, Action Plan for Enhancement and Conservation of Aquatic Resources in China approved by the State Council put forward several important tasks such as enhancement of fishery resource, conservation of biodiversity, protection of water ecology. In 2007, the Treasure Ministry of China approved the project on aquatic resource enhancement and conservation, and enhancement activities around the country were initiated by the Agriculture Ministry of China. On the same year, the Regulation of Intensifying Fishery Resource Enhancement Activities was issued by the Agriculture Ministry to standardize management of fishery resource enhancement. The regulation further defined the fishery resources enhancement and conservation work as a routine task of the local fishery administration.

At present, several local governments have brought the fishery resource enhancement into the ecological restoration plan and taken measures to make the task as a routine work. The provincial administration, autonomous regions and municipalities make the plan of releasing activity according to the fishery resource condition and decide the releasing area, species, size and quantity. Scientific management system is created at levels of local fishery administration department. Research on enhancement technology was undertaken by institutes and the inspection departments provide scientific basis and technological guide to releasing activity.

3.2.2 Funding mechanism

Aquatic resource enhancement and conservation are mainly an undertaking of social and public welfare. The funding of enhancement and conservation mostly comes from the financial allocation of central government and to a lesser extent from the donations of enterprises and individuals. As of 2009, the annual budget for inland fisheries enhancement and conservation was approximately 26.28 million RMB, with the five-year average of US$25.988 million (Table 5).

Table 5. Annual budgets for inland fisheries enhancement and conservation

Year	2005	2006	2007	2008	2009
Annual budget (million US$)	24.82	26.28	26.28	26.28	26.28

3.2.3 Seeds for releasing program

According to the regulation of Agriculture Ministry of China, the released species should be indigenous species. The hybrids, transgenic and impure species should not be stocked in the natural water. Releasing activity should not be carried out at the germplasm resource reserve or sensitive spawning grounds of economically important fishes, shrimps and crabs. The released species should be native and healthy. The exotic species such as red-scavenger, Egyptian catfish and tilapia should not be released. Releasing of non-native species should be approved by fishery administration department after safety evaluation.

The larvae used for enhancement should be provided by approved proliferation base, original species base and well-bred species stations, and the parents in these bases are introduced from the state original species base. Currently, China has 16 435 larvae bases, of which 51 are in national level, 200 are in provincial level. More than 90 species are used in enhancement activities. The number of larvae of shrimp, freshwater fish and shellfish for releasing was 392.8 billion, 687.3 billion and 1262.2 billion respectively.

3.2.4 Executing organization and public participation

The aquatic resource enhancement activity at national level is under by the Agriculture Ministry of China and the activity in lower levels is done by local fishery administration department. The provinces, autonomous regions or municipalities are the implementation and supporting organizations. The large-scale releasing activities in rivers, lakes and reservoirs are performed by the provinces, autonomous regions or municipality government. The small-scale releasing activities are done by local fishery offices, enterprises or individuals.

In recent years, an inspection system of fish fry and adults was established to ensure logical distribution, better technology and scientific management in Yangtze River basin, Pearl River basin, Yellow River basin and Heilongjiang River basin. In addition, there are 2800 executing agencies, more than 33 000 administrators, and over 2 100 boats in China, which could guarantee effective supervision and inspection of operation. The enhancement activities have therefore been placed on a preliminary legal track.

Aquatic resource enhancement and conservation is a social task and needs wide support and co-participation. The awareness procedure is needed to be introduced. The public participation at the planning stage, executing stage, benefit-sharing stage, evaluating and tracking stage is important.

3.3 Impact assessment mechanism

Currently, China mainly relies on some scientific institutions and universities to evaluate the result of enhancement and conservation. They include the Yangtze River Fisheries Research Institute of the Chinese Academy of Fishery Sciences, the Heilongjiang River Fisheries Research Institute of the Chinese Academy of Fishery Sciences, the Pearl River Fisheries Research Institute of the Chinese Academy of Fishery Sciences, the Hydrobiology Institute of the Chinese Academy of Sciences, the Huazhong Agriculture University, the Southwest Agriculture University and the aquatic technology extending stations.

Evaluation is mainly on the changes of biological characteristics, population distribution and composition, fishing yield and marking recapture of released species, and thus a more scientific enhancement plan will be created. The enhancement species are tracked and surveyed using both the dynamic monitoring of fishery resources and social investigation. The effects are analyzed and evaluated according to the result of the investigation and biological data as follows:

(1) Mark and recapturing. Mark-releasing is currently the general method of testing enhancement effect. First, mark certain proportion of releasing fishes, then recapture the marked fish through fishermen and analyze the survival rate and growth etc. thus evaluate the test enhancement effects scientifically.

(2) Investigation of the fishery production. Regularly visit the fishery production unit, understand the changes of the resources of released species, record production quantity, individual size, fish species composition and proportion of marked fish catch, etc.

(3) Fishing and investigating after releasing. Regularly investigate the resources of released species, understand its resources' change. During the forbidden fishing period, the selected fishing boats were given special fishing permits. Based on the survey data, organize national experts to research and evaluate the effect of enhancement to analyze the ecological benefit, economical benefit and social benefit. This will provide scientific basis for future enhancement work.

3.4 Important cases of enhancement and conservation activities and its impact

3.4.1 Fisheries resource enhancement and conservation in the Yangtze River

The Yangtze River is the largest and longest river in China. It has large number of tributaries. The extent of river basin accounts for 50 percent of freshwater areas of China. The Yangtze River is important in China's freshwater fisheries as it sustains the original or native species base of economic fish, which plays an important role of freshwater fisheries in China. Its fisheries yield accounts for 60 percent in China (Chen, 2002). With the economic development of the Yangtze River basin, the environmental quality has deteriorated resulting in the decline of the fisheries resources. The fry production of the four famous Chinese carps had decreased from 30 billion to less than 100 million annually, which directly impacted the sustainable development of Yangtze River fisheries.

Enforcement of forbidden fishing zones is an enhancement strategy in the Yangtze River basin. The Yangtze River has been divided into two management zones by the boundary of Gezhouba dam, and in each zone a closed season of three months has been imposed. The forbidden fishing periods of the section between Deqin and Gezhouba dam is from 12:00 on February 1 to 12:00 on April 30 and the period of the section below the Gezhouba dam is from 12:00 on April 1 to 12:00 on June 30. It has been predicted that with this management plan, 22.35 million spawning brood stocks of the four famous Chinese carps can be protected and 1.2243 trillion juveniles will be produced, which is extremely important to enhance the fishery resources in the Yangtze River.

Establishment of artificial nests for the carp, crucian carp and other kinds of fish laying adhesive eggs is also an enhancement strategy in this river basin. Artificial releasing of black carp, grass carp, silver carp, bighead carp, carp, crucian carp and other important economic fishes in the Yangtze River basin is also done but species released are different in different provinces and cities. In the upper reaches of Yangtze River, *Spinibarbus sinensis, Onychostoma sima, Sinilabeo rendahli, Schizothorax prenanti, Silurus meridionalis, Pelteobagrus vachelli, Leiocassis longirostris* etc. were released, and in the lower reaches of the Yangtze River *Megalobrama amblycephala, Plagiognathops microlepis, Xenocypris davidi, Squaliobarbus curriculus, Pelteobagrus fulvidraco, Siniperca chuatsi, Channa asiatica, Channa maculata, Culter alburnus, Hemisalanx prognathus* etc. were released. In addition, some rare fish species such as Chinese sturgeon, Chinese sucker and so on have also been released into the Yangtze River. According to incomplete statistics, China has released 4.53 million of different sizes of Chinese sturgeon juveniles into Yangtze River from 1984 to 2005 and 720 000 Chinese sucker from 2005 to 2007.

Recently a series of nature reserves for rare and endangered aquatic species have been built in the Yangtze River basin, such as the Rare and Endemic Fishes National Nature Reserve in the Upper Reaches of the Yangtze River, Chinese Sturgeon Provincial Nature Reserve in the Yichang reaches of the Yangtze River, Yangtze River Dolphin National Nature Reserve in Hubei Swan Island Reaches of the Yangtze River, Finless Porpoise National Nature Reserve in the Yangtze River, the Four Famous Asian Carps National Aquatic Germplasm Resources Protected Area in the Yangtze River, etc. The Rare and Endemic Fishes National Nature Reserve in the Upper Reaches of the Yangtze River is originally called the Endemic Fishes National Nature Reserve from Hejiang to Leibo Section of Yangtze River which established and approved by the State Council in April 2000. In April 2005, the State Council made an adjustment to the area of nature reserve and renamed it. The total length of adjusted nature reserve is 1 162.61 km, with a total area of 33 174.213 ha, involved Yunnan, Guizhou, Sichuan provinces and Chongqing municipality. Reduction of fishing capacity by providing alternative employments to fishermen would help conservation of biodiversity of rare and endangered fish in the nature reserves.

After the completion of the Three Gorges Dam, due to changes of ecological conditions, eight spawning grounds of four famous Asian carps in the Three Gorges Reservoir have disappeared, while 11 spawning grounds below the Three Gorges Dam have downsized. Also the fry quantity decreased drastically in the section of Jingjiang River below the Three Gorges Dam due to reduced amount of discharged water. The national protected areas of germplasm resources have been built for the four famous Chinese carps in each section of the Yangtze River in China, including the Chongqing section in the upper reaches of the Yangtze River, the Laojianghe of Jianli county and Swan alluvion of Shishou City in the middle reaches of the Yangtze River, the Huangshi section of Hubei province and Anqing section of Anhui province in the middle section of the Yangtze River, the Yangzhou section in Jiangsu province in the lower reaches of the Yangtze River. The establishment of these protected areas has a great impact on protection of the aquatic germplasm resources in the Yangtze River.

Presently, the enhancement and conservation activity in the Yangtze River is a successful management measure for fishery resources protection in China's inland waters, after years of practice, which has already been interiorized, caused extensive concern from public and produced good social influence. The ecological restoration effects among river sections have appeared, such as that the decline trend of resources has been slow down in Hubei section of Yangtze River, some fish population, fish catch and individual size have been increased in part of river sections. It is noteworthy that the quantity of *Coreius heterodon* has increased and become dominant population in Yichang, the fish catch has increased obviously in Shishou, the fishing size is neat and the fish age structure of the catches is rational in Yichang, Shishou, JiaYu, Wuhan and Tuanfeng. Fisheries resource enhancement and conservation in the Yangtze River not only maintain the natural species and biological diversity, but also brought great social and economic benefits.

3.4.2 Fisheries resource enhancement and conservation in Qinghai Lake

Qinghai Lake is the largest inland brackish lake in China. Its water salinity is 12‰~13‰. The original reserves of naked carp produced 0.32 million tonne. Since the development of fisheries in 1958, the catch of Qinghai Lake accounted for 85~90 percent of the total fish yield in Qinghai province. However, at the end of 1970s, the total fish yield of Qinghai Lake was declining year by year. In the late 1980s the yield was less than 1 000 tonnes. In 1994, the annual yield of the whole lake was only 700 tonnes (Zhang, 2005).

For restoring naked carp resources, the government of Qinghai province has carried out four times of forbidden fishing in Qinghai Lake. The first time was from November 1982 to November 1984, the quota of fishing yield was 4 000 tonnes, the second time from 1986 November to November 1989, the quota of fishing yield 2 000 tonnes, the third time from December 1994 to December 2000, the quota of fishing yield 700 tonnes, and the fourth time from January 2001 to December 2010, the quota of fishing yield zero. Monitoring during forbidden fishing period indicated that the naked carp's resource is difficult to resume on natural proliferation (Qin, 2008). Therefore, through artificial releasing to enhance the resources of naked carp has become the most effective method to the restoration of fishery resources in Qinghai Lake.

The fecundity of naked carp female of above 0.75 kg is more than 20 000 eggs. On the assumption that one female can produce more than 5 000 eggs, only 2 000 females (matched with 1 000 males) can produce more than 10 million eggs. In May 1991, Qinghai Fishery Institute obtained 4 000 naked carp fry with one female and one male, and 3 000 fry grew up to about 6-8 cm in length within 5 months with the survival rate of 75 percent. In 1992, 300 000 naked carp fry were produced through artificial breeding and larvae grown up to about 6 cm in length with the survival rate of about 75 percent, were released into Qinghai Lake in November.

In August 1997, the Farm of Original and Well-bred Fish Species in Qinghai Province passed the on-site evaluation held by the Ministry of Chinese Agriculture and China Fisheries Original (well-bred) Species of Examination Committee, and had been approved to upgrade as national original aquatic farm. The main task assigned to this farm was to collect and preserve the original species of naked carp, use perfect engineering, technical and strict management measures to ensure the original germplasm quality of naked carp, and then provide original species for enhancing the stock biomass of naked carp. In 1998, the Fisheries Bureau authorized to build the artificial releasing station for naked carp in the Shalia River of Qinghai Lake. In 2002 and 2003, 3.36 million and 6 million of artificial breeding naked carp fry were released into Qinghai Lake by this station.

In July 2003, the Farm of Original and Well-bred Fish Species of Qinghai Province and the Artificial Releasing Station of Shalia River of Qinghai Lake were merged to form the Naked Carp Rescue Centre to accomplish the assignment of resource rescue, original species conservation, enhancement and releasing, germplasm and environmental monitoring for naked carp. The project of Dynamics Monitoring and Management of Naked Carp Resource undertaken by the Naked Carp Rescue Center showed that the amount of naked carp resources was more than 5 000 tonnes in 2004, an increase of 67 percent over the 1999 level, which showed that forbidden fishing- measures have achieved positive results (Chen, 2006).

Since the commencement of captive breeding and releasing of naked carp from 2002, more than 41 million naked carp fry have been released. Consequently, harvestable stock biomass of naked carp increased from 2 600 tonnes in 2002 up to 24 340 tonnes in 2008 owing to the declaration of forbidden fishing zones in whole lake and releasing of artificially spawned juveniles (Chen *et al.,* 2009).

3.4.3 Fisheries resource enhancement and conservation in Danjiangkou Reservoir

Danjiangkou Reservoir is the largest artificial reservoir in Asia, but the fishery resources in the reservoir showed tendency of declining due to over-fishing. In recent years, the Danjiangkou Reservoir Management Bureau has promulgated the Danjiangkou Aquatic Resources Protection Regulations and other local laws to manage the fishery. Based on the Fisheries Law of People's Republic of China and other relevant laws and regulations, the Danjiangkou Reservoir Management Bureau is empowered to apprehend the fishing boats without licenses, the implementation of fishing rights system and the approval procedures of purchasing fishing vessels, so that the horsepower and number of fishing vessels are stabilized at the level of 2000 to ensure the spawning of brood stocks and the healthy growth of larvae.

Also, artificial reproduction and releasing of fish seeds have been practiced in the Danjiangkou Reservoir in order to restore the fisheries resources, protect the environment, promote the sustained development of fisheries and achieve integration of economic, ecological and social benefits in the reservoir fishery. From 2004 to 2008, the Xichuan County of Danjiangkou City has released more than 4 billion fry into Danjiangkou Reservoir. These measures have effectively protected the fishery resources of the reservoir and increased the incomes of fishermen. The reservoir fish yield and value has increased from 16.2 million tonnes and US$0.07 billion respectively in 2000 to 33.3 million tonnes and US$0.24 billion respectively in 2008. Through 7 years' of forbidden fishing season during spawning season, an annual average of about 10 billion of fish, shrimp, crab, frog and other aquatic resources has been proliferated in Danjiangkou Reservoir resulting in direct economic benefit of about 50 million RMB. In particular, there has an obvious restoration of black carp and members of Xenocyprininae such as *Xenocypris davidi, Xenocypris microlepis* etc. and aquatic organisms such as Chinese perch and Yellow catfish and aquatic animals such as wild ducks, egrets and otters.

4. CONSTRAINTS AND PROBLEMS

Inland fisheries resource enhancement and conservation in China has got remarkable results, but several problems also exist such as the insufficient basic research, immature operation and evaluation system of fisheries resource enhancement and conservation.

4.1 Technical constraints

Fisheries resource enhancement has still many unknown factors as it is an emerging technology integrated by many subjects such as aquaculture, fisheries resource, fishing industry, environment protecting, biological engineering and fishery management. Several problems need to be solved prior, during and after fish releasing. We don't have advanced tagging and tracking technology, some even use the original method of shearing fin ray and tied with a steel brand, which is only available to big fish and may cause negative effect such as inflammation.

In other countries, several advanced tagging technologies were adopted. To small fishes, coded wire tag or fluorochrome tag could be used. To big fishes, biotelemetry tag or satellite tag is normally used. It is not suitable to copy indiscriminately the advanced tagging technology in other countries. How to use the technology to different fishes in China? What questions may appear? In China, some high technologies like sonar have been used to evaluate fishing enhancement, but we still have long way when compared with advanced countries. Moreover, further research on where and when to release different fish species and how to balance the fisheries resource have to be undertaken.

4.2 Operational constrains

At present, there is no specialized agency to take charge of fisheries resource enhancement and conservation. The activities in most provinces are usually done by fishery law enforcement organization. The organization belongs to the local department of fishery administration, which is very disharmony with the distribution of fishery resource. As fishery resource and fishery ecological environment are symbiotic, but the system divides the resource area into many parts according to different region, which will bring inevitable problems.

The fishery law enforcement organization is guided by local department of fishery administration, which may cause a problem where the administration takes sides of the organization. So, we must attach importance to the system and solve the problem of feeble management, and finally meliorate the ecological structure.

The industry of fishery is feeble as the relaxed management, lagged methods and insufficient equipment. Especially the slack law enforcement restricts the sustainable development of fishery industry. Local fishery law enforcement organization has low funds, so they have to find for more income. Some of the organizations even don't have a boat, and they mostly manage the fishermen at fishing wharf. Furthermore, because of the deteriorated environment, high frequency fish diseases and low income of the fishermen, collide with the organization which added difficulty of executing the law.

4.3 Distribution of social benefit

First, we usually just think much of short-term benefit but overlook the long term benefit. Leaders in some region pay too much attention to single species fishery and adjust the industry structure eyeless. When one kind of resource is rich, all invest to the industry, then, if the amount of the resource becomes lower, all change their direction to another kind of resource, which is a vicious circle. Fishermen compete with each other to catch fish in order to obtain more benefits, so the whole inland fishery was neglected. Fishery resource enhancement and conservation activities were carried out every year throughout the whole country, but some greedy fishermen catch the larvae with small nets or electricity just in or after the activity, which cause the released larvae would not survive.

Second, the distribution of benefit is uneven. First of all, administrators are not strict in enforcement, they may don't obey the law and fine the fishermen not punish them according to the law. At the same time, some local leaders protected the regional fishermen and they just punish the boats of other districts or cities. Next, large quantity of non-fishery labors emerges crazily when the fishery labors are not shifted to other industry, which is very bad to the fragile fishery resource. What's worse is the non-fishery labors usually catch fish with electricity, they may get rich income, but the real fishermen are becoming poorer. Finally, many inland rivers or reservoirs belong to many provinces and the different local law also can bring uneven benefit distribution.

The most famous example is Taihu Lake which belongs to Jiangsu and Zhejiang provinces, the administrative personnel usually dispute as the different local law and benefit. In 2000, the two provinces survey and divide the lake another time, finally, in 2001 the district from Fuziling to Hulou of Taihu Lake was divides to Zhejiang province and they can explore the area according to the State Council. The area of this south part is about 300 square kilometers. But actually none circle net was warranted in the south lake even though the whole circle nets area is about 160 thousand Chinese acres. Every year over a billion was used to the enhancement activity, but the spots of releasing activity were usually at Wuxi, Wujiang and other places which are all belong to Jiangsu province. All of the above can cause uneven distribution of benefits.

4.4 Ecological influence and genetic diversity

Unreasonable enhancement or blind introduction may destroy the ecological system and fishery resource of natural waters. Artificial incubation community may copulation with field community, which will change the individual heredity, physiology and behavior of fishes and influence the biological diversity and ecological balance. The service function of ecosystem will be changed as the competition between artificial and field community. The functions of ecosystem include food chain, nutrition circulation, ecosystem relation as well as energy conversion transmission.

The ecological risks of fishery resource enhancement mainly include destroys from aboriginal species' enhancement and external species' introduction. Regarding the indigenous species, some artificial fishes may not be caught but integrate into natural population. Researches indicate that the productive capacity and productive forces of artificial population are poorer than natural population. The natural population may be replaced or weakened by the artificial ones. Otherwise, the risk of external species may be greater and the influence of them to natural population has been pointed out by many researchers. So, the governors should make reasonable policy of artificial proliferation and releasing.

The consequence of fishery enhancement may be very serious if without sufficient feasibility assessment of released species. For example, in Australia one kind of virus brought by released freshwater perch disperses and damage many fish species such as salmon and other small fishes. Another example is in America, in 1972 Asian bighead carp and silver carp were introduced to monitor the water quality of sewage treatment plant and aquaculture. From 1972 to 1990, the quantity of the two kinds of species is normal, but the bighead carp growth crazily from the early time of 1990s, especially the stage after 1999. Silver carp also increased from the late of 1990s. Rapid rise of the external species invaded seriously the space and threatened the survival and reproduction of local species. So, ecological and genetic problems should be considered when marked fish enhancement and releasing policies.

5. RECOMMENDATIONS

5.1 Further research of artificial enhancement

5.1.1 Size of released species

The size of released species should be standard. At present, we mostly release fishes into rivers, lakes or reservoirs, the environment of which is usually very complicate. So the size and physique of released species must be good. Ponds and reservoirs are enclosed water, the water environment is clam. So we can choose small active and healthy fishes between 0.05 and 0.1 kg per individual when the survival rate is guaranteed. But when we released fishes into rivers, bigger and vigorous fishes should be picked up as the rapid velocity of water. The size of released fishes in China now has not been standardized, which led high mortality rate, at the same time, energy, time and fund were wasted. Therefore, we should survey the water environment, research the ecological compatibility of different discharged species, choose feasible size, domesticate the released fishes and form a series of standards or criterions.

5.1.2 Quality of released species

The quality of released fishes and quarantine system should be further studied. We should research the breeding and cultivation technology of different released fish species and form a healthy breeding and cultivation technology system, study the idioplasmic resources and genetic diversity of the released fishes and put forward a quality evaluation system, research how to detect rapidly the quality of the larvae with kits and finally bring forward the suggestion of building a germplasm resources reserve.

5.1.3 Capacity of released species

The water's capacity should be evaluated. The ecosystem of released waters should be investigated before enhancement activity. We need to survey the primary productivity, food chain and nutrition of the water, and then the fish quantity, time and location of releasing activity can be confirmed. After releasing, we must track and evaluate the effect and adjust the quantity, time and location for the best performance.

5.1.4 Tagging of released species

The tag technology should be studied. Different released fish species adapt to different tag technology, which includes type of tag, part, larvae size, method and so on. We need to choose the most suitable tag method and form some patents.

5.1.5 Tracking of released species

The tracking investigation after fish releasing should be done. We can track the released fishes at fixed point and fixed time, also we can interview fishermen to see what they catch. Based on the statistic data of larvae's distribution, feeding habits, growth characteristic and recapture rate, we can evaluate the effect of fishery enhancement.

5.1.6 Evaluation of released species

The evaluation technology should be enhanced. The change of every fish species' resource before and after releasing activity needed to be investigated, based on which, dynamic change models can be acquired. In addition, the change of fishery economic benefit should be assessed. Finally, a set of economic and risk evaluation system can be set up.

5.1.7 Impact of released species

The influence of fishery enhancement and releasing to the water ecosystem should be studied. We can compare the primary production, secondary production, biology diversity and water environmental structure after releasing activity with the situation before fishes releasing. Then, an influence assessment system can be established.

5.1.8 Function of enhancement

The service function of fishery enhancement and releasing should be researched. Fishery enhancement and releasing has several functions such as providing aquatic product, ecological restoration and propagandize. If we know which fish species can be caught easily and has big economic benefit, the serious tendency of fishery resource at present can be alleviated. And if we know which aquatic species can purify the water quality and control water bloom, the population structure and quantity can be optimized. Otherwise, everyone should set up the idea of protecting resources and environment and joins in the fishery enhancement and releasing activities.

5.2 Amelioration of operation and evaluation

In view of the main problems in aquatic resources maintenance, necessary laws and regulations should be formulated. The financing should be added by expanding the financing channels and governments' support. Besides, the fund from punishment of water pollution and fishing should be used to resource enhancement and releasing. And the law enforcement officials should be trained, the equipment should be renewed, the enforcement capacity should be enhanced and the funds should be insured of course.

A perfect operation standard of fishery resource enhancement technology should be set up. The institute who choose the parent and cultivate the larvae should be censored. There are several links in the task such as survey the ecological environment and fishery resource, choose the releasing species, germplasm identification of the parents, cultivate the larvae, make certain the size and quantity of discharged larvae, examine the larvae, monitor the water environment, supervise the activity and evaluate the effect. Every link in the process should be scientific investigation and discussion. Regarding all of the above tasks, several can be executed by aquatic institute or universities for instance survey the ecological environment and fishery resource, choose the releasing species, make certain the size and quantity of released larvae, monitor the water environment and evaluate the effect, and others as germplasm identification of the parents and cultivate the larvae can be bid openly. So, a standard should be put forward to distinguish the different bid enterprises or institutes. The eligible ones can be ensured with a certificate.

Although fishery resource enhancement has been done for many years in China, the basic research is still scare, many researchers discuss the work just on theory but not on enough data or experiments. The former enhancement activities are normally blind and without scientific guide, several questions can't be explained such as the changeable recapture rate, so further research should be done.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN INDIA

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Abstract

India produces 4.6 million tonnes of fish annually from its inland water bodies, of which 1 million tonne originates from enhancement and capture fisheries of open waters. It is estimated that 1.5 million ha of small reservoirs are amenable for culture-based fisheries and 1.7 million ha of medium and large reservoirs can be developed on the basis of enhanced capture fisheries. Reservoirs of all categories together produce 94 000 tonnes of fish against a potential of nearly 1 million tonne. Wetlands situated at the floodplains, commonly called *beels* (300 000 ha) form an important resource for practising enhancement. Reservoirs and wetlands are stocked mainly with the Indian major carps for culture-based fisheries and enhanced capture fisheries. Sufficient numbers of fish fingerlings are not produced in the country to meet all stocking requirements. Species enhancement, though tried with tilapia, common carp and silver carp, has not been very successful. Instances of environmental enhancement and enhancement through cage and pen culture are not very popular either. River stocking attempts made so far are sporadic with very little impact.

Inland waters of India harbour a rich fish biodiversity supporting capture fisheries in rivers, estuaries, lagoons, upland lakes and mangroves. Decline of fish populations in rivers is due to a variety of factors including habitat loss, effluent discharge, water abstraction, and dams and hydraulic structures, besides other socio-legal reasons. Many initiatives have been taken by the government to conserve the biodiversity that include *in-situ* conservation, ranching, fish sperm and embryos cryopreservation, tissue banking, live gene banks and provision of fish passes. Government of India has enacted National Biodiversity Action Plan (NBAP) in 2008 and created a National Biodiversity Board.

Ownership of inland water bodies other than small ponds vests with the Government and the fishing rights of reservoirs and beels are given to individuals, groups and communities according to norms that vary across the States. Rivers are generally fished as a common pool resource with free access, except in a very few States that auction river stretches to individuals. The institutional, policy, legislative and financial environments under which enhancement and capture fisheries regimes exist are not conducive to the interests of the fishers. Strong tools for valuation of ecosystem goods and services, enabling governance arrangements and estimation of environmental flows are needed. Fishing communities need to be organized into strong co-management/participatory/community regimes in order to ensure that all stakeholders take part in decision making process and the benefits accrued are shared equitably by all.

Key words: Inland fisheries, enhancement, culture-based fisheries, stocking, aquatic biodiversity

1. INTRODUCTION

The fisheries sector in India has registered a commendable ten-fold growth during the last six decades, propelling the country to the forefront of fish producing nations in the world. Today, India ranks third in the world in fish production and is the second largest producer of inland fish. With an annual production of over 7.6 million tonnes that accounts for a turnover of INR 360 billion, fish contributes to more than 1 percent to the national GDP and 5 percent to agriculture GDP. While more than 14 million fishers and fish farmers depend on fishing and fish farming for their livelihoods, many times more that number eke out their living through support and the ancillary activities such as fish processing, trade and making of fishing crafts and gear. Often referred to as the 'rich food of the poor', fish is the cheapest animal food that is accessible to the poor at affordable prices. The annual export earnings from fish and shell fish are about INR 86 billion accounting for 18 percent of the country's total agriculture export.

Fish production in the country registered a ten-fold increase over the last six decades and today the country produces 7.6 million tonnes of fish from both marine (3.0 million tonnes) and inland (4.6 million tonnes) sources. Over the years, the contribution of marine fish in the total production has decreased from 71 percent in 1950s to 40 percent during 2008-2009 with a corresponding increase in inland fish production which now accounts for 60 percent of the total. This shift is the reflection of the contribution of fish produced through aquaculture (mainly freshwater aquaculture) and enhancement (mainly from reservoirs and wetlands). It has been recorded that 3.6 million tonnes of fish is produced through inland aquaculture in India (Ayyappan and Sugunan, 2009). The remaining 1.0 million tonne of inland fish is attributable to different types of inland open water systems. Although the breakup of catch from rivers, lakes, floodplain wetlands and reservoirs is not recorded, it is generally believed that the capture fisheries of rivers and estuaries contribute very little to the total inland production. The bulk of production from open waters emanates from reservoirs, small irrigation impoundments and floodplain wetlands. The main focus of management in these water bodies is culture-based fisheries and fisheries enhancement.

Aquaculture is unlikely to meet all the additional requirements of inland fish by 2020, which vary from 5.3 million tonnes (ENCA, 2008) to 8.4 million tonnes due to a number of reasons (Ayyappan and Sugunan, 2009). Therefore, a balanced growth of aquaculture and enhancements along with conservation of natural aquatic ecosystems is needed to meet the future food fish demands. Like any other development sector, Indian fisheries is also at cross roads. In the enthusiasm to produce more fish from all available water bodies, many developing countries in the past paid higher attention to production and yield, while ignoring some key issues such as environmental sustainability and social equity. India is no exception to this. A number of key ecosystem goods and services and their significance to the livelihood, nutritional and health security of riparian populations have almost been ignored, at least during the early years of development. Today, awareness about environmental impact assessment, biodiversity conservation and environmental flows is increasing. A substantial section of the scientific community in the country and its civil society at large are now aware of and committed to achieving trade-off between sustainability and increased productivity. This document tries to collate some key aspects related to fisheries enhancement and view them from a conservation angle. Hopefully, this will enable the policy makers and planners, both at national and international level, to view India's inland fisheries enhancement plans from the right perspective and dovetail into them the elements of environmental sustainability and social equity.

2. MAJOR PRACTICES OF ENHANCEMENT AND CONSERVATION

2.1 Capture fisheries, culture based fisheries and enhancement

India has rich natural resources in the form of rivers, ponds, lakes, reservoirs and floodplain wetlands. Inland fish production systems in the country can be summed up as the capture fisheries of the rivers, estuaries, lagoons and lakes; aquaculture in ponds; and various forms of enhancements (mainly culture-based fisheries and stock enhancement), being practiced in reservoirs, lakes and floodplain wetlands. Catch from the rivers and estuaries are on the decline due to negative impact of human activities on the aquatic environment. Information on the fisheries activities in the upland lakes is scanty. Since mangroves are protected areas where fishing is either prohibited or done on a subsistence basis, details of fish production in these water bodies are not available. The major inland fisheries resources in India and their mode of utilization are shown in Table 1.

The strategy for inland fisheries development should centre on sustainability and sustainable development, which according to the FAO, *is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations.* Such sustainable development should be environmentally non-degrading, technically viable and socially acceptable. Compared to intensive aquaculture, capture and culture-based fisheries provide management options, which are more compliant with the norms of sustainable development. Sustainability of fish production systems is inversely proportional to intensification (Figure 1).

Table 1. Open water fishery resources on India and their modes of fishery management

Resource	Resource Size	Common mode of Management
Rivers (km)	29 000	Capture fisheries
Mangroves (ha)	356 000	Subsistence
Estuaries (ha)	300 000	Capture fisheries
Estuarine wetlands (*bheries*) ha	39 600	Aquaculture
Backwaters/lagoons (ha)	190 500	Capture fisheries
Large and medium reservoirs (ha)	1 667 809	Stock and species enhancement
Small reservoirs	1 485 557	Culture-based fisheries
Floodplain wetlands	354 213	Culture-based fisheries
Upland lakes	720 000	Not known

Hyper-intensive culture systems are not environmentally sustainable and many times these work against social equity by affecting access to resources by many stakeholders. Therefore, in order to meet the national targets for future production, a right balance needs to be struck between intensive aquaculture and fisheries management. India's national policy is to follow a middle path in terms of intensification and encourage enhancement wherever possible. Future production targets by resources and production systems are shown in Figure 2.

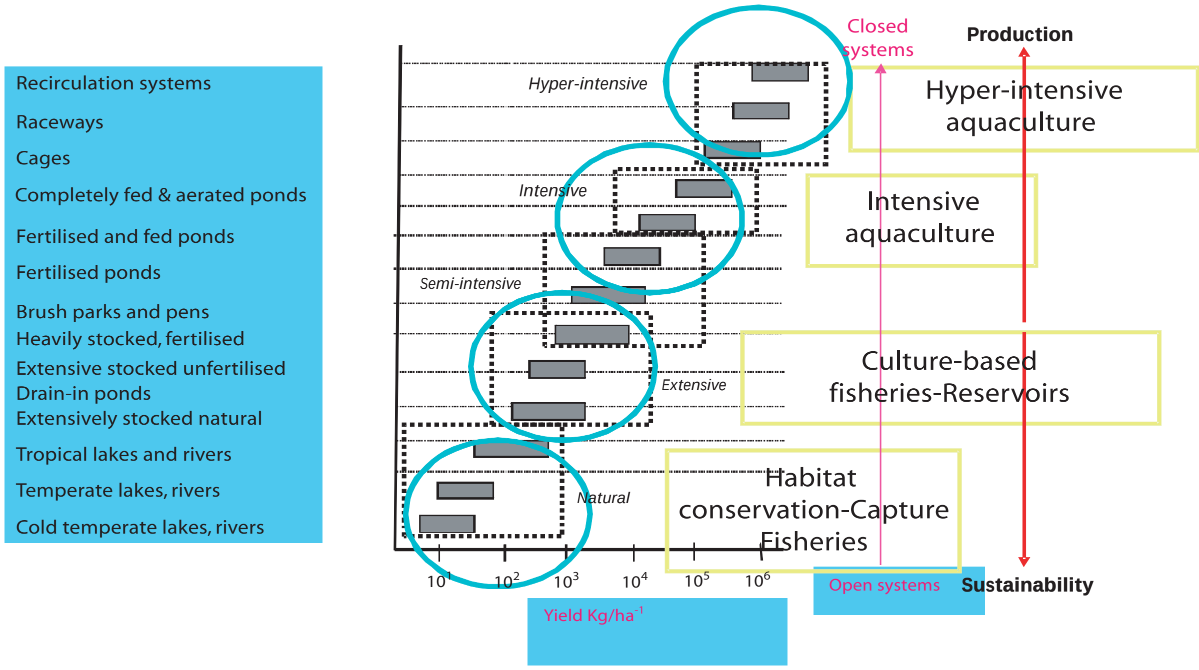

Figure 1. Fish production systems and their sustainability (modified from Welcomme and Bartley, 1998)

2.2 Species of aquatic organisms

2.2.1 Capture fisheries

Indian rivers and associated lakes and wetlands are known for their rich biodiversity. Hamilton (1822) and Hora (1929) reported about 265 and 272 fish species, respectively from the river Ganga and its tributaries alone. More recently, Payne *et al.* (2004) reported 140 freshwater fish species and NBFGR reported 143 fish species from the Ganga River basin. Inland waters of India can boast of 765 freshwater and 113 brackish water fish species (NBFGR, 2009). These include the culturable Indo-Gangetic carp species (*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*), and other commercially important fish species such as other carps (*C. cirrhosa*, *L. fimbriatus*, *L. calbasu*, *L. bata*), peninsular carp (*Puntius pulchellus*), pearl spot (*Etroplus suratensis*), mullets (*Liza parsia*, *Mugil cephalus*) golden mahseer (*Tor putitora*) other mahseers (*T. tor*, *T. mussullah*, *T. khudree*), chocolate mahseer (*Accrossochielus hexagonolepis*), catfishes (*Pangaisus pangasius*, *Aorichthys aor*, *A. seenghala*, *Silonia silondia*, *Mystus punctatus*), snow trouts (*Schizothorax richardsonii*, *Schizihoraichthys spp*), murrels (*Channa punctatus*, *C. marulius*), climbing perch (*Anabas testudineus*), magur (*Clarias batrachus*) and singhi (*Heteropneustes fossilis*) to name a few.

The important prawn and shrimp species that are regularly caught are giant freshwater prawns (*Macrobrachium rosenbergii*, *M. malcolmsonii*, *Penaeus monodon and P. indicus*). The commecially important molluscs are edible oysters (*Crassostrea madrasensis*) and mussels (*Perna virdis*).

2.2.2 Species for enhancements

Indian major carps (*C. catla*, *L. rohita and C. mrigala*) are the most common species used for stocking in culture-based fisheries, especially small reservoirs and floodplain wetlands. Among the three, *C. catla* is the most preferred for its faster growth and easy catchability. Indian water bodies are rich in plankton and the plankton feeding habit of *C. catla* enables it to achieve quick growth. In some of the reservoirs in south India, catla (*C. catla*) is reported to grow up to 1 kg during the first year of stocking. Rohu (*L. rohita*), known for its browsing habits, can effectively utilize periphyton and *C. mrigala*, a bottom feeder, is very suitable for stocking in floodplain wetlands with heavy detritus loads. In some parts of the country, especially the northeast and uplands, common carp (*Cyprinus carpio*) is preferred for stocking the reservoirs. Tilapia (*Oreochromis mossambicus*) was stocked in reservoirs of Tamil Nadu during the 1960s, but this fish is now not preferred by the reservoir fishery managers due to poor growth and early maturation. However, it still supports a good fishery in some of the Reservoirs like Malampuzha in Kerala state. Silver carp has established a natural population in Gobindsagar reservoir in Himachal Pradesh after an accidental introduction during the 1970s (also see sections 3.1.2; 6.4). Freshwater prawn (*M. rosenbergii*) has been tried as a candidate species for culture-based fisheries in some of the reservoirs with varying degrees of success (Yadava and Sugunan, 2009).

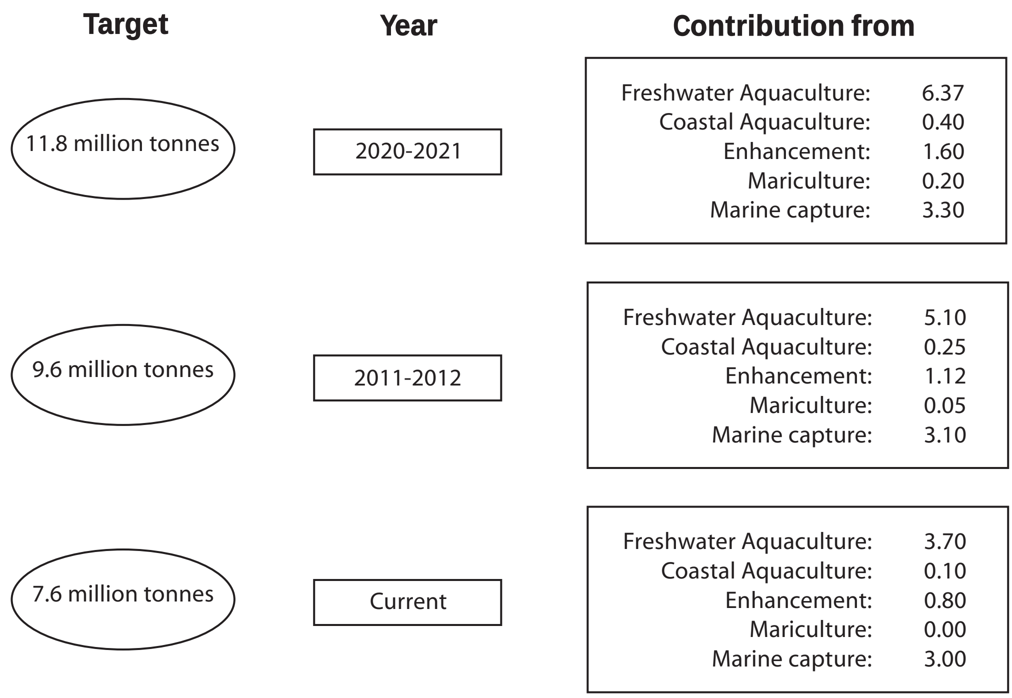

Figure 2 . Projected fish production and their source

3. INLAND FISHERIES ENHANCEMENT AND CONSERVATION IN INDIA

The present inland fish production systems in India fall under (a) enhancement and (b) capture fisheries. Enhancement is practiced in reservoirs and floodplain wetlands, where stocking is the main input, whereas in capture fisheries of rivers, estuaries, lagoons etc, the main emphasis lies on conserving the habitat and extracting fish stock from the wild on a sustainable basis.

3.1 Enhancement

FAO (1997) defines fisheries enhancements as technical interventions in existing aquatic resource systems, *which can substantially alter the environment, institutional and economic attributes of the system.* This is the process by which qualitative and quantitative improvements are achieved from water bodies through exercising specific management options. Enhancement *inter alia* includes 'culture-based fisheries (stock and recapture)', 'stock enhancement (enhanced capture fisheries)', 'species enhancement (introduction of species)', 'environmental enhancement (fertilizing water bodies)', 'management enhancement (introducing new management options)' and 'enhancement through new culture systems (cage culture, pen culture, FADs, etc.)'. Culture-based fishery is the most common mode of enhancement being followed in inland water bodies in India. When the fish harvest in an open water system depends solely or mainly on artificial recruitment (stocking), it is generally referred to as culture-based fishery. Reservoirs and floodplain wetlands offer scope for one or more forms of enhancement. The most suitable management strategy for a particular water body is chosen, based on its morphometric, edaphic and biological characteristics. The two most common forms of enhancement suitable for and followed in Indian reservoirs are:

- culture-based fisheries and
- stock enhancement

3.1.1 Culture-based fisheries

Culture-based fisheries is practiced in India in small reservoirs and closed floodplain wetlands. Of the 19 370 reservoirs (3.15 million ha), 19 134 (1.48 million ha) are small shallow irrigation impoundments, more than 70 percent of which either dry up completely or retain very little water during summer (Haniffa and Pandian, 1978). Another set of water bodies where culture-based fisheries is commonly practiced are the floodplain wetlands (*beels*) located mainly in the States of Assam, West Bengal, Uttar Pradesh and Bihar (see Sugunan *et al.*, 2000); Sugunan and Bhattacharjya, 2000 and Pathak *et al.*, 2004 for details). These water bodies allow relatively easy recapture of stocked fish and are suitable for culture-based fisheries. Conversely, the 180 (527 541 ha) medium and 56 (1.14 million ha) large reservoirs are relatively deeper where recapture of stocked fishes is rather uncertain. These water bodies are not considered suitable for culture-based fisheries and are managed on the basis of stock and species enhancement.

Detailed technical guidelines have been issued by the Department of Animal Husbandry, Dairying and Fisheries (DAHDF), Government of India and the Central Inland Fisheries Research Institute (CIFRI) on how to manage the culture-based fisheries in small reservoirs and closed *beels*. The key management parameters are estimation of fish yield potential, selection of fish species for stocking, stocking rate and size, period of growth and size at harvesting (Yadava and Sugunan, 2009; Sugunan *et al.*, 2000; Sugunan and Bhattacharjya, 2000). Ownership of stock, access to fishing and sharing of profit under a culture-based fishery vary considerably across and within the States of India. By and large, a cooperative society comprising the fishers exists in most of the water bodies, but their functioning is not always very effective (also see section 3.3).

Species in culture-based fisheries:

Since 1970, after the advent of carp seed production technology, most of the Indian states have a flourishing carp seed industry in the private sector, producing seed of *C. catla*, *C. mrigala*, and *L. rohita*. Consequently, the culture-based fisheries of small reservoirs and floodplain wetlands in India largely centres around these three species. The Indian major carps have an impressive growth rate and their feeding habits are suitable for utilisation of various food niches. Instances where stocking of Indian major carps became ineffective in small reservoirs are rare.

Stocking rates:

The main considerations in determining the stocking rate are growth rate of individual species stocked, the mortality rate, size at stocking and the growing time (Yadava and Sugunan, 2009, Sugunan et al., 2000; Sugunan and Bhattacharjya, 2000). A large country like India, with too many water bodies to stock, has inadequate infrastructure to meet all the stocking requirements, and has resulted in under-stocking in culture-based fisheries. Stocking densities need to be specified for individual water bodies or a group of them sharing common characteristics such as size, presence of natural fish populations, predation pressure, fishing effort, minimum marketable size, amenability to fertilisation and multiplicity of water use. *Beels* are suitable for practising culture-based fisheries for many reasons. Firstly, they are very rich in nutrients and fish food organisms, which enable the stocked fishes to grow faster to support a fishery. Thus, the growth is achieved at a faster rate compared to reservoirs. Secondly, the *beels* allow higher stocking density by virtue to their better growth performance and high yield. Thirdly, there are no irrigation canals and spillways as in the case of small reservoirs, which cause stock loss, and the lack of effective river connection prevents entry of unwanted stock. *Beels* also allow stocking of detritivores as the energy transfer takes place through the detritus chain.

Scope of culture-based fisheries:

Efforts made by the CIFRI in many small reservoirs across the country by introducing culture-based fisheries with stocking of Indian major carps have been very effective in improving the yields (also see section 4.1).

Indian reservoirs produce much less fish than their potential. Available estimates suggest that at a very modest rate of 500, 250 and 100 kg/ha/year respectively from the small, medium and large reservoirs of India, nearly 1 million tonne of fish can be produced every year by adopting fisheries management norms based on scientific advice (Fishing Chimes, 2010). Considering that this yield enhancement can be achieved on a sustainable and eco-friendly terms, reservoirs should receive adequate priority in future plans for inland fishery development. Culture-based fishery has been successful to a large extent in the closed *beels* of West Bengal where a production level up to 2 t/ha has been achieved mainly through very good organization of the community under a co-management framework (Sugunan *et al.*, 2000). It can be successfully adopted in the similar water bodies of Assam to increase the fish yield from the present level of 173 kg/ha/yr to at least 1 t/ha/yr (Sugunan and Bhattacharjya, 2000) The management measures to be adopted are clearing of aquatic weeds, creating infrastructure facilities for rearing fish seed and post harvest activities. Floodplain wetlands of Bihar (40 000 ha) and Uttar Pradesh (152 000 ha) are not being utilized properly for fish production. Indian Council of Agricultural Research (ICAR) has identified these water bodies in the two States for development on the basis of culture-based fisheries and pen culture in order to increase their inland fish production (ICAR, 2007).

3.1.2 Stock and species enhancement

Stock enhancement is being practiced in two ways (i) stocking of large and medium reservoirs and the open *beels* that retain connection with the parent river as part of enhanced capture fisheries and (ii) in river stocking as a part of river ranching. Reservoirs and *beels* are stocked with a view to establishing/supplementing a breeding population or as a temporary measure to compensate for recruitment failure. Species enhancement and introductions are sometimes resorted to for correcting imbalances in species spectrum

Enhanced capture fisheries:

Stocking attempts in medium and large reservoirs and open beels become successful only when the stocked fishes breed and propagate themselves. It is on record that *C. catla*, stocked in Sathanur, Gandhisagar and Ukai reservoirs have established itself in these reservoirs, eventually leading to increased yield and production, primarily because of its breeding success (Sreenivasan, 1984). In sharp contrast, in a number of reservoirs like

Nagarjunasagar, Bhavanisagar, Krishnagiri, Malampuzha and Peechi, the fish did not make any impact because of its failure to breed (Sreenivasan, 1976). It is important to stock at the early years of reservoir formation for facilitating the stocked fish to take advantage of the initial bursts in plankton and benthos. Thus, stock enhancement in the context of reservoirs is inducting and nurturing breeding populations of desirable species. The stock is managed through a number of management actions such as 'stock monitoring through manoeuvring of fishing effort', 'imposing mesh regulations', 'observance of closed seasons' and 'conserving habitats to allow natural recruitment and growth of target species'. Although regular annual stocking is not done after the target species get established, some supportive/corrective stocking might become necessary on special occasions such as breeding failure or stock loss. Some *beels* retain their riverine connection for a reasonably long time and these water bodies are relatively free from weed infestations. These *beels* are a typical continuum of rivers where the management strategy is essentially akin to riverine fisheries. Thus, the basic approach is to allow recruitment by conserving and protecting the brooders and juveniles. These measures have the dual advantage of conserving the natural habitat of the *beels* along with extending the benefits of conservation to the lotic ecosystem of the parent stream.

In capture fishery management, the natural fish stock is managed. Therefore, a thorough insight of population dynamics including recruitment, growth and mortality is very much essential. Identification and protection of breeding grounds, allowing free migration of brooders and juveniles, and conservation measures to protect brood stock and juveniles are important.

River stocking:

River stock enhancement by releasing seed of Indian major carps in river stretches is being practiced by the State Fisheries Departments such as West Bengal for many years. There are reports from some regions where local species are stocked into rivers. This is in addition to the practice of releasing fish as a part of religious rituals. The river stocking by the States is a sporadic activity followed in different parts of the country without any policy guidance from central agencies and no details on this have been documented. Usually, hatchery-reared fingerlings are procured by the State Fisheries Department from private agencies and stocked into rivers with an objective of enhancing and sustaining the natural stock in rivers, primarily as a welfare measure. But, the efficiency of the State machineries that undertake this activity and compliance in terms of quality and quantity is often doubtful. The National Bureau of Fish Genetic Resources and other agencies responsible central agencies have expressed concerns about inducting hatchery-bred seed into natural waters connected to the Ganga River system. A more serious concern arises from the fact that the fish breeding in India is practiced through mixed spawning, a process in which three species (Catla, rohu and mrigal) are spawned and fertilized in a common pool, resulting in genetically contaminated progeny. In view of all these adverse impacts, the national policy on this stipulates (as envisaged in the national draft model bill) using freshly collected brood fish for breeding to stock the rivers.

Species enhancement:

Sometimes, 'species enhancement' might be required when no suitable species are available in the system. It aims at augmenting the species range by adding fish species from outside with a view to colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop. The country's policy on stocking reservoirs, though not very explicit, disallows the introduction of exotic species into reservoirs. Despite this, several exotic fishes have found their way into Indian reservoirs. The tilapia, *O. mossambicus* was introduced in reservoirs of south India during the 1960s. Jhingran (1991a) reported a gradual decline in size of tilapia in reservoirs of Tamil Nadu and Kerala over the years. Today, fishery managers in India do not prefer *O. mossambicus* as a candidate for stocking (Sugunan, 1995). Common carp was brought into the country in 1957 for aquaculture purposes, but soon the fish found its way into all types of water bodies including reservoirs. But their performance in reservoirs was erratic despite heavy stocking. They are not frequently caught in a passive fishing gear like gill net due to their slow movement and bottom dwelling habit. An important disqualification of common carp is its propensity to compete with some indigenous carps like *C. mrigala, C. cirrhosa and C. reba*, with which it shares a food niche. However, the fish is very popular in reservoirs of the northeast, where it enjoys a favourable micro-climate and a good market. A spectacular performance of silver carp is recorded from Gobindsagar Reservoir (Himachal Pradesh) where the fish formed a breeding population and brought about a phenomenal increase in fish yield after an accidental introduction. Silver carp was instrumental in enhancing production of Gobindsagar from 160 tonnes in 1970-1971 to more than 1 000 tonnes at present.

In India, fish transferred on a trans-basin basis within the geographic boundaries of the country are not considered as exotic and there are no restrictions on such translocations. Thus, catla is not regarded as exotic to Cauvery or such other peninsular rivers. This is despite the fact that the species is outside its normal range of distribution and peninsular rivers have habitats, distinctly different from that of Ganga and Brahmaputra River systems. The small west-flowing drainages of the Western Ghats, the two large west flowing drainages, Narmada and Tapti, and a number of east flowing rivers of peninsular India, have ichthyofauna different from the Ganga and Brahmaputra River systems. Catla, rohu and mrigal have been stocked in the peninsular reservoirs for many decades now, with varying results. In some of the reservoirs in Southern India, they have established breeding populations. The hallmark of the country's policy on introductions is the heavy dependence on Indian major carps. The three exotic species brought in clandestinely by the fish farmers, bighead carp, *Aristichthys nobilis* and *O. niloticus* have not gained entry into the reservoir ecosystems so far and they remain restricted to the culture systems. Recently, the more dangerous African catfish (*C. gariepinus*) is being reported from more and more reservoirs in the country causing concern.

There is a case for examining the virtue of selective introduction of some exotic fish species in small reservoirs, which have no connections with the rivers, or those, which dry up completely in summer. However, such introductions should be made only after proper policy decisions are taken at the national level.

3.1.3 Other forms of enhancement

Environmental enhancement:

By improving the nutrient status through selective input of fertilisers in small reservoirs, stocks can be maintained at levels higher than the natural carrying capacity of the ecosystem. However, a careful consideration of the possible impact on the environment is needed before this option is resorted to in reservoirs. Scientific knowledge to guide the safe application of this type of enhancement and the methods to reverse the environmental degradation, if any, is still inadequate. Sreenivasan and Pillai (1979) Sreenivasan (1971), (Sugunan and Yadava, 1991 a, b) have reported application of this method with encouraging results. Environmental considerations and the possible conflicts of interest among various water users are the main factors that prevent the use of this option.

Although other enhancement options such as new culture systems (cage, pen culture) and management enhancement are possible in Indian reservoirs, many issues related to environmental sustainability, access by fishers and other equity concerns need to be resolved before adopting them on a large scale. In any case, it is always advisable to seek appropriate scientific advice before selecting the enhancement principle for a reservoir.

Pen culture in beels:

Culture of fishes and prawns in pen enclosures is a very useful option for yield enhancement in *beels* especially those infested with weeds. Pens are barricades erected on the periphery of beels to cordon off a portion of the water body to keep captive stocks of fish and prawn. Pen culture offers scope for utilizing all available water resources, optimal utilization of the fish food organisms for growth and complete harvest of the stock. Pens can be of any shape and size and they can be constructed by using a variety of locally available material. The CIFRI has standardized methods for the culture of freshwater prawn, *Macrobrachium rosenbergii* in pens (Sugunan, *et al.*, 2003).

3.2 Capture fisheries based on conservation of aquatic ecosystems

3.2.1 River fisheries

The river systems of India comprise 14 major rivers (basins >20 000 km^2), 44 medium rivers (basins 2 000 to 20 000 km^2) and innumerable small rivers and desert streams that have drainage of less than 2 000 km^2

(Rao, 1976). Different river systems of the country having a combined length of 29 000 km provide one of the richest fish genetic resources in the world. NBFGR (2009) reports 765 freshwater and 113 brackish water fish species from the inland waters of India; the Gangetic system alone accounting for not less than 143 species of fish. Similarly, 126 species belonging to 26 families have been recorded from Brahmaputra system. The peninsular rivers have been reported to bear at least 76 species fish species. The riverine scene, however, is a complex mix of artisanal, subsistence and traditional fisheries with highly dispersed and unorganized marketing systems, which frustrate all attempts to collect regular data on fish yield. A firm database on fish production trends of rivers is still elusive. Based on the information collected by CIFRI on selected stretches of the rivers Ganga, Brahmaputra, Narmada, Tapti, Godavari, and Krishna, fish yield from these rivers vary from 0.64 to 1.64 tonnes per km, with an average of 1 tonne per km.

River fisheries all over the country are under stress due to habitat loss, mainly attributable to various on-stream and off-stream developmental activities and to over-exploitation of fish stock. These are described in the section 4.2. The urgent need of the hour is to arrest the pace of habitat degradation and to restore the aquatic ecosystems and the fisheries they support.

The Ganga

The catch statistics over the years indicate some disturbing trends in the riverine fisheries, especially that of the Ganga. The biologically and economically desirable species have started giving way to the low value species, exhibiting an alarming swing in the population structure of the Gangetic carps (Sinha *et al.*, 1998). A sharp decline in fish production from five stretches of the Ganga *viz.*, Kanpur, Allahabad, Buxar, Patna and Bhagalpur is testimony to the deleterious effects of environmental changes on fish output. Average fish production from Ganga at Allahabad used to be around 205 tonnes between 1958-1959 to 1965-1966, and declined to 59 tonnes during 1996-1997. More marked is the fall in the production rate of prized Indian major carps, which declined from 91.35 tonnes in the 1950s to an abysmal 4.9 tonnes in 1996-1997. Thus, the percentage contribution of Indian major carps has declined from 44.5 to a mere 8 percent during the last four decades (Table 2). However, the total fish landings and the percentage composition of Indian major carps staged a slight recovery during the post Ganga Action Plan phase *i.e.*, between 1996-1997 to 2001-2008 (also see section 4.3.1). Appearance of exotic fishes in the riverine fish landings was noted during this period. A similar decline in qualitative and quantitative terms can be seen in Bhagalpur and Patna stretches of the river Ganga. In Patna, the total fish landings declined from 57.73 tonnes in 1986-1989 to 37.70 tonnes during 1990-1993. A further decline to 18 tonnes was recorded during 1996-1997. At Bhagalpur, total catch dropped from 90.95 tonnes during 1958-1966 to 35.8 tonnes during 1996-1997.

Table 2. Changes in catch structure in the Allahabad stretch of the river Ganga. Comparable changes have occurred in other strtches of the river (data not shown here)

	Major carps	Catfish	Hilsa	Miscellaneous	Exotics	Total
1958-1959 to 1965-1966	91.35 (44.5%)	46.66 (22.7%)	19.94 (9.7%)	47.48 (23.1%)	–	205.43
1973-1974 to 1985-1986	40.44 (28.7%)	30.82 (21.9%)	0.87 (0.6%)	68.79 (48.8%)	–	140.92
1989-1990 to 1994-1995	11.04 (11.5%)	21.50 (22.5%)	0.92 (1.0%)	62.10 (65.0%)		95.56
1996-1997	4.94 (8.3%)	14.28 (24.1%)	2.47 (4.2%)	37.61 (63.4%)		59.30
2001-2008	12.57 (14.2%)	9.02 (10.2%)	0.22 (0.2%)	47.48 (53.3%)	19.72 (22.1%)	89.01

Another glaring change in the catch structure is the increasing domination of lower age groups in the commercial catches. During the 1960s, II-year age groups in respect of *Cirrhinus mrigala*, II and III in respect of *Catla catla* and II in respect of *Labeo rohita*, dominated the fishery. The once lucrative hilsa fishery above the Farakka barrage collapsed due to obstruction of the fish's migratory path.

The Brahmaputra

Environmental degradation (as discussed in section 4.2) has its negative impact in river Brahmaputra too. A survey (Pathak, 2000) of river Brahmaputra in the State of Assam brought to light a significant decline in the fishery in many stretches of the river compared to 1973-1974. The average daily catch recorded at Tezpur during 1973 to 1979 was 196.9 kg/day, which consisted of major carps (19.4 percent). Presently, the daily catch at this stretch of Brahmaputra has declined to 137.3 kg/day with 11 percent contribution of major carps

Other rivers

Information is available on the river fisheries of Mahanadi, Godavari, Krishna, Cauvery, Narmada and Tapti Rivers. According to recent studies made by CIFRI, the river Mahanadi has 312 species of fish (85 from upper, 30 from middle and 197 from the lower stretches), and 12 species of prawns (*Macrobrachium rosenbergii* and *M. malcolmsonii*). The catch per day in the upper stretch was 44.8 kg and in the middle stretch it was 15.6 kg during Aug-Sept 1996 and the annual fish catch in the freshwater zone of the lower stretch was 86.2 tonnes while the estuarine zone landed 3 928.4 tonnes (Pathak *et al.*, 2007). Godavari River mainly harbours 11 species of fin fishes and one species of prawn. The catch is estimated at 263.1 tonnes during 1963-1969 for a 189 km stretch of the river. From the estuarine zone of the river about 2 728 tonnes of fish are landed (Jhingran, 1991b). Forty seven species of fishes are reported from the river Krishna and the river Cauvery has 80 species of fin fishes and two species of prawns are recorded from the river (Srivasatava *et al.*, 2009 and Jhingran, 1991b). Dwivedi *et al.*, 2002 report 90 species of fishes from the river Narmada, on which the largest reservoir in India – the Indirasagar reservoir – has come up. Miscellaneous fishes, followed by catfishes and major carps dominate the fishery. The monthly landings in the river Tapti during 1995-1996, based on observation in seven markets, were 2 605 kg. *Tor tor* was the major contributor to the fishery. Other commercial species are carps, catfishes, murrels and miscellaneous forms (Pisolkar, 1994).

Status of river fisheries and factors responsible for decline in yield

Indian rivers have been found to be producing much less fish than their biogenic potential. The CIFRI has estimated the production potential of selected stretches of Ganga and Brahmaputra as a function of the primary energy fixed by phytoplankton. Fish yields of the river Ganga at Kanpur, Allahabad, and Patna stretches were 24.30, 28.69 and 30.14 kg/ha/yr respectively against their potential of 74 249, and 192 kg/ha/yr respectively. In the Yamuna, the production potential was estimated at 106.7 kg/ha/yr against an actual yield of 18 kg/ha/yr. The production potential in lower Ganga was estimated at 198.28 kg/ha/yr, where the actual fish yield was 30.03 kg/ha/yr. Thus, only 15.15 percent of the potential are presently harvested (Figure 3). In the middle stretch, the utilization of the potential is marginally better than the lower stretch. However, in general, the potential is not fully utilized and there is enough scope for further improvement.

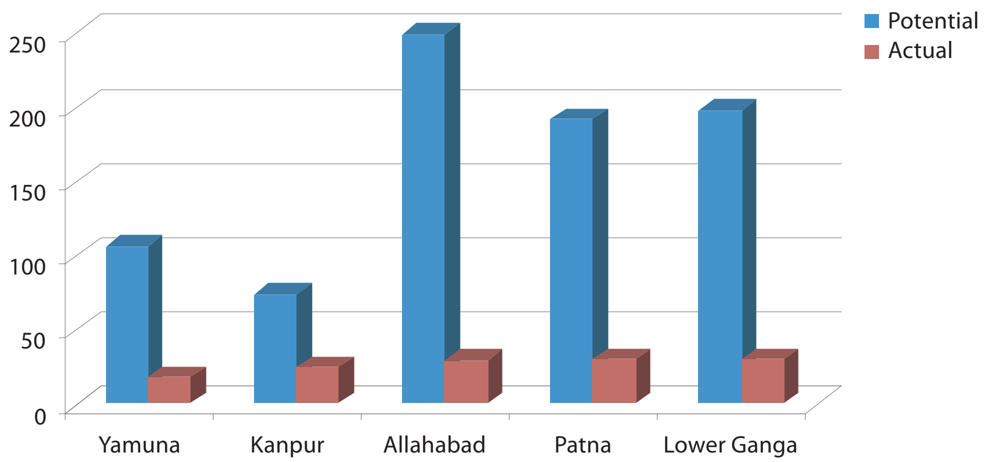

Figure 3. Fish production potential and actual production in the river Ganga (kg/ha/year)

3.2.2 Estuarine fisheries

Various estuarine systems spreading over 300 000 ha form an important component of the fisheries resources of India (Table 3). The fisheries of estuaries are above subsistence level and contribute significantly to the production. The average yield is estimated to vary from 45 to 75 kg/ha (Jhingran, 1991a). Though the fisheries of various estuarine systems have been studied sporadically, a continuous monitoring of the fisheries is being done only in the Hooghly-Matlah estuarine system, the largest estuarine complex in India. The winter migratory bag net fishery of the Hooghly estuary, which is active during annual periods of about three and half months and accounts for up to 67 percent of the total catch from the entire system with a landing figure of approximately 25 600 tonnes, has been studied and evaluated by the CIFRI. River course modifications have a negative impact on the estuarine fish populations. A glaring example is the overall decline in salinity of Hooghly-Matlah estuarine system after commissioning of the Farakka Barrage with gradient and marine zones being pushed down towards the sea. This has brought about drastic changes in the species composition of fishes caught with freshwater species making their appearance in tidal zones at the cost of some neritic species (Sinha, 1999). This major estuarine resource of the country has also been subjected to stresses like urbanization, pollution, land development, dams, degradation and over-exploitation in some areas.

Table 3. Major estuaries and associated inland water bodies in India and their fish production levels

Estuary	Area (ha)	Annual Fish Production (t)	Major Fisheries
Hooghly-Matlah	234 000	20 000-26 000	*Tenualosa ilisha*, *Harpodon mehereus*, *Setipinna phosa*, *Trichirus* sp. *Lates calcarifer*, prawn
Godavari Estuary	18 000	5 000	Mullets, prawn
Mahanadi Estuary	30 000	550	Mullets, *Lates calcarifer*, Siaenids, prawn
Narmada Estuary	–	4 000	Hilsa, mullets, prawns
Peninsular estuaries	–	2 000	Mullets, prawns elupeids, crabs
Chilka Lagoon	103 600	4 000	Prawns, mullets, catfishes, clupeids, perches, threadfins, sciaenids
Pulicat Lake	36 900	760-1 370	Prawns, mullets, perches, crabs, clupeids
Vembanad lake and other backwaters of Kerala	50 000	14 000-17 000	Prawns, mullets, *Lates calcarifer*, *Etroplus suratensis*, *Chanos chanos*
Estuarine wetlands (bheries)	42 600	37 500	Prawn, mullets, tilapia, *Lates calcarifer*
Mangroves	356 500	–	–

After Jhingran, 1988 and Sinha *et al.*, 1998

Mahanadi estuary is characterized by poor tidal oscillations and flood discharge due to sand bar formation in the sea mouth (Jhingran, 1988). This has already affected fish yield from the estuary. The Godavari fisheries too have been seriously affected by sand bar formation. Fisheries potential of Tapti estuary drastically declined after commissioning of the Ukai dam. Mushrooming industries on the bank of Mahi pose serious pollution problems in the estuary. CIFRI has undertaken a detailed study in Narmada with a view to assessing the impact of the series of dams under construction on the river, on ecology, yield and catch structure of the estuary. There could be 72 percent reduction in water availability downstream at 30 years after commencement of construction. Effect on migratory species like *Tenualosa ilisha* and *M. rosenbergii* are predicted. The most critical stage will be attained 45 years from the commencement construction, when the freshwater release from Narmada will cease completely. This will be associated with steep rise in salinity, badly affecting the freshwater species.

3.2.2.1 Lagoons and backwaters

Lagoons and backwaters associated with estuaries constitute an important inland fishery resource. Chilka and Pulicat Lake in the east coast and the Vembanad lagoon in the west coast are the major brackish water lakes in India. Regulated discharge through incoming rivers, siltation and anthropogenic pressure have made considerable negative impact on the fishery of Chilka Lake. On account of siltation, the lake area has shrunk from 906 km^2 in 1965 to 620 km^2 in 1995. Siltation at the lagoon bed and the connecting channel has resulted in profuse weed infestation 950-60 kg/m^2. There has been a qualitative and quantitative decline in fisheries. Total fish landing has decreased from 4 243 tonnes in 1990 to 1 270 tonnes in 1995. Prawn catch has declined from 28 to 14 percent. Overfishing and wanton destruction of stocks, barricading the outer channel with fixed small meshed gill nets, construction of pens with fine mesh nylon mosquito netting, increased number of operators, etc. are the factors attributed to the low fish output. The cumulative effect of all these factors has caused a sharp decline of the once lucrative commercial fishery of Chilka Lake. Fish catch from Pulicat lagoon is dependent on the ingress of fish and prawn seed from the sea. However, the sand bar formed at the mouth adversely affects recruitment. The production is reported to have dropped from 2 600 tonnes during 1945-1946 to less than 1 000 tonnes.

Vembanad backwaters: This sprawling lagoon is well known for the traditional trapping of prawn and fish seed in impounded areas and growing them to marketable size. In recent years, a marked decline in prawn catches, both from impoundments and open waters has been reported. Here also human intervention, mainly pollution and overfishing, appears to be the important factors to be reckoned. Both regulatory and biological methods for development have been suggested by different agencies and it is necessary to take appropriate actions without delay. The other estuarine systems and coastal lagoons are also equally important in the context of fisheries development, although their potential yields are much less.

Estuarine impoundments (bheries):

The estuarine wetlands around Calcutta, which form a very important source for meeting the city and suburban demand for fish, are fast depleting due to urban expansion programmes and pressure on the land.

Mangroves:

Mangroves are biologically sensitive ecosystems, which play a vital role in breeding and nursery phases of many riverine and marine organisms of commercial value besides contributing through its own fishery. Nearly 85 percent of the Indian mangroves are situated in the Sundarbans in West Bengal and Bay of Bengal islands. The Indian share of Sundarbans, which once covered an area of 4 262 km^2, has now shrunken to 3 560 km^2. Even this is under pressure from various human activities. The mangrove wealth existing in the coasts of Kutch and Cambey in Gujarat, Konkan and Malabar coasts in patches, Andaman and Nicobar group of islands, and in the estuaries of Cauvery, Mahanadi and Hooghly-Matlah system is reported to be reduced from 700 000 to 356 500 ha by 1975. Mangroves are declared as protected areas where fishing is prohibited. Several creeks are known to be the sites for fish and prawn seed collection. The Sundarbans fishery consists of 18 species of prawn, 34 species of crabs and 120 species of fish besides 4 species of turtles.

3.2.2.2 Upland lakes

Natural lakes situated in the colder upland regions of India are estimated to cover an area of 720 000 ha (Jhingran, 1988). But, these lakes have not been studied for their fishery potential. On account of their limnological characteristics, they are suitable for developing cold-water fisheries. These lakes support a lucrative indigenous and exotic fish fauna comprising schizotharcids, mahseers, trouts, tench, Crucian carps and the mirror carp. Annual fish yield in Deccan upland lakes range between 1.8 and 9.3 kg/ha in Kodaikanal, 16.7 and 49.5 kg/ha in Yercaud, and 33.0 and 111.0 kg/ha in Ooty (Vass, 1988). The yield rates from Himalayan lakes range from 8.0-22.5 kg/ha in Dal lake, 10.0-28.5 kg/ha in Anchar, 15-45.0 kg/ha in Wular, 2.0 to 6.0 kg/ha in Manasbal and 5.0 to 15.0 kg/ha in Sivalik lakes. The catches in most of these lakes are dominated by *C. carpio* with sizeable contribution to schizothoracids and mahseers in northern lakes and *Oreochromis mossambicus* in Deccan lakes.

Management norms for these upland lakes are virtually non-existent and limnological information is available only from a few. Some of these lakes in Kashmir Himalayas are experiencing a disturbed trend – the shizothoracids giving way to the common carp. The common carp introduced into the Kashmir valley now contributes 65-78 percent of the total fish landings of the region. The catch structure and composition have significantly altered in recent years. A parallel situation has been observed in case of mahseers in Kumaon and Sivalik lakes. In Bhimtal Lake, the common carp constitutes 21-67 percent of the catches leading to a decline by 27-45 percent of the *T. putitora* population. Very little is known about the fishery potential of upland lakes. On account of their remoteness and the low temperature regime, drastic increase in yield and production are not expected from these water bodies.

The rivers, estuaries, lagoons and upland lakes are the inland fishery resources, which are exploited on the capture fishery lines. All these systems show signs of environmental degradation and depletion of stock. It is very much evident that no substantial increase in fish production is possible from these water bodies, where future action plans should centre on arresting and reversing the biodiversity loss and conserving the ecosystem. Any substantial increase in production from open water systems should come from reservoirs and floodplain wetlands, which allow enhancement and culture-based fisheries.

3.3 Operations

3.3.1 Fishing rights systems

The fishing rights in Indian inland waters vary according to the resource and the policy of different State governments. In general, the capture fisheries of rivers, estuaries, lagoons and upland lakes is traditionally treated as a common pool resource and managed on the basis of free access for fishing (Paul *et al.*, 1997), with very few exceptions where river stretches are leased out to individuals (some parts of Ganga in Bihar and river Yamuna in Haryana) or to Fishers' Cooperative Societies (Ghaghara in Uttar Pradesh). However, due to decline in fish catch from most of the Indian rivers over time, this open access is being converted to limited access as common property of local fishers. When it comes to culture-based fisheries, the water bodies are generally owned by the State and the fishing rights are given away to a cooperative society or an individual for a fixed period against royalty/lease money (Figure 4). Stock enhancement in rivers is aimed at augmenting the fish stock for biodiversity conservation or as a welfare measure for the fishers and hence the cost for river ranching is always met from the public exchequer.

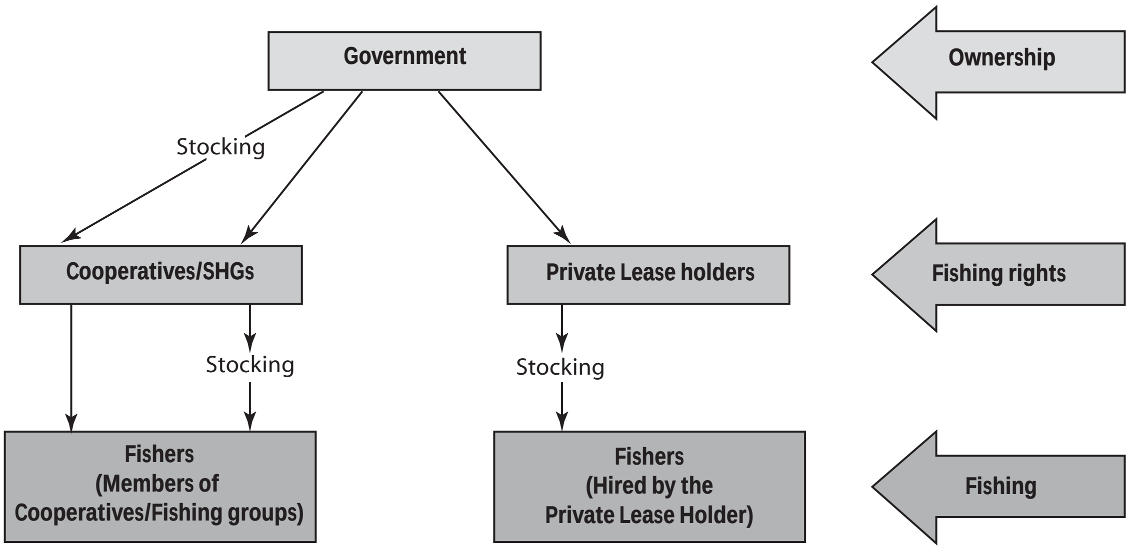

Figure 4. Ownership of water bodies and distribution of fishing rights in culture-based fisheries

3.3.2 Institutional, policy, legislative environments

Mostly, the State Fisheries Department or Fisheries Development Corporations owned by this Department have the authority to give away the fishing rights, but in some cases, the other Departments that own the dam such as Power, Irrigation and Forest do not part with this right leading to disputes. The royalty/lease amount accrues to the Government, but there is no clarity or uniformity on services provided by the government against this collection of public money. Sometimes, stocking is made by the Government, but generally the lessee has to stock in spite of paying royalty. Similarly, there is no fixed policy on fixing the lease value among and within states. There are cases where the royalty increases every year at the rate of 10 percent, often as a means to increase the government revenue. Under a cooperative regime, the society pays the lease amount to the government and they realise the amount from the member fishers through a cut in their daily catch either in cash or kind. This way, fishers have to pay from 15-60 percent of their catch to the society.

Cooperative societies, if managed well can result in good yield and inclusive growth as proved in *beels* of West Bengal and small reservoirs of Tamil Nadu and some pockets of Madhya Pradesh. In an effective cooperative set up, the fishers are empowered and motivated, where they, through collective action, participate in the management process, ensure compliance with stocking and harvesting norms, and effectively manage the post-harvest and marketing activities. However, in most of the cases, the cooperatives are ineffective due to poor empowerment and awareness among the fisher folks who continue to be exploited by some influential individuals in collusion with unscrupulous money lenders and market middlemen.

Another mode of managing culture-based fisheries is to auction to individuals. In some States like Rajasthan, all reservoirs are auctioned to individuals. In many States like Karnataka and Andhra Pradesh, local self Governments at district, taluk or village levels have the jurisdiction overfisheries in small irrigation reservoirs and seasonal tanks, which are leased out to individuals, while medium and large reservoirs are directly under the Government or Government owned Corporations which are given to cooperative societies. Many governments operate through departments like Revenue, Fisheries, Forest, Cooperative, Irrigation, Agriculture and General Administration to lease out these waters. Market and marketing agencies also influence the post-harvest activities, particularly through the remuneration for fish catch. Under a private lessee, the management requires proper supervision at stocking and fish harvesting stages as the private individual lease holder has the prime motive of harvesting maximum catch within the period of his lease term. As he hires the fishers on daily wages, they do not get any extra benefits even if the yield and production increases in the water body due to stocking. In an aquaculture venture, an entrepreneur who invests money gets his return through the fish production in the pond. Conversely, in a culture-based fishery, the fish production obtained is due to the growth of stocked fish through a natural process.

Culture-based fisheries of floodplain wetlands, especially in the eastern and northeastern India, is a mix of the cooperatives, individual leasing and some traditional rights for fishing as recognized in local cultures. Invariably, the fishers in the localities have the right to fish for self consumption, irrespective of the control and management agents. Similarly, the women have unlimited access to fish using small gear like traps, especially to catch small prawns and small indigenous fishes. In a few *beels*, all the people/groups in a locality are allowed to fish during the festival seasons for a few days in a year. In order to ensure that the fishers get the benefit of increased fish production, the Government of Assam has stipulated that the individual lease holders should hire the local fish communities for fishing and the remuneration should be on a catch sharing basis (60:40). This is not very effectively implemented due to poor empowerment of the fishers.

3.3.3 Legislative support

The activities of inland fisheries in most of the states are regulated by an Act based on the antiquated Indian Fisheries Act of 1897 and it lacks necessary provisions for sustainable development of fisheries and aquaculture. Therefore, Government of India through Model Bill on Inland Fisheries and Aquaculture intends to ensure sustainable fish production to meet future needs of the country. The model bill provides guidelines for successful implementation of activities and issues related to (1) responsible fisheries and aquaculture, (2) domestic marketing of fish, (3) institutional support, (4) inter-departmental coordination, (5) stakeholder participation for better management and conservation and stock enhancement.

3.3.4 Financial and institutional support

The financial and institutional arrangements to support implementation of fisheries policies fall under the mandate of Department of Animal Husbandry, Dairying and Fisheries (DAHDF) under the Ministry of Agriculture, Government of India at the Centre and Departments of Fisheries (DOF) at the States. The recently formed National Fisheries Development Board (NFDB) also works for fisheries development in the country. The role of DAHDF and DOFs is crucial for the implementation of national and state policies as they have the financial provisions and enabling mechanisms/linkages to develop infrastructure and disseminate technologies under different Central Sector or Centrally/State sponsored schemes. For sorting out problems on a continuous basis and provide congenial atmosphere for fisheries development on a sustainable and equitable basis, co-ordination with other Departments e.g. Ministry of Home Affairs, Defence and External Affairs, Commerce, Food Processing Industries, Rural Development, Panchayati Raj, etc. assumes importance.

The central budget of XI Five Year Plan for fisheries development is INR 28 billion, which supports welfare programmes, governance, transfer of technology and capacity building. NFDB, a registered body under the administrative control of the DAHDF of the Ministry of Agriculture, India is aimed at realizing the full potential of Indian fisheries through coordination of different agencies and public-private partnerships. The Board has total budget of INR 21 billion for 5 years from 2006 to 2012. The major activity of the Board for inland fisheries is reservoir fisheries development with a budget of INR 4 000 million. NABARD is a major source of Ground level credit (GLC) for fishers and fish farmers

Organization of fishing communities (Co-operative societies, SHGs, etc.)

The functioning and efficiency of inland fisheries co-operatives in India varies across different states. The success of fisheries co-operatives with high co-operative spirit, equitable distribution of benefits, high fish production and marketing efficiency and good management is documented in West Bengal and in some southern and western states, while such situations are rare in states of Uttar Pradesh and Bihar. In general, fisheries co-operatives perform better in the states, where DoFs or state co-operative departments efficiently monitor and control their functioning.

The Self Help Groups (SHGs) in the fisheries sector are comparatively of recent origin. There are some success stories for SHGs in the states of Andhra, Tamil Nadu, Bihar, Uttar Pradesh and Jharkhand. These organizations primarily play an important role in micro-finance/credit and capacity building. NABARD, the main source of micro-credit in the country operates through the SHGs. Fishing Groups (FGs) that are institutionalized in many parts of the country consist of groups of empowered fishers who undertake 'group fishing' or 'collective fishing'. The FGs generally comprise 7-8 members sharing common crafts and gears and they collectively bargain for access and they share the cost, risk as well as return among the members.

3.3.5 Logistic arrangements

Supply of inputs

The inland fisheries in the country are highly labour-intensive and the component of capital or biological inputs is minor. The major capital inputs required are for the crafts and gear, while the biological inputs are applicable only in case of culture-based fisheries in reservoirs or floodplain wetlands in the form of fish seed (fingerlings). The capital inputs are widely available except in some remote hilly areas. The fishers or the people belonging to fishing communities have the expertise to weave and repair the nets and construct a boat. Both the gears and crafts used in inland fisheries vary in types and dimensions for different waters and fishers belonging to different economic strata. The supply of biological inputs both in quantity and quality over time and space is a big constraint in inland fisheries development.

Raising stocking material

Stocking material is the most important constraint in development of culture-based fisheries in India. Very few inland waters have the space/facilities to produce adequate quantity of fish seed, particularly up to advanced fingerlings. Further, the fish seed farms producing fingerlings are not able to send the required quantity of desired quality seed over long distances, as it is very costly and has high probability of mortality. Some low-cost technologies are developed by institutions like CIFRI for *in situ* fish seed production in reservoirs and floodplain wetlands in enclosures (pen and cages). These are very effective and viable, as locally available inputs like bamboo and nylon net, etc. are used. It provides the quality fish stocking material at the target water body at a very low price of INR 0.40/per fingerling for cage and INR 0.70/fingerling in pen. The major problem for pen culture technology in reservoirs is the water level fluctuations that limit the rearing period.

3.3.6 Post-harvest handling, processing

Processing, value addition and hygienic handling are still and compliance to hygienic standards such as HACCP inadequate for the domestic market, especially that of inland fish.This is one of the factors that retard the growth of fisheries enhancement. Traditionally, fresh iced fish is being transported and consumed in the domestic market, while processing and value addition have been considered a luxury reserved for the lucrative overseas markets. However, the fish consumption and marketing pattern in India is fast undergoing changes. Buying capacity of domestic consumers has increased and so are their aspirations and consciousness about the product quality. Commensurate with these changes, there is a need for a paradigm shift in the strategy and approach to processing and value addition and hygienic standards of the domestic market. At present the outlets for domestic consumers are very pathetic from hygiene point of view and need upgrading. Indian markets are ready to accept more diversified products and Indian housewives are looking for more and more ready-to-cook and ready-to-eat products in the shelves of supermarkets.

Marketing arrangements

The domestic fish marketing in India is poorly organized and a national perspective or strategy on marketing and post harvest management of fish is still elusive, especially in the inland segment. Most of the problems that plague the fisheries sector can be directly attributed to this. If the successful experience of the Indian dairy sector in dealing with a similar perishable commodity- the milk- is any guide, this problem can be solved just by putting in place well-oiled post harvest/marketing machinery. The existing marketing arrangements do not favour the fishers. On the one hand, the fishers lament that the fish they catch in large quantities from reservoirs and *beels* are sold at ridiculously low price to local fish merchants. On the other, the price gets multiplied by many times as it reaches the retail outlets in cities, where consumers seldom get the fish of their choice at an affordable price. Many a times, the local fisher groups or merchants do not have the capacity to store fish or transport it in good condition to distant markets resulting in local gluts in small towns.

The fishers' share in the market chain for riverine catch is highest for open access regime (41-73 percent) followed by co-operative (33-52 percent) and private (20-29 percent). The remainder is the share of the fish marketing intermediaries of which the highest is for the retailer/contractor. The national strategy for fish post harvest operations and marketing should *inter alia* include:

- necessary market infrastructure including cold chains, hygienic wholesale and retail outlets to cater to the emerging requirements of domestic market,
- research support for development and commercialization of value-added products,
- national standards for processing, product development and food safety,
- quality control regime to certify products and ensure quality, and
- governmental support in the form of policy, institutional, legislative instruments.

4. IMPACT OF MAJOR ENHANCEMENT AND CONSERVATION ACTIVITIES AND IMPACT ASSESSMENT MECHANISMS

4.1 Impact of enhancement activities

Various enhancement practices such as culture-based fisheries, enhanced capture fisheries and river stock enhancement have been in vogue in India for many decades now. But, no assessment is known to be made on these stocking by any agency. Instances of river stocking, being very sporadic, seem to be insufficient to make any impact in terms of augmenting the natural populations of the indigenous species. However, some of the exotic species might have been accidentally introduced in the process. It is not known whether the stocking done in the majority of medium and large reservoirs have contributed to establishment of naturalized populations, except a few like Stanley reservoir in Tamil Nadu, Rihand in Uttar Pradesh and Gandhisagar in Madhya Pradesh. According to Sreenivasan (1984), 10 000 *C. catla*, stocked in Stanley reservoirs got established in Stanley reservoir that sustained a capture fisheries for many years. Similarly, it is on record that the same fish has established itself in Sathanur, Gandhisagar and Ukai reservoirs, eventually leading to increased yield and production, primarily because of its breeding success (Sugunan, 1995). In sharp contrast, in a number of reservoirs like Nagarjunasagar, Bhavanisagar, Krishnagiri, Malampuzha and Peechi, the fish did not make any impact because of its failure to breed. Sreenivasan (1976) reported that the reservoir stocking done without any planning did not make any impact.

In sharp contrast to what happened in large and medium reservoirs, stocking attempts in small shallow reservoirs have been successful to a large extent across the country. Aliyar reservoir in Tamil Nadu is a standing testimony to the efficacy of management strategy based on culture-based fishery leading to increase in fish production from 2 kg/ha in 1964-1965 to 194 kg/ha in 1990. Successful stocking has also been reported from a number of small reservoirs in India (Sugunan and Sinha, 2001). In Markonahalli, Karnataka, on account of stocking the percentage of major carps has increased to 61 percent and the yield increased to 63 kg/ha. Comparable examples can be seen from other States also (Table 4). Results from a World Bank-aided reservoir fisheries development project in India further confirmed the validity of stocking Indian major carps in the culture-based fisheries of small reservoirs. The project covered 78 reservoirs (24 613 ha) situated in three states viz., Andhra Pradesh, Orissa and Uttar Pradesh. The reservoirs belonged to three categories viz., A (<100 ha), B (100-300 ha) and C (>300 ha), the stocking rates for which have been fixed at 1 500/ha, 1 000/ha and 500/ha respectively. The Scheme provided for constructing pen nurseries in the reservoirs to ensure that the fish seed is reared to at least 100 mm in size before stocking. Loan was provided to the co-operative societies to buy boats and nets. The results were very encouraging and a perceptible relation between stocking and yield could be observed (Figure 5). This is an example, where the technical effectiveness of culture-based fishery in increasing yields of desired species has been demonstrated (Sugunan and Katiha, 2004).

Table 4. High yields obtained in small reservoirs due to management based on stocking

Reservoir	State	Stocking rate (number/ha)	Yield (kg/ha)
Aliyar	Tamil Nadu	353	194
Tirumoorthy	- do -	435	182
Meenakara	Kerala	1 226	107
Chullar	- do -	937	316
Markonahalli	Karnataka	922	63
Gulariya	Uttar Pradesh	517	150
Bachhra	- do -	763	140
Baghla	- do -	–	102
Bundh Beratha	Rajasthan	164	94

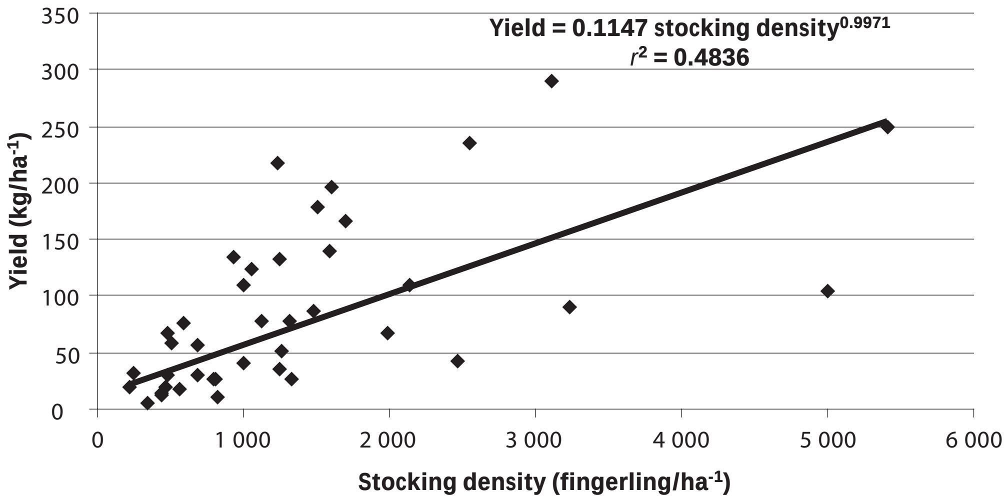

Figure 5. Impact of stocking in fish yield in reservoirs (Sugunan and Katiha, 2004)

4.2 Major initiatives on conservation and their impact

The natural populations and the inland aquatic habitats are under threat both from the impact of various developmental activities and from aquaculture. On the one side, various water abstraction, river basin modification and effluent discharges from industrial and urban sources adversely impact the species and the habitats, while on the other, natural water bodies like floodplain wetlands, swamps, river beds, mangroves and urban wetlands are being converted to aquaculture ponds causing loss of habitats for natural species. Owing to these anthropogenic stresses, the fish habitat is being destroyed, adversely affecting sustainability of aquatic ecosystems and eroding the natural gene pools and genetic diversity. With rapid overall development and owing to ever increasing demand for fish as food, the ecosystems are under constant pressure of man induced stresses to the detriment of aquatic fauna and flora. The decline of individual fish species is very often related to more than one proximate factor, but causes of imperilment of fishes in the aquatic ecosystem. Several initiatives are in place to mitigate these adverse impacts, which are described below:

4.2.1 Ganga Action Plan (GAP)

Ganga Action Plan (GAP), a massive river cleaning programme, launched in 1995 to combat environmental degradation in the river Ganga, was aimed at combating water pollution and improving water quality of the river to bathing standards. With the success of GAP, this activity was extended to cover pollution abatement 18 more national rivers spread over 12 States. Later, this programme has been extended to cover 29 rivers in 22 States and lakes were also brought under its purview.

4.2.2 In-situ conservation

Government of India has established 605 protected areas covering approximately 4.74 percent of the country under *in situ* conservation through a network of 96 National Parks, 509 Wildlife Sanctuaries and 3 Conservation reserves established under the Wildlife (Protection) Act. 25 wetlands in India, representing different habitats have been designated as Ramsar Sites. In Himachal Pradesh, the State Government has declared 5 lakes as sanctuaries for protection of mahseers and increased the catchable size of mahseer from 300 to 500 mm (1.2 kg), giving the opportunity to each fish to breed at least once before being caught. Some river stretches throughout the country are also protected on the basis of religious sentiments as they are located in the vicinity of holy places and shrines (temples). Nearly 30 fish sanctuaries exist in the Himalayan region (Jammu and Kashmir, Himachal Pradesh and Assam).

4.2.3 Ranching

The successful induced spawning and larval rearing of endangered species such as *T. (Hilsa) ilisha*, *T. khudree*, *T. putitora*, *L. dussumieri*, *Ompok pabda*, *O. malabaricus*, *O. bimaculatus*, *G. curmuca*, *Clarias dussumieri*, *Osteobrama* *belangeri*, *Chitala chitala*, *Nandus nandus*, *Anabas testudineus and Horabgrus brachysoma* have opened up avenues for their ranching in the depleted water bodies for stock replenishment. National Bureau of Fish Genetic Resources, (NBFGR) Lucknow, and Directorate of Cold water Fisheries Research (DCFR), Bhimtal have initiated a programme for ranching of artificially-bred golden mahseer fingerlings in Ladhiya, Sharda River and selected rivers of the NEH region. Ranching of the fingerlings in Pampa river of Kerala improved landings of the endangered *Labeo dussumieri.*

4.2.4 State fish: A new conservation approach

In an innovative approach to conservation, a Scheme has been launched by the Central Government wherein each State is being encouraged to adopt one fish as 'State fish' to facilitate its conservation. This involves integration of the key stakeholders in the conservation exercise by the strategies of declaring a State Fish. By now, 15 states have joined this activity.

4.2.5 Fish sperm and embryos cryopreservation

Species-specific sperm cryopreservation protocols have been developed for 17 prioritized endangered and commercial fish species viz., *C. catla*, *L. rohita*, *C. mrigala*, *L. dyocheilus*, *T. ilisha*, *T. khudree*, *T. putitora*, *L. dussumieri*, *H. brachysoma*, *O. malabaricus*, *Gonoproktopterus curmuca*, *C. batrachus*, *H. fossilis*, *Garra surendernathanii*, *Oncorhynchus mykiss*, *Salmo trutta fario* and *C. carpio. More species viz. L. dero*, *L. calbasu*, *Pangasius pangasius*, *Silonia silondia*, *Etroplus suratensis* and *Schizothorax richardsonii* are being covered. Recently, success has been achieved in developing cell cultures and cell lines from *T. putitora*, *L. calcarifer* and *L. rohita* in India and this work is being extended to cover embryonic stem cell research in Indian carps and catfishes.

4.2.6 Tissue banking

At NBFGR, Lucknow tissue repository accessions are being made with emphasis on the endemic fish resources of hot spot areas such as the Western Ghats and Northeastern states. Nearly 12 000 tissue accessions for fish species, collected across the country, are maintained in the tissue bank. To increase the effort for tissue banking of vast aquatic resources, there is need to develop a network of researchers across the country.

4.2.7 Live gene bank

Live gene banks have been established at Lucknow and Guwahati for species of high conservation significance like *T. putitora*, *Barilius* spp., *Garra* spp., *L. dayochilus*, *L. calbasu*, *W. attu*, *C. chitala*, *C. marulius* and *L. bata.* One of the important foci of the programme is to develop linkages with Regional Live Gene Banks to be established in different agro-climatic zones to cover more species. Regional Live gene banks have been established by National Bureau of Fish Genetic Resources in the north-eastern region in collaboration with Department of Fisheries, Govt. of Assam and Department of Zoology, Gauhati University, Assam.

4.2.8 EIA for river water development project

On growing awareness about the impact of development projects on aquatic ecosystem and fisheries it is now mandatory for all river water development projects especially for those involving construction of dams for irrigation, power generation, etc. to undertake environmental impact assessments. However, no standard protocols exist for doing this EIA and various agencies within the country and abroad are hired for undertaking such EIA studies.

4.2.9 Provision of fish passes

Although a number of dams in India have been provided with fish passes, the extend of their utility is often challenged as a large number of them remain ineffective due to poor design and lack of understanding about the target species. Of late, awareness on the role of fish passes increased and more knowledge has been created on fish pass design. Fish pass design to address the needs of mahseers, snow-trouts, etc. are being provided to dams that are being created in many parts of the country.

4.2.10 Threat categorization of fishes

Many inland fishes are under various threats. The Indian fishes are categorized according to the World Conservation Union (IUCN) red list (2000). In 1989 for the first time, a list of 21 vulnerable, four endangered and 17 threatened species were recorded. Subsequently, the National Bureau of Fish Genetic Resources recorded 17 cold water, 46 warm water, six brackish water and ten marine fish species placing them under endangered, vulnerable rare and indeterminate categories (Table 5).

Table 5. Conservation status of fish germplasm resources in India: by ecosystem

Ecosystem	Total Species	Endangered	Vulnerable	Rare	Indeterminate	Total
Coldwater	157 *	01	04	–	12	17
Warmwater	454 **	03	13	02	28	46
Brackishwater	182 ***	–	02	–	04	06
Marine	1 370	–	02	–	08	10
Total	2 163	04	21	02	52	79

* 34 species are common to cold and warm water; ** 68 taxa are common to warm and brackish water; ***20 species are found only in brackish water, 75 are common to warm, brackish and marine waters and 75 are common to brackish and marine waters.

Source: Annual Report, NBFGR, 2003-2004

4.3 Legislative framework for aquatic biodiversity

The Government of India has various acts, rules and regulations to conserve the fish and aquatic diversity and judiciously utilize it for the well being of the nation. Major landmark legislations are:

- Indian Fisheries Act of 1897
- Wildlife (Protection) Act, 1972
- Forest (Conservation) Act, 1980
- The Environment (Protection) Act, 1986
- Biological Diversity Act, 2002
- Coastal Aquaculture Authority Act, 2005 No. 24 of 2005 [23 June 2005]
- National Biodiversity Action Plan (NBAP), 2008

The State laws and statutes are framed under the broad parameters of the Central Acts. Policies and strategies directly relevant to biodiversity include National Conservation Strategy and Policy Statement for Environment and Sustainable Development; Comprehensive Marine Fisheries Policy, 2004, Ministry of Agriculture, National Fisheries Policy (under preparation); National Biodiversity Policy; the Environmental Action Plan; National Lake Conservation Plan (NLCP) and National River Conservation Plan (NRCP). National Environment Policy, 2006 seeks to achieve balance and harmony between conservation of natural resources and development processes and also forms the basic framework for the National Biodiversity Action Plan. The Ministry of Environment and Forest, Govt. of India has set up the National Ganga River Basin Authority (NGRBA) in February 2009 to ensure effective abatement of pollution and conservation of the river Ganga by adopting a river basin approach. One of the primary objectives of NGRBA is to maintain minimum ecological flows in the river with the aim of ensuring water quality and sustainable development.

4.4 The major ecosystems/species prioritized for conservation/restoration and major initiatives

Rivers, wetlands and mangroves have been prioritized for conservation and restoration activities. The major species targeted for conservation are Indian major carps (*L. rohita*, *C. catla*, *C. mrigala*) endangered mahseer species (*T. khudree*, *T. musullah*, *T. tor*, *T. putitora*), snow-trout (*S. richardsonii*) and catfishes (*C. batrachus and H. fossilis*)

(Nagpure *et al.*, 2001 and Kushwaha *et al.*, 2002). *C. batrachus* faces challenges from the exotic *C. gariepinus* and this is being studied using cytogenetic markers in C- and Nuclear Organizer Region (NOR) banding patterns (Nagpure *et al.*, 2002). Different techniques are being adopted to assist the conservation programmes which include (a) Molecular genetic markers, (b) Evolutionarily Significant Units (ESU), (c) Estimation of effective population size, (d) Detection of population size changes

5. SOCIO-ECONOMIC RELEVANCE OF INLAND FISHERIES DEVELOPMENT AND CONSERVATION OF ECOSYSTEMS

Inland fisheries development has some interesting economic and social dimensions which deserve mention. It has now been established that at least 1 million tonnes of fish can be produced through enhancement in reservoirs and floodplain wetlands with very low level of investment (mainly stocking), as opposed to the heavy capital investment required in aquaculture. There is also a social dimension of enhancement fisheries development. The benefits due to increased fish production obtained in the inland fisheries (under a good governance regime), are shared by a large number of fishers- the key stakeholders. There is this large cake and each stakeholder gets a slice, albeit small. Thus, the enhancement provides opportunities for inclusive growth, which is economically sound and socially justifiable.

Fish and other living aquatic resources of inland water ecosystems provide important services that are currently undervalued. Inland fisheries and aquaculture contribute more than half of the total fish produced and consumed in India, and this production is closely linked to ecological processes that occur in freshwater systems. The value of freshwater fish production to human nutrition and income is much greater than gross national product figures suggested mainly because many of the intangible benefits are not counted when valuation is done in monetary terms. The bulk of production is generated by small-scale activities, with exceedingly high levels of participation not only in catching and farming, but also in processing and marketing. Consumption of fish by the riparian community, especially the poor is not well recorded, but all the same it is a prime source of protein for more than half of the world population. Thus, inland fisheries is critical to local food security. As conservation is *sine qua non* for maintaining fish production systems on a sustainable basis, investment in conservation needs to be internalized and factored into the developmental initiatives.

Decisions on water management frequently do not take into account the impact on fish and fisheries and the rural livelihoods of the populations that depend on them. In part, this is because inland fisheries are greatly undervalued in water management at local, national and basin levels. Equally, there is a lack of knowledge on how to optimize ecosystem services, for example, through environmental flows and water productivity approaches that are needed to guide the allocation of sufficient water to sustain fish and fisheries. The water sector is a key entry point for poverty alleviation and gender empowerment. While professional fish capture is dominated by men, post-harvest and small-scale trade of fish is the women's domain, mainly because these activities do not demand much capital investment and high technical expertise (Dugan *et al.*, 2007).

6. CONSTRAINTS AND PROBLEMS

6.1 Technical constraints

Habitat degradation: All inland water bodies are under heavy anthropogenic stress and the level of technologies and infrastructure to combat this trend is grossly inadequate. This includes knowledge on diversion and safe treatment of sewage and industrial effluents, and means for maintenance of environmental flows in rivers.

Ecosystem and size overfishing: A serious problem faced by the inland fisheries sector is the overfishing both ecosystem and size and the use of irrational fishing devices. The highly dispersed nature of water bodies make it difficult to supervise and implement the existing regulations on these.

Technological inputs: Scientific principles on culture-based fisheries and stock enhancement, either receive low priority or overlooked altogether in the country leading to low productivity. Over-stocking, under-stocking, stocking at small size, catching fish at small size and lack of maintenance of stocking and harvesting schedules are the most common drawbacks noticed.

Stock loss: Indian major carps are observed to congregate above the spillways for breeding, which results in heavy escapement of the broodstock. This poses a serious problem for building up stocks of desirable fishes in such reservoirs. The situation is further worsened by heavy escapement of fingerlings and adults through irrigation canals. Development of fisheries in such water bodies, therefore, requires suitable screening of the spillway and the canal mouth.

Short supply of fish seed: The 900 hatcheries across the country produce more than 32 billion fry of Indian major carps annually (Ministry of Agriculture, 2008), but, they are seldom reared to fingerling size for stocking in reservoirs. Most of the fry produced in the hatcheries go to the aquaculture segment, managed by the private sector. The government and co-operative societies, which manage the reservoir fisheries, do not have enough infrastructures to raise the required number of fingerlings.

Valuation methods: Interests of aquatic ecosystems and fisheries do not receive the priority from water and land resource managers mainly because these are undervalued due to lack of appropriate valuation tools.

Resource assessment and management tools: Inland fisheries resources are highly scattered, unorganized and located in remote places, compared to more industrialized marine fisheries and intensive aquaculture. Reliable methodologies are needed to estimate the fish stocks, fish catch and fishery resources.

Craft and gear for sustainable fishing in inland waters: By and large, traditional fishing craft and gear are still in use in the inland fisheries sector. There is a need for improved designs of craft and gear for sustainable fishing in inland waters, especially special tools and techniques to fish torrential rivers like Brahmaputra and reservoirs with very high wind action.

6.2 Operational constraints

The governance challenge: The enhancement regimes will be successful only when the community that fishes in the water body is under a sound governance setup and the community owns and manages the fish stock. Co-management, where the representatives of the community and government take part in decision making process, is the most ideal for inland water bodies. All stakeholders should take part in the decision making process and the benefits accrued by implementing improved scientific norms should be equitably shared by all stakeholders. The State (the State Government, local Self Governments, NFDB, etc.) can play a pivotal role in improving the governance systems of reservoirs by providing an enabling policy environment for this purpose.

Inadequate marketing channels and marketing infrastructure: Inadequate marketing channels and marketing infrastructure often act as disincentives for the community to produce more fish by managing the resource in an appropriate manner. Proper arrangements including post-harvest processing and value addition will go a long way in improving production and these aspects need to be integrated into the management/development process.

Ownership of fishing rights: Ownership of reservoirs does not always rest with the Fisheries Department and in many cases; it has no access and authority to manage the fisheries in reservoirs. In an ideal situation, even if the reservoir is owned by other Departments, at least the fishing activities should be within the purview of the Fisheries Department of the respective State Government. The DAHDF and NFDB can take a lead in persuading the States to follow a common policy on this issue.

Shift in approach: The State Fisheries Departments need to shift from a 'revenue generation' approach to a 'development approach' and similarly, the enforcement (command and control) approach should give way to a participatory (co-management) approach.

6.3 Distribution of social benefits

The role played by fish and fisheries in the food, nutritional and livelihood security of the peoples, especially the riparian communities needs to be recognized. Most of the off-stream and on-stream water resource development projects take into account the water productivity in monetary value such as quantity of goods and money generated against unit quantity of water diverted from the river. Short-term benefits from such development might look attractive, but the long-term benefits from the ecosystems, especially those from biodiversity, and livelihood point of view cannot be ignored.

In water resource development, the social benefits accrued if water is allowed to stay in the river/wetland need to be taken into account in order to ensure that the development is inclusive. Reclamation of water sources for urban and industrial use or even for aquaculture can deprive people of their fish-related livelihood. Proper assessment of the livelihood value of the fisheries has to be done and fishers compensated adequately in case such reclamations become inevitable. This will ensure equitable distribution of social benefits out of development involving water resources. As far as possible, community-based enhancement should be preferred to capital-intensive aquaculture ventures for equitable distribution of benefits. Under the former, the extra wealth and income generated through application of enhancement technology should be more equitably distributed among all stakeholders. In the latter case, one or a few investors walk away with all the benefits from higher production, while the fishers get nothing or just wages for their labour.

6.4 Ecological impacts, genetic biodiversity

An instance of silver carp, *H. molitrix* impacting other species has been reported from Gobindsagar reservoir has been mentioned previously.

It is significant to note that despite its entry into a number of Indian reservoirs, by accident or otherwise, silver carp failed to get naturalized anywhere except Gobindsagar. Considering that the reservoir, with its temperate climate, is closer to the original habitat of the fish and has a distinctly cold water hypolimnion due to the discharge from Beas, the silver carp seems to have found a congenial habitat for growth and propagation. Although introduction of silver carp was never cleared by the Committee of Experts constituted by Government of India, the fish is being stocked in a number of reservoirs in the country. Nowhere did the fish make an impact as it did in Gobindsagar. Therefore, fears regarding the threat of extinction of catla from the Gangetic and peninsular India posed by silver carp are perhaps misplaced.

River stocking of Indian major carps: Many State Fisheries Departments have initiated river ranching programmes to rejuvenate the fish stocks in rivers, mainly with seed of Indian major carps. Although well-intended, this step can be counter-productive as induction of the hatchery-bred seed into nature can genetically contaminate the pristine riverine stock. An advisory has gone to all States discouraging stocking of rivers with hatchery-bred seed. An alternative is to breed fish using fresh brood stock collected from the river and the fingerlings so produced are stocked. A study conducted by the NBFGR has revealed that the stock has not been affected so far.

7. RECOMMENDATIONS

7.1. Develop seed rearing infrastructure for enhancement should receive national priority. A cluster approach to develop farms to cater to a group of contiguous reservoirs and cage pen culture are the solutions to this problem.

7.2. The practice of State Fisheries Department stocking the reservoirs needs to be discouraged. Instead, the Governments should act as facilitators to encourage, empower and facilitate the community to do stocking and manage the stock. This will give them a sense of ownership.

7.3. Responsibility of regulating/guiding fisheries development in reservoirs and *beels* should vest with Fisheries Departments of respective State Governments.

7.4. The government should shed the 'revenue approach' in favor of 'development approach' while leasing out water bodies. Outright auctioning of water bodies to private individuals needs to be discouraged. Cooperative societies, SHGs and other groups should be encouraged to manage culture-based fisheries in reservoir. The leasing terms should be long-term 5-10 years.

Similarly, 'enforcement' (command and control) approach should give way to a 'participatory' (co-management) approach.

7.5. Develop appropriate tools to collect resource and catch data on inland fisheries and to create stronger databases in inland fisheries to enable better planning.

7.6. Implement existing regulations on introduction of exotic fishes through public participation. Since rivers and wetlands are contiguous with neighboring countries, international and bilateral cooperation in preventing undesired introductions needs to be worked out.

7.7. Put up an integrated river management regime to plan and implement water resource development projects that recognize all tangible and intangible benefits of riverine resources. At present, many ecosystem services including those from fisheries are grossly undervalued in planning water resource development.

7.8. Develop valuation tools in understanding the value of ecosystem goods and services and internalizing them in development plans.

7.9. Develop appropriate environmental flow models to suit the Indian conditions and the provision of environmental flows needs to be integrated into the water resource planning regimes.

7.10. Develop adequate marketing channels and marketing infrastructure including facilities for value addition. Compliance of hygienic standards such as HACCP should be driven by the need for a national standard of products.

7.11. Most of the water bodies where enhancement is practiced are multi-use environments, where fishery is a secondary activity. This creates problems for governance and decreases the degree of freedom for optimization of fisheries activities. It is not the complexity of technology that comes in the way of achieving higher production from inland fisheries, but it is often the lack of appropriate governance arrangements that prevents appropriate development. Enhancement regimes will be successful only when the community that fishes in the water body is under sound governance set up and the community owns and manages the fish stock. Co-management, where the representatives of the community and government take part in decision making processes, are the most ideal for inland water bodies. All stakeholders should take part in the decision making process and the benefits accrued by implementing improved scientific norms should be equitably shared by all stakeholders. The State (the State Government, local Self Governments, NFDB, etc.) can play a pivotal role in improving the governance systems of reservoirs by providing an enabling policy environment for this purpose.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN INDONESIA

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Abstract

Indonesia has inland water area of 13.85 million ha. The inland fish production has increased steadily and significantly from 288 666 tonnes in 1998 to 494 395 tonnes in 2008. Fisheries resources conservation development in Indonesia is based on the protection of endangered and vulnerable freshwater species and maintaining biodiversity integrity, and has been developed with community participation. In order to increase the population and diversification of fish species in inland waters stock enhancement was carried out since the Dutch occupation when more than 17 species were stocked in inland waters in Indonesia. Those restocking and stock enhancement activities have been done since 1912, and since 2000 fish stock enhancement programs are in natural lake, floodplains area, and man-made lake based on scientific assessment data. The species used for stock enhancement were planktivorous, herbivorous, periphyton feeding and omnivorous species.

The purpose of stock enhancement and conservation are mainly to maintain and sustain populations of fish stock, increasing sustainable fish production and to protect endemic species, fish fauna ecosystems, as well as to maintain the populations of vulnerable and endangered species. Moreover, stock enhancement in Indonesia also aims to mitigate the negative impact due to overloading of the system from cage culture activities in reservoirs. The Ministry of Marine Affairs and Fisheries (MMAF) is the responsible authority for the development of stock enhancement and conservation in Indonesia. MMAF has issued a number of decrees to facilitate the objectives of fisheries enhancement and conservation. Financial aspects for inland fisheries stock enhancement and conservation generally was initiated by the Central or local government covering the purchase of fingerlings and transportation costs. Generally fish seed used for stock enhancement is from the government fish hatcheries and overall it is a public activity conducted by the authorities for public good.

Key words: Inland fisheries resource, enhancement, conservation, Indonesia

1. GENERAL OVERVIEW OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION

1.1 Introduction

Indonesia is an archipelago consisting of 17 508 islands with an inland water area of 13.85 million ha (Sukadi and Kartamihardja, 1995a) consisting of rivers and flood plains (12 million ha), natural lakes (1.8 million ha), man-made lakes (reservoirs; 0.05 million ha), and 5.590 main rivers with a total length of 94 573 km (Depkimpraswil, 2003). The inland waters are spread across the main islands: approximately 65, 23, 7.8, 3.5 and 0.7 percent in Kalimantan, Sumatera, Papua, Sulawesi, and Java, Bali and Nusa Tenggara, respectively (Sarnita, 1986; Kartamihardja, 2005).

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Inland fish production was estimated to be 288 666 tonnes in 1998, and increased significantly to 494 395 tonnes in 2008, an increase of 59.25 percent, (Figure 1) (Capture Fisheries Statistics of Indonesia, 2009). The decreasing production of some of the indigenous species and some becoming threatened/endangered have stimulated the Indonesian government to establish reserve areas locally referred to as “reservat” since 1970. The main species targeted for in conservation areas are ikan batak (*Tor dorouensis*) in Toba lake, pesut (*Orchella brevirostris*) in Semayang Lake East Kalimantan, Dragon fish (*Scleropages formosus*) in west and central Kalimantan and Botia (*Botia macracanthus*) (Soewito *et al.,* 2000).

Fisheries resources conservation (FRC) development in Indonesia can be divided into three eras as reported by the Directorate General of Marine, Coast and Small Island (DGMCSI) (2008) namely:

- 1970 era, fisheries resource conservation formally and originally based on protection of endangered freshwater species such as Dragon fish, balashark, and rainbow, DGMCSI (2008) reported that natural resources conservation in Indonesia commenced in 1640-1642 to focus on forestry while inland fisheries resources conservation (FRC) at Loa Kang and Batu Bumbun Lake of Mahakam River was developed by Dynasty Kutai Kartanegara, East Kalimantan 500 years ago.
- 1980 era, FRC was further developed, not only covering endangered species but also to encourage biodiversity integrity in accordance with the Convention on Biological Diversity (CBD). The aims of this FRC were to protect the species and its habitat.
- 1990 era, FRC was developed to encourage community participation, that means the activities and implementation of FRC conducted by government but also expected the participation from people living in the conservation areas and the vicinity.
- 2000 era up to the present, based on a new regulation that FRC not only is the central government responsible, but also extended to local governments with the primary aim to facilitate development, sustainability and community participation in the management.

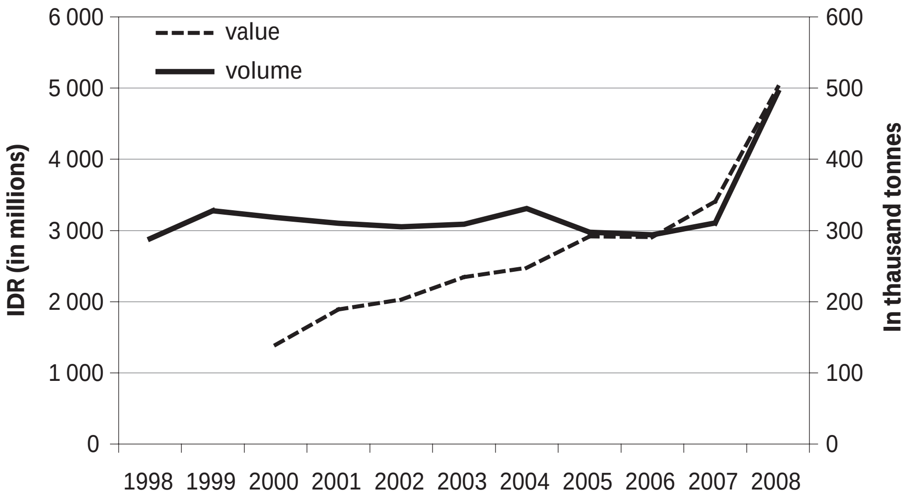


Figure 1. Inland capture fish production in the period 1998-2008 (Directorate General of Capture Fisheries, 2009)

According to Soewito *et al.* (2000) fish restocking and introductions in Indonesian inland waters have been done since 1912. They described the various steps in this regard as:

- Ikan Tambakan, kissing gouramy (*Helostoma temminkii*) has been introduced from South Kalimantan to East Kalimantan by Nobility of Pangeran Mangku in 1912 and the production was estimated to increase by 10 percent (3 800 tonnes/year).

- Common carp (*Cyprinus carpio*) was stocked in Laut Tawar Lake in Aceh in 1928/1929, in Toba Lake North Sumatera in 1937 and resulted in a 16 and a 28 percent increased production of these lake (30 tonnes/year) and (700 tonnes/year), respectively. In 1964 common carp was also stocked to Sentani Lake and Wamena River in Irian Jaya province.
- Ikan Mujair, java tilapia (*Oreochromis mossambicus*) was introduced to Rawa Besar, Rawa Pening at Central Java, Toba lake at North Sumatera in 1980 brought about an increased production of 40, 7 and 28 percent, respectively.
- Ikan Sepat Siam, (*Trichogaster pectoralis*) was imported from Thailand to Java Island in 1934, and then introduced to Tempe Lake of South Sulawesi in 1937, also to South Kalimantan in 1950 and East Kalimantan in 1953/1954.
- Java carp (*Barbonymus/Puntius gonionotus*), a herbivorous species from Java was introduced to Tempe Lake in 1930; this species like the other species introduced to Tempe Lake has established very well.
- Australian trout (*Salmo trutta, S. salar, and S. gaerdneri*), were introduced from Australia to Irian Jaya by Fisheries Central Government in 1984, but these species did not establish.

Moreover, Sarnita (1999) reported that stock enhancement was carried out since the Dutch occupation and recorded more than 17 species introduced to inland waters in Indonesia. Snakehead (*Channa striata*), grasscarp (*Ctenopharyngodon idella*) was imported from China to Indonesia in 1915, and common carp (*C. carpio*) was imported from China and Japan in 1920 (Sarnita, 1999).

1.2 Major practices of fisheries resource enhancement and conservation

1.2.1 Approach of enhancement and conservation

Although restocking and stock enhancement activities have been carried out since 1912, the results were such that no significant increase in production was apparent. This has been attributed to many factors and mainly the lack of a scientific approach based on available data (Kartamihardja, 2009). Since 2000, the Inland Fisheries Resource Enhancement and Conservation (IFREC) has implemented fish stock enhancement programs based on scientific assessment such as introduction of *Pangasianodon hypophthalamus* in Wonogiri reservoir, Central Java; *Macrobrachium rosenbergii* in Darma reservoir, West Java; Mystacoleucus padangensis in Toba Lake, and restocking of green catfish (*Mystus nemurus*) in Wadaslintang reservoir, Central Java. These efforts have significantly increased the total fish production by more than 15 percent (Kartamihardja, 2009).

1.2.2 Aquatic animal species

The species used for stock enhancement were mostly finfish and crustacean as follows:

- Planktivorous species: Kissing gouramy, Siamese gouramy, Silver carp, milk fish, and “bilih”
- Herbivorous species: Java barb, grass carp, and giant gouramy
- Periphyton species: Nile carp
- Omnivorous species: common carp, Tilapia, Catfish, fresh water giant prawn, green catfish, African catfish, and tor.

Seeds of these species were produced by the central and local government hatcheries located at the provincial and district level.

1.2.3 Water body where the activities are implemented:

Water bodies used for stock enhancement vary depending on the availability of natural resources and the government policy or the region. These water bodies can be classified as follows:

a. *Natural lakes:*

Natural lakes used for stock enhancement are Singkarak (West Sumatera), Toba (North Sumatera), Tempe (South Sulawesi), Limboto (Gorontalo, Sulawesi), Batur (Bali), and Kerinci (Jambi, Sumatera).

b. *Flood plain areas:*

Flood plains areas constitute potential area for nursery and growing out many fish species during the rainy season, and are stocked with freshwater species.

These are Lubuk arang-arang in Jambi province, Lubuk larangan in South Sumatera, Barito and Mahakam flood plains in Kalimantan.

c. *Man-made lakes (reservoirs):*

Reservoirs constructed mostly for the purposes of flood control, irrigation, generation of hydro-power, potable water and tourism. Besides these, reservoirs are also utilized for fish stock enhancement in: Kedungombo (Central Java), Wadaslintang (Central Java), Bade (Central Java), Saguling (West Java), Cirata (West Java), Ir. H Juanda (West Java), and Darma (West Java).

1.2.4 Scale of operation

Fisheries enhancement usually conducted in inland waters of Indonesia was mainly fish introduction using hatchery produced seed stocks. Lack of available seeds of indigenous species is one constraint in restocking. The stocking density and fish species stocked in inland waters usually does not conform to the productivity of the water bodies. Stocking strategy is solely of *ad hoc* nature. A planned stocking of 3 218 941 fingerlings of milk fish in Ir. H Juanda reservoirs conducted by Ministry of Marine Affairs and Fisheries (MMAF) in collaboration with ACIAR/NACA and the local government of Purwakarta district and West Java Province is in progress.

2. DETAILED DESCRIPTION AND ANALYSIS OF CURRENT PRACTICES OF INLAND FISHERIES ENHANCEMENT AND CONSERVATION

2.1 Technical description of major enhancement and conservation practices

2.1.1 Rationales and purpose of the activities

Indonesia has a high fish faunal diversity. Kottelat *et al.,* (1993) reported that in Western Indonesia and Sulawesi more than 950 fish species permanently and/or temporarily live in freshwater. Many of these fish are not consumed, but still play an important role in fisheries production by virtue of their position in the food webs (Kottelat et al., 1993). Most Indonesian reserves have been gazetted because of their mammal, bird or vegetation interest, and no reserve exists or has been proposed specifically to conserve the fish fauna (Kottelat et al., 1993). However, since 1960 there has been increasing fish faunal reserves being designated especially to protect the endemic and endangered species of dragon fish (*S. formosus*), and ikan pesut (*O. brevirostris*), as well as extinct species of silver shark (*B. melanopterus*), ikan batak (*Neolissochilus sumatranus*) (DGMCSI, 2008), and Botia (*B. macracanthus*) (Soewito *et al.,* 2000), jelawat (*Leptobarbus hoeveni*), kancra (*Tor* spp), belida (*Notopterus* spp), arengan (*Labeo chrysophaekadion*), patin jambal (*Pangasius djambal*) and siluk irian (*S. jardinii*) (Kartamihardja *et al.,* 2008). DGMCSI (2008) reported that since 2000 fisheries resource enhancement and conservation have been implemented using biodiversity and an ecosystem and community-based approach, and utilizing reserve areas both for Marine Fisheries Resource Enhancement and Conservation (MFREC) and IFREC.

The purpose of conservation is mainly to protect endemic species, fish faunal ecosystems such as spawning grounds, nursery grounds, and feeding grounds, as well as to maintain the populations of threatened and endangered species by establishing reserve area (DGMCSI, 2008). Meanwhile the aims of stock enhancement are to maintain and sustain population of fish stocks and to increase sustainable fish production by minimizing negative impacts or competition for food and niches of others indigenous species (Kartamihardja, 2007b).

Besides conservation, increase of fish populations and production in inland open waters, stock enhancement in Indonesia also aims to mitigate the negative impact due to overloading to the ecosystem by cage culture in reservoirs through co-management approach since 2008. In this strategy, the planktivorous and omnivorous species such as tilapia, silver carp and milkfish are stocked in the open waters to bring about sustainable fishery activities and also reduce and or minimize potential conflicts between open water fishers and fish farmers.

2.1.2 Technical description of the activities

In the last decade, stock enhancements were carried out in many places like lakes and flood plains and reservoirs from 1998 to 2009 (Table 1) to increase the population stock and fish production in inland open waters. . In order to mitigate the impact of overloading of the system of fish cage culture activities such the occurrence of plankton blooms and associated problems of massive fish kills, firstly 2.14 million fingerlings of milk fish were stocked in Ir. H Juanda reservoir West Java province in 2008 (Tables 1 and 2). Then another 3.8 million fingerlings of milk fish were released into the reservoir in October-November 2009 (Table 1).

Table 1. Fish stock enhancements in the inland waters of Indonesia, year 1998-2009

Species	Number of fingerlings	Location	Authority
Anabas testudineus	154 000	South Kalimantan	F SS K (2002)
Helostoma teminkii	27 000	South Kalimantan	
Trichogaster pectoralis	11 000	South Kalimantan	
Osphronemus gouramy	17 000	South Kalimantan	
Oreochromis niloticus	366 000	South Kalimantan	
Pangasianodon hypophthalamus	28 000	South Kalimantan	
Anabas testudineus	13 750	South Kalimantan	FADC M (2004)
Mystus nemurus	10 000	South Kalimantan	
Osphronemus gouramy	10 000	South Kalimantan	
P. hypophthalamus, O. gouramy, M. nemurus	332 000	South Kalimantan	F SS K (2007); F SS K (2002)
Ctenopharyngodon idella	20 000	North Sulawesi	FADC T (2009)
Oreochromis niloticus	20 000	North Sulawesi	
H. teminkii, A. testudineus	183 000	Jambi	Mashudi *et al.* (2003)
Osteochilus hasselti	1 015 000	Cirata reservoir	DFHE (2006)
Ctenopharyngodon idella	180 000	Cirata reservoir	
Hypopthalmichthys molitrix	10 000	Cirata reservoir	
Barbonymus gonionotus	100 000	Cirata reservoir	
Ctenopharyngodon idella	8 750	Saguling reservoir	
Chanos chanos	2 144 000	Ir. H Juanda reservoir	DFHE (2009)
Chanos chanos	3 800 000	Ir. H Juanda reservoir	
Macrobrachium rosenbergii	26 500	Darma reservoir	Kartamihardja (2009)
Pangasianodon hypophthalamus	45 000	Wonogiri reservoir	

Table 2. Number and size (length and weight) of milk fish stocked and harvested (sampled) in Ir. H Juanda reservoir 2008

Parameter	Milk fish fingerling stocked		Milk fish caught			
	July	August	September	October	November	December
Number	2 116 000		61	35	38	54
Length (cm)						
– Average	5.8	4.7	23.7	27.3	26.9	27.5
– Minimum	3.2	2.8	14.7	20.7	20.0	23.0
– Maximum	7.8	8.5	31.0	32.5	34.5	31.5
Weight (g)						
– Average	1.3	0.8	134	179	158	159
– Minimum	0.3	0.1	25	67	66	95
– Maximum	3.3	5.1	280	342	347	238

Source: LRPSI Jatiluhur, 2008

After three months of the first stocking, 65 tonnes of milk fish were caught (September-December 2008), with individual size ranging from 100-150 g, with a total value IDR 455 million (Kartamihardja, 2009). During the second fishing season, 12 545 tonnes of milk fish ranging in weight of 150-250 g, with a total value of IDR 75.27 million were caught. Milk fish fishers paid back IDR 600/kg (collecting a total of IDR 7.527 million) which was used to purchase fingerlings for the next stocking and thus making the process sustainable in the long term. The milk fish stock enhancement indicated positive impacts on water quality in terms of oxygen and some others important parameters (nitrate and phosphate) and to prevent algae blooming in Ir. H Juanda (Figure 2).

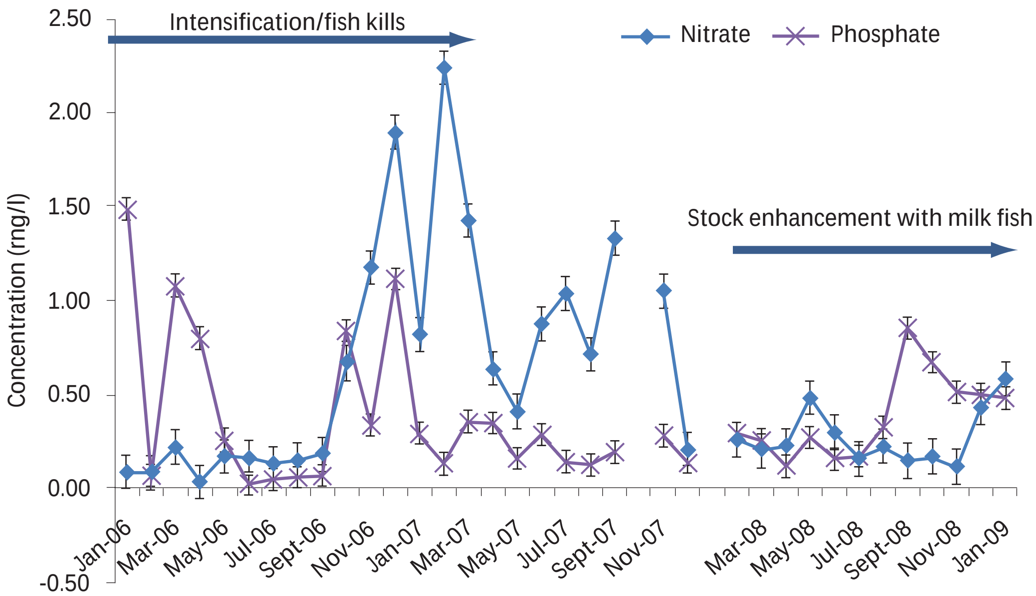


Figure 2. Effect of milk fish enhancement on nitrogen and phosphorus level in Ir. H Juanda

These stock enhancement practices were done in many ways as described by Kartamihardja (2008): a) Identification of inland fisheries water resource; b) Setting up of institutional management; c) Planning for fish seed stocking including number of fingerling, fish species and purpose of stocking; d) Implementation; e) Monitoring and evaluation. In some cases, after fish stocking to the water body, monitoring and evaluation were not conducted properly. Criteria and indicators of success stocked enhancement are shown in Box 1.

Box 1
Criteria and indicators/measurement of success of fish stock enhancement implementation (Kartamihardja, *et al.,* 2008)

Criteria	Indicators
Biology	Increasing of total catch of fish stocked
	Increasing of total fish catch
	Increasing of size of fish catch
Reserve fisheries resource	Increasing abundance of target fish and others fish in natural stock
	Increasing productivity of target fish population
	Improvement of target fish population integraty
	Improvement of food web dynamic
Cost and nomical benefide	Cost efficiency
	Improvement of income
	Efficiency of management cost
	Benefit cost of catchment of endogeneous fish loss.
	Efectiveness of research cost of Fisheries resource management (FRM)
	Increasing information value tooken for research of FRM
Contribution to livelihood	Kesetaraan keuntungan/manfaat
	Improvement of health benefit
	Improvement of skill and knowledge
	Generate networking and association
	Improvement of trust
	Accesibility to institution involved
	Accesibility to tourism and recreation
Institution sustainably	Establishment of institution management
	Regulation applied by *stakeholders*
	Regulation adaptation to change occured
	Flexibility of maintaining ecosystem

2.2 Operation

2.2.1 Policy making, planning and organization

The Ministry of Marine Affairs and Fisheries (MMAF), the responsible authority for development for stock enhancement and conservation in Indonesia, has issued a number of decrees to be used as legal and policy organization for fisheries enhancement and conservation.

MMAF's decree number: PER.07/MEN/2005 places fisheries conservation under the authority of the Directorate Conservation and National Ocean Parks and the Directorate General of Marine, Coastal, and Small Islands, while fisheries stock enhancement is under the Directorate of Fisheries Resource, the Directorate General of Fisheries of MMAF. In accordance with the Presidential decree No: 60/2007 MMAF, the local government (Provincial and District levels) will develop fisheries conservation areas to be a) National Fisheries Conservation Areas, b) Provincial Fisheries Conservation Areas, and c) Regency Fisheries Conservation Areas (RGMCSI, 2008). Recently MMAF has developed Regency Fisheries Conservation Areas (RFCA) in the region, and in 2007 a total of 24 RFCAs were established in many types of regencies across Indonesia, and they were further extended to develop at National and Provincial levels. So far Fisheries Conservation Area is categorized into our types of water reserves: a) National Water Parks, b) Natural Water Reserves, c) Water Ecotourism Parks, and d) Fisheries Reserves.

Under the local government (provincial and regency levels), stock enhancement and conservation are under the authority of Fisheries Services, where the water body is located. In case of big reservoirs such Cirata located in three regencies of Cianjur, West Bandung, and Purwakarta, the development of Cirata reservoir policy including stock enhancement and conservation will come under Fisheries Services of West Java Province based on agreement of the three regencies.

In addition to the two Directorate General of Fisheries and Marine, Coast, and Small Inland, the Directorate General of Aquaculture (DGA) MMAF, also has the mandate of restocking of inland water bodies. In some cases the DGA in collaboration with the local government of the province or the regency released fingerlings to inland water bodies such as lake, reservoirs, and flood plains, in order to increase fish stocks and production. In 2008 and 2009, the DGA collaborated with the Purwakarta regency and ACIAR project to stock more than five million fingerlings of milk fish into Ir. H Juanda reservoirs, West Java for improving the water quality due to plankton blooming and for increasing fish production in this reservoir.

2.2.2 Funding mechanisms

The financial aspects for inland fisheries stock enhancement and conservation are generally initiated by the Central government or the respective local government and include costs for purchasing fingerlings and transportation. The Central government, through the DGA of MMAF, initiated financial support for restocking of many inland waters bodies. This fund is mostly distributed to Fisheries Services of local governments where the local government had proposed restocking programs and intensively discussed with DGA based on scientific data and information of restocking planning and approved by DGA. The remaining restocking budget is handled by the DGA for restocking in strategic and potential water bodies in collaboration with the province or regency level. MMAF through DGA budget allocated IDR 3.7 billion to 14 provinces in 2003, and IDR 34.105 million for 20 provinces in 2004 (Directorate Fish Health and Environment, 2009). This initial funding had been ongoing for more than a decade. Up to now, there is no private sector or other financial institutions involved in the restocking programs. To promote generating funds for restocking from the private sector, MMAF in collaboration with ACIAR/NACA and local government commenced a pilot project for adoption of co-management approach in Ir. H Juanda reservoir, in 2008. By using co-management approach the fishers and the other stakeholders formulated a commitment for continuing the activities such as releasing fingerlings and the funding to be provided for through a levy imposed on the landings.

2.2.3 Key material inputs

In implementing stock enhancement programs through stocking, the most important input is seed. The species mostly used for stocking are cultured fish species or domesticated species, such as common carp, tilapia, kissing gourami, climbing perch, java barb, pangasius, grass carp, silver carp, milk fish, and giant gourami. Generally, fish seed used for stocking in the lakes, reservoirs, floodplains come from government fish hatcheries, as these are reputed to have a better broodstock management strategy and the price is negotiable compared to private hatcheries. Wildly caught seeds are rarely used for stocking inland water bodies due to unpredictable availability, varying quality and seasonal variations.

Indonesia has more than 30 freshwater fish hatchery units under the management of fisheries provincial levels. Seed production capacity ranges from 1-5 million fry/yr/unit depending on facilities, human resources and management. There are more than 416 fish hatchery units under the responsibility of the fisheries services at regency level. The production of seed ranges from 0.5-1 million per unit annually. Besides government hatcheries, there are 26 365 small-scale hatcheries owned by individuals or farmer groups. Most of individual farmer hatchery operators are small-scale, using traditional technology transfered from generation to generation (Budhiman, 2007).

Small-scale fish hatcheries usually have limited number of brood stock. Replenishment of brood stock is seldom and depends on availability of budget. Government hatcheries usually have better quality and higher number of brood stock compared to small-scale hatcheries. The brood stock in government hatcheries mostly come from government hatcheries at province level or from Technical Implementing Unit (TIU) of the Directorate-General of Aquaculture, MMAF. There are four TIU for freshwater aquaculture where one of the functions is to produce high quality seeds and freshwater species brood stock (Table 3).

Table 3. Freshwater Aquaculture Technical Implementing Unit (TIU)

TIU	Fish Species	Region
Main Center for Freshwater Aquaculture Development Sukabumi, West Java	Tilapia, common carp, african catfish, giant gourami, catfish, freshwater prawn, grass carp, silver carp	Java, Bali, Nusa Tenggara, Papua, Sulawesi Islands
Freshwater Aquaculture Development Center Jambi	Siamese catfish, djambal catfish, kissing gourami, tilapia, climbing perch, common carp, green catfish, botia	Sumatera Island
Freshwater Aquaculture Development Center Mandiangin, South Kalimantan	Siamese catfish, green catfish, tilapia, common carp, climbing perch, leptobarbus, kissing gourami, feather back	Kalimantan Island
Freshwater Aquaculture Development Center, Tatelu, North Sulawesi	Common carp, tilapia, grass carp, african catfish	Sulawesi Island

The size of seed stocked is very important for obtaining good results. Generally, 5-12 cm is the recommended size of seed at stocking as these will be able to compete with wild fish and result in better survival. Three examples of success stories of stock enhancements in Indonesia related to stocking size of fingerling are as follows: in Wonogiri reservoir Central Java the stocking size for Siamese catfish was 10-15 cm (10-20 g/fish), 10-16 cm (15-25 g/fish) for green catfish and were stocked in Wadaslintang Central Java, and 5-7 cm (1-2 g/fish) of bilih stocked to Toba Lake (MMAF, 2007).

2.2.4 Executing agencies

Based on Ministerial Decree No. PER.07/MEN/2005, the main national institution responsible for Inland fisheries enhancement and conservation are as follows:

- Directorate Conservation and National Ocean Park, Directorate General of Marine, Coast, and Small Inland. The task of this directorate is policy formulation, preparation of guidelines and evaluation conservation area, and rehabilitation of fisheries resources and their ecosystem.
- Directorate of Fisheries Resource, Directorate General of Capture Fisheries which is responsible for preparing guidelines and evaluation of stock enhancement and protection.
- Directorate of Fish Health and Environment, Directorate General of Aquaculture which is responsible for preparing policy formulation in fish health and environmental management, and providing guidance for fish health and environmental management.
- Research Institute for Stock Enhancement and Conservation at Jatiluhur, Research Center for Fisheries under Research Agency for Marine and Fisheries is responsible for doing research and assessment on stock enhancement and conservation and for providing scientific data and required information on stock enhancement and conservation to the central and local government.
- Technical Implementing Unit of Freshwater Aquaculture is responsible for producing fish seed for stocking in inland water bodies in the region.

There are 33 Provincial Fisheries Service offices and 414 regency fisheries service offices. The main task of these institutions is to execute the stock enhancement and conservation in their authority area as well as providing fish seed for restocking to the water body. These institutions play important role for developing inland fisheries enhancement and conservation collaboration with central government and local community.

2.2.5 Management/enforcement/participation

Fisheries resource enhancement and conservation of inland waters belong to the public sector, local community, or local government. In Indonesia, majority of the fisheries scientists are familiar with the word “Lebak-Lebung” or a flood plain area, where the utilization of these natural resources are managed sustainably by the local community. This system has been in existence for many years in South Sumatera (Table 4) and in "lubuk arang-arang" in Jambi province Sumatera Island. However, fisheries resource management practices in many reservoirs in Java Island such as Kedungombo, Wadaslintang, Saguling, Cirata, and Ir. H Juanda are initiated by the government. In order to improve and increase participation of local community and stakeholders to manage fisheries resources sustainably in the reservoirs, MMAF in collaboration with ACIAR/NACA is implementing a co-management approach for managing fisheries resources in Cirata and Ir. H Juanda reservoirs. The fishers and other stakeholders in Juanda reservoir are participating in the planning, releasing fish fingerlings, monitoring and harvesting of milk fish, and have also made commitment to share money from selling milk fish to buy fingerlings for subsequent stocking.

2.3 Impact assessment mechanism

2.3.1 Impact assessment agencies

The Environmental Management Act (EMA) superseded EMA No. 4/1892 and provides the basic (or umbrella) environmental law in Indonesia. It covers the principle, objective and target of environmental management in Indonesia, right and duties and the community roles, authorities to manage environment, and the function of sustaining the environment. Of particular interest: Article 8 of the law covers the environmental policy, and management aspect in relation to the natural resources including the genetic resources; and article 37 provides the community rights to file for class action and provide legal basis for the environment organizations to fight file suits against on behalf of public interest against unsustainable environmental practices (Phillip, *et al.,* 2009).

Table 4. Development of fisheries resources management in flood plains system, South Sumatera (Kartamihardja *et al.,* 2009)

<table>
<tr><th>ST</th><th>Management authority</th><th colspan="2">Pattern of management</th><th>Participant</th><th>Status of fisheries resources</th></tr>
<tr><td>I</td><td rowspan="2">Community wisdom (adat)</td><td colspan="2">Traditional with local wisdom</td><td rowspan="2">Local community members (adat lokal)</td><td>Sustainable fisheries resources</td></tr>
<tr><td>II (1600-s)</td><td rowspan="3">Oxygen</td><td rowspan="2">Reserve area</td><td>Abundance of fisheries resources relatively stable, due to sufficient reserve area so be able for natural recruitment of fish resources</td></tr>
<tr><td>III (1970-s)</td><td rowspan="3">Government</td><td rowspan="3">Local Investor (fishermen and non fishermen) & out of local investor</td><td>Abundance of fisheries resources decrease due to insufficient reserve area, so unable for natural recruitment fish resources</td></tr>
<tr><td>IV (2000-s)</td><td rowspan="2">Without Reserve area</td><td rowspan="2">Sustainable of fisheries resources threatened due to unable providing seed for renewing fisheries resources caused:
1) Abundance and fish diversity extremely decrease;
2) Population structure is changing:
a. Main species with high economic value disappeared, replace by low economic value
b. Size of fish tends to be small.</td></tr>
<tr><td>V (2008 → now)</td><td>Auctioned & Open access</td></tr>
</table>

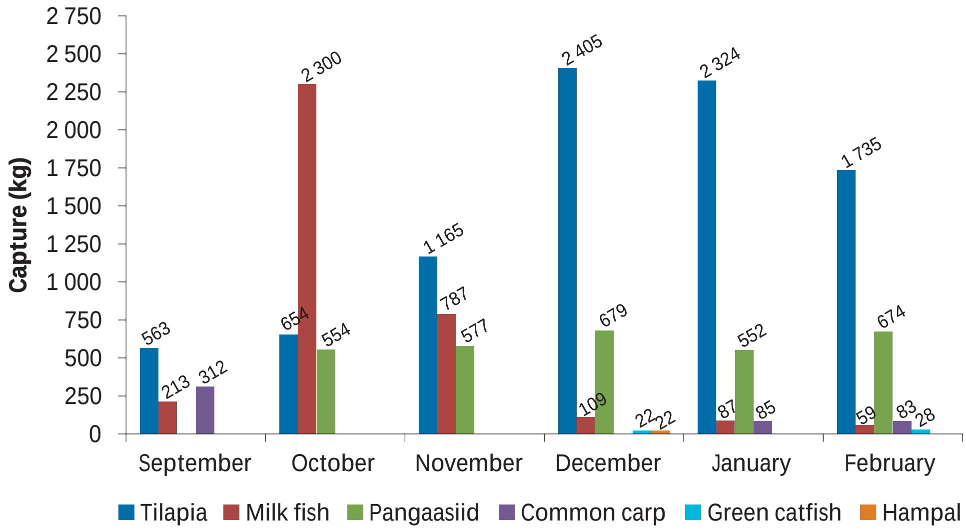
Environmental impact assessment as abbreviated in Bahasa Indonesia as AMDAL is a key responsibility of the Ministry of Environment and is an important instrument in determining the impact of the project on the environment. The Environmental Impact Management Agency (BAPEDAL) task include the implementation of the national environmental policy, the preparation of guidelines on environment impact management, the coordination of environment impact assessment process, the monitoring and management of waste discharge, the promotion on environmental awareness and the settlement of the environmental dispute (Phillip *et al.,* 2009).

2.4 Impacts of major enhancement and conservation activities

2.4.1 Impact on natural populations

Information on impacts of major enhancement and conservation activities in Indonesia is limited. Examples of stock enhancement and reports available are:

- In 1985-1991, common carp fingerling were introduced into Tondano Lake, South Sulawesi, and resulted in increasing production to 340 kg/ha (60 percent increase) (Sukadi & Kartamihardja, 1995b).
- In 2002, fingerlings of Siamese catfish (*P. hypopthalmus*) were stocked into Wonogiri reservoir Central Java that resulted in a catch of 112 215 kg with a total value IDR 785.5 million, increasing fisher income to 1.2 million IDR (Kartamihardja & Purnomo, 2004).
- In 2003 26 000 fingerlings of freshwater prawn (*M. rosernbergii*) were introduced to Darma reservoir in West Java and resulted production 33 765 kg with total value of IDR 13.5 million (Kartamihardja *et al.,* 2004).
- Kartamihardja & Purnomo (2006) reported that in 2003 endemic species of Singkarak Lake, bilih (*M. padangensis*) were stocked in Toba Lake, North Sumatera and resulted in a catch of 653.6 tonnes in 2005 with a total value IDR 3.9 billion.
- MMAF, collaboration with ACIAR/NACA and local government, was implementing a pilot project on co-management approach in Ir. H Juanda reservoir West Java with stocked 2 125 620 fingerlings of milk fish, total length of 2.8-8.5 cm and weighed 0.1-5.1 g in July-September 2008 (Figure 3).



Source: LRPSI Jatiluhur, 2009

Figure 3. Fish catch composition in weight (kg) on September 2008 – February 2009 in Ir. H Juanda (from 14 fishers daily)

2.4.2 Impact on biodiversity

Fisheries stock management is intended to protect and conserve existing fish populations, including stock enhancement. Introduction of fish to Indonesian inland water bodies has been done since the Dutch colonial time and recorded around 17 freshwater fish species (Sarnita, 1999), such as Snakehead (*C. striata*) which was first imported from China to Indonesia in 1915. Grass carp (*C. idella*) and mud carp (*Cirrhinus chinensis*) were imported from Malaysia while the common carp (*C. carpio*) was imported from China and Japan in 1920. Among those 17 species, snake head, common carp, sepat Siam (*T. trichopterus*), mujair (*O. mossambicus*), are well established in the inland waters of Indonesia and dominate the fish catch. In several water bodies, introducing and stock enhancement activities were successful in increasing fish catch. However, the long term environmental balance and sustainable benefits for fishers as well as supporting poor peoples' livelihoods point of view such stock enhancement activities were mostly was not successful (Kartamihardja and Wudianto, 2005.). Introducing fish without any consideration of precautionary approach and limno-biological characteristics of water bodies will generate negative impact on decreasing biodiversity of local indigenous species.

Research result of inventory on fish species reported by Kartamihardja (1993) and Kartamihrdja *et al.,* (1992) that fish catches in water bodies in Java, Bali and Nusa Tenggara Barat have remained static. However, in water bodies in Sumatera and Kalimantan it was different. In Kedungombo and Wadaslintang reservoirs fish catches were dominated by 12-14 species (Kartamihardja, 1993; Kartamihrdja *et al.,* 1992). Meanwhile in Ir. H Juanda reservoir, initially 29 species (Purnomo, 1993, Purnomo *et al.,* 1992a; 1994) had changed to 9 species and dominated by introduced species namely tilapia (Kartamihardja, 2004). In Cirata reservoir fish catches are still dominated by indigenous species of the Citarum River (Kartamihardja & Umar, 2005). In Komering river there are around 55 fish species (Gaffar & Utomo, 1992), in Musi river nearby Palembang account for 90 species (Ondara *et al.,* 1987), in Limboto lake 14 fish species (Sarnita, 1994b), in Sentani lake and Paniai were 20 dan 10 species respectively (Sarnita, 1994c; 1994d). In certain water bodies species that were thought to be extinct such as ikan batak (*Lisochillus* spp.) Toba lake, semah (*Labeobarbus duoroensis*) Komering river, ikan bungo (*Glossogobius giuris*) Tempe lake, ikan payangka (*Ophiocara porocephala*) in Limboto, rainbow (*Melanotaenia ayamaruensis*) and freshwater lobster (*Cherax* spp.) in Papua (Kartamihrdja and Wudianto, 2005) have been found.

2.4.3 Socio-economic benefits

Information and references on socio-economic benefits of fisheries resource enhancement and conservation impact assessment in Indonesia is very limited. Economic analysis on fisheries activities were carried out in Rawa Pening (Sadili *et al.,* 1992), Semayang and Melintang lakes (Purnomo *et al.,* 1994), flood plains of Lebak-lebung in South Sumatera (Nasution *et al.,* 1993), Ir. H Juanda and Saguling reservoir (Setyaningsih *et al.,* 1993a; 1993b; Sadili & Koeshendrayana 1989; Sadili *et al.,* 1991), and Cirata reservoir (Sadili, 1990), mostly based on profit utilization of fishing devices and aquaculture systems and its marketing (Kartamihardja and Wudianto, 2005).

The socio-economic impacts of stocking bilih in Toba Lake North Sumatera on 3 January 2003 by Research Center for Fisheries, Agency for Marine Affairs and Fisheries, contributed to the production share to fishers of seven districts from 2004 to 2008 (Table 5 and Figure 5).

Table 5. Production of bilih in seven districts in Toba Lake from 2004-2008

No.	District	Production/year (tonne)					Total
		2004	2005	2006	2007	2008	
1	Simalungun	–	–	–	–	15.00	15.00
2	Tobasa	–	–	45.40	71.50	354.50	471.40
3	Tapanuli Utara	–	10.20	14.30	17.20	27.70	69.40
4	Humbang Hasundutan	–	54.10	122.50	500.00	900.50	1 577.10
5	Samosir	53.70	104.40	133.50	538.50	286.36	1 116.46
6	Dairi	–	–	370.00	400.00	456.00	1 226.00
7	Karo	–	–	256.00	511.00	996.00	1 763.00
	Total	53.70	168.70	941.70	2 038.20	3 036.00	6 238.36

Source: Fisheries Services of North Sumatera Province, 2009

Table 6. Range of Bilih fish catch, its selling price and estimated fisher income at four landing places in 2008

Parameter	Fish landing place			
	Parapat	Tongging	Porsea	Balige
Fish catch (kg/fisher/day)	50-80	40-60	10-30	20-30
Total fish catch (tonne/day)	1.5-2.0	2.0-2.5	0.5-1.0	1.5-2.0
Selling price to PP (IDR/kg)	4 000	3 000	2 000	2 500
Income (x 1 000 IDR/fisher/day)	200-320	120-180	20-60	50-75
Retail price (IDR/kg)	6 000	6 000	5 000	6 000

Remark: PP: Fish collector; selling price = selling price at fish market.

3. CONSTRAINTS AND PROBLEMS

3.1 Technical constraints

Problems encountered in fisheries enhancement and conservation practices in inland waters of Indonesia are as follow:

- less understanding on techniques of fisheries enhancement by community as well as the policy makers;
- availability of sufficient fish seed, especially local species for stock enhancement;
- enhancement practices have not been based on sufficient scientific data and information so that the protocol and the strategies are often not clearly defined;
- impact analysis of fisheries enhancement practices has not been done;
- monitoring, evaluation and controlling of the fisheries enhancement applications have not been conducted;
- management institution units as one element in co-management has not been established; and
- property right systems in management of the water bodies has not been clearly defined.

3.2 Operational constraints

Since the inland waters authority is under the government at regency level, development of fisheries enhancement and conservation is very dependent on the attention of the policy makers at regency level. Until now, there is less understanding and appreciation of the policy makers at regency level on fisheries enhancement and conservation of inland water. Implementation of fish stock enhancement is mostly conducted based on a project oriented basis and as a ceremonial event without participation of the communities surrounding the water body.

Inland waters bodies of Indonesia have different limnological characteristics, high and varying fish biodiversity and distributed across several islands. Water body productivity is related to fisheries enhancement potential, while high fish biodiversity is related to risk impact of fish stock enhancement, especially fish introductions. Cost allocation for fisheries enhancement activities is also not sufficient for optimizing the resources. Moreover, since 2006, cost allocation for fisheries enhancement at regency level was funded by the Central Government and in some locations was also funded by local government at provincial level as well as regency level.

3.3 Distribution of social benefits

The success of fisheries enhancement should give long term benefits for the community surrounding the water bodies where fisheries enhancement implemented. The implementation of fisheries enhancement in Indonesian inland waters were generally conducted without sufficient planning for long term benefit. The fishers usually get the immediate benefits from the enhancement only for one or two years.

3.4 Ecological impacts, genetic biodiversity

As fish stock enhancement has not been conducted based on the scientific data and information, these impacts on the genetic biodiversity of the natural population are not known. Also, study on the impacts of fish stocking of wild species has not been conducted. Fish stock enhancement conducted in some water bodies resulted in a decline of wild species, such as the introduction of tilapia and common carp in Toba Lake that caused a decline of the endemic species, *Neolissochillus sumatranus.*

4. RECOMMENDATIONS

In the future, sustainable fisheries enhancement and conservation practices in inland waters of Indonesia should be done based on scientific data and information on eco-biological characteristics of the water body, fish population, socio-economics and legal aspects. Scientific data on the habitat characteristics and productivity of the water body, structure of the fish community and species composition, and the fisher groups should be considered.

Fish stock enhancement programs should also be conducted based on a clear step by step protocol, starting with the identification of suitable water resources, establishment of stock enhancement goals, establishment of species, number, size, and cost of fish stocking needed, development of a fish stock enhancement strategy, monitoring and evaluation, and development of fisheries management units.

Generally, to achieve these objectives and goals of fisheries enhancement practices, some recommendations are needed:

1) Capacity building and understanding of fisheries enhancement for policy makers, fishers and other stakeholders is needed. For this purpose, reseach results dissemination of fisheries enhancement technichues should be conducted.
2) Fisheries enhancement and conservation practices at every water body should be based on sufficient scientific data and information.
3) Before techniques of fisheries enhancements are applied, a protocol and a strategy should be defined.
4) Implementation of fisheries enhancement should involve community participation through development of fisheries co-management units.
5) To achieve the goals of fisheries enhancement the following are needed.
    - Support from water management authorities and local goverments, in addition to a management unit specialized in the fisheries sector.
    - Development of infrastructure such as hatchery units.
    - Development of pilot project on fisheries enhancements.
    - Formal legal fisheries management support or local wisdom as a legal foundation for the implementation of fisheries enhancement and conservation.
6) Management of fisheries in inland waters through fisheries enhancement and conservation program should continue to develop as an effort to increase fish production and sustainability of fisheries resources.
7) Implementation of fisheries enhancement and conservation should be coordinated with institutions responsible for managing and controlling fisheries development and its sustainability.
8) Water bodies allocated for fisheries development should be maintained in order to enhance fisheries sustainability and its environment.
9) To support fish stock enhancement programs, optimization of fish hatchery units at central, provincial and local level is needed.
10) Development of fisheries community participation and of fisher groups in order to manage the inland waters fisheries.
11) Regulate and control of environmentally destructive and unsound fishing practices.
12) Define a clear zoning of the water bodies to avoid conflicts among the users.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN THE REPUBLIC OF KOREA

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Abstract

The beginning of inland fisheries resource stock enhancement in the Republic of Korea dates back to the early 1970's, when fishing pressure was relatively low, and its development was closely related to the overall trends in the inland fisheries production. The annual average production of inland capture fisheries increased rapidly until the mid 1980's and was followed by a sharp decline thereafter. Paradoxically, such decrease in commercial capture fisheries brings an opportunity to promote aquaculture development and to reach a social agreement on the needs for intensive enhancement of inland fisheries resources. Consequently, since the 1990's about 70 percent of the annual inland fisheries production was from aquaculture in comparison to the contribution of nearly 94 percent from capture fisheries until 1980's. The development of aquaculture-related technology is of use to optimize stock enhancement efforts.

The release of hatchery reared juveniles of inland fisheries resources has become an increasingly common practice for stock enhancement and conservation over the last three decades. The primary purpose of the hatchery practice was to increase the stock size of commercially valuable species in the early stages but now this has changed to compensate for recruitment overfishing and to mitigate disturbances to the environment from human activities. As of 2007, the number of target species for enhancement is eleven, namely common carp, Crucian carp, Korean bullhead, far eastern catfish, Mandarin fish, Japanese eels, sweet fish, aucha perch, mitten crab, melanian snail and soft-shelled turtle. The average number of hatchery-reared juveniles of the eleven target species released is approximately 12 million during the last 5 years, valued at about US$1.3 million. In addition, about 13 million of hatchery-reared salmon were released.

Recently, two more initiatives on stock enhancement and conservation were started to aid depleted inland fisheries populations through the provision of artificial spawning facilities, development of seed production and supply techniques. The former aims to create artificial spawning and rearing environments as hatcheries and the latter to conserve and preserve native species. Regarding native species and ecosystems, the management of invasive alien species is increasingly being addressed. Two introduced species from abroad, largemouth bass and bluegill are listed as invasive alien species that threaten the native ecosystems. On the other hand, protective measures were undertaken such as the establishment of inland water protected areas, closed season for fishing, minimum size limits on fish and shellfish and restrictions on fishing gear.

An impact assessment on inland fisheries resource enhancement and conservation was undertaken in 2007 to deal with melanian snails, *Semisulcospira coreana* and *S. gottschei*, the results will be available in early 2010. The hatchery release programme initiated in 1973 is being successfully implemented. Eleven of 16 metropolitan areas and provinces in the Republic of Korea are participating in this programme under the overall guidance of the Ministry of Food, Agriculture, Forestry and Fisheries. Twelve national, provincial and municipal inland fisheries-related institutes play an important role in the implementation of the programme. To improve the current practices and to minimize any possible adverse ecological impacts of stock enhancement, it is recommended to estimate the maximum sustainable biomass, to use genetically sound breeding and seed production, to consider adaptation and mitigation of potential climate change-related impacts on inland fisheries and aquaculture and to raise public awareness.

Key words: Inland fisheries, stock enhancement and conservation, hatchery-reared fish, Republic of Korea

1. INTRODUCTION

The Republic of Korea has achieved rapid economic growth since the 1960's to become the 11th largest economy in the world and a member of the Organization for Economic Cooperation and Development (OECD) Development Co-operation Directorate (DAC) in 2009. However, some adverse environmental effects of such rapid development, typically known as water pollution, could not be avoided.

Fresh inland waters are essential to all life on earth, including sustaining human populations, and also as hotspots of biodiversity. It is generally known that aquatic organisms are vulnerable to environmental change and freshwater fish and mussels are among the highly endangered groups of animals on the planet (Ricciardi and Rasmussen, 1999). Jenkins (2003) reported that the rates of decline in vertebrate biodiversity are higher for freshwater than for either terrestrial or marine organisms.

Of the 269 fish and mollusk species, including 61 endemic species, distributed in inland waters of the Republic of Korea (hereafter referred to as Korea), two species are assumed to be extinct and twenty species are legally protected as endangered species and natural treasures. This means that eight percent of inland species are already threatened or in danger of becoming extinct. From the view point of fisheries, decreases in biodiversity of inland water ecosystems can be related to inland fisheries production that have been seen to decline since the late 1980's, mainly due to environmental degradation caused by human activities and increasing fishing pressure. Therefore, inland fisheries resource enhancement and conservation practices can be considered as a part of the management of inland waters for fish production.

2. OVERVIEW OF INLAND FISHERIES RESOURCES ENHANCEMENT AND CONSERVATION

2.1 History of inland fisheries resources enhancement and conservation

The beginning of inland fisheries resources enhancement in Korea dates back to the 1960s. The establishment of a National Fisheries Agency (also called Office of Fisheries) in 1965 to take responsibilities for affairs in the fisheries was a turning point for national inland fisheries development. For better understanding of stock enhancement practices, it is relevant to consider the overall trends in inland fisheries production and the related national policies.

2.1.1 Trends in inland fisheries production

The inland capture fisheries and aquaculture production data of Korea for this review are from the Food, Agriculture, Forestry and Fisheries Statistical Yearbook published by the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF). The national average annual fisheries production, consisting of inland fisheries, shallow-sea fisheries, shallow-sea aquacultures and deep sea fisheries, was 2.3 million tonnes over the last 46 years (1962-2007). The inland capture fisheries and aquaculture production accounted for one percent of the national total annual fisheries production.

The annual average production of inland fisheries and aquaculture in Korea was around 1 000 tonnes until 1974 (Figure 1). The annual production of inland fisheries and aquaculture increased dramatically since 1975 and peaked in 1987. The annual average inland fisheries production between 1975 and 1987 was around 40 thousand tonnes, about 40 times greater than that of any previous comparable years. However, right after 1987, the annual average production of inland fisheries declined sharply to a level of about 30 000 tonnes in 1990s and about 22 000 tonnes in 2000s. This decrease mainly resulted from capture fisheries changes, having accounted for 94 percent of the annual production of inland fisheries until 1987. The annual average production of inland capture fisheries was 40 000 in 1980s, declined by a quarter in 1990s and remained at the level of about 7 000 tonnes in 2000s. Water pollution, overfishing, habitat destruction and mismanagement of fisheries resources are thought to have resulted in the decrease in commercial capture fisheries.

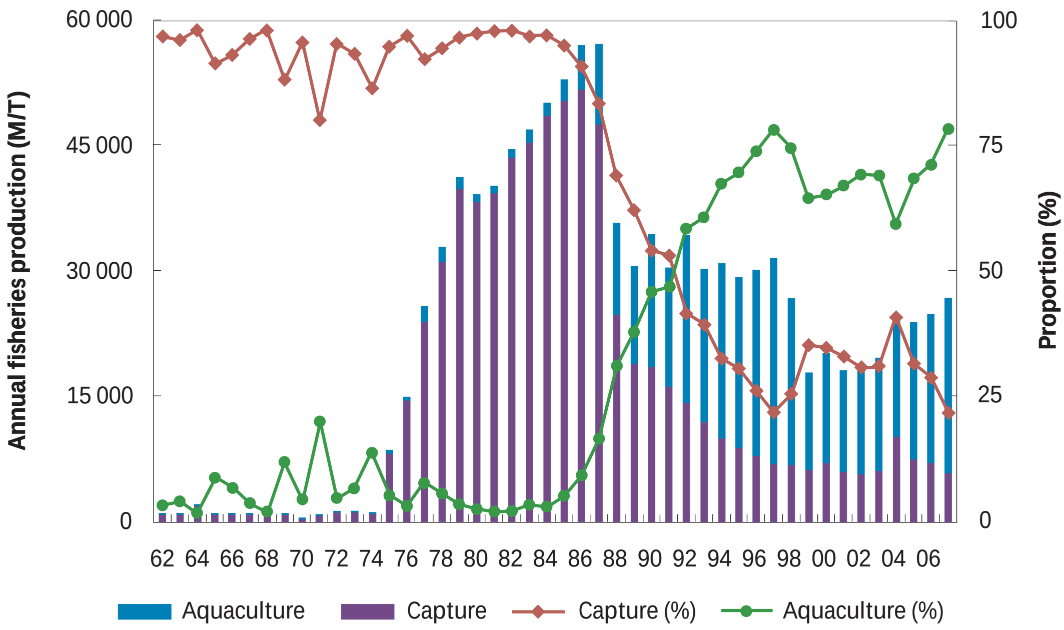

Figure 1. Annual inland capture fisheries and aquaculture production in Korea

Meanwhile, due to the development of a variety of aquaculture technologies and value-added aquaculture species, such as Japanese eel (*Anguilla japonica*), cherry salmon (*Oncorhynchus masou*), Israel carp (*Cyprinus carpio*) and far eastern catfish (*Silurus asotus*), the annual production of inland aquaculture increased rapidly throughout the 1980's. This bypassed that of inland capture fisheries in 1992 (Figure 1). Since then, about 70 percent of the inland fisheries production in Korea is from the aquaculture production. Over the past three decades, the inland aquaculture production increased by about 3 times; its annual production was 4 500 tonnes in 1980's, 19 000 tonnes in 1990s and 15 000 tonnes in 2000. Decrease in the annual aquaculture production in 2000 is related to the decreases of cage culture production. Taking into consideration the fact that cage culture has been blamed for freshwater quality deterioration, new cage culture licenses have not been permitted and the previous licences have not been renewed since 1998 when a policy on clear water supply was launched. On the other hand, aquaculture farming using land-based fish tank systems with water circulation designs has been developed and the production of land-based farming recently increased. Subsequently, the annual production of inland aquaculture begins to increase slightly each year from 2005.

2.1.2 National policies related to inland fisheries

The inland fisheries production in Korea was at negligible levels until the early 1970's, contributing only 0.1 percent of the national total annual fisheries production. Inland fisheries were firstly classified as one of major fisheries types in the fisheries statistical yearbook of Korea in 1968, three years after the establishment of the National Fisheries Agency. In the 1960's when fisheries were not commercialized as a whole, the highest priority for inland fisheries policy was to increase food fish supply as source of animal protein through full utilization of natural fisheries resources and the development of good quality fish seed.

In the early 1970's, issues on efficient use and development of inland waters for fish production and needs to promote inland fisheries as income sources for local people near inland water resources had already come to the fore, due to the nationwide construction of dams, artificial lakes and reservoirs. A national programme on release of hatchery reared seed was initiated in 1973 to increase stock size of commercially valuable fish species and thereby fishable stocks. An Inland Water Fisheries Development Promotion Act was established in 1975, when a wide variety of national policies have been implemented to promote the development and utilization of inland fisheries resources such as the improvement of existing technologies and the development of new technologies, and the development of new aquaculture species, including the introduction of commercially useful alien fish species. The national effort to promote inland fisheries was focused on the development of aquaculture production technology for common carp, eels, sweet fish, sea run dace and far eastern catfish. On the other hand, grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), white Crucian carp (*Carassius cuvieri*), Israel carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), blue gill (*Lepomis macrochirus*), tilapia (*Oreochromis* spp.), channel catfish (*Ictalurus punctatus*) and apple snail (*Pomacea canaliculata*) were introduced from abroad for the purpose of aquaculture as sources of food supply, employment and household income.

As time went by, it turned out that some introduced species for aquaculture and enhancement did not meet domestic consumer preferences (tastes) and failed to adapt to native ecosystems. Furthermore, some introduced species have been gradually known to have adverse effects on native ecosystems. In 1998, blue gill and largemouth bass were listed as invasive alien species that threaten native ecosystems. Therefore, native species such as Korean bullhead, mandarin fish and mitten crab became target species for the development of aquaculture production.

In the late1980's, Korean inland capture fisheries, depending on natural stock size, have been seen to decline sharply, mainly due to water pollution, overfishing, habitat destruction and mismanagement of fisheries resources. These were all the results of human activities during the period of rapid national industrialization and population concentration in larger urban areas. In 1998, the Korean government adopted a policy on clear water supply and implemented a wide range of freshwater conservation programmes. Restrictions on the development of inland fisheries were imposed and uses of inland waters, including for fisheries activities, became controlled by the central and local governments. In particular, a new cage culture license was not been permitted and the previous licences were not renewed because cage culture was been blamed for freshwater quality deterioration.

According to a Cadastral Statistical Annual Report, published by the National Geographic Information Institute of Korea in 2007, the total area of inland waters is approximately 5 700 km^2, and accounted for 5.8 percent of the total land area. Inland waters include rivers, streams, dams, lakes, reservoirs and waterways. Korea has launched a new national project, called "Four Major Rivers Restoration Project" in 2009, to cope with the increase in the frequency of heavy rainfall and drought in recent years, to secure freshwater supplies for present and future generations, and to improve overall quality. Considering that the area drained by the four major rivers in Korea which is about 55 000 km^2, the project will eventually contribute to a balanced development of the national territory and establishment of a baseline for green growth. However, some habitat destruction cannot be avoided. Since the management of inland fisheries toward sustainable development and use of inland waters is a segment of the rivers restoration project, the Korean government is currently preparing a Comprehensive National Plan for Inland Fisheries to promote the sustainable development of inland fisheries and aquaculture. The plan also includes the enhancement and conservation of inland fisheries resources.

2.1.3 Inland water fisheries species

Of the recorded 269 fish and mollusc species in inland waters of Korea, 61 are endemic. As of 2007, the fisheries statistical yearbook of Korea deals with 34 species, including two introduced species (channel catfish and blue gill), that can be referred to as commercially valuable fish species (Table 1).

Table 1. The number of species included in the fisheries statistical yearbook* of Korea where common names (in bold) indicate target species for stock enhancement in terms of hatchery release

Fishes	snakehead, sea perch, **Korean bullhead, far eastern catfish**, channel catfish, Chinese muddy loach, tilapia, **Japanese eel**, blue gill, **Crusian carp**, pond smelt, trout, cherry salmon, gray mullet, **mandarin fish**, salmon, estuary tailfin anchovy, **sweet fish**, fancy carp, **common carp**, Israel carp, pale chub, sea run dace, river puffer and goldfish
Crustaceans	**mitten crab** and shrimp
Mollusks	river snail, sunray surf clam, march clam and **melanian snail**
Algae	water shield
Other aquatic vertebrates	**soft-shelled turtle**

** The full title is "Food, Agriculture, Forestry and Fisheries Statistical Yearbook"*

2.2 Inland fisheries resource enhancement and conservation

A national programme on the release of hatchery produced seed was initiated in 1973 to maintain fisheries productivity of water bodies at the highest possible level. The source of stock for enhancement is obtained mainly from hatchery operations, which was possible through accumulated technology for artificial breeding and seed production originally developed for aquaculture. A scientific survey, prior to the implementation of the programme, was carried out along large dams and lakes to select the most appropriate species to be released in concerned areas. In the initial stage, hatchery-reared fish of commercially important species were released to increase stock size and thereby fishable stocks. This stock enhancement practice continues up to now using a different approach (since the late 1980's when a sharp decline in the inland capture fisheries production was seen), to compensate for recruitment overfishing and to mitigate the disturbances to the environment from human activities.

As of 2007, the number of target species for stock enhancement was eleven, namely common carp, Crucian carp, Korean bullhead, far eastern catfish, mandarin fish, Japanese eel, sweet fish, aucha perch, mitten crab, melanian snail and soft-shelled turtle (Table 1). The number of target species for stock enhancement will be gradually increased. Furthermore, a national project on artificial spawning facilities is being implemented since 2007 to aid depleted populations through artificial production by creating artificial spawning and rearing environments as hatcheries.

In addition to stock enhancement, protective measures to conserve viable and representative populations of species and ecosystems are being implemented such as designation of inland water protected areas, closed seasons for fishing, minimum size limits on fish and shell fish and restrictions on fishing gear. From the view point of biodiversity, the management of invasive alien species, including prevention of spreading, eradiation and control, has been strengthened to prevent further losses of biodiversity. In particular, blue gill and largemouth bass are listed in 1998 as invasive alien species that threatened native ecosystems. In more recent years, ecological conservation and preservation of native species are being increasingly addressed and a new national project on seed production and supply of native species was initiated in 2009.

3. DESCRIPTION AND ANALYSIS OF CURRENT PRACTICES OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION

3.1 Major enhancement and conservation practices

3.1.1 Release of hatchery reared fish

A national release programme of hatchery-reared fish has been implemented since 1973 to increase stock size and thereby fishable stocks. As of 2007, the number of target species were eleven, common carp, Crucian carp, Korean bullhead, far eastern catfish, mandarin fish, Japanese eel, sweet fish, aucha perch, mitten crab, melanian snail and soft-shelled turtle (Table 1). Target species for this practice have changed over time but its overall purposes remain the same that is to benefit wild stocks. The average number of hatchery-reared fish released in the recent five years is approximately 12 million, valued at about US$1.3 million (Table 2). The number of target species for stock enhancement, focused on native species, will be gradually increased.

Table 2. Number of hatchery reared fish released and budget spent

	2004	2005	2006	2007	2008
Number of hatchery reared fish released	6 724 000	8 744 000	12 541 000	10 973 000	19 449 000
Budget spent (US$)	604 000	787 000	1 219 000	1 459 500	2 171 000

In addition to the eleven target species for stock enhancement, approximately 12.5 million hatchery reared salmon have been released annually in recent years (Table 3). Despite increased release of hatchery reared salmon since 1973, the recapture rate of stocked fish is low.

Table 3. Number of hatchery reared salmon released and return rate

	1973	2001	2003	2005	2007
Number of hatchery reared fish released	481 000	5 620 000	14 735 000	11 250 000	13 790 000
Number of fish captured	182	43 802	36 259	22 833	91 551
Return rate (%)	0.06	0.23	0.19	0.22	0.71

3.1.2 Artificial spawning facilities

A national project on artificial spawning facilities has been initiated since 2007 to aid depleted inland fish populations through creating artificial spawning and rearing facilities. It has been reported that fish eggs spawned during the breeding season die from drying out because of lower water levels in dams, lakes and reservoirs during the dry season and increase in water use for agriculture during the farming season. Derelict fishing gear is also known to disturb movement and migration of inland fish and destroy fish habitats. Regarding loss of spawning habitat, artificial propagation can be considered as a tool to assist depleted populations, which benefit wild and natural stocks. Thirteen artificial spawning facilities were installed in 2007 and 15 in 2008. Annual budget for this project is approximately US$45 000. Its impact assessment is being undertaken in 2009 and the preliminary result will be available soon.

3.1.3 Seed production and supply of native species

A national project on seed production and supply initiated in 2009 aims to conserve and preserve native species that are special, endangered or threatened. The success of artificial breeding and seed production technology of target species may help in the recovery of depleted populations through stock enhancement. Furthermore, it may add value to native fish species through commercialization as food and aquarium fish and possibly for the purpose of recreational fishing.

3.1.4 Management of invasive alien species

Regarding loss of biodiversity in inland water ecosystems caused by invasive alien species, various scientific researches were carried out between 2007 and 2009. So far, adverse or deleterious effects of largemouth bass and blue gill, and are known as the most notorious alien species in Korea, on endemic ecosystem were assessed. These two species are also listed as invasive alien that threaten ecosystems. On the basis of scientific findings, national management guidelines for invasive alien species will be developed, including their prevention, eradiation and control measures.

3.1.5 Inland water protected area

Since 1978, 19 inland water protected areas have been designated in Korea to conserve viable and representative populations of species and ecosystems (Figure 2 and Table 4). The main purposes of the protected area management are wilderness protection, preservation of species, maintenance of environmental services and sustainable use of inland water resources from natural ecosystems. Fishing activities are strictly prohibited in protected areas. The protected areas occupy about six percent of the total national area of inland waters.

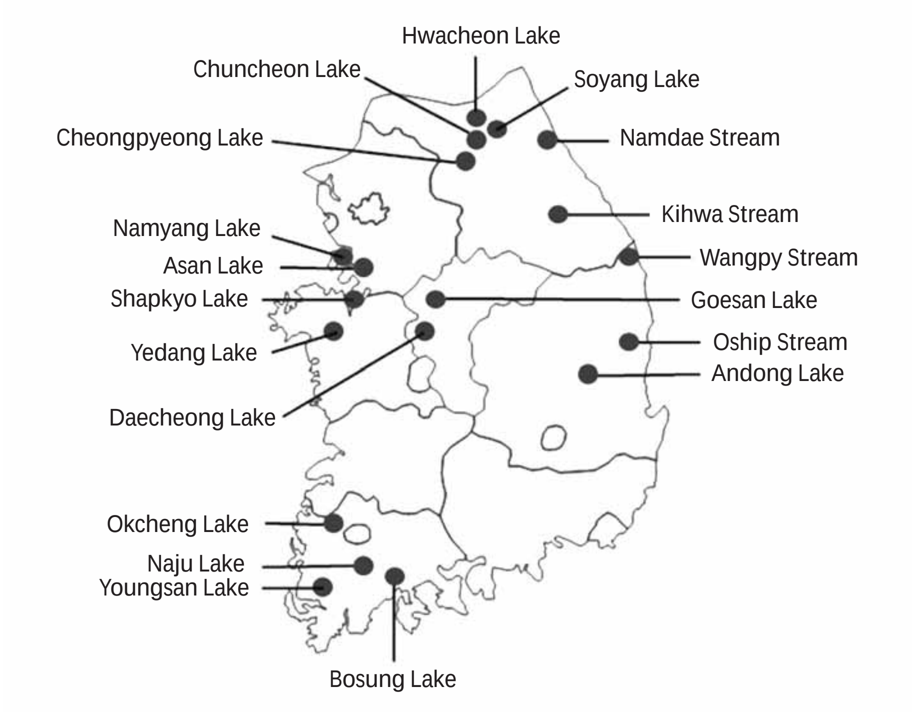

Figure 2. Inland water protected areas (19) in Korea

Table 4. Inland water protected areas in Korea

Inland water protected area	Area (km^2)	Year designated
Lakes		
Cheongpyeong Lake	8.165	1995
Asan Lake	28.794	"
Namyang Lake	10.578	"
Hwacheon Lake	29.16	1997
Soyang Lake	54.316	"
Chuncheon Lake	16.001	"
Daecheng Lake	15.479	1986
Goesan Lake	1.473	"
Yedang Lake	9.594	"
Shapkyo Lake	21.740	"
Okcheng Lake	15.420	1990
Naju Lake	5.591	1986
Bosung Lake	1.225	"
Youngsan Lake	40.193	"
Andong Lake	39.470	"
Streams		
Kihwa Stream (Dong River)	0.660	1984
Namdae Stream	1.120	1997
Oship Stream	19.613	1978
Wangpy Stream	11.438	1986

3.1.6 Closed seasons

According to the Fisheries Resources Conservation Regulation of Korea, closed seasons for fishing applies to six freshwater fish, crab and snail to protect special, endangered or recovering species (Table 5). The overall purpose of the regulation is to provide the highest level of fisheries productivity while protecting the inland water environment's ability to replace those fish. Closed seasons for certain species are also set by their spawning season.

Table 5. Closed season for species targeted

Target species	Closed season
Salmon, *Oncorhynchus keta*	1 October to 30 November
Mandarin fish, *Siniperca schezeri*	20 May to 30 June
Lenok, *Brachymystax lenok tsinlingensis*	1 March to 30 April
Sweet fish, *Plecoglossus altivelis*	1 to 31 May, 1 September to 31 October
Crab, *Eriocheir sinensis* and *E. japonicus*	1 August to 30 November
Melanian snail, *Semisulcospira* spp.	1 December to 28 February of following year

3.1.7 Minimum size limits on fish and shell fish

According to the Fisheries Resources Conservation Regulation of Korea, minimum size limits apply to certain freshwater fish, crab and snail species to protect special, endangered or recovering species (Table 6). This mean that fish below a certain size must be released and eventually contributes to effectively prevent catching of juvenile fish and reduce the number of discards and discard mortality to rebuild the stock sooner.

Table 6. Size limits for freshwater fish, crab and snail species

Target species	Minimum size limit
Trout, *Oncorhynchus masou masou*	20 cm
Cherry salmon, *Oncorhynchus masou masou*	12 cm
River puffer, *Takifugu obscures*	20 cm
Mitten crab, *Eriocheir sinensis* and *E. japonicus*	5 cm
Marsh clam, *Corbicula coreana*	1.5 cm
Melanian snail, *Semisulcospira coreana, S. gottschei, S. libertine, S. forticosta* and *S. tegulata*	1.5 cm

3.1.8 Restrictions on fishing gear

The Inland Fisheries Law prohibits the use of engine powered boats, scuba equipment for fishing, cast netting, and spear fishing in both commercial and sport fishing. In addition, the mayor, governor and chief of a borough can impose additional restrictions, if necessary and appropriate, to protect and conserve inland fisheries resources and their surrounding environment under their directorate.

3.2 Operational aspects

3.2.1 Institutional arrangement

Inland water fisheries resource enhancement and conservation are a part of the management of national inland waters which covers the full range of all aspects of the national water sector, including institutional aspects. Humans need freshwater not only for drinking and sanitary purposes but also for fisheries, agriculture, industry, transportation and many other sectors of the economy. Therefore, several ministries or different levels of government, with different purposes and targets, are involved in the management of inland water resources in Korea (Table 7). The Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF) is, in general, responsible for the development, management and use of inland fisheries resources.

Table 7. Ministries related to national inland fisheries resources

Categories	Target settled	Ministries	Related Laws and Regulations	Remarks
Biological resources	Wildlife	MOE[1]	Wildlife Conservation Law	Endangered species
	Fisheries resources	MIFAFF[2]	Inland Fisheries Law	Fisheries activities
Space resources	Leisure and recreation fishing	MIFAFF	Inland Fisheries Law	Restrictions on fishing activities and gear of leisure and recreation
		MLTM[3]	Aqua-leisure Safety Act	
	Use of rivers and streams	MLTM	Law of Rivers and Streams	Use permits for rivers and streams
	Use of water reservoirs	MIFAFF	Law of maintenance for Farming and Fishing Village	Occupation permits of reservoirs
Water resources	Water quality	MOE	Water Quality Law of Lakes and Marshes	Management of water quality
			Water and Environment Conservation Law	
	Dams and aggregates (sand)	MLTM	Regulation on Support near Dam Construction Site	Construction and management of dams
			Aggregate Extraction Law	Management of aggregate resource

[1] Ministry of Environment
[2] Ministry for Food, Agriculture, Forestry and Fisheries
[3] Ministry of Land, Transport and Maritime Affairs

Regarding the management of inland fisheries resources, the top three priorities set by MIFAFF are to promote stock enhancement through protection of natural spawning, nursery and feeding grounds and provision of artificial spawning grounds (facilities); to secure the health of inland water ecosystems through efficient management of invasive alien species; and to protect fisheries resources through the introduction of fishing license quotas. For inland fisheries resource enhancement and conservation, MIFAFF has continuously implemented the national programme on hatchery release since 1973.

3.2.2 Executing agencies

There are twelve national, provincial and municipal inland fisheries institutes in Korea participating in the implementation of the national programme on hatchery release (Figure 3). Three national institutes, namely the Inland Fisheries Research Institute, Inland Aquaculture Research Center and Cold-water Fish Research Center, belong to the National Fisheries Research and Development Institute under MIFAFF. Of seven metropolitan cities and nine provinces, eight have their own inland fisheries institute. In addition, there is one municipal institute.

A major difference between institutes is that the national institutes carry out research on developing and supporting national inland water-related policies, focused on fisheries resources, while activities of provincial and municipal institutes are project-based. National institutes work for the central government (ministry) while the provincial and municipal institutes are governed by the respective local government. For example, provincial and municipal institutes participate in the national programme on hatchery release, as implementing agencies, using technology for breeding, seed production and aquaculture already developed by national institutes. The national institutes are responsible for monitoring and improving the overall implementation of the programme, developing new species for the purpose of hatchery release, including the development of technology required, and selecting new release sites.

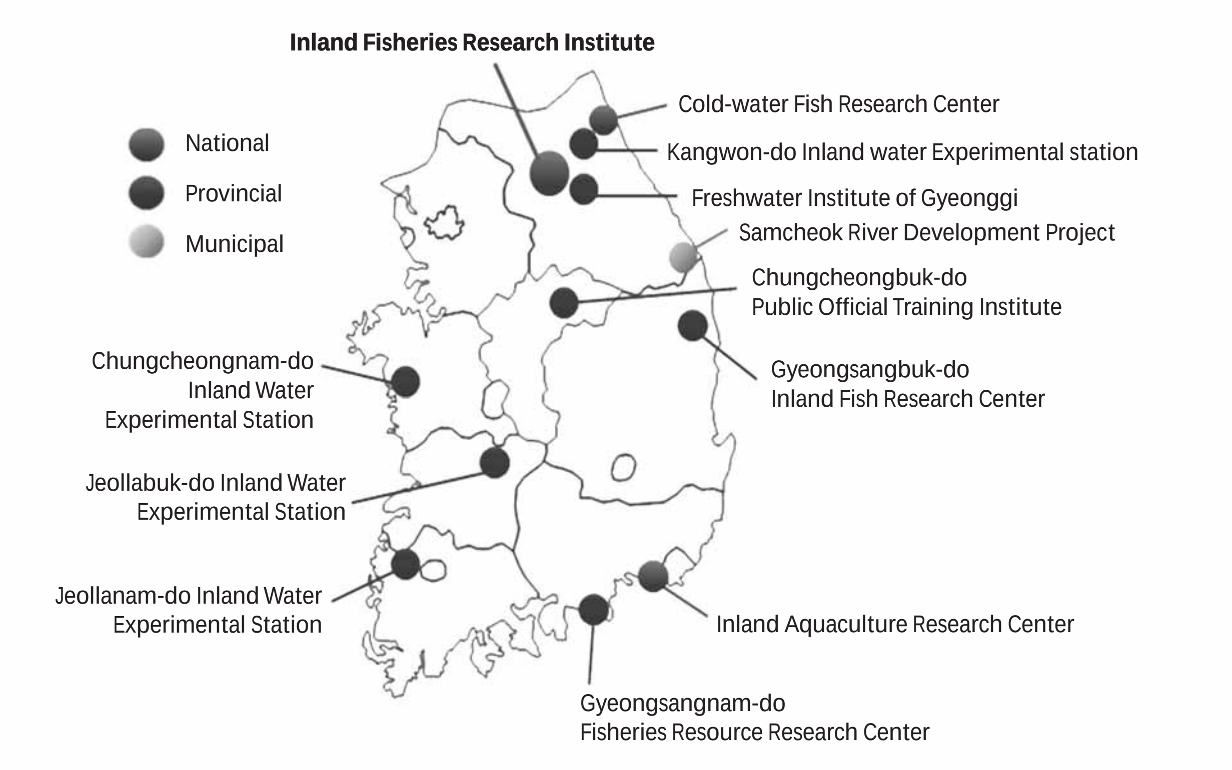

Figure 3. National, provincial and municipal institutes related to inland fisheries

3.2.3 Policy making, planning and organization

The Inland Fisheries Research Institute and its two centres carrying out comprehensive research on the management and conservation of inland fisheries resources and environments, is the central agency at the beginning stage of the policy making procedures. Its findings provide the baseline information and scientific know-how for the development and management of inland fisheries as well as propose new directions for national policy. Scientists from academia also participate in research activities. Prior to developing a new policy proposal, the Inland Fisheries Research Institute organizes an expert meeting represented by twelve national, provincial and municipal inland fisheries institutes and, if necessary, information gathering discussions with fishers and other stakeholders. MIFAFF, as a policy maker, takes into consideration the draft proposals raised by the institute and takes appropriate actions. MIFAFF often provides the institute with overall guidelines, including national priorities for inland waters for fisheries. It also plays a role in conflict settlement with other ministries involved in the management of inland waters with different purposes. If necessary, MIFAFF organizes public meetings or hearings to discuss new directions of national policy or to evaluate the ongoing programmes/ project where participation of representatives of related ministries/agencies, experts, scientists from academia, fishers and stakeholders are welcome.

3.2.4 Funding mechanisms

There are three major government funding sources related to inland fisheries in Korea, namely special accounts for agriculture, project funds for community development, and a fisheries development fund. As of 2008, the inland fisheries annual budget was approximately US$10 million, with the recent five-year average of US$7.4 million (Table 8). Approximately sixteen percent of the annual budget for inland fisheries was allocated to the hatchery release programme. Currently, eleven of the seven metropolitan cities and nine provinces are participating in the programme. At the local government level, 70 percent of the budget for stock enhancement is supported from MIFAFF and the remaining 30 percent is self-funded. In addition, about two percent and four percent of the annual budget for inland fisheries is allocated to artificial spawning facilities and seed production and supply of native fish species, respectively.

Table 8. Inland fisheries annual budget

	2004	2005	2006	2007	2008
Annual budget (US$)	6 000 000	4 000 000	8 000 000	10 000 000	10 000 000
Budget for stock enhancement	604 000 (10%)	787 000 (20%)	1 219 000 (15%)	1 459 500 (15%)	2 171 000 (22%)

3.2.5 Seeds for releasing programme and source of brood stock

The seed for stock enhancement is mostly obtained from hatchery operations. Of the eleven target species for hatchery release at present, the juvenile Japanese eels are captured from the wild. Wild and hatchery-reared juveniles are produced by eight provincial and one municipal institute and the private sector. The programme budget for hatchery release includes the operation costs of the eight provincial and the municipal institute to produce hatchery reared juveniles and costs of purchase of juveniles produced by the private sector (Table 8). Of 16 metropolitan and provinces in Korea, 11 are participating in the hatchery release programme with the financial support from the MIFAFF. In 2008, 19 449 wild and hatchery reared juveniles were released and the extent of contribution of the participating local governments is shown in Figure 4.

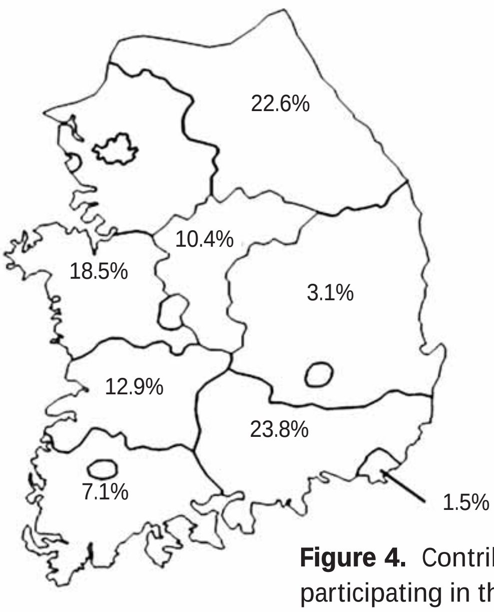

Figure 4. Contribution of metropolitan city and provinces participating in the hatchery release programme

3.3 Impact assessment

3.3.1 Impact assessment

From 2007, an impact assessment on the hatchery release programme, first initiated in 1973, has become common practice for inland fisheries enhancement and conservation in Korea. The number of species for the hatchery release programme is 44 as of 2008; 33 for marine species and eleven for inland species. Among these, the number of target species for the first three year's impact assessment was four and will be extended to six from 2010 with one inland species, Melanian snail, included. The annual budget for the assessment is 5 percent of that for the hatchery release programme. The assessment for sea fisheries is being carried out by the National Fisheries Research and Development Institute (NFRDI) and that for inland fisheries by the Inland Fisheries Research Institute which is also a branch of NFRDI.

For the impact assessment on the release of hatchery-reared juveniles of Melanian snail, *Semisulcospira coreana* and *S. gottschei,* field surveys were conducted once a month from March to November in the release sites selected through the feasibility studies. Before releasing, about 10 percent of hatchery reared juvenile snails were colour marked to observe survival rates and movements. Monitoring surveys were carried out twice a year in the Nakdong River, Kum River, Hongcheon River and Anyang Stream. Growth rates of released hatchery reared juvenile snails, rates of mixed catch, extent of reproduction, species composition and distribution density in the release sites were examined. Species distribution in major water bodies along the rivers and streams was also examined to improve the currently ongoing enhancement practice and to select the most appropriate species and sites for future releases. The result of the first three year's assessment will be available in early 2010. However, it appears difficult to assess impacts of the programme because it is implemented in larger water bodies that are often open-access waters used for fishing and public recreational purposes. In addition, a national project on artificial spawning facilities has been initiated since 2007 to aid recovery of depleted inland fisheries populations. Its assessment was first made in 2009 and no results are available at this moment.

3.3.2 Socio-economic benefits

Stock enhancement and conservation practices have become an increasingly common intervention in inland fisheries development over the past three decades. The primary purpose of such practices was to increase stock size of fish as a source of food fish supply, employment and household income until the 1980's and is now mainly to enhance fish stock for conservation. It is also true that natural fish stock still needs not only to compensate for recruitment overfishing but to mitigate a disturbance to the environment caused by human activities.

The national production statistics of inland capture fisheries show that the annual capture production, depending on the natural stock sizes, has not yet recovered to the previous levels such as the early 1970's when fishing pressure was not high (Figure 1). It is, however, noticeable that the annual capture production is stable and with a slight increase in recent years. This positive sign of capture fisheries production may be due to many reasons.

Although the impact assessment of stock enhancement and conservation has not yet been adequately assessed in Korea, it is understood that such assessment faces a number of practical difficulties. One reason for this was pointed out in the previous section. Besides, the overall freshwater quality has improved since the introduction of clean water supply policy in 1998 and thereafter through the implementation of a variety of water conservation and protection programmes and projects. The overfishing problem has been mostly resolved through strengthening the implementation of regulations to impose restrictions on uses of inland waters, including fisheries activities, over the last two decades. Appropriate actions have been taken to conserve major aquatic habitats, including restoration of destroyed habitats and installation of fish ladders. The overall inland fisheries management are also improved at the local and central government level. Therefore, any positive sign of wild stock recovery is not from the consequence of a single factor mentioned above but as a result of integrated efforts across the country.

When hatchery reared juveniles are released, the local governments and the other organization bodies in both public and private sectors hold, in general, a kind of event where the general public, including school children and youth, and NGOs are often invited. The event provides a good opportunity for raising public awareness of biodiversity and environmental sustainability as a whole. This is one of the great benefits obtained from the stock enhancement and conservation practices being implemented over the past three decades.

Experiences and technologies, on the other hand, accumulated through the implementation of stock enhancement and conservation practices provide know-how that can only be obtained from field work as part of the overall move forwards sustainable inland fisheries. For instance, the development of new species for the stock enhancement purposes most suited to maintain and conserve native ecosystems, including their breeding and seed production technology, is important for improving the ongoing practices and planning future activities on short, medium and long term time frames. Recently, native species that are special and threatened or endangered are the main target species for enhancement and conservation. When artificial breeding and seed production are successfully developed for such species, when it will be possible to commercialize such species as food and aquarium fish and possibly for the purpose of recreational fishing. It will also aid recovery of depleted populations as well as bring benefits to fishermen and local people.

Nowadays, more and more people enjoy water-related recreation, including recreational fishing. Regardless of the success or failure of the stock enhancement and conservation programmes, it is clear that clean inland water environments with plenty of aquatic organisms, as part of native ecosystems such as occurred in earlier times are increasingly important to attract the public, which will definitely benefit the economy of local community through tourism operations for a majority of the general public, clean water environments offer more spaces for outdoor recreation and leisure activities for pleasure and to refresh themselves, which also benefit public health and national capacities for development.

4. CONSTRAINTS AND PROBLEMS

4.1 Technical constraints

The ultimate goal of stock enhancement is to increase stock size or recruitment of fishable biomass. In Korea, stock enhancement practices up to now have been focused on the development of artificial propagation technology, including breeding, seed production and hatchery management, and the selection of the most appropriate species and sites for release. However, the carrying capacity is often not adequately considered. Carrying capacity can be defined as the maximum sustainable biomass of stocked and wild animals using the available habitat or the population size of the species that the environment can sustain indefinitely. From now on, it is necessary to estimate the maximum sustainable biomass of hatchery reared species and decide the amount of hatchery released juveniles.

The beginning of stock enhancement dates back to as early as 1973 when the country's per capita income was US$4 400. It increased to US$20 000 in the recent years. Since inland fisheries were a source of food fish, especially animal protein, until the 1970's, many species were introduced for purpose of aquaculture development and or stock enhancement. Among introduced species, blue gill and largemouth bass were successful in establishing populations and have begun to threaten native species as direct predators or competitors. They were listed as invasive alien species that threatened the ecosystems in 1998. As mentioned earlier, management of the invasive alien species has become one of the top priorities for Korean inland fisheries policy, one of the technical difficulties in successful implementation of stock enhancement and conservation practices is to control, or eradiate, invasive alien species.

4.2 Operational constraints

The hatchery release programme has become a common intervention in inland fisheries stock enhancement in Korea, even though its impact assessment has not yet been adequately assessed. Garaway (2006) mentioned that the results of the release of hatchery-reared juveniles are often different from initial expectations while it has the potential to yield sustainable benefits. One reason for this is the complexity of the environment into which enhancements are introduced, involving dynamic interactions between the biological characteristics of the resources, the technical intervention of enhancement, and most importantly, the people who use and manage these resources. In the case of Korea, the first three problems have been improved and can be mostly resolved through scientific studies to select the most appropriate species and sites for the hatchery release. With respect to management, however, it is difficult to protect hatchery-reared juveniles after release, from being caught intentionally or unintentionally. Stock enhancement practices are mainly implemented from March through June, overlapping with the beginning of water-related recreation and leisure activities season and continue through the following summer holiday season. Furthermore, hatchery-reared juveniles are released in large water bodies that are open, except inland water protected areas and some other limited areas designated for public purposes, for fishing and public recreational use.

In addition, to the eleven inland target species of the hatchery release programme, four species are currently under closed season for fishing which is regulated by their spawning season (Tables 1, 5). Closed season of a species itself does not protect hatchery reared juveniles after release, from being caught. Other tools include, size limits for fishing, regardless of season of the year, which are applied to two of the 11 target species for the programme (Tables 1, 6). Regarding the peak season for the hatchery release, from March to June, it is highly possible that right after releasing hatchery reared juveniles without size limits for fishing can be caught intentionally or unintentionally.

4.3 Genetic diversity

In the initial stage of stock enhancement in Korea, the primary purpose was to replenish wild stocks of freshwater species or depleted species and thereby increase recruitment to fishable stocks. Ecological balance to maintain and conserve native ecosystems was later considered, in terms of ecosystem-based approaches. Disease tests are now also conducted (from 2008) prior to stock release to prevent transfer of possible diseases from hatchery reared juveniles to the wild. However, the current practices are unlikely to take into consideration the existing gene pool of the species. Regarding the potential negative impacts of stock enhancement on the gene pool of wild populations, the genetically sound breeding and seed production technology are required.

5. RECOMMENDATIONS

5.1 Carrying capacity

The current approaches in selecting the most appropriate species and sites for enhancement do not consider the carrying capacity of the hatchery stock to be released to the environment. It is recommended to decide the amount of hatchery reared animals to be released, based on the estimation of the maximum sustainable biomass in a release site concerned, in order to improve their stocking effects and to minimize any possible adverse ecological impacts of stock enhancement.

5.2 Closed season for fishing

Of 11 inland target species of the hatchery release programme in Korea, closed season for fishing applies to four species (Tables 1 and 5). Since closed season for certain species is based on the spawning season, it does not protect hatchery-reared juvenile from being caught intentionally or unintentionally. It is recommended to install suitable notices for public attention at release sites providing information on the time of release of hatchery-reared animals and the purpose of the exercise. On the side of the programme implementation, it is recommended, prior to the hatchery release, to consider characteristics of the release sites such as major types of recreation and leisure activities taken place in order to avoid the peak season of outdoor activities.

5.3 Genetic diversity

The current stock enhancement practices are unlikely to consider the existing gene pool of the species. Regarding the potential negative impacts of stock enhancement on the gene pool of wild populations and biodiversity, it is recommended to develop national guidelines for the use of the genetically sound breeding and seed production for the hatchery release programme.

5.4 Climate change

Aquatic organisms are vulnerable to environmental change at scales ranging from local (e.g., extinctions of endemic species) to global climate changes. Furthermore, it is well understood that climate change accelerates loss of biodiversity in inland waters and affects fisheries production. It is suggested to consider adaptation and mitigation of the potential climate change-related impacts on inland fisheries and aquaculture when planning the stock enhancement in the mid and long-term time frames.

5.5 National database

The hatchery release programme is the most common practice for stock enhancement and conservation in Korea that engages the general public. This programme would be further promoted by active participation of the general public, in particular NGOs and community leaders and a variety of social clubs for water-related recreation and leisure activities. In this regard, it is suggested to establish a national database on the programme, including public and educational outreach, enabling the sharing of information on the overall goals, objectives and major outcomes of the programme as well as to exchange experiences with the general public in issues relating to the programme.

5.6 Good, best and worst practices

Consideration to evaluate the performance of the participating local governments and other organizations in both the public and private sector is suggested including the provision of financial incentives to discriminate between good, best and worst performance, in particular regarding the fact that the programme budget for the local governments is supported by the MIFAFF.

5.7 Public awareness

The hatchery release programme is the most common practice for stock enhancement and conservation in Korea that engages the general public. It is suggested that a certain amount of the annual budget for stock enhancement and conservation be allocated to public awareness raising. For this purpose, the media can be used as a tool to draw attention to stock enhancement and conservation as it has a unique and important function in the promotion of all aspects of environmental issues.

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INLAND FISHERIES RESOURCES ENHANCEMENT AND CONSERVATION PRACTICES IN MYANMAR

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Abstract

Myanmar has an extensive system of inland water resources, the great bulk of which are still in a pristine condition. Fish, consumed in fresh and many processed forms is an important component of the protein intake of the population; consumption is estimated at 43 kg capita^{-1}yr^{-1} in 2008-2009. Stock enhancement of inland waters in Myanmar has been conducted since 1967, initiated through a seed replenishing program to the natural water, such rivers, lake, dams even rice fields etc. The National Fisheries Development Plan and National Resource Management Policy aim to increase fish production by stocking fish and prawn seeds into dams, reservoirs, and other natural waters bodies and combined with improved public awareness on conservation of fisheries resources towards sustainable fisheries development.

Key words: Inland fisheries; replenishing and conservation.

1. INTRODUCTION

Myanmar is divided into seven major topographical regions: the Northern Hills, the Western Hills, the Shan Plateau, and the Central Belt, the lower Myanmar Delta, the Rakhine Coastal Region and the Tanintharyi Coastal Strip. Overall Myanmar posses a wide range of inland water resources, the major resources being associated with the two river systems, Ayeyarwaddy (2 170 km long), Chindwin (960 km) and Sittaung, and their vast flood plains and deltaic areas. In addition, there are three large natural lakes Lake Inle (in Shan Plateau), Indawgyi (in Kachin State) and Indaw (in Katha) with approximately water area of 15 500 ha, 12 000 ha and 2 850 ha, respectively.

Fish is a very important component of the diet of the people of Myanmar, with an estimated per caput consumption of 43 kg per year in 2008-2009, which is one of the highest in the region. Fish is consumed fresh and in various processed forms, fermented fish being a staple part of the daily diet of most people. All inland waters, except reservoirs, are utilized for inland fish production. However, most remains artisanal. Stock enhancement practices of varying forms were employed since 1967 to increase inland fish production, which currently stands around 899 430 tonnes.

The inland waters of Myanmar also possess a high biological diversity, particularly of finfish. For example the fish fauna of inland natural lakes exhibits a high degree of endemicity, and actions have been launched under the National Fisheries Development Plan and National Resource Management Policy to conserve the biodiversity of inland waters.

This review attempts to address the stock enhancement practices in inland waters of Myanmar and the actions taken to conserve biodiversity in the inland waters.

2. CURRENT STATUS OF INLAND FISHERIES IN MYANMAR

In 2008-2009, the total fish production in Myanmar was around 3 542 290 tonnes of which 899 430 tonnes is from inland fish and accounting for approximately 26 percent of the total (Table 1). Over the years, the contribution of inland fish production to the total, as in the case of aquaculture, has gradually increased (Figure 1) and consequently become an important means of food fish supply to the population. These increases in fish production have been achieved through the introduction of several measures, one of which is stock enhancement and other measures relevant to biodiversity conservation.

Table 1. Trends in fisheries production (in x 1000 tonnes) from 1989-1999 to 2008-2010 in Myanmar. Note that leasable and open fisheries are the main forms of inland fisheries

Year	Total	Culture	Leasable	Open	Marine
1989-1999	1 011.18	91.17	67.87	91.98	760.16
1999-2000	1 195.80	102.60	83.06	113.00	897.14
2000-2001	1 309.83	121.95	91.17	147.04	949.67
2001-2002	1 474.46	190.12	95.95	158.93	1 029.46
2002-2003	1 595.87	252.01	109.53	180.61	1 053.72
2003-2004	1 986.96	400.36	122.28	331.98	1 132.34
2004-2005	2 217.47	485.22	136.79	366.75	1 228.71
2005-2006	2 581.78	574.99	152.69	478.43	1 375.67
2006-2007	2 859.86	616.35	170.10	548.09	1 525.32
2007-2008	3 193.92	687.67	191.05	625.44	1 689.76
2008-2009	3 542.19	775.25	209.72	689.71	1 867.51

The main forms of inland fisheries in Myanmar are open water fisheries and leasable fisheries. Inland fisheries are all regulated by provisions in the Freshwater Fisheries Law (1991).

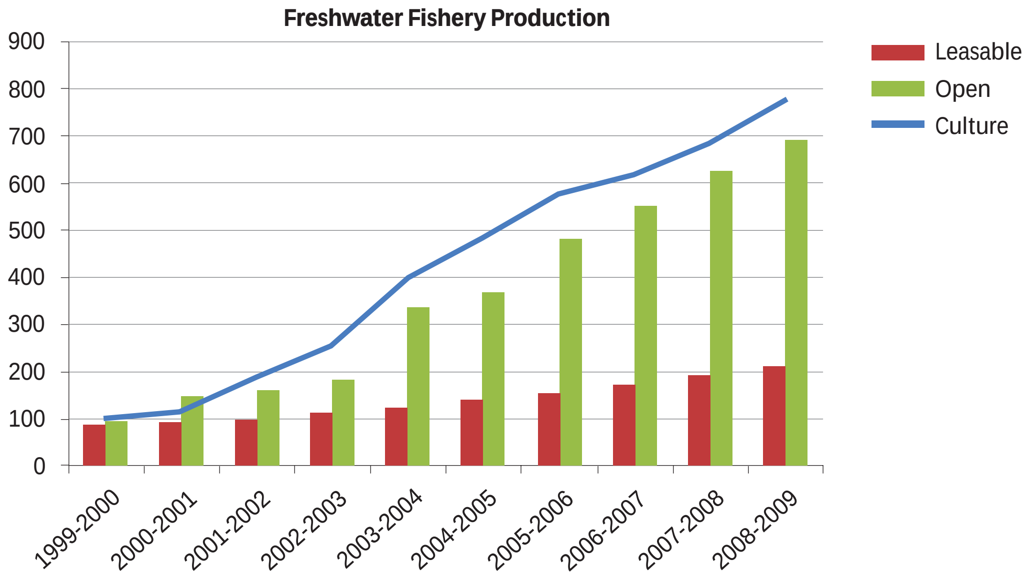

Figure 1. inland fisheries production in 10 years

2.1 Leasable fisheries

There are currently 3 717 leasable fisheries in Myanmar of which 3 453 are still exploitable and the licenses are issued by DOF (Department of Fisheries), Myanmar in 2008-2009. Leasable fisheries are key fishing grounds on floodplains which are cordoned off by barrage fences and fished using various methods. The peak fishing season involves capturing fishes migrating out of the floodplain as the water level recedes. This is referred to locally as the "Inn" fishery in Myanmar language. The leases are auctioned yearly, but DOF has extended the lease period up to nine years to promote improved long-term management (3 years x 3 times leases). The management systems of leasable fisheries are normally handled by the DOF, mainly through the auctions which are conducted in conjunction with townships and regional authorities.

In this leasable fishery, the lessee has the obligation and the right to exploit all the fish resources, using any form of gear. The lessee is obliged to adopt stock enhancement practices, often provided by the DOF. The peak fishing season is August to October, when the flood waters recede. The production from leasable fisheries have increased, albeit gradually, through the years and currently the production is around 200 000 tonnes (Table 1 and Figure 1).

Leasable fisheries could vary in intensity, from the management and production view point, some being treated in a manner similar to large fish ponds or small reservoirs, and taking the form of culture-based fisheries. For example, the leasable fishery of KanDawGyi (300 ha; permanent water body in Mandalay Division) has adopted an exclusive stocking (2-3 million fingerlings of major carps per year) and recapture 500 to 600 thousand full grown fish every year, averaging approximately 4 200 kg ha^{-1} yr^{-1} (FAO-NACA, 2003). In contrast, the leasable fishery of Thaung-Tha-Man (600 ha; in Mandalay township), 60 percent of the yield is of the exotic *Oreochromis niloticus* and the rest being of stocked species such as rohu, mrigal etc., with an overall average yield of 2 800 kg ha^{-1} yr^{-1} (FAO-NACA, 2003).

2.2 Open water fisheries

Open water fisheries in Myanmar refer to all forms of inland fisheries, except the leasable ones and reservoirs. Almost all open water fisheries in inland waters are artisanal, and fishing is often conducted using non-motorized, traditional wooden crafts. The permit or right to fish license is issued by DOF, Myanmar. All fishing gears require a respective implementation license. For most licensees there is a set fee. Some of the larger gear such as "stow net" set in rivers is allocated by tender system. Fees are variable between locations according to the production levels and capacities. License fees for small gears are low. All gear licensees are expected to report the daily catches to DOF. In some of the lakes, such as in Inle Lake, the gears that are used are unique to that body of water; for instance the use of a conical bamboo devise surrounded by a moveable and maneuverable small meshed net is typically used to catch fish by driving it to the bottom and lifting it gradually whilst closing the net.

2.3 Social dimensions of inland fisheries in Myanmar

The great bulk of open water fisheries in Myanmar are artisanal and subjected to a licensing system for use of any form of gear. However, there is an increasing tendency to auction the fishing rights of selected areas of lakes and such open waters, in a manner comparable to that of lease fisheries of flood plain areas. In general, the leasable fisheries, though in existence for over five decades, tend to marginalize the use of the water bodies by the community, as often the more productive areas being leased are held on an almost continuous basis by the richer more powerful segments of the society. This situation will be further exacerbated by the new plans to increase the lease period up to nine years.

On the other hand, a long term lease will induce the lessees to improve the production of the water bodies, adhere to more productive measures of stock enhancement, encourage more people be engaged in day to day management, harvesting, marketing and other activities.

3. BIODIVERSITY OF INLAND WATERS

The biodiversity aspects of inland waters in Myanmar is best documented with respect of its three large natural lakes, Inle, Indawgyi and Indaw, perhaps the best documentation among these being that of Lake Inle. Early studies (Annandale, 1917) reported 23 to 42 species are found in Lake Inle and its inflows and outflows, which included two endemic cyprinid genera, *Inlecypris* and *Sawbwa. More recent data* indicated that there are 36 species (Kullander, 1994), of which 16 are endemic to the Lake (Table 2), as well as seven species have been introduced into it.

The most extensive survey of the fishes to date in Lake Indawgyi is by Prashad and Mukerji (1929) in which 43 finfish species were recorded. They considered that three of these, *Barbus sewelli* (redescribed as *Puntius orphoides*), *Burbas myitkyinae* (redescribed as *Hypsibarbus myitkyinae* and *Indostomus paradoxus* were endemic to the lake. However, all three of these species have also been found in other localities. A total of 67 species were recorded in the Indawgyi Lake basin when inflowing streams and marshy areas were included. The endemic species found in lake (after further surveys and taxonomy changes) was the catfish *Aky prashadi.* However, there are several endemics that Prashad and Mukerjin recorded from pools and streams in the Indawgyi lake basin: *Gudusia variegata* (Clupeidae) which is mainly found in rivers in Myanmar, *Esomus altus* (Cyprinidae) and *Salmostoma sladoni* (Cyprinidae).

Table 2. Fish species list of Lake Inle

Non-endemics	Endemics	Introduced or status uncertain
Notopterus notoptopterus	*Cyprinus carpio intha*	*Colisa labiosa*
Clarias batrachus	*Neolissochilus nigrovittatus*	*Parambassis sp.*
Monopterus cuchia	*Cirrhinus lu*	*Parambassis lala*
Monopterus albus	*Physoschistura brunneana*	*Labeo rohita*
Channa striata	*Physoschistura shanensis*	*Ctenopharyngodon idellus*
Ophicephalus butleri	*Yunnanilus brevis*	*Glossogobius sp.*
Chaudhuria caudata	*Sawbwa resplendens*	*Trichogaster pectoralis*
Lepidocephalichthys berdmorei	*Microrasbora rubescens*	*Clarias garipinus*
Acanthocobitis botia	*Microrasbora erythromicron*	
Physoschistura rivulicola	*Barilius auropurpureus*	
Puntius stoliczcanus	*Danio erythromicron*	
Amphipnous cuchia	*Inlecypris auropurpurea*	
Lepidocephalus berdmorei	*Poropuntius schanicus*	
	Poropuntius sp.	
	Percocypris compressiformis	
	Gerra gravely	
	Silurus burmanensis	
	Channa harcourtbutleri	
	Macrognathus caudiocellatus	
	Mastacembelus oatesii	
	Mastacembelus caudiocellatus	
	Nemachilus brevis	
	Nemachilus brunncanus	
	Discognasthus lamta	
	Cirrhina latia	
	Barbus sarana caudimarginatus	
	Barbus scnanicus	
	Barbus stedmanensis	

4. STOCK ENHANCEMENT PRACITCES OF INLAND WATERS IN MYANMAR

Stock enhancement of inland waters has been conducted since 1967, some of which are obligatory for certain fisheries. For example, in leasable fisheries, the lessees are obliged to stock seed as recommended by the government. However, these are often provided by the government, consisting of both suitable indigenous species to augment the natural recruitment and alien species which are fast growing and capable of utilizing the food resources in the leased area. The latter species primarily consist of Indian and Chinese major carps, and in specific instances even tilapia (FAO-NACA, 2003).

Stock enhancement of rivers is regularly conducted using mainly rohu, *Labeo rohita*, fingerlings of 7 to 10 cm in length. Such enhancement is conducted on an annual basis, and in certain instances, required fingerlings are provided at a subsidized price to private owners of water bodies. The water bodies where the activities are mostly implemented are the main rivers viz: Ayeyarwaddy, Chindwin and their some river locations. In Kachin State, stock enhancement is mainly conducted in reservoirs and lakes.

The fingerling requirements for stock enhancement purposes are produced in 27 government-owned hatcheries spreading across the country in different water sheds (Table 3). The fish releasing program is also linked to

Table 3. Finfish hatcheries in states and divisions in Myanmar and the production of seed stock used for stock enhancement in 2008-2009

Location of hatcheries	Numbers	Production (millions)
Yangon division	3	178.99
Bago division	3	80.62
Mandalay division	5	303.10
Ayeyarwaddy division	5	120.81
Magway division	2	4.85
Kachin division	2	7.72
Sagaing division	3	31.41
Mon state	1	9.30
Shan state	2	3.59
Kayin state	1	0.31

a program of replenishment of brood stock of the major cultured species, in particular rohu and mrigal, *Cirrhinus cirrhosus*. In addition, other species are also used for stock enhancement purposes of open waters in Myanmar, these being *Cyprinus carpio, Catla catla, Ctenopharyngodon idella, Hypophthalmicthys molitrix, Tilapia* spp., *Puntius* spp., *Pangasius hypothalamus* etc. Overall, large numbers of seed have been stocked over the years to enhance fisheries of open inland waters in Myanmar (Table 4).

In areas where seed is released, such as along the Ayeyarwaddy River and associated floodplains, there is an agreement that fishers should in turn provide to the hatcheries certain number of potential broodstock candidates of major stocked species such as rohu, mrigal, etc., to partially replace poorly performing broodstocks with frequency of replacement ranging from every one to five years depending on the hatcheries (Aung *et al.,* 2010). Often, broodstocks of seven or more years old become less productive and are discarded, and the younger broodstocks are recruited periodically based on this practice. The practices described above, however, have been undertaken without detailed understanding of the genetic structure of the species and the impacts of the practices on wild and cultured stocks remain unknown. This process, a practical experience and welcome strategy, though open to science-based improvement, has avoided inbreeding of stocks and maintenance of genetic diversity to a very large degree (Aung *et al.,* 2010).

Table 4. The number of seed stocked (in millions) in different inland waters of Myanmar over the years. AR-Ayeyarwaddy River

Years	Numbers stocked						
	AR	Dams		Natural rivers and streams	Ponds	Rice-Fish culture	Total
		No. of Dams	No. Stocked				
1999-2000	2.05	47	25.99	27.8	1.07	–	54.92
2000-2001	126.22	53	34.72	27.48	23.59	–	85.79
2001-2002	134.70	77	34.67	41.59	16.55	–	92.82
2002-2003	159.25	81	38.80	39.05	56.48	–	134.33
2003-2004	178.01	105	109.99	62.27	43.08	3.28	218.63
2004-2005	186.73	164	108.70	63.27	59.76	4.84	236.57
2005-2006	199.06	218	117.79	56.18	25.49	6.17	205.63
2006-2007	214.92	228	85.93	44.38	6.04	6.55	142.90
2007-2008	181.45	219	90.62	80.40	3.18	7.08	181.27
2008-2009	197.10	228	103.17	91.72	3.41	7.10	205.40
2009-2010 (Dec)	182.70	228	110.17	75.98	2.46	7.44	196.06

Source: DoF, Myanmar

5. OTHER ENHANCEMENT PRACTICES

In addition to stock enhancement through the release of seed stocks there are other measures that are adopted for stock enhancement of inland waters. The main such measure is the implementation of closed seasons. All open fisheries are generally closed during June, July and August to permit spawning and recruitment. However, in a specific geographic area, closure could be different during the above period. This means that a closed season can be enforced in selected areas during spawning periods, through the prohibition of fishing in certain areas. These closed season provisions are enacted under the Fisheries Law of 1991.

The Freshwater Fisheries Law also prohibits some types of destructive fishing and activities which may have adverse impacts on fish stocks. Specifically, use of explosives and poisons are banned all together as well as some unspecified methods and equipment. Within a fishing area, it is prohibited to cut undergrowth or light a fire, to alter the natural flow of water or to cause pollution. The Law also states that "No one shall cultivate agricultural crops within the boundary of a fisheries creek".

6. IMPACTS OF MAJOR ENHANCEMENT AND CONSERVATION ACTIVITIES

Impact assessment studies *per se* on stock enhancement have not been undertaken in Myanmar. However, at least so far, there was no evidence of negative impacts on the natural fish populations because of stock replenishing programs in the nation. On the positive side, there are indications of higher catch rates by artisanal fishers in the villages near rivers. For instance in Inle Lake, grass carp are released on a regular basis to prevent the spread of aquatic macrophytes, which in turn also serve as feed for grass carp pond culture in the surrounding areas.

7. BIODIVERSITY CONSERVATION

Myanmar has been actively engaged in biodiversity conservation practices in inland waters. The leasable fisheries in flood plain areas are productive. In the same manner, these also are crucial to biodiversity conservation as these habitats, being the nursery grounds for maintaining the viable populations of indigenous wild stocks. The government realizing the importance of some leasable fisheries to biodiversity conservation has promulgated protective measures for these fisheries and transformed these areas to fish sanctuaries. Accordingly, over the years, the numbers of leasable fisheries has been reduced to 3 453 from 3 474, and are under constant scrutiny by the government.

Myanmar remains one of the few, if not the only country, in the region that does not have a reservoir fishery. This decision is based on the fact that development of reservoir fisheries will impact the reservoir catchment biodiversity, the catchments being under the jurisdiction of the Ministry of Agriculture and Irrigation.

Myanmar also has been active regarding introductions and the movement and use of alien species in fishery and aquaculture activities. For example, there is a complete ban on the use of the African catfish *Clarias gariepinus* including its use in aquaculture and even its sale in popular markets.

Areas in selected waters are being designated as conservation areas and the habitats thereof are often improved to provide favourable nursery and spawning grounds for selected indigenous species. In addition specific notifications are enforced for conservation purposes. For example:

- **Notification 2/92**

  This notification prohibits the catching or keeping in captivity of spawners, breeders, and fingerlings of freshwater fishes in the months of May, June, July and August without permission of Director General of DOF.

- **Notification 2/95 and 3/95**

  It prohibits the catching, for any purpose, of spawners and fingerlings of the freshwater prawn *Macrobrachium rosenbergii,* and *M. malcolmsonii* in the months of May, June and July, unless permitted by the Director General of DOF, Myanmar. If caught accidentally these should be released immediately.

8. CONSTRAINTS AND PROBLEMS

The main constraints encountered in stock enhancement programs in Myanmar are the limitations in seed stock availability, and particularly for stocking in remote places which are far from the hatcheries. These constraints are also associated with the cost of transportation and materials needed for effective transportation. In addition hatcheries may not be able to function at full capacity, particularly when electricity supply is interrupted. The situation with regard to fry and fingerling availability is further exacerbated by the demand of the aquaculture sector, which perhaps is witnessing one of the fastest growth rates in the region currently.

Although not a direct constraint it is important to improve public perceptions on the benefits of stock enhancement and the associated stocking programs, particularly at the implementation sites (release sites). In this regard there is a need to educate communities on the long term advantages of stock enhancement, and the basis of implementation of other strategies such as closed seasons, conservation areas, etc.

9. RECOMMENDATION

Much technological advancement is needed to place stock enhancement programs in inland waters in Myanmar on a firmer footing. For example, a variety of techniques ranging from culture supported capture fisheries to intensive aquaculture can be used to compensate for declines in fisheries due to overfishing, environmental changes or inadequacies in the natural ecosystem (Welcomme and Bartley, 1998) and some of these have to be adopted in Myanmar.

Introduction of the new species to exploit underutilized niches of the food chain and to compensate for loss of species due to environmental disturbance is needed.

Equally, there is need for engineering of the environment to improve levels of reproduction, shelter, food resources and vital habitats of the major species in the inland fisheries, as well as eliminate unwanted species that either compete with or predate upon target species.

So far, there is no evidence to support that stock enhancement strategies have brought about a reduction in genetic diversity of the wild stocks. There is a need for constant and regular monitoring of this aspect using modern molecular genetic tools. However, it should be noted that the current practices adopted in Myanmar in respect of replenishment of broodstocks, though not conducted strictly on a scientific basis, has been lauded as a good interim strategy which could be improved upon relatively easily with the application of modern scientific tools and approaches (Aung *et al.,* 2010).

There is an urgent need for improvement of operation and impact assessments in relation to stock enhancement in inland waters of Myanmar, which has been lagging behind most countries in the region.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN NEPAL

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Abstract

The ecological and biophysical diversity existing in Nepal offers comparative advantages and opportunities to develop and restore inland fishery resources for livelihood enhancement and poverty alleviation of rural communities. Through good governance and proper legislative measures it is required to establish improved environmental protection. Efforts need to target beneficiaries such as disadvantaged and marginalized ethnic communities with training and awareness raising, appropriate legal instruments; infrastructure development needs proper mitigation in hydropower generation/irrigation projects, particularly given the extensive new construction being planned in the future. Protection of biodiversity through scientifically guided indigenous fish breeding and restocking programs coupled with improved protection of natural populations is duly considered.

The economic well being of the Nepalese is very closely bound to its natural resources-arable land, water and forested areas. Nepal is in the process of developing legislation to protect and enhance its inland fishery resources. The fisheries sector contributes 2.72 percent to the Agricultural Gross Domestic Production (GDP) with a growth rate of 6.3 percent and contributes 1 percent to its National GDP.

Key words: Inland water bodies, fisher community, alternative livelihood, resource enhancement, conservation

1. INTRODUCTION AND OVERVIEW

Nepal is a small, mountainous, land locked country with a wide topographical diversity from alluvial plains to tableland, valleys, hills, mountains and Himalayas. The altitude ranges from 62.5 m to 8 848 m (Mt Everest) above sea level (MSL). It has a land area of 147 181 km^2 and is divided into three physiographic regions, from south to north: the Terai plain, the mid-hills and the Himalayas. Mountains and hills make up 83 percent of the area of Nepal while the Terai occupies only 17 percent. The Himalayas in the north strongly influence the climate of Nepal. The country may be divided into three climatic zones according to altitude: subtropical in the Terai, temperate in the hills, and alpine in the mountains. The climate varies little from east to west. Topographical diversity results in tropical, subtropical climate in Terai where temperature reaches 46^{o}C to temperate Tundra climate in the mountains where temperatures remains below freezing point throughout the year.

The economic well being of Nepal is very closely bound to its natural resources-arable land, water and forested areas. The total population engaged in agriculture has been reported to be 65.7 percent and the contribution of the agriculture sector to the national economy is 32.8 percent. Agricultural GDP has a growth rate of 2.8 percent in 2004-2005 (GEED, 2005). In fisheries, Nepal is in the process of developing legislation to protect and enhance its inland fishery resources, athough, the fisheries sector contributes only 2.72 percent to the Agricultural Gross Domestic Production with a growth rate of 6.3 percent (1 percent of the Country's GDP).

The present per capita availability of animal protein is very low as compared to standard recommendations of daily intake. The livestock and dairy subsector alone cannot meet the protein requirements. Fish is an important alternative source of animal protein as well as a livelihood to many people in Nepal.

Inland fishery is a time old tradition and only recently that inland waters have been increasingly impounded for hydropower generation, irrigation and other purposes (De Silva, 1992). Impounding submerges the plains suitable for human settlement, agricultural and several other uses, impacting the traditional livelihoods of local communities depending on those lands. Needless to say all these bring about severe and acute social problems especially in hilly areas where flat land is scarce.

Meanwhile, reservoir-based fisheries and aquaculture have been successful to generate food, income and job opportunities (Costa-Pierce and Hadikusumah, 1990; Sugunan, 1995; Costa-Pierce, 1998; Gurung *et al.,* 2008). However, there are limited studies that explicitly explain the role of fisheries and aquaculture on the issue of resettlement of communities displaced from impoundment. Similarly, cage-fish culture and enclosure culture in lakes (especially Pokhara valley lakes) have also been successful to provide food, income and job opportunities for the poor fishermen families (approx. 300 fishers) living around those lakes.

2. WATER RESOURCES

Nepal is endowed with vast inland water resources in the form of rivers, swamps, ponds and irrigated paddy field which provides about 0.82 million ha (Table 1) or and covers nearly 3 percent of the country's land. It is estimated a little over 1 percent of total water resources available have been used so far for fisheries enhancement activities. The existing water resources and their potential reveal that there is a tremendous scope for expansion of intensification of fish production in the country.

Table 1. Estimated water resources in Nepal

Resource Details	Estimated Area (ha)	Coverage Percent	Potential for Fisheries (ha)	Remarks
Natural Waters	**401500**	**48.8**	–	–
Rivers	395 000	48.0	–	–
Lakes	5 000	0.6	3 500	–
Reservoirs	1 500	0.2	78 000	Estimated to be developed in the future
Village Ponds	**6 735**	**0.8**	**14 000**	Projected to be added
Marginal Swamps	**12 500**	**1.4**	**12 500**	
Irrigated paddy Fields	**398 000**	**49.0**	**100 000**	It is increased to 1 million hectares (2007/08, DoA)
Total	**818 500**	**100**		

Source: Directorate of Fisheries Development (DOFD) 2002

2.1 Rivers

There are over 6 000 fast flowing rivers, rivulets and streams in Nepal. The three major river systems in Nepal are Koshi, Gandaki, and Karnali originating from the Himalayas flowing with significant discharge in the dry season as well. The medium rivers originate from the Mahabharata range with wide seasonal discharge fluctuation and there are a large number of minor rivers originating from the Siwalik range with very low flows during the dry season, all of which finally flows into the Ganges in India. These rivers are rich in aquatic lives, wildlife and waterfowl; some are tapped for irrigation, fishing and hydropower generation and most are important for ecological, economic cultural and recreational values. Artisanal and subsistence fishing is common in these rivers.

2.2 Lakes

Lakes in Nepal are glacial, ox-bow and tectonic (Sharma, 1977). The glacial lakes are oligotrophic and other lakes range from oligotrophic to mesotrophic and some eutrophic as well. To date fisheries enhancement/aquaculture activities are undertaken in Pokhara valley lakes only.

2.3 Reservoirs

There are few man-made reservoirs in Nepal, presently only comprising an area of 1 500 ha, and mainly built for hydropower and irrigation purposes (Pradhan, 1987). In these reservoirs aquaculture experiments are presently being undertaken. With the growing development of hydropower and irrigation projects, there is considerable potential for expanded fisheries enhancement.

2.4 Irrigated rice fields

Irrigated paddy fields are expanding due to the development of irrigation facilities using surface and underground water. This opens opportunities for paddy-cum-fish culture practices throughout the country. These are temporary form of water bodies only available during monsoon season which is also the time of rice cultivation in Nepal.

2.5 Marshy low lands, ghols, swamps, irrigations canals, etc.

Marshy lands and swamps serve as excellent habitat for migratory birds, fish, amphibians and mammals as well serving as rich habitats for high valued flora and fauna, wild rice varieties, etc. Such natural wetlands are necessary for preserving gene pools of diverse aquatic flora and fauna. Some of them are currently used for fisheries enhancement/aquaculture development in the far and mid-western regions of Nepal.

3. FISHERIES RESOURCES

Nepal's location in the centre of the Himalayan range places the country in the transitional zone between the eastern and western Himalayas. Nepal's rich biodiversity is a reflection of this unique geographic position as well as its altitudinal and climatic variations incorporating Palaearctic and Indo-Malayan bio-geographical regions and major floristic provinces of Asia, creating a unique and rich diversity of life. Although comprising only 0.09 percent of global land area, Nepal possesses a disproportionately large diversity of flora and fauna at genetic, species and ecosystem levels.

There are 185 species of fresh water fish found naturally in Nepal. Fishes of Nepal belong to a total of 11 orders, 31 families and 79 genera. Of the 185 species of fish,, eight are endemic to Nepal (Shrestha, 1995), and 34 are threatened and 61 species are of insufficiently known status. The endemic species include *Barilius jalkapoorei, Schizothoraichthys annandalei, Psilorhynchus pseudecheneis, Pseudeutropius murius bararensis, Lepidocephalichthys nepalensis* and three species of *Schizothorax* (*S nepalensis, S. macrophthalmus* and *S. raraensis*) are endemic to Rara Lake. Apart from the native species, 11 exotic fish species have been introduced into Nepal mostly for aquaculture. However, some exotic species such as silver carp (*Hypophtalmichthys molitrix*), bighead carp (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idella*) were introduced into the lakes of Pokhara (Phewa, Begnas and Rupa). Those lakes are now thriving habitats for those species. Almost all fishes found in Nepal are food fishes for the local people.

4. FISHERIES PRODUCTION AND PRODUCTIVITY

Although capture fisheries from rivers are practiced traditionally, very little is known about fish catches and production potential of the rivers of Nepal. Most of the studies undertaken have been by hydroelectric projects with patchy studies carried out on dam sites mostly for environmental impact assessment (EIA) purposes. These studies provide basic data on limnological and biological characteristics of certain stretches of rivers. To date, EIA studies have been conducted by Karnali (Himalayan Power Consultants, 1989), Kali Gandaki (Kali Gandaki A Associates, *et al.,* 1996). Arun (New ERA, 1991), Kabeli (Nepal consult and Hydro Engineering Services, 1998), Budhi Ganga (METCON Consultant, 1998), Raghughat Khola (WRC, 1998) (Swar and Shrestha, 1998) and Dudhkoshi (Shrestha and Swar, 1998), Similar studies have been conducted on the Madi River (Ministry of Agriculture, 1994), Danda Khola River (Ministry of agriculture, 1994), Trishuli River (Masuda and Karki, 1980; and Fisheries Research

Centre (FRC), Trishuli, 1993 and 1996 and Sunkoshi River (Bisgard and Rangit, 1999, unpublished). In recent years fisheries surveys have been undertaken in some tributaries of Koshi, Gandaki, Karnali river systems by the government. Based on these studies the production of fish from capture fisheries is estimated to be 21 500 tonnes contributing 44 percent to the total fish production in the country (Table 2). Capture fishery yield is decreasing, however, it is projected that by 2018 overall fish production will have doubled through aquaculture promotion and conservation. (Fisheries Perspective Plan (FPP), 2000, DOFD).

Table 2. Production and productivity from capture fisheries

Water Bodies	Area (ha)	Fish Production (mt)	Productivity (mt/ha)
Rivers	395 000	7 110	18 kg
Lakes	5 000	850	170 kg
Reservoirs	1 500	385	260 kg
Ghols	11 100	5 990	540 kg
Irrigated Paddy Fields	398 000	7 165	18 kg
Total	818 600	21 500	Contributes 44 %

Source: DOFD, GoN, 2008

5. AQUATIC RESOURCES AND LIVELIHOODS

There are approximately 24 groups of ethnic people. Most of them are marginalized and poor dependent on inland fisheries resources in Nepal. Swar and Fernando (1980) have estimated that more than 20 000 fishers are actively involved in capture fisheries. In 2005-2006, the Directorate of Fisheries Development (DOFD), estimated that 106 257 families with 578 036 beneficiaries were actively involved in capture fisheries for their livelihood.

Indigenous fish species are an important component of biodiversity and are valuable genetic resource for the future generations but unfortunately many of these fishes are threatened due to environmental degradation and other human activities.

6. CURRENT INLAND FISHERIES PRACTICES

Inland water resources are nature's precious gift to a nation, often with important social and economic values based on multi dimensional uses and a shifting priority away from sole dependence on fisheries to include a variety of other uses. Still fisheries is an important source of food, nutrition and income for its rural people, with an estimated 2 percent of the population in Nepal being dependent on fisheries and allied activities.

The economic level of people living around natural water bodies, such as rivers, lakes, reservoirs and wetlands (specially the fishing communities) are typically marginal often with many surviving on very low incomes, which may trigger the illegal use of the resources. Most of these communities either have very little land or have no land at all. They are mainly dependent on fishing activities and often engaged as agricultural labors.

Government policy usually gives priority to agricultural activities. For water resource use, priority typically goes to hydropower generation and irrigation needs. This is true even though the present agriculture policy has made fisheries a priority program (P1) but in terms of program formulations and implementation it is not so.

As a part of a successful mitigation measure, the example of cage fish culture is an alternative livelihood option for communities displaced by reservoir impoundment in Kulekhani. In the 1980's, fisheries and aquaculture were hardly envisaged during the planning of hydropower projects. Here, the government of Nepal and International Development Research Centre (IDRC), Canada jointly demonstrated that cage fish culture in the reservoir is a promising alternative livelihood option for displaced communities. Among 500 families displaced in 1982 due to impoundment, nearly 81 percent adopted cage farming and 231 families are now engaged in fish production from the reservoir. These families are organized in 11 groups and produce approximately 165 tonnes of fish (2005-2006) out of which 130 tonnes from cage culture fisheries (80 000 m^3) and rest from open water stocking and harvesting.

Human interference has effected fish populations and production in many natural water bodies. These are constant threats to the maintenance of fishery resources and aquatic biodiversity, even though, the government of Nepal has formulated rules, regulations, plans and policies to counter these threats, very little success has been achieved so far.

6.1 Effect of impoundment on the indigenous fishes in Kulekhani reservoir (Indrasaroboar)

The first documented survey of fish species composition of the stretch of the Kulekhani River now occupied by Indrasarobar was conducted in 1980 (Shrestha *et. al.,* unpublished). It was reported that Cyprinidae were the most abundant family, represented by *Garra lamta, Neolissochilus hexagonolepis, S. richardsoni, Puntius chilinoides, P. ticto* and *P.* spp. The families Cobitidae and Channidae were represented by *Noemacheilus* spp. and *Channa orientalis* respectively. The family Sisoridae was represented by *Glyptosternum* spp. and *Coraglanis* spp. A survey of the fish fauna of the Kulekhani River upstream of the reservoir revealed that Cyprinidae were the most abundant family followed in order of abundance by Sisoridae, Cobitidae and Channidae (Pradhan, 1986). A further comprehensive investigation of the fish populations in Indrasarobar Reservoir from January 1985 to June 1989 examined the impacts of the construction of the Kulekhani dam and the conversion of 7 km of the river into a lake. This transformed a varied but unstable riverine environment into a relatively stable lacustrine one although subject to extensive drawdown. A profound change in the relative abundance of many species occurred within a short time of the lake's formation (Swar, 1992; 1994). These changes included:

- A drastic decline in the number of snow trout *S. richardsoni*;
- The disappearance of *Puntius* spp., *G. lamta, Neomacheilus* spp., *C. gachua, Glyptosternum* spp. and *Coraglanis* spp.
- Two indigenous species, *N. hexagonolepis* (katle) and *P. chilinoides* (karange) remained dominant.
- Three species *H. molitrix*, silver carp; *A. nobilis*, bighead carp and *Tor tor*, mahaseer which were not native to the Kulekhani River, appeared in the catches of 1986/87. They formed a considerable percentage of the catches in 1987/88 and 1988/89. These species were not deliberately introduced in the open water, but escaped from cages.

Table 3. Changes in fish species in Indrasarobar Reservoir, Nepal from 1980 to 1989 (Swar, 1992).

Introduced	Disappeared	Dwindled	Now dominant
T. tor *A. nobilis* *H. molitrix*	*G. lamta* *P. ticto* *Puntius* spp. *Neomacheilus* spp. *C. gachus* *Glyptosternum* spp. *Coraglanis* spp.	*S. Richardsoni* *P. chilinoides*	*N. hexagonolepis*

6.2 Conservation strategies

Conservation aims to maintain genetic biodiversity at present and in future and seek to provide a regular supply of aquatic products for human consumption. Increasing efforts are being made for effective implementation of "community water bodies" and awareness of aquatic life protection act and rehabilitation of depleted fishes by stocking with hatchery produced seed of important indigenous species. At the same time, implementation of a new policy to manage the import of exotic fish species is also tried. Conservation of fish through participatory management is emphasized, including the conducting of training and awareness programs. Similarly, improved monitoring of the environment coupled with the provision of alternative livelihood activities like aquaculture for displaced as well as affected people is being expanded in various areas.

6.3 Water Resources Strategy (WRS)

For decades, Nepal's economic development efforts have focused on its water resources. Although the country has an abundance of water in terms of annual surface flow and groundwater reserves, the progress towards utilization of this water for basic uses and economic growth has been slow. In recognition of this fact, the Government of Nepal prepared a long-term Water Resources Strategy, capable of guiding water sector activities towards sustainability of the resource, while providing for hazard mitigation, environmental protection, economic growth and constructive methods of resolving water use conflicts. The main objectives of the WRS are:

1. Every Nepali citizen, now and in the future, should have access to safe water for drinking and appropriate sanitation, as well as enough water to produce food and energy at reasonable cost.
2. Nepal needs to promote ways of managing its water at the river basin level to achieve long-term sustainability for the benefit of its entire people. This will require a holistic, systematic approach that honors, respects and adheres to the principles of integrated water resources management.

6.4 National Water Plan (2005)

In order to implement the activities identified by the Water Resources Strategy (WRS), the Government of Nepal approved the National Water Plan 1 (NWP), in 2005. The NWP1 recognizes the broad objectives of the WRS and lays down short, medium and long-term action plans for the water resources sector, including investments and human resource development. The NWP1 attempts to address environmental concerns, which are reflected by the incorporation of the Environmental Management Plan in the document. This Environmental Management Plan will contribute to maximizing positive impacts and minimizing or mitigating adverse impacts in line with environment sustainability concerns. Two component of the NWP1 are particularly relevant here.

6.4.1 Management of watersheds and aquatic ecosystem

The targets in this sub-sector as mentioned in the NWP are:

- By 2007: A management plan for nationally important watersheds and aquatic system is prepared and initiated and water quality and wastewater quality standards are developed and enforced.
- By 2017: Full scale environmental protection and management projects are implemented in all priority watersheds and aquatic ecosystems and stakeholders' participation in environmental protection and management is provided for.
- By 2027: Quality of watersheds is increased by 80 percent in all regions and adequate water quality is attained for aquatic habitat, including fish, human consumption and recreation in all rivers and lakes.

The following action programs are detailed out for the purpose of achieving the targets mentioned above:

- improve environmental database system;
- map important, critical and priority watersheds and aquatic ecosystems;
- develop and implement water and wastewater quality standards and regulations;
- implement nationally important watersheds and aquatic ecosystems protection, rehabilitation and management programs;

- implement water conservation education program;
- develop strategic environmental assessment in water resources management;
- ensure compliance of EIA;
- promote community participation in the management of watersheds and aquatic ecosystems;
- enhance institutional capacity and coordination; and
- develop watershed management policy

6.4.2 River basin management

Similarly for the River Basin management, the following action programs are detailed out in NWP:

- Mainstreaming Inland Water Resource Management (IWRM) and the river basin concept
- Development of river basin plans
- Development and implementation of Decision Support System (DSS) in water resources programs
- Establishment as well as strengthening of institutions for river basin planning

6.4.3 Agencies involved in conservation and management

The main organizations actively involved in the management of IWRM/wetlands are:

GOVERNMENT AGENCIES: Ministry of Environment, Water Resources, Forest and Soil Conservation, Agriculture and Co-operatives (Directorate of Fisheries Development) and the National Planning Commission.

AUTONOMOUS BODIES: Water and Energy Commission, Environment Protection Council, Nepal Agriculture Research Council, Nepal Academy of Science and Technology, Tribhuvan University Kathmandu University, Nepal Electricity Authority.

INGO'S AND DONOR AGENCIES: Finnida, Care Nepal, JICA, IUCN – The world conservation union, Asian Wetland Bureau, International Crane Foundation, Worldwide Fund for Nature, Asian Development Bank.

NON-GOVERNMENT ORGANIZATIONS: King Mahendra Trust for Nature Conservation, Nepal Bird Watching Club, Save Bagmati Campaign, Save Phewa Lake, Nepal Heritage Society, Nepal Nature Conservation Society, Association for Protection of Environment and Culture.

PROFESSIONAL ORGANIZATIONS: Nepal Fisheries Society, Informal Wetland Group, Institute of Biodiversity of Nepal (IBN), Nepal Botanical Society, Nepal zoological Society, Natural History Society of Nepal, Cultural Green Club etc.

6.5 Existing conservation and mitigation measures

In response to the growing global awareness about the importance of maintaining a balance between economic development and environmental conservation, the Nepal Environmental Policy and Action Plan (NEPAP) has been launched. NEPAP is a part of the Government's continuing effort to incorporate environmental concerns into the country development process. Efficient and sustainable management of natural and physical resources and mitigating the adverse environmental impacts of development projects and human action are the main themes of NEPAP. Conservation of fishery resources is part and parcel of the broad NEPAP. National wetland policy and strategic plan for biodiversity conservation has also been prepared by Government of Nepal in order to protect aquatic resources. National wetland policy is based on local people's participation. It aims to conserve and manage aquatic resources with local people's participation for their benefit, while maintaining environmental integrity. At the same time, it also aims at wise use of wetland resources by providing equal opportunities on the basis of local people's participatory management of wetlands to conserve natural resources for the benefit of present and future generations. Similarly, the strategic plan for biodiversity conservation aims at conserving biological diversity and the sustainable use of its components and ecosystems. The following measures have been carried out to till now to conserve fisheries resource in Nepalese water systems.

6.5.1 Legislative arrangements

Conservation of aquatic life is addressed by the Aquatic Animal Protection Act (AAPA) 2017/1961, which prohibits the use of explosive or poisonous substances in any water body where the intention is to catch or kill aquatic life. The Government of Nepal has formulated aquatic life protection regulation and the procedure of its implementation. It regulates fishing gears, size of the fish and season. Examination of the impacts of development projects on fishery resources and implementation of mitigation measures has been made mandatory under this regulation. Along with AAPA there is legislation impacting Wetland Biodiversity and Ecosystem Conservation in Nepal such as the Forest Act, and a similar set of Acts covering environmental protection, national parks and wildlife protection soil and watershed conservation, and related issues.

6.5.2 Environmental impact assessments

After the implementation of the NEPAP, Nepal has introduced legal or institutional mechanisms for the use of EIA. Different EIA reports recorded fish species (for example see the list of aquatic flora and fauna as given in Annex 1). Impacts of development projects on aquatic life are thoroughly assessed and mitigation measures established, such as the establishment of a fish hatchery and recommendation for fish trapping and hauling, restocking fingerlings activities under Kali Gandaki "A" Hydropower Project.

6.5.3 Establishment of fish sanctuaries

The majority of fish inhabiting rivers are extremely sensitive to environmental changes that occur in modified rivers. An extensive network of protected areas has now been established in Nepal. Nepal has nine national parks, three wildlife reserves and one hunting reserve, four conservation areas, eleven buffer zones covering an area of 28 998 km^2 (19.7 percent of the country's total area). Similarly, nine water bodies with an area of 34 455 ha have been declared as Ramsar sites.

6.5.4 Protections of endangered species

The present status of fish species (based on an older account listing 185 species) were given in Table 3. Native fish species recommended for legal protection are listed in Table 4. One species (*Tor tor*) is listed as endangered while 9 species as vulnerable.

There are twenty six mammals, nine birds and three reptiles listed as threatened species in Nepal. However, until now none of the fish species has been included in the list of IUCN.

Table 4. Status of fish species in Nepal (adapted from Shrestha, 1995)

Status	Number
Common/occasional	90
Insufficiently known	61
Vulnerable	9
Endangered	1
Rare	24
Total	185

6.5.5 Promulgation of aquatic animal protection regulations

The Aquatic Animal Protection Act (AAPA) was passed in 1961; in 1999 the Government promulgated the AAPA regulations. The guidance, policies, and experience related to the development of fisheries have now been defined. In the past fisheries in inland water bodies have often been subject to ecological damage from poisoning, bombing, poaching and stealing of fish. In order to protect national interests and the legal rights of fishermen, the law defines concrete administrative penalties, civil liabilities and responsibilities. However, its implementation is far from satisfactory.

Table 5. List of species recommended for legal protection under the AAP regulation

Scientific name	Common name	NRDB code	Distribution
Neolissocheilus hexagonolepis	Katle	V	Koshi, Gandaki, Karnali, Mahakali
Chagunius chagunio	Rewa	V	Koshi, Gandaki, Karnali, Mahakali
Tor putitora	Mahseer	V	Koshi, Gandaki, Karnali
Tor tor	Sahar	E	Gandaki, Mahakali
Danio rerio	Zebra macha	V	Gandaki, Karnali
Schizothorax plagiostomus	Buchhe asla	V	Koshi, Bheri, Gandaki, Karnali, Mahakali, Phewa, Lake, Gandaki
Schizothorax richardsonii	Asala soal	V	Koshi, Gandaki, Karnali
Schizothoraichthys progastus	Chuche asala	V	Koshi, Gandaki, Karnali
Psilorhynchus pseudecheneis	Tite macha	V	Koshi
Anguilla bengalensis	Rajabam	V	Koshi, Gandaki, Karnali

V = Vulnerable; E = Endangered

6.5.6 Fish trapping and hauling

Fish trapping and hauling is another alternative for assisting natural fish migration. Fish trapping can be used for a variety of fish species and sizes. Migratory species can be captured and hauled. However, there are drawbacks to the fish trapping and hauling approach; stress related mortalities may occur. Risk of poaching may be another disadvantage. However, fish trapping and hauling has been recommended at Kali Gandaki "A" Hydroelectric Project. However, it has not yet been practiced.

6.5.7 Fish ladders

One of the remedies commonly proposed for blockages to migrations caused by dams is the construction of fish passes or ladders. Most of the existing and proposed water development projects in Nepal do not have fish passes. Although almost all the prominent rivers of Nepal are dammed for various development purposes, there are only a few examples of fish ladders (e.g., Koshi Barrage; Chandra Nahar in Trijuga; Andhi Khola, Gandak Barrage). However, little data is available on fish ladder performance. The fish ladder in the Trijuga River is not in operational condition due to the lack of maintenance and inappropriate design. In the Koshi Barrage the upper chambers of the ladder are frequently used as fish traps for illegal harvesting by local fishers (D.B. Swar, personal observation).

6.5.8 Fish hatcheries

Establishment of fish hatcheries is another measure for mitigating the impact of a dam building on the native fish fauna. Hatcheries can play an important role in fish conservation and management in developing countries. In recent years, their efficiency has increased with better knowledge of the biological and reproductive requirements of fish while other issues such as genetics remain controversial. A fish hatchery was established at Kali Gandaki "A" Hydropower Project. The main objective of the hatchery is to propagate mahseer (*Tor putitora*), katle (*N. hexagonolepis*), snow trout (*S. richardsonii*); jalkapoor (*C. garua*) and other important native fish species affected by the construction of the dam. However, to date only six out of fifty-four species reported from the Kali Gandaki River are being bred.

6.5.9 Open water stocking

Among the indigenous fish species of Nepal, *N. hexagonolepis* (katle), *Labeo* spp., *T. Tor, T. putitora* (sahar, mahseer or mahaseer), and *S. richardsonii, S. progastus* (snow trout or asala) have been identified as important for sport fishery as well as being excellent food fish. Their domestication started in the 1970s. Fish fry are being produced in hatcheries and trials are going on to culture them in captivity. Seeds of these species are released in various rivers, lakes and reservoirs but the impact assessment is not properly done.

6.5.10 Awareness programmes

The Government of Nepal through the Directorate of Fisheries Development has started awareness programmes in highly affected areas by using participatory methods with concerned/affected people including putting up public notice (hoarding boards) at various locations.

7. CONSTRAINTS AND PROBLEMS

Nepal is in the process of developing legislation to protect and enhance its fisheries and aquatic resources. Very little has been done in terms of fisheries resource enhancement and conservation. The major constraints include:

1. Lack of adequate legal instruments to reduce loss of its rich biodiversity (note that new regulations under Aquatic Animal Protection Act, 1961 are in the process of formulation and execution by Nepal Government) due to urbanization, encroachment, construction of large hydro-dams/barrages/roads, sand and gravels/boulders mining, and illegal fishing.
2. Although, Inland water fishing is very popular and has great potential in Nepal; the present status of fisheries resources are not known due to absence of adequate scientific and data which prevents sustainable use of the available resources.
3. Absence of coordination among various government and other agencies involved in inland water resource use; lack of integrated land and water resources use planning.
4. Low levels of public awareness and participation in resource enhancement, development and conservation.
5. Limited technical capabilities, infrastructure facilities and human resources development.

8. RECOMMENDATIONS

The ecological and biophysical diversity existing in Nepal offers comparative advantages and opportunities for developing and restoring inland fishery resources for livelihood enhancement and poverty alleviation of rural communities. Improved environmental protection is required. Efforts need to target beneficiaries such as disadvantaged and marginalized ethnic communities with training and awareness raising, appropriate legal instruments; infrastructure development needs proper mitigation in hydropower generation/irrigation projects, particularly given the extensive new construction being planned in the future and as well as the protection of biodiversity through scientifically guided indigenous fish breeding and restocking programmes coupled with improved protection of natural populations. Specific recommendations for a sound inland resources/fisheries management include:

- Base line data development: Prioritizing accessible and important water bodies, development of tools for systematic and comprehensive collection of fisheries statistics.
- Improved Governance: Establishment of a National Water Resource Development and Conservation Committee at the national level to adopt and implement a cleat cut policy for natural water conservation and utilization.
- Monitoring and Evaluation: Strict and periodic monitoring and evaluation of the impact of enhancement activities are suggested to be carried out by independent bodies.
- Capacity building including institutional development and/or strengthening: Facilitate the preparation and/or implementation of national strategies, plans for priority programmes and activities for conservation of biological diversity and sustainable use of its components.
- Participatory valuation: At present, the rivers of Nepal are utilized either for generating hydroelectric power or for irrigation purposes only, with little consideration being given to their fisheries value. For the conservation of the freshwater fishery resources it is important to involve fisheries professionals and local communities in the planning and feasibility studies.

- Regional cooperative effort: It is suggested among the countries of the Trans-Himalayan region that share many important inland water and fishery resources.
- User involvement: Identification of critical habitat and protection measures needs to embrace community participation, protection of rights of users and exact legislation for the conservation and sustainable use of Inland Water Resources more generally.
- Improved control measures: Sanctuaries and/or no fishing zones, closed-seasons, control on illegal fishing and use of gears needs greater priority particularly to protect indigenous threatened species.

  Political Will: increased support from decision makers will be crucial to all of the above.

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN SRI LANKA

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Abstract

Early attempts of fisheries enhancement in Sri Lankan freshwaters were aimed at establishing commercial fisheries and consequently, exotic cichlid species were introduced during the second half of the last century. A fisheries enhancement strategy was introduced to village reservoirs of the country in 1980s on a trial basis. This is termed as culture-based fisheries (CBF), which combines elements of aquaculture and capture fisheries and relies entirely on the natural productivity of the water body for growth of fish, and on artificial stocking as a means of recruitment. These efforts were however, unsuccessful under the technological and sociological milieu that prevailed, and further aggravated after the discontinuation of state patronage for inland fisheries and aquaculture development in Sri Lanka during 1990-1994.

Presently, inland fisheries enhancement strategies in Sri Lanka are practiced in seasonal reservoirs and minor perennial reservoirs. The annual CBF production from these reservoirs is about 6 600 tonnes, accounting for about 17 percent of the inland fisheries production. The aquaculture extension officers of National Aquaculture Development Authority (NAQDA) and several NGOs have been conducting awareness programs to educate rural farmers on CBF management and development of business plans, facilitating inland fisheries resources enhancement in the country.

The major seed resources for fisheries enhancement are fingerlings of Chinese and Indian major carps. State-owned aquaculture development centres (AQDCs) of NAQDA are responsible for induced breeding and rearing of post-larvae to fry stage. Community-based organizations (CBOs) and private pond owners have a significant role in fingerling rearing for fisheries enhancement.

Although there has been a significant policy developments providing legal provisions for fisheries and aquaculture development in small reservoirs, in some parts of the country, CBF activity is still considered as a secondary use of reservoirs with low priority. Furthermore, possible impacts of fisheries enhancement on the biodiversity of native flora and fauna cannot be completely ignored and as such a procedure for impact assessment should be introduced. The provincial and central government fisheries authorities can play the role of project proponent and as part of the extension mechanism, for conducting EIAs or IEEs.

Key words: Culture-based fisheries; cichlidae; Chinese carps; Indian carps; introduced fish; stocking strategies; tropical reservoirs

1. INTRODUCTION

In some Asian countries such as Sri Lanka, reservoir construction was an integral part of ancient civilization. The sovereignty of ancient hydraulic civilization in Sri Lanka is witnessed by extant reservoirs some of which have been as old as 2000 years (Brohier, 1934, 1937; Fernando and De Silva, 1984; De Silva, 1988). The rural communities in Sri Lanka have traditionally developed various management practices leading to sustainable utilization of fishery resources in village irrigation systems (Siriweera, 1994; Ulluwishewa, 1995). In the past, fish production from inland reservoirs was based on indigenous species and there was no commercial scale inland fishing in ancient Sri Lanka. In reservoirs, there are great opportunities for improved fish production from enhancement of natural production (Petr, 1994, 1998; Lorenzen *et al.,* 2001). Fisheries enhancements are defined as limited technological interventions in the life cycle of common pool aquatic resources (Lorenzen *et al.,* 2001). The present review is essentially based on this definition.

Enhancement strategies are implemented in the existing water bodies, mainly inhabited by indigenous fish species. Through the enhancement strategies, conservation efforts should not be compromised especially because Sri Lanka is one of the biodiversity hotspots of the world (Bossuyt *et al.,* 2004). Being a country with high degree of endemism in the freshwater fauna, sufficient legal provisions exist in the Fisheries and Aquatic Resources Act of Sri Lanka (Anon., 1996a), for the conservation of aquatic organisms. Accordingly, conservation areas can be declared to afford special protection to the aquatic resources in danger of extinction in such waters or land and to protect and preserve the natural breeding grounds and habitat of fish and other aquatic animals.

1.1 History of inland fisheries resource enhancement and conservation

A commercial scale inland fishery of Sri Lanka is essentially a post-1950 development in major reservoirs of the island, and occurred after the introduction of *Oreochromis mossambicus* (Fernando and Indrasena, 1969; Fernando and De Silva, 1984; De Silva, 1988). Presently, contribution of inland fish production to the total national fish production is in the range of 9-14 percent (Figure 1).

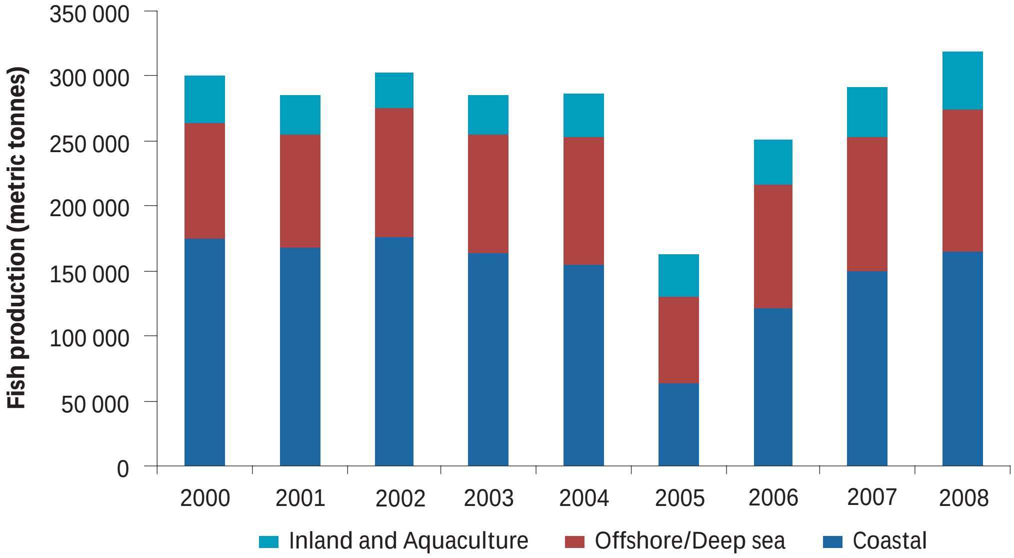

Figure 1. Annual fish production in Sri Lanka from different sub-sectors (2000-2008)

The inland capture fisheries are primarily from major irrigation and hydroelectric reservoirs (>750 ha) and the total extent of such reservoirs is about 70 000 ha (about 42 percent of the total extent of lentic water bodies). Small-scale fisheries exist in the medium-scale reservoirs (250-750 ha), which form about 10 percent of the total. The minor irrigation reservoirs (<250 ha), generally referred to as "village tanks" with a cumulative extent of about 39 000 ha, can be categorized into two groups depending on the water retention period. Those that retain water throughout the year are called "minor perennial reservoirs" and those which retain water for 7-9 months each year are locally known as "seasonal reservoirs" or "non-perennial reservoirs" (Mendis, 1977; Thayaparan, 1982). In the minor perennial reservoirs, subsistence level fisheries exist (Murray *et al.,* 2001; Pushpalatha and Chandrasoma, 2010). The non-perennial reservoirs are small (<60 ha) and are largely rain-fed (from inter-monsoonal rains from October to January). They tend to be eutrophic due to the addition of nutrients from the catchment areas. These village reservoirs were thought to be used as 'fish ponds' for stocking of fish fingerlings after filling with water from the inter-monsoonal rains. A number of attempts were made to utilise these waters for fish production over the years through stock enhancement (Anon., 1964; Indrasena, 1964, 1965; Fernando and Ellepola, 1969). This enhancement strategy termed as culture-based fisheries (CBF) was suggested to be managed by the rural communities, whose livelihoods were dependent on reservoirs for irrigation of agricultural lands, watering their cattle and buffaloes and domestic uses (Mendis, 1977). CBF combines elements of aquaculture and capture fisheries and relies entirely on the natural productivity of the water body for growth of fish, and on artificial stocking as a means of recruitment (Lorenzen, 1995). In CBF, hatchery reared fish are released into water bodies not primarily managed for fish production, and are recaptured upon reaching a desirable size (De Silva, 2003).

CBF development in village reservoirs was incorporated in the national fisheries development plan of the country (Rosenthal, 1979; Oglesby, 1981), and pilot scale projects were initiated in the early 1980s (FAO/UNDP, 1980; Thayaparan, 1982). From these CBF trials, yields ranging from 220 to 2 300 kg ha^{-1} in 15 seasonal reservoirs (mean 892 kg ha^{-1}) within a growing season were reported (Chandrasoma and Kumarasiri, 1986).

In spite of the high potential for the development of CBF in village reservoirs, the program did not sustain itself. De Silva (2003) mentioned the likely reasons for the overall failure of the strategy as follows:

- lack of a guaranteed fingerling supply, which frustrated the stakeholders, as at times tanks were under-stocked or were unable to be stocked to make use of the growing season fully;
- oversupply of fish supply in the market both in space and time;
- rules and regulations, and responsibilities of stakeholder organizations were not well thought out and/or planned; and
- supply of undersized fingerlings resulting in low returns, which brought about a disinterest in the future of the program.

Furthermore, a politically inspired withdrawal of state patronage for the development of the inland fisheries sector from 1990 to 1994 was also a major setback to the development of CBF (De Silva, 1991; Amarasinghe, 1998), because this activity was highly dependent on state subsidies for fingerling supply. The lack of guaranteed fingerling supply from the government hatcheries, which were leased out to the private sector after discontinuation of government support in 1990 brought about a general collapse of CBF development activities in village reservoirs.

It is generally believed that introduced fish species pose threats to the biodiversity. In fact, *O. mossambicus*, the mainstay of the inland fishery of Sri Lanka is labelled as one of the worst invasive alien species in the world (Lowe *et al.,* 2000). In Sri Lankan freshwaters however, clear habitat segregations are evident in indigenous and endemic freshwater fish species that inhabit in rivers and streams of higher elevations (Moyle and Senanayake, 1984; Kortmulder, 1987; Wikramanayake and Moyle, 1989) whereas the exotic cichlids have colonized lacustrine habitats of reservoirs and slow-flowing, isolated habitats in a few streams (Amarasinghe *et al.,* 2006). Due to this habitat segregation, any adverse effect of the exotic cichlids species on the diversity of indigenous freshwater is unlikely (Fernando *et al.,* 2002; Amarasinghe *et al.,* 2008).

1.2 Major practices of fisheries resource enhancement and management

As mentioned above, major practices of inland fisheries enhancement in Sri Lanka until early 1980s were of *ad hoc* nature and involved in introduction of exotic species into Sri Lankan reservoirs. Many reports on stocking of reservoirs are available, for example, Chinese and Indian major carps and *O. niloticus* (Jayasekara, 1989), *L. rohita* (Chandrasoma, 1992). However, when a broad database was used fish yields of exotic carp species showed a negative curvilinear relationship with the reservoir area, indicating that high fish yields through stocking can only be achieved in small (<800 ha) reservoirs (Amarasinghe, 1998), as demonstrated for elsewhere in the world. (De Silva *et al.,* 1992; Sugunan, 1995; Welcomme and Bartley, 1998).

The early phase of capture fisheries development in Sri Lankan waters during the second half of the twentieth century can be considered as a fisheries enhancement approach because introduction and stocking of exotic fish species played a major role in the development strategy. As the capture fisheries in major perennial reservoirs are managed mainly for self-recruiting tilapias, which have been well established, now account for over 90 percent of the landings (Amarasinghe, 1998). As such, established profitable capture fishery in major perennial reservoirs of Sri Lanka does not have the features of enhancement, as defined by Lorenzen *et al.* (2001). However since January 2009, the government has initiated subsidized stocking of fingerlings in all reservoirs including major perennial reservoirs (see below). Nevertheless, the outcomes of these stocking regimes remain to be evaluated.

After the general collapse of the major enhancement program, in village reservoirs in the 1980s for the reasons mentioned above, several attempts were made in mid 1990s for CBF development. For example, under a project funded by Australian Centre for International Agricultural Research (ACIAR), a research team from the University of Kelaniya and National Aquaculture Development Authority of Sri Lanka in collaboration with Deakin University, Australia, has carried out an extensive study in 47 village reservoirs in five administrative districts of Sri Lanka, focusing on developing holistic management strategies for CBF in village reservoirs incorporating biological, physical, and socio-economic factors.

Until the 1980s, the general practice was to produce fingerlings in state-owned hatcheries and as such, the limited pond space in those hatcheries was major setback for supplying sufficient numbers of fingerlings. This situation was aggravated after the government-owned fish breeding centres were leased out to the private sector in 1990. However, after the revival of state patronage for inland fisheries and aquaculture development in 1994, fingerling production for stocking inland water bodies through community participation was recognized as a feasible strategy. Induced breeding and rearing of post-larvae up to fry stage (2-3 cm in size) were recognized as the purview of government hatcheries. Also, extension mechanism in the inland fisheries and aquaculture sub-sector was strengthened (Amarasinghe, 1998). NAQDA was established under a Parliamentary Act in 1998 (Anon., 1998a; Anon., 2006a) as the responsible agency for the development of inland fisheries and aquaculture in the country.

1.3 Fish species cultured

In Sri Lankan indigenous fish fauna, fast-growing fish species which feed on lower trophic levels are absent and as such, there is a heavy reliance on exotic species for inland fisheries enhancement strategies. Hatchery-produced fingerlings of catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*) silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) are generally stocked in seasonal reservoirs and minor perennial reservoirs. In addition, Nile tilapia (*O. niloticus*) GIFT (genetically improved farmed tilapia) strain of *O. niloticus* and freshwater prawn (*Macrobrachium rosenbergii*) are stocked by some community-based organizations (CBOs). Wijenayake *et al.* (2007) have however, shown that GIFT strain on Nile tilapia is not suitable for fisheries enhancement through CBF in village reservoirs of Sri Lanka because they showed poor growth performance perhaps due to their inability to compete with other stocked species for natural food. As density-dependent factors also influence the CBF yields, a positive second order relationship was evident between stocking density and yield (Wijenayake *et al.,* 2005). Accordingly, the optimal stocking density of major carps (stocking size of 5-6 cm) was found to be about 3 500 fingerlings/ha.

In small reservoirs which are utilized for CBF development, especially those which do not dry completely in the dry season, naturally recruiting carnivorous fish species from the associated water ways such as *Ophicephalus striatus, Mystus keletius* and *Anabas testudineus* also influence performance of stocked species in the CBF. In such reservoirs, CBF harvests of stocked species are low due to predation (Wijenayake *et al.,* 2005). In 1980s during the pilot-scale CBF trials, these undesired species were eradicated by adding biodegradable substances such as bleaching powder before stocking reservoirs (De Silva, 1988). From the point of view of biodiversity conservation, stocking of large (>10 cm) fingerlings is advisable.

1.4 Scale of operation

Inland fisheries enhancement in Sri Lanka comes under the purview of NAQDA. The Aquatic Resources Development and Quality Improvement Project (ARDQIP), funded by Asian Development Bank from 2003 to 2009 has been instrumental in implementing inland fisheries enhancement strategies in the country. The ARDQIP supports aquatic resource development and quality improvement to enhance food security and reduce poverty, especially in rural areas of Sri Lanka. The project assists NAQDA to build its technical and financial capacity to support aquaculture development, and to become a financially self-sustaining organization.

The current stocking strategies in reservoirs are supposedly driven by the desires of resource users. For example, in large and medium-sized reservoirs, stocking is carried out guided the complaints by reservoir fishers about the status of the fisheries. As mentioned by Cowx (1998), fishers' complaints about the status of the fishery might not be accurate because such trends may be due to natural production cycles and as such, long-term beneficial effects of stocking in such water bodies are unlikely. Details on the stock enhancements in 2007/08 in relation to the type of water body are summarised in Table 1.

Table 1. Details on the stocking of the different types of reservoirs. (Fingerling numbers are in millions) (Anon., 2009).

Reservoir type	Stocking details	
	Water bodies	Fingerlings
Large reservoirs (2007/08)	Not known	11.4
Minor perennial reservoirs		
2007	213	4.61
2008	218	5.70
Seasonal reservoirs		
2007	472	4.06
2008	321	3.00

2. CURRENT PRACTICES OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION

CBF development in seasonal reservoirs is essentially dependent on the rainfall pattern in the dry zone of the country. As the fingerlings should be stocked in seasonal reservoirs just after the heaviest rainy season (November-January) in the dry zone of the country, correct timing of production of fingerlings is necessary for successful implementation of culture based fisheries in seasonal reservoirs. Also, fingerlings are not required for stocking in seasonal reservoirs for all the seasons, so that they can be stocked into small perennial reservoirs (Chandrasoma, 1992).

2.1 Seed resources

For inland fisheries enhancement, major seed resources (i.e., fingerlings of Chinese and Indian major carps) are supplied by three AQDCs functioning under NAQDA. As the technology of induced breeding has not yet been adopted by rural farmers or private sector, AQDCs are responsible for induced breeding and rearing of post-larvae to fry stage. AQDCs however, have limited pond space for fingerling rearing (Weerakoon, 2007). Currently, community-based organizations (CBOs) and private pond owners (PPOs) have a significant role in fingerling rearing for fisheries enhancement. Under the Asian Development Bank (ADB) funded ARDQIP project, establishment of 25 mini-nurseries was envisaged for rearing fish fry up to fingerling sizes. The initial capital investment is borne by ARDQIP on the condition that the CBOs must pay back the total amount in 60 instalments to NAQDA (Anon., 2006b). Presently, twenty one (21) mini-nurseries are fully operational. Details of mini-nurseries in operation as of 2005 are given by Weerakoon (2007).

2.2 Contribution of CBF to total inland fish production

Until 2004, national fish production statistics in Sri Lanka is reported in three sub-sectors namely: coastal marine fish production, offshore/deep sea fish production and inland fish production. Since 2005, inland fish production has been reported as (i) inland capture fisheries production; (ii) culture-based fisheries in seasonal reservoirs; and (iii) coastal aquaculture production. Although stocking of minor perennial reservoirs commenced in 2004 as a means of inland fisheries enhancement, CBF production from minor perennial reservoirs is not reported separately, but included within the category of inland capture fisheries production.

In the present review, an attempt was made to deduce CBF production of minor perennial reservoirs (Table 2) on the basis of published information on fish stocking (Anon., 2009) and average fish production (Pushpalatha and Chandrasoma, 2010). In 2009, it was envisaged that 7.75 million fingerlings be stocked in minor perennial reservoirs. With the average stocking density of 750 fingerlings per ha, the cumulative extent of minor perennial reservoirs to be stocked in 2009 could be deduced as 10 330 ha. As the average CBF production in minor perennial reservoirs is 208 kg ha^{-1} yr^{-1} (Pushpalatha and Chandrasoma, 2010), the total CBF production from minor perennial reservoirs in 2009 will be in the order of above 2 000 tonnes.

Table 2. Annual CBF production of minor perennial reservoirs as deduced from the available information

	2007	2008
Number of fingerlings stocked in minor perennial reservoirs (x 10^6)[a]	4.61	5.70
Estimated total extent of minor perennial reservoirs stocked (ha)[b]	6 147	7 600
Estimated CBF production from minor perennial reservoirs (tonnes)[c]	1 279	1 581
Total inland capture fisheries production (tonnes)[a]	30 200	37 170
CBF production from minor perennial reservoirs as a percentage of total inland capture fisheries production	4.24	4.25

[a] *Source* – Anon., 2009; [b] Estimated on the basis of average stocking density of 750 fingerlings in minor perennial reservoirs; [c] Estimated assuming average CBF production of minor perennial reservoirs as 208 kg ha^{-1} yr^{-1} (Pushpalatha and Chandrasoma, 2010).

The annual CBF production from seasonal reservoirs in 2007-2008 was in the range of 4 600-5 100 tonnes (Anon., 2009), forming 12.0-13.2 percent of total inland fisheries production. With the estimated total CBF production from minor perennial reservoirs of about 1 500 tonnes (Table 2), total CBF production in the country is about 6 600 tonnes. Accordingly, inland fisheries resources enhancement (i.e., CBF) can be considered to account for about 17 percent of inland fisheries production in the country (Figure 2).

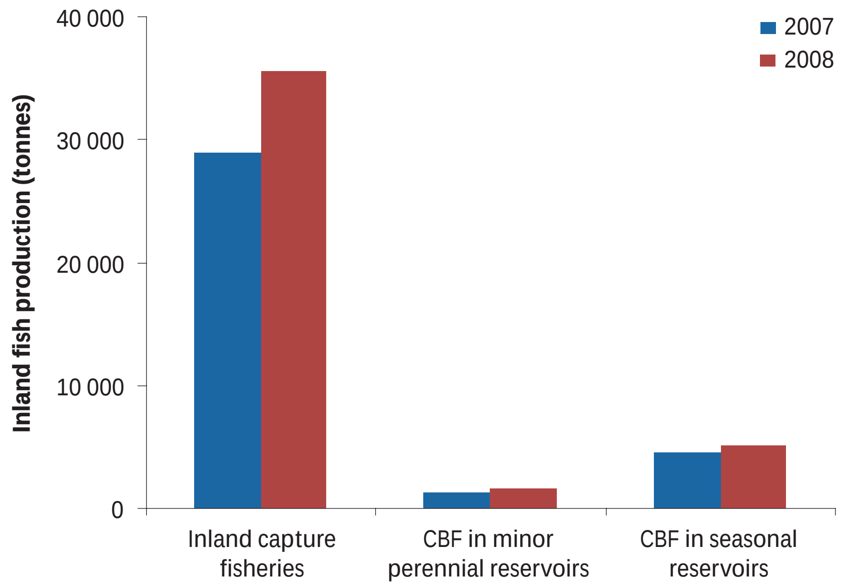

Figure 2. The annual inland fisheries production from capture fisheries and culture-based fisheries during 2007-2008

2.3 Rationale and purpose of inland fisheries enhancement

Under the "Ten Year Development Policy Framework of the Fisheries and Aquatic Resources Sector 2007-2016" (Anon., 2007), it has been targeted that inland fisheries and aquaculture production in Sri Lanka be increased from the figure of 36 530 mt in 2006 to 74 450 mt in 2016. To achieve this target of 104 percent increase, the following strategies have been identified.

- Increase fish production in minor perennial reservoirs and seasonal tanks through culture based fisheries;
- Increase Indian carp production through stock enhancement programs in major and medium perennial reservoirs;

- Increase supply of fish seed for stock enhancement by rehabilitating Government centres and construction of mini nurseries to be operated by Community-based Organizations (CBOs);
- Strictly implement community based fisheries management in perennial reservoirs;
- Promote the efficient collection of catch statistics from perennial reservoirs;
- Promote commercial aquaculture through public/private sector participatory demonstration projects in collaboration with SME banks;
- Promote carp culture in estate tanks; and
- Undertake aquaculture research and development in collaboration with research agencies.

The ADB funded ARDQIP project (2003-2009) has been instrumental in implementing many of the above strategies. Under this project, physical facilities in AQDCs were improved for facilitating induced breeding of major carps, and rearing of postlarvae, fry and fingerlings. For inland fisheries enhancement in seasonal and minor perennial reservoirs, social mobilization and enterprise development activities were undertaken in rural areas, through the aquaculture extension mechanism of NAQDA.

2.4 Technicalities in fisheries enhancement

As in any rural aquaculture scheme, one of the major pre-requisites for sustainability of CBF in village reservoirs of Sri Lanka is the availability of fish fingerlings in sufficient quantities at the correct time. Realizing this regional issue, attempts have already made to evaluate the current constraints and challenges faced by the inland fisheries sector in the tropical region by identifying measures that would contribute to the sustainable development of this sector (Bondad-Reantaso, 2007).

The main technology of producing seeds of major carps in the hatcheries of AQDCs is induced breeding with the use of Ovaprim, Sufrefact, Human Chorionic Gonadotropin (HCG), Luteinizing Hormone Release Hormone Analog (LHRH Analog) and Pituitary Glands (PG) (Weerakoon, 2007). The trained aquaculturists in the AQDCs are responsible for the whole process in AQDCs including broodstock management, hatchery management, larval rearing and feeding.

2.5 Operational aspects

Prior to 1990, fingerlings were issued to fisheries societies and farmers free-of-charge for fisheries enhancement in inland reservoirs (Amarasinghe, 1995; Weerakoon, 2007). Currently, the mini-nurseries established by CBOs purchase fish fry from AQDCs at the rate of SLRs. 0.25 per fry (In December 2009, US$1 = SLRs. 114). Selling fish fry and fingerlings to stakeholders has been a recent development following a policy decision taken by NAQDA after its establishment in 1998 (Weerakoon, 2007). The fingerlings are sold at the unit price of SLRs. 2.00 per fingerling.

The aquaculture extension officers of NAQDA and several NGOs have been conducting awareness programs to educate rural farmers on CBF management and development of business plans (Weerakoon, 2007). Due to the creation of demand for fish fry and fingerlings through this process, normal market forces of demand and supply govern the process of seed supply for enhancement strategies. Seasonality of induced breeding in AQDCs associated with the gonad maturity cycles of broodstocks however, restricts supply of fish fry in spite of peak demand.

3. CURRENT PRACTICES OF INLAND FISHERIES ENHANCEMENT

In Sri Lanka, inland fisheries enhancement strategies involve CBF development in non-perennial (seasonal) reservoirs and minor perennial reservoirs (<250 ha). In these two categories of reservoirs, two different types of fisheries enhancement activities are practiced. The features of enhancement strategies and regulatory measures in the two types of reservoirs are given in Table 3.

Table 3. The features of enhancement strategies and regulatory measures in the two types of reservoirs in Sri Lanka

	Non-perennial reservoirs	**Minor perennial reservoirs**
Ownership and jurisdiction of water uses	Agrarian Development Department; Farmer organizations	Irrigation Department or Agrarian Development Department; Farmer organizations
Responsible community group for CBF	Agricultural farmers (traditionally non-fishers)	Agricultural farmers (traditionally non-fishers) and/or fishers
Stocking density (nos/ha, yr)	2 000-2 500	217-870
Stocking size (cm)		
Major carps	5-6	5-6
Nile tilapia	6-8	6-8
Stocking frequency	After peak rainy season in November-January	Once a year when fingerlings are not needed for stocking seasonal reservoirs
Harvesting	During dry season; complete harvesting	Year-round harvesting of surplus biomass
Harvesting methods	Seining; gillnetting, cast netting	Gillnetting (8.5-20 cm mesh)
Management	Farmer organizations (FOs)	Farmer organization/fishers
Funding for CBF	Revolving fund raised by the FO	Revolving fund raised by the FO/fisheries society

Sources of information: De Silva *et al.,* 2006; Pushpalatha and Chandrasoma, 2010.

The majority of village reservoirs which are suitable for fisheries enhancement through the development of CBF are controlled and managed by farmer organizations, whose legal status is assured by the Department of Agrarian Development (DAD). The minor perennial reservoirs (<250 ha) are under the jurisdiction of either the Department of Agrarian Development or the Department of Irrigation (DI). In each village, agricultural farmers are organized into 'Farmers organizations' (FO), formed under the provision of the Agrarian Development Act. The village reservoirs are traditionally used for irrigation and various other communal activities. The other economic activities such as CBF development in village reservoirs are therefore needed to be carried out within the constraints of multiple uses of water resources.

Divisional Agriculture Committees (DvACs) are responsible for coordinating fisheries and agriculture activities in villages. DvACs are presided by the Divisional Secretary (DS). DOs, local technical officers and the office bearers of the FOs also attend these meetings, so that there is a grass-root level involvement in making decisions over the management of village reservoirs. The Aquaculture Extension Officer (AEO) of NAQDA is also invited to attend the monthly meetings of DvAC. There are legal provisions for various rural development activities through the FOs, under the Agrarian Development Act No. 46 of 2000 (Anon., 2000), which include provisions for the development of CBF in village reservoirs.

After the 13th amendment to the Constitution in November 1987, provincial councils were established for decentralization of administrative powers. The fisheries authorities of the provincial councils are also engaged in inland fisheries enhancement through stocking village reservoirs. Due to inadequacies in extension mechanisms in the fisheries authorities of provincial councils, and lack of coordination with the central government (i.e., NAQDA), in some instances there is a conflict of interest between the provincial authorities and the central government.

As CBF falls within the realm of aquaculture (De Silva, 2003), defining ownership of the CBF system is a prerequisite for sustainability. Under Section 39 of the Fisheries and Aquatic Resources Act No. 2 of 1996 (Anon., 1996a) and amended act No. 22 of 2006 (Anon., 2006c), there is a provision for licensing aquaculture enterprises. Under these legal provisions, aquaculture management regulations were implemented in 1996 (Anon., 1996b). From the conservation point of view, there are legal provisions to protect fish and aquatic resources from harmful fishing methods and to regulate export and import of fish under the same act. The export and import of live fish regulations (Anon., 1998b) that specify the species of live fish that cannot be exported, species of live fish that may be exported with a license issued by the Director, and species of live fish that cannot be imported.

3.1 Seasonal reservoirs

In the 1980s, CBF development activities were carried out by the Inland Fisheries Division of the Ministry of Fisheries, in seasonal reservoirs in many parts of the dry zone of the country. This strategy was essentially based on considerable government inputs such as supplying fingerlings free-of-charge for stocking and direct involvement of fisheries officials at all stages from stocking to harvesting. This activity came to a standstill after discontinuation of the state patronage for inland fisheries development in Sri Lanka in 1990 in the absence of the monitoring procedure by the centralized management unit (i.e., Inland Fisheries Division of the Ministry of Fisheries) and lack of subsidized fingerling supply for stocking. Also as mentioned by De Silva (2003), non-availability of effective procedures for selecting suitable reservoirs for CBF and determining appropriate stocking densities based on biological and socio-economic criteria, lack of means of fingerling production and over-emphasis on the biology of reservoirs, are also largely responsible for poor performance of CBF in seasonal reservoirs.

The ACIAR-funded project mainly focused on the development of holistic management strategies for CBF in village reservoirs incorporating biological, physical and socio-economic factors. Accordingly, attempts were made to develop a suitable ranking system or a scale, taking into consideration aspects such as the physico-chemical, biological, catchment and hydrological characteristics of the water bodies, as well as socio-economic aspects (De Silva *et al.,* 2005). Jayasinghe *et al.* (2005a, 2005b, 2006) have shown that it would be possible to classify non-perennial reservoirs in Sri Lanka based on the limnological attributes such as Secchi disc depth, total phosphorus, chlorophyll-*a* and organic turbidity as well as reservoir morphology measured as shoreline/area ratio, in order to develop CBF. Due to natural recruitment of carnivorous fish species (such as *Ophiocephalus striatus, Mystus keletius*) from associated waterways into village reservoirs which do not dry up completely, CBF harvests of stocked species are low due to their high predation (Wijenayake *et al.,* 2005). It has also been found that socio-economic characteristics favouring collective decision making for CBF development included good leadership of officers in the society, high percentages of active members with common interest and high degree of participation in collective work, small group size and high percentage of kinship in the group (Kularatne *et al.,* 2009).

All the agricultural farmers have to cooperate in CBF in village reservoirs. These agricultural farmers are traditionally non-fishers. They have adopted CBF through adaptive learning. This participatory involvement of rural farmers is essentially the social capital in CBF that cannot be given a monetary value.

The CBF production in 120 reservoirs from 8 administrative districts during 2007 (Dr D.E.M. Weerakoon, pers. comm.) indicated that CBF yield varied from 14 kg/ha in Halmilla wewa in Kurunegala district to 2300 kg/ha in Ratapera wewa in Badulla district. Stocking densities ranged from 111 fingerlings/ha in Bayawa wewa to 4 115 fingerlings in Ganegoda wewa both in Kurunegala district. Indian major carps, common carp and bighead carp have mainly contributed to CBF harvests in seasonal reservoirs.

3.2 Minor perennial reservoirs

The demand for fish fingerlings for CBF development in seasonal reservoirs exists only after the peak rainy period in November-January in the dry zone of the country. As such, fingerlings that are produced during the seasons when not required for stocking seasonal reservoirs can be used for CBF development in minor perennial reservoirs. Water management in these reservoirs comes under the jurisdiction of either Irrigation Department (those with command area of over 80 ha) or Department of Agrarian Development (those with command area of <80 ha).

In 2003, Ministry of Fisheries and Aquatic Resources (MFAR) of Sri Lanka initiated through ARDQIP, a program to introduce CBF in minor perennial reservoirs (<250 ha). In most of these reservoirs, only subsistence level fisheries existed. There had been neither stocking nor proper management of fisheries in minor perennial reservoirs (Pushpalatha and Chandrasoma, 2010).

Pushpalatha and Chandrasoma (2010) listed the following physical, biological and socio-economic criteria for selection on minor perennial reservoirs for fisheries enhancement.

- Water spread at full supply level to be between 50-250 ha;
- Retention of sufficient water in the reservoirs to sustain CBF during dry seasons;
- Absence or low abundance of rooted or floating aquatic macrophytes;
- Absence or less abundance of impediments for fishing such as submerged decaying tree stumps;
- Location of reservoir in the vicinity of the village community and close proximity to markets;
- Absence of major conflicts among water users;
- Concurrence of FO with fishers for CBF development; and
- Willingness of the community to be engaged in CBF.

Under the ARDQIP project, fisheries enhancement commenced in 15 minor perennial reservoirs in 2004. In these reservoirs CBOs were formed or re-organized and the members of CBOs were given training in basic aspects of CBF including community-based management, leadership, simple accounting, book keeping etc. The members of each CBO, with the assistance of aquaculture extension officers, prepared a plan for the development of CBF. This included agreements on fish species to be stocked (based on the consumer preferences and availability of seeds), stocking densities to be adopted, time for stocking, sources of fish seed, and CBF management measures to be adopted.

Species stocked were *C. catla*, *L. rohita* and *O. niloticus*. In some reservoirs, CBOs stocked *M. rosenbergii* and *C. carpio*. According to the records maintained by CBOs in the 15 reservoirs for 2004-2007 period (gleaned by the author), annual stocking density (SD) ranged from 146 fingerings per ha in Mahagal wewa in 2004 to 2780 fingerlings per ha in Ranawa in 2006. There was a positive second order relationship (although not significant at 0.05 probability level (r = 0.35; p >0.05)), between the mean SD during 2005-2006 to mean annual fish yield during 2005-2007 (Figure 3), indicating that the optimal SD for minor perennial reservoir for fisheries enhancement is about 814 fingerlings per ha.

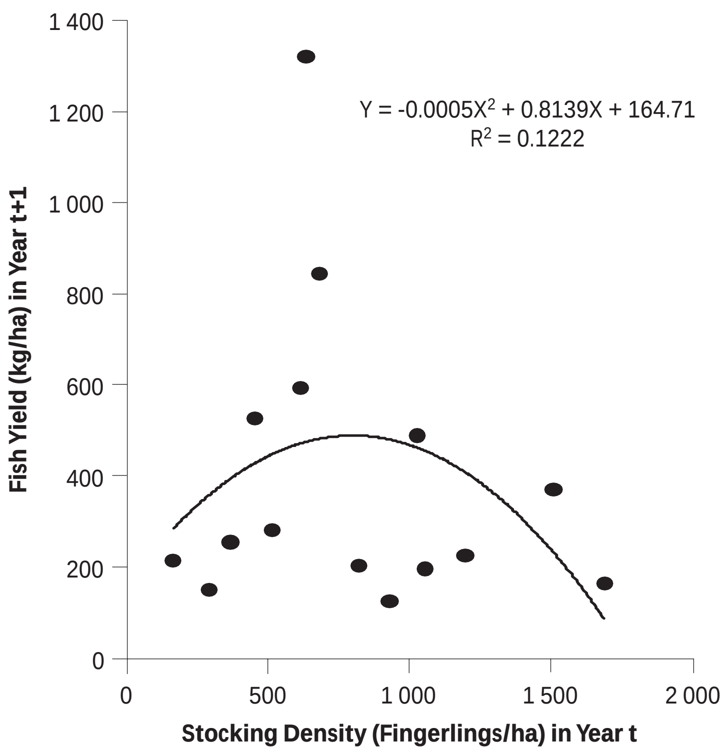

Figure 3. The relationship between mean SD during 2005-2006 (time t) and mean annual fish yield during 2005-2007 (time t+1) in minor perennial reservoirs (Source of data: Pushpalatha and Chandrasoma, 2010).

Unlike in seasonal reservoirs, harvesting of fish in minor perennial reservoirs is a year-round activity. Fishers working on non-mechanized canoes (2 fishers per canoe) use gillnets of stretched mesh sizes ranging from 8.5 to 20 cm. In all non-perennial reservoirs where CBF were introduced, *O. niloticus* was the most abundant species forming over 80 percent of the landings, prior to introduction of CBF. Other important species were *Channa striata, Clarias brachysoma, Anabas testudineus, Trichogaster pectoralis* and *Mystus keletius*. According to Pushpalatha and Chandrasoma (2010), *O. niloticus* continued to be the highest contributor to the harvest, even after the introduction of CBF. In the 15 reservoirs studied, mean annual contribution of *O. niloticus* to the CBF harvest was 47.4 percent (ranging from 19.7 to 66.5 percent). The overall mean contributions of three species of exotic carps namely *C. catla, L. rohita* and *C. carpio* were 27.2, 16.9 and 4.3 percent, respectively. Pushpalatha and Chandrasoma (2010) further indicated that in 11 reservoirs where *Macrobrachium rosenbergii* was also stocked, its mean contribution to the harvest was 0.7 percent. Pushpalatha and Chandrasoma (2010) reported that percent increase in mean annual fish production due to introduction of CBF ranged from 42.8 to 1 344 percent, with an overall average increase of 263 percent. Prior to introduction of CBF, mean annual fish yield in the 15 reservoirs was 57.3 kg ha^{-1} and after introduction of CBF, it increased up to 208 kg ha^{-1}.

3.3 Major reservoirs

The inland fisheries production from major reservoirs (>750 ha) is essentially a capture fishery, based on the natural recruitment of feral fish populations. The fishery is based on two exotic species, *O. mossambicus* and *O. niloticus*, which form over 70 percent of the landings. As mentioned earlier, in recent years state-sponsored stocking programs are being carried out in these large reservoirs.

4. REGULATIONS FOR MANAGEMENT AND CONSERVATION

Fisheries enhancement in seasonal reservoirs through introduction of CBF is essentially a secondary use of small-sized village reservoirs, which have not been traditionally used for fish production (Amarasinghe and Nguyen, 2009). CBF in village reservoirs is essentially practised by agrarian communities rather than fishers, although this strategy is advanced by the fisheries sector institutions. As the village reservoirs (with command area of less than 80 ha) come under the jurisdiction of Department of Agrarian Development, legal provisions in the Agrarian Development Act No. 46 of 2000 for incorporating fisheries and aquaculture aspects in reservoir management, facilitate fisheries enhancement.

The *Kanna* meeting (a community meeting held at the beginning of the cropping season) of the FOs is held at the onset of cultivation season and is facilitated by the Agrarian Research and Production Assistant (ARPA) of the DAD. The major purposes of this meeting include, planning of agricultural activities and making collective decisions that cannot be changed by individuals until the end of the cultivation seasons, unless there is any special circumstance. In addition, important decisions on CBF activities are also made. In most instances, aquaculture management committees (AMCs) are established among FOs. For CBF activities, strategies for stocking, guarding and harvesting are decided. The members also arrive at agreements on sharing of CBF profit between fish farmers and agricultural farmers. Levy paid by AMC to FOs is generally about 5 percent of the profit. FOs use this income for rehabilitation work in the reservoir. Hence, unlike in capture fisheries in major reservoirs with co-management strategies (Amarasinghe and De Silva, 1999) where the fishers use the resource on individual basis, in CBF group members become partners in a community-managed enterprise of which benefits are shared on agreed basis.

Aquaculture Management Regulations of 1996 (Anon., 1996b), imposed under the Fisheries and Aquatic Resources Act of 1996, made it possible to obtain aquaculture licenses for CBF in seasonal reservoirs. This assures ownership of stocked fish so that poaching can be effectively prevented.

In minor perennial reservoirs, fishers have to adhere to fisheries regulations of Fisheries and Aquatic Resources Act of 1996 (Anon., 1996a). Accordingly, fishers use only gillnets of stretched mesh sizes above 8.5 cm. The fishing gear that are forbidden in inland capture fisheries of Sri Lanka (i.e., mono-filament gillnets, trammel nets, surrounding nets and seine nets) are not used in minor perennial reservoirs. Pushpalatha and Chandrasoma (2010) have reported that certain CBOs introduced larger mesh (>11.5 cm) gillnets and declared closed seasons.

From the conservation point of view, (De Silva 2003), CBF development in seasonal reservoirs is environmentally friendly because this strategy involves use of existing waters with minimal external inputs such as artificial feeds.

Most seasonal reservoirs do not harbour any indigenous fish, except in some reservoirs where puddles of water remain during dry seasons supporting survival of some indigenous species such as *C. striata, A. testudineus, M. vittatus* and *M. keletius*. Also in minor perennial reservoirs, indigenous fish species that are present are essentially riverine species, which utilize lacustrine environments in reservoirs as feeding grounds (Amarasinghe and Weerakoon, 2009). However, these species, according to IUCN criteria, are not considered as endangered, threatened or vulnerable species (IUCN Sri Lanka and the Ministry of Environment and Natural Resources, 2007). Although it has been recognized that displacement of native species is a negative impact of CBF (Gutiérrez and Reaser, 2005), hitherto this has not been a serious issue in Sri Lanka. This is especially due to the fact that there is clear habitat segregation between indigenous and endemic freshwater fish species, which thrive in riverine habitats and exotic fish species that are stocked in seasonal and minor perennial reservoirs for fisheries enhancement. Nevertheless, as most reservoirs have connections with rivers and streams, and as all exotic carp species are known to be riverine species, impact of exotic species on freshwater biodiversity in riverine habitats cannot be simply negated. Further studies on the impact of alien species are therefore warranted.

5. IMPACT ASSESSMENT

The enactment of the National Environment Act (NEA) in 1980, which was amended by Act No. 46 of 1980, Act No. 58 of 1988 and Act No. 53 of 2000, included a provision for the environmental impact assessment (EIA) process. Also under the Coastal Conservation Act, amended Fauna and Flora Protection Ordinance, Northwestern Provincial Council Environmental Statute No. 12 of 1990 and National Heritage and Wilderness Act, there are provisions to further strengthen regulations of the EIA process. The EIA process under the NEA however, applies only to 31 categories of projects termed as "Prescribed Projects", which have been specified and gazetted by the Minister of Environment. Fisheries related projects are also included under this category. In addition to these prescribed projects, those which fall within a declared environmentally sensitive area (e.g., wildlife sanctuary, nature reserve), irrespective of magnitude, are required to undergo EIAs.

The Central Environmental Authority of Sri Lanka is responsible for executing NEA and delegates the responsibilities of evaluation of environmental impact to various government agencies depending on the project. The evaluating agency is referred to as project-approving agency (PAA). When the PAA is also the project proponent, the CEA designates an appropriate PAA and in the event of doubt or difficulty in identifying the appropriate PAA, CEA plays the role of PAA. For fisheries-related projects, PAA is essentially the MFAR. However, according to Gazette notification of "Prescribed Projects" fisheries-related projects which require EIA are restricted to, (i) Aquaculture development projects exceeding 4 ha; (ii) Construction of fisheries harbours; and (iii) Fisheries harbour expansion projects involving an increase of 50 percent or more in fish handling capacity per annum.

In the EIA procedure in Sri Lanka (CEA, 1998, 2003), the project proponent (PP) has to submit preliminary information to the CEA. Upon receiving this preliminary information, the appropriate PAA conducts a scoping study and decides whether an EIA is required. If the proposed project is less damaging, an initial environmental evaluation (IEE) is sufficient. It must be noted however, that the EIAs reported from Sri Lanka do not include quantitative and testable predictions of impacts, which are useful for post-impact monitoring programs (Samarakoon and Rowan, 2008). Samarakoon and Rowan (2008), who reviewed environmental practices in Sri Lanka, have indicated that in most environmental impact statements, the ecological impact assessment was restricted to tokenistic presentation of reconnaissance-level species lists without further analysis of the development implications for individual organisms or communities. As such, the effectiveness of implementation of Sri Lanka's EIA procedure to assess the impact of fisheries enhancement on biodiversity is questionable.

However, for CBF activities in Sri Lanka, no impact assessment is carried out. Apparently, CBF is considered as an activity that does not have significant negative environmental impacts. However, as mentioned above, there may be negative environmental impacts on the biodiversity due to introduction of exotic species. Furthermore, as a result of introduction of CBF in village reservoirs, rural communities have benefited.

As a means of biodiversity conservation, the live export of 13 endemic freshwater species is prohibited to be exported in live form (Anon., 1998b). Under the same regulations, 8 endemic freshwater fish species are restricted from export in live form which requires obtaining permits for export. They were declared as protected species on the basis of available scientific information on their conservation status. However, as mentioned above, the preferred natural habitats of all these endemic species are hill-country streams (Kortmulder, 1987; Amarasinghe *et al.,* 2006). As such, there are no apparent adverse impacts of fisheries enhancement practiced in low-country reservoirs, on freshwater fish biodiversity conservation.

6. CONSTRAINTS AND PROBLEMS ASSOCIATED WITH INLAND FISHERIES ENHANCEMENT

6.1 Technical constraints

Major technical constraints to the CBF development include lack of adequate supply of fish fingerlings at the correct time. Of the inland reservoirs numbering over 10 000, only 745 reservoirs (12.7 million fingerlings) in 2007 and 611 reservoirs (16.1 million fingerlings) in 2008 were stocked (Anon., 2009). This low percentage of reservoirs stocked was due to inadequate supply of fingerlings and probably insufficient extension mechanisms.

6.2 Operational constraints

6.2.1 Policy level

In village reservoirs, which come under the jurisdiction of DAD fisheries and CBF development is still not a high priority area. As CBF development is carried out by NAQDA under its mandate, DAD has less responsibility to get involved in CBF activities. Active involvement of Agrarian Research and Development Assistants of DAD in CBF activities would facilitate the process.

In addition, provincial councils are also involved in stock enhancement activities. The strategies that are adopted by fisheries authorities of provincial councils are quite different from those of the central government. Generally, establishment of CBOs is not practised by the fisheries authorities of provincial councils and as a result, CBF activities in reservoirs where provincial councils are involved are in a poor state. Active involvement of FOs in CBF is an essential pre-requisite for its sustainability because ownership of stocked fish is assured through this process. Stocking of fish fingerlings as part of political agenda of the provincial councils has not been an effective means of CBF development.

In minor perennial reservoirs, fisheries enhancement is essentially carried out by professional fishers. NAQDA's involvement for mobilizing the fisher communities through preparation of CBF management plans helps significantly for its sustainability. As fishers have experienced socio-economic benefits of these enhancement strategies, continuous demand for stocking materials prevails in many minor perennial reservoirs of the country.

6.2.2 Resource availability and cost sharing

The costs involved in CBF in seasonal reservoirs include cost of fingerlings (unit price of Rs. 2.00 per fingerling, which has been fixed by NAQDA), cost of packing, transport, aquaculture license fee, cost of guarding stocked fish, hiring seine nets for harvesting, and levy paid to farmer organizations of the reservoir by the aquaculture committee. However, in 2009, as part of the state-sponsored program for food security, fingerling supply was subsidized and commencing January 2009, fingerlings supplied free-of-charge for stocking inland waters. Levies paid by AMC's (generally about 5 percent of profit) to FOs are generally used for rehabilitation works in the village reservoir.

6.3 Distribution of social benefits

Amarasinghe and Nguyen (2009) examined financial benefits of CBF in 23 seasonal reservoirs. The farm-gate price per kg of fish ranged from Rs. 30 to Rs. 75. From every harvest, villagers took fish for home consumption. Especially in reservoirs with rich harvests, aquaculture committees gave villagers fish free-of-charge. However, this portion of the harvest was significant and ranged from 3 to 47 percent. Considering the value of the 'home-consumption' portion of the harvest (i.e., subsistence harvest), as determined on the basis of farm-gate value of fish, the net profit ranged from SLRs. 47 372 to SLRs. 729 339 (In December 2009, US$1 = SLRs 114). Of the 23 reservoirs sampled, net profit in 17 reservoirs was above SLRs. 100 000. CBF development in seasonal reservoirs is essentially associated with rainfall patterns in the dry zone of Sri Lanka. Accordingly, harvesting is also necessarily bound with the dry season when the receding water levels prevail in these reservoirs. The peak CBF production in seasonal reservoirs occurs in the August-October period because it is the harvesting period in all seasonal reservoirs utilized for CBF. De Silva (1988, 2003) advocated staggered harvesting of CBF production to prevent flooding of markets within a short period as well as to reduce size variation of the harvest.

Normally, the AMC in each village reservoir where CBF is practiced consists of around 10 members (Kularatne *et al.,* 2009). This membership is less than 10 percent of the FO. As such, the financial benefit the AMC gains from the CBF activities results in unequal distribution of benefit. However, establishment of AMCs for CBF development in the village reservoirs assures that those who reap the benefits bear the costs. This process is analogous to allocation of community transferable quotas in fisheries management, where social impacts due to individual benefits are minimized (Wingard, 2000). Introduction of a rotational system for sharing benefits among all members of FO from year to year would further ensure benefiting all members.

6.4 Ecological impacts of enhancement strategies

As inland fisheries enhancement is essentially based on exotic species, there may be negative impacts of released animals on the genetic biodiversity of the natural populations. However, no attempts have been made in Sri Lanka to investigate such impacts. In Sri Lanka, inland fisheries enhancement activities are conducted in quasi-natural water bodies. As De Silva and Funge-Smith (2005) mentioned, the impact of exotic species used in enhancement activities on the biodiversity of indigenous flora and fauna of these artificially created water bodies cannot be strictly considered to be serious. When the exotic species and indigenous species share food resources with great abundance, competition between exotic and native species is unlikely (Weliange and Amarasinghe, 2003).

7. RECOMMENDATIONS

- Fisheries enhancement in inland waters of Sri Lanka is successful in small village reservoirs and minor perennial reservoirs (<250 ha). De Silva and Funge-Smith (2005) have shown that stock enhancement in large lacustrine water bodies has not been successful except in a few cases. The enhancement strategies should therefore be restricted to small, village reservoirs and minor perennial reservoirs, at least until the outcomes of stocking of large reservoirs is evaluated and until the constraints such as inadequacy of fingerlings are overcome.

- Density-dependent growth and size-dependent mortality of stocked fish in CBF activities in small water bodies are shown to influence CBF yields (Lorenzen, 2001). Further studies on this line are therefore warranted for optimizing CBF yields in minor perennial reservoirs.

- As there is an increasing demand for fingerlings for enhancement activities, expansion of fingerling production is necessary. In most Asian countries backyard fish hatcheries are common for the propagation of Chinese and Indian major carps. As such, transfer of this technology would be useful for sustaining CBF in the small reservoirs of Sri Lanka. Furthermore, establishment of backyard hatcheries for propagation of major carps would provide rural communities with additional household income.

- At the full pace of CBF development in village reservoirs as envisaged in the ten year development policy framework of the fisheries and aquatic resources sector of Sri Lanka (Anon., 2007), there will be a possibility of surplus production flooding of the market. De Silva (1988) and De Silva and Funge-Smith (2005) suggested that this problem can be addressed through the introduction of planned, staggered harvesting, inter-community cooperation and improved market channels.

- Impact of stocking of exotic species on biodiversity should also be a major concern in fisheries enhancement strategies.

- Development of processing methods of the species commonly used for CBF is also an important subject for further investigation. It will help preventing flooding of the market during a concentrated harvest period. Furthermore, it may expand consumer acceptability of the product.

- CBF activity is still considered as a secondary use of reservoirs with low priority relative to irrigation. Quantification of benefits from multiple uses of village reservoirs might therefore be useful for convincing mid-level officials about the advantages of CBF development for improving livelihoods of rural communities. Also, as social traditions still prevail as integral parts of rural living, this sociological aspect should be a priority area to be considered in fisheries enhancement in village reservoirs. In some Sri Lankan rural communities, in spite of the obvious benefits from CBF, traditional practices among communities associated with religious beliefs, prevent CBF development.

- Lack of knowledge about the appropriate species combinations of stocked fish might result in sub-optimal utilization of biological productivity. Development of appropriate models for optimizing CBF yields therefore warrants further investigations.

- Development of low-cost feed from minor cyprinids using appropriate technology at affordable prices therefore encompasses two aspects. First, this approach supports economic viability of fingerling rearing for CBF development. Secondly, exploitation of hitherto unexploited fishery resource from Sri Lankan reservoirs will ensure more complete utilization of biological productivity, as mentioned by De Silva and Sirisena (1987), Amarasinghe (1990) and Pet *et al.* (1996).

- Community mobilization for fisheries enhancement is gradually taking a good shape in some parts of the country. Stock enhancement practices should not however be used for the sole purpose of political gain because such practises are bound to be unsustainable (De Silva and Funge-Smith, 2005). Further strengthening of extension mechanisms is therefore much needed and the NGOs can play a major role in this regard.

- As there are different administrative bodies responsible for reservoir uses other than fisheries, there is a poor coordination of the stocking of fingerlings with water release schedules. At least in one minor perennial reservoir (Kimbulwanaoya reservoir in Kurunegala district), with the permission from irrigation authorities, an effective netting structure is installed by fishers near the sluice gate to prevent the loss of stocked fish. According to fishers, this has considerably increased CBF yield in the reservoir (personal observations). However, no quantified data are available for evaluating impact of installation of such structures. Collection of such data is suggested to evaluate the effectiveness of such structures. As practised in Kimbulwanaoya reservoir, fishers can bear the cost of installation.

- Generally, information on economic analyses of fisheries enhancement is poor and such information will be useful for mobilizing communities. Recently under the ARDQIP, NAQDA has introduced a procedure to prepare a business plan associated with CBF, although at present in a somewhat crude form. Proper information on the economic viability of fisheries enhancement in different types of reservoirs in different geographical regions can be used for refining such business plans.

- Although there are legal provisions for conducting impact assessment for inland fisheries enhancement, such exercises are not carried out in Sri Lanka. Strategic environmental assessment (SEA) is also the process for assessing, at the earliest possible stage, the environmental impacts of decisions made from the policy level downwards. As Samarakoon and Rowan (2008) recommended, introduction of SEA is important to strengthen institutional capacity of government institutions of the country to implement current regulations. SEA is a promising means to strengthen awareness of biodiversity conservation issues in the context of national priorities in terms of social and economic development.

- The ecosystem approach to fisheries and aquaculture addresses both human and ecological well-being (Staples and Funge-Smith, 2009). As such, studies towards this direction in fisheries enhancement and conservation strategies are useful to combine two important aspects that are of ecological and societal interest. Here, a balance is achieved between conservation of biodiversity and ecosystem functioning, and improvement of livelihoods and provision of food through fishery resources enhancement.

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INLAND FISHERY RESOURCE ENHANCEMENT AND CONSERVATION IN THAILAND

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Abstract

The production from inland capture fisheries in Thailand is about 1 million tonnes per annum. To sustain this production, various types of resource enhancement and conservation practices have been implemented. Engineering the environment and fish stocking are the two major practices adopted, and closed-season fishing as well as control of fishing gears are used for conservation purposes. Fish stocking programs date back to the 1950s have been continuously conducted. Fish stocking programs are totally subsidized by the government and the stocked species include indigenous and exotic species (Chinese and Indian major carps as well as Nile tilapia) and also giant freshwater prawn. Exotic fish are commonly stocked in village ponds and show good returns both in terms of production and economics. On the other hand, stocked exotic fish in large water bodies contribute a small proportion of the catches. Stocking of giant freshwater prawns however, resulted in significant increase in economic returns even though recapture rate was low (<1 percent). Conservation measures are not entirely successful since violations are common unless there is a significant investment in patrolling.

No significant impacts of stocked fish on the ecosystem were observed in terms of native fish species richness and diversity indices. However, it is experienced that stock enhancement using hatchery populations has led to loss of genetic variation and genetic identity of wild populations. The major constraint, to better practices, is the institutional aspect. This is because people are not aware on the importance of these issues with very low levels of user participation. Limited understanding of the wider set of ecosystem processes of these stocked water bodies is also a major constraint to improved enhancement. Options to improve both practices are discussed and new directions recommended.

Key words: Inland fisheries, Resource enhancement, Conservation, Operation, Assessment and evaluation, Thailand

1. INTRODUCTION

1.1 Inland fisheries in Thailand

Thailand has an extensive inland water area of about 4.5 million ha consisting of about 4.1 million ha of natural water bodies (i.e. rivers, lake and swamps) and about 0.4 million ha of reservoirs. There are 47 major rivers in seven major river basins *viz.*, Chao Phraya Basin, Mekong Basin, Eastern Basin, Southern Basin, Salween Basin, Mekhlong Basin and Tenasserim Basin (Jutagate, 2009). Songkhla Lake (96 000 ha is the only freshwater/brackishwater) lake in the south and three large natural lakes include Beung[1] Borapet (13 000 ha) in the Central Region, Nong Harn (12 500 ha) in the Northeastern Region and Kwan Payao (2 100 ha) in the Northern Region (Pawaputanon, 1992), meanwhile about 8 000 swamps are ubiquitous country-wide (Bhukaswan, 1985). Most of the Thai reservoirs were impounded in the second half of the 20th century (De Silva and Funge-Smith, 2005) and in 2009, there were 25 reservoirs with a surface area larger than 1 000 ha (Vongkamolchoon, 2006), of which Pasak Jolasid is the newest reservoir, impounded in 1998) (Thapanand *et al.*, 2007; 2009).

[1] "*Bueng*" means the lake surrounding by wetlands.

Thailand is recognized as having one of the most highly diverse freshwater fish fauna (573 species) in Southeast Asia with more than 150 species identified in the catches from inland waters (Vidthayanon *et al.*, 1997). Inland fisheries have been long recognized and operated in the major rivers, floodplains, canals, swamps, wetlands, lakes and reservoirs and fishing is a long standing tradition in the country (Coates, 2002). In the past there were intensive fisheries in inland water bodies and the rivers and floodplains, where approximately 90 percent of total freshwater production was derived from the flooded area (Bhukaswan, 1985). This has now declined, while production from reservoir fisheries has increased significantly. Virapat *et al.* (2000) estimated that fish production, from these reservoirs in 2000 as between 122 314 and 318 909 tonnes per year from the 28 956 reservoirs, ranging in size from 0.01 ha to more than 1 000 ha.

The inland capture fisheries in Thailand was about 5 percent of the total Asian inland capture fishery (De Silva and Funge-Smith, 2005) and the production increased over the years from about 200 000 tonnes in 1995 (Virapat and Mattson, 2001) to about 203 000 tonnes in 2004 (DOF, 2007a). Inland fisheries provide about 3 kg/caput/yr to the fish availability in the country, or about 38 percent of the availability from the total fish production in inland waters (De Silva and Funge-Smith, 2005). A more recent re-estimate of production in inland fisheries based on indicators other than catch landings indicates that inland fisheries production could be in the range of 1 016 239-1 104 401 tonnes yr^{-1} (Lymer *et al.*, 2008). This indicates that fish consumption would be about 10 kg $caput^{-1}$ yr^{-1} and significantly higher in those areas where freshwater fish consumption is more predominant.

In general, inland fishing is often not well targeted and fishers catch all species regardless of size variation (Bhukaswan and Chookajorn, 1988), except for certain fisheries such as traps for giant freshwater prawn fishery. The inland fisheries are essentially artisanal and are based mainly on the indigenous species (80-90 percent), which comprises mostly of cyprinids (e.g. carps, barbs and minnows) as well as snakeheads and catfishes (Virapat and Mattson, 2001). The composition, distribution and abundance in fish assemblages depend mainly on topographical condition and environmental factors of the water body. Various kinds of fishing gears are employed, gillnets as a common gear with mesh sizes from 2.5 to 18 cm, and 4.5 to 7.0 cm being the most popular. The larger mesh gillnets are used during the rainy season (Jutagate and Mattson, 2003). The other traditional fishing gears include longline, cast nets, lift nets, scoop nets as well as hook and lines.

1.2 History of inland fisheries resource enhancement and conservation in Thailand

Fishing is a long standing tradition in the country and is considered an integral part of the heritage and culture, particularly in rural areas (Coates, 2002). During the administrative reforms in 1901, the owners of the largest fishing gear, i.e. bag-net (Pong Pang) in the floodplains were licensed for tax collection. The tariffs are used to rehabilitate the fishing area. However, the license system was revoked to ensure a steady contribution of fish for national consumption as well as export. This could be considered as one of the first legislative attempts for management and conservation of inland fishery resources in the country.

In 1920, a decline of fish abundance was observed in the inland fisheries central area presumably due to heavy exploitation. In 1921, a unit of fish propagation and conservation was established under the Ministry of Agriculture resulting in the establishment of the "Department of Fisheries (DOF)" 1926. The DOF is responsible for protecting and conserving fishery resources and the promotion of aquaculture in the Kingdom. Since then, fish propagation, stocking and conservation programs have been applied in the country.

The Fisheries Law of 1947 was enacted for freshwater fisheries, which was the leading sector at that time. Section 32 of Fisheries Law 1947 allows the Minister/Governor to issue decrees on fishery regulations. Most of the current regulations are issued under this law. Other relevant sections are Sections 6 and 7. According to Section 6, fishing grounds are divided into four types: sanctuary, auction, permission, and public areas while Section 7 grants authority to provincial committees to announce specific fishing measures in their provinces as per approval of the Minister (Sihapitukgiat *et al.*, 2002).

The official freshwater fish stocking program, for maintaining and increasing fisheries productivity in Thailand can be dated back to the 1950s, when the program was conducted in Bhumibhol and Ubolratana reservoirs and some of the large lakes such as Kwan Payao and Beung Borapet by the Department of Fisheries (Virapat, 1993). This program had been intensified by regular stocking in large water bodies under "The Nation-wide Fish Stocking Program", in which more than 700 million fish and shellfish were stocked in about 5.6 million ha of water bodies (Bhukaswan, 1989).

2. TECHNIQUES FOR STOCK ENHANCEMENT FOR INLAND FISHERIES

2.1 Engineering the environment

The common practices are removal of aquatic weeds, clearing of accumulated bottom sediments and maintaining optimum water levels. Presently, to implement both activities, DOF manages the large swamps and lakes while the other water bodies are managed by various authorities i.e. the river and irrigation reservoirs by the Royal Irrigation Department (RID), hydropower reservoirs by the Electric Generating Authority of Thailand (EGAT) and village ponds by the sub-district administration organization in each area. Sediments and weed removal are done regularly in large water bodies and extensively for village ponds. In 2009, DOF had conducted sediment removal in the important large three lakes (see 1.1), totaling 2 450 000 m^3 and weed removal of 200 000 tonnes (DOF, 2008). Meanwhile maintenance of optimum water levels are mainly through construction of the gates in the outlet area such as the cases of Beung Borapet where the water level is maintained at +23.8 m above **MSL** (Srinoparatwatana, 2009) or 157.5 m above **MSL** for Nong Harn (Srichareondham and Ko-anantakul, 1993), with the purpose of extending the flooding area and duration of the flooded area in order to extend the production area and period.

Other examples of engineering the environment in Thailand can be listed as:

- Construction of artificial habitats or "*Baan Pla*" (*or* "fish house"): this activity is done by providing substrates for natural colonization by food organisms, which act as a refuge as well as feeding grounds (Welcomme and Bartley, 1998).
- Construction of fish passages: this construction aims to enhance the fish production, especially in the upstream area, through the construction of weirs or dam across river channel, particularly in the major rivers (Suntornratana, 2003). However, the effectiveness of the fish passage is still questioned since with many species of fish there is usually not a good fit with designs for a single type fish passage (Jutagate *et al.*, 2005)
- Fertilization: Introducing nutrients, into the ecosystem in order to boost primary productivity, to increase fish production. This activity has been widely applied particularly in village ponds with high stocking densities, in which chicken manure is usually used as the source of nutrients (ADB, 2005).

2.2 Fish stocking programs

The most recognized fisheries resource enhancement in inland water bodies in Thailand is the fish stocking program. Fish stocking is regularly employed in large water bodies for the general benefit of the open-access fishers who continue to rely on these resources (De Silva and Funge-Smith, 2005). Generally it is suggested that there are four categories of fish stocking in the country (Cowx, 1998; Welcomme and Bartley, 1998).

- Creation of new fisheries: A good example of this strategy is the stocking of giant freshwater prawn, *Macrobrachium rosenbergii* into reservoirs, large inland water bodies and rivers. This activity has been conducted over a fairly long period of time; however, reliable data on stocking are available only since 1998 (De Silva and Funge-Smith, 2005). The stocking of this species is relatively uncommon and it has to be restocked regularly since it requires brackish water in its early development stages, which is usually not available in the natural or man-made lakes in the country, except Songkhla Lake. *M. rosenbergii* has been regularly stocked in lacustrine water bodies since 1990. From 1998-2003, fifteen Thai rivers were stocked in one or more years, with nearly 70 million post-larvae.

- Compensation/mitigation: stocking for the purpose to mitigate serious disturbances of aquatic environment caused by human activities has been conducted as in the case of fish stocking in Pong and Chi Rivers (Northeastern region) after the polluted condition in both rivers in 1992 caused by the sewages from the "Pulp & Paper" company (Inland Fisheries Resources Group, 1993) and the case of Chao Phraya River in 2007 caused by the sinking of the "sugar" containers (PCD, 2007)

- Conservation: stocking to retain the endangered and threatened species is also a common practice led by DOF such as stocking of the threatened Chao Phraya giant catfish *Pangasius sanitwongsei* (Juntasutra *et al*., 1989; Hogan *et al*., 2008) and the Mekong giant catfish, *Pangasianodon gigas* (Polprasit and Tevaratmaneekul, 1997; Sriphairoj et al., 2007). Moreover, on special occasions such as on the birthday of the royal family members or religious ceremonies, there are also programs to stock Thai indigenous fishes into rivers country-wide, through a project under the patronage of Her Majesty the Queen (Sinchaipanich and Sookthis, 2001).

- Enhancement: From 1950s to 1970s, the common stocked species were Chinese carps viz., grass carp, *Ctenopharyngodon idella*, mud carp, *Cirrhinus molitorella*, silver carp, *Hypophthalmichthys molitrix*, common carp, *Cyprinus carpio* and bighead carp, *Aristichthys nobilis*, Indian major carps viz., mrigal, *Cirrhinus mrigala* and rohu, *Labeo rohit*a (Pawaputanon, 1988), tilapia, *Oreochromis niloticus* and giant freshwater prawn *M. rosenbergii* (Bhukaswan, 1989). However, only a few species were reported as successfully established such as rohu, tilapia and giant freshwater prawn (Pawaputanon 1986; Pawaputanon 1987; Virapat, 1993). According to De Silva (2003), stocking of these fishes, except for tilapia, is closer to culture-based fisheries rather fish stocking. Although these species are capable of reproducing, they cannot form sufficiently large populations that could be exploited commercially unless re-stocking is practiced.

Since 1980, the stocking of indigenous species was initiated as one of the DOF policies on fisheries conservation in natural waters in Thailand (Anonymous, 1988). One of the major reasons is the attempt that these species could self-recruit, which could be harvested regularly without regular stocking (Little, 2002). The popular species for stocking are silver barb *Barbonymus gonionotus*, seven-line barb *Probarbus jullieni*, broad-head walking catfish *Clarias macrocephalus*, common Siamese barb *Henicorhynchus siamensis*, iridescent shark catfish. *P. hypophthalmus*, tinfoil barb *Barbodes schwanenfeldi*, golden barb *Barbonymus altus*, black eye shark catfish *Pangasius larnaudii* and tiny scale barb *Thynnichthys thynnoides*. In 2009, the total numbers of stocked fish and giant freshwater prawn into inland water bodies country-wide was estimated at 2 500 million (Table 1) and the genetically improved strains (Table 2). Meanwhile 1 950 million fish were stocked in 2008 (DOF, 2008).

Table 1. Targeted numbers ($\times 10^3$) of stocked fish for inland fish stocking program in Thailand for the fiscal year 2009 (October 2008 – September 2009) country-wide (DOF, 2008)

Species	Total	Species	Total
Shellfish		**Fish**	
Macrobrachium rosenbergii	**350 000**	*Barbonymus schwanenfeldii*	**18 850**
Fish		*Pangasius hypopthalmus*	**12 631**
Barbonymus gonionotus	**382 250**	*Clarias macrocephalus*	**8 300**
*Labeo rohita**	**224 350**	*O. niloticus* (GIFT)	**6 500**
*Cirrhinus mrigala**	**104 670**	*Morulius chrysophekadion*	**6 200**
*Cyprinus carpio**	**78 100**	*Systomus orphoides*	**5 200**
Oreochromis niloticus	**72 700**	*Hypophthalmichtys molitrix**	**4 050**
Leptobarbus hoevenii	**40 720**	*Ctenopharyngodon idellus**	**2 850**
Barbordes schwanderfii	**39 780**	*Trichogaster pectoralis*	**2 500**
Henicorhynchus siamensis	**26 120**	*Miscellaneous***	**14 229**

Note: * exotic species
** Miscellaneous includes *Clarias macrocephalus*, *Hemibagrus wyckiodes*, *H. nemurus*, *Pangasius conchophilus*, *Probarbus jullieni* and other indigenous species for conservation purpose.

Table 2. Targeted numbers (× 10^3) of genetically improved strain fish for inland fish stocking program in Thailand for the fiscal year 2009 (October 2008 – September 2009) in country-wide* (DOF, 2008)

Species	Total	Species	Total
Shellfish			
Giant Freshwater prawn	**14 000**	Common carp	**4 600**
Fish		Tilapia (Chitralada strain)	**4 000**
Silver barb	**16 800**	Red tilapia	**1 200**
Rohu	**8 100**	Miscellaneous**	**1 300**

Note: * All strains are genetically improved by National Aquaculture Genetic Institute, DOF
** Miscellaneous includes pangasiid and clariid catfishes

3. CONSERVATION PRACTICES FOR INLAND FISHERIES IN THAILAND

3.1 Closed fishing season

The legal basis for the statutory closed fishing season and closed areas is to protect the broodstock from the impacts of fisheries during the breeding season. Although the fish composition is very diverse in the country, the dominant group is the cyprinids, most of which spawn during the early part of the rainy season (De Silva, 1983). Therefore, the closed season in inland waters is set during this period and last for four months, i.e. from 16 May to 15 September country-wide except in some specific areas, where seasons are more closely related to the onset of rainy season in each area (Table 3). However, fishing for household consumption is permitted.

Table 3. Closed fishing seasons for the inland fisheries of Thailand

Province (Region)	Closed fishing season
Lamphun (North)	1 June – 30 September
Lampang (North)	1 May – 31 August
Khon Kaen, Udon Thani and Nong Bualampoo (Northeast)	16 June – 15 October
Nakhon Nayok (Central)	13 April – 12 August
Phatthalung (South)	1 October - 31 January
Pang Nga (South)	1 May – 31 August
Narathiwat (South)	1 September – 31 December

3.2 Fish conservation zones (or Closed areas)

This measure aims to prevent fishing pressure on the broodstocks and recruits, especially during the spawning season. Moreover, a secondary benefit of this measure is through the conservation of biodiversity. Thus, declaration of the fish conservation zone in each inland water body is based on scientific evidence on spawning- and nursery-grounds, which could be temporary during spawning season, e.g. Pasak Jolasid (Vongkamolchoon, 2006), or permanent, e.g. Beung Borapet (Srinoparatwatana, 2009). Moreover, there are cases where fish conservation zones are established at the village level and are often associated with animist beliefs and often fish in the temple areas are consciously protected for religious reasons (Baird, 2006).

3.3 Control of fishing gears

The Fishery Act of 1947 prohibits destructive fishing practices such as poisoning, electro-fishing, and the use of explosives. The fishing gears, that often inflict serious damage to fish stocks, such as trawl, purse seine and push net, are also banned. Mesh size regulations are difficult to apply to select a certain size of one species in these very multi-species fisheries, which target a diversity of fish sizes (Pawaputanon, 2007). In general, the minimum mesh size designed for inland fisheries is set at 5 cm (stretched mesh), which allows the juveniles and sub-adults of many species to escape from the gear (Jutagate and Mattson, 2003).

4. OPERATIONS

4.1 Authorized organizations

The Department of Fisheries (DOF) is the main organization responsible for aquatic resources enhancement and conservation as indicated in the National Environmental Quality Act B.B. 2535 (i.e. 1992). According to DOF, inland stock enhancements are implemented by the Inland Fisheries Research and Development Bureau (IFRDB) wherein, seed supplies are propagated in its 27 inland fishery stations and 31 inland fisheries research and development centers. These seed are stocked in the large and small water bodies. Apart from providing seed, DOF also (i) support the rehabilitation or construction of village ponds; (ii) train local support personnel; and (iii) provide technical advisory services (Chantarawarathit, 1989). Moreover, DOF also established 162 fish breeding centers (FBCs) based in local communities to supply seeds to stock in small water bodies but only 39 FBCs are currently in operation, with a seed production capability of about 6.8 million fingerlings (ADB, 2005).

The Bureau of Fisheries Administration and Management (BFAM) is responsible for freshwater fish conservation purposes. There are 18 units and seven centers for inland fishery patrol, surveillance and control of the fisheries, especially in the spawning and nursing grounds during the closed season, covering 43 rivers (112 115.8 ha), 13 natural lakes (84 995 ha) and 65 reservoirs (356 973 ha) country-wide (BFAM, 2009). Moreover, as mentioned in 2.1, the main purpose of reservoir construction in Thailand is for either hydropower or irrigation. EGAT and RID are the authorized organizations in charge of maintenance and rehabilitation of the ecosystems of man-made lakes under their control.

The 1997 Kingdom's Constitution contains provisions for administrative devolution, so that people, or groups of people (e.g. Provincial Administrative Organizations (PAOs): see 1.2), can take part in the management of their own natural resources, including fish resources. They may participate in drafting sets of rules to manage their fish resources and fisheries. These include the periodic stocking in the water bodies within the provinces, demarcation of fishing grounds, prohibition of some fishing gears, and introduction of fishing seasons and fishing fees (Sihapitukgiat *et al.*, 2002). In terms of village ponds and reservoirs, these practices are controlled by the Sub-district Administrative Organizations (SAOs) (DOF, 2007b).

4.2 Funding mechanisms

Majority of the budget for inland fish stock enhancement and conservations is allocated by the government through DOF. In the 2009, 815.8 million Thai Baht was allocated for stock enhancements of both for inland and marine fisheries and 281.2 million Thai Baht for implementing conservation practices. Moreover, the Ministry of Interior, through Department of Local Administration, annually allocates a budget to the PAOs and SAOs for their natural resources management and the budget for village pond construction has been progressively transferred to SAOs since 2000 (ADB, 2005).

4.3 Management/enforcement/participation

4.3.1 Engineering the environment

Removal of aquatic weeds and clearing of accumulated bottom sediments are done regularly in the three large lakes by DOF (DOF, 2008) while for large reservoirs this is done by EGAT and RID. These activities are the done regularly in the rivers by RID and irregularly by the PAOs and SAOs with the people's participation, particularly for purposes of flood defense, irrigation and navigation. SAOs also have responsibility for the rehabilitation of the village ponds in their communities.

4.3.2 Fish stocking in small water bodies

This stocking refers to the fish stocking into the village ponds and reservoirs, which are built and maintained primarily to store water for domestic use and irrigation (Lorenzen et al., 1998); with an average size of 8 ha and depth at 2.5 m and 1.5 m in wet and dry seasons, respectively (Suraswadi, 1987) and water storage could be at least 8 months in a year (Terdvongvorakul, 2002). The common stocked species are forage species such as tilapia, Indian major and Chinese carps, except common carp *C. carpio*, as well as silver barb; where the seed supplies are partly subsidized by DOF and purchase from private traders (Chantarawarathit, 1989; Lorenzen *et al.*, 1998). The stocked fish are generally 2-3 cm with the recommended stocking density at 50 000 fish ha^{-1} (DOF, 2007b) but commonly at 10 000 fish ha^{-1} (Lorenzen *et al.*, 1998). Fish are stocked during the wet season and raised for 6 to 8 months (DOF, 2007b).

Fish stocking in village ponds are controlled by the SAO, through the village fishery committee, which assumes responsibility for pond management and also trained on relevant management techniques (Lorenzen *et al.*, 1998). Pond management is also conducted both before stocking (e.g. controlling of bank erosion, elimination of predators, liming and fertilization) and during rearing (e.g. feeding with rice bran or artificial pellets, fertilization and surveillance against poaching). Terdvongvorakul (2004) reported that about 60 to 70 percent of village ponds were limed/fertilized before stocking.

Three types of harvesting methods in the village pond (DOF, 2007b):

- *Harvesting once a year:* This type can be applied by setting an annual fishing day, once the fish grow to market size (about 6-8 months after stocking). Tickets are sold to both individuals within and outside the village for catching fish (Lorenzen *et al.*, 1998) and the income is for the village fund. Ticket prices depend on the types of fishing gear used, numbers of stocked fish, numbers of fish expected to survive and condition of the pond (Chantarawarathit, 1989). There are also cases in which the pond is rented out to private groups to operate stocking and the production is either harvested by the lessee or through the sale of tickets. However, although the pond is leased, the villagers still have a right to access the pond for agricultural water supply and household uses (Chantarawarathit, 1989). About 25 percent of village ponds in northeast of Thailand are harvested under this regime (Terdvongvorakul, 2002).

- *Staggered harvesting:* In the perennial pond, the fish could be harvested periodically and with regular re-stocking to sustain the production in the pond. Stocking of self-recruiting-species (SRS) is also recommended, especially tilapia. This is a very common harvesting practice, which takes place in about 70 percent of village ponds operated under this regime (Terdvongvorakul, 2002).

- *Combined type:* If the water body is large enough, zoning is recommended. The water body could be divided into an open zone (fishing for daily consumption) and the reserved zone (fishing at an annual fishing day), which can provide income to the village. Regular re-stocking and intensive pond management are recommended.

4.3.3 Fish stocking in large water body

The main stocked species comprise of exotic and indigenous species as well as the giant freshwater prawn. The genetically improved strain which show higher growth rate such as "GIFT" strain of *O. niloticus* (GIFT-genetically improved farmed tilapia) and genetically improved silver barb *B. gonionotus* are also stocked (Pongtana and Autlerd, 2005). The stocking densities generally follow the protocol set by the DOF advisory team (IFRDB, 2009) as follows:

- From 125 to 300 fish ha^{-1} in the lakes (natural and man-made) that are larger than 16 000 ha
- About 625 fish ha^{-1} in the lakes (natural and man-made) that are smaller than 16 000 ha
- More than 625 fish ha-^{1} in rivers, and
- About 625 fish ha^{-1} in small to medium lakes (natural and man-made) that range between 10 and 160 ha.

The seed fish range from 3-5 cm and are nursed in hapas for 45 days to sizes between 5 and 7 cm before releasing. Equal proportions (in numbers) of each stocked species are recommended in the small to medium lakes. Giant freshwater prawn released as post larvae (PL) 30 days, i.e. stage PL30 (Sripatrprasite and Lin, 2003a).

Fish stocking is generally conducted during the rainy season (i.e. May to August) to guarantee the abundance of natural food (i.e. phytoplankton) and shelter for the stocked seed, especially in the flooded forest. On the stocking day, DOF staff also promotes through media people to get involved in the activity on a voluntary basis with the objective to let them be aware of the importance of aquatic animals (Sinchaipanich and Sookthis, 2001). Massive numbers of fingerlings are also stocked during Songkran festival (i.e. a Thai traditional New Year), which starts on April 13 and lasts for 3 days. April 13 is declared as the national fisheries day, in which fish stocking is one of the main activities of the day.

4.3.4 Conservation practices

Surveillance and monitoring on the use of the destructive fishing methods are continuously conducted by the inland fishery patrol units. During the closed fishing season, the units pay particular attention to spawning and nursery grounds. There are staff in charge of giving infringement warnings and prosecutions of those fishers who violate the regulations (BFAM, 2009). Community education and extension to disseminate the fishery information, encourage the people to be more aware of the importance of aquatic animals and a responsible fishery, are also the duties of these units (Sinchaipanich and Sookthis, 2001). Community-based management has also been initiated, especially in large lakes and reservoirs, with the purpose of sharing the responsibility and authority between the government and communities in a decentralized approach to increase compliance to these measures.

5. EVALUATION AND ASSESSMENT

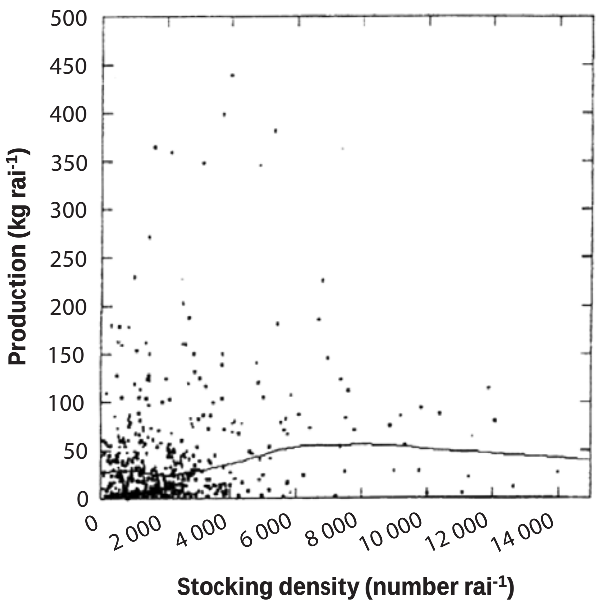
5.1 Engineering the environment

The surface area of large lakes is generally increased by about 20 percent after rehabilitation (Inland Fisheries Division, 1997a). Significant increases of the fish standing crops after rehabilitation was observed such as from 22 kg ha^{-1} to 61 kg ha^{-1} in Nong Harn (Duangswasdi *et al.*, 1994), from 6 kg ha^{-1} to 26 kg ha^{-1} in Beung Borapet (Rithcharung and Pongchawee, 1995) and from 3 kg ha^{-1} to 11 kg ha^{-1} in Kwan Payao (Inland Fisheries Division, 1997). Similar results also are retrieved from the medium-sized reservoirs, where the fish standing crops changed from 29 kg ha^{-1} to 60 kg ha^{-1} (Chunchom and Taruwan, 2006). There is also evidence that after rehabilitation, the ratio between forage and carnivorous fish (F/C ratio) shifted to a more optimum range, from 3 to 6, in many lakes (Inland Fisheries Division, 1997).

Effectiveness of fish passages had been also evaluated and their performances generally noted to be poor. Only the sub-adults and small-sized species can utilize the passages, which as a consequence provides limited enhancement of the yields in the headwaters compared to when there was no barrier (Jutagate *et al.*, 2005). Sripatrprasite and Lin (2003b) estimated that about 10 percent of the fish caught in the Pak Mun Reservoir were from the fish that ascended the fish ladder. There is no study, so far, to determine the effectiveness of artificial habitats in terms of yield enhancement. However, Welcomme and Bartley (1998) suspected that this kind of construction is mainly a fish aggregating device with no increase in overall productivity.

5.2 Fish stocking in small water body

The average yield from stocking program in village pond is around 290 kg ha^{-1} yr^{-1} for poorly managed village ponds (Terdvongvorakul, 2002) and could be as high as 3 000 kg ha^{-1} yr^{-1} (Lorenzen *et al.*, 1998). It is estimated that the average high yield at 375 kg ha^{-1} yr^{1} could be achieved at a stocking rate of 37 500 fish ha^{-1} and yield trend to decrease when stocking beyond this rate (Figure 1: Inland Fisheries Division, 1997b). De Silva and Funge-Smith (2005) suggested that increasing fish numbers through stocking will not be effective and there is the possibility for it to be counter-productive by diminishing growth. The common stocking species revealed



Note: Rai is a Thai measurement scale, in which 6.25 rai equals 1 ha

Figure 1. Relationship between productions (kg rai^{-1}) and stocking density (numbers rai^{-1}) (Inland Fisheries Division, 1997b)

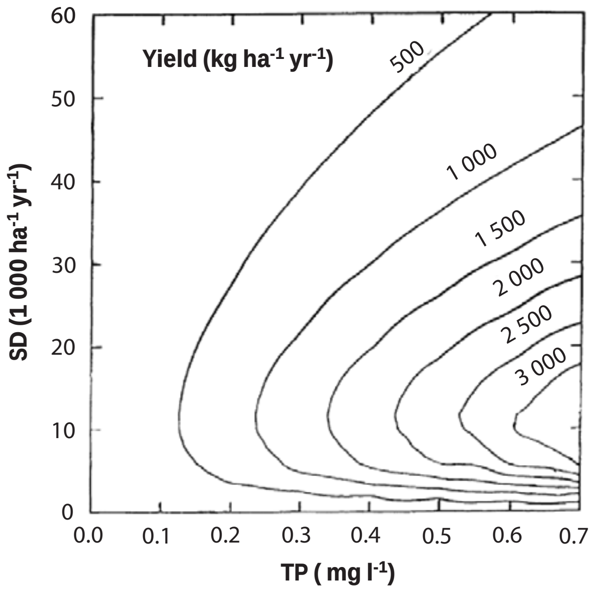
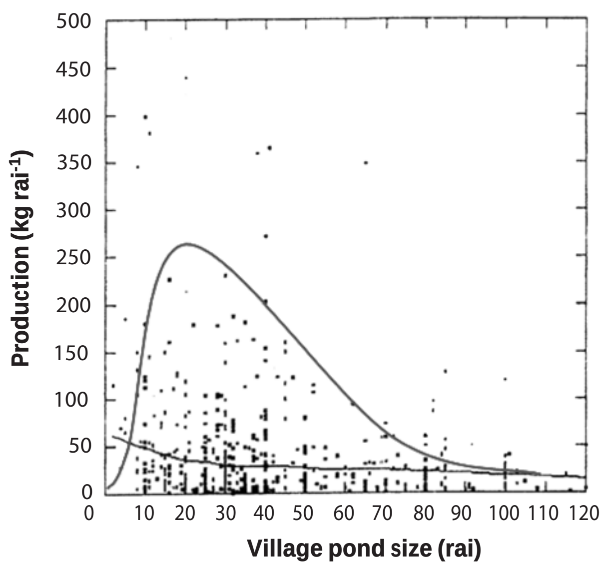


Figure 2. Predicted yield as a function of total phosphorus (TP) and stocking density (SD) in village ponds in NE of Thailand (Lorenzen *et al.*, 1998)



Note: Rai is a Thai measurement scale, in which 6.25 rai equals 1 ha

Figure 3. The positive skewed distribution of the production in relation to village ponds (Inland Fisheries Division, 1997b).

good growth performance, where they can grow beyond 30 cm i.e. considered as marketable size, within one year in a small irrigated reservoir (Saowakoon, 2009). Meanwhile, the fish could grow slower in village ponds, i.e. less than 1 kg within a year (Lorenzen *et al.*, 1998).

The recapture rates of stocked fish fluctuated and ranged from 14.5 to 100 percent of total catch with the average of 51 percent in small swamps and lakes (NIFI, 1984; NIFI, 1988) and could be as high as 60 percent in village ponds (Lorenzen *et al.*, 1998). In village ponds, stocking performance is influenced by stocking density and trophic status of the water body (Figure 2: Lorenzen *et al.*, 1998), meanwhile Terdvongvorakul (2004) had added water level and drying period of pond as controlling factors on fish production. Size of village pond is considered as another factor that has negative relationship to fish yield. Fish yield decreased from about 310 to 94 kg ha^{-1} yr^{-1} in ponds sized 62.5 and 750 ha, respectively (Inland Fisheries Division, 1997b) and the production in relation to village ponds tended to be positively skewed (Figure 3: Inland Fisheries Division, 1997b; Terdvongvorakul, 2002).

5.3 Fish stocking in large water body

Fish stocking may be claimed to be the most successful enhancement activity particularly in large lacustrine water bodies (Bhukaswan, 1980). However, the contribution of exotic stocked species (i.e. Chinese and Indian major carps) to the total yield is very limited, except for tilapia, which has the ability to self-recruit in the system. The indigenous species, on the other hand, have proven to be successful based on the high yields of snake-skin gourami *T. pectoralis* (Bhukaswan, 1980) and Smith barb *P. proctozystron* in Ubolratana Reservoir (Petr, 1989) since they had been stocked in 1969 and 1977, respectively. Silver barb *B. gonionotus* has also been recognized as a successful stocked species for improvement of fish yields in many Thai reservoirs (Pawaputanon, 1992). Nevertheless, not all indigenous stocked species have performed well in enhancement. For instance, the poor contribution of some indigenous stocked species such as Mekong giant catfish *P. gigas*, Chao Phraya giant catfish *P. sanitwongsei*, iridescent shark *P. sutchi*, Isok barb *P. julieni* and Giant barb *C. siamensis*, especially in lakes (Virapat, 1993). Stocking of species which are endangered, for conservation purposes to improve the status of wild stocks (Mattson *et al.*, 2002) and of migratory species that need to migrate to a riverine habitat for breeding (De Silva and Funge-Smith, 2005) are also noted.

Benchakarn and Nookour (1988) studied the survival rate of rohu *L. rohita* fingerlings of sizes ranging from 3.15 to 13 cm in polyethylene net pens before stocking and found that the overall survival rate was 18 percent after 49 days of stocking. In general, the survival rate of the stocked Indian major carps was estimated at about 10 percent and less for Chinese carps, which could be due to the fact that the fingerlings of Chinese carps are slow swimming fish and thus are more susceptible to predation than the fast swimming Indian major carp fingerlings (Virapat, 1993). Moreover, the seed fish are typically removed rapidly from the ecosystem by fishing since the commonly used gillnets are both small to large mesh sizes, which are effective in catching matured natural species of relative small-size and young age-classes of stocked species (Virapat, 1993).

Pawaputanon (1988) studied the most effective released size of three stocked species *viz*., bighead carp, mrigal and rohu at three different size classes, large (9-10 cm), medium (7-8 cm) and small (3-5 cm). The recaptured rates were about 10.2 and less than 1 percent for the large, medium- and small-sized fingerling, respectively. The appropriate stocked size, therefore, was recommended at 9-10 cm. This result was reconfirmed by a number of reports (e.g. Siripun, 1988; Virapat, 1993) that the 9 cm size-class for Indian major carps is recommended when considered in terms of survival rate, yield and economic viability. Nonetheless, the stocked size is generally at 5-7 cm since the limited budget of DOF to rear the stocked fingerlings to attain the recommended size (see 4.3.3) and if the fish are stocked at appropriate size, they could attain the marketable size within eight months to an year (Pawaputanon, 1988), Unfortunately, there is no report that provides statistical information and performance of stocked Thai indigenous species.

For the giant freshwater prawn, the average weight of individuals after a year of release (at stage PL30) ranged from 110 to 167 g with the average relative growth rate at 20.7 g mth^{-1} and could grow up to about 400 g (Sripatrprasite and Lin, 2003a; Renunual and Silapachai, 2005). The recapture rate of the giant freshwater prawn is very low ranging from 0.83 percent in run-of-the river type reservoir (Jaiyen, 2005) to about 2 percent in the lake-type reservoir (Benjakarn, 1984; Renunual and Silapachai, 2005). However, the recapture rate of the stocked giant freshwater prawn in natural lakes such as Beung Borapet could as high as 10 percent (Rithcharung and Srichareondham, 1998). There is no study about the optimum stocking size and density but the stocked rate of freshwater prawn is at about 2 500 prawn ha^{-1} (Jaiyen, 2005). There is no study yet on the relationship between the stocking quantity and yield but in Pak Mun Reservoir, stocking of 2 million juveniles resulted in the production of 3 kg ha^{-1} yr^{-1} (Sripatrprasite and Lin, 2003a) and by stocking 40 million juveniles in 2003, the production was as high as 11.5 kg ha^{-1} yr^{1} (Jaiyen, 2005).

5.4 Conservation practices

It can be said that, in general, the conservation practices implemented by DOF in inland waterbodies are not entirely successful. The strict regulations to prohibit fishing during the rainy season have been shown to be ineffective since the highest yield of inland fisheries is during this period (Benchakarn, 1986). During this period, all freshwater fisheries resources are very productive and yearling fish grow to full size and are the target of fishers (Pawaputanon, 2003). Fishers have adopted practices to minimize the chance of being arrested by fishery patrol such as setting their fishing gears in the zone that the fishery patrols infrequently survey during the closed seasons (Srinoparatwatana, 2009).

One would expect a higher species richness and biomass in fish conservation zones (FCZ). However, a recent study by Srinoparatwatana (2009), at Beung Borapet revealed inconsistent patterns among fish species between the fished zone and FCZ. Some dominant species such as barb *Cyclocheilichthys enoplos*, barb *Amblyrhynchichthys truncatus*, giant gourami *O. gouramy* and Smith barb *P. proctozystron* had higher densities in the FCZ, whereas the other dominant species such as catropa *Pristolepis fasciatus*, Nile tilapia *O. niloticus*, Beardless barb *Cyclocheilichthys apogon* and glass fish *P. siamensis* had higher densities in the fishing zone. Moreover, protection only appeared to increase the size of a few dominant species e.g. *O. gouramy* and Silver barb *B. gonionotus*. Nevertheless, strict control of fishing activities by fishery patrol within the spawning and nursery grounds particularly during spawning periods has been successful in terms of reducing mortality of broodstock and increasing recruitment in many lakes and rivers that are patrolled effectively (JICA, 2001; Vongkamolchoon, 2006; Chansri *et al.*, 2008).

Since the nature of inland fisheries in Thailand is often not targeted and the fishers take all species regardless of size variations (Bhukaswan and Chookajorn, 1988), it is difficult to make an effective control by designing a single mesh size especially for the commonly used fishing gear such as gillnet (Jutagate and Mattson, 2003). Presently, the minimum mesh size restriction is 5 cm as announced by the DOF but the lesser mesh sizes are always commonly deployed. Chansri *et al.* (2008) reported that even though the percentage of the perception of fishers on the conservation practices, implemented by DOF, was high (57 percent), the rate of compliance was very low because they have no alternative source of income, especially during the closed season.

6. IMPACTS OF MAJOR ENHANCEMENT AND CONSERVATION ACTIVITIES

6.1 Impact of stocked fish on ecosystem

Koranantakul (1973) reported on the impact of common carp *C. carpio* on the disturbance of the ecosystem in village ponds by stirring up sediment leading to increased water turbidity due to re-suspension of sediment granules and a higher level of particulate inorganic matter, resulting in a decrease of the pond's primary productivity. This is the reason why this species is not popular for stocking in such systems (see 4.3.2). Other impacts of stocked species had been mentioned but there has not yet been any in-depth studies on topics such as (a) decline in local fish species because their eggs are eaten by *C. carpio* and Nile tilapia *O. niloticus* or (b) loss of native habitat, especially in the vegetation areas due to the foraging of excess stocked grass carp *C. idella* (Welcomme and Vidthayanond, 2000).

Arthur *et al.* (2010) conducted experiments in wetlands in southern Lao, which has the similar zoogeographical condition as the northeast of Thailand and found that the native fish biomass was not affected by stocking of the non-native species. No significant impacts on native fish species richness, diversity indices, species composition or feeding guild composition were detected. De Silva and Funge-Smith (2005) mentioned that the primary reason that most stocked species (particularly the Chinese and Indian major carps) do not tend to influence the biodiversity of large inland, lacustrine water bodies is that they are generally unable to reproduce in such waters and form large populations that would compete for common resources. Among the exotic stocked species, only Nile tilapia reveal the potential to self recruit after release (Virapat, 1993) meanwhile the other stocked exotic species seem to acclimatize gradually due to lack of spawning sites and habitat of parental sites (Villanueva *et al.*, 2008). In terms of niche overlap, Nile tilapia has a large niche breadth, i.e. high ability to consume a variety of diet types (Nithirojpakdee *et al.*, 2006). Meanwhile the other exotic carps have small niche breadth and compete for food sources with indigenous fishes (Villanueva *et al.*, 2008). However, low gross efficiency transfer of primary production through the catches (i.e. range from 0.1 to 0.2), are commonly found in Thai inland waters (Jutagate *et al.*, 2002; Villanueva *et al.*, 2008; Thapanand *et al.*, 2009) suggesting that there is a large excess production of phytoplankton and plants and implying that these food sources are not strongly affected by competition within the fish groups.

6.2 Impact of stocked species on the genetic biodiversity of the natural population

Releasing of indigenous species can lead to genetic effects if interbreeding between released fish and wild fish occur. Generally, released fish are hatchery bred. Interbreeding of these fish with wild population will result in alteration of the genetic structure of the wild populations and reduction in genetic diversity, if the hatchery population released has lower genetic diversity than the wild populations. Genetic variation in hatchery populations can be lost by domestication, inbreeding and selective breeding. Moreover, the released hatchery population may not originate from local populations, which is greatly different in the genetic make up from wild populations, resulting in genetic homogenization among populations and loss of genetic identity. Finally, this effect can reduce local adaptation and viability of wild populations. To date, there are only limited numbers of genetic studies regarding the impacts of releasing indigenous species in Thailand. Kamonrat (1996) studied the genetic structure of Thai silver barb, *B. gonionotus* natural populations and hatchery stocks from three river basins (including Chao Phraya, Mekong) and reported that over 70 percent of river populations were from hatchery populations, possibly resulting from restocking. Similarly, a study on *B. gonionotus* and *H. siamensis* populations from the lower Mun River before and after stocking indicated that stock enhancement using hatchery population has led to loss of genetic variation and genetic identity of wild population (Kamonrat, 2008).

In Thailand, Senanan *et al.* (2004) and Na-Nakhorn *et al.* (2004) observed the introgression of African catfish, *C. gariepinus* gene into native catfish, *C. macrocephalus* in wild populations caused by the release/escape of hybrid catfish (*C. macrocephalus x*, *C. gariepinus*). Na-Nakorn *et al.* (2004) observed that *C. macrocephalus* in the wild may be directly replaced by the hybrid catfish that have higher growth rate and suggested that a better strain of *C. macrocephalus* should be developed to avoid spreading of hybrid catfish in the wild. Moreover hybrid catfish has been thought to be a species contributing to the decline of native *C. batrachus* in the Mekong Delta (Welcomme and Vidthayanon, 2003).

6.3 Socio-economic benefit

Recently, DOF has launched a project (started in 2007) to assess the catch per unit effort (CPUE) by using standard gillnets, in a number of large water bodies to assess the success of enhancement programs and mitigation measures by setting the goal at 1 percent higher in CPUE compared to the previous year (IFRDB, 2007). It is anticipated that this rate of increase will provide more benefits to the people in the area, particularly in terms of food security. Chantarawarathit (1993) and Pimolbutra (1994) reported that more than 80 percent of the people living in the vicinity of large natural lakes were satisfied with the condition of the lakes after rehabilitation but numbers of fishers claimed that their catches had declined after lake rehabilitation, which also could be caused by the increasing water levels.

Fish stocking in village ponds is always harvested in a way that produces income for the village or SAO (Garaway,, 1995) by selling tickets to fish on fishing days and outside of this day, fishing is prohibited but the people are still allowed to access the pond for agricultural water supply (Chantarawarathit, 1989). Village revenue from the ticket sales could be as high as 27 000 Thai Baht ha^{-1} and there is a positive relationship between revenue and yield on a total and per area basis but not revenue and pond area (Lorenzen *et al.*, 1998). Nevertheless, as the main objective to increase animal protein in the diet of rural people (Suraswadi, 1987). The SAO has to look for other small water bodies nearby the village to stock fish for the benefit of the communities (DOF, 2007b). Because if the people, especially the poorest groups, have no alternative, they would suffer the most from the restriction of access to small water body resources brought about by stocking initiatives (Garaway *et al.*, 2001).

So far, there is no directed study that deals with the socio-economic benefits of stocking programs, either of indigenous or exotic species, in large water bodies in Thailand. It is suggested that this is due firstly, to the difficulty to identify the stocked populations from the natural ones, particularly the indigenous fish and Nile tilapia. Secondly, because of the relatively small contribution of stocked exotic fish, they could not make significant impact on fishers (Kitivorachate *et al.*, 1985a; Kitivorachate *et al.*, 1985b). Moreover, in terms of income, prices of the stocked exotic fish are comparatively low (i.e. less than 20 Thai Baht kg^{-1}) while the indigenous species normally cost more than 50 Thai Baht kg^{-1}. The financial return in relation to the size at release, which maximizes fishing income in relation to the cost of stocking, had been studied by Virapat (1993), when it was demonstrated that the yields and the corresponding benefit gained from stocked Chinese and Indian major carps increased with size-at-release. He concluded that although stocking of Chinese and Indian major carps in large water bodies in Thailand are ineffective in purely economic terms, the stocking program obviously has considerable social value because most fishers are relatively poor and have little opportunity of improving their livelihoods and living conditions. However, he also remarked that the benefit gained from the fishery, in terms of revenues, were largely to the middlemen since they controlled the market system.

In contrast to exotic fish stocking, regular stocking of *M. rosenbergii* resulted in higher income for the fishers from catching and selling prawns. Moreover, the high market price of prawns benefits traders at various levels, job creation and income for all related sectors (Jaiyen, 2005). For example, Sripatrprasite and Lin (2003) reported that in a run-of-river type Pak Mun Reservoir, which has been regularly stocked with giant river prawn since 1995, totaling 22 million fry up to 2000, the catches (16 646 kg/yr) contributed 53.8 percent to the total fish catch by weight, but 97 percent to the economic value of the landings. Similar results were obtained by Renunual and Silapachai (2005), who found that only with a low recapture rate of 1.8 percent of stocked *M. rosenbergii* in Bangpra Reservoir, led to economic profit of 721.64 percent.

Although there are few studies assessing the effectiveness of fishery regulations, especially on the socio-economic outcomes in the Lower Mekong countries (Baird and Flaherty, 2005), fishers generally agree that conservation practices benefits them especially in terms of sustaining the fisheries. The main measures, recognized by fishers were closed fishing areas and season as well as restriction on the use of some fishing gears (Chansri *et al.*, 2008; Hortle and Suntornratana, 2008). Nevertheless, lack of compliance to the measures is quite common, especially on using small mesh gillnets. In terms of social objectives, the restriction will directly affect some fishers, who particularly catch small and mostly low-cost species (Pawaputanon, 1982; Virapat, 1993).

7. CONSTRAINTS AND PROBLEMS

The major constraint on stock enhancement programs and conservation practices relates to institutional aspects. People (i.e. resource users) are not aware of the importance of such projects (Chantarawarathit, 1989) which could due to a lack of continuous input by local fishery committees and support from the government, as well as inefficient transfer of appropriate technology to local operations (ADB, 2005). Moreover, the people have less participation in the meeting concerning establishment of fisheries measures (Chansri *et al.*, 2008) and this issue leads to limited investigation of the needs, constraints and expectations of the resource users (Garaway *et al.*, 2006). Uncertainty regarding the outcomes of stock enhancement programs and conservation practices could also result from the fact that the underlying biological process is still not fully understood (Garaway *et al.*, 2001). For example, for stocking programs, De Silva and Funge-Smith (2005) mentioned that the species combinations used may have been more of a reflection of availability rather than specific knowledge both in small and large water bodies. Moreover, it is also apparent that, in most of the cases, there was no attempt to correlate the amount stocked to the potential productivity of the particular water body and which ecological niches should be covered. Pawaputanon (1982) mentioned that lack of the fundamental knowledge of fish biology and ecology makes it difficult to establish the appropriate conservation measures for multi-species fisheries as in Thailand. The problems of implementation of inland fishery measures involve ineffective law enforcement, unclear the boundaries of some conservation zones and poor information dissemination (Chansri *et al.*, 2008).

There are two specific problems regarding the fish stocking program in Thai large inland water bodies (Virapat, 1993): first, inadequate planning and monitoring of the programs to obtain information on growth and survival rates of the stocked species and second, no specific time of stocking; it is usually done whenever the fingerlings are available. Two main factors influence the size chosen for stocking material; cost and survival rates (Welcomme and Bartley, 1998). Although the optimum sizes of release for yielding high survival rate are recommended (e.g. Benchakarn and Nookour, 1988; Pawaputanon, 1988; Virapat, 1993), the budget to produce sufficient numbers for stocking of those sizes is always a limiting factor (see Section 5.3). Another constraint, for fish stocking program in large water bodies is the lack of program economic viability (De Silva and Funge-Smith, 2005). This is because this program is not expected to be an income-generating activity but to provide a source of food and to increase employment through fishery development. Therefore, economic aspects of the program are always neglected leading to questions on the degree of successful, particularly in terms of economic returns.

8. RECOMMENDATIONS

It is clearly seen from this review that although a number of studies have dealt with the results of stock enhancement and conservation practices, so far, using of the lesson learned (though highly recommended for further implementation) are scanty mostly due to budgetary constraints and lack of information of individual water bodies related to the stock enhancement or conservation practices. Stocking program in large water bodies seem to be not as well organized with inadequate solid scientific bases such as productivity and empty niches in the ecosystem, optimum stocking density, forage/carnivore ratio and suitable area and season to release the fish. Performance (biology, ecology and contributions in catches) of the stocked species in large water bodies has not been seriously studied since Virapat (1993). For conservation practices, although there is the recent work by Srinoparatwatana (2009) and including previous studies, solid conclusions could not be retrieved from these in terms of a quantitative approach. This is due to the questionable economic viability of many programs (De Silva and Funge-Smith, 2005). Therefore, to cover the economic viability and investigate the benefit-gain to people (or resource users), especially for the purpose to improve the living standard of fishers, more and improved socio-economic studies of the results from stock enhancement and conservation practices should be carried out simultaneously with the existing programs. Moreover, alternative sources of income for the fishers during the closed season and area should be implemented by the authorized organizations

For the fish stocking program in large water bodies, it is clearly seen that the current yield of the stocked exotic species is low compared to the native ones. Therefore, indigenous species, such as Smith barb *P. falcifer*, should be a good candidate for stocking since they are capable of establishing breeding populations and forming fishable populations within the system. Appropriate size at release and stocking density of individual species must be examine and monitoring program to obtain information of growth and survival rates of the stocked species must be initiated. Moreover, stock enhancement should be performed by using brood stock that have the most genetic similarity to wild populations (stock). In small water bodies, indigenous self-recruiting species that can tolerate the local conditions (e.g. low dissolved oxygen and high turbidity), such as snake-skin gourami *T. pectoralis* should be tried. Before stocking, suitable period and locations to release the seed fish should be determined.

In terms of institutional aspects, participatory adaptive learning, involving external agencies working with local communities should be expanded. This process provides for an increase in knowledge about the resource systems and enables the refinement of management policy, which will likely be ultimately better accepted by the communities (Garaway *et al.*, 2001). Lastly, academic capacity building of the DOF and authorized staffs should be considered. For DOF, most of the staff were trained in aquaculture, and lack skills in inland fisheries management and have little experience in the field of ecological principles underlying inland fisheries production. This situation is not conductive to good management of the resource, and contributes to neglect in management planning (Barlow, 2009).

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INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN VIETNAM

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Key words: Inland fisheries, resource enhancement and conservation, Icefish, *Prochidolus lineatus*

1. GENERAL OVERVIEW OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION PRACTICES IN VIETNAM

1.1 History of inland fisheries resource enhancement and conservation in Vietnam

According to the assessment of MONRE (2003), Vietnam has a dense river network, including 2 360 rivers with a length over 10 km. Eight have large basins with catchments of more than 10 000 km^2. This river network includes many international rivers that originate in other countries (MOFI and World Bank, 2005).

The total water surface potentially available for aquaculture, inland or culture-based capture fisheries has been estimated at 1.7 million ha (MOFI and World Bank, 2005). Of this total, around 120 000 ha are small ponds, lakes, canals, gardens; 340 000 ha are large water surface reservoirs (Nguyen, 1994; Ngo and Le, 2001); 580 000 ha are paddy fields which can be used for aquaculture purpose, and 660 000 ha are tidal areas (IFEP, 1997). However, these figures do not include the water surface of rivers and about 300 000-400 000 ha of straits, bays and lagoons along the coast (MOFI and World Bank, 2005). The number of reservoir must be higher because many new reservoirs have been constructed in recent years.

Vietnam has a very high biodiversity in aquatic resources with 1 027 freshwater fishes (belonging to 97 families) (Nguyen and Ngo, 2001), 1 438 micro algae, more than 800 invertebrate species. It diversifies with much kind of groups such as freshwater fishes, invertebrates and migratory species. There are some high value freshwater fish species that fetch prices as high as marine fishes such as *Hemibagrus* species.

In the past, freshwater capture fisheries were important for the economy in many regions and important food source for the Vietnamese people and the soldiers (Dinh, 1995; Bui, 2006). The government (GoV) was the exclusive harvesting sector for all reservoirs (Ngo and Le, 2001). In the 1970s, there were more than 70 fishing cooperatives with annual production of several thousand tonnes. However, this system collapsed due to over-exploitation of resources change in the country's economic system (Ngo and Le, 2001; Bui, 2006), which caused a reduction in the resource and most cooperatives of fishers changed their operation to other activities at the end (Dinh, 1995).

There are several threats that directly impact the diversity of inland resources and ecosystem such as over-exploitation, development of agricultural areas to industrial zones, pollution, overutilization of the water supply system caused changed in hydrography, construction of new dams/reservoirs, etc. (MARD, 2009).

However, inland fisheries in Vietnam still play an important role as a source of food, creating job opportunities and sustaining the livelihood for most of people in rural areas. Any changes from these resources would cause the influence to people in the regions. The annual statistics, presented by the Government's Statistics Office

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presented a peak of 244 000 tonnes of fish in 2001, declining to 209 000 tonnes in 2003, probably due to drought. Although inland fish production has contribution from culture-based fisheries activity through the stocking of lakes, dams and other inland waters, mainly with carps and tilapia, but fish consumption was still very low at 14 kg/person based on the FAO fish consumption survey (Lem, 2002).

Figure 1 showed that capture fisheries production has not developed very much in the last 30 years (FAO, 2007). This could be due to the strong aquaculture development in Vietnam in the last three decades. In 1980s-1990s, fisheries production was stable due to the existence of government intervention. However, the figure also pointed out that the contribution of the private sector in inland fisheries could be more visible since 1990s as mentioned by Nguyen and Nguyen (2000), Nguyen (2001) and Bui (2006).

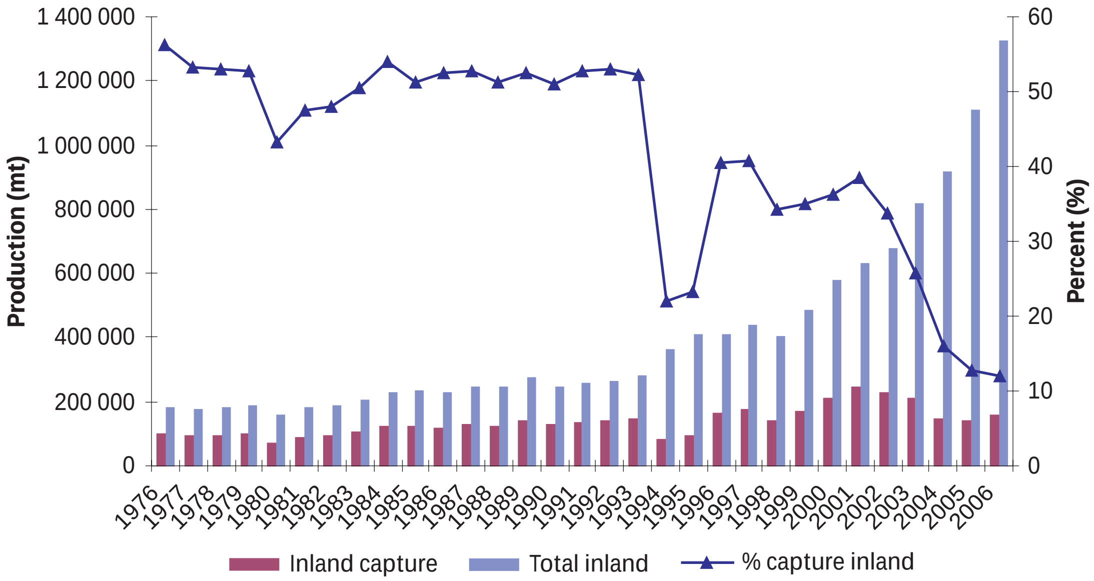


Figure 1. Contribution of the inland capture to the total inland fish production of Vietnam (FAO, 2007).

Basically, inland fisheries resource enhancement has been considered a major component of reservoir fisheries management since 1962 (Nguyen, 2001). Multipurpose reservoir construction commenced about the 1960s for irrigation, hydropower generation, flood control, etc. (Dinh, 1995; Ngo and Le, 2001; Bui, 2006; Phan, 2006). Reservoir fisheries is always a secondary or tertiary activity and are given low priority (Ngo and Le, 2001; Bui, 2006). However, Bui (2006) and Phan (2006) reported that the government had issued policies to utilize the reservoir water resources for fishery activities, both as a means of increasing fish food supplies in rural areas, and as an avenue for employment for displaced people. Inland fisheries resource enhancement aims to increase the fish production in the related water bodies due to poor natural fish stocks and low nutrition. Therefore, a large number of state fisheries agencies were set up in order to produce mass stocking materials for all the reservoirs. However, due to economic crisis and the consequent termination of subsidies by the Government to the stocking program (Nguyen and Nguyen, 2000; Nguyen, 2001), reservoir fisheries has been affected seriously. Many governmental sponsored fisheries companies could not continue their own activities without subsides and thus were abandoned. Stocking program stopped for all reservoirs in the period of 1990s (Nguyen and Nguyen, 2000; Nguyen, 2001; Bui, 2006) due to the economic crisis.

According to Nguyen (2001), stocking fish to the reservoirs can improve quality of fish fauna, increase reservoir productivity, and hence increase fish yield. Recently, the Government has restarted the stocking program for some reservoirs including the newly constructed ones such as Tuyen Quang reservoir, Son La reservoir with the aim to develop fisheries activities and create new opportunities in the regions. The government also established co-management models to manage the fisheries and fisheries resources in some inland water-bodies.

Vietnam was the 50th country in the world that signed in the Ramsar Convention in 1989. In 1993, Vietnamese Government again signed the International Convention on Biodiversity in Rio de Janeiro (Brazil). This convention was approved by government assembly in October 1994. These are the two basic conventions on biodiversity and resources conservation in the world that Vietnam had joined.

The Vietnamese Government has done many statistical researches or status assessments on biodiversity in order to plan for the conservation and utilization of the natural resources based on the above conventions.

In 2008, the Prime Minister approved the decision No. 1479/QĐ-TTg for the establishment of the water inland conservation zones until 2020. There are 45 conservation zones being established under this decision, including 16 national conservation zones and 29 provincial conservation zones.

1.2 Major practices of fisheries resource enhancement and conservation

In Vietnam, stocking has been considered a major component of reservoir fisheries management (Nguyen, 2001). The technology of artificial breeding of cultivated fish species has been successfully applied and provides opportunity for supplying mass stocking material. In the past, there were several hatcheries built around the reservoirs in order to produce fingerlings to be released into new reservoirs. The fingerlings were stocked into reservoirs as the annual work plan of the state fisheries enterprises/cooperatives. Capture fisheries activities in the water bodies were managed by state fisheries agencies to catch fish.

In addition, Dinh (1995) reported that by the application of new fishing technology from China, such as the use of trammel and integrated nets, the fishing techniques were improved and contributed to higher yields. Annual yields of 26 tonnes, 108 tonnes and 47 tonnes were reported in Tam Hoa, Cam Son and Thac Ba reservoirs in 1971, 1974 and 1978 respectively. During this period, the state fisheries agencies had planned seasonal capturing calendar according to the set regulations and that no one has the right to catch fish in the reservoirs/lakes without state workers.

Among cultivated species, silver and bighead carps are the most suitable species to release into reservoir. These species could utilize the rich nutrients and conditions of the reservoir water. Nguyen (2001) demonstrated that cultivated species contribute 30-90 percent of total catch of the reservoir, fish production is closely related to stocking density and recapture rate. Bui (2006) indicated that higher yield could be obtained after two years of stocking.

After 1993, many reservoir fisheries all over the country had collapsed due to the economic crisis and the changes in reservoir fishery policies of the Government. Most of the small and some medium-sized reservoir were leased to the private sectors for culture-based fisheries. However, all large-sized reservoirs were still managed by the government. So there were big changes in the stocking program for these reservoirs. The small and medium-sized reservoirs applied new stocking composition and technology similar to that for big ponds. Traditional species such as silver carp, bighead carp, Indian major carps, common carp, grass carp and silver barb were stocked for culture-based fisheries. It totally changed the view on reservoir fisheries production in the last 10 years. The government had realized that reservoir fisheries could play an important role in increasing freshwater fish production to supply high protein food for the people and create job opportunities for the poor and displaced people (Phan and De Silva, 2000; Nguyen, 2001). Therefore, it was a government policy for the period 2000-2010 to develop reservoir fisheries and the target is to produce 200 000 tonnes of fish of which 20-25 percent fish products should be suitable for export. The Government expected these activities would provide employment to 75 000 people.

In the large-sized reservoirs, the stocking composition had changed to have more species such as silver barb, common carp, Indian major carps, grass carp, and some other species such as *Prochidolus lineatus* (which introduced from South America), icefish. Recently, MARD wants to introduce high value native species into these reservoirs like *Hemibagrus guttatus*. Nowadays, the government changed its policy to stock fishes for some new reservoirs (Tuyen Quang or Son La hydropower reservoirs) instead of leaving this activity to the local government as previously practices. There was a 5-year project approved to release fingerlings at the Tuyen Quang reservoir from 2010-2015. In parallel, Son La reservoir was applied for a long term stocking and reservoir fisheries development program by using the fund from revenue of power generation. The government is considering this plan to allow fisheries agencies to have a certain percent of this fund from the hydropower plan.

Stocking of Chinese major carps has contributed to reservoir fisheries in Vietnam significantly. Fisheries enhancement in Thac Ba reservoir, northern Vietnam is a good example.

Thac Ba reservoir (23 500 ha) is located about 170 km west of Hanoi. It was constructed by impounding Chay River (one of the tributary of Red River) commencing in 1962 and finishing in 1970 primarily for hydropower generation. Thac Ba reservoir was the first hydropower generation built in Vietnam and was recorded as an important reservoir to supply food production and employment opportunities to the people in the vicinity particularly the displaced people (Dinh, 1995; Nguyen, 2000; Bui, 2006).

In this reservoir, 90 percent of the fish species caught are Cyprinidae. The most common species caught are *Toxabramis houdemeri*, *Pseudohemiculter dispar, Culter erythropterus, Erythroculter* spp., common carp, *Hemiculter leucisculus, Carassioides cantonensis* with the rarely contribution of exotic species.

In the 70-80s, fish production steadily went down and drop rapidly since 1990. However, with the changes to market driven economy coming with reduction of state management, the contribution of the private sector to reservoir fisheries rapidly increased. Accordingly, due to the increase in the number of fishers and fishing gears, the fish production doubled (about 600 tonnes yr^{-1}) (Nguyen, 2000; Bui, 2006).

With the above features, the reservoir fisheries provided a significant contribution to nearly 300 000 people (Nguyen, 2000) living in the vicinity to utilize the reservoir resources and create a new livelihood for poor people, particularly for displaced people.

In this reservoir, stocking program mainly based on silver carp and rohu (*Labeo rohita*) amd grass carp, silver barb had been stocked as trial species in 1997-1998 and 2000, respectively. After a long time of not stocking, the reservoir has been re-stocked with 250 thousands to 760 thousand fingerlings in 2003 and nearly 700 thousand in 2004 (Nguyen, 2000; Nguyen, 2001; Bui, 2006).

Recently, there are two exotic species (icefish and *Prochidolus lineatus*) successfully stocked into the reservoir, but its impact has not been fully recognized and studied.

In case of icefish (*Neosalanx tangkakii*), this species grew and developed rapidly after four year of stocking. With the fish production of about 30-40 tonnes in 2008 (Nguyen Hai Son, private communication), this species could contribute as a major source for Thac Ba reservoir fisheries. However, without any management activities, this fishery is going to collapse and witness rapid reduction in fish production.

Icefish has been known as a small fish eating zooplankton (*Cladoceroms, Leptodora, Calanoid copepods* và *Cladoceromd*). In 2002, 112 million eggs were released into Thac Ba reservoir (appx. 23 500 ha) by the Chinese enterprise. There was a commercial proposal submitted to the local government about the high value and visible economic benefit of stocking this species into the reservoir. With the initial assessment on reservoir environment by the Chinese experts, it was recommended to stock this species into the reservoir. However, this process took a long period (about 3 years) to get approval from local government.

In 2003, very little fish was found in the reservoir. However, by 2006-2007 fishes were found everywhere and more concentrated in the centre and upstream area of the reservoir. Fish were caught by using lighted lift-net and seine net with the mesh size about 0.5-1 cm. According to Nguyen (2010, personal communication), CPUE of icefish is about 150-200 kg/day for 12-15 day a month.

In 2007, icefish production was estimated to be about 50 tonnes and reduced to about 40 tonnes in 2008 (fish yield contributed about 5 percent, but its value is about 25 percent). It was even worse in 2009 with very few icefish caught due to over-exploitation and open access on this resource. This phenomenon has been well recognized in China but it has not been fully assessed in Vietnam.

It was found that icefish has two populations in the reservoir and it reproduces twice a year, in August and February. The government is currently funding a study on icefish impact assessment in order to identify about the fish biological and reproduction features and aims to introduce this species into other reservoirs which has similar physical and ecological conditions as the Thac Ba reservoir. However, more time is needed to fully recognize the impact assessment results on this species.

Another species could be considered as a potential fishery in the reservoir is the *Prochidolus lineatus*. In 2003, this species has been illegally transplanted into Vietnam from Brazil through China. However, local people did not know about its origin so they called it as Yangtze mud carp (local name: cá Trôi tru˒ò˒ng giang). The tracking of this fish origin started in 2007 with the funding from the government. The study revealed that the fish truly originated from Brazil (Bui *et al.,* 2009).

This species is found in many inland water bodies such as rivers, ponds, lakes and reservoirs, which was either released by the local government or escaping from cages or released by farmers. It can survive in the very cold winter in Vietnam. The fish is easy to reproduce with high survival rate (70-80 percent) and now every hatchery can produce seed of this fish, especially in low land area. It is easily used for poly-culture in pond with the stocking density about 2 fish/m^2, usually at a ratio of 70/30 with grass carp and tilapia (Bui *et al.,* 2009). Total production of the fish has not been estimated but only Bac Giang province harvested 200 tonnes in 2008. This fish fetches quite good market price of about 1 USD/kg.

Recently studies on this species found that Thac Ba reservoir has this species. It was stocked into reservoir by the local fisheries agency in 2005 (Bui *et al.,* 2009). A lot of information revealed that this species easy spread out and could be a dominant species in the water body. Bayley (1973), Capeleti and Petrere (2006) described this species (*Prochidolus lineatus*) having highest production in Pilcomayo River. In 1987, the most species caught in Cachoeira de Emas of Mogi-Gaucu River was *Prochidolus lineatus*, contributing about 90 percent of the capture yield (Petrere, 1989).

Currently, in Thac Ba reservoir, it just contributed about 2-3 percent of total catch in the reservoir (Bui *et al.,* 2009). So it should be considered to culture this species in the natural water bodies such as rivers and reservoirs or lakes. However, this species is widely spread in the low land areas as a common cultivated species in ponds and it could multi-culture with other species in ponds. This species is now put into a research program of MARD to assess the impact and potential of releasing it in the reservoirs and other water bodies in Vietnam.

Presently, there are no activities on river enhancement implemented in Vietnam. However, there is an exception where China has collaborated with some provinces of Vietnam located along the border to release fishes into rivers. The places are in the border area between the two countries and the impact of this activity has not been studied.

On the conservation activities, the government had funded many programs to protect the gene sources of high value and endanger species in situ. According to Department of Science and Technology-MOFI study (2001), 37 species has been protected and the gene sources are kept in the three Research Institute for Aquaculture 1, 2, 3 in Vietnam (Table 1). Besides, the government also funded to study artificial propagation on some endangered species. To date, three species have been successfully reproduced and the technology has been transferred to the local fisheries agencies in Vietnam (Table 2).

Recently, the Prime Minister of Vietnam has just approved a program to establish decision No. 1479/QĐ-TTg for the establishment of the water inland conservation zones until 2020. There are 45 conservation zones being established under this program, including 16 national conservation zones and 29 provincial conservation zones in all over the country. This program aims to maintain and protect the biodiversity of inland aquatic resources of Vietnam.

Table 1. The list of protected fishes maintained in national broodstock and research centres in Vietnam

No.	English name	Scientific name
1	Cá Ba sa (Vietnamese)	*Pangasius bocourti*
2	Marble goby	*Oxyeleotris marmorata*
3	Mad barb	*Leptobarbus hoevenii*
4	Common carp	*Cyprinus carpio*
5	Hungarian common carp	*Cyprinus carpio*
6	Hungarian common carp	*Cyprinus carpio*
7	Indonesian common carp	*Cyprinus carpio*
8	Vietnamese common carp	*Cyprinus carpio*
9	V1 Vietnamese strain common carp	*Cyprinus carpio*
10	V1 Hungarian strain common carp	*Cyprinus carpio*
11	V1 yellow strain common carp	*Cyprinus carpio*
12	Catla	*Gibelion catla*
13	Red tailed tinfoil	*Barbonymus altus*
14	NA	*Hemibagrus guttatus*
15	Giant snakehead	*Channa micropeltes*
16	Vietnam silver carp	*Hypophthalmichthys harmandi*
17	Silver carp	*Hypophthalmichthys molitrix*
18	Bighead carp	*Aristichthys nobilis*
19	Java barb	*Barbonymus gonionotus*
20	Mrigal	*Cirrhinus cirrhosus*
21	Snakeskin gourami	*Trichogaster pectoralis*
22	Giant gourami	*Osphronemus goramy*
23	Striped catfish	*Pangasianodon hypophthalmus*
24	Black carp	*Mylopharyngodon piceus*
25	Grass carp	*Ctenopharyngodon idellus*
26	Whitespotted clarias	*Clarias fuscus*
27	North African catfish	*Clarias gariepinus*
28	Bighead catfish	*Clarias macrocephalus*
29	Mud carp	*Cirrhinus molitorella*
30	Climbing perch	*Anabas testudineus*
31	Rohu	*Labeo rohita*
32	Blue tilapia	*Oreochromis aureus*
33	Nile tilapia	*Oreochromis niloticus niloticus*
34	Viet strain tilapia	*Oreochromis niloticus*
35	Thai strain tilapia	*Oreochromis niloticus*
36	GIFT strain tilapia	*Oreochromis niloticus*
37	Egypt-Swansea strain	*Oreochromis niloticus*

Note: NA – not available

Table 2. List of endanger species in conservation program in Vietnam

No.	English name	Scientific name
1	Reeve's shad	*Tenualosa reevesii*
2	Chinese gizzard shad	*Clupanodon thrissa*
3	Konoshiro gizzard shad	*Konosirus punctatus*
4	Drápenka široká (Czech)	*Onychostoma laticeps*
5	Labeo znamenané (Czech)	***Semilabeo notabilis***
6	NA	*Similabeo rendahli*
7	Cá Hoà (Vietnamese)	*Bangana tonkinensis*
8	NA	*Similabeo graffenili*
9	Spiny barb	*Spinibarbus hollandi*
10	Spiny barb	*Spinibarbus denticulatus*
11	Mahsír hongkongský (Czech)	*Folifer brevifilis*
12	Black carp	*Mylopharyngodon piceus*
13	NA	*Hemibagrus guttatus*
14	Black Amur bream	*Megalobrama terminalis*
15	Helmet catfish	*Cranoglanis bouderius*
16	Goonch	*Bagarius yarrelli*
17	Four-eyed sleeper	*Bostrychus sinensis*

Notes: Bold names are species successful with artificial propagation; NA – not available

2. CURRENT PRACTICES OF INLAND FISHERIES ENHANCEMENT AND CONSERVATION

2.1 Inland fisheries resources enhancement

During the past ten years, the inland fisheries resource enhancement practices have not changed. As discussed above, it was basically implemented in the reservoirs and based on the size and management schemes in each situation. Ngo and Le (2001) indicated that the latter was more oriented on production rather than on management. There were no strong links between the different sectors using the water resource for various purposes such as irrigation and/or industry. According to Ngo and Le (2001), the inland fisheries resource enhancement could be categorized into two types:

- Reservoir fisheries enhancement, and
- Culture-based fisheries

2.2 Reservoir fisheries enhancement

The activities of this type are mainly based on Government activity and orientation and could be under the management of the local government and state enterprise. This activity is always applied for large and medium-sized reservoirs where there is a large number of people/community living around the reservoir. Fisheries enhancement, therefore, would provide job opportunities to people in vicinity, develop the socio-economic condition of the region and provide food for poor people.

In some large-sized reservoirs, which are mainly constructed for hydropower generation, stocking program is controlled by the local government with the orientation from central government. Thac Ba reservoir is an example (Figure 2). Stocking program is funded by local government and fishers must register to the fisheries center to get fishing license for catching fish in the reservoir. But it only works with the big fishing gears because these people are working everyday in the reservoir while other people living around were just using small boat and simple gears to catch fish. There is another way to control these people. Commune committees are authorized to collect fishing fees from the fishers living in the commune based on their fishing facilities such as the size and

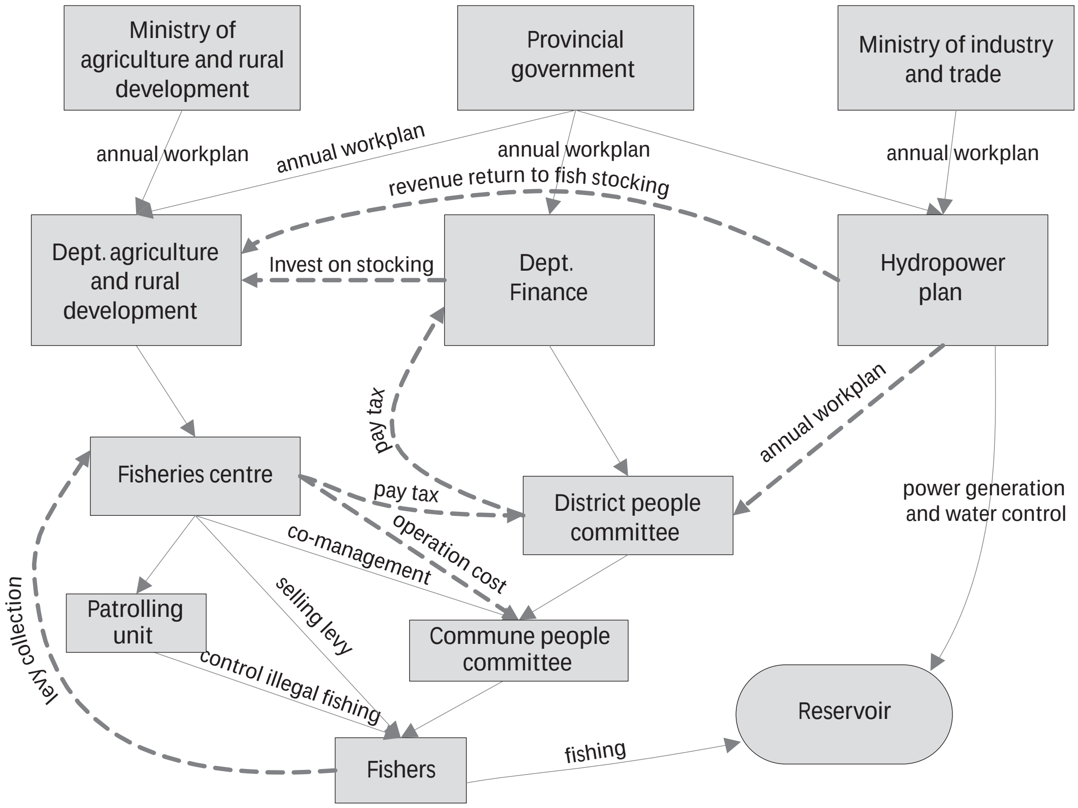


Figure 2. Schematic representation of government arrangements managing fisheries and enhancement in large and medium-sized reservoirs in Vietnam

number of boats owned, total amount of gear used (by type) and number of cages operated (Bui, 2006; Bui *et al.,* 2008). A part of the collected income will be given to the community and the remaining will constitute the local government tax (Nguyen, 2000; Ngo and Le, 2001). In turn, the local government will pay for the wages of the personnel while the centre will bear all costs associated with stocking and extension activities in relation to aquaculture operations.

However, in some large and medium-sized reservoirs, the enhancement activities are carried out by local fishery enterprises. They stock the fish into the reservoir and control the harvesting activities. This could be observed in Tri An (Figure 3), Nui Coc and Dau Tieng reservoirs. The advantage of this management pattern is that the enterprise has the official ownership of the fish resources. A production plan is initiated by the enterprise depending on their investment capacity and market availability. However, the disadvantage of this type is that it cannot stop illegal fishing due to the large reservoir area and difficult morphology.

The enterprise sells daily and/or periodical fishing licenses to prospective fishers depending on the type of the gear. The income from the sale of licenses is utilized for staff salaries, running costs, taxes and fingerlings stocking. Accordingly, the enterprise has major socio-economic links with the surrounding population whose livelihoods are dependent on the fishery resources in the reservoir. Although the right of fishery management has been transferred by provincial authorities it has no obligations with regard to the conservational aspects of the flora and fauna of the reservoirs. Also, there is potential conflict between different water users, particularly between tourist agencies, irrigation units and fishers.

The last type of fisheries enhancement is carried out in some hydropower reservoirs such as Hoa Binh, Ke Go and Cam Son reservoirs (Figure 4). This is open access fishing. The local fisheries agencies only have administrative jurisdiction on area, water use, and transportation, and let fishers access freely the reservoir resources. No particular fishery management activities are in operation and stocking just restarted in the last few years.

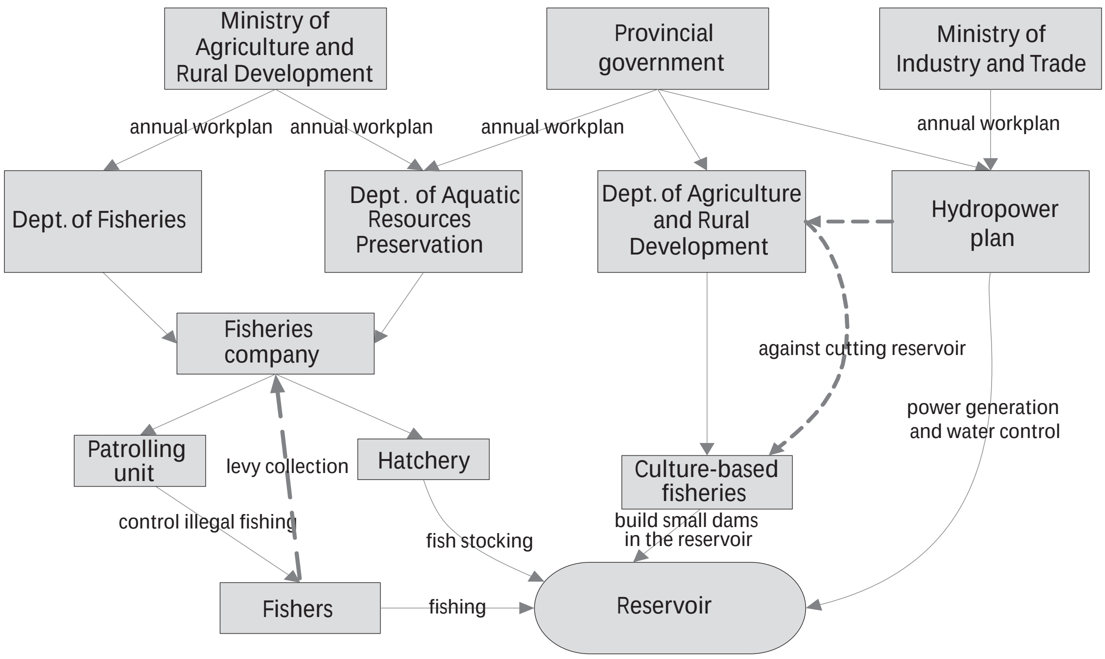


Figure 3. Schematic representation of fisheries management and enhancement of local enterprise in Vietnam

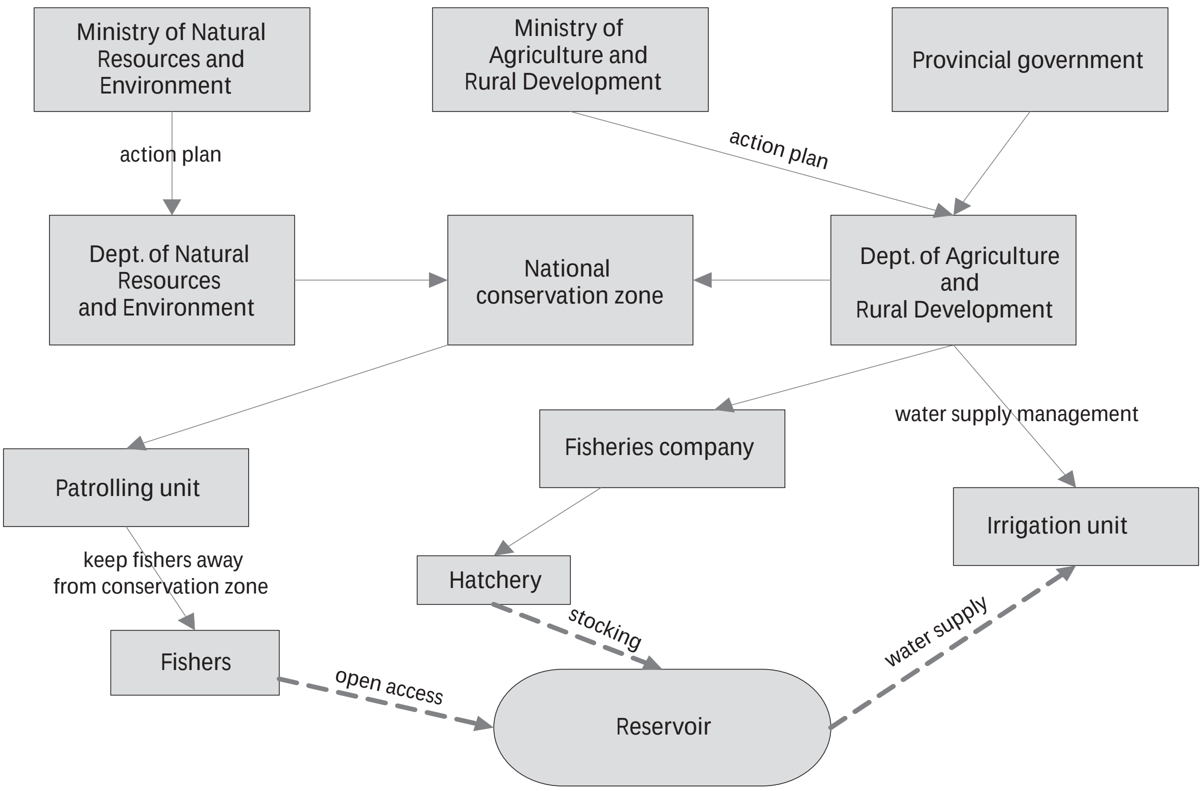


Figure 4. Schematic representation of open access reservoir fisheries in Vietnam

In this form of management, there are several organizations that share the waters but fisheries never have the highest priority over the control of the resource. There are conflicts between the official organizations on fishery resources management. As consequence, an open access policy to the water is still maintained.

2.3 Culture-based fisheries

In the last decade, culture-based fisheries had been done in some small-sized reservoirs which had been built for enhancement purposes as well as supplying seed to neighboring farmers (Nguyen, 2006). However, based on the 10-year development plan to obtain a production level of about 50 000 tonnes from reservoir fisheries, most of small irrigation reservoirs in Vietnam now are leased to farmers, farmer group or local organizations to conduct culture-based fisheries activities (Nguyen, 2006). These people run business together including stocking, harvesting and marketing.

In this type of fisheries, stocking normally starts from April to June when the water level is high. According to Nguyen (2006), stocked fishes depends mainly on availability in the regions and proximity to the supplies, and generally include common species such as grass carp, silver carp, bighead carp, mrigal and silver barb. In these reservoirs, people prefer using silver carp and silver barb more than other species with 40-50 percent of stocking composition. Sometimes, farmers stock high value species such as snakehead, *Hemibagrus guttatus*, etc. Fish is harvested during March to May because the water is used for paddy culture during this period. Nguyen *et al.* (2001; 2005) have shown that stocked species contribute more than 80 percent of total weight at harvest.

It was observed that high variations between reservoirs related to the size of each reservoir and generally, yields were lower in the larger reservoirs (Nguyen *et al.,* 2001). Nguyen (2006) found that most small irrigation reservoirs are seen as appropriate for developing culture-based fisheries in Vietnam. Therefore, culture-based fisheries could provide a means for producing cheap source of animal protein to meet the increasing demand for food in rural areas of Vietnam.

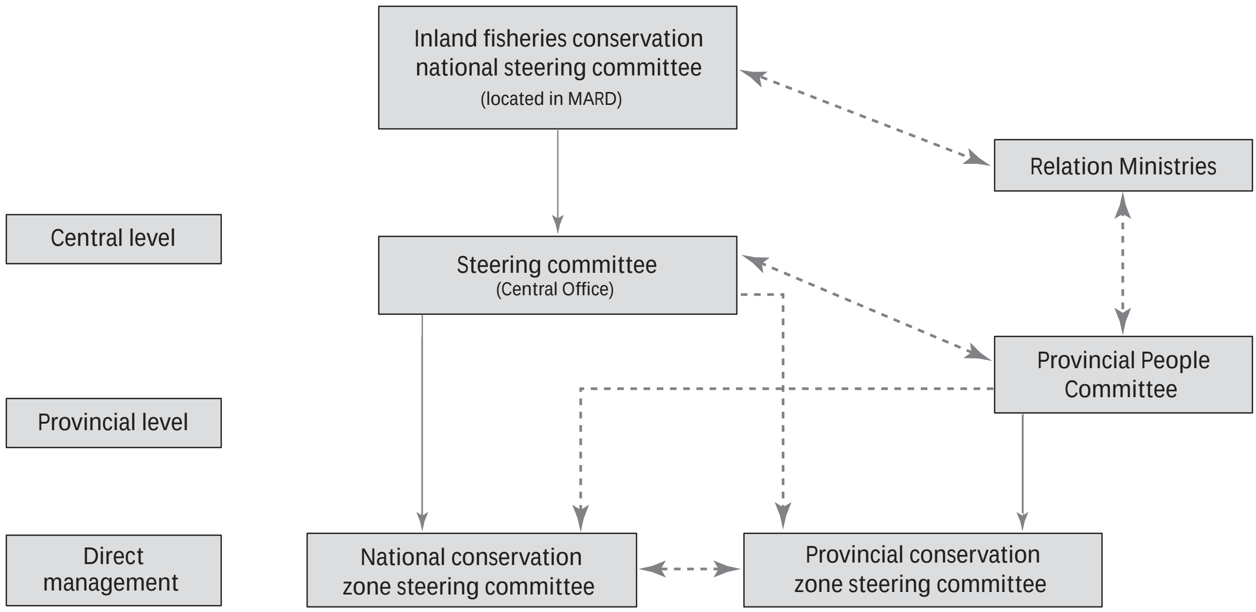
2.4 Inland fisheries resource conservation

According to the assessment of MONRE (2003), Vietnam has a dense river network, with several types of inland water bodies such as running water bodies (river, stream, estuarine and channel) and close water bodies (lake, reservoir, pond, swamp, paddy filed, etc.). Inland water body resources of Vietnam are very diverse with high biodiversity of flora, fishes, invertebrate, etc. Furthermore, Vietnam morphology is related with other countries which make up the biodiversity of the fauna in the country.

A new policy on resources conservation has been issued to different ministries such as the Ministry of Natural Resources and Environment (MONRE) is now responsible for Ramsar areas and the Ministry of Agriculture and Rural Development (MARD) is responsible for Inland Fisheries Resources Conservation zones. There are still some conflicts between these two ministries because of overlapping areas/zones. However, MARD manages all activities related to aquatic resources and coordinate other related activities with other organizations.

Figure 5 shows the schematic on management framework of the inland conservation areas in Vietnam. There are two management levels, the national and the local management level. The criteria to select and determine conservation zone is the same between these two levels. Except specific zones, the local government controls all the conservation zones located in their administration area. MARD only take the administrative works on the large conservation area at the national, inter-province and inter-country levels.

The National Steering Committee on Marine and Inland Conservation areas belongs to MARD. It is responsible in coordinating, , formulating government policies, decide and approve the annual work plan. MARD heads this committee which consists of representatives from the Ministry of Public Security, the Ministry of Education and Training, the Ministry of Planning an Investment, the Ministry of Science and Technology, the Ministry of National Defense, MONRE, the Ministry of Finance, the Ministry of Trade, Ministry of Culture and Information, the Hanoi National University, the Hochiminh National University, the Department of Tourism, the Vietnam Institute of Science and Technology and the Coordinating Office (Department of Department of Capture Fisheries and Resources Protection-MARD). The mission of Coordinating Office is to coordinate the activities, monitor and assess the effects, support and monitor the financial activities and propagate and collate the constructive ideas.



Note: dashed line: subordinated relation; stroke line: guidance relation

Figure 5. Management frame work of the inland conservation zones in Vietnam

The Provincial People Committee (PPC) receives advice from the Department of Agriculture and Rural Development (DARD) who directly manage the conservation area in the province. Under DARD, there is a management unit to control all activities in the areas.

There are also international donors and NGOs involved in the research activities in conservation areas of Vietnam. These organizations provide funding and technical supports and build projects.

Although inland fisheries conservation recently has received more attention from the central government of Vietnam, but the impact assessment on natural population has not been fully realized and implemented carefully in Vietnam.

Many inland water bodies are still facing issues of illegal importation and release of alien species. The example of *Prochidolus lineatus* species is a very clear example. Without tracking the right origin of the introduced species, the mangers or farmers could make it to be a bigger issue when the species dominate the area. It may affect the indigenous species and other fisheries in the area. Such of illegal transplantation should be controlled seriously and strictly in order to preserve the biodiversity of the inland water bodies in Vietnam.

The unsustainability of icefish fisheries development in Thac Ba reservoir could affect other fisheries in the reservoir and the local socio-economic conditions. The wide application of lift-net to catch icefish in the reservoir could also catch a lot of small fish, which are at the larvae or fingerling size, to directly affect other fisheries. In addition, the impact on ecosystem of this species should be assessed to determine its effects to other species. For example, this species eats zooplankton (*Cladoceroms, Leptodora, Calanoid copepods* và *Cladoceromd*) so it could compete the food with other species in the reservoir.

In the last 10 years, the Government of Vietnam has tried to conduct studies on indigenous species. They have funded for many research programs to preserve the native stock species and multiply these species in their national hatcheries and research centers. Presently, Vietnam has successfully reproduced some indigenous species and currently, they have a plan to re-stock them in the wild and some medium-sized reservoirs such as Nui Coc or Na Hang reservoirs to conserve its stock in wild.

Moreover, the central government has established many conservation zones to maintain and increase the population of these species in the wild. Besides, these areas could be the best way to conserve the biodiversity of the inland water bodies.

It is a very clear that inland fisheries bring more opportunities to the fishers and people living around in the area of such water bodies. Bui (2006) demonstrated that a number of fishers increased rapidly when the private sector is allowed to join together with the state fisheries. Figure 6 shows the trend of the private sector in Thac Ba reservoir fisheries. However, present fish production data is just recorded by the state so it could not described exactly of the private sector contribution.

According to Bui (2006), currently the fish production of this reservoir could get up to over 700 tonne a year and it only comes from private sector contribution, which are now about more than 2000 fishers. Also, in the recent study Bui *et al.* (2008) pointed out that the main income of fishers are from reservoir fisheries. This demonstrates that reservoir fisheries are the secondary priority but they bring a lot of opportunities to the local people. It also provides foods and low-cost feed ingredient to the local livestock and cage culture/aquaculture activities (Bui *et al.*, 2008).

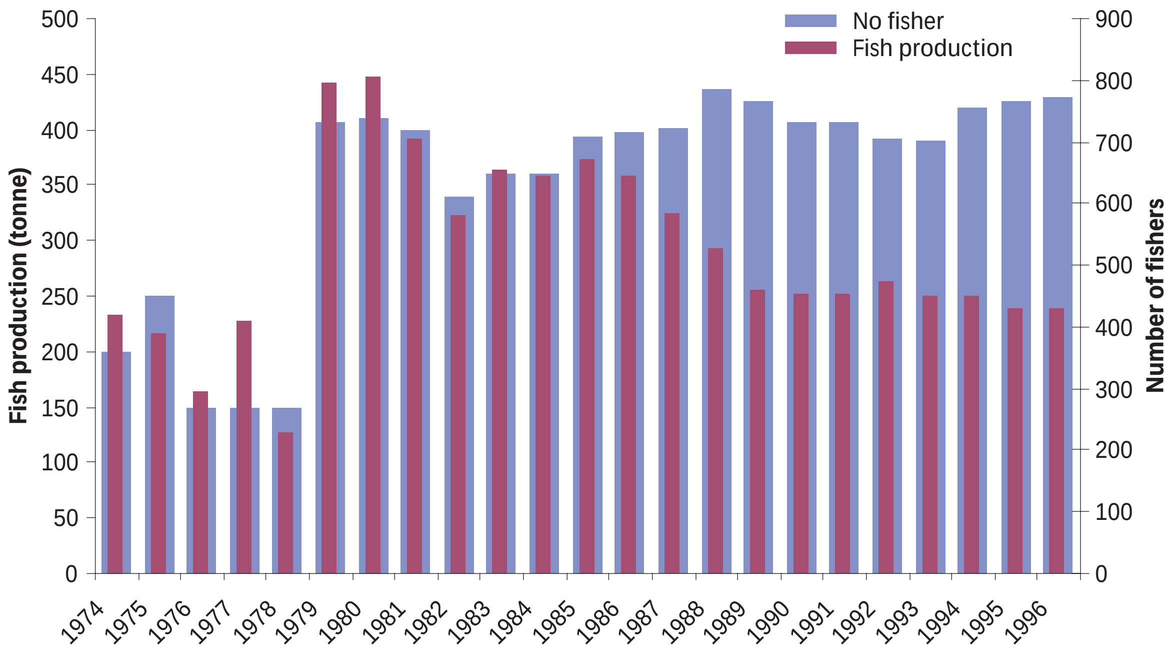


Figure 6. Relationship between number of fishers and fish production in Thac Ba reservoir (Bui, 2006; Bui *et al.*, 2008).

3. CONSTRAINTS AND PROBLEMS

Although the Vietnamese government had issued many decisions, plans and policies to improve the inland fisheries resources enhancement and conservation in recent years, it has not still achieved many good results. This could be due to the overlapping in management responsibilities, lack of adequate information and the merging of the management organizations (Ministry of Fisheries merged into MARD). Consequently, the information is still scattered and not continuous.

Besides, there has been no good species introduced or released into reservoirs/lakes/rivers in the last two decades, except the traditional species. This fact can not change the figure to increase fish production in the water bodies.

Artificial propagation techniques on several fish species are very popular and easy for farmer to learn and this helps in the aquaculture sector but also competes with the state supply system. State hatcheries located around the reservoirs are finding it difficult to develop and maintain their role in the region. These hatcheries have been impacted by the strong development of the private sector.

There are some successful programs with some indigenous species, which have been done with high values species. But, the technology is still in small-scale and need to be transferred all over the country.

As the above discussions, there is an overlap in the fisheries management systems of Vietnam. The conflicts between two or several organizations managing the reservoirs/rivers still exist and there is still no good solution to this problem. It is also the same with the management in several conservation areas. The overlapping role or work between the two organizations will cause the collapse of the system. It causes the directions go in the wrong ways and wastes government investment.

Moreover, the conflicts between the water users such as fisher and fisheries agencies in sharing and utilizing resources are also a constraint. Some conservation areas ban people harvesting fish in their area, even it is allowed (that is the forestry conservation zone) because the manger brings them in a group of thefts. The poor coordination between the management organizations also brings a lot of troubles to fishers when they need to contact these units. There is no proper legal document from these organizations to instruct local people what to do.

Although there are quite a lot program to assess about the impacts of environment and biodiversity, the information is still lacking to provide for decision maker and other relevant organizations to build the policies and programs on resources conservation in Vietnam.

4. RECOMMENDATIONS

Due to some constraints and problems above, there are some recommendations needed to be considered:

- Government need to improve the framework of management organizations in order to reduce the overlapping jurisdiction and/or responsibilities in the future implementation;
- More studies should be carried out on selecting good species to replace the common fishes currently stocked to increase the fish production and its value; (give some more valuable impacts)
- There should be certain control on introduction new species to Vietnam.
- The environmental and biodiversity impact assessment activities should be concentrated to keep the balance for the inland resources of Vietnam.
- There is need to carry out studies on estimating the quantity of the available water bodies/reservoir which could be utilized for fisheries development and build up the development program in the future based on such studies.

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ENHANCEMENT AND CONSERVATION OF INLAND FISHERY RESOURCES IN ASIA[1]

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1. INTRODUCTION

In contrast to stagnant marine capture fisheries in the past two decades or more, it is now widely acknowledged that in capture fisheries the greatest potential for growth lies in the inland sector (FAO, 2008), and realisation of this potential would also impact on rural livelihoods and nutrition of rural masses in developing countries in particular. Admittedly, the inland fishery sector, until now has not attracted the attention it should have, in many fronts, such as in gearing government policies, research and development efforts, technologies and marketing among others.

Inland fisheries in developing countries are for food fish production, as opposed to those in developed countries which are primarily for recreational purposes (Welcomme, 1997; Welcomme and Bartley, 1998). As such the development strategies that will drive these two types of fisheries are different, with some commonalities, however.

FAO (1997) defines fisheries enhancements as technical interventions in existing aquatic resource systems, which can substantially alter the environment, institutional and economic attributes of the system. This is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. In addition to the above is the enhancement of fish populations through stocking, either using hatchery produced seed or wild collected seed (e.g. freshwater eels), for varying purposes. Accordingly, such interventions, direct and indirect management enhancements (e.g. introduction of closed seasons, habitat improvements etc.) may result in enhanced fish production through capture fisheries, culture based fisheries, etc. Enhancements may also lead to biodiversity conservation through the establishment of "conservation units", sanctuaries and other managerial measures referred to earlier.

Inland fisheries resource enhancement and conservation have been practiced in the region by many countries for various purposes for decades. However, the practices, management and effectiveness vary greatly country from country due to constraints in knowledge, resources and institutional setup. Fisheries resource enhancement and conservation not only contribute to supply of fish products and generate livelihood for the population mass in the inland areas, but also have significant impacts on aquatic biodiversity and ecological functions of inland water bodies. However, aspects on stock inland fishery enhancements in the region have received limited attention previously (Petr, 1998; De Silva and Funge-Smith, 2005). The current synthesis is based on a FAO regional review study on fisheries stock enhancement and biodiversity conservation covering ten Asian nations (Bangladesh, China, India, Indonesia, Myanmar, Nepal, Republic of Korea, Sri Lanka, Thailand and Vietnam) which formed the basis for the FAO regional consultation conducted over a four day period in February 2010. This consultation had the following objectives:

- Exchange and share successful experiences and lessons on inland fisheries enhancement and conservation practices across the countries participating in the review study,
- Assess the impacts of inland fisheries resource enhancement and conservation practices, identify the constraints and related problems from a regional perspective, and
- Recommend regional collaborative activities to promote improved practices of inland fisheries resource enhancement and conservation.

[1] This synthesis should be read in conjunction with the country reviews that are included in this volume. The country reviews are not specifically referred to in the text, however.

In addition, relevant, additional published information on the subject was utilised in the preparation of the synthesis. In order to place the material in a proper perspective the synthesis also deals with the current status of inland fisheries in the region and its contribution to the global inland food fish supplies, and including a brief summary of the current inland fishery practices.

2. INLAND WATER RESOURCES AND FINFISH BIODIVERSITY

The earth is estimated to have only 35 029 000 km^3 of freshwater, or only 2.5 percent of all water resources, of which only 23.5 percent is habitable (Shiklomanov, 1993, 1998; Smith, 1998). The amount of freshwater available as rivers, lakes, wetlands etc. amounts only to 0.01 percent of the earth's water resources or only 113 000 km^3. Generally, a fact that is often not appreciated is that, of the world water resources, less than 0.01 percent occurs as surface waters, and is the home to a very high level of biodiversity. The multitudes of such forms have created varying ranges of habitats that are the home to the great diversity of freshwater fauna, of which the vertebrate fauna in freshwaters accounts for nearly 25 percent of the global vertebrate diversity, but these also happen to be among the world's most threatened ecosystems (Groombridge, 1992). It has been suggested that global freshwater biodiversity is declining at far greater rates than is true for even the most affected terrestrial ecosystems (Riccardi and Rasmussen, 1999). It is in this context that future developments in the sector have to take into consideration aspects on biodiversity conservation.

Asia is known to be blessed with the highest amount of useable, surface freshwater resources of all continents, but the per capita availability of the resource is the least (Nguyen and De Silva, 2006). The freshwater resources occur in many forms, such as rivers, streams, marshes, lakes, flood plains and the like, and those from anthropogenic interventions such as reservoirs and pools. Freshwaters utilised for fishery enhancements are variable form country to country in the region (Table 1). It should also be noted that all the acreage is not necessarily utilised for fishery enhancements, which provides an indication of the scope of enhancements that is possible with a consequent increase in food fish production and provision of livelihoods.

Table 1. The varying types of freshwater resources utilised for fishery enhancements in ten countries

Country	Rivers	Flood-plains (ha)	Lakes (ha)	Reservoirs (ha)	
				large & medium	Small
Bangladesh	24 000 km^2	2 946 950*		58 300	
China	7 650 000 (ha)	NA	7 140 000	211 000	
India	29 000 (km)	354 213**	720 000	1 667 809	1 485 557
Indonesia	12 000 000 (ha)		1 800 000	50 000	
Myanmar	1 300 000 (ha)	8 100 000		115 687	
Nepal	395 000 (ha)		5 000	1 500	
Republic of Korea	2 800 km^2			110 800	
Sri Lanka	NA	4 049		109 450	39 271
Thailand	4 100 000 (ha)				400 000
Vietnam				340 000	

NA – data not available; * includes ox bow lakes, beels, haors and baors; ** includes flood-plain lakes and associated wetlands

The freshwater fish diversity of the Asian continent is high and diverse with an estimated cumulative total of 7 447 species, which accounts for approximately 25 percent of all known global finfish species (Nguyen and De Silva, 2006). It has also been pointed out that the Asian freshwater fish species diversity is higher when compared to other continents, but lower in familial diversity. In Asian freshwater fish fauna the dominant groups are cyprinids (Cyprinidae, about 1 000 species), loaches (about 400 species) of the families Balitoridae and Cobitiidae, gobids (Gobiidae, 300 species), catfishes (Bagridae, about 100 species), and the Osphronemidae (85 species).

With such a high faunal diversity, and an equally high degree of endemicity inland fishery enhancements need to revolve around practices that do not overly impact on this diversity. Most of the countries that have contributed to this synthesis have a diverse and a rich freshwater fish fauna, perhaps with the exception of Sri Lanka, a continental island which has only 62 species recorded but of which over 25 percent is endemic to the island. Similarly, in the Republic of Korea of 269 species and mollusks 61 species are endemic to the country. Bangladesh on the other hand, has a fish fauna of 267 species, belonging to 156 genera and 52 families, whilst 109 species are known from the River Ganga system in India, out of a total of 765 of the whole sub-continent.

Obviously, not all of the rich fish fauna is used for fishery enhancement purposes in any of the countries. Fish species selected for enhancement usually fall into tow major groups, species of great economic important (e.g. carp species) and species in danger or serious depletion of population, which are of great scientific value (e.g. Chinese sturgeon). For example, the Republic of Korea has recognized seven finfish species (Korean bullhead, *Psedobugrus fulvidrac*; far eastern catfish, *Silurus asotus*; Japanese eel, *Anguilla japonicus*; Crusian carp, *Carassius auratus*; mandarin fish, *Siniperca scherzeri*; sweet fish, *Plecoglossus altivelis*; common carp, *Cyprinus carpio*) for stock enhancement, together with one crustacean, one mollusk and one turtle species. In general, in the region, the main indigenous species utilized for stock enhancement purposes are the common carp, and the Chinese and Indian major carps, supplemented by other species, case by case. In most countries in the region in addition to indigenous species alien species are also used for enhancement purposes.

The selection of species for stock enhancement purposes varies from case to case. In most instances, especially in enhancement food fish purposes, the choice is based on the high growth rate, feeding habit, often omnivorous fish species being preferred, and consumer acceptability. The best examples of such species are the Chinese and Indian major carp species. In certain instances stock enhancement may be carried out to fill a vacant niche in a water body, such as for example the use of ice fish in China and Vietnam.

3. INLAND FISHERIES

3.1 An overall perspective

The contribution of inland fisheries to the global fish supplies can be considered as small, being around 10 to 12 percent of the total capture fisheries production. However and very importantly, the bulk of the inland fishery production occurs in Asia, the region contributing almost 70 percent to the global production (Figure 1), a trend that has existed over the last two decades or more, being ample evidence of its significance to the region as a whole. Also, it is evident that inland fisheries production has been rising, albeit slowly, the major impetus coming from the Asian region. China is a major contributor to the inland fisheries production in the region, approximating about 35 percent.

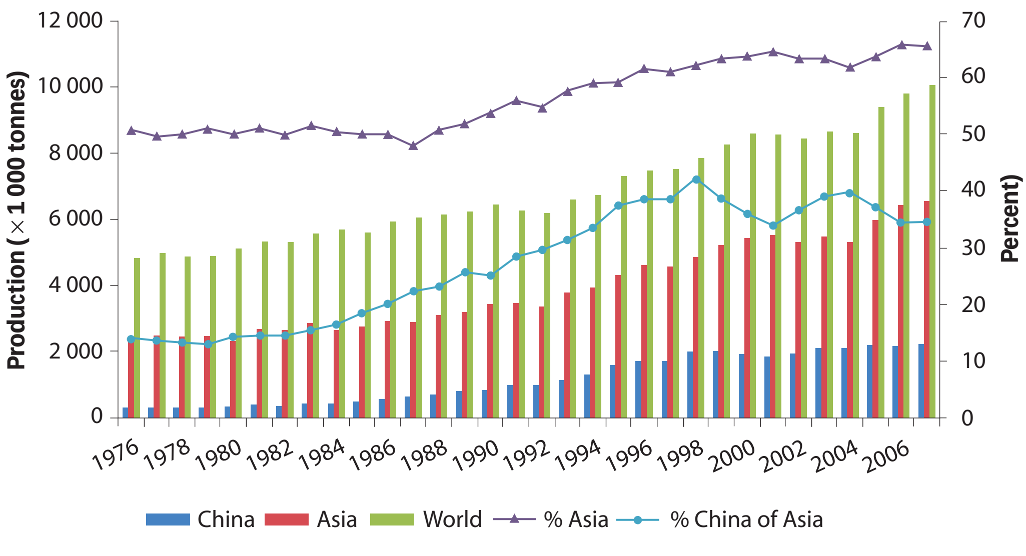

Figure 1. The trend in inland fish production in PR China, Asia and the world and the percent contribution of the former to the word production.

It is often said that overall the inland fish production and hence its contribution to global food fish supplies is underestimated, and it has been specifically demonstrated for example for the Lower Mekong Basin (LMB) fisheries (Coates, 2002). Coates (2002) estimated that the fishery of the LMB accounts for nearly 2.5 million tonnes per year, and pointed out the difficulties in obtaining reliable inland fish production statistics. Hortle (2007), with reference to the Lower Mekong Basin riparian countries demonstrated that the estimates of inland fish production of the FAO (equivalent to those reported by individual countries) are significantly lower, for some countries as low as three fold. Hortle (2007) emphasised the need for harmonization of basic statistical data collation and reporting. Similarly, fresh estimates based on consumption surveys in 2005 have indicated that the inland fish production from inland waters in Thailand to be 1 062 696 tonnes (Lymer *et al.*, 2008), almost a five fold higher estimate than that reported by the Royal Government of Thailand estimates.

In most developing countries, and particularly in Asia, inland fishery produce are almost totally used for human consumption, fresh and or processed into such products as sun-dried fish, fish paste, fish sauces etc. However, there are a few exceptions, such as in the case of Mekong Delta flood plain fishery where some amounts of the catch is used for converting into dried fish powder to be later used in the preparation of feeds for cultured stocks (De Silva, 2008), and or fed directly as raw fish to such stocks. It is also important to note that inland fisheries in Asia are rural and therefore benefits rural communities who generally tend to be poor.

3.2 Overview of Asian inland fishery practices

The importance, magnitude and the nature of inland fisheries in Asia are very wide ranging and diverse, much of which are based on traditional practices. In most countries in Asia the bulk of inland fisheries for food fish production occur in lacustrine waters, while the riverine fisheries, apart from that of the Lower Mekong Basin, (which supports a large fishery and millions of livelihoods), have declined over the years. The more recent developments in inland fisheries in Asia have occurred in the vastly increased acreage of reservoirs in the region (Nguyen and De Silva, 2006), impounded for irrigation, flood protection and hydroelectricity generation and or for multi-purposes with fisheries becoming an important secondary user of these impounded waters. In some nations such as in Myanmar and Bangladesh, countries with very large flood-plain waters, there are organized flood plain fisheries, referred to as leasable fisheries in Myanmar, based on naturally recruited and stocked species, augmented by stocking.

The individual fisheries vary in intensity (Table 2, FAO, 2010), modes of operation and production within and between countries. In most countries in Asia inland fisheries tend to be artisanal, where small motorized and or non-motorized crafts, manned by two persons, using either gill nets or traps are the main mode of operation. On the other hand, in large water bodies mechanised boats are used to operate purse seines, often only small numbers (e.g. Thailand) and using integrated nets as gear (e.g. China). In countries such as Indonesia, Myanmar and Sri Lanka use of motorized crafts in inland fishery activities is prohibited. Shore seines for example are permitted in India but not in Sri Lanka. It is also important to reiterate, as pointed out in Section 2, the potential gross underestimation of inland fish production in some countries, such as for example in most of the Lower Mekong Basin riparian countries (Hortle, 2007; Lymer *et al.*, 2009).

In most countries in Asia, the main species in inland fisheries tend to be indigenous species, at times translocated across their natural range of distribution within the country boundaries. For example, the inland fisheries in China are predominated by major Chinese carp species, such as silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), common carp (*Cyprinus carpio*) etc., whereas those in India and Bangladesh are predominated by Indian major carps, such as rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigal*), catla (*Catla catla*) etc. Similarly, in Thailand the inland fisheries are predominated by indigenous catfish and snakehead species, as well in some waters by the native pelagic freshwater clupeid, the river sprat, *Clupeichthys aesarnensis* (Jutagate *et al.*, 2003).

However, in Sri Lanka, an island state with a relatively depauperate native fish fauna, the backbone of the inland fishery, particularly those based on self-recruitment, in large reservoirs, is almost entirely predominated by exotic tilapias. In Vietnam the inland fisheries in the past was based primarily on alien species, regularly stocked, but in

Table 2. The inland capture fishery production (FAO, 2010) and the main sources of production

Country	Production (tonnes)	Observations
Bangladesh	1 060 181	Flood plains; rivers, reservoirs
China	2 248 347	Ponds, rivers, Lakes and reservoirs (including aquaculture)
India	953 106	Rivers, estuaries, lagoons and upland lakes (through capture fisheries); small reservoirs and closed wetlands (through culture based fisheries); medium and large reservoirs, and open wetlands (through enhanced capture fisheries)
Indonesia	323 150	Lakes, reservoirs, flood plains, rivers
Myanmar	814 740	Flood plain leasable fisheries, river fisheries
Nepal	21 500	Rivers, lakes, reservoirs
Republic of Korea	5 202	Rivers, lakes and reservoirs
Sri Lanka	44 500	Open water reservoir fisheries; culture based fisheries in small water bodies
Thailand*	231 100*	Riverine and reservoirs, culture-based fisheries
Vietnam	140 900	Riverine and open water reservoir fisheries; culture based fisheries in small water bodies

* note that Lymer *et al.* (2009) estimated at 1 062 696 tonnes

the last decade there had been a gradual shift to a predominance of indigenous species, small cyprinids species such as *Toxobramis houdemeri*, *Pseudohemiculter dispar*, *Coulter erythropterus*, *Cranoglanis* spp., etc.

In essence in the large lakes and reservoirs, fisheries are based on naturally recruiting stocks, occasionally of alien species. However, the major exception is China, where even large reservoirs and lakes (e.g., Danjiangkou and Qinghaihu, etc.) are stocked with seed of suitable species, primarily Chinese major carps, common carp, naked carp, etc. on a regular basis, and harvested using integrated nets.

4. STOCK ENHANCEMENT

4.1 Reasons for stock enhancement in the region

Fish stock enhancement in the region is carried out for varying purposes and reasons, and differs from country to country. The great bulk of stock enhancement is conducted for public good to increase food fish production and even for purposes of uplifting existing fisheries. Some stock enhancements are associated with conservation of fish stocks, revitalising endangered fish stocks/populations as well as for mitigating environmental degradation resulting from anthropogenic impacts.

Fish stock enhancement is also sometimes carried out to mitigate the negative environmental impacts of intensive aquaculture activities, such as with the regular occurrence of fish kills due to poor water quality, which in turn enables the maintenance of fish production and livelihoods and fisher communities who also happen to be poor and most wanting (Abery *et al.*, 2005).

Fish stock enhancement of small water bodies, often non perennial, for food fish production and provision of livelihoods, as conducted in India, Lao PDR, Sri Lanka, Thailand and Vietnam, borders on aquaculture, as often there is ownership of the enhanced stocks.

In addition to all of the above, is the practice, in countries such as Cambodia, Lao PDR, Myanmar and Thailand, of "fish releases", an indirect form of enhancement that is conducted for symbolic and cultural reasons, related to traditional yearly water festival celebrations (i.e. water-flushing "Songkran" festival as practiced in Cambodia, Lao PDR and Thailand). These activities have been ongoing for over five to six decades and are associated with extensive community involvement in the festivities.

4.2 Summary of current stock enhancement practices

Stock enhancement through seeding of water bodies has been in practice in many countries in the region for long periods of time, for varying purposes. For example, the stocking of artificially propagated Chao Phraya giant catfish seed (*Pangasius sanitwongsei*) into rivers in Thailand was conducted entirely for the purpose of conservation of this endangered species. A summary list of species used in stock enhancement purposes and those that are indirectly impacted upon by the various practices, for each country, is given in Annex I. It is evident from Annex I that a wide variety species are included in stock enhancement practices in the region, and in all probability this list of species is far from complete either.

For convenience and clarity the current stock enhancement practices in Asia are considered in the following sections in the context of the broad water types.

4.2.1 Stock enhancement in rivers

Stock enhancement of rivers is conducted in China, India, Malaysia, Myanmar, Republic of Korea and Thailand. Such activities are not necessarily associated with a view to increasing food fish production and or supporting livelihoods, but primarily towards conserving and or restoring the riverine stocks, and on occasions for purposes of environmental improvement. In general, stock enhancement of rivers is based on indigenous species, such as for example the Indian and Chinese major carps being used to enhance the respective riverine stocks in each of the countries, and or the use of mahseer (*Tor*) species in India and Malaysia. However, there is a dearth of information on the impacts, environmentally, production wise and economically, from such enhancement activities.

On the other hand, river stock enhancement is conducted as a compensatory measure (e.g. Thailand) when anthropogenic impacts such as discharge of pollutants result in mass mortalities of the riverine fish. In Bangladesh, fish aggregating devices, such as brush parks, created using bushy tree branches and twigs, locally known as *katha*, are used in secondary rivers and canals, as the fish are harvested as the water recedes after six to eight months of operation (Kibria and Ahmed, 2005). The effectiveness of use of brush parks as fish aggregating devices in the tropics was reviewed by Welcomme (2002), and its advantages as a fishery enhancement practice, benefiting poor communities were demonstrated.

4.2.2 Stock enhancement in flood-plains

Stock enhancement in flood-plains and associated waters as in the case of Bangladesh flood plain depressions (e.g. termed as baors and hoars), is conducted for food fish production both in Bangladesh and Myanmar. In Myanmar, the process is termed "leasable fisheries" where areas of the flood plain are leased out through auction to the highest bidders. This form of a fishery has been in existence for over five decades. The lessees often enhance the fish stocks in their leases with a view to increasing production, and accordingly the production has increased from 91 980 in 1998-1999 to 209 720 tonnes in 2008-2009. It is also important to point out that there had not been a significant change in the number of leasable fisheries in Myanmar, ranging from 3 280 to 3 450 since the 1990s, indicative of the regulatory aspects of permitting leasable fisheries.

In Bangladesh a similar process occurs in baors and haors of the flood plains. Baors (5 488 ha) are ox bow lakes whereas haors (2 832 790 ha) are flooded plains between two rivers and their tributaries, and are generally non-perennial in nature, retaining water for 4 to 6 months in the year, but highly productive, biologically. The fish populations of these waters are enhanced through stocking, primarily of indigenous Indian major carps, and the total yields from baors and haors in 2008 were reported to be 77 500 (679 kg/ha/yr) and 819 500 (290 kg/ha/yr) tonnes, respectively, perhaps far exceeding the natural fish productivity should there be no enhancement. Also in almost all instances of flood plain stock enhancements indigenous species are utilised, but there is some appearance of exotics, for example tilapia in the case of flood plain leasable fisheries in Mandalay, Myanmar.

Both of the above fisheries also have social implications, for instance, by limiting access and alienating the communities living in the vicinity of these waters from fishing and or obtaining fish for consumption. In

Bangladesh this social problem is being addressed through the implementation of co-management of the fishery resources of baors and haors where the community as a whole is able to benefit from accessing the fishery resources (Valbo-Jørgensen and Thompson, 2007).

4.2.3 Stock enhancement in static water bodies (lakes and reservoirs)

As mentioned previously Asia has the largest reservoir acreage in the world, and the great bulk of these reservoirs have been impounded in the second half of the last century. Fisheries are becoming very significant secondary users of water resources in all countries, except in Myanmar where fisheries development in reservoirs is banned. In general, in the region reservoir fisheries contribute significantly to inland food fish production and provision of livelihoods (see Table 2).

Fish stock enhancement activities in static water bodies differ from country to country, and between water bodies. In China for example, there is regular stock enhancement for large and medium-size reservoirs and lakes, often with Chinese major carps, and common and crucian carp and associated fisheries which are well managed and regulated. Some of these fisheries can be considered to be industrial scale. The other end of the scale is the fisheries of large perennial reservoirs in Sri Lanka where the fisheries are primarily based on exotic tilapias, with minimal stock enhancement conducted on a regular basis, the fisheries are almost entirely based on natural recruitment. On the other hand, in Thailand although large reservoirs are stocked with exotic species such as Chinese and Indian major carp species on a regular basis, (in accordance with a decree by the King of Thailand), but these species account for a small amount of the reservoir fish production, which is predominated by indigenous cyprinids, snakeheads and catfishes, and in some instances the riverine clupeid, *Clupeichthys aesarnensis* (Jutagate *et al.*, 2003). In all of the above instances, including in other countries in Asia, e.g. Bangladesh, India, Indonesia, Lao PDR, Vietnam fisher communities are established and operate these fisheries. However, there is a general lack of understanding of the direct returns from stock enhancements of large static waters. Perhaps the balance of evidence suggest that stocking of large reservoirs will have minimal impact on food fish production except in instances where the reservoir water management and fishery management work cooperatively, such as for example enabling complete harvesting, having devices to prevention the escape of stocked seed, stocking of larger sized seed, provisions for use of integrated nets/appropriate gear, etc., as in China.

Perhaps one of the most notable successes of a stock enhancement activity in a natural lake in Indonesia is that of Lake Toba, North Sumatera, Indonesia. Stock enhancement commenced in 2003, with bilih (*Mystacoleucus padangensis*) at which time the total fish production of the lake was only 53.7 tonnes and reached nearly 3 036 tonnes in 2008, with an average catch of 0.5 to 2.0 tonnes/day. Interestingly, in this case the above species was translocated from a naturally occurring population(s) of Singkarak Lake (West Sumatera), and in a manner is comparable to the icefish (*Neosalanx* spp.) translocation across China and indeed introduction of the latter to reservoirs in Vietnam.

In all of the above cases it is imperative that the success of stock enhancement will finally depend on effective fishery management, a fact that it not adequately appreciated.

Different to the above stock enhancement practices are those conducted in smaller, often non-perennial water reservoirs, such as in India (Sugunan, 1995; Sugunan and Sinha, 2001), Lao PDR (Saphakdy *et al.*, 2009), Sri Lanka (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009), Thailand (Lorenzen *et al.*, 1998) and Vietnam (Nguyen Son *et al.*, 2001) where the water bodies are stocked with suitable species and are harvested as the water recedes. The fisheries are communal based, co-managed, and border on aquaculture as the stock is owned by the community. The sustainability of such operations are ensured to a significant degree through the collection of levies for continued stocking for the following growth cycles, as exemplified in the case of the culture-based fishery operations in Sri Lanka.

4.3 Other enhancement practices

In addition to stock enhancement practices in operation in the region there are many fishery related enhancements that are in operation, in all of the above water types dealt with previously. The most important aspects of enhancement in the above regard are summarised as follows.

(a) *Provision of fish sanctuaries/protected/conservation areas:*

The above is practiced in natural water bodies in most countries, for example in the flood plains of Bangladesh. The establishment of sanctuaries is decided on technical advice of the authorities in cooperation with the community, and agreed sanctuary size could range from 1 to few hectares, the area designated being clearly demarcated by some form of fencing. The habitats in the demarcated areas are further enhanced by adding substrates etc. In the Republic of Korea there are 19 (15 lakes and 4 streams; total of 330 km^2) designated as protected areas, amounting to 6 percent of the country's inland waters. Similarly, 605 protected areas exist in India in the form of National Parks, Wildlife Sanctuaries and Conservation Reserves, covering approximately 4.74 percent of the total geographical area of the country.

In all of the above, fishing is strictly prohibited and such regulations are strictly enforced.

(b) *Provision/improvement to spawning habitats:*

In some countries in the region, e.g. China there is an ongoing program to provide and or improve spawning habitats, in particular for non-migratory species, such as common carp and crucian carp.

(c) *Habitat improvements:*

Habitat improvement is conducted in respect of many fisheries. Improvements are related to augmenting the nature of spawning grounds of specific species, particularly in larger water bodies. In flood plain fisheries introduction/modification of habitats to enhance refuges for naturally recruited young is often undertaken by the provision of structures such as brush piles. Brush piles are also utilised in culture based fisheries, as they have been shown (also see Section 5.2.1.) to enhance periphyton growth and are thought to provide an additional food sources for most omnivorous fish (Azim *et al.*, 2005).

Other enhancements include weed removal and desiltation, which are commonly undertaken in Thailand for instance.

(d) *Introduction of closed seasons:*

Most countries have introduced closed seasons for stock enhancement purposes mostly in water bodies that have established fisheries. Such closed seasons are related to the knowledge on the reproductive seasonality of the predominant species of the respective fisheries, such as for example in inland waters in Thailand (dates: 16-05 to 15-09, country-wide), where the fisheries are mostly dependent on indigenous species. The above period coincides with the onset of rains when the predominant group of fishes, mainly cyprinids, tend to breed. However, even in this period, fishing for household consumption is permitted.

In the Republic of Korea the operation of closed seasons are even more regulated, with specific time periods being applied for each of the target species. For example, for salmon, *Oncorhynchus keta*, mandarin fish, *Siniperca schezeri* and sweet fish, *Plecoglossus altivelis* the closed seasons are 01-10 to 30-11, 20-05 to 30-06, and 01 to 31-05 and 01-09 to 31-10, respectively. Closed seasons, when operating, are generally strictly enforced by the authorities.

(e) *Gear restrictions:*

In most inland fishery operations gear restrictions apply, and are fairly strictly enforced. In Sri Lanka and Thailand for example, seine nets are prohibited in most large reservoir and lake fisheries, whilst it is permitted in India. In general, seine nets are used in harvesting in culture based fisheries. In China, in most medium and large-sized water bodies the main gear used is an combined fishing method using blocking net, driving net, gill net and set bag-net simultaneously in one fishing operation, which ensures the capture of a significant proportion of stocked fish of specific size range, in a few operations.

4.4 Key issues related to stock enhancement of inland waters

4.4.1 Size of seed for releasing and stocking

In the region, in general, the size of released/stocked seed in those practices on which fisheries are based take care to ensure that it is optimal for stocking. However, strict guidelines in this regard are not readily available in most countries. In China for example strict guidelines are adhered to on the size of seed for stocking, often around 15 cm in body length. On the other hand, those enhancements that are conducted for symbolic and cultural purposes often tend to use undersized seed stock, the returns from such practices for building up natural populations is likely to be insignificant.

4.4.2 Seed quality

In all instances there is very little attention paid to the quality of seed stock used, and their genetic compatibility with that of the natural stocks, an aspect that warrants attention. In general there is very limited or no evaluation of the hygiene of the seed stock and risk assessments. These are imperatives if improvements are to be brought to stock enhancement practices in the region, which would help minimise negative impacts.

The general notion is that stock enhancement of indigenous species may not be genetically harmful to the natural populations has been shown to be incorrect as shown by many studies in the northern hemisphere in respect of salmonoids in particular. Bearing in mind that seed required for stock enhancement purposes have to be from hatchery produced stocks, which are known to be of lower quality than its wild counterparts, the most pragmatic option would be to secure proper broodstock management plans and closely associate the enhancements to remain compatible with the genetic diversity of specific wild populations of the species. Needless to mention that introduction of such programs have a cost, require high technical skills, and therefore will need a rationalised approach in the selection of species and the extent of adherence to designed management plans. This aspect is dealt in further detail in Section 6.4.

4.4.3 Socio-economic aspects

There is no doubt that adoption of stock enhancement procedures that have led to establishment of fisheries have had a socio-economic impact by providing livelihood opportunities, and in all probability an improvement in the nutrition of rural populations by making available affordable food fish supplies. On the other hand, as pointed out in Section 3.2.2 lease of waters such as in Bangladesh and Myanmar would limit the access to these resources by the poor. It is encouraging to note that the above is being addressed to some degree in Bangladesh by reverting to a co-management of the resources, leading to a sharing of the benefits (Valbo-Jørgensen and Thompson, 2007).

The most detailed socio-economic gains of stock enhancement are evident in the case of culture based fishery activities in many countries; best exemplified by the example from India, Lao PDR (Garaway *et al.*, 2006; Saphakdy, 2009), Sri Lanka (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009) and Thailand (Garaway *et al.*, 2001).

Experience in Vietnam (Nguyen Son *et al.*, 2001) showed that leasing of waters, for culture based fisheries, on a short-term basis may not be most appropriate as the lessees are discouraged from bringing about improvements to physical attributes of the water body that could enhance fish production. Medium to long-term leases may encourage more responsible management, provided it is associated with regular monitoring by authorities.

The involvement of the private sector for management, including stock enhancement and associated aspects of water bodies for fisheries development as evident in the case of Vietnam, is a new initiative in the region as a whole. This initiative, which is to be extended to new major impoundments, is likely to have socio-economic impacts on the communities living in the vicinity, as well as fisher livelihoods prior to impounding, through marginalization of the latter. Close monitoring of this will be of use to the region as a whole in making suitable policy decisions in this regard.

4.4.4 Governance issues

Admittedly the governance issues are rather complex and vary widely between countries. One common denominator in this regard, however, is that almost all water bodies used for food fish production and conservation purposes come under the purview of many governmental agencies, often operating under different ministries. Overall, in the region, reservoir fisheries are a secondary activity and the water management of the impoundments come under the purview of different authorities, such as for example in Thailand under the Electricity Generating Authority of Thailand (EGAT), Irrigation Department in most cases in Sri Lanka, under the Forestry Department in Myanmar and so forth.

A better dialogue with the water management authorities and fishery authorities is likely to bring about improved impacts on fish production, without necessarily impacting negatively on the primary user purposes. However, there is increasing evidence to believe that with the creation of new impoundments there is a realization that the secondary use of the waters for food fish production and livelihood generation could be of significant value, both socially and economically. In this respect the best examples could be drawn from Indonesia (Citarum water shed reservoirs; see Abery *et al.*, 2005) and Nepal (Kulekhani reservoir; see Gurung *et al.*, 2009) where cage culture activities for displaced communities were accepted and supported as an alternate means of livelihoods, and more importantly there activities have been sustained for more than 20 years, with a concurrent development of a capture fishery, which is enhanced through a variety of measures.

Adoption of fishery enhancement practices has also resulted in relevant changes in governance that have facilitated the development of such activities. For example, in Sri Lanka non-perennial reservoirs were not permitted to be used for fishery enhancement under the Agrarian laws that were prevalent. However, the law was amended to permit fishery enhancement through culture based fisheries development and this change has further facilitated these developments (Amarasinghe and Nguyen, 2009). In Indonesia, with the stock enhancement of reservoirs in the Citarum watershed with milkfish, for mitigating purposes, were accompanied by the introduction of mesh size restrictions by the District Governing authorities, in concurrence with the fisher communities, which enabled the establishment of the activity and a further step towards the sustainability of the practice.

The successful introduction of the tagal system (see Section 5.4.f), a partnership between communities and the government, for protecting, rehabilitating, conserving and managing fishery resources in the state is a good example of a management system involving aboriginal communities. Each community must have traditional user rights, to be eligible to participate in this partnership, preferably rights to several deep pools in the river and manage and use its fishery resources under the leadership of the headman of the community (Wong, 2006). By 2006, the 'Tagal' system of management had been set up at 234 sites in 11 districts involving 124 rivers and, consequently, had successfully revived the depleted river fish populations, including many with mahseer (Wong 2006). A similar approach has been reported from Corbett Park in India, in which the 'Conserving the "tiger fish" (i.e. mahseer)' project aims to tap the potential of ecotourism in the buffer area of Corbett National Park. Guided by enhancement of the prospects for tourism, residents from several villages have been working to conserve mahseer in the River Ramganga and in other streams in the region. Locals have been taught about the importance of conserving the mahseer species, thus leading to increases in population size of mahseer (Anonymous 2008).

4.5 Investments/Returns from stock enhancements

The investment to fish stock enhancement in the region has been increasing significantly recently. For instance, the budget allocation by the central government for implementing enhancement activities in major river systems in China has been maintained around UDS26 million annually in recently years. In general, investment for enhancement program for public goods, particularly releasing program in major river systems and large lakes is usually borne by the central government (China, Republic of Korea and Thailand). The seed releasing and other enhancement activities in water bodies (such as medium and small-size lakes and reservoirs) with well managed fisheries are often multi-source funded, which include mainly budget allocation from local government and contribution from direct beneficiaries (fishers). One common practice for the later is payment of resource enhancement fee at renewal of fishing license. It is worth to notice that there has been steady increase of public donation for stock enhancement in some countries with the increasing public awareness of importance to protect the aquatic biodiversity and ecosystem.

Overall and in general terms the investment related return from stock enhancement is little known, except from the smaller water bodies as in the case of Thailand and Sri Lanka, where the total production is essentially from stocked seed and the other inputs are quantified (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009). Without regular stock enhancement of many flood plain water bodies, large reservoirs, where the natural recruitment is relatively poor, fisheries would likely not have developed. In most countries the cost of stock enhancement, particularly those associated with conservation purposes, is often borne by government agencies, central and or regional. In Thailand for example there are stock enhancements that are conducted under a decree of the Queen. In other enhancements, for example for CBF, mitigating environmental impacts such as in Indonesia, the government and or other agencies may kick start the fishery development, but as the activity progresses the community benefiting from it will begin to bear the costs of enhancements.

There is also a trend, such as in Vietnam where the cost of all stock enhancements and the associated fishery benefits are handed over to the private sector, almost akin to a lease. The enhancement of the high valued giant freshwater prawn, *Macrobrachium rosenbergii*, in Pak Mun Reservoir (a run-of-the river type dam), Thailand, provides a useful case study on investment-returns of stock enhancement as well as the use of the process for a conflict resolution where the closure of the dam impacted negatively on the livelihoods of the river fishers. In this instance although the recapture rates were less than 2 percent, giant freshwater prawn accounted for 54 percent of the total catch and 97 percent of the total income of the fish landings (Sripatrprasite and Lin, 2003). The cost of stocking, however, is borne by the government as an indirect compensation measure.

In a comparable case in Indonesia, in the reservoirs of the Citarum watershed (Jatiluhur, Cirata and Saguling) where cage culture, proliferated and intensified and impacted negatively on the water quality, resulting in fish kills that adversely affected fishers. In this instance stock enhancement, primarily milkfish, *Chanos chanos*, and the introduction of an associated co-management practice, involving all stakeholder groups, has resulted in improvements in water quality, and negated potential conflicts (Abery *et al.*, 2005) between fishers and fish farmers. Most of all the practice has increased the income of fishers, whose payment of a nominal levy of IDR 600/kg (IDR 9 300 = 1 US$) on the landings of the stocked species has also sustained the stock enhancement program, which was initially borne by the government. It is also believed that the use of milkfish, which is unlikely to establish reproductive populations in the reservoirs and the associated river system, would be ecologically less impacting than the use of other filter feeding fish species.

It is also important to note the socio-economic success of enhancement of translocations of species such as bilih into lake Toba, Indonesia, which has stimulated the consolidation and a significant enhancement of the fishery (three fold), generating extra livelihoods, and enabling higher fisher earnings, reaching a maximum of 320 000 IDR/fisher/day.

4.6 Monitoring and impact assessment to releasing and other conservation program

Fish seed releasing and other stock enhancement activities have been extensively carried out in the region and for decades in some countries. There has been general lack of effective monitoring and impacts assessment to various enhancement and conservation activities such as seed releasing, protected area and sanctuary etc. except for limited assessment studies conducted for releasing program implemented for few species, such as Chinese sturgeon and salmonoids. Most stock enhancement programs have been carried out without considering follow-up monitoring to assess the effectiveness and impacts.

Lack of effective monitoring and impact assessment is mainly due to technical difficulty and resource limitation. Currently, there is still lacking of effective and economical methods and tools for monitoring and assessing impact of large scale releasing activities in the region. On the other hand, almost no financial resource is allocated for monitoring and impact assessment activities even though huge budget is allocated to releasing of fish seed. The reluctance of government in allocating fund for monitoring and impact assessment is often due to difficulty in monitoring the use of the fund and long time-span of the work. In addition, monitoring and impact assessment are not so eye-catching compared with the releasing activities which usually easily attract public attention.

Obviously, it is not possible to understand the actual effect of seed releasing and other stock enhancement activities without reasonable monitoring activities. Therefore, the actual impacts of most stock enhancement activities in large open water bodies in the region have remained questionable although it has been believed significant ecological and socio-economic benefits achieved. More importantly, it is difficult to make informed decision on improving the methodologies, operation and follow-up management to achieve better results with limited resources.

4.7 Issues related to marketing

The general notion is that all of the inland fish production is used directly or in a processed form for human consumption, which contrasts to that of the marine production where nearly 25 to 30 percent is used for reduction into fish meal and fish oil (Delgado *et al.*, 2003). However, it has been pointed out in Section 2 most such inland fish production is used for aquaculture purposes directly or indirectly. In general the marketing aspects, though important, have taken a backstage (De Silva, 2008).

With increasing potential in culture-based-fisheries, and its increasing adoption in the region with developments in India, Indonesia, Thailand, Sri Lanka and Vietnam, where the harvesting is essentially dictated by the weather-receding water levels-there is a need to address this aspect, to avoid an excess supply (within a narrow time frame, in a small geographic area). In this regard some countries have adopted a staggered harvesting strategy, thereby ensuring a wider spread of the time frame and a reasonable farm gate price. In Myanmar the involvement of women in marketing of culture-based-fishery produce in some instances (FAO-NACA, 2003) have brought about an added dimension of livelihood supportfor the poorer sectors but this needs to be further encouraged.

On the other hand, in large water bodies the marketing chains are relatively well established, with middle persons playing a vital role (De Silva, 2008). In China, where a single days harvest, by the use of integrated nets, could be very large. Fish may be kept in pens within the water body and marketed in small quantities over a few days, thereby ensuring a fair farm gate price and avoiding an oversupply. In Vietnam most middle persons operate in boats when a group of fishers would sell their fish to same middle person, at times on a barter basis, the former then in turn markets through wholesale buyers on shore.

5. STOCK ENHANCEMENT AND BIODIVERSITY CONSERVATION

5.1 Physical and management measures

Inland fisheries enhancements and biodiversity conservation in most countries in the region are intrinsically linked. As pointed out in Section 5.3 there are direct steps taken towards biodiversity conservation by creation of fish sanctuaries and refuges, introduction of closed seasons, complete prohibition of fishing operations in selected waters and so forth. Whilst such ‘physical and management’ measures are widely adopted one of the main concerns with regard to biodiversity conservation is the introduction of alien species and trans-boundary movement of indigenous species across their natural range of distribution for stock enhancement purposes.

5.2 Retaining connectivity among waters

The inland waterways have been greatly impacted through interference from anthropogenic activities, primarily for irrigation purposes, by impeding connectivity. Although large dams attract attention of conservationists, the numerous weirs, sluices and even roads and other similar man made structures impede free movement of fish, and consequently impact on biodiversity, both directly and indirectly. Admittedly however, the quantitative information available in this regard on the region's waterways is rather meagre.

One of the most advocated mitigating measures is the construction of fish passages and or fish ladders, which some suggest has proven to be a viable option in the northern hemisphere, particularly in respect of facilitating salmonid migrations. On the other hand, in the region there are only a few structures, of various forms, in operation. For instance in the Pak Mun Dam, Thailand, the available information suggests that it is not significantly effective in facilitating upstream migrations. In addition, a number of fish passes are in operation in Bangladesh; e.g. Sariakandi fishpass (92.4 m long and 15 m wide) on the west bank of Jamuna river and the east bank of Bangali river (at Sariakandi upazilla sub-district) permitting fish movement between the Jamuna and Bangali rivers. In Bangladesh all fish passes come under a management authority headed by the Bangladesh Water Development Board.

5.3 Introduction of alien species and indigenous species translocations

Introduction of alien species is a global 'bone of contention', and especially so as it is often alleged that such introductions are a main cause of loss of biodiversity (e.g. Moyle and Leidy, 1992; IUCN, 2000), even though and more often than not, there is a lack of explicit scientific evidence in this regard. Admittedly, the relevant issues with regard to aquaculture globally, and regionally arebetter known (see recent review by De Silva *et al.*, 2009) including the controversial introduction into the region of tilapias for aquaculture (De Silva *et al.*, 2004).

Amongst alien species use of tilapias in stock enhancement purposes perhaps can be considered as one of the most significant examples in the region. In Sri Lanka introduction of *Oreochromis mossambicus* in 1952 is considered to have triggered the development of an inland fishery in the vast acreage of perennial reservoirs, ancient and modern. There were later stock enhancements with the Nile tilapia, *Oreochromis nitloticus.* Currently, these species collectively account for over 70 percent of inland food fish production, which also provides many fisher livelihoods in rural areas (Amarasinghe and De Silva, 1999; Amarasinghe and Weerakoon 2009). Tilapias continue to contribute to reservoir fishery production in Lao PDR, India, Indonesia, the Philippines and Thailand. However, apart from occasional stock enhancement with a view to building up reproductive populations, there is no regular activity in this regard, and the fisheries sustain themselves through self recruiting populations. All evidence indicates that this introduction in the region, though the species were brought in for aquaculture development, have not had apparent negative impacts on biodiversity (De Silva *et al.*, 2004).

In addition Chinese and Indian major carps have been extensively translocated regionally for stock enhancement purposes, and provide major contributions to culture-based fisheries, flood plain fisheries, lease fisheries and the like in most countries in the region. In some instances escapees from aquaculture practices have resulted in the establishment of relatively large fisheries, a case in point being the Gobhindasagar Reservoir, India (Sugunan, 1995), where silver carp is the predominant species of the fishery, and has also resulted in an overall increase in production and number of fishers.

Interestingly ice fish, *Neosalanx* spp., endemic to Taihu Lake, China, has been extensively translocated in to other reservoirs in China (Liu *et al.*, 2009). However, these translocations have resulted in mixed results with populations fluctuating over the years, and the fisheries not being consistent. More recently, ice fish has been transplanted into a large reservoir, Thac Ba Reservoir, in Northern Vietnam. There is evidence emerging that a relatively significant fishery has commenced four to five years after the transplantation (see Country Review on Vietnam). More importantly, for example there were no risk assessment studies undertaken with regard to the above translocations and also there is no evidence of monitoring of biodiversity impacts either. Bearing in mind that this group of fish are zooplankton feeders the potential for biodiversity conservation impacts remain likely.

Comparable to the trans-boundary translocation of ice fish in China, beyond its natural range of distribution, is the example of translocation of bilih (*Mystacoleucus padangensis*) into Lake Toba, North Sumatera, from Sinkarak Lake (West Sumatera) in Indonesia (see Section 5.2.3 for further details). Although this translocation has resulted in positive impacts on the fishery and related livelihoods, and the socio-economic status of the fishing communities, its impacts on biodiversity conservation are yet unknown.

5.4 Genetic aspects related to stock enhancement practices

The common notion, at least until recently, was that use of indigenous species in stock enhancement practices impact on biodiversity to a lesser extent than alien species. The use of modern genetic tools in population studies have shown that unplanned stock enhancement practices based on indigenous species could lead to negative biodiversity impacts and loss of genetic diversity of the natural stocks. Such detrimental impacts have been clearly demonstrated for northern hemisphere salmonid strains/species e.g., Dowling and Childs, 1992; Leary *et al.*, 1993; Allendorf and Leary, 1998).

In Asia the above aspects are not well documented and or known and had been relatively less studied. It has been demonstrated that in Thailand stock enhancement of the Thai silver barb, *Barbonymus* (= *Puntius*) *gonionotus* has resulted in the loss of genetic diversity of the wild stocks (Kamonrat, 1996). Also, it has been acknowledged that the escapees from aquaculture practices have led to a reduction in genetic diversity of Thai catfish, *Clarias macrocephalus* wild populations (Senanan *et al.*, 2004).

As pointed out in Section 5.1 traditional stock enhancement practices conducted for cultural and symbolic purposes in some countries in the region do not pay much heed to genetic aspects, and it is possible that juveniles produced from one hatchery and broodstock derived from a single population are utilised along long distances of a river or unconnected water ways. It is suggested that as the science is better known that such practices may be suitably modified to ensure that genetic aspects are taken into account to reduce impacts on biodiversity in the long term.

The use of milkfish for stock enhancement and mitigation of the negative impacts on water quality in reservoirs of the Citarum watershed is an interesting example, where the assumption is made that as this species is unlikely to establish breeding population in the reservoirs thus having minimal impact on biodiversity. This presumption may not necessarily be always correct as indirect genetic impacts are known to occur as a result of such an introductions (Waples, 1994).

Overall, it is evident that there is a need to step up monitoring on genetic impacts of stock enhancement practices in the region, and where relevant begin to introduce the use of genetic tools that are available to make enhancement practices more science based.

6. SUMMARY OF MAJOR CONCLUSIONS ON STOCK ENHANCEMENT AND BIODIVERSITY CONSERVATION

- In the region overall, enhancement of inland fisheries has resulted in an increasein food fish availability, providing additional livelihood opportunities to rural poor, and contributing to socio-economic well being.
- However, not all enhancements in the region are socially equitable, particularly with regard to flood plain and reservoir leasable fisheries and the like. Such enhancement protocols although bringing about an increase in food fish production could marginalise other users in gaining access to a potential food source and a subsidiary income opportunity. Interestingly, this fact is being addressed by some countries, such as Bangladesh, where the leases are provided to communities rather than individuals, and consequently benefits are shared by the community.
- In general, culture based fisheries, in smaller, often non-perennial water bodies, is a major form of enhancement and in most instances whole communities tend to benefit and it is becoming increasingly popular as a means of increasing food fish production and provision of subsidiary income to rural communities.
- Enhancement of large and medium sized reservoirs is only successful if the stocks become established and start to breed/recruit, perhaps with the exception of China where this aspect is built into the overall reservoir management planning. Successful enhancement in such waters is therefore also reliant on effective fishery management.

- To further facilitate the benefits of fisheries enhancement activities, there is a need to rationalise the water management regimes, which often tend to be beyond the purview of fishery authorities.

- The statistical data collation and reporting on inland fisheries is open for significant improvement. There is evidence that inland fisheries production is often under estimated and there is a need to rationalise the different methods utilised in production estimation. Equally, there is a need to step up the socio-economic gains and losses from inland fishery enhancements, on a much wider scale than at present. Proper data on the status of the fisheries and the human resources involved in such activities will facilitate the improved recognition of the sector as a significant food security, nutrition and poverty alleviation activity for rural communities, in developing countries.

- Overall, there is a paucity of monitoring of impacts of enhancements, from social, environmental and economic view points, and there is an urgent need for authorities to introduce monitoring measures for all types of water bodies.

- The region's approach to biodiversity conservation related to fisheries enhancements are significant, with the introduction of sanctuaries, closed seasons, gear restrictions, habitat improvements, seed releasing programs and so forth.

- The stock enhancement activities in the region sometimes use alien species and translocation of indigenous species across watersheds, beyond the ranges of natural distribution. Although explicit evidence is lacking with regard to impacts on biodiversity in relation to such enhancements regular monitoring and evaluations of these would be desirable to introduce any mitigating measures where needed.

- On the other hand, stock enhancement activities have paid little attention to potential genetic impacts and there is a need to address these issues sooner rather than later.

- The ecosystem approach to inland fisheries needs to go beyond the scope of the water body per se, as the production of most inland waters are highly impacted upon by the catchment features and its activities. Accordingly, more holistic approaches to inland water resources enhancements and management are needed.

7. WAY FORWARD

- A concerted effort needs to be made to impress upon governments and responsible authorities of the increasing importance of inland fisheries resource enhancement as a means of contributing to food fish supplies and food security of rural communities in addition to protection of aquatic biodiversity and also encourage more cooperation between fishery and water management authorities to reap the full benefits. In this context attempts should be made to increase the visibility of the sector, through for instance the Committee on Fisheries of the FAO.

- In the region as a whole, there is very little emphasis on pre-and post-impact assessments of fishery resource enhancement practices, primarily as consequence of the lack of an accepted protocol for this purpose and limited capacity available to undertake such activities. Accordingly, there is need to develop guidelines/protocols for inland fishery enhancements for the different water body types, and build capacity on impact assessment/monitoring of fishery enhancements in the region as required.

- In the region though a majority of fishery resource enhancements has been beneficial, socio-economically, there is very limited monitoring of the costs vs. benefits of major, specific practices. Monitoring of cost benefits of enhancements will provide much needed information and an impetus to furthering the activities and bringing about improvements thereof.

- The region has a number of institutions that are directly and or indirectly involved in enhancement related activities/programs. Equally, the capabilities in this regard differ markedly between countries, and there is lot to be learned from each other to place fishery enhancements in the region on a firmer footing. In this regard the establishment of a mechanism for networking/continuing interaction for sharing of experience on enhancement and conservation of inland fisheries resources would be most beneficial to the all countries and to the sector's improvement and consolidation.

- All attempts should be made to ensure minimizing potential impacts on biodiversity conservation arising from inland fishery resource enhancements. In this regard more attention needs to be paid to maintaining genetic diversity of wild stocks/populations, and programs need to be introduced to incorporate scientific knowledge into enhancement practices, even those that have been conducted over long periods for cultural and symbolic purposes. Strategic environmental assessment (SEA) is the process for assessing, at the earliest possible stage, the environmental impacts of decisions made from the policy level downwards. SEA is a promising means to strengthen awareness of biodiversity conservation issues in the context of national priorities in terms of social and economic development.

- Regular monitoring needs to be undertaken on the impacts of alien species and translocation of indigenous species across watersheds for stock enhancement practices. New such translocations should be undertaken only after a detailed risk assessment and when and if absolutely necessary.

- Over the last two decades there has been an emphasis on aquaculture education, particularly tertiary, in the region, for good reason. However, this impetus has not been carried on with regard to inland fisheries in many countries, leaving a gap in the knowledge of personnel that are called upon to manage the latter. Accordingly, there is a need to raise awareness in tertiary and vocational institutions on the need to introduce curricula and step up training provided in inland fisheries management.

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ANNEXES

Annex I. Species used directly in stock enhancement practices and those that are directly and or indirectly impacted through inland fisheries enhancement programs/activities (in at least 2 countries)

Species	Bgd	China	India	Indo	Myn	Nepel	RoK	SL	Th	Vn
Anabas testudineu	+		+	+						+
Anguilla japonicus		+					+			
Hypophthalmichtys nobilis	+*	+	+*		+*	+*		+*	+*	+*
Barbonymus gonionotus	+			+*					+	
Clarias gariepinus				+					+	
Carassius auratus	+*	+	+		+*	+*	+			+*
Catla catla	+		+		+	+		+*	+*	+*
Chana striata				+	+					+
Chitala chitala				+	+					
Cirrhinus mrigala	+		+		+	+		+*	+*	+*
Ctenopharyndogon idellus	+*	+	+*	+*	+*	+*		+*	+*	+*
Cyprinus carpio	+*	+	+*	+*	+*	+*	+	+*	+*	+*
Eriocheir sinensis		+					+			
Heteropneustes fossilis	+			+	+					
Hypophthalmichtys molitrix	+*	+	+*	+*	+*	+*		+*	+*	+*
L. rohita	+		+		+	+		+*	+*	+*
Leptobarbus hoevenii				+					+	
Macrobrachium rosenbergii	+		+	+	+			+	+	
Mastacembelus armatus	+		+		+					
Morulius chrysophekadion				+*					+	
Mylopharyngodon piceus		+								+
Neosalanx spp.		+**								+*
Oncorhynchus mykiss#						+				+
Oreochromis mossambicus#	+		+	+	+			+	+	
O. niloticus#	+		+	+	+	+		+	+	+
Osteochilus hasselti				+					+	
Pangasianodon hypopthalmus				+*	+				+	
Probarbus jullieni				+*					+	
Salmo gairdneri#		+		+					+	+
S. salar#		+		+						
S. trutta#		+		+					+	+
S. richardsonii#					+	+				
Tor douroensis			+	+						
T. putitora			+			+				
T. Tor			+		+	+				
Trichogaster pectoralis				+*	+*				+	
Trionyx sinensis		+					+			

alien to the region; * alien to the country; ** translocated across water sheds with in a country for stock enhancement purposes

Bgd = Bangladesh; Indo = Indonesia; Myn = Myanmar; RoK = Republic of Korea; SL = Sri Lanka; Th = Thailand; Vn = Vietnam

Annex II. Species used directly in stock enhancement practices and those that are directly and or indirectly impacted through inland fisheries enhancement programs/activities in individual country

Country	Species
China	*Acipenser dabryanus, A. sinensis, C. asiatica, C. maculate, Chinese sucker, Coreius heterodon, Culter alburnus, Hemisalanx prognathus, Leiocassis longirostris, Megalobrama amblycephala, Parabramis pekinensis, Pelteobagrus fulvidraco, P. vachelli, Plagiognathops microlepis, S. prenanti, Silurus meridionales, Sinilabeo rendahli, Siniperca chuatsi, Spinibarbus sinensis, Squaliobarbus curriculus, Xenocypris davidi, X. microlepis*
India	*T. khudree*
Indonesia	*Balantiocheilos melanopterus, Botia macracanthus, Chanos chanos, Helostoma teminkki, Mystus nemurus, Orchella brevirostris, Osphoronemus gouramy, Sclerophages formosus, S. yardinii, T. trichopterus, Mystacoleucus padangensis***
Myanmar	*C. labiosa, Ompok paba, Osteobrama belangeri, Tenualosa ilisha, Wallago attu, Colisa fasciata*, Glossogobius sp.*, P. lala*, Parambassis sp.**
Nepal	*Barilius* spp., *Schizothorax plagiostomus, Schizothaichthys progastus, S. annandaeli*
Republic of Korea	*Coreoperca herzi, E. japonicus, Plecoglossus altivelis, Psedobugrus fulvidrac, S. asotus, S. schezeri*
Sri Lanka	*Labeo dussumieri*
Thailand	*B. schwanenfeldi, B. schwanenfeldii, C. macrocephalus, Clarias macrocephalus, Hemibagrus nemurus, Henicorhynchus siamensis, P. sanitwongsei, Systomus orphoides*
Vietnam	*Acipenser schrenckii*, Barbodes altus, Barbonymus altus, C. micropeltis, H. guttatus, P. larnaudii, P. bocourti, Prochidolus lineatus*

* alien to the country

** translocated across water sheds with in a country for stock enhancement purposes

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