Impact of Overexploitation of Shellfish: Northeastern Coast of India

Author(s): Asokkumar Bhattacharya and Santosh Kumar Sarkar
Source: AMBIO: A Journal of the Human Environment, 32(1):70-75. 2003.
Published By: Royal Swedish Academy of Sciences
DOI: http://dx.doi.org/10.1579/0044-7447-32.1.70
URL: http://www.bioone.org/doi/full/10.1579/0044-7447-32.1.70

Article

Asokkumar Bhattacharya and Santosh Kumar Sarkar

Impact of Overexploitation of Shellfish: Northeastern Coast of India

India has a very extensive coastline of about 7515 km, rich in diverse living resources. These resources continue to deteriorate with rampant harvesting or are altered for other uses such as aquaculture and fisheries. The present paper deals with degrading coastal habitats in northeastern India, and projects the intensity of the stress arising from the collection of tiger prawn seeds (*Penaeus monodon*) for aquacultural farms and molluskan shells for poultry feed and edible lime. Indiscriminate exploitation of these resources leads to a heavy reduction of the species concerned and other associated marine communities. The magnitude of such destruction has been quantified. The impacts of biodiversity loss and their after-effects on the ecobalance of this coastal system have become a matter of great concern to ecologists to maintain security and sustainability. The authors propose a public awareness program on themes relating to the importance of biodiversity for human livelihoods.

INTRODUCTION

Biological diversity or biodiversity, is a fundamental property of the structure and function of ecosystems. It is a cluster of concepts (1) encompassing many interrelated aspects, from genetics and molecular biology to community structure and habitat heterogeneity (2). Ecologists measure diversity by a number of indices all of which relate, more or less directly, the number of species to abundance and/or numerical dominance (3). Variability among individual species responses is consistent with a positive, but idiosyncratic pattern of ecosystem function with increased diversity (4). The Earth's biological diversity provides both economic and social benefits to mankind. Effective programs for sustaining biological diversity must, therefore, incorporate conservation objectives (5).

With a coastline of about 7515 km, an exclusive economic zone (EEZ) of 2 014 900 km^2, and a shelf area of 452 100 km^2, India is recognized as one of the 12 megabiodiversity countries of the world and is divided into 10 biogeographic regions (6). The Indian coast with its diverse geomorphic set up, with rocky, sandy and muddy systems and diversified habitats harbors a wide array of flora and fauna, many of which are endemic (7). The present study area is confined to 400-km long coastal zone of West Bengal and Orissa, the 2 maritime states of northeastern India (Fig. 1). The West Bengal coast supports the Indian Sundarbans (21°32' to 22°40' N and 88°85' N to 89°00' E) at the apex of the Bay of Bengal. The Sundarbans is regarded as the natural treasure house of biological resources. Situated in the low-lying, meso-macrotidal, humid and tropical belt, the Sundarbans harbors a luxuriant mangrove chunk together with associated flora and fauna. Furthermore, geomorphologically, the coastal zone of West Bengal (ca. 220 km) is characterized by sandy deltaic beaches, muddy tidal flats, mangrove swamps, sea

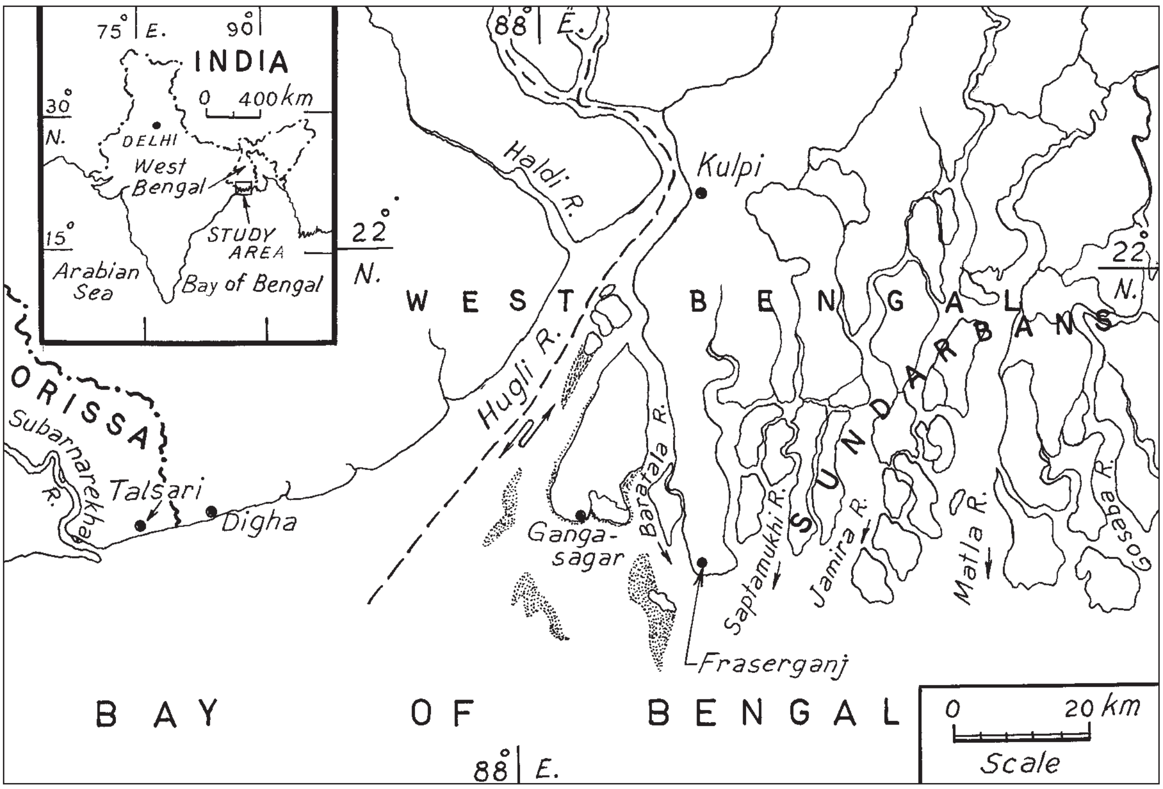

Figure 1. Map of coastal areas of West Bengal and Orissa showing sites mentioned in the text.

The size-classified shells are heaped up before crushing. Bags containing crushed shells are stacked for transportation. Photo: A. Bhattacharya.

grass and algal beds, tidal creeks and estuaries each having definite ecological characteristics. These complex ecosystems play a major role in supporting local people with food, cash, and energy (8).

The Orissa coast adjacent to the state of West Bengal is mesotidal and is characterized by beach-related tidal flats bordering tidal creek systems. Marsh vegetation occupies the upper mudflats. A succession of macrobenthic communities develops from the upper to the lower mudflats and these include ghost shrimps (crustacean), polychaetes (annelida), bivalves and gastropods (mollusks) (9). A stretch of about 180 km of the Orissa coast (21°37' N; 87°25' E) bordering the Bay of Bengal was the subject of the present study. The coastal zone of the state of Orissa including Asia's largest brackishwater tidal Chilka lagoon, is recognized as one of the hotspots of biodiversity in India (10). It is known as a large wintering ground for migratory waterfowl, several rare, and vulnerable and endangered species listed in the IUCN Red List of Threatened Animals. This zone belongs to a highly productive ecosystem with rich fishery resources. More than 100 000 fishermen depend on the natural resources of Chilka lagoon for their subsistence(10).

These coastal environs of the northeastern states of India are facing enormous pressure directly or indirectly from human interference. This phenomenon of environmental stress, leading eventually to environmental degradation, appears inevitable and is expected to continue unchecked if some short- and long-term measures are not implemented without delay. The local inhabitants of Sundarbans, West Bengal, because of extremely poor socioeconomic conditions, are disturbing the delicate natural balance of the coastal ecosystems by overharvesting natural resources. For the last few decades, the productive coast of Orissa, has also been experiencing signs of degradation due to siltation and overexploitation of natural resources (11).

Among the wide array of diverse animal communities on these coasts, many species and genera are endemic, including some monotypic species (i.e. with only a single species in a genus). Many of these endemic species are of special value for both commercial fisheries and scientific research. Shellfish and finfish, the essential components of ecosystem health in this coastal belt, are endangered due to indiscriminate exploitation (12, 13). With rapidly increasing population growth, destruction of sensitive habitats and the resultant loss of biodiversity in the coastal areas of West Bengal and Orissa, there is a need for more integrated studies that will provide information for the beneficiaries and effective coastal zone management. This paper discusses and suggests strategies for managing the use of coastal resources through an integrated approach. The coastal zone is presented as a unified ecosystem because of the interlinkages between different habitats.

The climatic domain of this coastal zone is tropical oceanic. Monthly air temperature in winter ranges from 12° to 25°C and in summer from 26° to 36°C. Relative humidity ranges from 78–90%. Annual rainfall ranges from 1480–2209 mm. Tide is semidiurnal with slight diurnal inequality. Tropical cyclones affect the coastal zone 3-4 times every year. Littoral drift is eastward. Very often cyclones initiate large-scale littoral drift.

WILD PRAWN SEED COLLECTION

The commercial prawns of India can be grouped into penaeid and nonpenaeid ones. The omnivorous tiger prawn *Penaeus monodon*, the largest Indian marine penaeid prawn, is a very important commercial species supporting the export industry of marine prawn fishery in India (14). This species is common along the east coast of India, especially along the West Bengal and Orissa coasts and all along the west coast of the subcontinent (14). They spawn throughout the year and show special abundance during the new moon fortnight (15). Postlarvae of this prawn, measuring 9-14 mm, enter the Hugli estuary of West Bengal (Fig. 1) throughout the year with peaks during September/October.

The estuarine system with its intricate network of inlets and the creeks of Sundarbans mingled with thick mangrove foliage, offer excellent nursery grounds for most of the euryhaline finfish and shellfish. Millions of tiny larvae, postlarvae and juveniles enter the ecosystem with the high tides. The collection of prawn seed and other encountered species is a year round phenomenon and can be divided into 3 seasonal activities; premonsoonal (March to June), monsoonal (July to October), and postmonsoonal (November to February) catches carried out. Seed collection is done by 95% of the local inhabitants with the peak period during September–October when 2000–2800 prawn seeds are caught by a person in one day. During this season, salinity drops abruptly (2.5–3.8‰) and the optimum salinity of the water inside the aluminum containers (capacity 30 L) in which the seeds are collected, is maintained by adding common salt. This crude process helps to reduce the mortality rate of the collected seed. Data obtained from field surveys revealed that as many as 70% of the local fishermen spend 4–5 hrs day^{-1} collecting seeds throughout the year.

For the purpose of seed collection of mobile net gear, including shoot net and drag nets, is the most effective. However, 90% of the working fishermen cannot use such gear because of the expense. Stationary gear with specific mesh size is used to trap the postlarval stage PL20 of *P. monodon*. The major portion of the haul containing the juveniles of several species of finfish and shellfish (Table 1) is discarded on the tidal mudflats or beachflats. The data cited in Table 1 are a cumulative representation of the major finfish and shellfish collected seasonally during the period 1996–2000. The by-catch includes a wide variety of holoplankters (copepods, mysids, chaetognaths and lucifers) and crustacean meroplankters (decapod larvae, megalopa, alima larvae, and anomuran larvae).

The specific stage of the post-larvae of *P. monodon* (9–14 mm in length) is readily identified by the presence of a red streak along the entire ventral side of the abdomen. The randomly collected samples were sorted and enumerated directly. Our study records collection of prawn seeds along with their respective costs from Gangasagar at the mouth of the Hugli river during 1996–2000 (Fig. 1; Table 2). Surveys are made twice monthly, i.e. a total of 8 days per season. The authors interviewed the seed collectors and transporters in 3 different seasons to obtain an account of the catch size rate of seed transportation, rate of seed mortality, and income incurred in the process. After collection, segregation of tiger prawn seed is mostly done by the females and children before transportation.

The fishermen mostly store the assorted seed in large aluminum containers (10–15 L capacity). From the segregation stage to trade, the mortality rate is about 40%, because of inappropriate handling and transportation difficulties. A rough estimate shows that there are more than 50 000 seed collectors engaged in *P. monodon* seed collection from various estuarine creeks in the Sundarbans. Bhoumik et al. (16) observed 5000 seed collectors, operating 7000 nets in the collection of *P. monodon* postlarvae in the upper stretch of the Hugli river around

Table 1. List of encountered species of finfish and shellfish from Gangasagar in the western part of Sundarbans, West Bengal.

Finfish	Shellfish
Reconda russeliana Gray	*Metapenaeus monoceros* (Fabricius)
Cynoglossus arel Bloch and Schneider	*M. lysianassa* (de-Man)
Liza tade (Forsskal)	*M. brevicornis* (H.Milne-Edwards)
L. parsia (Hamilton)	*Palaemon tenuipes* (Henderson)
Leiognathus daura (Cuvier)	*Parapenaeopsis stylifera* (H.Milne Edwards)
Setipinna phasa (Hamilton-Buchanan)	*Acetes indicus* (H.Milne Edwards)
Corica soborna Hamilton-Buchanan	*Penaeus indicus* H.Milne Edwards
Ophisthopterus tardoore (Cuvier)	*Alphaeus* sp.
Colia dussumieri Valenciennes	
Stolephorus buccaneeri Strasburg	
Strongylura strongylura (Van Hasseelt)	
Neenchelys buitendijki Weber and de Beaufort	
Pama pama (Hamilton)	
Pellonaditchela sp.	
Anguilla bengalensis bengalensis (Gray and Hardwicke)	

Table 2. Annual variations (average of premonsoon, monsoon and postmonsoon season) in collection, transport, rate of mortality, and amount paid for collection of prawn seeds from tidal water of Gangasagar, Sundarbans.

Year	Average no. of seeds captured per person per day	Average no. of seeds collected per transporter per day	Total no. of seeds transported per day	Average mortality rate of seeds (%) per 1000	Payment for 1000 prawn seeds (Rs.)[a]
1996	1088 ± 289	42 000 ± 7316	128 000 ± 4898	85 ± 13	1245 ± 67
1997	764 ± 75	24 000 ± 5052	85 000 ± 6794	52 ± 19	1548 ± 94
1998	538 ± 76	9000 ± 2028	110 000 ± 9495	12 ± 2	1285 ± 116
1999	128 ± 41	5000 ± 2503	44 000 ± 5052	22 ± 4	870 ± 160
2000	86 ± 32	7000 ± 1492	34 000 ± 2379	34 ± 4	1125 ± 160

[a] 1 USD = Rs. 50.

Kulpi (Fig. 1), another collection center in Sundarbans. Total annual collection of *P. monodon* seed by these fishermen is estimated to be around 429 million. Such intensive prawn seed collection activity has resulted in a manifold decrease in the catch net^{-1} hr^{-1} as revealed by the calender of brackish water fish and prawn availability (17, 18).

ADVERSE IMPACTS

The seed collectors retain only the seeds of tiger shrimp (target species) and discard the by-catches. This results in indiscriminate killing of huge numbers of juvenile finfish, shellfish (non-target species) and other commercially and ecologically important species. The present study reveals that in order to catch 9586 tiger prawn seeds, collectors destroy approximately 1 562 862 juveniles of other prawn species, 56 000 fishes, 1.9 million crabs, 8000 mollusks and a huge bulk of holoplankters (copepods, chaetognaths, mysids, lucifers etc.) and meroplankters (megalopa, alima and anomuran larvae). This results in potentially negative effects on the offshore demersal fishery. Such a magnitude of destruction has also been reported from other regions of Sundarbans (19). The destruction of seed of finfish and shellfish has been estimated at a total of 454.6 million during the collection seasons in a year. It has further been assessed that only 0.25–0.27% of the total biota is being taken care of by the seed collectors for onward transmission to the aquaculture farms. This magnitude of loss of valuable larvae of pelagic biota, *inter alia*, would lead to severe stock depletion that would obviously hamper the energy transference through the food webs in this marine ecosystem (20).

It is evident from field studies that constant dragging of nets along the coast and tidal creeks leads to soil erosion, uprooting the mangrove seedlings and saltmarsh vegetation like *Ipomea pescarpae* (Chagal kuri), *Sueda maritima* (Gira saak), *Salicornia* sp. In addition, due to direct and prolonged contact with the seawater, the male and female collectors develop occupational hazards like waterborne diseases, skin infections, reproductive tract disease (in females) and many other contiguous diseases. Injuries due to shark bites (locally called '*commot*') are also common among those associated with the profession.

As a result of human pressure, the population density and diversity of the macrobenthos (e.g. polychaetes, sipunculids, echiroids, nermertines, gastropods and bivalve mollusks) and meiobenthos (harpacticoid copepods, cumaceans, gastrotrichs etc.,) in this coastal zone are being depleted every year. This decrease has an adverse impact on the population of coastal birds, since the macrobenthos serve as a major source of their food (21).

With growing aquaculture farms there has been a dramatic increase in the number of local people engaged in the collection of prawn seeds. The supply of seeds, thus, has become a lucrative trade since the 1980s because of an ever-increasing demand for seeds, a high market price of the seeds throughout the year, particularly in the monsoon months when the availability of seeds becomes scarce and easy and nontechnical means of netting decrease. These have led to overexploitation of the seeds together with colossal wastage of the by-catches.

OTHER CAUSES FOR DEPLETION OF PRAWN AND FISH SEED RESOURCES

The installation of Farakka barrage in 1975, across the river Ganges (upper stretch of Hugli river) for management of water resources of the two neighboring countries India and Bangladesh, brought about dramatic changes in the salinity of coastal waters. This appears to be a major reason for the decreased abundance of prawn and fish seeds in the coastal waters of Sundarbans during the post-Farakka barrage period than in the pre-Farakka period. The information on the greater availability of commercially important prawn and fish seed in the estuaries of Sundarbans during pre-Farakka barrage period has been reported by many authors (22–25). The rate of exploitation during the pre-Farakka period was also relatively low and, thus, its effect on the ecosystem was not too serious. However, due to the rapid increase in population and the poor socioeconomic conditions of the local people, the rate of exploitation has increased during the last two decades.

BIVALVE SHELLS: COLLECTION AND PROCESSING

Marine bivalves (mussels, cockles, oysters and clams) constitute a major community and occur within a wide range of bathymetric depths extending from the shallow intertidal sandflat and mudflat complexes to the offshore mud bottom. Many of these species, e.g. *Meretrix meretrix*, *Pelecyora trigona* are surface grazers, while others such as *Macoma birmanica* burrow into the substrate. Bivalve shells are generally collected by netting from the offshore areas and by hand-picking from intertidal flats. The shells are mainly exploited by the coastal inhabitants for preparation of poultry feed and edible lime. For the manufacture of food for the poultry fowl, the shells are scattered on the ground for sun-drying so that the viscera and other soft portion can be removed easily. The thin-valved shells are then mixed with the thick-valved shells (Table 3) at a ratio of 4:1. These bivalves were seasonally collected by the authors from the crushing site for species identification in the laboratory. The total qualitative assessment of these species has been shown in Table 3, in which there is a list of 9 thick-shelled species and 8 thin-shelled species. The mixed dry shells are then crushed by a crusher and sieved into different sizes. These raw crushed shell materials are then packed in 50 kg bags and sent to different centers where they are mixed with dry fish (*Chanda* sp.), crushed wheat or maize and molasses to prepare the finished food for poultry fowl.

It is estimated that a person involved in collection of 100 kg of live bivalves for commercial use, receives a wage of Rs. 75 (USD 1.5) per working day, which is far below the cost of living. Data collected from Talsari, Orissa, revealed that the selling price of one quintal of crushed shell material is Rs. 300 (USD 6). There are 3 crushers at Talsari which work for 8–9 hours a day almost throughout the year excluding the monsoon months. During the peak monsoon months (August and September), when the availability of the bivalve shells falls, the rate of crushing work also declines. In addition to the preparation of poultry feed, the manufacture of edible lime (CaO) for local consumption is also an age-old practice in this coastal area. Here also the bivalve shells are exploited, cleaned and burnt in local indigenous kilns for the manufacture of lime.

ADVERSE IMPACTS

Because of rampant and indiscriminate harvesting, populations of this group of organisms are threatened and a marked decline in their number has been obvious for the last two decades. The mudflat of Talsari has experienced a severe decline in the popu-

Table 3. List of bivalve species being used in the processing of poultry feed.

Thick-shelled species	Thin-shelled species
Meretrix meretrix (Linnaeus)	*Paphia undulata* (Born)
M. casta Gmelin	*Macoma birmanica* (Philippi)
Saccostrea cucullata (Born)	*Scapharca deyrollee* (Joussearme)
S. gryphoides (Schlotheim)	*Barnea candida* (Linnaeus)
Marcia pinguis (Scgrieter)	*Donax scortum* (Linnaeus)
Anadara granosa (Linnaeus)	*D. incarnatus* (Gmelon)
Pinctada anomiodes (Reeve)	*Glauconome sculpta* Sowerby
Pelecyora trigona (Reeve)	*Pholas* sp.
Mactra luzonica Deshayes	

lation of *M. meretrix*, the target species in this area. It was relatively abundant, i.e. 15–20 m^{-2}, during 1995–1996. This number had declined to 2–5 m^{-2} toward the end of 2000. The anthropogenic stresses originating from harvesting of bivalves, intense trawling, fishing and tourism in this area are jeopardizing not only the local environment, but have also led to total extinction of target species from some densely populated pockets during the last 5 years.

Bivalves also play a significant role as a major benthic-pelagic coupling mechanism and have a number of good indicator and biomonitoring species (26, 27). They act as "ecosystem engineers" (28, 29) and indirectly modulate the availability of resources to other species, by causing a physical change in biotic and abiotic materials. In doing so, these engineering organisms modify, maintain, and create habitats. Because of their rapid response and sensitivity to environmental change, they are good environment impact indicators and are important in the sustainability of ecosystems (12). The adverse effects of excessive harvesting of these important bivalves from this coastal zone are obvious. This practice of overfishing alters the organization and structure of the marine communities through cascading trophic chain reactions (30, 31).

CONSERVATION STRATEGY

From the above discussion it is clear that habitat destruction and degradation, overexploitation of coastal resources and recent emphasis on unplanned coastal aquaculture in Sundarbans are major threats to faunal diversity on this coast. Construction of unplanned and unauthorized structures for the tourist industry and growing townships also offer serious threats to this highly susceptible and fragile environment. However, a number of preventive measures may be undertaken to mitigate those problems that are related to the socioeconomic situation of the coastal people.

Socioeconomic Aspects

Population control

Rapidly growing population (> 110 million persons in the deltaic areas of India and Bangladesh) is a key factor in Sundarbans and is an important issue in reserve management strategies. The main occupation of many of the local people is harvesting and hunting natural resources. This sharp increase in population growth is a serious threat to the existing natural resources. Education, family planning measures and economic incentives for local inhabitants without impinging on their coast-dependent activities is necessary. Again, many beach resorts on the coast of the Bay of Bengal have a seasonal population growth because of a religious fair and tourism-related campaign programs. These areas include Talsari (Orissa), Digha, Gangasagar and Fraserganj (West Bengal).

The town and hotel effluents in these areas are often disposed directly into the coastal marine environment without treatment. Thus, biodiversity on this coast is affected by *i*) indiscriminate exploitation of natural resources; and *ii*) effluent-borne pollutants. The untreated effluents discharged from the jute mills, textile and tannery industries, thermal power stations and oil factories of West Bengal into the Hugli river settle in the estuarine and river mouth regions. The concentration of pesticides and other halogenated hydrocarbons is also known to be much higher in the eastern coast of India (32), and these chemicals are transported through the Hugli drainage basin to the lower deltaic plains. Biodiversity conservation will only be possible if the stakeholders are sensitive to these issues and if they adopt awareness and treatment measures.

Developing local economy and increasing incomes for local people

The most important reason for biodiversity loss is anthropogenic, and this is related to the poor economic conditions of the local inhabitants. Therefore, developing local economies and improving socioeconomic structures, within the framework of sustainable use of natural resources, is a key factor in biodiversity conservation. Introduction of algal and mushroom culture, apiculture, livestock rearing, fruit growing, kitchen gardening, and fish culture in ditches and small ponds, could be effective in developing local economies, and are ecofriendly (33, 34). In addition, these are not exclusively coast-dependent. Financial and infrastructural facilities from government and nongovernmental agencies may encourage alternative means of livelihood for the local inhabitants, irrespective of caste, creed, age or sex.

Improving local environment education system

Due to the lack of knowledge about biodiversity conservation, the majority of the local population knows very little about the consequences of biodiversity loss. Thus, more attention should be given to the education of the rural children and adults about the conservation of ecosystems. The implementation of informal education within the formal education system is growing in India, but is still not adequate and yet to achieve its holistic and interdisciplinary objectives. Nonformal environmental education is of great value particularly to the illiterate and economically backward people of Sundarbans. This may be encouraged by arranging visits to nature parks and biodiversity exhibits (35).

Building awareness of the marine environment

The issues involved in the exploitation of the coastal marine environment are complex and may result in user conflicts. Sometimes, it becomes difficult to manage marine resources by means of law only because of the multiplicity of the issues. The problems that hamper awareness building include inadequate information, lack of motivated and educated personnel and lack of campaigning facilities due to inaccesibilities in many parts of the coastal zone.

Considering the magnitude of the problems the authors suggest formulation of public awareness programs for educating the users about the sustainable use of living and nonliving resources by holding workshops/seminars, exhibitions and with the help of translated educational resource materials using models, charts, audiovisual play, etc. (36). Simultaneously, field demonstrations may be arranged to explain the adverse effects of overexploitation on natural systems. The local people should also be motivated not to destroy endangered species. They should also be made aware of the prevailing legislative processes and of the advantages of following them.

This approach would have a positive impact on the protection of endangered species as well as on ecological conservation and the economic viability of coastal environs. Environmental education is an effective tool for coastal resource management, and should be interactive and participatory.

Scientific Aspects

It is imperative that sales of bivalve shells and prawn seeds should be reduced until sufficient data on ecology and population dynamics are known. Random activities of trawling in the coastal waters of West Bengal and Orissa have detrimental effects not only on soft-bottom community structures and habitats, but also have negative consequences for the socioeconomic conditions of the coastal people. Other adverse effects of trawling include modification of bottom-topography, increment of turbidity and a rise in the mortality rate of nontarget species (37, 38). Legislation needs to be framed and executed immediately to protect these valuable resources. This should not only protect the nursery and spawning grounds, but also lessen conflicts between owners of commercial fishing trawlers and low-income group fishermen using drift and dragnets. Biodiversity is lost when habitats are destroyed. Therefore, ways of slowing habitat degradation by dredging and trawling have to be worked out.

In order to improve our understanding of the coastal resources of West Bengal and Orissa, scientific and other investigations should be taken into consideration as listed below:

– Detailed bio-ecological survey of endangered and commercially important species.
– Community-based socioeconomic survey of the local user groups.
– Scientific evaluation of the existing resources and the carrying capacity of the ecosystem.
– Formulation of effective conservation and sustainable use of resources through interactive and participatory processes.
– Restoration of degraded zones by natural and artificial means of engineering construction.
– Aquaculture research to be encouraged considering ecological conditions, institutional issues and socioeconomic settings.
– Organization of interdisciplinary programs involving governmental and nongovernmental officials and local communities.

CONCLUSIONS

The natural resources of the coasts of West Bengal and Orissa are being overexploitated, due to population growth, poverty, illiteracy, and poor awareness. As a result, there has been a drastic reduction in species richness and distribution of the existing communities. Many of the species have been identified as endangered or threatened and some are already extinct (7, 8, 10, 11, 19). In the process of exploitation of the target species—bivalve mollusks and tiger prawns—other associated nontarget species are also affected together with destruction and modification of sensitive habitats. To achieve short-term gains the coastal people are extracting and exploiting natural resources excessively. Concentration is especially on overexploiting the shellfish that are abundantly available in the coastal zone. Year-round activities related to prawn seed and live molluskan shell collection have led to alarming stock depletion. Due to the prevailing grave situation, we propose implementation of certain immediate protective, conservation measures and the sustainable use of the resources. Legislation and mass awareness programs are recommended as necessary tools to save this coastal environment.

References and Notes

1. Contoli, L. 1991. Diversita biologica. *SltE Notizie 12*, 19–22. (In Italian).
2. Battaglia, B. 1996. La biodiversita marina a livello intraspecifico. *Biol. Mar. Mediter. 3*, 1–12. (In Italian).
3. Magurran, A.E. 1988. *Ecological Diversity and Its Measurement*. Croom Helm, London.
4. Emmerson, M.C., Solan, M., Emes, C., Peterson, D.M., and Raffaell, D. 2001. Consistent patterns and the idiosyncratic effects of biodiversity in marine ecosystem. *Nature 3*, 73–77.
5. Groombridge, B. 1992. *Global Biodiversity, Status of the Earth's Living Resources*. Chapman and Hall, London.
6. Sarat Babu, G.V. 1999. Hotspots of biodiversity. *Enviro News 3*, 3–6.
7. Anon, 1995. *Hugli Matla Estuary West Bengal*. Director, Zoological Survey of India, Calcutta (ed.). Estuarine Ecosystem Series, Part 2.
8. Guha Bakkkshi, D.N., Sanyal, P. and Naskar, K.R. (eds). 1999. *Sundarbans Mangal*. Naya Prakash, Calcutta, India.
9. Bhattacharya, A. and Sarkar, S.K. 1997. Saltmarsh and mesotidal beach facies from the coastal zone. *Proc. International Conference in Ocean Engineering*. Allied Publishers, India, 475– 479.
10. Pattanaik, A.K. 2000. Conservation of Chilka—an overview. *Chilka Newsletter 1*, 3–5.
11. Trisal, C.L. 2000. Sustainable development and biodiversity conservation of Chilka lagoon. *Chilka Newsletter 1*, 6–8.
12. Dame, R.F. 1996. *Ecology of Marine Bivalves—An Ecosystem Approach*. CRC Press, Boca Raton, Florida.
13. Das, G. and Bhattacharya, A.K. 1999. Rampant exploitation of post-larval penaeid prawn (*Penaeus monodon*) from the salt water courses of the deltaic Sundarbans, West Bengal—a threat to the balance of nature. *J. Indian Soc. Coastal Agric. Res. 17*, 373–386.
14. Kurian, C.V. and Sebastian, V. 1982. *Prawn and Prawn Fisheries of India*. Hindustan Publishing Corporation, Delhi, India.
15. Subrahmanyan, M. 1967. Further observations on lunar periodicity to the prawn abundance in the Godavari estuarine system. *J. Mar. Biol. Ass. India 9*, 111–115.
16. Bhoumik, U., Saha, S. and Chatterjee, J.G. 1991. Need for conservation to protect the brackishwater finfish and shellfish seed resources in Sunderbans. *Environ. Ecol. 10*, 919–922.
17. Anon, 1991. *Brackishwater Prawn Seed Resource, Survey in South 24 Parganas District*. Department of Fisheries, Government of West Bengal.
18. Saha, G.N., Thakurta, S.C., Laha, G.C., Nandy, A.C., Karmakar, H.C., Naskar, K.R., Das, P.B. and Chatterjee, S.K. 1986. Ecology and fishery management in brackishwater bheries in West Bengal, Technical Bulletin, *CIFRI, Barrackpore, West Bengal*, *46*. 1–23.
19. Das, A.K. and Nandi, N.C. 1999. Fauna of Sundarban biosphere reserve. *Enviro News 3*, 7–8.
20. Brown, B.E. 1997. *Integrated Coastal Management: South Asia*. Department for International Development.
21. Das, A.K. and Nandy, N.C. 1999. Fauna of the Indian Sundarbans Mangal and their role in the ecosystem. In: *Sundarbans Mangal*. Guha Bakshi, D.N., Sanyal, P. and Naskar, K.R. (eds). Naya Prakash, Calcutta, India, pp. 417–427.
22. Gopalkrishnan, V. 1968. Collection of brackishwater fish seed from the Hugli estuary. In: *Proc. Seminar on Production of Quality of Fish Seed for Fish Culture*, Centre Inland Fisheries Research Institute, Indian Council of Agricultural Research, Barrackpore, West Bengal, pp. 232–247.
23. Bhanot, K.K. 1971. Observations on the availability of brackishwater fish seed in the Matlah estuary around Port Canning. *J. Mar. Biol. Ass. India 13*, 274–278.
24. De, D.K. 1977. On the procurement and transportation of chapra, *Penaeus indicus* (H.Milne Edwards) under oxygen packing. *J. Mar. Biol. Ass. India 13*, 184–190.
25. De, D.K., Chakaraborty, R.K. and Subramanian, M. 1978. Preliminary survey on the availability of culturable brackishwater prawn seed in the Haldia estuary around Baughata, West Bengal. *J. Inland Fish. Soc. India 10*, 142–143.
26. Sarkar, S.K. and Bhattacharya, B. 1994. The suitability of tropical marine bivalves as biomonitors of heavy metals in deltaic Sundarbans, northeast India. *Chemosphere 29*, 759–770.
27. Sarkar, S.K., Bhattacharya, B. Debnath, S. and Bhattacharya, A. 1996. *Meretrix meretrix*: a biological monitor of coastal pollution. *Proc. International Conf. on Ocean Engineering*. Allied Publishers, India, pp. 480–484.
28. Lawton, J.H. and Jones, C.G. 1995. Linking species and ecosystems: Organisms as ecosystem engineers. In: *Linking Species and Ecosystems*. Jones, C.G. and Lawton, J.H. (eds), Chapman and Hall, New York, pp. 141–150.
29. Jones, C.G., Lawton, J.H. and Shachak, M. 1994. Organisms as ecosystem engineers. *Oikos 69*, 37 –386.
30. Hay, M.E. 1984. Patterns of fish and urchin grazing on Caribbean coral reefs : are previous results typical ? *Ecology 65*, 446–454.
31. Sala, E., Boudouresque, C.F. and Harmelin-Vivien, M. 1998. Fishing, trophic cascades, and the structure of algal assemblages: evaluation of an old but untested paradigm. *Oikos 83*, 15.
32. DarsanKumar, H. and Hader, D. 1999. *Global Aquatic and Atmospheric Environment*. Springer– Verlag.
33. Sarkar, N. 1999. Mushroom cultivation—new potential for rural economy. In: *Sundarbans Mangal*. Guha Bakshi, D.N., Sanyal, P. and Naskar, K.R. (eds). Naya Prakash, Calcutta, India, pp. 712–718.
34. Mukherjee, K.D. 1999. Scope and possibilities of apiculture in the mangrove reclaimed areas of the Sundarbans. In: *Sundarbans Mangal*. Guha Bakshi, D.N., Sanyal, P. and Naskar, K.R. (eds). Naya Prakash, Calcutta, India, pp. 719–734.
35. Bagarinao, T. 1998. Nature parks, museums, gardens and zoos for biodiversity conservation and environment education. *Ambio 27*, 230–236.
36. Lenzen, M. 2001. The importance of goods and services consumption in household greenhouse gas calculators. *Ambio 30*, 439–442.
37. Dayton, P.K., Thursh, S.F., Agardy, M.T. and Hoffman, R.J. 1995. Environmental effects of marine fishing. *Aquat. Cons. Mar. Freshw. Ecosystem 5*, 205–232.
38. Peterson, C.H., Summerson, H.C. and Fegley, S.R. 1987. Ecological consequences of mechanical harvesting of clams. *Fish. Bull. 85*, 281–298.

39. We are specially indebted to the two anonymous referees and Editorial Board of Ambio for the improvement of the manuscript with their valuable suggestions and comments.
40. First submitted 10 Sept. 2001. Accepted for publication after revision 11 Febr. 2002.

Asokkumar Bhattacharya is professor and Head of the Department of Marine Science at the University of Calcutta. He has special interest in coastal geomorphology and sedimentology. Professor Bhattacharya has a PhD in fluvial sedimentology. He discovered nontidal fleser bedding, swash- and -backwash ripples and current crescents lacking preservation of obstacles from the fluvial and beach environments. His address: Department of Marine Science, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019, India.
E-mail: akb_marine@yahoo.co.in

Santosh Kumar Sarkar is a Reader at the Department of Marine Science, University of Calcutta. His research interest is in the biodiversity of marine zooplankton and macrozoobenthos. He has a PhD in ecology of estuarine zooplankton and has particular interest in biotic interactions and resource constraints. He has identified bivalve mollusks as a bioindicator of heavy metal contamination. His address: Department of Marine Science, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019, India.
E-mail: sarkar22@yahoo.com