RAP PUBLICATION 2010/22

Inland fisheries resource enhancement and conservation in Asia

APFIC

FAO
FIAT PANIS

RAP PUBLICATION 2010/22

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN ASIA

Edited by Miao Weimin
Sena De Silva
Brian Davy

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
Bangkok, 2010

ISBN 978-92-5-106751-2

For copies please write to:

Aquaculture Officer
FAO Regional Office for Asia and the Pacific
Maliwan Mansion, 39 Phra Athit Road
Bangkok 10200
THAILAND
Tel: (+66) 2 697 4119
Fax: (+66) 2 697 4445
E-mail: FAO-RAP@fao.org

For bibliographic purposes, please reference this publication as:

Miao W., Silva S.D., Davy B. (eds.) (2010) Inland Fisheries Enhancement and Conservation in Asia. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2010/22, 189 pp.

FOREWORD

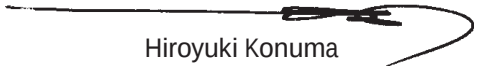
Inland capture fisheries provide an important source of food and livelihoods for many people in rural areas. In 2008, inland capture fisheries provided 10.2 million tonnes of fish worldwide (FAO, 2010), which was largely used for direct human consumption. Asia has overwhelmingly contributed to the world's 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.

ACKNOWLEDGEMENTS

The completion of the publication was attributable to the joint efforts of all the country review authors and editorial team. Much gratitude is due to the country review authors who made their best efforts in preparing the country papers and showed enormous patience with the many revisions requested of them. Simon Funge-Smith, Senior Fisheries Officer, FAO Regional Office for Asia and the Pacific is gratefully acknowledged for his technical advice and contribution to the expert workshop. Special thanks are due to Pornsuda David for her assistance in the final language editing and in facilitating publication of the document.

Finally, Jiansan Jia, Chief of the FAO Aquaculture Management Service is gratefully acknowledged for his technical support.

TABLE OF CONTENTS

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN BANGLADESH

Mostafa A R Hossain
Department of Fish, Biology and Genetics, BAU, Mymensingh-2202, Bangladesh
E-mail: marhossain@yahoo.com

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.

REFERENCES

Ahmed, A.T.A. & Ali, M.L. 1996. Fisheries Resources Potential in Bangladesh and Manpower Development for Fisheries Activities. In: Population Dimension of Fisheries Development and Management Policies of Bangladesh. Dhaka, Bangladesh.

Ahmed, K. & Ahmed, M. 2002. Fish Sanctuary: necessity concept practices and prospects. Technological Assistance for Rural Advancement (TARA): Dhaka, Bangladesh.

Ahmed, K.K.U., Ahamed, S.U., Hasan, K.R. & Mustafa, M.G. 2007. Option for formulating community based fish sanctuary and its management in beel ecosystem in Brahmanbaria. *Bangladesh J. Fish. (Special Issue)*, 30: 1-10.

Ali, M.L., Hossain, M.A.R. & Ahmed, M. 2009. Impact of Sanctuary on Fish Production and Biodiversity in Bangladesh. Final Project Report. Bangladesh Fisheries Research Forum (BFRF), Dhaka, Bangladesh. 80 p.

Ali, M.Y. 1997. Fish, water and people, Reflections on inland openwater fisheries resources in Bangladesh. The University Press Limited, Dhaka, 154 p.

Azher, S.A., Dewan, S., Wahab, M.A., Habib, M.A.B. & Mustafa, M.G. 2007. Impacts of fish sanctuaries on production and biodiversity of fish and prawn in Dopi beel, Joanshahi haor, Kishoregonj. *Bangladesh J. Fish. (Special Issue)* 30: 23-36.

Banglapedia, 2004. National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, 1st edn. February 2004. Dhaka, Bangladesh. Available from URL: www.banglapedia.org.

DOF (Department of Fisheries), 2005. Matshya Pakkhya Saranika-2005. Department of Fisheries, Ministry of Fisheries and Livestock. The Government of the Peoples Republic of Bangladesh, Ramna, Dhaka. Bangladesh. 109 p.

DOF (Department of Fisheries), 2008. Matshya Pakkhya Saranika-2008. Department of Fisheries, Ministry of Fisheries and Livestock. The Government of the Peoples Republic of Bangladesh, Ramna, Dhaka. Bangladesh. 96 p.

ESCAP (Economic and Social Commission for Asia and the Pacific), 1998. Integrating Environmental Considerations into the Economic Decision Making Process. ESCAP, Bangkok, Thailand. www.unescap.org/drpad/pub3/integra/modalities/bangladesh/4bl02b01.htm.

FAP (Flood Action Plan)-17, 1994. Fisheries Studies and Pilot Project-Final Report. ODA, UK. 185 P.

FRSS, 2009. Fisheries Statistical Yearbook of Bangladesh (2007-2008). Department of Fisheries (DOF), Ministry of Fisheries and Livestock (MOFL), Dhaka, Bangladesh

Haque, M., Ahmed, M. & Mustafa G. 2007. Preferences of fishes to different types of Katha materials used in sanctuaries in three rivers of Netrokona. *Bangladesh. Bangladesh J. Fish. (Special Issue)* 30: 147-156.

Hossain, M.A.R. & Wahab, M.A. 2010. The diversity of Cypriniforms throughout Bangladesh: present status and conservation challenges. In: Species Diversity and Extinction. Geraldine H. Tepper (ed). Nova Science Publishers Inc., New York, USA. (in press)

IUCN, 2002. Fish Pass and Fish Friendly Regulators Study. Draft Final Report, Fourth Fisheries Project, Department of Fisheries, Government of the People's Republic of Bangladesh, August 2002, Dhaka.

Lahnsteiner, F. 2004. Cryopreservation of semen of the Salmonidae with special reference to large-scale fertilization. *Methods in Molecular Biology* 253: 1-12.

MAECH, 2006. Restoring Wetlands through Improved Governance: Community based Co-management in Bangladesh – The MAECH Experience MAECH Technical Paper 1, Dhaka, Bangladesh. 26 p.

Petr, T. (ed.), 1998. Inland fishery enhancements. Papers presented at the FAO/DFID Expert Consultation on Inland Fishery Enhancements. Dhaka, Bangladesh, 7-11 April 1997. FAO Fisheries Technical Paper. No. 374. Rome, FAO. 463 p.

Pullin, R.S.V., Eknath, A.E., Gjedrem, T., Tayamen, M., Julie, M. & Tereso, A. 1991. The genetic improvement of farmed tilapias (GIFT) Project. *Naga, the ICLARM Quarterly* 14(2): 210-315.

Siddique, H.M. 1990. Flood control and drainage development: Physical environmental issues. In: Rahman, A.A., S. Huq and G.R. Coanway (eds.) Environment aspects of surface water systems of Bangladesh. Dhaka University Press Ltd., pp.104-108.

Sultana, P. & Thompson, P.M. 2007. Community Based Fisheries Management and Fisher Livelihoods: Bangladesh Case Studies. *Human Ecology* 35: 527-546. DOI 10.1007/s10745-006-9092-3.

Thompson, P.M., Sultana, P., Islam, M.N., Kabir, M.M., Hossain, M.M. & Kabir, M.S. 1999. An assessment of co-management arrangements developed by the Community Based Fisheries Management Project in Bangladesh. Paper presented at the international workshop on fisheries co-management, 23-28 August 1999, Penang, Malaysia.

Thompson, P.M. 2003. Status of fish sanctuary established in Bangladesh. Paper presented in the workshop on status of fish sanctuaries established in Wolfish center assisted CBFM-2 project included rivers and *beels,* held on 5 February 2003, organized by DOF, Dhaka, Bangladesh.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN CHINA

Chen Daqing, Li Shijiang and Wang Ke
Yangtze River Fisheries Research Institute of Chinese Academy of Fishery Science, Jingzhou, 434000, China
E-mail: chdq@yfi.ac.cn

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.

Acknowledgements

This study was jointly financed by Ministry of Agriculture of the People's Republic of China (200903048) and Food and Agriculture Organizations Regional Office for Asia and the Pacific (200911012).

REFERENCES

Bing, X., Xu P. and Yan X. 2005. The advice of freshwater aquaculture proliferation discipline and development direction. The proceeding of Chinese aquaculture frontier disciplines and development strategy at Chinese fishery association meeting 05, Beijing, China. pp. 2.

Chen D. 2002. On the dynamics of fishery resources of the Yangtze River and its management. Acta Hydrobiologica Sinica, 26(6): 685-690.

Chen D. 2006. Polymorphism of D-loop sequence from mitochondrial genomes of different broodstocks of *Gymnocypris przewalskii* (Kessler). Journal of Fishery Sciences of China, 13(5): 800-806.

Chen D., Zhang X. & Tan X. 2009. Hydroacoustic study of spatial and temporal distribution of Gymnocypris przewalskii (Kessler, 1876) in Qinghai Lake, China. Envion. Biol. Fish, 84: 231-239.

Hong B. 2009. Evaluation of the fishery resource enhancement and releasing in the upper reach of the Huangpu River. Aquatic technology, (4): 178-181.

Li W. 2005. Protection of ecological resource in the Pearl River — The starting ritual of fishery resource enhancement and releasing of the Pearl River was held in Wuzhou of Guangxi province. China aquatic, (11): 2-3.

Qin Y. 2008. The problem and countermeasure of the fishery resources and ecological environment management about Qinghai Lake. fishery administration, (3): 18-20.

Shen Y. 2008. Fishery enhancement and culture. Beijing, China. pp. 2-6.

Shi W., Zhang M. and Liu K. 2009. Stress of hydraulic engineering on fisheries in the lower reaches of the Yangtze River and compensation. J. Lake Sci., 21(1): 10-20.

Team of Fishery Resource Investigation in the Yangtze River. 1990. Fishery resource in the Yangtze River. Peking, China, pp. 13-35.

Wu L. & Wan C. 2009. The field enhancement was successful done in Wuzhou of Guangxi province. Friend of agriculture, (06): 7-12.

Yin Z. & Zhang S. 2008. Problems of the fishery resource enhancement and releasing in China. China aquatic sci., (3): 9-11.

Zhang X. 2005. Problem and countermeasure of resource protection in *Gymnocypris przewalskii* in Qianghai Lake. Freshwater Fisheries, 35(4): 57-60.

Zhu B. & Zheng H. 2009. Fish stocking program in the Yangtze River. Chinese fisheries economics, 27(2): 74-87.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN INDIA

V.V. Sugunan
Indian Council of Agricultural Research, KAB II, Pusa, New Delhi 110012
E-mail: vasu_sugunan@yahoo.com

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.

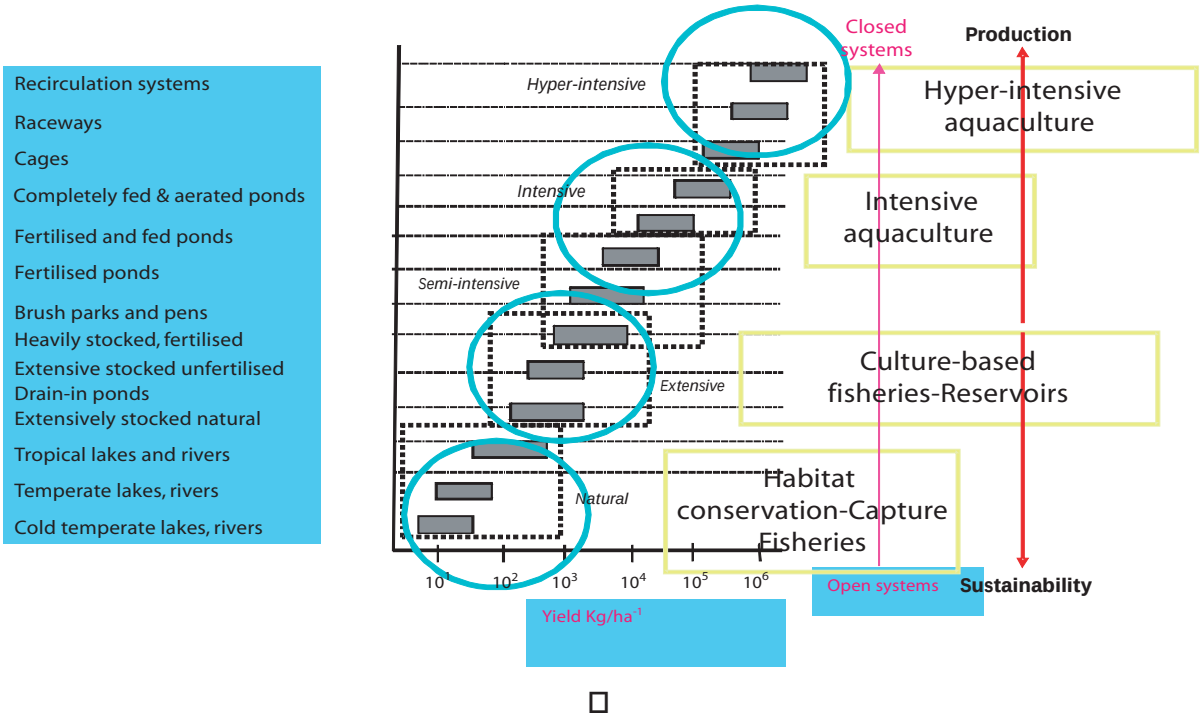


Figure 1. Fish production systems and their sustainability (modified from Welcomme and Bartley, 1998)

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).

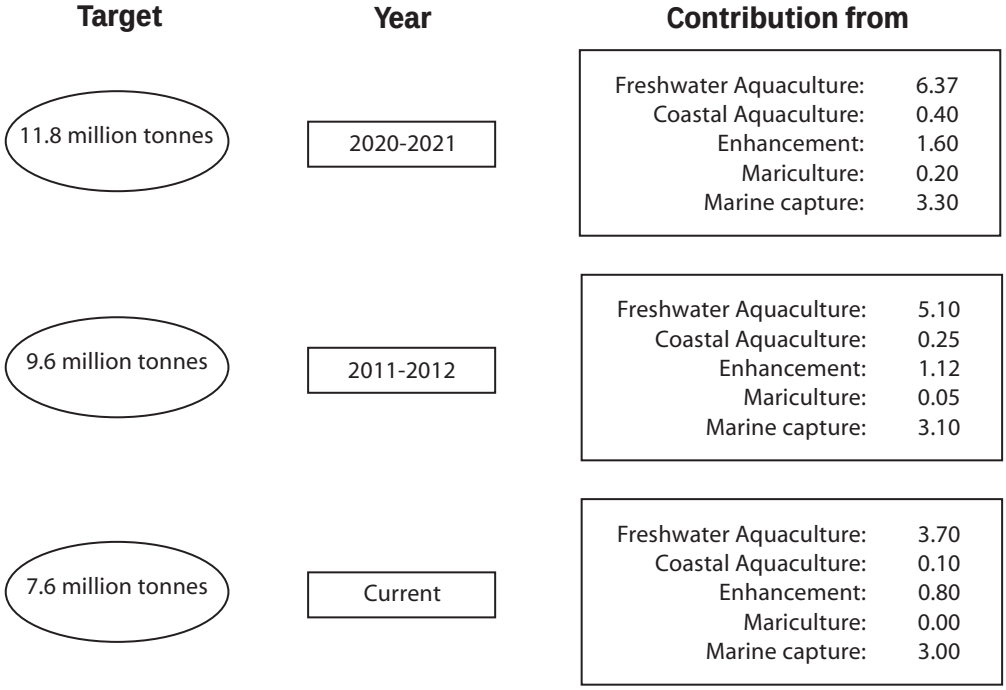


Figure 2 . Projected fish production and their source

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.

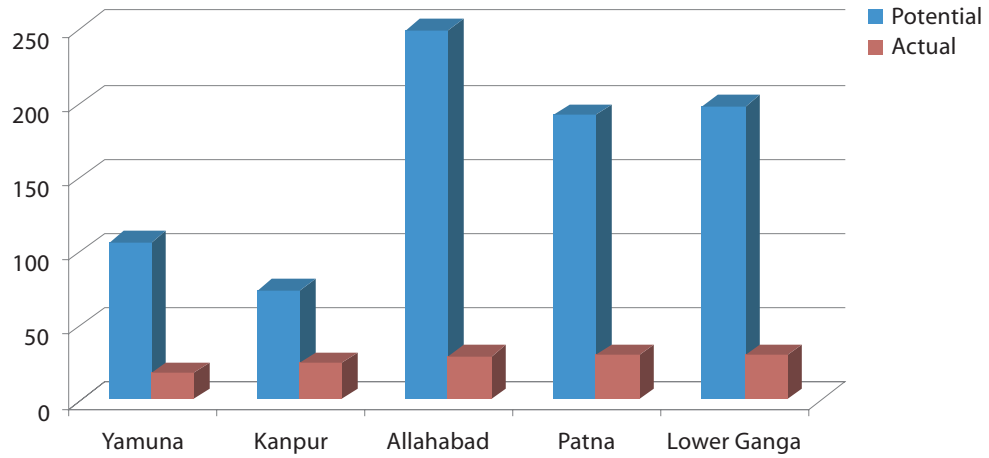


Figure 3. Fish production potential and actual production in the river Ganga (kg/ha/year)

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.

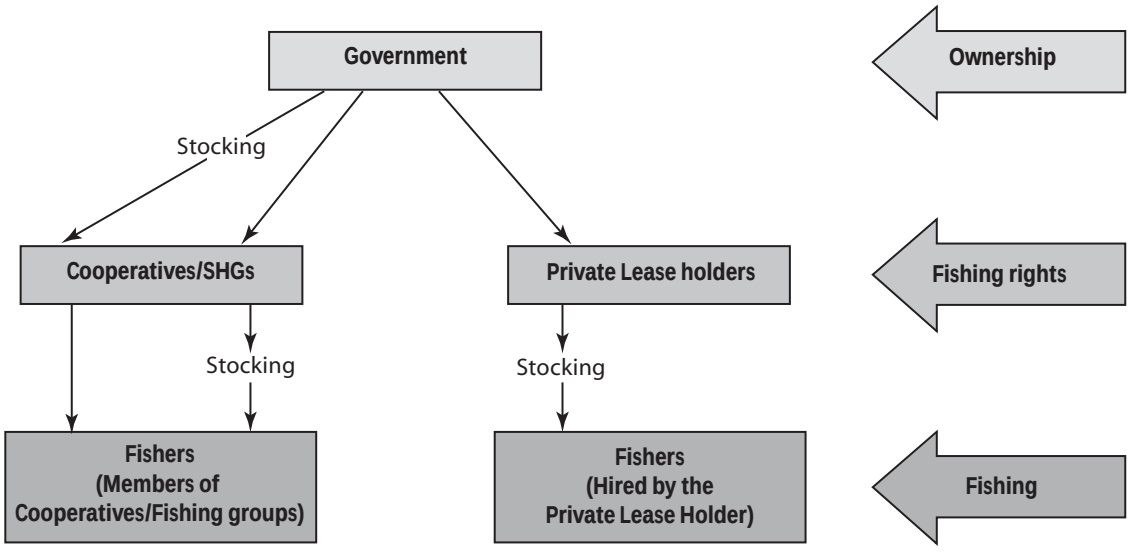


Figure 4. Ownership of water bodies and distribution of fishing rights in culture-based fisheries

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

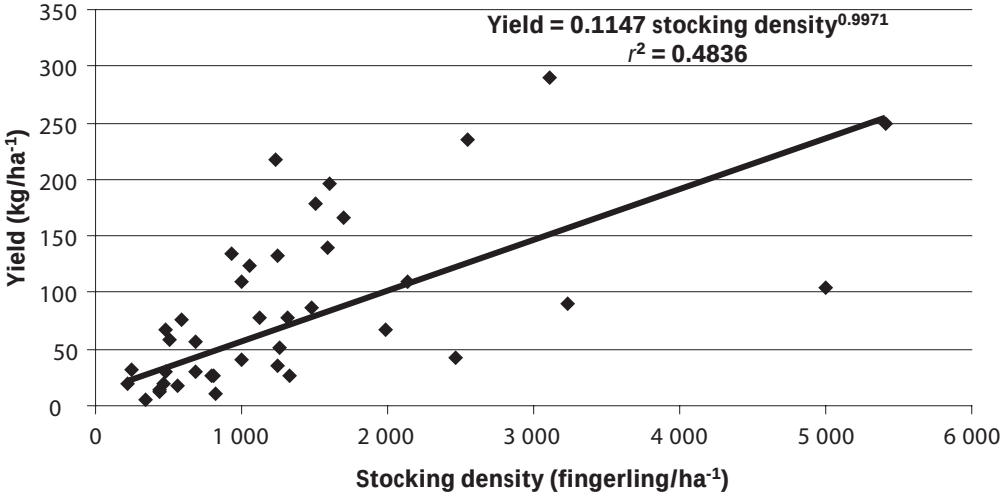


Figure 5. Impact of stocking in fish yield in reservoirs (Sugunan and Katiha, 2004)

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.

REFERENCES

Ayyappan, S. & Sugunan, V. V. 2009. Fishery resources in the context of nutritional security in India. *Indian Farming* 59(7): 29-35.

Dugan, P., Sugunan, V. V., Welcomme, R.L.,. Bene, C. & Brummett, R.E. 2007. Inland fisheries and aquaculture. *In* Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan and Colombo: International Water Management Institute. p. 459-483.

Dwivedi, K., Pathak, V., Mishra, J.P. & Mahavar, L.R. 2002. Ecological status and production potential of river Narmada. *In:* V. V. Sugunan, G.K. Vinci, P. K. Katiha and M.K. Das. 208-215.

ENCAP, 2008. Exploring market opportunities for fisheries sector in India. National Centre for Agricultural Economics and Policy Research (ICAR) New Delhi 110012 pp. 426.

FAO, 1997. Aquaculture development. FAO technical guidelines for responsible fisheries Food and Agriculture Organization of the Unites Nations No. 6 pp. 40.

Fishing Chimes. 2010. Why is the giant sleeping still? (Editorial) *Fishing Chimes,* 29(10) p. 5-6.

Hamilton, F. 1822. An account of the fishes found in the River Ganges and its branches. *Edinburgh, UK, Constable and Co.* pp. 405.

Haniffa, M.A. & Pandian, T.J. 1978. Morphometry, primary productivity and energy flow in a tropical pond. *Hydrobiologia* 59: 23-48.

Hora, S.L. 1929. An aid to the study of Hamilton-Buchanan's "Gangetic fishes". *Mem. Indian Mus.* 9: 169-192.

ICAR, 2007. State-specific technological interventions for higher agricultural growth. Indian Council of Agricultural research New Delhi pp. 132.

Jhingran, A.G. 1988. A general review of the inland capture fisheries situation in India Souvenir Central Inland Capture Fisheries Research Institute 14-16 December 1988 41 pp.

Jhingran, A.G. 1991a. Development potential and constraints of inland fisheries management in India IPFC Proceedings, Bogor, Indonesia 24-29 June 1991, *FAO Fisheries Report* No. 458 FAO Rome, 143-161.

Jhingran, V.G. & Natarajan, A.V. 1978. Recommendations for stocking silver carp in Gobindsagar (H.P.) and Nagarjunasagar (A.P.) together with an account of scope and limitations of silver carp stocking in rivers and reservoirs in India. *Bull No. 28*. Central Inland Fisheries Research Institute, Barrackpore India pp. 8.

Jhingran, V.G. 1991b. Fish and fisheries of India, *Hindustan Publishing Corporation* (India), Third Edition: 727 p.

Kushwaha, B., Nagpure, N.S., Srivastava, S.K., Kumar, R. & Verma M.S. 2002. Variation of micronuclei in perepheral blood cells of Channa punctatus. *Ind. J. Animal Sci.* 73: 1192-1199.

Nagpure, N.S., Kushwaha, B., Srivastava, S.K. & Ponniah, A.G. 2001. Comparative cytogenetic studies in Indian major carps *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* (Cyprinidae). *Chromosomes Sci.* 5: 153-158.

Nagpure, N.S., Kushwaha, B., Srivastava, S.K., Haldar, A. & Ponniah, A.G. 2002. Comparative chromosome painting in fish using human sex chromosome probe. *Indian J. Fish.* 50: 103-106.

NBFGR, 2009. *Annual Report* 2008-09. National Bureau of Fish Genetic Resources, Lucknow India pp. 111.

NBFGR, 2004. *Annual Report* 2003-04. National Bureau of Fish Genetic Resources, Lucknow India pp. 120.

Pathak, V., 2000. Ecology and production dynamics of river Brahmaputra with special emphasis on its tributaries *Bull. No. 97* Central Inland Capture Fisheries Research Institute Barrackpore 743101 West Bengal India 49 pp.

Pathak, V., Tyagi, R.K. & Balbir Singh. 2004. Ecological status and production dynamics of wetlands of Uttar Pradesh. *Bull. No. 131. Central Inland Capture Fisheries Research Institute.* 44 p.

Pathak, V., Srivastava, N.P., Chakraborti, P.K. & Das, A.K. 2007. Ecological status and production dynamics of river Mahanadi. *Bull. No. 149* Central Inland Fisheries Research Institute, Barrackpore, India. Pp. 40.

Paul, S.; Mitra, P.M.; De, D.K.; Sen, H.K.; Mandal, N.C. & Singh. P. 1997. Winter Bagnet Fishery of the Hooghly Estuary – An Economic Evaluation. *Bull. No. 76.* Central Inland Capture Fisheries Research Institute, Barrackpore. 17 p.

Payne, A.I., Sinha, R.K., Singh H.R. & Haq, S. 2004. A review of the Ganges Basin: its fish and fisheries. *In* (eds. R.L. Welcomme and T. Peter) Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Vol. 1, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2004/16, pp. 229-251.

Pisolkar, M.D., 1994. Declined fish species of Tapti and its tributaries, Threatened fishes of India, *Natcon Publication*, 4: 109-16.

Rao, K.L., 1976. India's water wealth. *Orient Longman Ltd.*, New Delhi pp. 267.

Sinha, M., 1999. Inland fisheries development-achievements and destinations for twentieth century *Souvenir*, Central Inland Capture Fisheries Research Institute Barrackpore 22-23 December 1999 35 pp.

Sinha, M., De, D.K., Jha, B.C.,1998. The Ganga – Environment & fishery, CIFRI, Barrackpore, 142 p.

Sreenivasan, A., 1971. Limiting of an upland lake. *Madras J. Fish.*, 6: 9-13.

Sreenivasan, A., 1976. Fish production and fish population changes in some south Indian reservoirs. *Indian J. Fish.* 23 (1&2): 133-152.

Sreenivasan, A., 1984. Influence of stocking on fish production in reservoirs of India. *Fishing Chimes* 13(1): 18-21.

Sreenivasan, A. & Venkatanarasimha Pillai, K. 1979. Fertilization of fishery waters – Experimental fertilization of a small reservoir. *Madras J. Fish.*, 8: 143-145.

Srivasatava, N.P., Jha, B.C., Nath, D. & Karmakar, H.C. 2009. Krishna estuary-Ecology and fisheries. *Bull. No. 158.* Central Inland Fisheries Research Institute, Barrackpore, India 700120. pp. 22.

Sugunan, V.V. 1995. Reservoir Fisheries of India. *FAO Fisheries Technical Paper*, No. 345. Rome, FAO.1995. pp. 423.

Sugunan, V.V. & Yadava, Y.S. 1991a. Feasibility studies for inland fisheries development of Kyrdemkulai reservoir. Central Inland Capture Fisheries Research Institute, Barrackpore, pp. 34.

Sugunan, V.V. & Yadava, Y.S. 1991b. Feasibility studies for inland fisheries development of Nongmahir reservoir. Central Inland Fisheries Research Institute, Barrackpore, pp. 30.

Sugunan, V.V. & Bhattacharjya, B.K. 2000. Ecology and Fisheries of *beels* in Assam. *Bull.* No. 104, *Central Inland Capture Fisheries Research Institute*, Barrackpore, pp. 65.

Sugunan, V.V., Vinci, G.K., Bhattacharjya, B.K. & Hassan, M.A. 2000. Ecology and fisheries of *beels* in West Bengal. *Bull.* No. 103, Central Inland Capture Fisheries Research Institute, Barrackpore, pp. 53.

Sugunan, V.V. & Sinha, M. 2001. Sustainable capture and culture-based fisheries of freshwaters of India. *In:* Sustainable Indian Fisheries (Ed) T.J. Pandian, National Academy of Agricultural Sciences New Delhi. 43-70.

Sugunan V.V., Saha P.K. & Barik N.K. 2003. Handbook on pen culture of fish and prawn, CIFRI , Barrackpore, 65 p.

Sugunan, V.V. & Katiha, P.K. 2004. Impact of stocking on yield in small reservoirs in Andhra Pradesh, India. *Fisheries Management and Ecology*, 11: 65-69.

Vass, K.K. 1988. Fisheries of upland lakes in India In (eds.) Jhingran, A.G. & Sugunan, V.V. Conservation and management of inland capture fisheries resources of India inland Fisheries Society of India Central Inland Capture Fisheries Research Institute Barrackpore India 275 pp.

Welcomme, R.L. & Bartley, D.M. 1998. An evaluation of present techniques for the enhancement of fisheries. *Journal of Fisheries Ecology and Management* (5): 351-82.

Yadava, Y.S. & Sugunan, V.V. 2009. Guidelines for Culture-based Fisheries Management of Small Reservoirs in India. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India, pp. 36.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN INDONESIA

Maskur[1] Endi Setiadi Kartamihardja[2]
and Sonny Koeshendrajana[2]

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).

[1] Head of Main Center for Freshwater Aquaculture Developement Sukabumi, Directorate General of Aquaculture, Ministry of Marine Affairs and Fisheries, Indonesia; E-mail: maskurfish@yahoo.com

[2] Researcher of the Agency for Marine and Fisheries Research, Ministry of the Marine Affairs and Fisheries, Indonesia; E-mail: endi_prpt@indo.net.id; sonny_koes@yahoo.com

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.

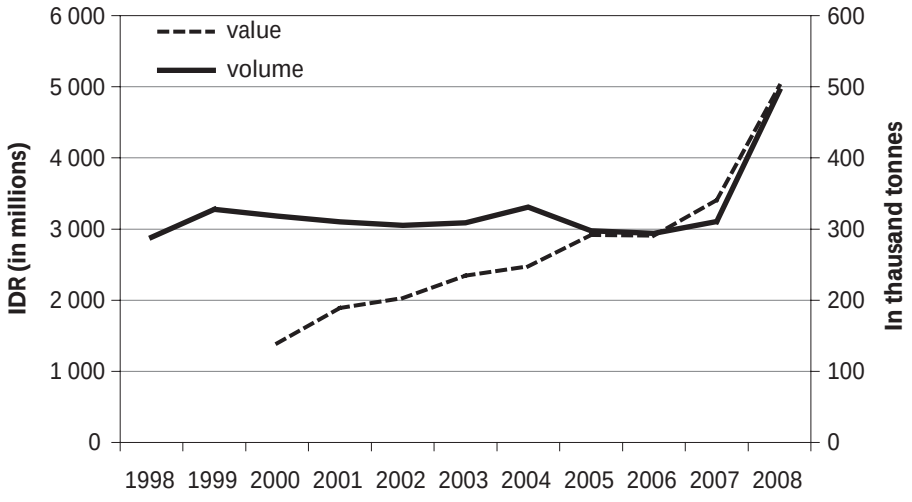


Figure 1. Inland capture fish production in the period 1998-2008 (Directorate General of Capture Fisheries, 2009)

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).

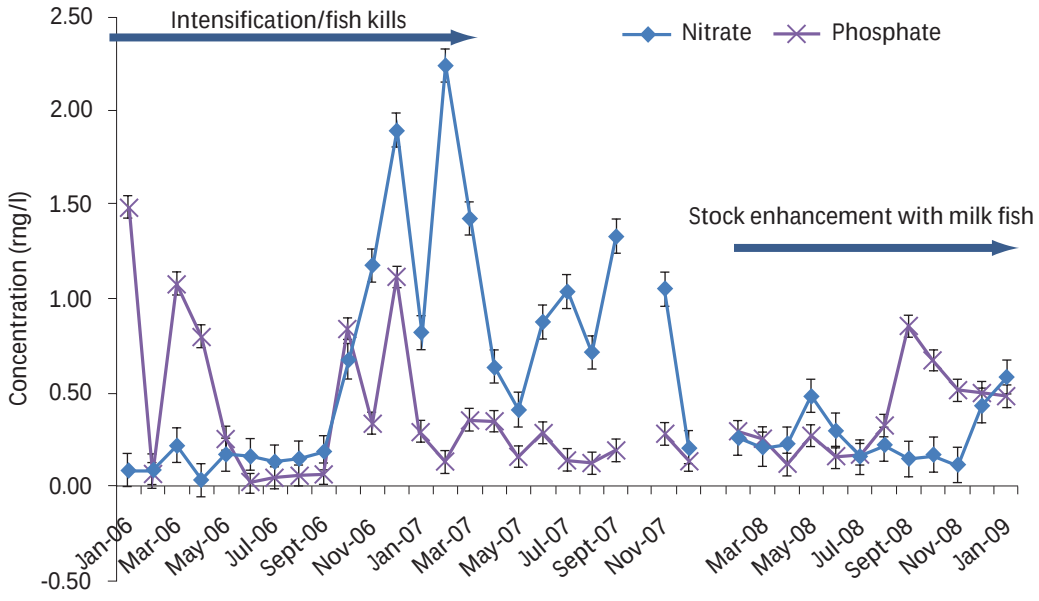


Figure 2. Effect of milk fish enhancement on nitrogen and phosphorus level in Ir. H Juanda

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="4">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

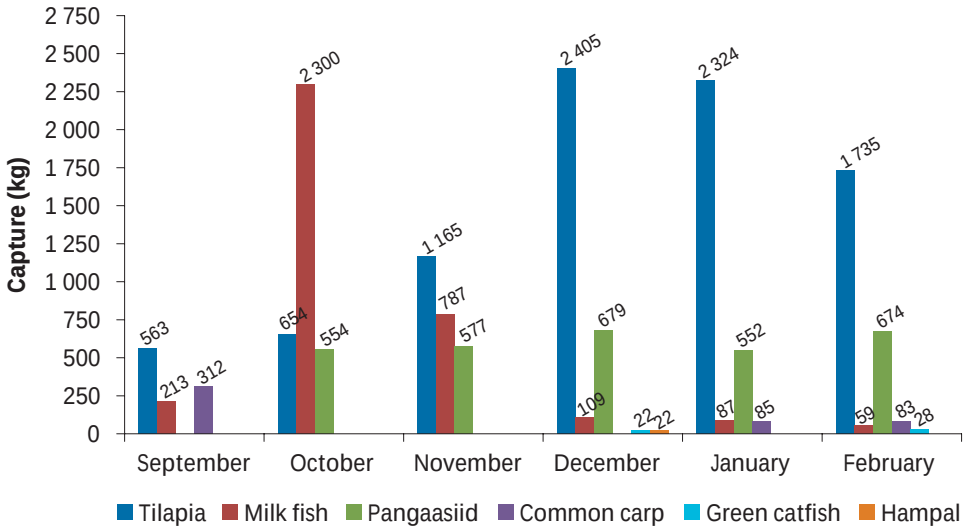
coordination of environment impact assessment process, the monitoring and management of waste discharge, the promotion on environmental awareness and the settlement of the environmental dispute (Phillip *et al.,* 2009).

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.

REFERENCES

Budhiman, A. 2007. Freshwater fish seed resources in Indonesia, pp. 329-341. In: M.G. Bondad-Reantaso (ed.). Assessment on freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical paper. No. 501. Rome, FAO. 2007. 628 p.

Directorate General of Capture Fisheries. 2009. Capture Fisheries Statistic of Indonesia (in Indonesian and English). DGCF, Ministry of Marine Affair and Fisheries. Jakarta.

Depkimpraswil (Departemen Pemukiman dan Prasarana Wilayah). 2003. Water resource data (in Indonesian). http://sda.kimpraswil.go.id

Directorate Fish Health and Environment. 2009. Fish restocking to inland waters year 2003-2009. Technical report, Directorate General of Aquaculture, MMAF.

Directorate Fish Health and Environment. 2006. Fish seed providing for stocking and intensification in inland open water (in Indonesian). Directorate General of Aquaculture, MMAF. Jakarta.

Directorate General of Marine, Coast and Small Island. 2008. Fisheries resources Conservation in Indonesia. MMAF. Jakarta.

Fisheries Services of South Kalimantan Province. 2009. Report on fish stock enhancement on inland open water at Benua Tengah village, Tanah Laut district, and Pandaman village, Hulu sungai Utara district, South Kalimantan (in Indonesian). Banjarbaru, South Kalimantan

Fisheries Services of South Kalimantan Province. 2007. Report on fish stock enhancement in inland open water at Riam Kanan reservoir, Banjar district, and Landasan Ulin Barat village, Banjarbaru city (in Indonesian). Banjarbaru, South Kalimantan. Fisheries Services of South Kalimantan Province. 2002. Restocking profile. Technical report. Banjarbaru Kalimantan Selatan.

Freshwater Aquaculture Development Center Mandiangin. 2004. Fish restocking at Hatiwin reservoir (Cek dam Ness 13), Tapin district (in Indonesian). FADC Mandiangin, DGA. Banjarbaru, South Kalimantan.

Fisheries Services of South Kalimantan Province. 2009. Report on fish stock enhancement in inland open water at Benua Tengah village, Tanah laut district, and Pandaman village, Hulu Sungai Utara district (in Indonesian). Banjarbaru South Kalimantan.

Fisheries Services of South Kalimantan Province. 2002. Restocking profile. Technical report, Banjarbaru, Kalimantan Selatan.

Freshwater Aquaculture Development Center Tatelu. 2009. Report on fish restocking at Tondano Lake, Minahasa district (in Indonesian). FADC Tatelu, Manado.

Kartamihardja, E.S. and Wudianto. 2005. Review on research results of inland fisheries in Indonesia 1990-2005. Technical paper, Research Center for Capture Fisheries, Ministry of Marine Affairs and Fisheries, Jakarta.

Kartamihardja, E.S. 2009. Supporting research for fisheries stock enhancement in Indonesia (in Indonesian). Research Centre for Capture Fisheries, Research and Development Agency, MMAF. Jakarta.

Kartamihardja, E.S, S. Koeshendrajana & Z. Nasution. 2009. Fisheries management through auction system at lebak-lebung, Ogan Komering Ilir regency, South Sumatera (in Indonesian). Research Centre for Capture Fisheries, Research and Development Agency for Marine and Fisheries, MMAF. Jakarta.

Kartamihardja, E.S., K. Purnomo, D.W.H. Tjahyo, C. Umar, M.T.D. Sunarno & S. Koeshendrajana. 2008. Guideline for inland fisheries stock enhancement in Indonesia (in Indonesian). Research Centre fo Capture Fisheries. Research Agency for Marine Affairs and Fisheries, Ministry of Marine Affairs and Fisheries.

Kartamihardja, E.S. & C. Umar. 2005. Culture, Capture Conflict: Sustaining Fish Production and Livelihoods in Indonesian Reservoir: Capture Fisheries Component (in Indonesian). A Technical Report of the Year 2005, (Project No. FIS/2002/111), DGA-ACIAR.

Kartamihardja, E.S. 1993. Some aspects of the Biology and Population dynamics of the Dominant Fish Species in Kedungombo Reservoir, Central Java, Indonesia. MS Thesis. University Pertanian Malaysia Selangor (un published).

Kartamihardja, E.S., Wijopriono, K. Purnomo & Z. Fahmi. 2005. Habitat and fish stock assessment at Seruyan River, Central Kalimantan and Barito River, South Kalimantan. Technical paper of research result (in Indonesian). Research Centre for Capture Fisheries, Research and Development Agency for Marine and Fisheries, MMAF. Jakarta unpublished).

Kartamihardja, E.S. & K. Purnomo. 2004. The successful of siamese catfish, Pangasius hypoppthalmus introduction and its impact on the fish composition and catch at Wonogiri Reservoir, Central Java (in Indonesian). Prosiding Inland water Forum I. Inland water research Institute, Research Centre for Capture Fisheries, Research and Development Agency for Marine and Fisheries, MMAF. Jakarta.

Kartamihardja, E.S. 2004. Change of fish community and its affecting important factors after thirthy five years of Djuanda Reservoir impounded(in Indonesian). Specific topic paper. Postgraduate School Program, Bogor Agricultural University. Bogor (unpublished).

Kartamihardja, E.S., F.M. Sukadi & Sutomo. 1992. Fish resources assessment for optimation of fish yield at Kedungombo Reservoir (in Indonesian). Report collaboration research between AARP of Research and Development for Agriculture and Ministry of Education and Culture. Jakarta.

Kottelat, M., A.J. Whitten, S.R. Kartikasari & S. Wirjoatmojo. 1993. Freshwater Fishes of Western Indonesia and Sulawesi, Ikan Air Tawar Indonesia Bagian Barat dan Sulawesi (in Indonesian & English). Periplus Edition (HK) Ltd. 293 hal + 84 plate.

Mashudi, I.M. Harahap & Suryana. 2003. Report on fish restocking at Dano Mahligai, Danolamo village, Muaro Jambi district (in Indonesian). FADC Jambi, DGA, MMAF. Jambi Ministry of Marine Affairs and Fisheries. 2007. Guideline for Reservoirs Fisheries co-management in Indonesia(in Indonesian). MMAF colaboration with Australian Centre for International Agricultural Research Center. Jakarta.

Ministry of Marine Affairs and Fisheries. 2006. Regulation Ministry Marine Affairs and Fisheries No. PER.07/MEN/2005, concerning Organisation structure of Marine Affairs and Fisheries (in Indonesian). MMAF. Jakarta.

Ondara & Samuel. 1987. Preliminary research on aquatic plant at Lubuk Lampam, South Sumatera (in Indonesian). Bull. Inland Fisheries Research, Vol. 6(1): 6-9.

Phillip, M.J., Enyuan, F., Gavine, F., Hooi, T.K., Kutty, M.N., Lopez, N.A., Mungkung, R., Ngan, T.T., White, P.G., Yamamoto, K. & Yokoyama, H. 2009. Review on environmental impact assessment and monitoring in aquaculture in Asia-Pacific. In FAO. Environmental impact assessment and monitoring in aquaculture. FAO Fisheries and Aquaculture Technical Paper. No. 527. Rome, FAO. Pp. 153-283.

Purnomo, K. 1993. Fish potensial yield of Semayang and Melintang Lakes – (in Indonesian). Frontir. UNMUL. Samarinda, Indonesia. No. 14. Pp.123-136.

Purnomo, K., D.W.H. Tjahjo, H. Satria, C. Umar & A. Sarnita. 1992a. Research on inland water resources potency at Semayang, Melintang, dan Jempang Lake in East Kalimantan (In Indonesian). Freshwater Aquaculture Research Institute Bogor. Prosiding Freshwater aquaculture seminar 1991/1992. Pp. 274-283.

Purnomo, K., H. Sattria & A. Aziz. 1994. Fish diversity at Semayang and Melintang Lake, South Kalimantan (in Indonesian). Freshwater Aquaculture Research Institute Bogor. Prosiding Freshwater aquaculture seminar 1992/1993. Sukamandi, 24-26 Mei 1993. Pp. 299-308.

Purnomo K., E.S. Kartamihardja, Wijopriono, Z. Fahmi, M.M. Wahyono, R. Faizah & A.S. Sarnita. 2005. Research on fisheries resource capacity mapping and Environment in Toba Lake, Nort Sumatera (in Indonesian). Technical report year 2005. Research Center for Capture Fisheries, Research and Development of Marine and Fisheries. MMAF.

Sarnita, A.S. 1994b. Fish Potential Yield and Fisheries of Limboto Lake, North Sulawesi (in Indonesian). Freshwater Aquaculture Research Institute, Bogor. Prosiding Freshwater aquaculture seminar 1992/1993. Sukamandi, 24-26 Mei 1993. Pp. 330-336.

Soewito, Subono, M.S. Malangjoedo, V. Soesanto, Soehardi, R. Budiono, Martono, H.T. Asikin & S. Rachmatun. 2000. Fisheries History in Indonesia. Yasamina, Jakarta.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN THE REPUBLIC OF KOREA

Jeung Sook PARK (Ph.D.)
Inland Fisheries Research Institute
National Fisheries Research and Development Institute Ministry of Food,
Agriculture, Forestry and Fisheries
E-mail: jtspark@nfrdi.go.kr

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.

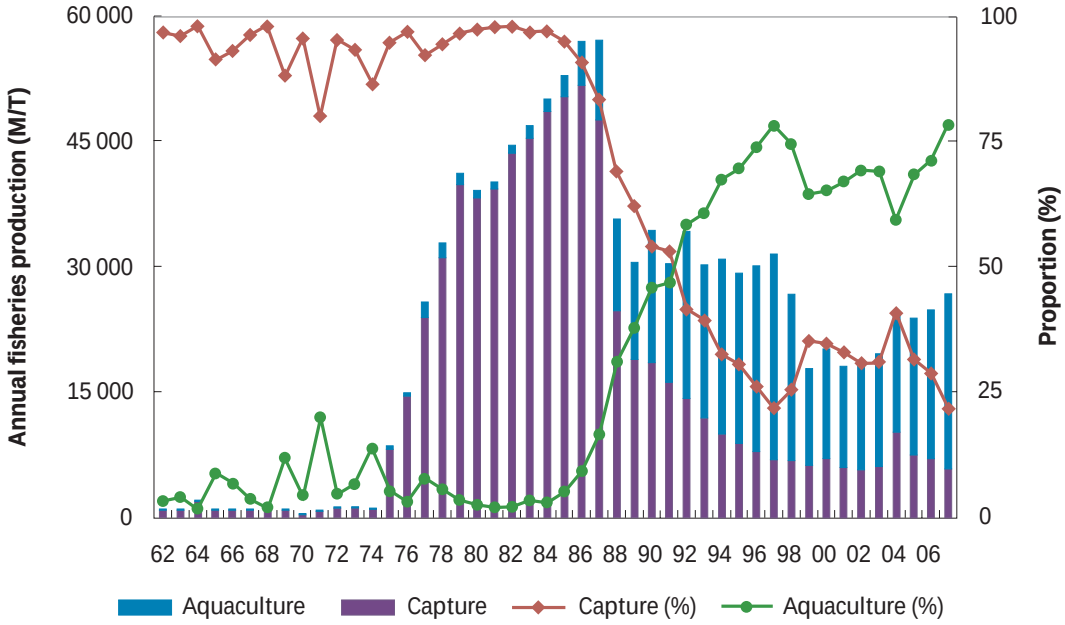


Figure 1. Annual inland capture fisheries and aquaculture production in Korea

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.

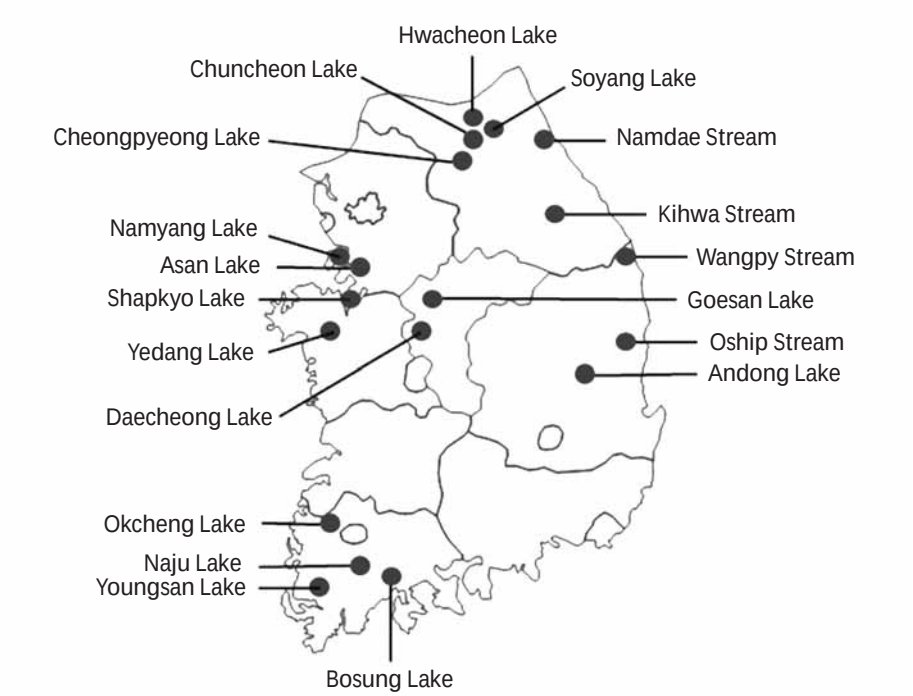


Figure 2. Inland water protected areas (19) in Korea

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.

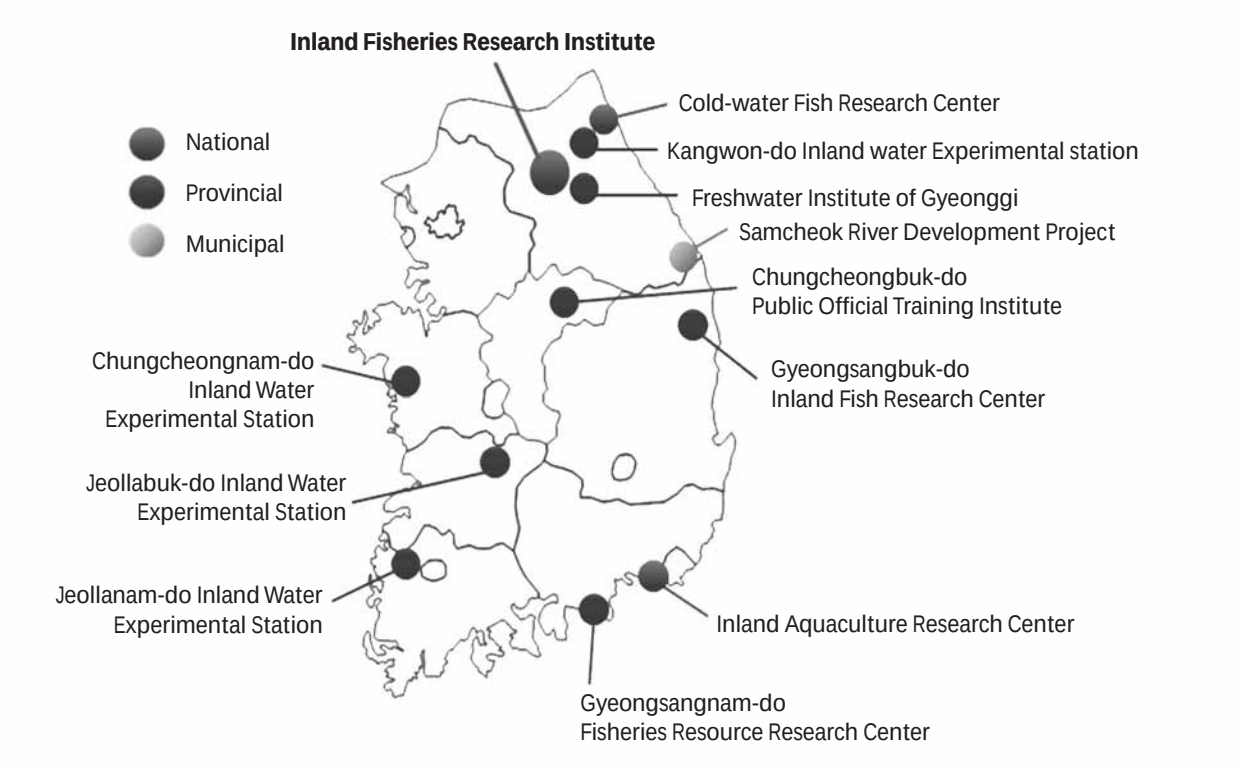


Figure 3. National, provincial and municipal institutes related to inland fisheries

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

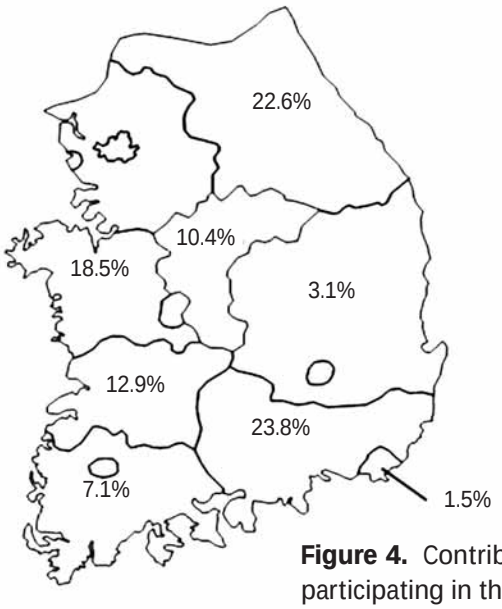


Figure 4. Contribution of metropolitan city and provinces participating in the hatchery release programme

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.

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.

REFERENCES

Garaway, C.J., Arthur, R.I., Chamsingh, B., Homekingkeo, P., Lorenzen, K., Saengvilaikham, B. & Sidavong, K. 2006. A social science perspective on stock enhancement outcomes: lessons learned from inland fisheries in southern Lao PRR. *Fisheries Research,* 80: 37-45.

Jenkins, M. 2003. Prospects for biodiversity. *Science,* 302: 1175-77.

Ricciardi, A. & Rasmussen J.B. 1999. Extinction rates of North American freshwater fauna. *Conservation Biology*, 13: 1220-22.

Year Book of Fisheries Statistics. 1962~1965, Fisheries Bureau of the Ministry of Agriculture, Republic of Korea.

Year Book of Fisheries Statistics. 1966 ~1977, Office of Fisheries, Republic of Korea.

Year Book of Fisheries Statistics. 1978~1996, Ministry of Agriculture and Fisheries, Republic of Korea.

Statistical Year Book of Maritime Affairs and Fisheries. 1997~2007, Ministry of Maritime Affairs and Fisheries, Republic of Korea.

Food, Agriculture, Forestry and Fisheries Statistical Year Book. 2008, Ministry of Food, Agriculture, Forestry and Fisheries, Republic of Korea.

Cadastral Statistical Annual Report. 2007, National Geographic Information Institute of the Republic of Korea.