Sustainable use of mangrove fisheries resources of Sundarbans, Bangladesh

M. Enamul Hoq
Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh

Accepted 17th September 2003

ABSTRACT

The Sundarbans forms an ideal mangrove ecosystem, which supports large group of fish, shrimp, edible crab and also supply food and cash to local coastal communities. In Sundarbans mangrove, exploitation of major fish groups like white fish and marketable shrimp has been reduced over the years, whereas catch of *Scylla serrata* shows an increasing trend. The *Penaeus monodon* post larvae abundance was also declining. Present study suggested that any set of management practice is almost non-existent in Sundarbans Reserve Forest, resulting in serious over-exploitation of all the fish stocks and warrant immediate attention.

Key words: Mangrove fisheries, Sundarbans, *P. monodon*, Biodiversity

INTRODUCTION

The Sundarbans, the largest single block of mangrove ecosystem in the world, is located in the estuary of the river Ganges, spanning an area of about one million hectares in South-west Bangladesh and South-eastern part of the State of West Bengal in India. The Sundarbans mangrove forest was declared as "Reserve Forest" in 1875-76 under the first Forest Act of the then British India. As a reserve forest, control over fishing within Sundarbans is exercised by the Forest Department and the output from the fishery being regarded as "minor forest products" (IUCN 1994). Activities of the Forest Department in the fisheries are almost exclusively focused on revenue collection. A number of enclosure regulations are enacted, but are not rigorously enforced. The fisheries resources is exploited on maximum sustainable yield (MSY) which is not ideal for sustainable management for the fisheries of Sundarbans (Pena 1994).

Mangrove waters are very rich in fishery resources and act as nurseries and spawning grounds for a large number of fishes, crabs, shrimps and various kinds of molluscs (Tzeng and Wang 1992, Robertson and Blaber 1992, Rajendran and Kathiresan 1999). By this relationship, it can be seen that many mangrove dwellers catch marine animals around mangrove forests. Aquaculture is also widely practiced in mangrove areas, particularly in Southeast Asian countries (Macintosh 1982).

Although denudation of the Sundarbans mangrove forest due to shrimp farming is negligible, the unregulated encroachment of shrimp farming practice into the inland fertile rice growing fields in the buffer zone of the Sundarbans has caused increase salinity of soils due to salt water seepage (Shahid and Islam 2002). With over 3.5 million people from the surrounding areas depending directly or indirectly on the Sundarbans for their livelihood, the forest has been reduced alarmingly. Over-fishing, particularly, collecting *P. monodon* post larvae from mangrove and near-shore waters for increasing demand from shrimp farming, and over exploitation of plant and wildlife species are placing increasing amounts of stress on the viability of this delicate ecosystem. The present study aimed at evaluating the fisheries structure based on analysis of statistical records, and present management practices in Sundarbans Reserve Forest.

METHODS AND DATA SOURCES

The present study was based on both primary and secondary data as well as a comprehensive review of available literatures. Collection of primary data was made by field observation and fishermans' interview using structured questionnaire. Secondary data was collected from the following sources: Department of Forest (Dhaka and Khulna offices), Department of Fisheries, Khulna, Bangladesh Fisheries Research Institute, Brackishwater Station, Paikgacha, Khulna, Khulna University, Bangladesh Space Research & Remote Sensing Organization etc. Along with these data, published and unpublished relevant documents were also reviewed and analyzed.

Forecasting production trend of major fisheries group in SRF was performed using statistical programme, NCSS 2000 software package.

RESULTS

Resource exploitation

Table 1 represents commercial landings of major

Table 1. Fish production (000 MT) from Sundarbans Reserve Forest

Year	Group-wise production							
	White fish	Marketable shrimp	Undersized shrimp	*Tenulosa ilisha*	*Scylla serrata*	Crab & shrimp residues	Dry fish	*Penaeus monodon* fry (million)
1985-86	NA	0.46	0.57	0.66	NA	NA	NA	NA
1986-87	NA	0.48	0.32	0.62	NA	NA	NA	NA
1987-88	3.86	0.54	0.26	0.97	0.02	0.004	0.58	14.10
1988-89	3.75	0.51	0.14	0.53	0.01	0.01	0.37	30.43
1989-90	3.15	0.37	0.18	0.90	0.04	0.01	0.45	40.34
1990-91	2.95	0.33	0.17	0.65	0.12	0.02	0.61	72.69
1991-92	2.82	0.32	0.18	0.55	0.27	0.03	0.53	110.32
1992-93	3.09	0.31	0.18	0.50	0.49	0.11	0.79	126.97
1993-94	2.53	0.27	0.19	0.59	0.53	0.19	0.86	209.64
1994-95	2.58	0.28	0.20	0.45	0.70	0.35	0.59	263.41
1995-96	2.53	0.28	0.13	0.54	0.64	0.36	0.65	253.07
1996-97	2.53	0.26	0.08	0.39	1.00	0.25	0.74	142.22
1997-98	2.50	0.24	0.10	0.41	0.82	0.36	0.65	127.90
1998-99	1.95	0.20	0.13	0.33	0.42	0.32	0.52	87.97
1999-00	1.92	0.21	0.10	0.46	0.37	0.05	0.25	57.22

Table 2. Yield, exploitation rate and MSY of fisheries resources in the Sundarbans

Species	Yield (tons)	Exploitation rate	MSY (tons)	Remarks
Tenualosa ilisha	762	0.41	523	Over exploited
Lates calcarifer	150	0.35	160	Fully exploited
Pomadasys hasta	232	0.40	457	Optimum
Johnius argentus	548	0.47	593	Optimum
Pangasius pangasius	135	0.42	92	Over exploited
Plotossus canius	141	0.36	92	Over exploited
Macrobrachium rosenbergii	274	0.30	711	Optimum
Penaeus monodon	180	-	26	Optimum
Scylla serrata	375	-	283	Over exploited
Oyster	3000	-	6000	Under exploited
Gastropod	35	-	113	Under exploited
P. monodon fry	1453 million	-	672 million	Over exploited

Sources: Chantarasri (1994) and Smith (1995)

fisheries group as recorded by Forest Department from 1985-86 to 1999-00. Landing of white fish which represents major share of Sundarbans fisheries gradually decreased. Marketable shrimp landings also showed a decreasing trend. *Tenulosa ilisha* landing and dried fish production are fluctuating. *Penaeus monodon* fry collection was in peak during 1993-94 to 1996-97, during last 2 years their collection reduced remarkably. Harvesting of *Scylla serrata* increased from 93-94 which was also reduced during last 2 years.

A 4-year forecasting on yield of Sundarbans fisheries (based on landed data) shows marked decline of white fish, *S. serrata* and *P. monodon* fry catch (Fig. 1). Estimation of yield, exploitation rate and MSY of major shell- and finfish species in SRF are presented in Table 2. The fishery of *T. ilisha, Pangasius pangasius, Plotossus* spp., *S. serrata* were found to be over-exploited at E= 0.36 to 0.42. The exploitation of *Lates calcarifer* was estimated to be at optimum at present. The yield was about 150 MT. Increased the effort would give a lower yield. The fishing of *Johnius argentus* is nearly fully

Table 3. Threatened fish species of the Sundarbans*

Family	Species	Status	Global status
Ambassidae	*Pseudambassis baculis*	VU	-
	Pseudambassis ranga	VU	-
Anguillidae	*Anguilla bengalensis*	VU	-
Carcharhindiae	*Carcharhinus limbatus*	-	VU
	Glyphis gangeticus	-	CR
Eleotridae	*Butis butis*	NO	LR
Plotosidae	*Plotossus canius*	VU	-
Pristidae	*Pristis microdon*	-	EN
Scatophagidae	*Scatophagus argus*	EN	-
Schilbeidae	*Pangasius pangasius*	CR	-
	Silonia silondia	EN	-
Syngnathidae	*Hippocampus kuda*	-	VU
	Microphis deocata	EN	-

CR - Critically endangered, DD - Data deficient, EN - Endangered, LR - Lower risk, NO - Not threatened, VU - Vulnerable

* Modified from IUCN (2000) Red Book of threatened fishes of Bangladesh.

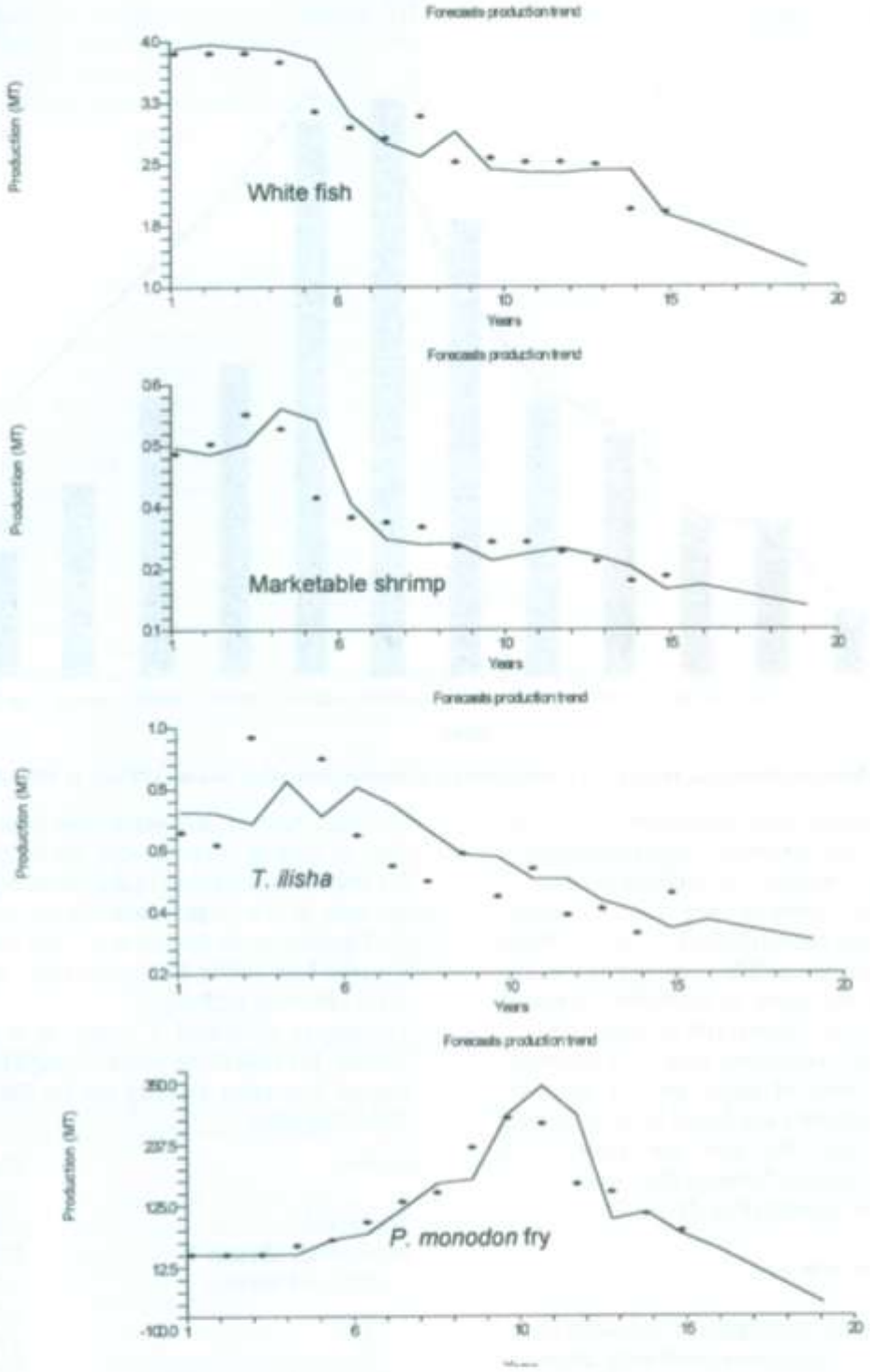

Fig. 1. Prediction of major groups of fisheries in Sundarbans.

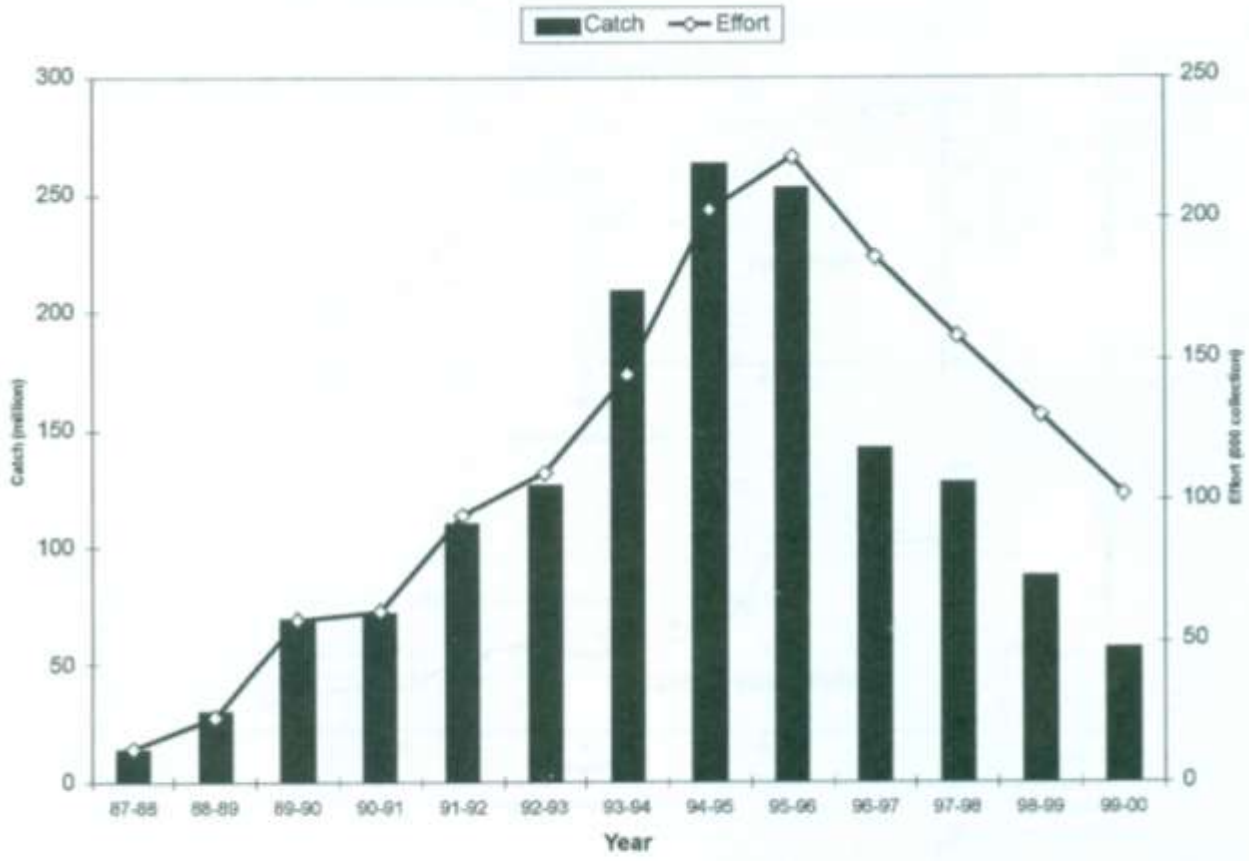

Fig. 2. Relationship between fishermen engaged in *P. monodon* PL collection and effort during 1987-88 to 1999-2000.

exploited. The present *Macrobrachium rosenbergii* fishery is far from the optimum. The exploitation of gastropod and oyster seems to be underutilized.

The IUCN listed some species of Sundarbans as threatened which are accomplished in Table 3. Stock abundance of riverine catfish *P. pangasius* in the SRF is very low and close to extinction. Another popular catfish *P. canius* also at risk of extinction.

P. monodon fry collecting gears are generally operated in the rivers of upper part of the SRF. Number of fry collectors are found to be increased considerably during the last ten years with corresponding increase in fishing effort whereas the volume of fry catch reduced (Fig. 2).

Management practices

The Forest Department exercises its control on fisheries in SRF through collection of tolls, taxes and revenue from fishing boats, fishermen and fishery products. Fishing within the Sundarbans is controlled by issuing permits and collection of revenue at the forest stations. Every fishing unit/party needs to get a license at the rate of Tk. 1,500, which is renewable each year at @ Tk 750. Failure of renewal of license within 2 year of issuing license, a new license must have to be taken. At the time of issuing permits from the forest stations, tax for fishing and staying in the forest is determined at the rate of Tk. 3/person/week for fishing and Tk 0.25/person/week for staying in the forest. In failure to come back in the designated time, a penalty of Tk 3/person/week is charged.

Fishing is permitted 3 times in a month. After fishing, the fishermen return through the same forest station they enter and pay tax for their catch at the following rates:

Fishery	Payable tax
White fish	1.30/kg
Marketable shrimp	8.00/kg
Undersized shrimp	1.30/kg
T. Ilisha	2.00/kg
Crab	1.00/kg
Shrimp & crab residues	0.60/kg
Dried fish	1.75/kg
P. monodon PL	0.20/PL

1 US$ = Tk. 59.00

The management aspect of fisheries in SRF only covers revenue collection, although some Acts/Regulations exists (Table 4). From theTable it

is clear that management of fisheries resources in SRF from technical point of view started in the 1989 with the closing of 18 khals to accelerate the fish breeding. Closed season and wildlife sanctuary regulations were introduced very recently. In September 2000 Government banned collection of *P. monodon* PL from coastal rivers including Sundarbans.

DISCUSSION

The fisheries status and management of SRF was scientifically studied in 1994 through a FAO assisted project, from which fisheries structure of Sundarbans was understood, although Rabanal (1984) under another FAO assisted project (FO:TCP/BGD/2309) observed some basic fisheries of SRF. In depth study on fisheries of Sundarbans was first studied by Chantarasri (1994), where description and MSY of major fisheries resources of Sundarbans was estimated and some management issues were addressed. The data produced by that study were very comprehensive one year data and after that no long term data collection was continued to provide more information and ensure the sustainable exploitation. In Sundarbans, the major problem for fisheries management is the absence of fishery experts with overall responsibility of fisheries of SRF. At present no working linkage exists between FD and Department of Fisheries or Bangladesh Fisheries Research Institute (BFRI). Due to lack of facilities, research of BFRI are concentrated mainly on coastal aquaculture, although Brackishwater Station of BFRI conducted a detailed study on colossal loss of fisheries resources during *P. monodon* PL collection in coastal rivers including Sundarbans boundaries (Islam *et al.* 1995). From mid 2000 another massive project "Sundarbans Biodiversity Conservation" was undertake by FD which is still on-going. Under this project a fisheries management unit named "Aquatic Resources Division" is formed which is responsible

Table 4. Existing and proposed fisheries management and conservation rules in SRF

Legislation	Summary of regulations	Implementing agencies
Indian Forest Act 1878	Empowers the Forest Department to manage the inshore and offshore fisheries in the Sundarbans and 20 km marine waters.	Forest Department
Hunting and Fishing Rules 1959	A fishing permit is required to fish in reserved or protected forests. Royality may be levied on fish caught in tidal waters of reserved and protected forests. It is illegal to use poison, explosives or fixed engine fishing gears, or to dam or bale water in reserve and protected forests.	Forest Department
Major Fisheries Regulations for SRF	Khal Closure Regulation (1989): closes 18 khals permanently for fishing to allow fish breeding. Collection & Export of Live Crab Regulation (1995): closes the entire SRF for crab fishing from December to February to allow crab breeding. Closed Season Regulation (2000): closes fishing in the entire SRF for 5 species (*P. pangasius, P. canius, L. calcarifer, M. rosenbergii, S. serrata*) during 1st May to 30 June to allow breeding.	Forest Department
Wildlife Sanctuary Regulations	Fishing is permanently prohibited since 1999 in the 3 wildlife sanctuaries.	Forest Department
Other Regulations for Fisheries in SRF	It is illegal to place a net across a khal and thereby completely block it. It is illegal to sting a rope transversely across a water way.	Forest Department
	Proposed Regulations	
Proposed by FAO through its project (BGD/84/056) in 1994	Introduction of closed seasons and protected zones i.e fish sanctuaries. Introduction of minimum size limits- 30 cm for *L. calcarifer* and 10 cm for *J. Argentatus*. Restriction of numbers of gillnets. Maintenance of exploitation rates for commercial species at current levels except *P. monodon* fry.	Some of the FAO proposal have been been implemented by Forest Department
Proposed by World Bank through its project in 1998	Closure for 12 months of small khals (less than 30 m wide) within 5 km radius of Forest Office in SRF, in alternating years. Permanent closure for wildlife sanctuaries and any other protected areas. Maintenance of records of permits issued and catch for individual fishermen. Annual harvest limit (TAC) for various species, initially *T. ilisha*, all catfishes and mud crab. Issuance of catch quotas to individual fishermen based on a share of the total allowable catch (TAC). Restriction of shrimp fry catch to boundary rivers only. Prohibition on harvesting brood crabs or female crabs with egg. Minimum weight of 200 g for male and 120 g for female crabs.	Some of the regulations have been implemented and others implementation are questionable

for developing new management implications for SRF.

Overexploitation and loss of biodiversity

A positive correlation between near-shore yields of fish/shrimp and mangrove area has been documented elsewhere (Martosubroto and Naamin 1977, Staples *et al.* 1985, Camacho and Bagarinao 1987). The Sundarbans water supports 208 species of fish and crustaceans belonging to 84 families (IUCN 1994), a higher total than that for other tropical mangroves (Robertson and Blaber 1992). The mean fish biomass is 39 kg/ha (Ahsanullah 1995), comparable to the *Rhizophora*-dominated forests of Malaysia (Sasekumar *et al.* 1994). Near-shore fisheries of Sundarbans ecosystem are believed to be over-exploited. The extensive use of destructive set bag nets is responsible for this in the estuarine and neritic waters. The magnitude of stock of fishery resources in Sundarbans waters has not been assessed systematically and there is very little information on their quality. The production figure gathered by the FD shows sharp fluctuations from year to year and can not be used to gauge possible availability of stocks. A prominent feature of the SRF fishery is that its size has been gradually expanding. The present production is about 12,000 MT, almost double from 10 yeas back. This expansion will need to be controlled if shell- and finfish stocks are to be conserved for the future. Without control, over-fishing will occur and stocks of the currently most heavily exploited species will crash. Fishermen will then target other, currently less desirable species, and under increased fishing pressure, these populations too will crash.

Catch control is based on determining the MSY of a fish stock and then setting a total allowable catch. The total allowable catch size can be adjusted from year to year based on the status of the stock in relation to MSY. Thus if the stock is depressed, a relatively low target would be set out to allow the stock to recover. Environmental and biological factors, in addition to the conventional socioeconomic factor also contribute in determining allowable catch. Fish stock assessment in the Sundarbans water can be made with data from the commercial fisheries rather than research vessel survey data. A long term fisheries data may contain facts reflecting extreme situation and then define the upper and lower limits for predictions of yield and stock size (Sparre and Venema 1992).

Inshore, estuarine and coastal fisheries of Sundarbans provide a major source of food and employment for about 200,000 fishermen operating daily in the Sundarbans water. Hilsa (*T. ilisha*) still represents about 15% of the total fish production of Bangladesh even after showing a declining trend over the last few years. Out of an annual total of 200,000 MT, nearly 400 MT come from the Sundarbans. Hilsa landing in SRF was reduced by 56% in recent years in comparison to 10 years back. The size of hilsa catch in SRF is probably dependent on the size of the stock in the northern Bay of Bengal and controlled by the factors which include the spawning migration. Long-term changes in biological behavior, particularly in spawning and migratory habits as a result of changes in the morphology and hydrology of the major river systems of Bangladesh, may be responsible for this. The capture of juvenile hilsa (*jatka*) is detrimental to the hilsa stock. It is highly probable that fishing mortality on the Sundarban's hilsa stock has little impact on recruitment of the main hilsa stock of the country.

Giant prawn *M. rosenbergii* is most valuable crustacean in Sundarbans water. It is not clear whether *M. rosenbergii* is being overexploited or not. However, a large numbers of juveniles (< 3 cm carapace length) are being harvested. The mud crab (*S. serrata*) is harvested on an increasing scale from the Sundarbans and is currently an export oriented lucrative business. The fishery has come under heavy fishing pressure in recent years and is considered to be overexploited. There is a significant price variation in the market which promotes some selectivity of the capture: berried female are more valuable than female without eggs, while males are least valuable. Females without egg are sold for fattening in ponds which then export as berried females. Mud crab fishing takes place throughout the SRF and about 30% of the catch year round is berried females. The potential of crab fishery seems to be vast and the prospects of its culture, just as with shrimp, need to be explored. During shrimp fry collection crab seed are indiscriminately destroyed. The presence of a high abundance of crab megalopa in Sundarbans water would allow for a new mud crab aquaculture grow-out industry to develop in addition to the current small crab fattening industry.

Coastal shrimp farming in Bangladesh by and large relies on the supply of wild fry, although sizable number of hatcheries are producing post-larvae (PL), however, the quality of PL could not ensure maximum production benefits. Though shrimp fry collection practice have offered a good source of income for coastal people, this practice brings substantial negative impacts on estuarine, marine fish and shrimp stock. Mass shrimp fry collection is a threat to the coastal ecosystem,

causing damage to the nursery grounds of many species, and to newly planted mangroves as well as to reserve forests (Saikat 1992). During last ten years, availability of most desired *P. monodon* PL has gradually decreased with the increased level of colossal loss in the coastal rivers as shown in Table 5.

The recruitment of other finfishes and shrimps, and macro-zooplanktons which act as a component of food chain for other groups of aquatic animals will severely hamper as a consequence of extensive *P. monodon* shrimp fry harvesting from the Sundarbans waters. It is essential for the shrimp fry to reach the small creeks and brackishwater of the estuaries to find shelter and food. The actual stock recruitment of shrimp in the deep sea is directly dependent on the survival of the juvenile in the mangrove nursery grounds and their return to sea. However, if the nursery grounds are reclaimed or the juveniles are captured resulting in drastic reduction of juveniles returning to the sea will lead to the scarcity of mature mother stock and eventually the total availability in the sea and in the estuary for breeding. From September 2000, collection of *P. monodon* PL as well as fish and crustacean larvae in coastal waters including SRF was prohibited by Presidential order, execution of which in practice is doubtful.

Management practices

Scientific management of forest resources was first initiated in the Sundarbans in the 1870s when a Forest Management Division was established exclusively for the management of Sundarbans in the Gangetic Delta. Fishery is a very large scale activity in the creeks and rivers of Sundarbans and is a major source of animal protein to forest dwellers as well as surrounding population. Sustained yield management of mangroves for forestry production is carried out by various countries, particularly in south-east Asia. Regarding sustained yield management of mangroves for coastal fisheries, the mangroves are kept for providing nutrients for increased productivity of fisheries, sheltering nursery grounds as permanent habitats and breeding grounds. A multiple-use management system or so called "Silvifishery system" is being operated in some Asian countries including Indian Sundarbans (BOBP 1990). The practice is that fish or shrimp ponds are constructed around mangrove plantations, and this method is successful in Indonesia (Soemodihardjo and Soerianegara 1989).

Mangrove forest management is based on the sciences and skills of geology, pedology, climatology, hydrology, botany, ecology, silviculture, forest technology and economics - in the selection and treatment of both wood and non-wood resource (FAO 1984). In Sundarbans, fishermen's practices contribute to the degradation of both wood and non-wood resources. About 90% of the boats that regularly enter the forest are small boats which require anchor posts. The FD permits boat owners to have one set of the anchor posts per year on payment of royalty. In practice, however, fishermen collect more than permitted. Normally they cut the mother trees of gewa and/or sundri. The larger boats do not require anchor posts, but do require poles for balancing their boats and vertical posts for tying up their cargo. Generally winter fishermen temporarily stay for sea fishing and fish drying in the islands of southern Sundarbans and use wood resources to build jetties, drying beds, shelters and also for cooking purposes.

Baseline information on the Sundarbans mangrove is still insufficient, especially on its relation to aquatic resources within the coastal zone. There is also a need to assess the extent of the use of SRF to quantify its economic benefits. Many Asian countries have established many tools that can provide better baseline information which includes remote sensing, GIS and environment impact assessment studies. Sundarbans is still behind in using such techniques. In the Sundarbans, all other products from the forest including timber, *Nypa* leaves, grasses, honey and bee wax, shells etc. are sold in small lots which allows anyone with a small capital to engage in these activities. There is no provision for allowing the grant of any concessions to large scale entrepreneurs. The exception is a paper mill which is allowed to harvest a predetermined quantity of *Excoecaria agallocha* pulpwood each year. Based on ecological as well as socioeconomic consideration different types of mangrove species needs to be managed. Mangrove resources adjoining the rivers systems and adjacent to the productive

Table 5. Colossal loss (%) of shell- and finfish for harvesting *P. monodon* PL in coastal waters of Bangladesh

Year	*P. Monodon*	Other shrimp	Finfishes	Macrozooplankton	References
1990	1.20	21.5	30.79	46.5	Deb *et al.* (1994)
1992	0.64	16.02	9.97	73.37	Rahman *et al.* (1996)
1995	0.49	13.16	3.19	83.16	Ahmed *et al.* (1998)
1996	0.17	7.6	2.11	90.12	Islam *et al.* (1999)
1999	0.17	17.2	7.19	75.44	Hoq *et al.* (2001)

nursery and fishing ground should be conserved. For maintaining the ecological balance, we need to ensure continuous use for minor forest products, ensure breeding, spawning and nursery ground of fishes and marine animals.

ACKNOWLEDGEMENTS

The partial funding from World Bank financed ARMP (Agricultural Research Management Project-FRI part) is greatly acknowledged.

REFERENCES

Ahmed SS, Alam MS, Rokeya JA and Islam MA 1998 Observation on the availability of shrimp fry (*Penaeus monodon*) in Khulna and Bagerhat region. Bangladesh J. Fish. 21(2): 71-75.

Ahsanullah M 1995 Fish harvesting and marketing. In: Integrated Resource Development of the Sundarbans Reserved Forest, Bangladesh (BGD/84/056)- Draft Final Report. FAO/UNDP, Khulna, Bangladesh. 82pp.

BOBP 1990 Silvipisciculture project in Sundarbans, West Bengal: A summary report of BOBP's assistance. BOBP/WP/62. Bay of Bengal Programme, Madras, India. 40pp.

Camacho AS and Bagarinao TU 1987 Impact of fish pond development on the mangrove ecosystem in the Philippines. In: Mangroves of Asia and the Pacific: Status and Management, Technical report UNDP/UNESCO Res. and Train. Pilot Prog. on Mangrove Ecosystems in Asia and the Pacific (RAS/79/002). National Resources Management Centre and National Mangrove Committee, Ministry of Natural Resources, Philippines. pp. 383-405.

Chantarasri S 1994 Fisheries resources management for the Sundarbans reserved forest. In: Integrated Resource Development of the Sundarbans Reserved Forest, Bangladesh (BGD/84/056)- 4th Draft Final Report. FAO/UNDP, Khulna, Bangladesh. 171pp.

Deb AK 1998 Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean & Coastal Management* 41: 63-88.

FAO 1984 Mangrove Forest Management Guidelines. Forestry Paper No. 117. Rome, FAO.

Hoq ME, Islam MN, Kamal M and Wahab MA 2001 Abundance and seasonal distribution of *Penaeus monodon* postlarvae in the Sundarbans mangrove, Bangladesh. Hydrobiologia 457: 97-104.

Islam MM, Rahman SL, Mazid MA and Halder GC 1995 Extent of damage on different crustacians and fin fishes in collecting *Penaeus monodon* post larvae in Satkhira coastal region. J. Mar. Biol. Assoc. India 38(1&2): 1-7

Islam MS, Islam MM and Ahmed SU 1999 Colossal loss of shell and fin-fish larvae during collection of *Penaeus monodon* (Fab.) fry in the rivers of Satkhira. Bangladesh J. Fish. Res. 3(1): 107-110

IUCN Bangladesh 2000 Red Book of Threatened Fishes of Bangladesh. IUCN- The World Conservation Union. 116 p.

IUCN- The World Conservation Union 1994 Mangroves of Sundarbans Volume Two: Bangladesh, (eds Z Hussain and G Acharya). IUCN- The World Conservation Union, Bangkok, Thailand. 230pp.

Macintosh DJ 1982 Fisheries and aquaculture significance of mangrove swamps, with special reference to the Indo-West Pacific region. In: Recent Advances in Aquaculture (eds JF Muir and RJ Roberts). Croom Helm, London. pp. 3-85.

Martosubroto P and Naamin N 1977 Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. Mar. Res. Indonesia 18: 81-86.

Pena MS 1994 Activity Report on Fishery Harvesting and Marketing. *In*: Integrated Resource Development of the Sundarbans Reserved Forest, Bangladesh (BGD/84/056). FAO/UNDP, Khulna, Bangladesh. 10pp.

Rabanal HR 1984 Fisheries integrated development in the Sundarbans. *In*: Integrated Development of the Sundarbans, Bangladesh- Report for TA Project (FO:TCP/BGD/2309). FAO, Rome. 28pp.

Rahman SL, Islam MM and Ahmed SU 1996 Extent of damage on different macro-aquatic zooplankters while collecting *Penaeus monodon* post-larvae in Khulna estuaries. The J. NOAMI **13**(1-2): 1-7.

Rajendran N and Kathiresan K 1999 Seasonal occurrence of juvenile prawn and environmental factors in a *Rhizophora* mangal, southeast coast of India. Hydrobiologia 394: 193-200.

Robertson AI and Blaber SJM 1992 Plankton, epibenthos and fish communities. In: Tropical Mangrove Ecosystem (eds AI Robertson and DM Alongi). Coastal and Estuarine Studies 41. American Geophysical Union, Washington D.C. pp. 173-224.

Saikat SQ 1992 Impact of shrimp seed collection. The Dhaka Courier 9(2), 14 August 1992. p7.

Sasekumar A, Chong VC, Lim KH and Singh HR 1994 The fish community of Matang mangrove waters, Malaysia. Proc. 3rd ASEAN-Australia symposium on Living Coastal Resources, Vol. 2: Research Papers (eds S Sudara, CR Wilkinson and LM Chou). Chulalongkorn University, Bangkok, Thailand. pp. 457-464.

Shahid MA and Islam J 2002 Impact of denudation of mangrove forest due to shrimp farming on coastal environment in Bangladesh. Paper presented in the BAU-NORAD workshop on environmental and socioeconomic impacts of shrimp farming in Bangladesh, Dhaka, 5 March 2002.

Smith TJ 1995 Integrated Resource Development of the Sundarbans Reserve Forest, Bangladesh (Further analysis of fisheries data, BGD/84/056, FAO/UNDP). Khulna University, Khulna, Bangladesh. 45 pp.

Soemodihardjo S and Soerianegara I 1989 Indonesia (country report). In: Mangrove management: its ecological and economic considerations. BIOTROP Special publication No. 37. SAEMED-BIOTROP. Bogor, Indonesia.

Sparre P and Venema SC 1992 Introduction to tropical fish stock assessment. FAO Fish. Tech. Paper 306/1, 2: 62 pp.

Staples DJ, Vance DJ and Heales DS 1985 Habitat requirements of juvenile penaeid prawns and their relationship of offshore fishes. In: Second Australian National Prawn Seminar (eds PC Rothlisberg, BJ Hill and DJ Staples). NPS2, Cleveland, Australia. pp. 47-54.

Tzeng W-N and Wang Y-T 1992 Structure, composition and seasonal dynamics of the larval and juvenile fish community in the mangrove estuary of Tanshui river, Taiwan. Mar. Biol. 113: 481-490.