INLAND FISHERIES RESOURCES ENHANCEMENT AND CONSERVATION PRACTICES IN MYANMAR

Aung Htay Oo
Department of Fisheries, Ministry of Livestock and Fisheries
E-mail: aunghtayoo21@gmail.com

Abstract

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

Key words: Inland fisheries; replenishing and conservation.

1. INTRODUCTION

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

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

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

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

2. CURRENT STATUS OF INLAND FISHERIES IN MYANMAR

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

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

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

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

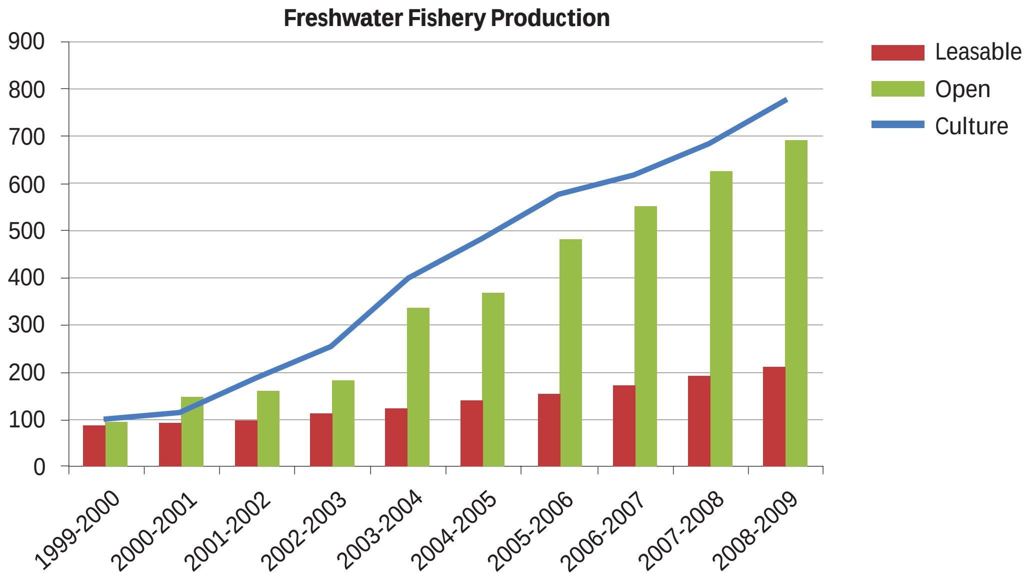


Figure 1. inland fisheries production in 10 years

2.1 Leasable fisheries

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

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

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

2.2 Open water fisheries

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

2.3 Social dimensions of inland fisheries in Myanmar

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

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

3. BIODIVERSITY OF INLAND WATERS

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

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

Table 2. Fish species list of Lake Inle

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

4. STOCK ENHANCEMENT PRACITCES OF INLAND WATERS IN MYANMAR

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

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

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

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

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

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

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

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

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

Source: DoF, Myanmar

5. OTHER ENHANCEMENT PRACTICES

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

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

6. IMPACTS OF MAJOR ENHANCEMENT AND CONSERVATION ACTIVITIES

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

7. BIODIVERSITY CONSERVATION

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

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

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

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

- **Notification 2/92**

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

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

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

8. CONSTRAINTS AND PROBLEMS

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

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

9. RECOMMENDATION

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

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

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

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

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

REFERENCE

Aung, O., Nguyen, Thuy T.T., Poompuang Supawadee & Kamonrat Wongpathom. 2010. Microsatellite DNA markers revealed genetic population structure among captive stocks and wild populations of mrigal, Cirrhinus cirrhosus in Myanmar. Aquaculture, 299, 237-243.

DOF, Myanmar. 2008. Fishery Statistics (2008-2009). Department of fisheries, Myanmar, Yangon, 97 pp.

FAO-NACA. 2003. Myanmar aquaculture and inland fisheries. RAP Publication 2003/18, 62 pp. Welcomme, R.L., Bartley, D.M., 1998. Current approaches to the enhancement of fisheries. *Fisheries anagement and Ecology,* 5, 351-382.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN NEPAL

Kishore Kumar Upadhyaya
Directorate of Fisheries Development
E-mail: kishor.upadhyaya@gmail.com

Abstract

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

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

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

1. INTRODUCTION AND OVERVIEW

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

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

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

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

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

2. WATER RESOURCES

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

Table 1. Estimated water resources in Nepal

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

Source: Directorate of Fisheries Development (DOFD) 2002

2.1 Rivers

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

2.2 Lakes

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

2.3 Reservoirs

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

2.4 Irrigated rice fields

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

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

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

3. FISHERIES RESOURCES

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

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

4. FISHERIES PRODUCTION AND PRODUCTIVITY

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

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

Table 2. Production and productivity from capture fisheries

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

Source: DOFD, GoN, 2008

5. AQUATIC RESOURCES AND LIVELIHOODS

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

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

6. CURRENT INLAND FISHERIES PRACTICES

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

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

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

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

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

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

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

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

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

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

6.2 Conservation strategies

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

6.3 Water Resources Strategy (WRS)

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

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

6.4 National Water Plan (2005)

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

6.4.1 Management of watersheds and aquatic ecosystem

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

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

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

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

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

6.4.2 River basin management

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

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

6.4.3 Agencies involved in conservation and management

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

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

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

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

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

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

6.5 Existing conservation and mitigation measures

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

6.5.1 Legislative arrangements

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

6.5.2 Environmental impact assessments

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

6.5.3 Establishment of fish sanctuaries

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

6.5.4 Protections of endangered species

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

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

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

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

6.5.5 Promulgation of aquatic animal protection regulations

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

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

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

V = Vulnerable; E = Endangered

6.5.6 Fish trapping and hauling

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

6.5.7 Fish ladders

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

6.5.8 Fish hatcheries

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

6.5.9 Open water stocking

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

6.5.10 Awareness programmes

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

7. CONSTRAINTS AND PROBLEMS

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

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

8. RECOMMENDATIONS

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

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

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

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

REFERENCES

Country Profile-Nepal. 2008/09. Directorate of Fisheries Development, Central Fisheries Building, Kathmandu, Nepal.

Cernea M.M. 1997. Hydropower dams and social impacts: A sociological perspective. Environmentally Sustainable Development (ESD). The World Bank. pp 1-37.

Costa-Pierce B.A. and H.Y. Hadikusumah. 1990. Research on reservoir-based cage aquaculture systems in Saguling Reservoir, West Java, Indonesia. In: Costa-Pierce, B.A. and O. Soemarwoto (eds.). Reservoir fisheries and aquaculture development for resettlement in Indonesia. ICLARM, Technical Report 23. International Centre for Living Aquatic Resources Management (ICLARM), Manila.

Gubhaju, S.R. 2001. Impact of Damming on the Aquatic Fauna in Rivers. Paper presented at "Symposium on Cold Water Fishes of the Trans-Himalayan Region. 10-13 July, 2001. Kathmandu, Nepal.

Tek B. Gurung, Raja M. Mulmi, Kalyan K.C., G. Wagle, Gagan B. Pradhan, K. Upadhyaya & Ash K. Rai. 2008. The success on adoption of cage fish culture as an alternative livelihood option for communities displaced by reservoir impounded in Kulekhani, Nepal.

IUCN. 1994. Proceedings of the National Workshop on Wetlands Management in Nepal.

National Wetland Policy, 2003. Ministry of Forests and Soil Conservation, Government of Nepal, Singhdurbar, Kathmandu.

Nepal Bio-diversity Strategy, 2002. Ministry of Forest and Soil Conservation, Government of Nepal.

Pradhan, B.R. 1987. Potential of reservoirs fishery development in Nepal. IDRC Workshop Proceedings.

Sharma, C.K. 1977. River systems of Nepal. Kathmandu: P.P.W. Ltd.

Sharma, C.K. 1997. A treatise on water resources of Nepal. P.P.W. Ltd.

Swar, D.B. 2001, The Status of Cold Water Fish and Fisheries in Nepal and prospects of Their Utilization for Poverty Reduction. Paper presented at "Symposium on Cold Water Fishes of the Trans-Himalayan Region. 10-13 July 2001. Kathmandu, Nepal.

Swar, D.B. & C.H. Fernando. 1980. Some studies on the ecology of limnetic crustacean zooplankton in lake Begnas and Rupa of Pokhara Valley, Nepal. Hydrobiologia 70: 235.

Swar, D.B., G.B.N. Pradhan & L.M. Lofvall Westlund (Eds.). 1997. Proceedings of the National Symposium on the Role of Fisheries and Aquaculture in the Economic Development of Rural Nepal, 1996, 15-16 August. Kathmandu, NEFIS, Nepal.

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

Swar D.B. 1992. Effect of impoundment on indigenous fish population in Indrasarobar Reservoir, Nepal. Proceedings of the second Workshop on Reservoir Fishery Management in Asia (S.S. De Silva (ed.). IDRC, Ottawa, 111-118.

Swar D.B. & T.B. Gurung. 1988. Introduction and cage culture of exotic carps and their impact on fish harvested in Lake Begnas, Nepal. *Hydrobiologia* 166: 277-283.

Swar D.B. & B.R. Pradhan. 1992. Cage fish culture in lakes of Pokhara Valley, Nepal, and its impact on local fishers. *Asian Fisheries Science* 5: 1-13.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN SRI LANKA

Upali S. Amarasinghe
Department of Zoology, University of Kelaniya, Kelaniya GQ 11600, Sri Lanka
E-mail: zoousa@kln.ac.lk

Abstract

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

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

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

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

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

1. INTRODUCTION

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

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

1.1 History of inland fisheries resource enhancement and conservation

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

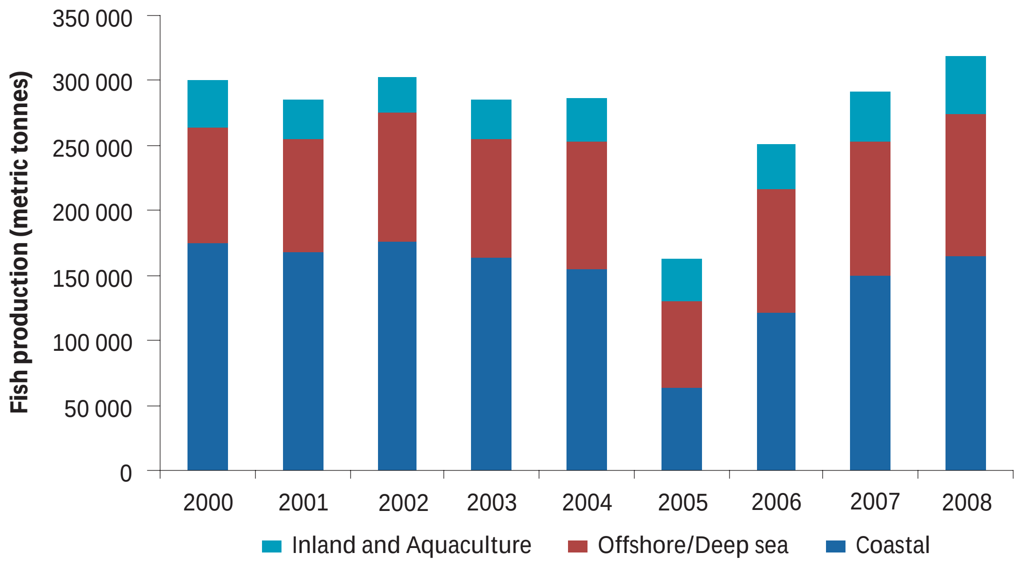


Figure 1. Annual fish production in Sri Lanka from different sub-sectors (2000-2008)

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

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

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

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

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

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

1.2 Major practices of fisheries resource enhancement and management

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

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

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

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

1.3 Fish species cultured

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

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

1.4 Scale of operation

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

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

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

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

2. CURRENT PRACTICES OF INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION

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

2.1 Seed resources

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

2.2 Contribution of CBF to total inland fish production

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

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

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

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

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

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

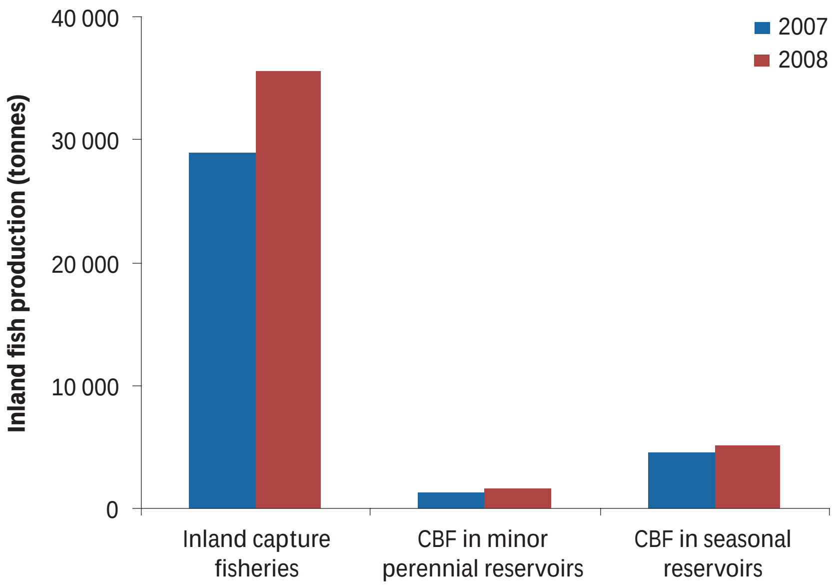


Figure 2. The annual inland fisheries production from capture fisheries and culture-based fisheries during 2007-2008

2.3 Rationale and purpose of inland fisheries enhancement

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

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

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

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

2.4 Technicalities in fisheries enhancement

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

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

2.5 Operational aspects

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

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

3. CURRENT PRACTICES OF INLAND FISHERIES ENHANCEMENT

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

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

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

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

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

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

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

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

3.1 Seasonal reservoirs

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

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

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

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

3.2 Minor perennial reservoirs

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

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

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

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

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

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

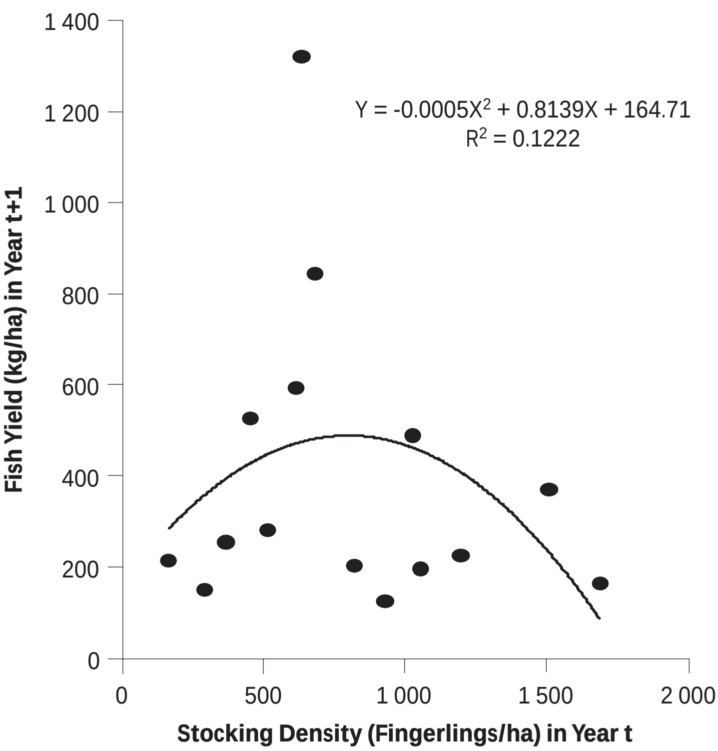


Figure 3. The relationship between mean SD during 2005-2006 (time t) and mean annual fish yield during 2005-2007 (time t+1) in minor perennial reservoirs (Source of data: Pushpalatha and Chandrasoma, 2010).

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

3.3 Major reservoirs

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

4. REGULATIONS FOR MANAGEMENT AND CONSERVATION

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

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

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

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

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

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

5. IMPACT ASSESSMENT

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

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

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

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

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

6. CONSTRAINTS AND PROBLEMS ASSOCIATED WITH INLAND FISHERIES ENHANCEMENT

6.1 Technical constraints

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

6.2 Operational constraints

6.2.1 Policy level

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

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

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

6.2.2 Resource availability and cost sharing

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

6.3 Distribution of social benefits

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

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

6.4 Ecological impacts of enhancement strategies

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

7. RECOMMENDATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ACKNOWLEDGEMENTS

I am thankful to Dr D.E.M. Weerakoon (former Director General of NAQDA) for providing me data CBF activities in 120 seasonal reservoirs of Sri Lanka.

REFERENCES

Amarasinghe, U.S. 1990. Minor cyprinid resources in a man-made lake in Sri Lanka: a potential supplementary source of income for fishermen. *Fisheries Research* 9: 81-89.

Amarasinghe, U.S. 1995. The inland fishery of Sri Lanka. In T. Petr and M. Morris, eds. *FAO Fisheries Report* No. 512, Suppl. pp. 254-262. Rome, FAO.

Amarasinghe, U.S. 1998. How effective are the stocking strategies for the management of reservoir fisheries of Sri Lanka? *In* I.G. Cowx, ed. *Stocking and Introductions of Fish.* pp. 422-436. Oxford, Fishing News Books, Blackwell Science Ltd.

Amarasinghe, U.S. & De Silva, S.S. 1999. The Sri Lankan reservoir fishery: a case for introduction of a co-management strategy. *Fisheries Management and Ecology* 6: 387-399.

Amarasinghe, U.S. & Nguyen, T.T.T. 2009. Enhancing rural farmer income through fish production: Secondary use of water resources in Sri Lanka and elsewhere. *In* S.S. De Silva and F.B. Davy, eds. *Success Stories in Asian Aquaculture.* pp. 103-130. Dordrecht, Springer Science.

Amarasinghe, U.S. & Weerakoon, D.E.M. 2009. Present status and future strategies for the management of reservoir fisheries in Sri Lanka. In S.S. De Silva and U.S. Amarasinghe, eds. *Status of reservoir fisheries in five Asian countries.* pp. 69-98. NACA Monograph No. 2. Bangkok, Network of Aquaculture Centres in Asia-Pacific. 116 p.

Amarasinghe, U.S., Cumaranatunge, P.R.T. & Hettiarachchi, C.P. 2008. Does the invasiveness of introduced cichlids in Sri Lankan freshwaters lead to adverse impacts on native freshwater fish fauna? Paper presented at the National Symposium on Alien Invasive Species, 11 November 2008, Colombo, Sri Lanka.

Amarasinghe, U.S., Shirantha, R.R.A.R. & Wijeyaratne, M.J.S. 2006. Some aspects of ecology of endemic fresh water fishes of Sri Lanka. In C. Bambaradeniya, ed. *Fauna of Sri Lanka: Status of Taxonomy, Research and Conservation.* pp. 113-124. Colombo, The World Conservation Union and Government of Sri Lanka, viii+308 pp.

Anon. 1996a. *Fisheries and Aquatic Resources Act No. 2 of 1996.* Colombo, Sri Lanka, The Gazette of Sri Lanka of 11 January 1996.

Anon. 1996b. *Aquaculture Management Regulations of 1996.* Colombo, Sri Lanka, The Gazette of Sri Lanka (Extraordinary) of 7 November 1996.

Anon. 1998a. The National Aquaculture Development Authority of Sri Lanka Act, No. 53 of 1998, Colombo, Sri Lanka.

Anon. 1998b. *The Export and Import of Live Fish Regulations of 1998.* The Gazette of Sri Lanka No. 1036/13 of 16 July 1998. Colombo, Sri Lanka.

Anon. 2000. *Agrarian Development Act No. 46 of 2000.* Colombo, Sri Lanka, The Gazette of Sri Lanka of 18 August 2000.

Anon. 2006a. *National Aquaculture Development Authority of Sri Lanka (Amendment) Act, No. 23 of 2006.* 16 August 2006. Colombo, Sri Lanka, Parliament of Sri Lanka.

Anon. 2006b. Mini nursery program. *Aquaculture News,* NAQDA Newsletter (September-December 2006) 3: 1.

Anon. 2006c. *Fisheries and Aquatic Resources (Amendment) Act No. 22 of 2006. 16 August 2006.* Parliament of Sri Lanka, Colombo, Sri Lanka.

Anon. 2007. *Ten Year Development Policy Framework of the Fisheries and Aquatic Resources Sector 2007-2016.* Ministry of Fisheries and Aquatic Resources, Colombo, Sri Lanka. 24 p.

Anon. 2009. Annual Fisheries Statistics, Ministry of Fisheries and Aquatic Resources, Sri Lanka. http://www.fisheries.gov.lk/statistics.html (accessed on 25 November 2009).

Bondad-Reantaso, M.G. (ed.) 2007. Assessment of freshwater fish seed resources for sustainable aquaculture. *FAO Fish. Tech. Pap.* No. 501, 628 p. Rome.

Bossuyt, F., Meegaskumbura, M., Beenaerts, N., Gower, D.J., Pethiyagoda, R,. Roelants, K.,. Mannaert, A., Wilkinson, M. & Bahir, M.M. 2004. Local endemism within the Western Ghats – Sri Lanka biodiversity hotspot. *Science* 306: 479-481.

CEA. 1998. *A guide for implementing EIA process, No. 1, 1998.* Colombo, Sri Lanka, Central Environmental Authority. 58 p.

CEA. 2003. *Guidance for implementing EIA process, No. 2: A general guide for conducting environmental scoping, 2003.* Colombo, Sri Lanka, Central Environmental Authority. 35 p.

Chandrasoma, J. 1992. Performance of Rohu, Labeo rohita (Ham.), in some perennial reservoirs of Sri Lanka – an evaluation. *J. Applied Ichthyol.* 8: 228-233.

Chandrasoma, J. & Kumarasiri, W.S.A.L. 1986. Observations in polyculture of fish in seasonal tanks in Rathnapura and Monaragala districts of Sri Lanka – an evaluation. *J. Inland Fish. Sri Lanka* 3: 49-55.

Cowx, I.G. 1998. Stocking strategies: Issues and options for future enhancement programs. *In* I.G. Cowx, ed. *Stocking and Introductions of fish.* pp. 3-13. Oxford, Fishing News Books, Blackwell Science Ltd.

De Silva, K.H.G.M. 1991. The predicament of the freshwater fisheries and aquaculture of Sri Lanka. *NAGA, the ICLARM Quarterly* 14: 6-7.

De Silva, S.S. 1988. Reservoirs of Sri Lanka and their fisheries. *FAO Fisheries Technical Paper* 298, 128 p. Rome.

De Silva, S.S. 2003. Culture-based fisheries: an underutilized opportunity in aquaculture development. *Aquaculture* 221: 221-243.

De Silva, S.S. & Funge-Smith, S.J. 2005. *A review of stock enhancement practices in the inland water fisheries of Asia.* Asia-Pacific Fishery Commission, Bangkok, Thailand. RAP Publication No. 2005/12, 93 p.

De Silva, S.S. & Sirisena, H.K.G. 1987. New fish resources of reservoirs in Sri Lanka. Feasibility of introduction of a subsidiary gillnet fishery for minor cyprinids. *Fisheries Ressearch* 6: 17-34.

De Silva, S.S., Lin, Y. & Tan, G. 1992. Possible yield-predictive models based on morphometric characteristics and stocking rates for three groups of Chinese reservoirs. *Fisheries Research* 13: 369-380.

De Silva, S.S., Wijenayake, W.M.H.K., Gunaratne, A.B.A.K. & Amarasinghe, U.S. 2005. Use of GIS tools to develop a scale for the selection of non-perennial reservoirs for culture-based fisheries activities. *In* T. Nishida, P.J. Kailola and C.E. Hollingworth, eds. *GIS Spatial Analyses in Fishery and Aquatic Sciences* (Volume 2). pp. 559-572. Japan, Fishery and Aquatic GIS Research Group.

FAO/UNDP. 1980. *Strategy for development of aquaculture in Sri Lanka.* Report of a planning mission, September-October 1980. ADCP/MR/81/15.

Fernando, C.H. & De Silva, S.S. 1984. Man made lakes: Ancient heritage and modern biological resources. *In* C.H. Fernando, ed. *Ecology and biogeography of Sri Lanka.* pp. 431-451. The Hague, Dr W. Junk Publishers.

Fernando, C.H., Shirantha, R.R.A.R., Wijeyaratne, M.J.S. & Cumaranatunga, P.R.T. 2002. Tilapias and indigenous fish biodiversity in Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 7: 1-22.

Gutiérrez, A.T. & Reaser, J.K. 2005. *Linkages between development assistance and invasive alien species in freshwater systems of southeast Asia.* Washington, DC, USAID Asia and Near East Bureau. *Research Station, Ceylon* 17: 287-289.

IUCN Sri Lanka and the Ministry of Environment and Natural Resources. 2007. *The 2007 Red List of Threatened Fauna and Flora of Sri Lanka.* Colombo. xii+148 pp.

Jayasekara, A.M. 1989. The use of common carp and Asian carps in the management of larger inland water bodies in Sri Lanka. *In* T. Petr, ed. Papers contributed to the workshop on the use of cyprinids in the fisheries management of larger inland water bodies of the Indo-Pacific, 8-10 September 1988, Kathmandu, Nepal, and country reports presented at the fourth session of the Indo-Pacific Fishery Commission working party of experts on inland fisheries, 8-14 September 1988, Kathmandu, Nepal. pp. 114-141. F*AO Fish. Rep.* No. 405 (Suppl.), Rome.

Jayasinghe, U.A.D., Amarasinghe, U.S. & De Silva, S.S. 2005a. Trophic classification of non-perennial reservoirs utilized for the development of culture-based fisheries, Sri Lanka. *International Review of Hydrobiology* 90: 209-222.

Jayasinghe, U.A.D., Amarasinghe, U.S. & De Silva, S.S. 2005b. Limnology and culture-based fisheries in non-perennial reservoirs of Sri Lanka. *Lakes and Reservoirs: Research and Management* 10: 157-166.

Jayasinghe, U.A.D., Amarasinghe, U.S. & De Silva, S.S. 2006. Culture-based fisheries in non-perennial reservoirs of Sri Lanka: influence of reservoir morphometry and stocking density on yield. *Fisheries Management and Ecology* 13: 157-164.

Kortmulder, K. 1987. Ecology and behaviour of tropical freshwater fish communities. *Archiv für Hydrobiologie* 28: 503-513.

Kularatne, M.G., Amarasinghe, U.S., Wattage, P. & De Silva, S.S. 2009. Evaluation of community participation for the development of culture-based fisheries in village reservoirs of Sri Lanka. *Aquaculture Econonimc and Management* 13: 22-38.

Lorenzen, K. 1995. Population dynamics and management of culture based fisheries. *Fisheries Management and Ecology* 2: 61-73.

Lorenzen, K. 2001. Using population models to assess culture-based fisheries: A brief review with an application to the analysis of stocking experiments. *In* S.S. De Silva, ed. *Reservoir and Culture-based Fisheries: Biology and Management* pp. 257-265. Canberra, Australian Centre for International Agricultural Research.

Lorenzen, K., Amarasinghe, U.S., Bartley, D.M., Bell, J.D., Bilio, M., De Silva, S.S., Garaway, C.J., Hartman, W.D., Kapetsky, J.M., Laleye, P., Moreau, J., Sugunan, V.V. & Swar, D.B. 2001. Strategic review of enhancements and culture-based fisheries. *In* R.P. Subasinghe, P. Beuno, M.J. Phillips, C. Hough, S.E. McGladdery and J.R. Arthur, eds. *Aquaculture in the Third Millenium.* Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 221-237. Bangkok, NACA and Rome, FAO.

Lowe, S., Browne, M., Boudjelas, S. & De Pooter, M. 2000. *100 of the World's Worst Invasive Alien Species. A Selection from the Global Invasive Species Database.* Publication of the Invasive Species Specialist Group (ISSG), a special group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). 12 p. First published as special lift-out in Aliens 12, December 2000. Updated and reprinted version: November 2004 (Electronic version: www.issg.org/booklet.pdf)

Moyle, P.B. & Senanayake, F.R. 1984. Resources partitioning among the fishes of rainforest streams in Sri Lanka. *Journal of Zoology, London* 202: 195-223.

Murray, F.J., Kodituwakku, S. & Little, D.C. 2001. Fisheries marketing system in Sri Lanka and their relevance to local reservoir fishery development. *In* S.S. De Silva, ed. *Reservoir and Culture-based Fisheries: Biology and Management.* pp. 56-65. ACIAR Proceedings No. 98, Canberra, Australian Centre for International Agricultural Research.

Oglesby, R.T. 1981. *Inland fisheries of Sri Lanka and their management.* Interim report to the FAO of the project TCP/SRL/8804 (Development of fisheries in man made lakes and reservoirs) 79 p.

Pet, J.S., Gevers, G.J.M., van Densen, W.L.T. & Vijverberg, J. 1996. Management options for a more complete utilization of the biological fish production in Sri Lankan reservoirs. *Ecology of Freshwater Fish* 5: 1-14.

Petr, T. 1994. Intensification of reservoir fisheries in tropical and subtropical countries. *Internationale Revue gesamten Hydrobiologie* 79(1): 131-138.

Petr, T. (ed.) 1998. Inland fishery enhancements. *FAO Fisheries Technical Paper* 374: 460 p. Rome.

Pushpalatha, K.B.C. & Chandrasoma, J. 2010. Culture-based fisheries in minor perennial reservoirs in Sri Lanka: variability in production, stocked species and yield implications. *Journal of Applied Ichthyology* 26: 99-104.

Siriweera, W.I. 1994. *A study of the economic history of pre-modern Sri Lanka* New Deihi,. Vikas Publishing House. 176 p.

Staples, D. & Funge-Smith, S. 2009. *Ecosystem approach to fisheries and aquaculture: Implementing the FAO Code of Conduct for Responsible Fisheries*. FAO Regional Office for Asia and the Pacific, Bangkok. RAP Publication 2009/11, 48 pp.

Sugunan, V.V. 1995. Reservoir fisheries in India. *FAO Fisheries Technical Paper* 352: 423 p. Rome.

Thayaparan, K. 1982. The role of seasonal tanks in the development of fresh water fisheries in Sri Lanka. *Journal of Inland Fisheries, Sri Lanka* 1: 133-167.

Ulluwishewa, R. 1995. Traditional practices of inland fishery resource management in the dry zone of Sri Lanka: Implications for sustainability. *Environmental Conservation* 22: 127-132.

Weerakoon, D.E.M. 2007. Freshwater fish seed resources in Sri Lanka. *In* M.G. Bondad-Reantaso, ed. Assessment of freshwater fish seed resources for sustainable aquaculture. pp. 425-440. *FAO Fisheries Technical Paper* 501: 628 p. Rome.

Welcomme, R.L. & Bartely, D.M. 1998. Current approaches to the enhancement of fisheries. *Fisheries Management and Ecology* 5: 351-382.

Weliange, W.S. & Amarasinghe, U.S. 2003. Seasonality in dietary shifts in size-structured freshwater fish assemblages in three reservoirs of Sri Lanka. *Environmental Biology of Fishes* 68(3): 269-282.

Wijenayake, W.M.H.K., Amarasinghe, U.S. & De Silva, S.S. 2007. Performance of GIFT strain of *Oreochromis niloticus* in culture-based fisheries in non-perennial reservoirs, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 12: 1-18.

Wijenayake, W.M.H.K., Jayasinghe, U.A.D., Amarasinghe, U.S., Athula, J.A., Pushpalatha, K.B.C. & De Silva, S.S. 2005. Culture-based fisheries in non-perennial reservoirs in Sri Lanka: Production and relative performance of stocked species. *Fisheries Management and Ecology* 12: 249-258.

Wikramanayake, E.D. & Moyle, P.B. 1989. Ecological structure of tropical fish assembledges in wet-zone streams of Sri Lanka. *Journal of Zoology, London* 218: 503-526.

Wingard, J.D. 2000. Community transferable quotas: Internalizing externalities and minimizing social impacts of fisheries management. *Human Organization* 59: 48-57.

INLAND FISHERY RESOURCE ENHANCEMENT AND CONSERVATION IN THAILAND

Tuantong Jutagate and Achara Rattanachai
Faculty of Agriculture, Ubon Ratchathani University
Warin Chamrab, Ubon Ratchathani, Thailand 34190
E-mail: tjuta@agri.ubu.ac.th and acharar@agri.ubu.ac.th

Abstract

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

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

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

1. INTRODUCTION

1.1 Inland fisheries in Thailand

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

---

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

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

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

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

1.2 History of inland fisheries resource enhancement and conservation in Thailand

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

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

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

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

2. TECHNIQUES FOR STOCK ENHANCEMENT FOR INLAND FISHERIES

2.1 Engineering the environment

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

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

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

2.2 Fish stocking programs

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

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

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

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

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

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

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

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

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

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

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

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

3. CONSERVATION PRACTICES FOR INLAND FISHERIES IN THAILAND

3.1 Closed fishing season

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

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

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

3.2 Fish conservation zones (or Closed areas)

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

3.3 Control of fishing gears

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

4. OPERATIONS

4.1 Authorized organizations

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

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

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

4.2 Funding mechanisms

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

4.3 Management/enforcement/participation

4.3.1 Engineering the environment

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

4.3.2 Fish stocking in small water bodies

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

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

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

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

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

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

4.3.3 Fish stocking in large water body

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

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

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

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

4.3.4 Conservation practices

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

5. EVALUATION AND ASSESSMENT

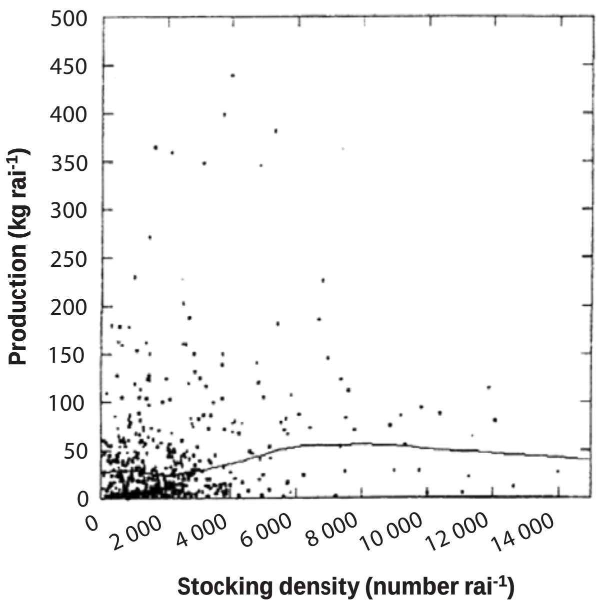
5.1 Engineering the environment

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

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

5.2 Fish stocking in small water body

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



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

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

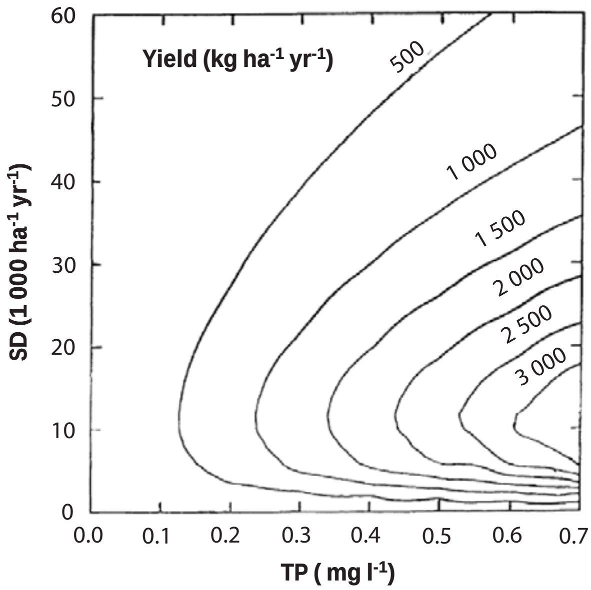
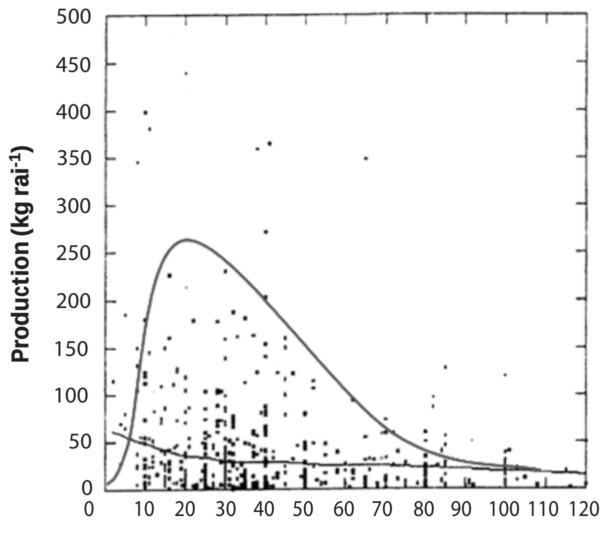


Figure 2. Predicted yield as a function of total phosphorus (TP) and stocking density (SD) in village ponds in NE of Thailand (Lorenzen *et al.*, 1998)



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

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

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

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

5.3 Fish stocking in large water body

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

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

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

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

5.4 Conservation practices

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

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

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

6. IMPACTS OF MAJOR ENHANCEMENT AND CONSERVATION ACTIVITIES

6.1 Impact of stocked fish on ecosystem

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

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

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

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

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

6.3 Socio-economic benefit

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

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

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

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

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

7. CONSTRAINTS AND PROBLEMS

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

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

8. RECOMMENDATIONS

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

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

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

REFERENCES

Asian Development Bank. 2005. *An evaluation of small-scale freshwater rural aquaculture development for poverty reduction.* Asian Development Bank, Manila. 164 pp.

Anonymous. 1988. *Rehabilitation of Thai freshwater fish and aquatic animals.* National Inland fisheries Institute, Department of Fisheries, Bangkok. 17 pp. *(In Thai)*

Arthur, R.I., Lorenzen, K., Homekingkeo, P., Sidavong, K., Sengvilaikham, B. & Garaway, C.J. 2010. Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. Aquaculture 299: 81-88.

Baird, I.G. 2006. Strength in diversity: fish sanctuaries and deep-water pools in Lao PDR. Fisheries Management and Ecology 13: 1-8.

Baird, I.G. & Flaherty, M.S. 2005. Mekong River fish conservation zones in Southern Laos: Assessing effectiveness using local ecological knowledge. Environmental Management 36: 439-454.

Barlow, C. 2009. Need for inland fisheries management training in Southeast Asia. Book of Abstract: International Symposium on Aquaculture & Fisheries Education. Asian Institute of Technology, Bangkok. p. 49.

Benjakarn, M. 1984. *Stocking Macrobrachium rosenbergii in Ubolrattana Reservoir.* Fisheries Development in Ubolratana Reservoir. Division of Inland Fisheries, Department of Fisheries, Bangkok. 30 pp. *(In Thai)*

Benchakarn, M. 1986. *Fishing season for some fish species in Ubolratana Reservoir.* Report No. 3/1986. Inland Fisheries Division, Department of Fisheries, Bangkok. 19 pp. *(In Thai)*

Benchakarn, M. & Nookuor, A. 1988. Increase efficiency of stocking fish in the fingerling of rohu by pen culture in Ubolratana Reservoir. Annual Report, Ubolratana Reservoir Fisheries Development Station, Department of Fisheries. pp. 35-43. *(In Thai)*

Bhukaswan, T. 1980. *Management of Asia reservoir fisheries.* FAO Fisheries Technical Paper No. 207. 69 pp.

Bhukaswan, T. 1985. *The fisheries of Thailand.* National Inland Fisheries Institute, Department of Fisheries, Bangkok. 26 pp.

Bhukaswan, T. 1989. The use of cyprinids in fisheries management of the larger inland water bodies in Thailand *In:* Petr, T. (ed.) Indo-Pacific Fisheries commission, Papers contributed to the Workshop on the Use of Cyprinids in the Fisheries Management of Larger Inland Water Bodies of the Indo-Pacific. FAO Fisheries Report. 405. pp.142-150.

Bhukaswan, T. & Chookajorn, T. 1988. Present status of the reservoir fisheries in Thailand *In:* De Silva S.S. (ed.). Reservoir Fisheries Management and Development in Asia. International Development Research Center, Ottawa. pp. 154-157.

Bureau of Fisheries Administration and Management. 2009. Section for Freshwater Fisheries. Available at http://www.fisheries.go.th/if-manange/*(In Thai)*

Chansri, P., Phiwkham, P. & Khumsri, M. 2008. *Effectiveness of fisheries management measures in Lampao Reservoir, Kalasin Province.* Inland Fisheries Research and Development Bureau, Department of Fisheries, Bangkok. 58 pp. *(In Thai)*

Chantarawarathit, C. 1993. Effects of fishery activities on socio-economic situation of the rural inhabitants after Beung Boraped Rehabilitation. Abstract of the research articles in 1993. National Inland Fisheries Institute, Department of Fisheries, Bangkok. p. 113. *(In Thai)*

Chantarawarathit, N. 1989. The *DOF village fisheries project: an analysis of its problems and impact in Udonthani Province, Thailand.* M.Sc. Thesis, Asian Institute of Technology, Bangkok. 236 pp.

Chuchom, C. & Taruwan, W. 2006. *Hydrobiological and fishery resources in Thawatchai Reservoir after rehabilitation, Roi Et Province.* Technical Paper No. 13/2006. Kalasin Inland Fisheries Station, Department of Fisheries, Kalasin. 37 pp. *(In Thai)*

Coates, D. 2002. *Inland capture fishery statistics of Southeast Asia: current status and information needs.* FAO RAP Publication 2002/11. Food and Agriculture Organization of the United Nations, Bangkok. 114 pp.

Cowx, I. 1998. An appraisal of stocking strategies in the light of developing country constraint *In:* Petr T. (ed.) Inland fisheries enhancement. FAO Fisheries Technical paper No. 374. FAO, Rome. pp. 119-132.

De Silva, S.S. 1983. Reproductive strategies of some major fish species in Parakrama Samudra Reservoir and their possible impact on the ecosystem – a theoretical consideration. In: Schiemer F. (ed.) Limnology of Parakrama Samudra, Sri Lanka: a case study of an ancient man-made lake in the tropics. The Hague, the Netherlands. pp. 185-191.

De Silva, S.S. 2003. Culture-based fisheries: an underutilized opportunity in aquaculture development. Aquaculture 221: 221-243.

De Silva, S.S. & Funge-Smith, S.J. 2005. *A review of stock enhancement practices in the inland water fisheries of Asia.* RAP Publication No. 2005/12. Asia-Pacific Fishery Commission, Bangkok, Thailand. 93 pp.

Department of Fisheries. 2007a. Fisheries statistics of Thailand. Available at http://www.fisheries.go.th/it-stat/*(In Thai)*

Department of Fisheries. 2007b. *Manual for sub-district administrative organization (Fisheries): Village pond management and aquaculture.* Department of Fisheries, Bangkok. 43 pp. *(In Thai)*

Department of Fisheries. 2008. *Action plans of Department of Fisheries for the fiscal year 2009.* Planning Division, Department of Fisheries, Bangkok. 170 pp. *(In Thai)*

Duangswasdi, S., Leenanond, Y., Srichareondham, B. & Rattanajamnong, D. 1994. *Fishery resources and fishery activities in Nong Harn after rehabilitation.* Technical paper No. 158. National Inland Fisheries Institute, Department of Fisheries, Bangkok. 43 pp. *(In Thai)*

Garaway, C.J. 1995. *Communal ponds in NE Thailand under different use-rights systems: a participatory rural appraisal of their differing roles in people's livelihoods.* MRAG Ltd., London. 106 pp.

Garaway, C.J. 1999. *Small waterbody fisheries and the potential for community-led enhancement: case studies from Lao PDR.* Ph.D. thesis, University of London. 414 p.

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 PDR. Fisheries Research 80: 37-45.

Garaway, C., Lorenzen, K. & Chamsingh, B. 2001. Developing fisheries enhancement in small waterbodies: lessons from Lao PDR and Northeast Thailand In: S.S. De Silva (ed.) Reservoir and culture-based fisheries: biology and management. ACIAR Proceeding No. 98. Australian Centre for International Agricultural Research, Canberra. pp. 227-234.

Hogan, Z., Na-Nakorn, U. & Kong, H. 2008. Threatened fishes of the world: *Pangasius sanitwongsei* Smith 1931 (Siluriformes: Pangasiidae). Environmental Biology of Fishes 84(3): 305-306.

Hortle, K. & Suntornratana, U. 2008. *Socio-economics of the fisheries of the lower Songkram River Basin, northeast Thailand.* MRC Technical Paper No. 17. Mekong River Commission, Vientiane. 85 pp.

Inland Fisheries Research and Development Bureau. 2009. *Action plan in 2010 for the inland fisheries assessment: catch per unit of effort.* IFRBD, Department of Fisheries, Bangkog. 41 pp. *(In Thai)*

Inland Fisheries Division. 1997a. *Hydrobiological and fishery resource surveys in Payao Reservoir, Payao Province after rehabilitation.* Department of Fisheries, Bangkok. 38 pp. *(In Thai)*

Inland Fisheries Division. 1997b. *Preliminary quantitative assessment of fish stocking program in community fish ponds in the northeast of Thailand.* Technical Paper No. 27/1997. Department of Fisheries, Bangkok. 38 pp. *(In Thai)*

Inland Fisheries Resources Group. 1993. *Fish monitoring in Pong-Chi-Mun Rivers after the discharge of sewage from Phoenix Pulp & Paper Public Company.* National Inland Freshwater Institute, Department of Fisheries, Bangkok. 43 pp. *(In Thai)*

Jaiyen P. 2003. *Evaluation of stocking giant freshwater prawn in 2003 in Pak Mun Dam, Ubon Ratchathani Province.* Department of Fisheries, Bangkok. 38 pp. *(In Thai)*

Japan International Cooperation Agency. 2001. Thailand: Large swamp inland fisheries project *In:* JICA Post-evaluation report in fiscal year 2001, JICA, Tokyo. pp. 40-51.

Juntasutra, M., Vivatcharakoset, S., Leesa-nga, S., Pongchavee, K., Pimonbutra, S. & Ratanatraiwongse, V. 1989. Breeding of Pla Tepa *Pangasius sanitwongsei* in 1989. Thai Fisheries Gazette 43(2): 95-97.

Jutagate, T., Mattson, N., Moreau, J., Srichareondham, B. & Kumsri, M. 2002. Ecosystem of Sirindhorn and Nam Ngum Reservoirs: a comparison. Kasetsart Fisheries Research Bulletin No. 24: 1-14.

Jutagate, T., Krudpan, C., Ngamsnae, P., Lamkom, T. & Payooha, K. 2005. Changes in the fish catches during the trial of opening the sluice gates of a run-of-the river reservoir in Thailand. Fisheries Management and Ecology 12: 57-62.

Jutagate, T. 2009. Reservoir fisheries in Thailand *In:* De Silva S.S. and Amarasinghe U.S. (eds.): Reservoir Fisheries in Asia and Pacific. Network for Aquaculture Centers in Asia-Pacific, Bangkok. pp. 96-113.

Jutagate, T. & Mattson, N.S. 2003. Optimized fishing gear operations in Sirinthorn reservoir, Thailand. The Natural History Bulletin of the Siam Society 51: 109-126.

Kamonrat, W. 1996. *Spatial genetic structure of Thai silver barb* ***Puntius gonionotus*** *(Bleeker) population in Thailand.* Ph.D. Dissertation. Dalhousie University, Halifax. 193 pp.

Kamonrat, W. 2008. Genetic diversity of *Barbonymus gonionotus* and *Henicorhynchus siamensis* populations in the lower Mun River after restocking programme: a case study in Pak-Mun Dam. Thai Fisheries Gazette 62: 493-497. *(In Thai)*

Kitivorachate, R., Chanswang, B., Leelanond, Y., Wanagosoom, C., Chomcheoi, C., Sasiwimol, W., Tarnsutath, S. & Kaewjaroon, P. 1985a. *Evaluation of fisheries resources and socio-economics study in Bang Phra Reservoir, Chon Buri Province.* Technical Paper No. 57. National Inland Fisheries Institute, Department of Fisheries, Bangkok. 21 pp. *(In Thai)*

Kitivorachate, R., Chanswang , B., Leelanond, Y., Wanagosoom, C., Chomcheoi, C., Sasiwimol, W., Tarnsutath, S. & Kaewjaroon, P. 1985b. *Evaluation of fisheries resources and socio-economics study in Dokgrai Reservoir, Rayong Province.* Technical Paper No. 59. National Inland Fisheries Institute, Department of Fisheries, Bangkok. 23 pp. *(In Thai)*

Kor-anantakul, K. 1973. Evaluation of stocking Tilapia nilotica and *Cyprinus carpio* in irrigation tank *In:* Annual Report of Mahasarakharm Fishery Station. pp. 59-64.

Little, D.C. 2002. Self-recruiting species in farmer managed aquatic systems — a new approach in aquaculture. Aquaculture News 28, 10-11.

Lorenzen, K., Juntana, J., Bundit, J. & Tourongruang, D. 1998 Assessing culture fisheries practices in small water bodies: a study of village fisheries in Northeast Thailand. Aquaculture Research 29: 211-224.

Lymer, D., Funge-Smith, S., Khemnakorn, P., Naruepon, S. & Ubolratana, S. 2008. *A review and synthesis of capture fisheries data in Thailand: large versus small-scale fisheries.* FAO/RAP Publication 2008/17. FAO Regional Office for Asia and the Pacific, Bangkok. 51 pp.

Mattson, N.S., Buakhamvongsa, K., Sukumasavin, N., Tuan, N. & Vibol, O. 2002. *Cambodia Mekong giant fish species: on their management and biology.* MRC Technical Paper No. 3, Mekong River Commission, Phnom Penh. 29 pp.

Na-Nakorn U., Kamonrat W. & Ngamsiri T. 2004. Genetic diversity of walking catfish, *Clarias macrocephalus*, in Thailand and evidence of genetic introgression from introduced farmed *C. gariepinus.* Aquaculture 240: 145-163.

National Inland Fisheries Institute. 1984. *Evaluation on the 1983 nationwide fish propagation project.* Department of Fisheries, Bangkok. 51 pp. *(In Thai)*

National Inland Fisheries Institute. 1988. *Evaluation on the 1987 nationwide fish propagation project.* Department of Fisheries, Bangkok. 40 pp. *(In Thai)*

Nithirojpakdee, P., Jitapalapong, T. & Senanan, W. 2006. Diet diversity and diet overlap among three fish species, Nile tilapia (*Oreochromis niloticus* Linneaus), Silver barb (*Barbodes gonionotus* Bleeker) and Bagrid catfish (*Mystus mysticetus* Roberts) in Bangphra Reservoir. Thai Fisheries Gazette 60(3): 215-222.

Pawaputanon, O. 1986. Fisheries and fishery management of large reservoir in Thailand *In:* McClean J.L., Dizon D.B. and Hosillos L.V. (eds.) Proceedings of the first Asian fisheries forum. Asian Fisheries Society, Manila. pp. 389-392.

Pawaputanon, O. 1987. Management of fish populations in Ubolratana Reservoir. Archiv für Hydrobiologie – Beiheft Ergebnisse der Limnologie 28: 309-317.

Pawaputanon, O. 1988. *Study of determine the most effective size of seed fish for stocking in public water.* Technology and Production Plan No. 2/1986, Northeast Fishery Project. Department of Fisheries, Bangkok. 11 pp. *(In Thai)*

Pawaputanon, O. 1992. Inland capture fisheries in Thailand. FAO Inland Fisheries Report No. 458, Supplement. FAO, Rome. pp. 106-111.

Pawaputanon, O. 2003. Inland fisheries information in Thailand *In:* New approaches for the improvement of inland capture fishery statistics in the Mekong Basin. RAP Publication 2003/01 (Clayton, T., ed.). Bangkok, Thailand: Erewan Press. pp. 32-34.

Pawaputanon, O. 2007. *An Introduction to the Mekong Fisheries of Thailand.* Mekong Development Series No. 5. Vientiane, Lao PDR: Mekong River Commission. 54 p.

Petr, T. 1989. The use of cyprinids in fisheries management of large inland water bodies of the Indo-Pacific *In:* Petr T. (ed.) Papers contributed to the workshop on the use of cyprinids in fisheries management of large inland water bodies of the Indo-Pacific. FAO Fishery Report No. 405 (Suppl.) pp. 1-5.

Pollution Control Department. 2007. *Report to the cabinet on the case of massive fish mortality in Chao Phraya River.* Pollution Control Department, Bangkok. 18 pp. *(In Thai)*

Pimolbutra, U. 1994. *Socio-economic situation of the rural inhabitants after Payao swamp Rehabilitation.* Abstract of the research articles in 1994. National Inland Fisheries Institute, Department of Fisheries, Bangkok. p. 58. *(In Thai)*

Polprasit, S. & Tevaratmaneekul, P. 1997. Biology and culture of the Mekong giant catfish *Pangasianodon gigas* (Chevey, 1930). Thai Fisheries. Gazette 50: 441-457. *(In Thai)*

Pongtana, N. & Autlerd, T. 2005. Genetic improvement of silver barb *Barbonymus gonionotus.* Thai Fisheries Gazette 58: 545-549. *(In Thai)*

Renunual, A. & Silapachai, W. 2005. *Evaluation on the stocking program of the giant freshwater prawn (Macrobrachium rosenbergii de Man) in Bang Phra Reservoir, Chon Buri Province.* Chon Buri Inland Fisheries Research and Development Centre, Chon Buri. 37 pp. *(In Thai)*

Rithcharung, S. & Pongchawee, K. 1995. *Hydrobiological and fisheries survey in Boraped Swamp after rehabilitation.* Technical Paper No. 28/1995. National Inland Fisheries Institute, Department of Fisheries, Bangkok. 103 pp. *(In Thai)*

Rithcharung, S. & Srichareondham, B. 1998. *Evaluation on the stocking program of the giant freshwater prawn (**Macrobrachium rosenbergii** de Man) in Beung Borapet, Nakhonsawan Province.* Nakhonsawan Inland Fisheries Research and Development Centre, Nakhon Sawan. 40 p. *(In Thai)*

Saowakoon, S. 2009. *Fisheries management in the irrigated man-made lakes in Thailand: case studies in Huay Saneng and Ampuen reservoirs, Surin Province.* Ph.D. thesis, Ubon Ratchathani University, Ubon Ratchathani. 297 pp.

Senanan, W., Kapuscinski, A.R., Na-Nakorn, U. & Miller, L. 2004. Genetic impacts of hybrid catfish farming (*Clarias macrocephalus x C. gariepinus*) on native catfish populations in central Thailand. Aquaculture 235: 167-184.

Sihapitukgiat, P., Junsawang, B., Srichareontham, B., Ingthamchit, S., Chittapalapong, T., Su-a-run, K., Ratanachumnong, D., Kakkaew, M., Boonchuwong, P., Sidthimunka, C. & Noradee, P. 2002. *Limnological, fisheries and socio-economical characteristics of Ubolratana Reservior, Khon Kaen, Thailand.* National Inland Fisheries Institute, Department of Fisheries, Bangkok. 66 p. *(In Thai)*

Sinchaipanich, C. & Sookthis, S. 2001 April 13, 2000: once again for the national fisheries day. Thai Fisheries Gazette 54(3): 221-226. *(In Thai)*

Siripun, N. 1988. Study on suitable size of seed fish for stocking in Huay Luang Reservoir. Annual Report: Udon Thani Freshwater Fishery Development Centre, Department of Fisheries, Udon Thani. pp. 165-192. *(In Thai)*

Srichareondham, B. & Ko-anantakul, K. 1993. *Fish catch and fisheries survey during the rehabilitation program of Nong Harn Swamp, Sakhon Nakhon Province, 1992.* National Inland Fisheries Institute, Bangkok. 32 pp. *(In Thai)*

Srinoparatwatana, C. 2009. *Population biology of two key fish species and the dynamics and management of the trap fishery in Beung Borapet, Thailand.* Ph.D. thesis, Edith Cowan University, Western Australia. 144 p.

Sripatrprasite, P. & Lin, C.K. 2003a. Stocking and recapture of freshwater prawn (*Macrobrachium rosenbergii* De Man) in a run of-river type dam (Pak Mun Dam) in Thailand. Asian Fisheries Science 16: 167-174.

Sripatrprasite, P. & Lin, C.K. 2003b. Effect of a fish ladder on migratory fish species at the Pak Mun Dam in Thailand. Thai Fisheries Gazette 56(4): 329-336.

Sriphairoja, K., Kamonrat, W. & Na-Nakorn, U. 2007. Genetic aspect in broodstock management of the critically endangered Mekong giant catfish, *Pangasianodon gigas* in Thailand. Aquaculture 264: 36-46.

Suraswadi, P. 1987. The role of aquaculture in the improvement of living standards of fishing community in Thailand *In:* Fishermen and fishing communities in the Asia-Pacific Region. RAPA Publication 1987/4. RAPA, FAO, Bangkok.

Terdvongvorakul, Y. 2002. *Assessment of the Accelerated Aquaculture Development Program in the Northeast of Thailand from 1998-1999.* Technical Paper No. 4/2002, Fisheries Engineering Division, Department of Fisheries, Bangkok. 85 pp. (*(In Thai)*

Terdvongvorakul, Y. & Nuansang, A. 2004. *Relationship between fish production and physical factors and management technique factor for small water bodies in the northeast of Thailand.* Technical Paper No. 10/2004. Inland Fisheries Research and Development Bureau, Department of Fisheries, Bangkok. 42 pp. *(In Thai)*

Thapanand, T., Moreau, J., Jutagate, T., Wongrat, P., Lekchonlayuta, T., Meksumpun, C., Janekitkarn, S., Rodloi, A., Dulyapruk, V. & Wongrat, L. 2007. Towards possible fishery management strategies in a newly impounded man-made lake in Thailand. Ecological Modelling 204: 143-155.

Thapanand, T., Jutagate, T., Wongrat, P., Lekchonlayuta, T., Meksumpun, C., Janekitkarn, S., Rodloi, A., Moreau, J. & Wongrat, L. 2009. Trophic relationships and ecosystem characteristics in a newly impounded man-made lake in Thailand. Fisheries Management and Ecology 16: 77-87.

Vidthayanon, C., Karnasuta, J. & Nabhitabhata, J. 1997. Diversity of freshwater fishes in Thailand. Office of Environmental Policy and Planning, Bangkok. 102 pp.

Villanueva, M.C., Moreau, J., Amarasinghe, U.S. & Schiemer, F. 2008. Foodweb and the trophic structure of two Asian reservoirs using Ecopath with Ecosim and Ecospace: a comparative study *In:* Schiemer F., Simon D., Amarasinghe U.S. and. Moreau J., (eds.) Aquatic ecosystems and development: comparative Asian perspectives. Backhuys Publishers, Leiden. pp. 413-434.

Virapat, C. 1993. *Bionomics of fish stocking in two Thai reservoirs; biological, management and development perspectives.* Ph.D. Thesis, Dalhousie University, Nova Scotia. 428 pp.

Virapat, C. & Mattson, N.S. 2001. Inventory of reservoir fishery resources in Thailand *In:* De Silva S.S. (ed.) Reservoir and Culture-based Fisheries: Biology and Management. ACIAR Proceeding No. 98. Australian Centre for International Agricultural Research, Canberra. pp. 43-47.

Virapat, C., Phimonbutra, U. & Chantarawaratid, C. 2000. *Fishery and fisheries management in Thai reservoirs: review and assessment.* Mekong River Commission, Vientiane. 42 pp.

Vongkamolchoon, C. 2006. *Inland fishery resources management in the Pasak Jolasid Reservoir.* Department of Fisheries, Bangkok. 72 pp. *(In Thai)*

Welcomme, R. & Bartley D.M. 1998. An evaluation of present techniques for the enhancement of fisheries *In:* Petr, T. (ed.) Inland fisheries enhancement FAO Fisheries Technical Paper No. 374. FAO, Rome. pp. 1-36.

Welcomme, R.L. & Vidthayanon, C. 2000. *The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control.* Mekong River Commission. Vientiane, Lao PDR. 35 pp.

INLAND FISHERIES RESOURCE ENHANCEMENT AND CONSERVATION IN VIETNAM

Bui The Anh[1] and Phan Dinh Phuc[2]

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

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

1.1 History of inland fisheries resource enhancement and conservation in Vietnam

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

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

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

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

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

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

---

[1] Aquatic Resources and Inland Fisheries Department, Research Institute for Aquaculture No. 1, Bac Ninh, Vietnam; E-mail: atbu@ria1.org

[2] Central Plateau Broodstock Center, Research Institute for Aquaculture No. 3, Daklak, Vietnam; E-mail: phucdinhphan@gmail.com

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

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

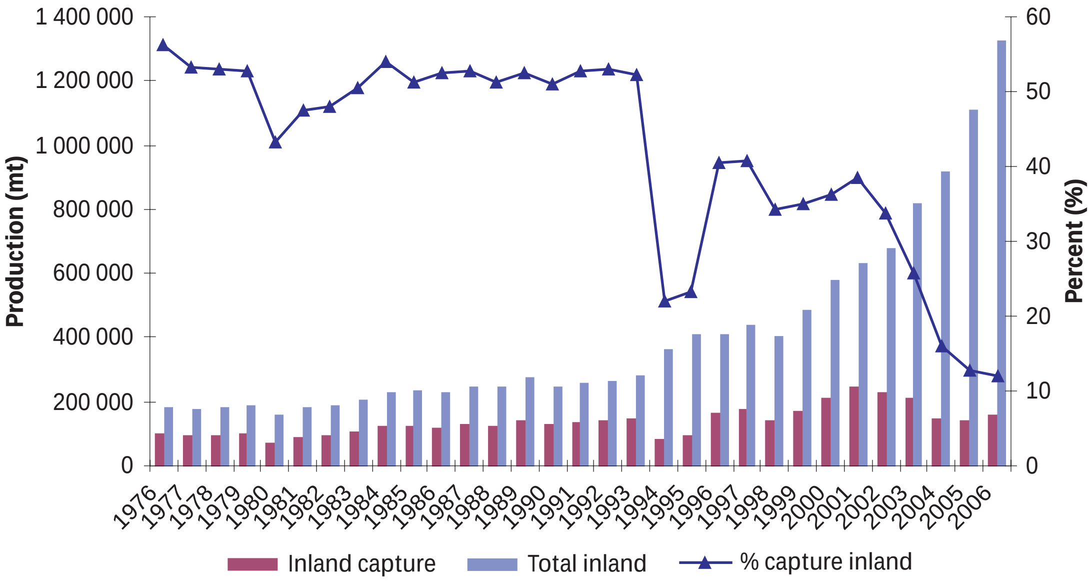


Figure 1. Contribution of the inland capture to the total inland fish production of Vietnam (FAO, 2007).

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

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

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

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

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

1.2 Major practices of fisheries resource enhancement and conservation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Note: NA – not available

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

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

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

2. CURRENT PRACTICES OF INLAND FISHERIES ENHANCEMENT AND CONSERVATION

2.1 Inland fisheries resources enhancement

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

- Reservoir fisheries enhancement, and
- Culture-based fisheries

2.2 Reservoir fisheries enhancement

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

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

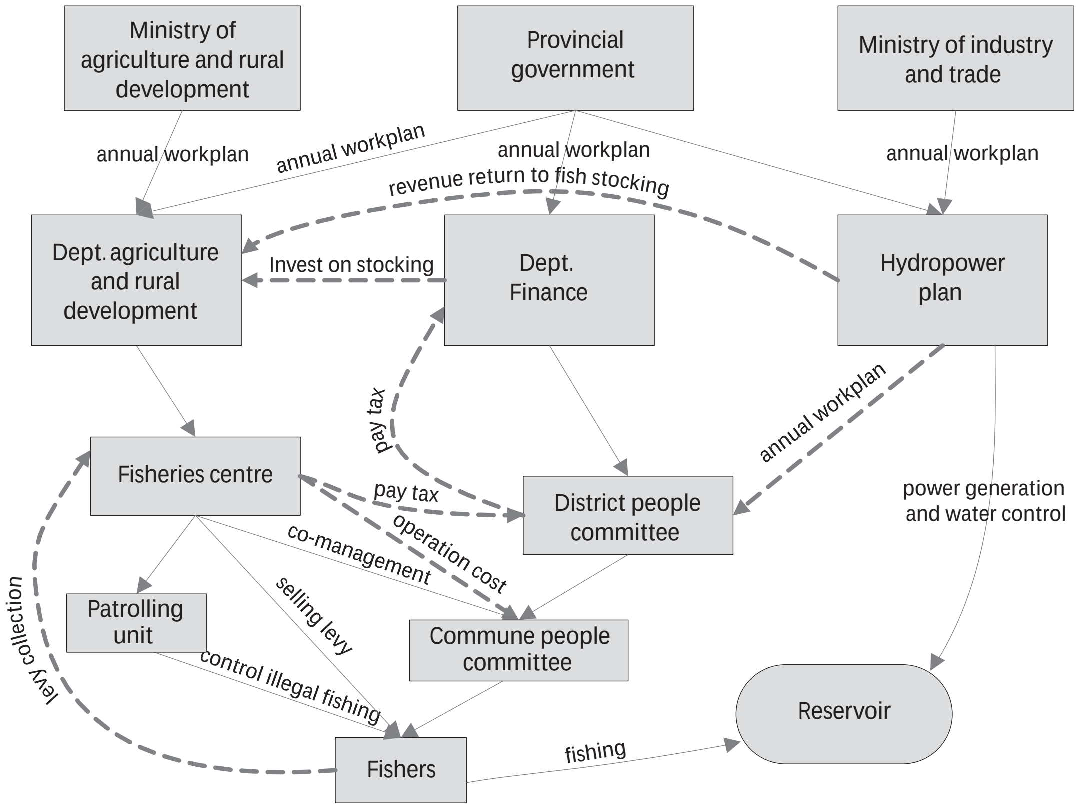


Figure 2. Schematic representation of government arrangements managing fisheries and enhancement in large and medium-sized reservoirs in Vietnam

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

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

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

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

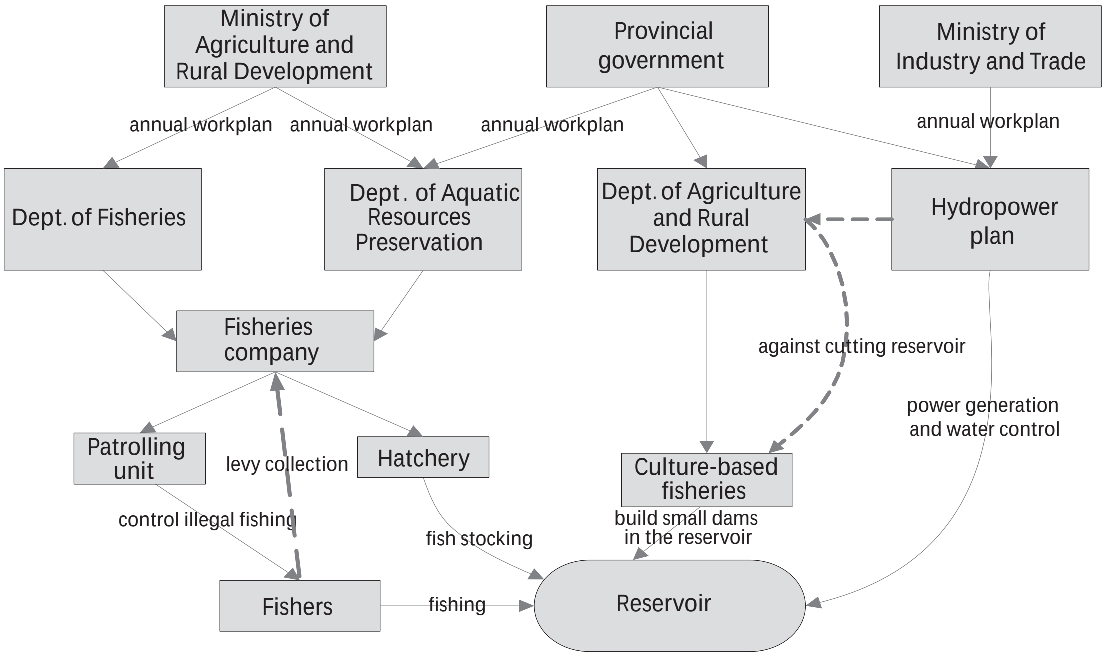


Figure 3. Schematic representation of fisheries management and enhancement of local enterprise in Vietnam

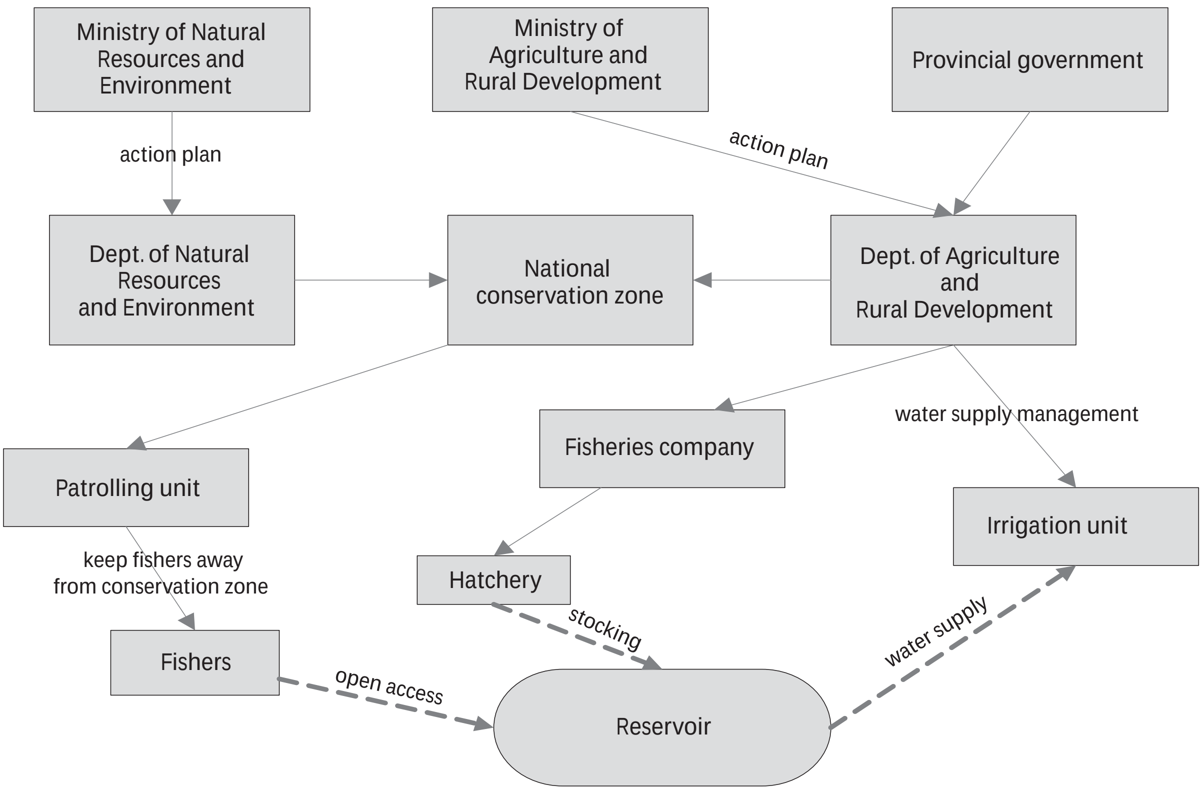


Figure 4. Schematic representation of open access reservoir fisheries in Vietnam

In this form of management, there are several organizations that share the waters but fisheries never have the highest priority over the control of the resource. There are conflicts between the official organizations on fishery resources management. As consequence, an open access policy to the water is still maintained.

2.3 Culture-based fisheries

In the last decade, culture-based fisheries had been done in some small-sized reservoirs which had been built for enhancement purposes as well as supplying seed to neighboring farmers (Nguyen, 2006). However, based on the 10-year development plan to obtain a production level of about 50 000 tonnes from reservoir fisheries, most of small irrigation reservoirs in Vietnam now are leased to farmers, farmer group or local organizations to conduct culture-based fisheries activities (Nguyen, 2006). These people run business together including stocking, harvesting and marketing.

In this type of fisheries, stocking normally starts from April to June when the water level is high. According to Nguyen (2006), stocked fishes depends mainly on availability in the regions and proximity to the supplies, and generally include common species such as grass carp, silver carp, bighead carp, mrigal and silver barb. In these reservoirs, people prefer using silver carp and silver barb more than other species with 40-50 percent of stocking composition. Sometimes, farmers stock high value species such as snakehead, *Hemibagrus guttatus*, etc. Fish is harvested during March to May because the water is used for paddy culture during this period. Nguyen *et al.* (2001; 2005) have shown that stocked species contribute more than 80 percent of total weight at harvest.

It was observed that high variations between reservoirs related to the size of each reservoir and generally, yields were lower in the larger reservoirs (Nguyen *et al.,* 2001). Nguyen (2006) found that most small irrigation reservoirs are seen as appropriate for developing culture-based fisheries in Vietnam. Therefore, culture-based fisheries could provide a means for producing cheap source of animal protein to meet the increasing demand for food in rural areas of Vietnam.

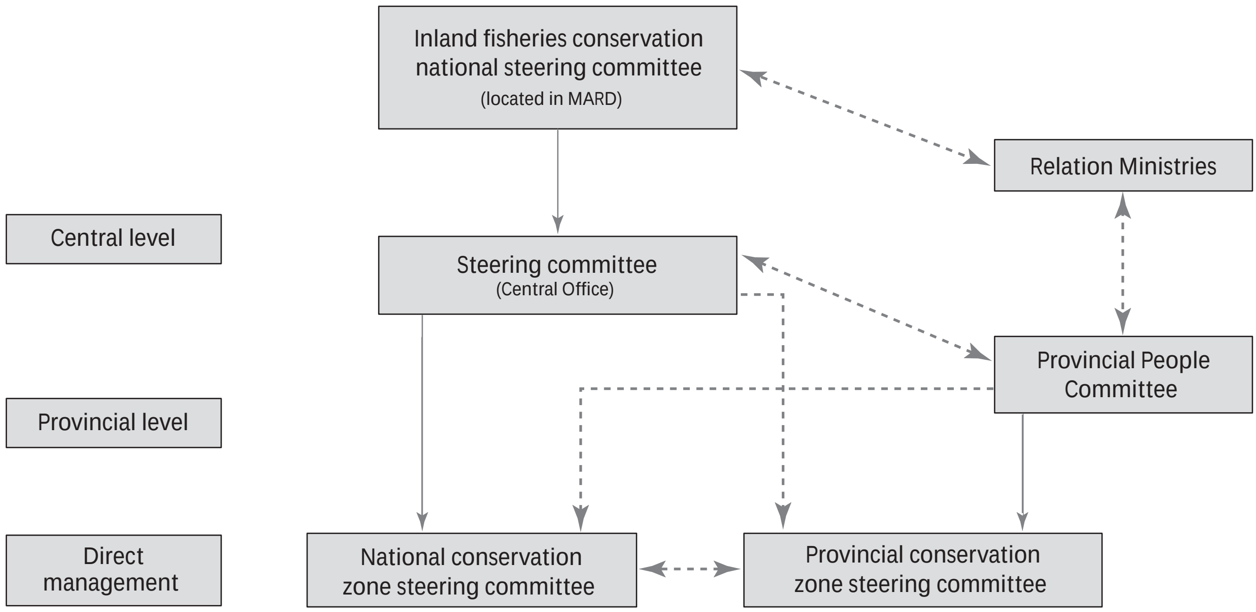
2.4 Inland fisheries resource conservation

According to the assessment of MONRE (2003), Vietnam has a dense river network, with several types of inland water bodies such as running water bodies (river, stream, estuarine and channel) and close water bodies (lake, reservoir, pond, swamp, paddy filed, etc.). Inland water body resources of Vietnam are very diverse with high biodiversity of flora, fishes, invertebrate, etc. Furthermore, Vietnam morphology is related with other countries which make up the biodiversity of the fauna in the country.

A new policy on resources conservation has been issued to different ministries such as the Ministry of Natural Resources and Environment (MONRE) is now responsible for Ramsar areas and the Ministry of Agriculture and Rural Development (MARD) is responsible for Inland Fisheries Resources Conservation zones. There are still some conflicts between these two ministries because of overlapping areas/zones. However, MARD manages all activities related to aquatic resources and coordinate other related activities with other organizations.

Figure 5 shows the schematic on management framework of the inland conservation areas in Vietnam. There are two management levels, the national and the local management level. The criteria to select and determine conservation zone is the same between these two levels. Except specific zones, the local government controls all the conservation zones located in their administration area. MARD only take the administrative works on the large conservation area at the national, inter-province and inter-country levels.

The National Steering Committee on Marine and Inland Conservation areas belongs to MARD. It is responsible in coordinating, , formulating government policies, decide and approve the annual work plan. MARD heads this committee which consists of representatives from the Ministry of Public Security, the Ministry of Education and Training, the Ministry of Planning an Investment, the Ministry of Science and Technology, the Ministry of National Defense, MONRE, the Ministry of Finance, the Ministry of Trade, Ministry of Culture and Information, the Hanoi National University, the Hochiminh National University, the Department of Tourism, the Vietnam Institute of Science and Technology and the Coordinating Office (Department of Department of Capture Fisheries and Resources Protection-MARD). The mission of Coordinating Office is to coordinate the activities, monitor and assess the effects, support and monitor the financial activities and propagate and collate the constructive ideas.



Note: dashed line: subordinated relation; stroke line: guidance relation

Figure 5. Management frame work of the inland conservation zones in Vietnam

The Provincial People Committee (PPC) receives advice from the Department of Agriculture and Rural Development (DARD) who directly manage the conservation area in the province. Under DARD, there is a management unit to control all activities in the areas.

There are also international donors and NGOs involved in the research activities in conservation areas of Vietnam. These organizations provide funding and technical supports and build projects.

Although inland fisheries conservation recently has received more attention from the central government of Vietnam, but the impact assessment on natural population has not been fully realized and implemented carefully in Vietnam.

Many inland water bodies are still facing issues of illegal importation and release of alien species. The example of *Prochidolus lineatus* species is a very clear example. Without tracking the right origin of the introduced species, the mangers or farmers could make it to be a bigger issue when the species dominate the area. It may affect the indigenous species and other fisheries in the area. Such of illegal transplantation should be controlled seriously and strictly in order to preserve the biodiversity of the inland water bodies in Vietnam.

The unsustainability of icefish fisheries development in Thac Ba reservoir could affect other fisheries in the reservoir and the local socio-economic conditions. The wide application of lift-net to catch icefish in the reservoir could also catch a lot of small fish, which are at the larvae or fingerling size, to directly affect other fisheries. In addition, the impact on ecosystem of this species should be assessed to determine its effects to other species. For example, this species eats zooplankton (*Cladoceroms, Leptodora, Calanoid copepods* và *Cladoceromd*) so it could compete the food with other species in the reservoir.

In the last 10 years, the Government of Vietnam has tried to conduct studies on indigenous species. They have funded for many research programs to preserve the native stock species and multiply these species in their national hatcheries and research centers. Presently, Vietnam has successfully reproduced some indigenous species and currently, they have a plan to re-stock them in the wild and some medium-sized reservoirs such as Nui Coc or Na Hang reservoirs to conserve its stock in wild.

Moreover, the central government has established many conservation zones to maintain and increase the population of these species in the wild. Besides, these areas could be the best way to conserve the biodiversity of the inland water bodies.

It is a very clear that inland fisheries bring more opportunities to the fishers and people living around in the area of such water bodies. Bui (2006) demonstrated that a number of fishers increased rapidly when the private sector is allowed to join together with the state fisheries. Figure 6 shows the trend of the private sector in Thac Ba reservoir fisheries. However, present fish production data is just recorded by the state so it could not described exactly of the private sector contribution.

According to Bui (2006), currently the fish production of this reservoir could get up to over 700 tonne a year and it only comes from private sector contribution, which are now about more than 2000 fishers. Also, in the recent study Bui *et al.* (2008) pointed out that the main income of fishers are from reservoir fisheries. This demonstrates that reservoir fisheries are the secondary priority but they bring a lot of opportunities to the local people. It also provides foods and low-cost feed ingredient to the local livestock and cage culture/aquaculture activities (Bui *et al.*, 2008).

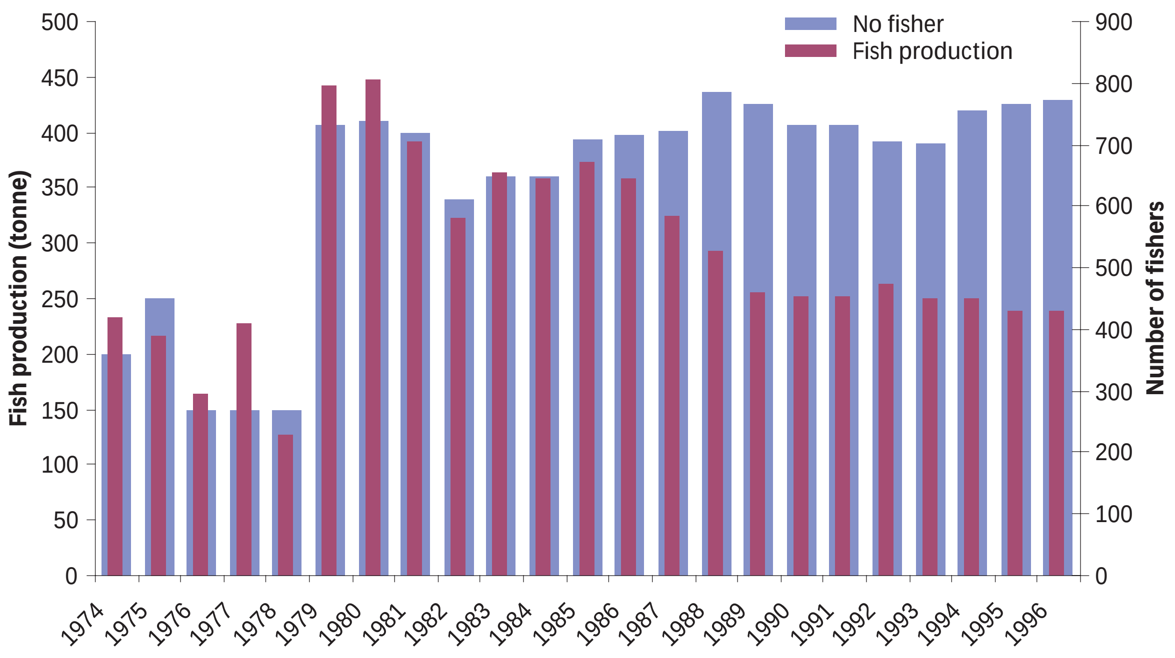


Figure 6. Relationship between number of fishers and fish production in Thac Ba reservoir (Bui, 2006; Bui *et al.*, 2008).

3. CONSTRAINTS AND PROBLEMS

Although the Vietnamese government had issued many decisions, plans and policies to improve the inland fisheries resources enhancement and conservation in recent years, it has not still achieved many good results. This could be due to the overlapping in management responsibilities, lack of adequate information and the merging of the management organizations (Ministry of Fisheries merged into MARD). Consequently, the information is still scattered and not continuous.

Besides, there has been no good species introduced or released into reservoirs/lakes/rivers in the last two decades, except the traditional species. This fact can not change the figure to increase fish production in the water bodies.

Artificial propagation techniques on several fish species are very popular and easy for farmer to learn and this helps in the aquaculture sector but also competes with the state supply system. State hatcheries located around the reservoirs are finding it difficult to develop and maintain their role in the region. These hatcheries have been impacted by the strong development of the private sector.

There are some successful programs with some indigenous species, which have been done with high values species. But, the technology is still in small-scale and need to be transferred all over the country.

As the above discussions, there is an overlap in the fisheries management systems of Vietnam. The conflicts between two or several organizations managing the reservoirs/rivers still exist and there is still no good solution to this problem. It is also the same with the management in several conservation areas. The overlapping role or work between the two organizations will cause the collapse of the system. It causes the directions go in the wrong ways and wastes government investment.

Moreover, the conflicts between the water users such as fisher and fisheries agencies in sharing and utilizing resources are also a constraint. Some conservation areas ban people harvesting fish in their area, even it is allowed (that is the forestry conservation zone) because the manger brings them in a group of thefts. The poor coordination between the management organizations also brings a lot of troubles to fishers when they need to contact these units. There is no proper legal document from these organizations to instruct local people what to do.

Although there are quite a lot program to assess about the impacts of environment and biodiversity, the information is still lacking to provide for decision maker and other relevant organizations to build the policies and programs on resources conservation in Vietnam.

4. RECOMMENDATIONS

Due to some constraints and problems above, there are some recommendations needed to be considered:

- Government need to improve the framework of management organizations in order to reduce the overlapping jurisdiction and/or responsibilities in the future implementation;
- More studies should be carried out on selecting good species to replace the common fishes currently stocked to increase the fish production and its value; (give some more valuable impacts)
- There should be certain control on introduction new species to Vietnam.
- The environmental and biodiversity impact assessment activities should be concentrated to keep the balance for the inland resources of Vietnam.
- There is need to carry out studies on estimating the quantity of the available water bodies/reservoir which could be utilized for fisheries development and build up the development program in the future based on such studies.

REFERENCES

Bayley, P.B. 1973. Studies on migratory characin, *Prochidolus platensis* Holmberg 1889 (Pisces, characoidei), in the River Pilcomayco, South America. *Journal of Fish Biology* **5:** pp. 25-40.

Bui, T.A. 2006. *Fish and Fisheries in Large and Medium-sized reservoir in Vietnam* Thesis submitted for the degree of Doctor of Philosophy (Aquatic Science). Deakin University, Warrnambool, Victoria, Australia.

Bui, T.A., H.S. Nguyen, Q.T. Nguyen & H.N. Vu. 2009. *Impact assessment on three introduced species: icefish, golden mahseer and Prochidolus lineatus* RIA1, Bac Ninh. p. 115 *(in Vietnamese).*

Bui, T.A., Q.D. Nguyen, D.P. Phan & V.T. Nguyen. 2008. *The final report on solutions finding for reservoir fisheries development in Thac Ba, Hoa Binh and other representative reservoirs in the south and central plateau of Vietnam* Research Institute for Aquaculture No. 1, Bac Ninh. p. 84.

Capeleti, A.R. & I.M. Petrere. 2006. Migration of the Curimbatá *Prochilodus lineatus* (Valenciennes, 1836) (Pisces, Prochilodontidae) at the waterfall "Cachoeira De Emas" of the Mogi-Guacu River – Sao Paulo, Brazil. *Brazilian Journal of Biology* **66:** pp. 651-659

Department of Science and Technology-MOFI. 2001. Report on fisheries resources and gene sources conservation in the period 1996-2000 and recommend mission for period 2001-2005. In: *Summarizing the gene source of animal, flora and microorganism conservation activities in period 1996-2000 and orientation for mission in the period 2001-2005*, Ministry of Science and Technology (ed.) pp. 33-43. Ministry of Science and Technology *(in Vietnamese).*

Dinh, T.T. 1995. Status of reservoir fisheries, orientations and development strategies for the future. In: *The Second of National Workshop on Reservoir Fisheries,* V.V. Tran (ed.) pp. 2-10. Ministry of Fisheries, Hanoi, Vietnam *(in Vietnamese).*

FAO. 2007. FISHSTAT plus. Food and Agricluture Organization of United Nations, Rome, Italy.

IFEP. 1997. *Master plan project for fisheries development to the year 2010: Operational policies and strategies to realize fisheries development objectives* DANIDA/Ministry of Fisheries, Hanoi, Vietnam.

Lem, A. 2002. Chapter 5 – Economic Modeling and Fish Consumption. *FAO Fisheries Circular.*

MARD. 2009. *Planning on inland aquatic resources conservation system to 2020*. MARD. p. 95 *(in Vietnamese)*.

MOFI and The World Bank. 2005. *Vietnam Fisheries and Aquaculture Sector Study.* Hanoi, Vietnam. p. 49

MONRE. 2003. *Vietnam Environment Monitor-Water.*

Ngo, V.S. & L.T. Le. 2001. Status of reservoir fisheries in Vietnam. In: *Reservoir and Culture-Based fisheries: Biology and Management,* S.S. De Silva (ed.), **Vol. 98**, pp. 29-35. ACIAR, Canberra, Australia.

Ngo, V.S. & T.A. Pham. 2005. *Status and solutions for development of natural fish resources in some provinces in Northern Vietnam* Paper presented in National Workshop on Environmental Aquatic Resources Conservation Research Institute for Marine Science, HaiPhong, Vietnam *(in Vietnamese)*.

Nguyen, C.D. 1994. *General reservoir fisheries development plans for 1995-2010 period.* p. 103 Institute of Economy and Planning for Fisheries, Hanoi, Vietnam, *(in Vietnamese)*.

Nguyen, H.S. 2006. Culture-based fisheries development in Vietnam: a case study. In: *Better-practice approaches for culture-based fisheries development in Asia.* S.S. De Silva, U.S. Amarasinghe and T.T.T. Nguyen (eds.). **ACIAR monograph 120**, pp. 73-82. ACIAR, Canberra, Australia.

Nguyen, H.S., T.A. Bui, T.L. Le, T.T.T. Nguyen & S.S. De Silva. 2001. The cuture-based fisheries in small, farmer-managed reservoirs in two provinces of northern Vietnam: an evaluation based on three production cycles. *Aquaculture Research* **32:** pp. 975-990.

Nguyen, H.S., T.A. Bui, Q.D. Nguyen, Q.D. Truong, T.L. Le, N.W. Abery & S.S. De Silva. 2005. Culture-based fisheries in small reservoirs in northern Vietnam: effect of stocking density and species combinations. *Aquaculture Research* **36:** pp. 1037-1048.

Nguyen, H.V. & V.S. Ngo. 2001. *The freshwater fishes of Vietnam. Part I: Cyprinidae* p. 622 Ministry of Fisheries, Hanoi *(in Vietnamese)*.

Nguyen, L.V. 2000. *Preliminary results of Thac Ba reservoir fisheries co-management in Yen Bai province.* Paper presented in The Third National Workshop on Reservoir Fisheries in Vietnam. Research Institute for Aquaculture No. 1, Bac Ninh, Vietnam *(in Vietnamese)*.

Nguyen, Q.A. 2001. Effectiveness of stocking in reservoirs in Vietnam. In: *Reservoir and Culture-Based Fisheries: Biology and Management,* S.S. De Silva (ed.), **Vol. 98**, pp. 235-245. ACIAR, Canberra, Australia.

Nguyen, Q.A. & L.X. Nguyen. 2000. C*ontribution of reservoir fishery development to the improvement of the aquaculture development program in Vietnam*. Paper presented in The Third National Workshop on Reservoir Fisheries Development in Vietnam. Research Institute for Aquaculture No. 1, Bacninh, Vietnam *(in Vietnamese)*.

Nguyen, T.T., K. Ha, D.C. Bui & M.T. Tran, Eds. 1996. *Vietnam Aquatic Resources.* Agricultural Publisher, Hanoi. *(in Vietnamese).*

Petrere, I.M. 1989. River fisheries in Brazil: A review. *Regulated Rivers: Research & Management* **4:** pp. 1-16.

Phan, D.P. 2006. *The Fishery, Biology and Management of Three Inland Water Bodies, Vietnam.* Thesis submitted for the degree of Doctor of Philosophy. Deakin University, Australia. p. 199.

Phan, P.D. & S.S. De Silva. 2000. The fishery of the Ea Kao reservoir, southern Vietnam: a fishery based on a combination of stock and recapture, and self-recruiting populations. *Fisheries Management and Ecology* **7:** pp. 251-264.

ENHANCEMENT AND CONSERVATION OF INLAND FISHERY RESOURCES IN ASIA[1]

Sena S De Silva
Network of Aquaculture Centres in Asia-Pacific,
Bangkok, Thailand

1. INTRODUCTION

In contrast to stagnant marine capture fisheries in the past two decades or more, it is now widely acknowledged that in capture fisheries the greatest potential for growth lies in the inland sector (FAO, 2008), and realisation of this potential would also impact on rural livelihoods and nutrition of rural masses in developing countries in particular. Admittedly, the inland fishery sector, until now has not attracted the attention it should have, in many fronts, such as in gearing government policies, research and development efforts, technologies and marketing among others.

Inland fisheries in developing countries are for food fish production, as opposed to those in developed countries which are primarily for recreational purposes (Welcomme, 1997; Welcomme and Bartley, 1998). As such the development strategies that will drive these two types of fisheries are different, with some commonalities, however.

FAO (1997) defines fisheries enhancements as technical interventions in existing aquatic resource systems, which can substantially alter the environment, institutional and economic attributes of the system. This is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. In addition to the above is the enhancement of fish populations through stocking, either using hatchery produced seed or wild collected seed (e.g. freshwater eels), for varying purposes. Accordingly, such interventions, direct and indirect management enhancements (e.g. introduction of closed seasons, habitat improvements etc.) may result in enhanced fish production through capture fisheries, culture based fisheries, etc. Enhancements may also lead to biodiversity conservation through the establishment of "conservation units", sanctuaries and other managerial measures referred to earlier.

Inland fisheries resource enhancement and conservation have been practiced in the region by many countries for various purposes for decades. However, the practices, management and effectiveness vary greatly country from country due to constraints in knowledge, resources and institutional setup. Fisheries resource enhancement and conservation not only contribute to supply of fish products and generate livelihood for the population mass in the inland areas, but also have significant impacts on aquatic biodiversity and ecological functions of inland water bodies. However, aspects on stock inland fishery enhancements in the region have received limited attention previously (Petr, 1998; De Silva and Funge-Smith, 2005). The current synthesis is based on a FAO regional review study on fisheries stock enhancement and biodiversity conservation covering ten Asian nations (Bangladesh, China, India, Indonesia, Myanmar, Nepal, Republic of Korea, Sri Lanka, Thailand and Vietnam) which formed the basis for the FAO regional consultation conducted over a four day period in February 2010. This consultation had the following objectives:

- Exchange and share successful experiences and lessons on inland fisheries enhancement and conservation practices across the countries participating in the review study,
- Assess the impacts of inland fisheries resource enhancement and conservation practices, identify the constraints and related problems from a regional perspective, and
- Recommend regional collaborative activities to promote improved practices of inland fisheries resource enhancement and conservation.

[1] This synthesis should be read in conjunction with the country reviews that are included in this volume. The country reviews are not specifically referred to in the text, however.

In addition, relevant, additional published information on the subject was utilised in the preparation of the synthesis. In order to place the material in a proper perspective the synthesis also deals with the current status of inland fisheries in the region and its contribution to the global inland food fish supplies, and including a brief summary of the current inland fishery practices.

2. INLAND WATER RESOURCES AND FINFISH BIODIVERSITY

The earth is estimated to have only 35 029 000 km^3 of freshwater, or only 2.5 percent of all water resources, of which only 23.5 percent is habitable (Shiklomanov, 1993, 1998; Smith, 1998). The amount of freshwater available as rivers, lakes, wetlands etc. amounts only to 0.01 percent of the earth's water resources or only 113 000 km^3. Generally, a fact that is often not appreciated is that, of the world water resources, less than 0.01 percent occurs as surface waters, and is the home to a very high level of biodiversity. The multitudes of such forms have created varying ranges of habitats that are the home to the great diversity of freshwater fauna, of which the vertebrate fauna in freshwaters accounts for nearly 25 percent of the global vertebrate diversity, but these also happen to be among the world's most threatened ecosystems (Groombridge, 1992). It has been suggested that global freshwater biodiversity is declining at far greater rates than is true for even the most affected terrestrial ecosystems (Riccardi and Rasmussen, 1999). It is in this context that future developments in the sector have to take into consideration aspects on biodiversity conservation.

Asia is known to be blessed with the highest amount of useable, surface freshwater resources of all continents, but the per capita availability of the resource is the least (Nguyen and De Silva, 2006). The freshwater resources occur in many forms, such as rivers, streams, marshes, lakes, flood plains and the like, and those from anthropogenic interventions such as reservoirs and pools. Freshwaters utilised for fishery enhancements are variable form country to country in the region (Table 1). It should also be noted that all the acreage is not necessarily utilised for fishery enhancements, which provides an indication of the scope of enhancements that is possible with a consequent increase in food fish production and provision of livelihoods.

Table 1. The varying types of freshwater resources utilised for fishery enhancements in ten countries

Country	Rivers	Flood-plains (ha)	Lakes (ha)	Reservoirs (ha)	
				large & medium	Small
Bangladesh	24 000 km^2	2 946 950*		58 300	
China	7 650 000 (ha)	NA	7 140 000	211 000	
India	29 000 (km)	354 213**	720 000	1 667 809	1 485 557
Indonesia	12 000 000 (ha)		1 800 000	50 000	
Myanmar	1 300 000 (ha)	8 100 000		115 687	
Nepal	395 000 (ha)		5 000	1 500	
Republic of Korea	2 800 km^2			110 800	
Sri Lanka	NA	4 049		109 450	39 271
Thailand	4 100 000 (ha)				400 000
Vietnam				340 000	

NA – data not available; * includes ox bow lakes, beels, haors and baors; ** includes flood-plain lakes and associated wetlands

The freshwater fish diversity of the Asian continent is high and diverse with an estimated cumulative total of 7 447 species, which accounts for approximately 25 percent of all known global finfish species (Nguyen and De Silva, 2006). It has also been pointed out that the Asian freshwater fish species diversity is higher when compared to other continents, but lower in familial diversity. In Asian freshwater fish fauna the dominant groups are cyprinids (Cyprinidae, about 1 000 species), loaches (about 400 species) of the families Balitoridae and Cobitiidae, gobids (Gobiidae, 300 species), catfishes (Bagridae, about 100 species), and the Osphronemidae (85 species).

With such a high faunal diversity, and an equally high degree of endemicity inland fishery enhancements need to revolve around practices that do not overly impact on this diversity. Most of the countries that have contributed to this synthesis have a diverse and a rich freshwater fish fauna, perhaps with the exception of Sri Lanka, a continental island which has only 62 species recorded but of which over 25 percent is endemic to the island. Similarly, in the Republic of Korea of 269 species and mollusks 61 species are endemic to the country. Bangladesh on the other hand, has a fish fauna of 267 species, belonging to 156 genera and 52 families, whilst 109 species are known from the River Ganga system in India, out of a total of 765 of the whole sub-continent.

Obviously, not all of the rich fish fauna is used for fishery enhancement purposes in any of the countries. Fish species selected for enhancement usually fall into tow major groups, species of great economic important (e.g. carp species) and species in danger or serious depletion of population, which are of great scientific value (e.g. Chinese sturgeon). For example, the Republic of Korea has recognized seven finfish species (Korean bullhead, *Psedobugrus fulvidrac*; far eastern catfish, *Silurus asotus*; Japanese eel, *Anguilla japonicus*; Crusian carp, *Carassius auratus*; mandarin fish, *Siniperca scherzeri*; sweet fish, *Plecoglossus altivelis*; common carp, *Cyprinus carpio*) for stock enhancement, together with one crustacean, one mollusk and one turtle species. In general, in the region, the main indigenous species utilized for stock enhancement purposes are the common carp, and the Chinese and Indian major carps, supplemented by other species, case by case. In most countries in the region in addition to indigenous species alien species are also used for enhancement purposes.

The selection of species for stock enhancement purposes varies from case to case. In most instances, especially in enhancement food fish purposes, the choice is based on the high growth rate, feeding habit, often omnivorous fish species being preferred, and consumer acceptability. The best examples of such species are the Chinese and Indian major carp species. In certain instances stock enhancement may be carried out to fill a vacant niche in a water body, such as for example the use of ice fish in China and Vietnam.

3. INLAND FISHERIES

3.1 An overall perspective

The contribution of inland fisheries to the global fish supplies can be considered as small, being around 10 to 12 percent of the total capture fisheries production. However and very importantly, the bulk of the inland fishery production occurs in Asia, the region contributing almost 70 percent to the global production (Figure 1), a trend that has existed over the last two decades or more, being ample evidence of its significance to the region as a whole. Also, it is evident that inland fisheries production has been rising, albeit slowly, the major impetus coming from the Asian region. China is a major contributor to the inland fisheries production in the region, approximating about 35 percent.

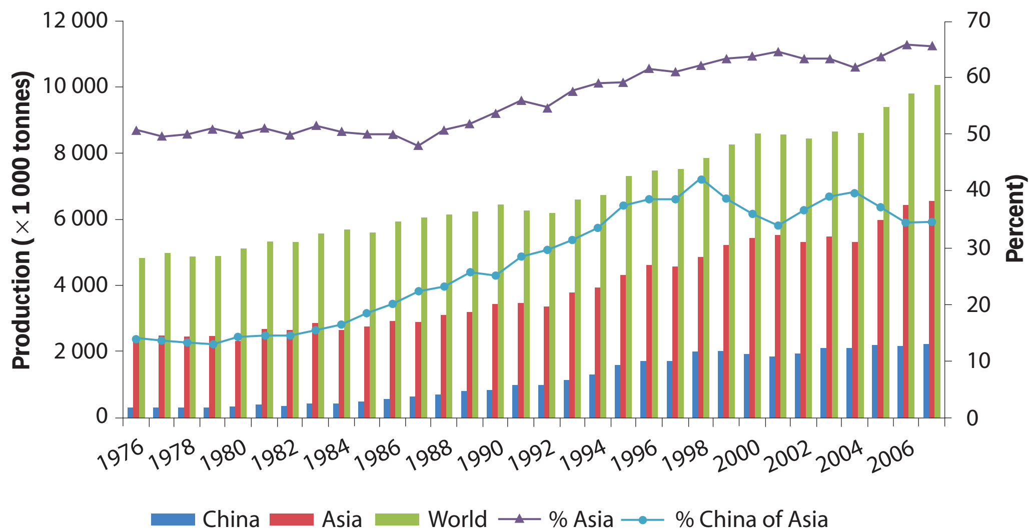


Figure 1. The trend in inland fish production in PR China, Asia and the world and the percent contribution of the former to the word production.

It is often said that overall the inland fish production and hence its contribution to global food fish supplies is underestimated, and it has been specifically demonstrated for example for the Lower Mekong Basin (LMB) fisheries (Coates, 2002). Coates (2002) estimated that the fishery of the LMB accounts for nearly 2.5 million tonnes per year, and pointed out the difficulties in obtaining reliable inland fish production statistics. Hortle (2007), with reference to the Lower Mekong Basin riparian countries demonstrated that the estimates of inland fish production of the FAO (equivalent to those reported by individual countries) are significantly lower, for some countries as low as three fold. Hortle (2007) emphasised the need for harmonization of basic statistical data collation and reporting. Similarly, fresh estimates based on consumption surveys in 2005 have indicated that the inland fish production from inland waters in Thailand to be 1 062 696 tonnes (Lymer *et al.*, 2008), almost a five fold higher estimate than that reported by the Royal Government of Thailand estimates.

In most developing countries, and particularly in Asia, inland fishery produce are almost totally used for human consumption, fresh and or processed into such products as sun-dried fish, fish paste, fish sauces etc. However, there are a few exceptions, such as in the case of Mekong Delta flood plain fishery where some amounts of the catch is used for converting into dried fish powder to be later used in the preparation of feeds for cultured stocks (De Silva, 2008), and or fed directly as raw fish to such stocks. It is also important to note that inland fisheries in Asia are rural and therefore benefits rural communities who generally tend to be poor.

3.2 Overview of Asian inland fishery practices

The importance, magnitude and the nature of inland fisheries in Asia are very wide ranging and diverse, much of which are based on traditional practices. In most countries in Asia the bulk of inland fisheries for food fish production occur in lacustrine waters, while the riverine fisheries, apart from that of the Lower Mekong Basin, (which supports a large fishery and millions of livelihoods), have declined over the years. The more recent developments in inland fisheries in Asia have occurred in the vastly increased acreage of reservoirs in the region (Nguyen and De Silva, 2006), impounded for irrigation, flood protection and hydroelectricity generation and or for multi-purposes with fisheries becoming an important secondary user of these impounded waters. In some nations such as in Myanmar and Bangladesh, countries with very large flood-plain waters, there are organized flood plain fisheries, referred to as leasable fisheries in Myanmar, based on naturally recruited and stocked species, augmented by stocking.

The individual fisheries vary in intensity (Table 2, FAO, 2010), modes of operation and production within and between countries. In most countries in Asia inland fisheries tend to be artisanal, where small motorized and or non-motorized crafts, manned by two persons, using either gill nets or traps are the main mode of operation. On the other hand, in large water bodies mechanised boats are used to operate purse seines, often only small numbers (e.g. Thailand) and using integrated nets as gear (e.g. China). In countries such as Indonesia, Myanmar and Sri Lanka use of motorized crafts in inland fishery activities is prohibited. Shore seines for example are permitted in India but not in Sri Lanka. It is also important to reiterate, as pointed out in Section 2, the potential gross underestimation of inland fish production in some countries, such as for example in most of the Lower Mekong Basin riparian countries (Hortle, 2007; Lymer *et al.*, 2009).

In most countries in Asia, the main species in inland fisheries tend to be indigenous species, at times translocated across their natural range of distribution within the country boundaries. For example, the inland fisheries in China are predominated by major Chinese carp species, such as silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), common carp (*Cyprinus carpio*) etc., whereas those in India and Bangladesh are predominated by Indian major carps, such as rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigal*), catla (*Catla catla*) etc. Similarly, in Thailand the inland fisheries are predominated by indigenous catfish and snakehead species, as well in some waters by the native pelagic freshwater clupeid, the river sprat, *Clupeichthys aesarnensis* (Jutagate *et al.*, 2003).

However, in Sri Lanka, an island state with a relatively depauperate native fish fauna, the backbone of the inland fishery, particularly those based on self-recruitment, in large reservoirs, is almost entirely predominated by exotic tilapias. In Vietnam the inland fisheries in the past was based primarily on alien species, regularly stocked, but in

Table 2. The inland capture fishery production (FAO, 2010) and the main sources of production

Country	Production (tonnes)	Observations
Bangladesh	1 060 181	Flood plains; rivers, reservoirs
China	2 248 347	Ponds, rivers, Lakes and reservoirs (including aquaculture)
India	953 106	Rivers, estuaries, lagoons and upland lakes (through capture fisheries); small reservoirs and closed wetlands (through culture based fisheries); medium and large reservoirs, and open wetlands (through enhanced capture fisheries)
Indonesia	323 150	Lakes, reservoirs, flood plains, rivers
Myanmar	814 740	Flood plain leasable fisheries, river fisheries
Nepal	21 500	Rivers, lakes, reservoirs
Republic of Korea	5 202	Rivers, lakes and reservoirs
Sri Lanka	44 500	Open water reservoir fisheries; culture based fisheries in small water bodies
Thailand*	231 100*	Riverine and reservoirs, culture-based fisheries
Vietnam	140 900	Riverine and open water reservoir fisheries; culture based fisheries in small water bodies

* note that Lymer *et al.* (2009) estimated at 1 062 696 tonnes

the last decade there had been a gradual shift to a predominance of indigenous species, small cyprinids species such as *Toxobramis houdemeri*, *Pseudohemiculter dispar*, *Coulter erythropterus*, *Cranoglanis* spp., etc.

In essence in the large lakes and reservoirs, fisheries are based on naturally recruiting stocks, occasionally of alien species. However, the major exception is China, where even large reservoirs and lakes (e.g., Danjiangkou and Qinghaihu, etc.) are stocked with seed of suitable species, primarily Chinese major carps, common carp, naked carp, etc. on a regular basis, and harvested using integrated nets.

4. STOCK ENHANCEMENT

4.1 Reasons for stock enhancement in the region

Fish stock enhancement in the region is carried out for varying purposes and reasons, and differs from country to country. The great bulk of stock enhancement is conducted for public good to increase food fish production and even for purposes of uplifting existing fisheries. Some stock enhancements are associated with conservation of fish stocks, revitalising endangered fish stocks/populations as well as for mitigating environmental degradation resulting from anthropogenic impacts.

Fish stock enhancement is also sometimes carried out to mitigate the negative environmental impacts of intensive aquaculture activities, such as with the regular occurrence of fish kills due to poor water quality, which in turn enables the maintenance of fish production and livelihoods and fisher communities who also happen to be poor and most wanting (Abery *et al.*, 2005).

Fish stock enhancement of small water bodies, often non perennial, for food fish production and provision of livelihoods, as conducted in India, Lao PDR, Sri Lanka, Thailand and Vietnam, borders on aquaculture, as often there is ownership of the enhanced stocks.

In addition to all of the above, is the practice, in countries such as Cambodia, Lao PDR, Myanmar and Thailand, of "fish releases", an indirect form of enhancement that is conducted for symbolic and cultural reasons, related to traditional yearly water festival celebrations (i.e. water-flushing "Songkran" festival as practiced in Cambodia, Lao PDR and Thailand). These activities have been ongoing for over five to six decades and are associated with extensive community involvement in the festivities.

4.2 Summary of current stock enhancement practices

Stock enhancement through seeding of water bodies has been in practice in many countries in the region for long periods of time, for varying purposes. For example, the stocking of artificially propagated Chao Phraya giant catfish seed (*Pangasius sanitwongsei*) into rivers in Thailand was conducted entirely for the purpose of conservation of this endangered species. A summary list of species used in stock enhancement purposes and those that are indirectly impacted upon by the various practices, for each country, is given in Annex I. It is evident from Annex I that a wide variety species are included in stock enhancement practices in the region, and in all probability this list of species is far from complete either.

For convenience and clarity the current stock enhancement practices in Asia are considered in the following sections in the context of the broad water types.

4.2.1 Stock enhancement in rivers

Stock enhancement of rivers is conducted in China, India, Malaysia, Myanmar, Republic of Korea and Thailand. Such activities are not necessarily associated with a view to increasing food fish production and or supporting livelihoods, but primarily towards conserving and or restoring the riverine stocks, and on occasions for purposes of environmental improvement. In general, stock enhancement of rivers is based on indigenous species, such as for example the Indian and Chinese major carps being used to enhance the respective riverine stocks in each of the countries, and or the use of mahseer (*Tor*) species in India and Malaysia. However, there is a dearth of information on the impacts, environmentally, production wise and economically, from such enhancement activities.

On the other hand, river stock enhancement is conducted as a compensatory measure (e.g. Thailand) when anthropogenic impacts such as discharge of pollutants result in mass mortalities of the riverine fish. In Bangladesh, fish aggregating devices, such as brush parks, created using bushy tree branches and twigs, locally known as *katha*, are used in secondary rivers and canals, as the fish are harvested as the water recedes after six to eight months of operation (Kibria and Ahmed, 2005). The effectiveness of use of brush parks as fish aggregating devices in the tropics was reviewed by Welcomme (2002), and its advantages as a fishery enhancement practice, benefiting poor communities were demonstrated.

4.2.2 Stock enhancement in flood-plains

Stock enhancement in flood-plains and associated waters as in the case of Bangladesh flood plain depressions (e.g. termed as baors and hoars), is conducted for food fish production both in Bangladesh and Myanmar. In Myanmar, the process is termed "leasable fisheries" where areas of the flood plain are leased out through auction to the highest bidders. This form of a fishery has been in existence for over five decades. The lessees often enhance the fish stocks in their leases with a view to increasing production, and accordingly the production has increased from 91 980 in 1998-1999 to 209 720 tonnes in 2008-2009. It is also important to point out that there had not been a significant change in the number of leasable fisheries in Myanmar, ranging from 3 280 to 3 450 since the 1990s, indicative of the regulatory aspects of permitting leasable fisheries.

In Bangladesh a similar process occurs in baors and haors of the flood plains. Baors (5 488 ha) are ox bow lakes whereas haors (2 832 790 ha) are flooded plains between two rivers and their tributaries, and are generally non-perennial in nature, retaining water for 4 to 6 months in the year, but highly productive, biologically. The fish populations of these waters are enhanced through stocking, primarily of indigenous Indian major carps, and the total yields from baors and haors in 2008 were reported to be 77 500 (679 kg/ha/yr) and 819 500 (290 kg/ha/yr) tonnes, respectively, perhaps far exceeding the natural fish productivity should there be no enhancement. Also in almost all instances of flood plain stock enhancements indigenous species are utilised, but there is some appearance of exotics, for example tilapia in the case of flood plain leasable fisheries in Mandalay, Myanmar.

Both of the above fisheries also have social implications, for instance, by limiting access and alienating the communities living in the vicinity of these waters from fishing and or obtaining fish for consumption. In

Bangladesh this social problem is being addressed through the implementation of co-management of the fishery resources of baors and haors where the community as a whole is able to benefit from accessing the fishery resources (Valbo-Jørgensen and Thompson, 2007).

4.2.3 Stock enhancement in static water bodies (lakes and reservoirs)

As mentioned previously Asia has the largest reservoir acreage in the world, and the great bulk of these reservoirs have been impounded in the second half of the last century. Fisheries are becoming very significant secondary users of water resources in all countries, except in Myanmar where fisheries development in reservoirs is banned. In general, in the region reservoir fisheries contribute significantly to inland food fish production and provision of livelihoods (see Table 2).

Fish stock enhancement activities in static water bodies differ from country to country, and between water bodies. In China for example, there is regular stock enhancement for large and medium-size reservoirs and lakes, often with Chinese major carps, and common and crucian carp and associated fisheries which are well managed and regulated. Some of these fisheries can be considered to be industrial scale. The other end of the scale is the fisheries of large perennial reservoirs in Sri Lanka where the fisheries are primarily based on exotic tilapias, with minimal stock enhancement conducted on a regular basis, the fisheries are almost entirely based on natural recruitment. On the other hand, in Thailand although large reservoirs are stocked with exotic species such as Chinese and Indian major carp species on a regular basis, (in accordance with a decree by the King of Thailand), but these species account for a small amount of the reservoir fish production, which is predominated by indigenous cyprinids, snakeheads and catfishes, and in some instances the riverine clupeid, *Clupeichthys aesarnensis* (Jutagate *et al.*, 2003). In all of the above instances, including in other countries in Asia, e.g. Bangladesh, India, Indonesia, Lao PDR, Vietnam fisher communities are established and operate these fisheries. However, there is a general lack of understanding of the direct returns from stock enhancements of large static waters. Perhaps the balance of evidence suggest that stocking of large reservoirs will have minimal impact on food fish production except in instances where the reservoir water management and fishery management work cooperatively, such as for example enabling complete harvesting, having devices to prevention the escape of stocked seed, stocking of larger sized seed, provisions for use of integrated nets/appropriate gear, etc., as in China.

Perhaps one of the most notable successes of a stock enhancement activity in a natural lake in Indonesia is that of Lake Toba, North Sumatera, Indonesia. Stock enhancement commenced in 2003, with bilih (*Mystacoleucus padangensis*) at which time the total fish production of the lake was only 53.7 tonnes and reached nearly 3 036 tonnes in 2008, with an average catch of 0.5 to 2.0 tonnes/day. Interestingly, in this case the above species was translocated from a naturally occurring population(s) of Singkarak Lake (West Sumatera), and in a manner is comparable to the icefish (*Neosalanx* spp.) translocation across China and indeed introduction of the latter to reservoirs in Vietnam.

In all of the above cases it is imperative that the success of stock enhancement will finally depend on effective fishery management, a fact that it not adequately appreciated.

Different to the above stock enhancement practices are those conducted in smaller, often non-perennial water reservoirs, such as in India (Sugunan, 1995; Sugunan and Sinha, 2001), Lao PDR (Saphakdy *et al.*, 2009), Sri Lanka (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009), Thailand (Lorenzen *et al.*, 1998) and Vietnam (Nguyen Son *et al.*, 2001) where the water bodies are stocked with suitable species and are harvested as the water recedes. The fisheries are communal based, co-managed, and border on aquaculture as the stock is owned by the community. The sustainability of such operations are ensured to a significant degree through the collection of levies for continued stocking for the following growth cycles, as exemplified in the case of the culture-based fishery operations in Sri Lanka.

4.3 Other enhancement practices

In addition to stock enhancement practices in operation in the region there are many fishery related enhancements that are in operation, in all of the above water types dealt with previously. The most important aspects of enhancement in the above regard are summarised as follows.

(a) *Provision of fish sanctuaries/protected/conservation areas:*

The above is practiced in natural water bodies in most countries, for example in the flood plains of Bangladesh. The establishment of sanctuaries is decided on technical advice of the authorities in cooperation with the community, and agreed sanctuary size could range from 1 to few hectares, the area designated being clearly demarcated by some form of fencing. The habitats in the demarcated areas are further enhanced by adding substrates etc. In the Republic of Korea there are 19 (15 lakes and 4 streams; total of 330 km^2) designated as protected areas, amounting to 6 percent of the country's inland waters. Similarly, 605 protected areas exist in India in the form of National Parks, Wildlife Sanctuaries and Conservation Reserves, covering approximately 4.74 percent of the total geographical area of the country.

In all of the above, fishing is strictly prohibited and such regulations are strictly enforced.

(b) *Provision/improvement to spawning habitats:*

In some countries in the region, e.g. China there is an ongoing program to provide and or improve spawning habitats, in particular for non-migratory species, such as common carp and crucian carp.

(c) *Habitat improvements:*

Habitat improvement is conducted in respect of many fisheries. Improvements are related to augmenting the nature of spawning grounds of specific species, particularly in larger water bodies. In flood plain fisheries introduction/modification of habitats to enhance refuges for naturally recruited young is often undertaken by the provision of structures such as brush piles. Brush piles are also utilised in culture based fisheries, as they have been shown (also see Section 5.2.1.) to enhance periphyton growth and are thought to provide an additional food sources for most omnivorous fish (Azim *et al*., 2005).

Other enhancements include weed removal and desiltation, which are commonly undertaken in Thailand for instance.

(d) *Introduction of closed seasons:*

Most countries have introduced closed seasons for stock enhancement purposes mostly in water bodies that have established fisheries. Such closed seasons are related to the knowledge on the reproductive seasonality of the predominant species of the respective fisheries, such as for example in inland waters in Thailand (dates: 16-05 to 15-09, country-wide), where the fisheries are mostly dependent on indigenous species. The above period coincides with the onset of rains when the predominant group of fishes, mainly cyprinids, tend to breed. However, even in this period, fishing for household consumption is permitted.

In the Republic of Korea the operation of closed seasons are even more regulated, with specific time periods being applied for each of the target species. For example, for salmon, *Oncorhynchus keta*, mandarin fish, *Siniperca schezeri* and sweet fish, *Plecoglossus altivelis* the closed seasons are 01-10 to 30-11, 20-05 to 30-06, and 01 to 31-05 and 01-09 to 31-10, respectively. Closed seasons, when operating, are generally strictly enforced by the authorities.

(e) *Gear restrictions:*

In most inland fishery operations gear restrictions apply, and are fairly strictly enforced. In Sri Lanka and Thailand for example, seine nets are prohibited in most large reservoir and lake fisheries, whilst it is permitted in India. In general, seine nets are used in harvesting in culture based fisheries. In China, in most medium and large-sized water bodies the main gear used is an combined fishing method using blocking net, driving net, gill net and set bag-net simultaneously in one fishing operation, which ensures the capture of a significant proportion of stocked fish of specific size range, in a few operations.

4.4 Key issues related to stock enhancement of inland waters

4.4.1 Size of seed for releasing and stocking

In the region, in general, the size of released/stocked seed in those practices on which fisheries are based take care to ensure that it is optimal for stocking. However, strict guidelines in this regard are not readily available in most countries. In China for example strict guidelines are adhered to on the size of seed for stocking, often around 15 cm in body length. On the other hand, those enhancements that are conducted for symbolic and cultural purposes often tend to use undersized seed stock, the returns from such practices for building up natural populations is likely to be insignificant.

4.4.2 Seed quality

In all instances there is very little attention paid to the quality of seed stock used, and their genetic compatibility with that of the natural stocks, an aspect that warrants attention. In general there is very limited or no evaluation of the hygiene of the seed stock and risk assessments. These are imperatives if improvements are to be brought to stock enhancement practices in the region, which would help minimise negative impacts.

The general notion is that stock enhancement of indigenous species may not be genetically harmful to the natural populations has been shown to be incorrect as shown by many studies in the northern hemisphere in respect of salmonoids in particular. Bearing in mind that seed required for stock enhancement purposes have to be from hatchery produced stocks, which are known to be of lower quality than its wild counterparts, the most pragmatic option would be to secure proper broodstock management plans and closely associate the enhancements to remain compatible with the genetic diversity of specific wild populations of the species. Needless to mention that introduction of such programs have a cost, require high technical skills, and therefore will need a rationalised approach in the selection of species and the extent of adherence to designed management plans. This aspect is dealt in further detail in Section 6.4.

4.4.3 Socio-economic aspects

There is no doubt that adoption of stock enhancement procedures that have led to establishment of fisheries have had a socio-economic impact by providing livelihood opportunities, and in all probability an improvement in the nutrition of rural populations by making available affordable food fish supplies. On the other hand, as pointed out in Section 3.2.2 lease of waters such as in Bangladesh and Myanmar would limit the access to these resources by the poor. It is encouraging to note that the above is being addressed to some degree in Bangladesh by reverting to a co-management of the resources, leading to a sharing of the benefits (Valbo-Jørgensen and Thompson, 2007).

The most detailed socio-economic gains of stock enhancement are evident in the case of culture based fishery activities in many countries; best exemplified by the example from India, Lao PDR (Garaway *et al.*, 2006; Saphakdy, 2009), Sri Lanka (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009) and Thailand (Garaway *et al.*, 2001).

Experience in Vietnam (Nguyen Son *et al.*, 2001) showed that leasing of waters, for culture based fisheries, on a short-term basis may not be most appropriate as the lessees are discouraged from bringing about improvements to physical attributes of the water body that could enhance fish production. Medium to long-term leases may encourage more responsible management, provided it is associated with regular monitoring by authorities.

The involvement of the private sector for management, including stock enhancement and associated aspects of water bodies for fisheries development as evident in the case of Vietnam, is a new initiative in the region as a whole. This initiative, which is to be extended to new major impoundments, is likely to have socio-economic impacts on the communities living in the vicinity, as well as fisher livelihoods prior to impounding, through marginalization of the latter. Close monitoring of this will be of use to the region as a whole in making suitable policy decisions in this regard.

4.4.4 Governance issues

Admittedly the governance issues are rather complex and vary widely between countries. One common denominator in this regard, however, is that almost all water bodies used for food fish production and conservation purposes come under the purview of many governmental agencies, often operating under different ministries. Overall, in the region, reservoir fisheries are a secondary activity and the water management of the impoundments come under the purview of different authorities, such as for example in Thailand under the Electricity Generating Authority of Thailand (EGAT), Irrigation Department in most cases in Sri Lanka, under the Forestry Department in Myanmar and so forth.

A better dialogue with the water management authorities and fishery authorities is likely to bring about improved impacts on fish production, without necessarily impacting negatively on the primary user purposes. However, there is increasing evidence to believe that with the creation of new impoundments there is a realization that the secondary use of the waters for food fish production and livelihood generation could be of significant value, both socially and economically. In this respect the best examples could be drawn from Indonesia (Citarum water shed reservoirs; see Abery *et al.*, 2005) and Nepal (Kulekhani reservoir; see Gurung *et al.*, 2009) where cage culture activities for displaced communities were accepted and supported as an alternate means of livelihoods, and more importantly there activities have been sustained for more than 20 years, with a concurrent development of a capture fishery, which is enhanced through a variety of measures.

Adoption of fishery enhancement practices has also resulted in relevant changes in governance that have facilitated the development of such activities. For example, in Sri Lanka non-perennial reservoirs were not permitted to be used for fishery enhancement under the Agrarian laws that were prevalent. However, the law was amended to permit fishery enhancement through culture based fisheries development and this change has further facilitated these developments (Amarasinghe and Nguyen, 2009). In Indonesia, with the stock enhancement of reservoirs in the Citarum watershed with milkfish, for mitigating purposes, were accompanied by the introduction of mesh size restrictions by the District Governing authorities, in concurrence with the fisher communities, which enabled the establishment of the activity and a further step towards the sustainability of the practice.

The successful introduction of the tagal system (see Section 5.4.f), a partnership between communities and the government, for protecting, rehabilitating, conserving and managing fishery resources in the state is a good example of a management system involving aboriginal communities. Each community must have traditional user rights, to be eligible to participate in this partnership, preferably rights to several deep pools in the river and manage and use its fishery resources under the leadership of the headman of the community (Wong, 2006). By 2006, the 'Tagal' system of management had been set up at 234 sites in 11 districts involving 124 rivers and, consequently, had successfully revived the depleted river fish populations, including many with mahseer (Wong 2006). A similar approach has been reported from Corbett Park in India, in which the 'Conserving the "tiger fish" (i.e. mahseer)' project aims to tap the potential of ecotourism in the buffer area of Corbett National Park. Guided by enhancement of the prospects for tourism, residents from several villages have been working to conserve mahseer in the River Ramganga and in other streams in the region. Locals have been taught about the importance of conserving the mahseer species, thus leading to increases in population size of mahseer (Anonymous 2008).

4.5 Investments/Returns from stock enhancements

The investment to fish stock enhancement in the region has been increasing significantly recently. For instance, the budget allocation by the central government for implementing enhancement activities in major river systems in China has been maintained around UDS26 million annually in recently years. In general, investment for enhancement program for public goods, particularly releasing program in major river systems and large lakes is usually borne by the central government (China, Republic of Korea and Thailand). The seed releasing and other enhancement activities in water bodies (such as medium and small-size lakes and reservoirs) with well managed fisheries are often multi-source funded, which include mainly budget allocation from local government and contribution from direct beneficiaries (fishers). One common practice for the later is payment of resource enhancement fee at renewal of fishing license. It is worth to notice that there has been steady increase of public donation for stock enhancement in some countries with the increasing public awareness of importance to protect the aquatic biodiversity and ecosystem.

Overall and in general terms the investment related return from stock enhancement is little known, except from the smaller water bodies as in the case of Thailand and Sri Lanka, where the total production is essentially from stocked seed and the other inputs are quantified (Amarasinghe and Nguyen, 2009; Kularatne *et al.*, 2009). Without regular stock enhancement of many flood plain water bodies, large reservoirs, where the natural recruitment is relatively poor, fisheries would likely not have developed. In most countries the cost of stock enhancement, particularly those associated with conservation purposes, is often borne by government agencies, central and or regional. In Thailand for example there are stock enhancements that are conducted under a decree of the Queen. In other enhancements, for example for CBF, mitigating environmental impacts such as in Indonesia, the government and or other agencies may kick start the fishery development, but as the activity progresses the community benefiting from it will begin to bear the costs of enhancements.

There is also a trend, such as in Vietnam where the cost of all stock enhancements and the associated fishery benefits are handed over to the private sector, almost akin to a lease. The enhancement of the high valued giant freshwater prawn, *Macrobrachium rosenbergii*, in Pak Mun Reservoir (a run-of-the river type dam), Thailand, provides a useful case study on investment-returns of stock enhancement as well as the use of the process for a conflict resolution where the closure of the dam impacted negatively on the livelihoods of the river fishers. In this instance although the recapture rates were less than 2 percent, giant freshwater prawn accounted for 54 percent of the total catch and 97 percent of the total income of the fish landings (Sripatrprasite and Lin, 2003). The cost of stocking, however, is borne by the government as an indirect compensation measure.

In a comparable case in Indonesia, in the reservoirs of the Citarum watershed (Jatiluhur, Cirata and Saguling) where cage culture, proliferated and intensified and impacted negatively on the water quality, resulting in fish kills that adversely affected fishers. In this instance stock enhancement, primarily milkfish, *Chanos chanos*, and the introduction of an associated co-management practice, involving all stakeholder groups, has resulted in improvements in water quality, and negated potential conflicts (Abery *et al.*, 2005) between fishers and fish farmers. Most of all the practice has increased the income of fishers, whose payment of a nominal levy of IDR 600/kg (IDR 9 300 = 1 US$) on the landings of the stocked species has also sustained the stock enhancement program, which was initially borne by the government. It is also believed that the use of milkfish, which is unlikely to establish reproductive populations in the reservoirs and the associated river system, would be ecologically less impacting than the use of other filter feeding fish species.

It is also important to note the socio-economic success of enhancement of translocations of species such as bilih into lake Toba, Indonesia, which has stimulated the consolidation and a significant enhancement of the fishery (three fold), generating extra livelihoods, and enabling higher fisher earnings, reaching a maximum of 320 000 IDR/fisher/day.

4.6 Monitoring and impact assessment to releasing and other conservation program

Fish seed releasing and other stock enhancement activities have been extensively carried out in the region and for decades in some countries. There has been general lack of effective monitoring and impacts assessment to various enhancement and conservation activities such as seed releasing, protected area and sanctuary etc. except for limited assessment studies conducted for releasing program implemented for few species, such as Chinese sturgeon and salmonoids. Most stock enhancement programs have been carried out without considering follow-up monitoring to assess the effectiveness and impacts.

Lack of effective monitoring and impact assessment is mainly due to technical difficulty and resource limitation. Currently, there is still lacking of effective and economical methods and tools for monitoring and assessing impact of large scale releasing activities in the region. On the other hand, almost no financial resource is allocated for monitoring and impact assessment activities even though huge budget is allocated to releasing of fish seed. The reluctance of government in allocating fund for monitoring and impact assessment is often due to difficulty in monitoring the use of the fund and long time-span of the work. In addition, monitoring and impact assessment are not so eye-catching compared with the releasing activities which usually easily attract public attention.

Obviously, it is not possible to understand the actual effect of seed releasing and other stock enhancement activities without reasonable monitoring activities. Therefore, the actual impacts of most stock enhancement activities in large open water bodies in the region have remained questionable although it has been believed significant ecological and socio-economic benefits achieved. More importantly, it is difficult to make informed decision on improving the methodologies, operation and follow-up management to achieve better results with limited resources.

4.7 Issues related to marketing

The general notion is that all of the inland fish production is used directly or in a processed form for human consumption, which contrasts to that of the marine production where nearly 25 to 30 percent is used for reduction into fish meal and fish oil (Delgado *et al.*, 2003). However, it has been pointed out in Section 2 most such inland fish production is used for aquaculture purposes directly or indirectly. In general the marketing aspects, though important, have taken a backstage (De Silva, 2008).

With increasing potential in culture-based-fisheries, and its increasing adoption in the region with developments in India, Indonesia, Thailand, Sri Lanka and Vietnam, where the harvesting is essentially dictated by the weather-receding water levels-there is a need to address this aspect, to avoid an excess supply (within a narrow time frame, in a small geographic area). In this regard some countries have adopted a staggered harvesting strategy, thereby ensuring a wider spread of the time frame and a reasonable farm gate price. In Myanmar the involvement of women in marketing of culture-based-fishery produce in some instances (FAO-NACA, 2003) have brought about an added dimension of livelihood supportfor the poorer sectors but this needs to be further encouraged.

On the other hand, in large water bodies the marketing chains are relatively well established, with middle persons playing a vital role (De Silva, 2008). In China, where a single days harvest, by the use of integrated nets, could be very large. Fish may be kept in pens within the water body and marketed in small quantities over a few days, thereby ensuring a fair farm gate price and avoiding an oversupply. In Vietnam most middle persons operate in boats when a group of fishers would sell their fish to same middle person, at times on a barter basis, the former then in turn markets through wholesale buyers on shore.

5. STOCK ENHANCEMENT AND BIODIVERSITY CONSERVATION

5.1 Physical and management measures

Inland fisheries enhancements and biodiversity conservation in most countries in the region are intrinsically linked. As pointed out in Section 5.3 there are direct steps taken towards biodiversity conservation by creation of fish sanctuaries and refuges, introduction of closed seasons, complete prohibition of fishing operations in selected waters and so forth. Whilst such ‘physical and management’ measures are widely adopted one of the main concerns with regard to biodiversity conservation is the introduction of alien species and trans-boundary movement of indigenous species across their natural range of distribution for stock enhancement purposes.

5.2 Retaining connectivity among waters

The inland waterways have been greatly impacted through interference from anthropogenic activities, primarily for irrigation purposes, by impeding connectivity. Although large dams attract attention of conservationists, the numerous weirs, sluices and even roads and other similar man made structures impede free movement of fish, and consequently impact on biodiversity, both directly and indirectly. Admittedly however, the quantitative information available in this regard on the region's waterways is rather meagre.

One of the most advocated mitigating measures is the construction of fish passages and or fish ladders, which some suggest has proven to be a viable option in the northern hemisphere, particularly in respect of facilitating salmonid migrations. On the other hand, in the region there are only a few structures, of various forms, in operation. For instance in the Pak Mun Dam, Thailand, the available information suggests that it is not significantly effective in facilitating upstream migrations. In addition, a number of fish passes are in operation in Bangladesh; e.g. Sariakandi fishpass (92.4 m long and 15 m wide) on the west bank of Jamuna river and the east bank of Bangali river (at Sariakandi upazilla sub-district) permitting fish movement between the Jamuna and Bangali rivers. In Bangladesh all fish passes come under a management authority headed by the Bangladesh Water Development Board.

5.3 Introduction of alien species and indigenous species translocations

Introduction of alien species is a global 'bone of contention', and especially so as it is often alleged that such introductions are a main cause of loss of biodiversity (e.g. Moyle and Leidy, 1992; IUCN, 2000), even though and more often than not, there is a lack of explicit scientific evidence in this regard. Admittedly, the relevant issues with regard to aquaculture globally, and regionally arebetter known (see recent review by De Silva *et al.*, 2009) including the controversial introduction into the region of tilapias for aquaculture (De Silva *et al.*, 2004).

Amongst alien species use of tilapias in stock enhancement purposes perhaps can be considered as one of the most significant examples in the region. In Sri Lanka introduction of *Oreochromis mossambicus* in 1952 is considered to have triggered the development of an inland fishery in the vast acreage of perennial reservoirs, ancient and modern. There were later stock enhancements with the Nile tilapia, *Oreochromis nitloticus.* Currently, these species collectively account for over 70 percent of inland food fish production, which also provides many fisher livelihoods in rural areas (Amarasinghe and De Silva, 1999; Amarasinghe and Weerakoon 2009). Tilapias continue to contribute to reservoir fishery production in Lao PDR, India, Indonesia, the Philippines and Thailand. However, apart from occasional stock enhancement with a view to building up reproductive populations, there is no regular activity in this regard, and the fisheries sustain themselves through self recruiting populations. All evidence indicates that this introduction in the region, though the species were brought in for aquaculture development, have not had apparent negative impacts on biodiversity (De Silva *et al.*, 2004).

In addition Chinese and Indian major carps have been extensively translocated regionally for stock enhancement purposes, and provide major contributions to culture-based fisheries, flood plain fisheries, lease fisheries and the like in most countries in the region. In some instances escapees from aquaculture practices have resulted in the establishment of relatively large fisheries, a case in point being the Gobhindasagar Reservoir, India (Sugunan, 1995), where silver carp is the predominant species of the fishery, and has also resulted in an overall increase in production and number of fishers.

Interestingly ice fish, *Neosalanx* spp., endemic to Taihu Lake, China, has been extensively translocated in to other reservoirs in China (Liu *et al.*, 2009). However, these translocations have resulted in mixed results with populations fluctuating over the years, and the fisheries not being consistent. More recently, ice fish has been transplanted into a large reservoir, Thac Ba Reservoir, in Northern Vietnam. There is evidence emerging that a relatively significant fishery has commenced four to five years after the transplantation (see Country Review on Vietnam). More importantly, for example there were no risk assessment studies undertaken with regard to the above translocations and also there is no evidence of monitoring of biodiversity impacts either. Bearing in mind that this group of fish are zooplankton feeders the potential for biodiversity conservation impacts remain likely.

Comparable to the trans-boundary translocation of ice fish in China, beyond its natural range of distribution, is the example of translocation of bilih (*Mystacoleucus padangensis*) into Lake Toba, North Sumatera, from Sinkarak Lake (West Sumatera) in Indonesia (see Section 5.2.3 for further details). Although this translocation has resulted in positive impacts on the fishery and related livelihoods, and the socio-economic status of the fishing communities, its impacts on biodiversity conservation are yet unknown.

5.4 Genetic aspects related to stock enhancement practices

The common notion, at least until recently, was that use of indigenous species in stock enhancement practices impact on biodiversity to a lesser extent than alien species. The use of modern genetic tools in population studies have shown that unplanned stock enhancement practices based on indigenous species could lead to negative biodiversity impacts and loss of genetic diversity of the natural stocks. Such detrimental impacts have been clearly demonstrated for northern hemisphere salmonid strains/species e.g., Dowling and Childs, 1992; Leary *et al.*, 1993; Allendorf and Leary, 1998).

In Asia the above aspects are not well documented and or known and had been relatively less studied. It has been demonstrated that in Thailand stock enhancement of the Thai silver barb, *Barbonymus* (= *Puntius*) *gonionotus* has resulted in the loss of genetic diversity of the wild stocks (Kamonrat, 1996). Also, it has been acknowledged that the escapees from aquaculture practices have led to a reduction in genetic diversity of Thai catfish, *Clarias macrocephalus* wild populations (Senanan *et al.*, 2004).

As pointed out in Section 5.1 traditional stock enhancement practices conducted for cultural and symbolic purposes in some countries in the region do not pay much heed to genetic aspects, and it is possible that juveniles produced from one hatchery and broodstock derived from a single population are utilised along long distances of a river or unconnected water ways. It is suggested that as the science is better known that such practices may be suitably modified to ensure that genetic aspects are taken into account to reduce impacts on biodiversity in the long term.

The use of milkfish for stock enhancement and mitigation of the negative impacts on water quality in reservoirs of the Citarum watershed is an interesting example, where the assumption is made that as this species is unlikely to establish breeding population in the reservoirs thus having minimal impact on biodiversity. This presumption may not necessarily be always correct as indirect genetic impacts are known to occur as a result of such an introductions (Waples, 1994).

Overall, it is evident that there is a need to step up monitoring on genetic impacts of stock enhancement practices in the region, and where relevant begin to introduce the use of genetic tools that are available to make enhancement practices more science based.

6. SUMMARY OF MAJOR CONCLUSIONS ON STOCK ENHANCEMENT AND BIODIVERSITY CONSERVATION

- In the region overall, enhancement of inland fisheries has resulted in an increasein food fish availability, providing additional livelihood opportunities to rural poor, and contributing to socio-economic well being.
- However, not all enhancements in the region are socially equitable, particularly with regard to flood plain and reservoir leasable fisheries and the like. Such enhancement protocols although bringing about an increase in food fish production could marginalise other users in gaining access to a potential food source and a subsidiary income opportunity. Interestingly, this fact is being addressed by some countries, such as Bangladesh, where the leases are provided to communities rather than individuals, and consequently benefits are shared by the community.
- In general, culture based fisheries, in smaller, often non-perennial water bodies, is a major form of enhancement and in most instances whole communities tend to benefit and it is becoming increasingly popular as a means of increasing food fish production and provision of subsidiary income to rural communities.
- Enhancement of large and medium sized reservoirs is only successful if the stocks become established and start to breed/recruit, perhaps with the exception of China where this aspect is built into the overall reservoir management planning. Successful enhancement in such waters is therefore also reliant on effective fishery management.

- To further facilitate the benefits of fisheries enhancement activities, there is a need to rationalise the water management regimes, which often tend to be beyond the purview of fishery authorities.

- The statistical data collation and reporting on inland fisheries is open for significant improvement. There is evidence that inland fisheries production is often under estimated and there is a need to rationalise the different methods utilised in production estimation. Equally, there is a need to step up the socio-economic gains and losses from inland fishery enhancements, on a much wider scale than at present. Proper data on the status of the fisheries and the human resources involved in such activities will facilitate the improved recognition of the sector as a significant food security, nutrition and poverty alleviation activity for rural communities, in developing countries.

- Overall, there is a paucity of monitoring of impacts of enhancements, from social, environmental and economic view points, and there is an urgent need for authorities to introduce monitoring measures for all types of water bodies.

- The region's approach to biodiversity conservation related to fisheries enhancements are significant, with the introduction of sanctuaries, closed seasons, gear restrictions, habitat improvements, seed releasing programs and so forth.

- The stock enhancement activities in the region sometimes use alien species and translocation of indigenous species across watersheds, beyond the ranges of natural distribution. Although explicit evidence is lacking with regard to impacts on biodiversity in relation to such enhancements regular monitoring and evaluations of these would be desirable to introduce any mitigating measures where needed.

- On the other hand, stock enhancement activities have paid little attention to potential genetic impacts and there is a need to address these issues sooner rather than later.

- The ecosystem approach to inland fisheries needs to go beyond the scope of the water body per se, as the production of most inland waters are highly impacted upon by the catchment features and its activities. Accordingly, more holistic approaches to inland water resources enhancements and management are needed.

7. WAY FORWARD

- A concerted effort needs to be made to impress upon governments and responsible authorities of the increasing importance of inland fisheries resource enhancement as a means of contributing to food fish supplies and food security of rural communities in addition to protection of aquatic biodiversity and also encourage more cooperation between fishery and water management authorities to reap the full benefits. In this context attempts should be made to increase the visibility of the sector, through for instance the Committee on Fisheries of the FAO.

- In the region as a whole, there is very little emphasis on pre-and post-impact assessments of fishery resource enhancement practices, primarily as consequence of the lack of an accepted protocol for this purpose and limited capacity available to undertake such activities. Accordingly, there is need to develop guidelines/protocols for inland fishery enhancements for the different water body types, and build capacity on impact assessment/monitoring of fishery enhancements in the region as required.

- In the region though a majority of fishery resource enhancements has been beneficial, socio-economically, there is very limited monitoring of the costs vs. benefits of major, specific practices. Monitoring of cost benefits of enhancements will provide much needed information and an impetus to furthering the activities and bringing about improvements thereof.

- The region has a number of institutions that are directly and or indirectly involved in enhancement related activities/programs. Equally, the capabilities in this regard differ markedly between countries, and there is lot to be learned from each other to place fishery enhancements in the region on a firmer footing. In this regard the establishment of a mechanism for networking/continuing interaction for sharing of experience on enhancement and conservation of inland fisheries resources would be most beneficial to the all countries and to the sector's improvement and consolidation.

- All attempts should be made to ensure minimizing potential impacts on biodiversity conservation arising from inland fishery resource enhancements. In this regard more attention needs to be paid to maintaining genetic diversity of wild stocks/populations, and programs need to be introduced to incorporate scientific knowledge into enhancement practices, even those that have been conducted over long periods for cultural and symbolic purposes. Strategic environmental assessment (SEA) is the process for assessing, at the earliest possible stage, the environmental impacts of decisions made from the policy level downwards. SEA is a promising means to strengthen awareness of biodiversity conservation issues in the context of national priorities in terms of social and economic development.

- Regular monitoring needs to be undertaken on the impacts of alien species and translocation of indigenous species across watersheds for stock enhancement practices. New such translocations should be undertaken only after a detailed risk assessment and when and if absolutely necessary.

- Over the last two decades there has been an emphasis on aquaculture education, particularly tertiary, in the region, for good reason. However, this impetus has not been carried on with regard to inland fisheries in many countries, leaving a gap in the knowledge of personnel that are called upon to manage the latter. Accordingly, there is a need to raise awareness in tertiary and vocational institutions on the need to introduce curricula and step up training provided in inland fisheries management.

REFERENCES

Abery, N.W., Sukadi, F., Budhiman, A.A., Kartamihardja, E.S., Koeshendrajana, S., Buddhiman & De Silva, S.S. 2005. Fisheries and cage culture of three reservoirs in west Java, Indonesia; a case study of ambitious developments and resulting interactions. *Fisheries Management and Ecology*, 12, 315-330.

Allendorf, F.W. & Leary, R.F. 1998. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology, 2, 170-184.

Amarasinghe, U.S. & De Silva, S.S. 1999. The Sri Lankan reservoir fishery: a case for introduction of a co-management strategy. Fisheries Management and Ecology, 6, 387-400.

Amarasinghe, U.S. & Nguyen, T.T.N. 2009. Enhancing rural farmer income through fish production: secondary use of water resources in Sri Lanka. In: Success Stories in Asian Aquaculture (S.S. De Silva, F.B. Davy, eds.), pp. 105-133. Springer-IDRC-NACA, Dordrecht.

Amarasinghe, U.S. & Weerakoon, D.E.M. 2009. Present status and future strategies for the management of reservoir fisheries in Sri Lanka. 69-98 pp. In: De Silva, S.S. and U.S. Amarasinghe (eds.), Status of reservoir fisheries in five Asian countries. NACA Monograph No. 2. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand. 116 p. http://library.enaca.org/inland/reservoirs08/status_reservoir_fisheries_asia.pdf

Anonymous. 2008. Conserving 'fighting tiger fish' in Corbett Park. The Economics Times: 9 April 2008.

Azim, M.E., Verdegem, M.C.J., van Dam, A.A. & Beveridge, M.C.M. 2005. Periphyton: Ecology, exploitation and management. CABI Publishing, Wallingford, Oxfordshire, UK. 352 pp.

Coates, D. 2002. Inland capture fishery statistics of Southeast Asia: current status and information needs. RAP Publication 2002/11, 114 pp.

Delgabo, C.L., Wada, N., Rosegrant, M.W., Meijer, S. & Ahmed, M. 2003. Fish to 2020: Supply and demand in changing global market. International Food Policy Research Institute, Washington, D.C., and World Fish Centre, Penang. 226 pp.

De Silva, S.S. 2008. Market chain of non-high value cultured aquatic commodities: case studies from Aisa. FAO Fisheries and Aquaculture Circular, 1032, 46 pp.

De Silva, S.S. & Funge-Smith, S. 2005. A review of stock enhancement practices in the inland water fisheries of Asia. Asia-Pacific Fishery Commission, , RAP Publication 2005/12, 90 pp.

De Silva, S.S., Subasinghe, R.P., Bartley, D.M. & Lowther, A. 2004. Tilapias as alien aquatics in Asia and the Pacific: a review. FAO Fisheries Technical Paper, 453, 65 pp.

De Silva, S.S., Nguyen, Thuy T.T., Turchini G.M., Amarasinghe U.S. & Abery N.W. 2009. Alien species in aquaculture and biodiversity: a paradox in food production. Ambio 38, 24-28.

Dowling, T.E. & Childs, M.R. 1992. Impact of hybridisation on a threatened trout of the Southwestern United States. Conservation Biology, 6, 355-364.

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

FAO-NACA. 2003. Myanmar aquaculture and inland fisheries. RAP Publication 2003/18, 62 pp.

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 PDR. Fisheries Research 80: 37-45.

Garaway, C., Lorenzen, K. & Chamsingh, B. 2001. Developing fisheries enhancement in small water bodies: lessons from Lao PDR and Northeast Thailand In: S.S. De Silva (ed.) Reservoir and culture-based fisheries: biology and management. ACIAR Proceeding No. 98. Australian Centre for International Agricultural Research, Canberra. pp. 227-234.

Groombridge, B. (ed.) 1992. Global Biodiversity: Status of the Earth's Living Resources. Chapman and Hall, London.

Gurung, T., Mulmi, R.M., Kalyan, K.C., Wagle, G., Pradahan, G.B., Upadhayaya, K. & Rai, A.K. 2009. Cage fish culture: an alternative livelihoods option for communities displaced by reservoir impoundment in Kulekhani, Nepal. In: Success Stories in Asian Aquaculture (S.S. De Silva and F.B. Davy, eds.), pp. 85-102. Springer-NACA-IDRC, Drodecht, Netherlands.

Hortle, K.G. 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16, 87 pp. Mekong River Commission, Vientiane.

IUCN/SSC Invasive Species Specialist Group. 2000. Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species. IUCN, Gland, Switzerland. also available on https://www.iunc.o0rg/themes/sss/news/invasives.htm)

Jutagate, T., De Silva, S.S. & Mattson, N.S. 2003. Yield, growth and mortality rate of the Thai river sprat, Clupeichthys aesarnensis, in Sirinthorn Reservoir, Thailand. Fisheries Management and Ecology, 10, 221-231.

Kamonrat, W. 1996. Spatial Genetic Structure of Thai Silver Barb Puntius gonionotus (Bleeker) Population in Thailand. Ph.D. Thesis, Dalhousie University, Halifax, Canada.

Kibria, G. Md. & Ahmed, K.K.U. 2005. Diversity of selective and non-selective fishing gear and their impacts on inland fisheries in Bangladesh. NAGA World Fish Centre Newsletter, 28 (1/2), 38-46.

Kularatne, M.G., Amarasinghe, U.S., Wattage, P. & De Silva, S.S. 2009. Evaluation of community participation for the Development of culture-based fisheries in village Reservoirs of Sri Lanka. Aquaculture Economics & Management, 13, 22-38, 2009.

Leary, R.F., Allendorf, F.W. & Forbes, S.H. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology, 7, 856-865.

Liu, J., Li, Z., Xie, S., Miao, W., Gong, W. & Wu, L. 2009. Role of fish species introduction in reservoirs in China: case study on icefish. 15 pp. http://library.enaca.org/inland/reservoirs08/icefish-introduction-china.pdf

Lorenzen, K., Juntana, J., Bundit, J. & Tourongruang, D. 1998. Assessing culture fisheries practices in small water bodies: a study of village fisheries in Northeast Thailand. Aquaculture Research, 29, 211-224.

Lymer, D., Funge-Smith, S., Khemakorn, P., Naruepon, S. & Ubolratana, S. 2008. A review and synthesis of capture fisheries data in Thailand. Large versus Small scale fisheries. FAO RAP Publication 2008/17, 51 pp.

Moyle, P.B. & Leidy, R.A. 1992. Loss of biodiversity in aquatic ecosystems; evidence from fish faunas. In: Fielder P.L., Jain S.K. (eds), Conservation biology: the theory and practice of nature conservation, pp. 129-161. Chapman and Hall, UK.

Nguyen Son H., Bui Anh T., Le Luu T., Nguyen Thuy T.T. & De Silva, S.S. 2001. Aspects of the culture-based fisheries in small, farmer-managed reservoirs, based on three production cycles, in two provinces of northern Vietnam. Aquaculture Research 32, 975-990.

Nguyen, T.T.T. & De Silva, S.S. 2006. Freshwater finfish biodiversity and conservation: an Asian perspective. Biodiversity and Conservation, 15: 3543-3568.

Ogale, S.N. 2002. Mahseer breeding and conservation and possibilities of commercial culture. The Indian experience. FAO Fisheries Technical Paper, 431, pp. 193-212. FAO, Rome.

Ogale, S.N. 2006. Mahseer breeding and culture: recent advances and research needs. Paper presented at the International Symposium on the Mahseer, 29-30 March 2006, Kuala Lumpur, Malaysia.

Petr, T. (ed.) 1998. Inland fishery enhancements. FAO Fish. Tech. Pap. 374: 460 pp.

Ricciardi, A. & Rasmussen, J.B. (1999) Extinction rates of North American freshwater fauna. Conservation Biology, 13, 1220-1222.

Saphakdy, B., Phomsouvanh, A., Davy, B., Nguyen, T.T.T. & De Silva, S.S. 2009. Contrasting community management and revenue sharing practices of culture-based fisheries in Lao PDR. Aquaculture Asia, 14, July-September 2008, pp. 3-7.

Senanan, W., Kapuscinski, A.R., Na-Nakorn, U. & Miller, L. 2004. Genetic impacts of hybrid catfish farming (Clarias macrocephalus x C. gariepinus) on native catfish populations in central Thailand. Aquaculture, 235, 167-184.

Shiklomanov, I.A. 1993. World freshwater resources. Water in Crisis: A Guide to the World's Fresh Water Resources (ed. by P.H. Gleick), pp. 13-24. Oxford University Press, New York.

Shiklomanov, I.A. 1998. Archive of world water resources and world water use. Global Water Data Files: StateHydrological Institute. Data archive on CD-ROM from State Hydrological Institute, St. Petersburg, Russia.

Smith, D.I. 1998. Water in Australia. Oxford University Press, Oxford. 384 pp.

Sripatrprasite, P. & Lin, C.K. 2003. Stocking and recapture of freshwater prawn (*Macrobrachium rosenbergii* De Man) in a run-of-river type dam (Pak Mun dam) in Thailand. Asian Fisheries Science, 16, 167-174.

Subasinghe, R., Jia, J. & Soto, D. 2009. Global aquaculture and its role in sustainable development. Reviews in Aquaculture, 1, 2-9.

Sugunan, V.V. 1995. Reservoir fisheries of India. FAO Fisheries Technical Paper, 345, pp. 423.

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

Valbo-Jørgensen, J. & Thompson, P.M. 2007. Culture-based fisheries in Bangladesh. A socio-economic perspective. FAO Fisheries Technical Paper, 499, 41 pp.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences, 48, 124-133.

Welcomme, R.L. 1997. Stocking as a technique for enhancement of fisheries. FAO Aquaculture Newsletter 14, 8-12.

Welcomme, R.L. 2002. An evaluation of tropical brush and vegetation park fisheries. Fisheries Management and Ecology, 9, 175-188.

Welcomme, R.L. & Bartley, D.M. 1998. Current approaches to the enhancement of fisheries. Fisheries Management and Ecology 5: 351-382.

ANNEXES

Annex I. Species used directly in stock enhancement practices and those that are directly and or indirectly impacted through inland fisheries enhancement programs/activities (in at least 2 countries)

Species	Bgd	China	India	Indo	Myn	Nepel	RoK	SL	Th	Vn
Anabas testudineu	+		+	+						+
Anguilla japonicus		+					+			
Hypophthalmichtys nobilis	+*	+	+*		+*	+*		+*	+*	+*
Barbonymus gonionotus	+			+*					+	
Clarias gariepinus				+					+	
Carassius auratus	+*	+	+		+*	+*	+			+*
Catla catla	+		+		+	+		+*	+*	+*
Chana striata				+	+					+
Chitala chitala				+	+					
Cirrhinus mrigala	+		+		+	+		+*	+*	+*
Ctenopharyndogon idellus	+*	+	+*	+*	+*	+*		+*	+*	+*
Cyprinus carpio	+*	+	+*	+*	+*	+*	+	+*	+*	+*
Eriocheir sinensis		+					+			
Heteropneustes fossilis	+			+	+					
Hypophthalmichtys molitrix	+*	+	+*	+*	+*	+*		+*	+*	+*
L. rohita	+		+		+	+		+*	+*	+*
Leptobarbus hoevenii				+					+	
Macrobrachium rosenbergii	+		+	+	+			+	+	
Mastacembelus armatus	+		+		+					
Morulius chrysophekadion				+*					+	
Mylopharyngodon piceus		+								+
Neosalanx spp.		+**								+*
Oncorhynchus mykiss[#]						+				+
Oreochromis mossambicus[#]	+		+	+	+			+	+	
O. niloticus[#]	+		+	+	+	+		+	+	+
Osteochilus hasselti				+					+	
Pangasianodon hypopthalmus				+*	+				+	
Probarbus jullieni				+*					+	
Salmo gairdneri[#]		+		+					+	+
S. salar[#]		+		+						
S. trutta[#]		+		+					+	+
S. richardsonii[#]					+	+				
Tor douroensis			+	+						
T. putitora			+			+				
T. Tor			+		+	+				
Trichogaster pectoralis				+*	+*				+	
Trionyx sinensis		+					+			

[#] alien to the region; * alien to the country; ** translocated across water sheds with in a country for stock enhancement purposes

Bgd = Bangladesh; Indo = Indonesia; Myn = Myanmar; RoK = Republic of Korea; SL = Sri Lanka; Th = Thailand; Vn = Vietnam

Annex II. Species used directly in stock enhancement practices and those that are directly and or indirectly impacted through inland fisheries enhancement programs/activities in individual country

Country	Species
China	*Acipenser dabryanus, A. sinensis, C. asiatica, C. maculate, Chinese sucker, Coreius heterodon, Culter alburnus, Hemisalanx prognathus, Leiocassis longirostris, Megalobrama amblycephala, Parabramis pekinensis, Pelteobagrus fulvidraco, P. vachelli, Plagiognathops microlepis, S. prenanti, Silurus meridionales, Sinilabeo rendahli, Siniperca chuatsi, Spinibarbus sinensis, Squaliobarbus curriculus, Xenocypris davidi, X. microlepis*
India	*T. khudree*
Indonesia	*Balantiocheilos melanopterus, Botia macracanthus, Chanos chanos, Helostoma teminkki, Mystus nemurus, Orchella brevirostris, Osphoronemus gouramy, Sclerophages formosus, S. yardinii, T. trichopterus, Mystacoleucus padangensis***
Myanmar	*C. labiosa, Ompok paba, Osteobrama belangeri, Tenualosa ilisha, Wallago attu, Colisa fasciata**, *Glossogobius sp.**, *P. lala**, *Parambassis sp.**
Nepal	*Barilius* spp., *Schizothorax plagiostomus, Schizothaichthys progastus, S. annandaeli*
Republic of Korea	*Coreoperca herzi, E. japonicus, Plecoglossus altivelis, Psedobugrus fulvidrac, S. asotus, S. schezeri*
Sri Lanka	*Labeo dussumieri*
Thailand	*B. schwanenfeldi, B. schwanenfeldii, C. macrocephalus, Clarias macrocephalus, Hemibagrus nemurus, Henicorhynchus siamensis, P. sanitwongsei, Systomus orphoides*
Vietnam	*Acipenser schrenckii**, *Barbodes altus, Barbonymus altus, C. micropeltis, H. guttatus, P. larnaudii, P. bocourti, Prochidolus lineatus*

* alien to the country

** translocated across water sheds with in a country for stock enhancement purposes

Supported by

FAO Aquaculture Management Service (FIRA)
Rome, Italy

ASIA-PACIFIC FISHERY COMMISSION
FAO Regional Office for Asia and the Pacific
39 Phra Athit Road, Bangkok, Thailand
www.apfic.org

ISBN 978-92-5-106751-2

9 789251 067512

I1984E/1/01.11