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REVIEW PAPER

Fishing for Prawn Larvae in Bangladesh: An Important Coastal Livelihood Causing Negative Effects on the Environment

Nesar Ahmed · Max Troell

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Abstract Freshwater prawn (*Macrobrachium rosenbergii*) farming in Bangladesh has, to a large extent, been dependent on the supply of wild larvae. Although there are 81 freshwater prawn hatcheries in the country, a lack of technical knowledge, inadequate skilled manpower, and an insufficient supply of wild broods have limited hatchery production. Many thousands of coastal poor people, including women, are engaged in fishing for wild prawn larvae along the coastline during a few months each year. On average, 40% of the total yearly income for these people comes from prawn larvae fishing activity. However, indiscriminate fishing of wild larvae, with high levels of bycatch of juvenile fish and crustaceans, may impact negatively on production and biodiversity in coastal ecosystems. This concern has provoked the imposition of restrictions on larvae collection. The ban has, however, not been firmly enforced because of the limited availability of hatchery-raised larvae, the lack of an alternative livelihood for people involved in larvae fishing, and weak enforcement power. This article discusses the environmental and social consequences of prawn larvae fishing and concludes that, by increasing awareness among fry fishers, improving fishing techniques (reducing bycatch mortality), and improving the survival of fry in the market chain, a temporal ban may be a prudent measure when considering the potential negative impacts of bycatch. However, it also suggests that more research is needed to find out about the impact of larvae fishing on nontarget organisms and on the populations of targeted species.

Keywords Prawn · Larvae · Fishing · Coastal · Environment · Bangladesh

N. Ahmed (✉)
Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
e-mail: nesar_2000@yahoo.com

M. Troell
Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences, 104 05 Stockholm, Sweden
e-mail: max@beijer.kva.se

Introduction

In Bangladesh, freshwater prawn (*Macrobrachium rosenbergii*) farming still remains dependent on the capture of wild larvae (Angell 1990, 1994; Ahmed 2000; Ahmed et al. 2008). Fishing for prawn larvae started in the southwestern region in the early 1970s (Mazid 1994). Locals learned to catch prawn larvae from people on the western side of the Ichamati River at Debhata near the Satkhira area, on the border between Bangladesh and India (Bay of Bengal Programme (BOBP) 1990). Since then, fishing for larvae has become an important source of income for many people. Today, thousands of landless poor and unemployed are engaged in fishing for prawn larvae. Traditionally, prawn farmers prefer to stock wild larvae rather than hatchery-produced larvae because hatchery production has been limited and farmers consider wild larvae to be of superior quality (Angell 1992; Ahmed et al. 2005). The survival of wild larvae has been reported to be much higher than that of hatchery-produced larvae (Ahmed 2001). There are currently 81 freshwater prawn hatcheries in Bangladesh, although only 38 (47%) are operational, producing about 100 million larvae annually (Winrock International 2007; Ahmed 2008). Lack of knowledge of the complex technology of prawn hatcheries, inadequate skilled manpower, and an insufficient supply of wild brood may be reasons for the poor results of many hatcheries.

Present hatchery production can only supply 20% of total demand, implying that wild larvae fishing is likely to continue as prawn farming expands rapidly at an average 10–20% annum^{-1} (Muir 2003; Khondaker 2007).

In September 2000, the Department of Fisheries (DOF) in Bangladesh imposed a ban on wild prawn larvae fishing. This ban primarily originated from concern for potential negative effects on biodiversity from high levels of bycatch (i.e., nontarget species caught incidentally) (DOF 2002). A similar ban on the collection of shrimp (*Penaeus monodon*) larvae has been in place in India since 1999 (Rönnbäck et al. 2003). This ban has, however, not resulted in a complete end to larvae fishing, and the reason for this may be that the ban is seen by many merely as a recommendation (Central Marine Fisheries Research Institute, Kakinada, India—pers.comm.). However, even though the ban on prawn larvae was obligatory in Bangladesh, fishing for larvae has also continued there. The lack of alternative livelihoods for poor people engaged in larvae fishing is one reason for this, and another is the difficulty in the implementation of the ban. The difference between the Bangladesh situation and that in India may be due to India having sufficient numbers of *P. monodon* hatcheries to meet the demand as well as an apparent preference for hatchery-produced larvae among farmers (Rönnbäck et al. 2003). The significant decline in Indian shrimp production, due to disease problems, may also explain the difference. Nevertheless, the concern arises in Bangladesh about the willingness of the government to enforce the ban. In addition, the government of Bangladesh today has inadequate resources to enforce the ban (DOF 2002), but there is a growing concern among poor fishing communities engaged in larvae fishing that this will change.

The livelihoods of around 400,000 people, many of them women and children, are associated with prawn and shrimp larvae fishing in coastal Bangladesh (United States Agency for International Development (USAID) 2006). Some 1,500–2,000 million larvae, valued at around US$30 million, are fished from the wild by fishers and associated groups every year (Environmental Justice Foundation (EJF) 2004). Larvae fishers are mostly the rural poor, and fishing larvae is an alternative livelihood coping strategy, offering a substantial part of their income (Ahmed et al. 2005; Rosenberry 1992). Larvae fishing contributes substantially to the local and regional economy and also is a part of foreign exchange earnings (i.e., almost all prawns are exported to international markets, particularly to the US, Europe, and Japan), although the larvae fishers benefit little. Larvae fishers are usually socially, economically, and educationally disadvantaged and lack financial resources (Ahmed 2001); thus, they constitute the most marginalized people in coastal communities.

Although larvae fishing is a valuable industry, it has been accompanied by concerns over social, economic, and environmental impacts (Guimaraes 2002; Islam et al. 2004). This study aims to describe how the prawn larvae fishing sector in Bangladesh is structured. Further aims are to identify how fishing for prawn larvae impacts coastal ecosystems and what the socioeconomic consequences will be from stronger implementation of the ban on prawn larvae fishing. Alternative livelihoods for larvae fishers and measures to minimize the adverse environmental impacts of larvae fishing are also briefly discussed in a poverty reduction context.

Methodology

Study Area

The study was conducted in Bagerhat District, a coastal area of the Bay of Bengal, situated in the southwestern part of Bangladesh. Due to the close availability of wild larvae, Bagerhat has been identified as the most important and promising area for freshwater prawn culture. Study sites were selected along the Pasur River, from Mongla through Joymoni on the coast near the Sundarbans mangrove forest (Fig. 1). A large number of people living in the area are engaged in fishing for prawn larvae.

Data Collection Methods

Field research was conducted for a period of 12 months from January to December 2006. A combination of the following participatory, qualitative, and quantitative methods was used for primary data collection.

Questionnaire Interviews

A total of 100 fishers were interviewed, 50 each from those using pull nets and set bag nets. Some 25 women were included in the fishing group using pull nets. No women were involved in application of set bag nets. Fishers were divided into two groups, based on fishing gear, for comparative studies. Fishers were selected through random sampling. They were interviewed at the fishing sites and/or river banks. A boat was hired for data collection and observation of fishing practices. Time required for each individual interview was about 1 h. The interviews focused on prawn larvae fishing, duration of fishing time, catch rate, daily income, constraints of fishing, major risks, environmental impacts, and socioeconomic status. Quantification of larvae catch using different methods, together with the quantification of bycatch rates, was performed with the help of four to six volunteers from the coastal community under study. Bycatch identification was performed using dissecting microscopes and was carried out with the help of postgraduate students from Bangladesh Agricultural University.

Prawn larvae fishing by a woman with pull net (Photo: Nesar Ahmed)

Set bag net fishing by a group of fishers (Photo: Nesar Ahmed)

Prawn larvae marketing in a coastal market (Photo: Nesar Ahmed)

Participatory Rural Appraisal

The participatory rural appraisal (PRA) tool focus group discussion (FGD) was conducted with members of coastal fishing communities, including larvae collectors, fry traders, women, and children. A total of 20 FGD sessions were conducted with a group size of 6–12 persons (total 187); the duration of each session was approximately 2 h. FGD sessions were held on the river banks, at fishers' houses, and at larvae markets—wherever there were spontaneous gatherings and where participants could sit, feel comfortable, and be easily observed. FGD was used to get an overview of qualitative information on larvae fishing and marketing systems, environmental impacts of larvae fishing, overall constraints of fishers, and their socioeconomic conditions.

Cross-Check Interviews with Key Informants

A key informant is someone with special knowledge on prawn larvae fishing and associated activities. Cross-check interviews were conducted with 21 key informants, such as district and subdistrict fisheries officers, researchers, relevant project staff, and nongovernmental organization (NGO) workers. In addition, a number of discussions were conducted with various stakeholders (e.g., policymakers, fishery experts, government staff, and donors) in workshops, seminars, meetings, and training sessions about coastal fisheries management throughout the coastal region and in Dhaka, the capital city of Bangladesh.

Data Analysis

Data from questionnaire interviews were coded and entered into a database system using Microsoft Excel software. The statistical software SPSS (Statistical Package for Social Science) was used to analyze the data, producing descriptive statistics. Results from the data analysis, in combination with qualitative information collected through PRA and cross-check interviews with key informants, were used to describe prawn larvae fishing, its environmental impacts, and socioeconomic consequences. Comparisons among the two fishing groups were made by ANOVA F-test, and a two-tailed $P < 0.05$ indicated statistically significant differences.

Results and Discussion

Prawn Larvae Fishing

According to the survey, two types of nets are used for prawn larvae fishing in the study area: pull net and set bag

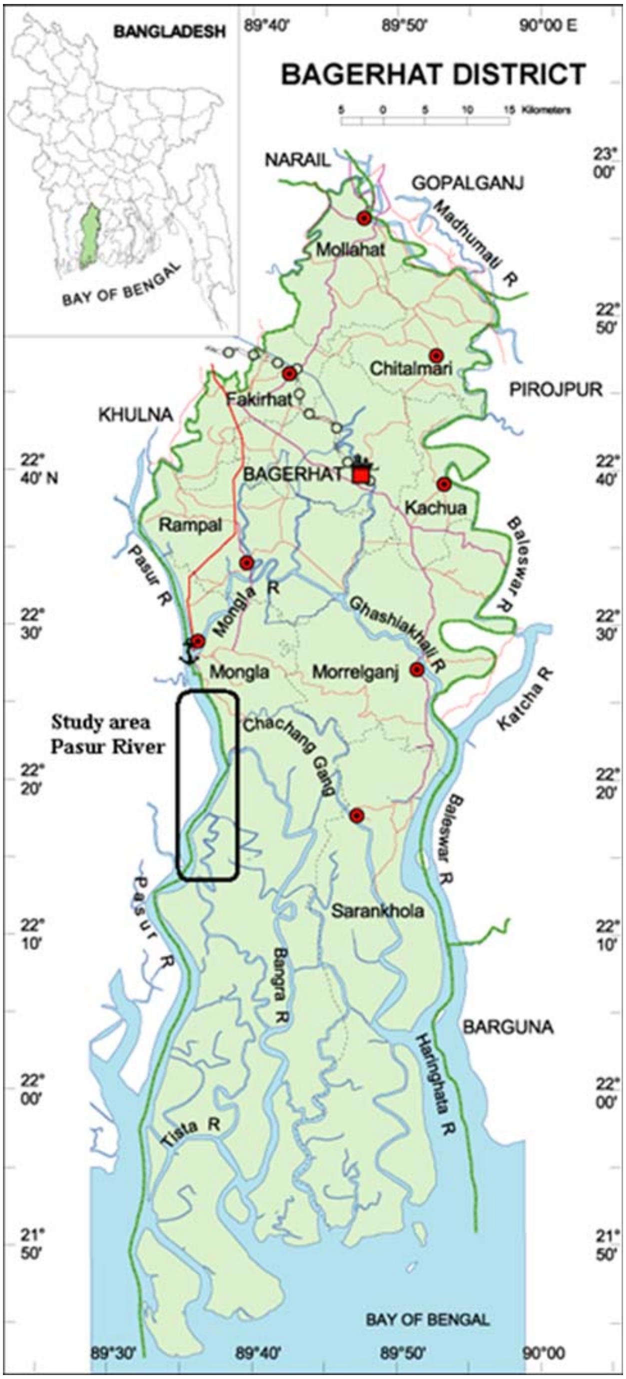

Fig. 1 Map of Bangladesh showing the study area. *Source*: Banglapedia

net. Fishing for prawn larvae is a seasonal activity that takes place from April to June; during the rest of the year, fishers are involved in other types of fishing, including shrimp (*P. monodon*) larvae and finfish. According to questionnaire interviews, prawn larvae fishers are active for an average of 9.9 years, and set bag net fishers continue fishing longer (an average of 11.3 years) than those involved in pull net fishing (an average of 8.5 years).

A pull net is operated by a single fisher; the length of pull net varies from 1.5 to 2 m, and the width varies from 2 to 2.5 m. A pull net is pulled in the surface layer against the tidal water in shallow areas along river banks. A pull net is also used close to the shoreline since it is fixed to the bottom by a bamboo pole. Usually, fishers operate their nets once each day during low tide, from 12 a.m. to 6 p.m., for an average 5 h of fishing and a range of 4–6 h. During operation, the net is emptied at 5- to 10-min intervals. Fishers keep all the larvae in aluminum containers, and separate the prawn larvae by using white plate and spoon. All other species captured are discarded during sorting on the shore.

Series of set bag nets are fixed across the Pasur River, and each net is usually operated by a single fisher from a boat. The typical size of set bag net is 10–15 m in length and 2–4 m in width. The set bag net has a rectangular mouth, with an average size of 5 m. The mouth is kept open by a vertical bamboo pole fastened to the corners of the upper and lower panels. The set bag net tends to be used in the surface layer against the tidal water in the deeper part of the river. During operation, the net is emptied at 20- to 25-min intervals. Fishers operate their nets twice each day during high tide from 8 a.m. to 2 p.m. and from 7 p.m. to 10 p.m., for an average of 7.5 h of fishing, ranging from 6 to 9 h. Sorting of larvae is performed as for the pull net operation with the exception that some bycatch is thrown back into the river.

According to the fishers, fishing effort is high during the season, especially during the full moons, when larvae concentration in surface layers is at its maximum. It is difficult to estimate the number of larvae caught by the different methods, but it has been suggested by the fishers that the use of set bag nets accounts for as much as 60–70% of total catch. The study showed an overall low prawn larvae catch rate, with each fisher of set bag nets catching an average of 82 larvae daily during the season, while each pull net fisher caught, on average, 39 larvae (Table 1). The significant difference ($P < 0.05$) in catch rate among fishing groups was probably due to differences in fishing gear, but fishing time, the duration of fishing, and the choice of fishing locations (i.e., close to the shoreline or in the deeper

Table 1 Prawn larvae catch rate by different fishing methods in 2006 on the Pasur River, based on 100 fishers' catch quantifications

Catch rate (number of larvae fisher^{-1} day^{-1})	Pull net ($n = 50$)	Set bag net ($n = 50$)
Mean	39	82
Standard deviation	18	31
Minimum	16	35
Maximum	83	179

n Sample size of larvae fishers

part of the river) also should have an effect on quantity and type of bycatch.

Almost all larvae fishers in the survey expressed concern about declining larvae catches in the study area. According to questionnaire interviews, the catch of larvae has declined by an estimated 20% over the last 5 years. This finding was in accordance with a general decrease in set bag net fishing in coastal Bangladesh, decreasing from 2,000 larvae day^{-1} in 1982 to 85–100 day^{-1} in 1992 (Dev 1998; Nuruzzaman 1993). It is difficult to identify a single reason for the decline, but factors like overfishing of larvae, the use of habitat-destructive gear, uncontrolled fishing of prawn broodstock, water pollution (mainly industrial waste and oil pollution), poison fishing, the destruction of mangrove forests, and river erosion were mentioned by the fishers themselves.

Fishers sell their catches at the coastal markets in Mongla, and the market chain from fishers to farmers passes through a number of intermediaries: transporters, suppliers, fry traders, and local agents. The average price of larvae was reported to be US$38 for 1,000 larvae in 2006. The income of fishers using a set bag net was higher than that of fishers using a pull net because of the higher catch rate. The average daily net income (accounting for the cost for fishing gear, boat, and transportation to market) differed significantly ($P < 0.05$) between fishers using a set bag net (US$1.9) and pull net fishers (US$0.9). On average, 40% of total annual income originated from prawn larvae fishing, 46 and 33% from set bag net and pull net, respectively. Almost all fishers noted that their income had decreased over the last few years (since 2002) due to the declining availability of prawn larvae. Increased market prices for prawn larvae did not compensate enough for this decline. Fishers reported that around 25% of the larvae catch is lost during sorting, holding, and carrying from fishing sites to markets. According to DOF, around 40% of prawn larvae are lost from the time they are caught to the time they are stocked in a farmer's pond (DOF 2002). Thus, this indicates an additional mortality rate of 15% after the larvae have reached the market.

Environmental Impacts

According to questionnaire interviews, the majority (68%) of fishers believed that larvae fishing is not harmful to the environment. Their argument was that they have been fishing for larvae year after year. However, the other respondents (32%) acknowledged that fishing for prawn larvae could have a negative impact on the environment mainly due to bycatch. Discarded bycatch has also been the main argument behind the ban on larvae collection (DOF 2002). The bycatch rate is high in prawn larvae fishing as very fine mesh (1.5-mm) nets are used (although the government earlier allowed a minimum 30-mm mesh). As a result, a huge number of fish and other crustacean larvae and juveniles are caught and later discarded on land. The set bag net was responsible for higher bycatch than the pull net (Table 2), but the bycatch rate was lower compared to rates reported for tiger shrimp larvae fishing in Bangladesh (Table 3). Nevertheless, prawn and shrimp larvae fishing have the highest bycatch rates of any fishery in the world, resulting in the loss of more than 98 thousand million juvenile fish and crustaceans every year (Environmental Justice Foundation (EJF) 2004; Food and Agricultural Organization (FAO) 2001; Latif et al. 2002).

Table 2 Average amount of bycatch for each *M. rosenbergii* larvae collection in 2006 on the Pasur River, based on sampling of 100 fishers

Bycatch	Pull net (n = 50)	Set bag net (n = 50)
Shrimp and other prawn	34 (4%)	97 (9%)
Finfish	186 (23%)	253 (24%)
Macrozooplankton	587 (73%)	726 (67%)
Total	807 (100%)	1,076 (100%)

n Sample size of larvae fishers

Negative environmental impacts from prawn larvae fishing are mainly associated with bycatch, which may cause declines in capture fisheries and in overall biodiversity. Intensive fishing can also result in the physical destruction of nursery grounds, decreased prawn broodstock, the prevention of fish migration, and reduced wildlife.

Capture Fisheries

Fishing for *M. rosenbergii* larvae results in bycatch of commercially important species groups. Bycatch from the sampling of larvae fishing on the Pasur River in 2006, using both pull nets and set bag nets, was composed of: (i) prawns—*Macrobrachium malcolmsonii*, *Macrobrachium villosimanus*, *Macrobrachium mirabilis*, *Macrobrachium birmanicus*, *Macrobrachium rude*, and *Macrobrachium dayanus*; (ii) shrimp—*P. monodon*, *Penaeus indicus*, *Penaeus merguensis*, and *Metapenaeus conoceros*; and (iii) fish—*Tenualosa ilisha*, *Gadusia chapra*, and *Lates calcarifer*. Larvae fishers, who are also involved in capture fisheries, expressed concern over declining catches of prawns, shrimp, and fish. They estimated a 25% decline during the past 5 years, an estimate that was also supported by most key informants.

Nursery Grounds

Because it is a transitional zone between freshwater and seawater, the Pasur River serves as a seasonal habitat for many freshwater and marine species and, as such, is richer

Table 3 Bycatch ratios of prawn and shrimp larvae in Bangladesh and other countries

Prawn/shrimp:bycatch	Country	References
Prawn larvae:bycatch = 1:942	Bangladesh	This study (2006)
Shrimp larvae:bycatch = 1:1,341	Bangladesh	EJF (2004)
Shrimp larvae:bycatch = 1:525–1,666	Bangladesh	Hoq et al. (2001)
Shrimp larvae:bycatch = 1:80–100	Bangladesh	Dev et al. (1994)
Shrimp larvae:bycatch = 1:47–999	India	Primavera (1998)
Shrimp larvae:bycatch = 1:475	Malaysia	Chong et al. (1990)
Shrimp larvae:bycatch = 1:15–330	Philippines	Primavera (1998)

than either freshwater or seawater alone in terms of its biological and genetic resources (Islam 2003; Hoq 2007). Many species, both freshwater and marine, are dependent on brackish water for nursery grounds. Massive prawn larvae fishing in these areas, therefore, constitutes a threat to these key coastal ecosystems. This was also confirmed by most key informants. Excessive larvae collection has a severe impact on the aquatic ecology, and the physical disturbance (i.e., erosion) caused by fishers is reported to be affecting the nursery grounds for many species, potentially undermining the basis for wild fish, prawn, and shrimp production.

Biodiversity

According to the field survey, not only are finfish larvae discarded, but different shellfish and crustaceans also are indiscriminately exploited along with targeted prawn larvae. Besides the many fish species, the brackish water supports many species of prawns and shrimp with high ecological and commercial value. The tiger shrimp (*P. monodon*) stands out in terms of its commercial importance and availability. Larvae fishers reported that the availability of *P. monodon* has gradually declined during the last few years. The excessive removal of ecologically important species may lead to serious problems for long-term fisheries development in the Pasur River, including the Sundarbans. The significance and extent of larvae fishing are, however, difficult to assess quantitatively at that larger scale.

Broodstock

Prawn larvae use estuaries to find shelter and food. The freshwater prawn *M. rosenbergii* requires brackish water in the initial stages of its life cycle and is, therefore, found in water that is directly or indirectly connected with the sea (New and Singholka 1985). The actual stock recruitment of prawn in the sea is directly dependent on the survival of the larvae and their return to the sea. However, due to massive larvae fishing, the return of prawn to the sea may have been reduced, potentially leading to the scarcity of broodstock. The fishers reported reduced availability of broodstock in the estuary of the Pasur River, and this was confirmed by most key informants.

Migratory Species

Fishing of prawn larvae also is likely to affect the recruitment of migratory species. The overexploitation of larvae has been reported by most respondents to decrease the availability of migratory fish from year to year, and this has severe consequences for artisanal and commercial fisheries. Hilsa shade (*T. ilisha*), the national fish of Bangladesh that migrates 50–100 km in some river systems, once contributed to 30% of the total fish production in Bangladesh. By 2006, this number had decreased to only 12% (DOF 2007). According to the larvae fishers and key informants, *T. ilisha* catch has been reduced by multiple factors: overfishing, capture of juveniles and berried females, environmental degradation, and intensive larvae fishing.

Wildlife

The Pasur River adjacent to the Sundarbans is also an important nursery, feeding, and breeding grounds for many species of wildlife, including crabs, snails, oysters, mollusks, and turtles. The bycatch of turtles (*Lepidochelys olivacea*) and other wildlife in pull nets and set bag nets seems to be of great concern for the conservation of aquatic biodiversity. According to the larvae fishers, turtles are slow swimmers and can be passively swept into nets by the tide. They cannot find their way out and most of them drown and die in the net. Snails and mollusks are of ecological importance for converting leaf litter into detritus (Gain 1998; Khan 1998; Haque 2003), and excessive removal of these organisms is likely to have ecological consequences. According to group discussions with community members, snails are not discarded; instead, people use the snail meat as prawn feed, a widespread practice in southwestern Bangladesh.

Socioeconomic Status of Larvae Fishers

The households of the interviewed larvae fishers face a variety of constraints for their livelihood (Table 4). The

Table 4 Major socioeconomic constraints faced by the households of larvae fishers on the Pasur River in 2006 (multiple responses)

Key constraint (according to importance)	Pull net			Set bag net fishers
	Fishers ($n = 25$)	Fisherwomen ($n = 25$)	Total ($n = 50$)	($n = 50$)
Poor income	24 (96%)	25 (100%)	49 (98%)	47 (94%)
Shortage of food	24 (96%)	24 (96%)	48 (96%)	46 (92%)
Lack of health facilities	20 (80%)	23 (92%)	43 (86%)	39 (78%)
Poor supply of drinking water	17 (68%)	21 (84%)	38 (76%)	32 (64%)
Storm damage of house and other properties	16 (64%)	15 (60%)	31 (62%)	28 (56%)
Loss of fishing equipment due to cyclone	6 (24%)	1 (4%)	7 (14%)	21 (42%)
Lack of children's education	7 (28%)	3 (12%)	10 (20%)	14 (28%)
Scarcity of cooking fuel	3 (12%)	6 (24%)	9 (18%)	8 (16%)

n Sample size of larvae fishers

most serious constraint is income decline due to a decline in catches of prawn larvae. Most larvae fishers reported that their families could no longer afford to have three meals each day (i.e., now they mainly have two meals each day). The study also reveals that households of coastal larvae fishers face severe health and sanitary problems with no medical facilities. People often suffer from diarrhea, cholera, dysentery, skin diseases, malnutrition, and mosquito-borne diseases such as dengue fever and malaria. Only a few households of fishers (less than 10%) see the village doctor (i.e., an unqualified practitioner) when they have serious health problems. According to key informants, poor nutrition in coastal communities has been linked to birth defects, stunted growth of children, night blindness, and increased incidences of miscarriages and maternal mortality. Some fisherwomen reported a correlation between miscarriages and pull net fishing as it is laborious work for women. Fisherwomen have fewer livelihood options compared to fishermen, and thus their involvement in larvae fishing is very important.

Most of the larvae fishers live in very poor housing conditions: their houses are typically made of mud and leaves from the Nypa palm (*Nypa fruticans*, referred to locally as *gol pata*) collected from the Sundarbans mangrove forest. These houses do not completely prevent the entry of rainwater and are very susceptible to storm damage. Fishing families also lack fresh drinking water because of poor tube-well facilities and the intrusion of saline waters in the soil. Most of the households of larvae fishers in the survey area relied on river water for bathing and washing, and women had to walk long distances (in some cases up to 3 km) to procure drinking water from tube-wells. Apart from salinity, arsenic is also a common problem for drinking water in tube-wells in the study area (Ahmed 2001).

Larvae fishers also mentioned other problems they face, including piracy and storms (such as cyclones, which reduce fishing days). The entire coastal zone in Bangladesh is prone to violent storms and tropical cyclones during premonsoon and postmonsoon seasons (Hossain 2001). Cyclones originate in the deep Indian Ocean and track through the Bay of Bengal. Sometimes cyclones associated with tidal waves cause great loss of lives and property. In November 2007, the coastal area of Bangladesh was affected by Cyclone Sidr, the worst tropical cyclone (hurricane category 4) in 10 years. More than 8.7 million people were affected, with a death toll of 3,295, a further 871 people missing, and 52,810 people injured. Material damage was severe, with over 363,877 houses destroyed and a further 940,438 partially damaged; boats, nets, and other fishing equipment lost; more than 2.2 million acres of crops damaged; and over 1.68 million livestock killed (United Nations 2007). Due to a lack of weather forecasts reaching the fishers, they often risk their lives and fishing gear during storms.

On average, 90% of the larvae fishers are functionally illiterate (i.e., 92% of pull net and 88% of set bag net fishers). The fishers do not appreciate the importance of educating their children because of their own poor education level, and instead they try to involve them in fishing or engage them in other supplementary activities for additional income to the household. The children of the fishers were interested in going to school, but their families were too poor to pay for educational expenses and also needed the children's earnings.

According to discussions with coastal community people and key informants, the rapid population increase in coastal communities and limited alternative employment opportunities have made the lives of larvae fishers even more difficult. Larvae fishing families specifically face problems from the scarcity of cooking fuel. In general, cow dung, paddy straw, and wood—including tree branches and dry leaves—are used as cooking fuel. However, almost all surveyed larvae fishers reported that cattle raising had significantly decreased due to reductions in grazing land, and the resulting decreased availability of cow dung, milk, and meat. It was reported by respondents that the total production of cows and buffalos has declined by 60%. The production of poultry has also declined significantly, and the mortality of chickens is high in areas where salinity is very high. Also, raising ducks has become difficult due to salinity and the reduced availability of snails to feed the ducks.

According to the field survey, larvae fishers increasingly have to collect fuel wood from the Sundarbans, thus contributing to the degradation of mangrove forests. They also search for food (e.g., fruits and honey) and construction materials and establish settlements in the forest. This has resulted in severe degradation of the mangroves. It was reported that fishers use large sundry (*Heretiera fomes*) timber as poles to anchor their nets and boats, and goran (*Ceriops decadra*) and gewa (*Excoecaria agalocha*) sticks as cooking fuel and fish-drying racks. Mangrove palm leaves are used for thatching the houses and boats.

Most larvae fishers (78%) are landless and, therefore, have few opportunities for alternative income-generating activities involving agriculture. Those who own agricultural land stated that rice production has decreased due to saline water intrusion, resulting in the decreased availability of paddy straw, which is used for cooking fuel, building materials for housing, and fodder for cattle. The reduction of rice fields and increase in saline soils have negatively affected the population of the Indian bullfrog *Rana tigrina*, which plays an important role in rice farming systems as a pest controller (Chengjie 1995). Fruit trees (known as fishers' saving banks), such as coconut, beetle nut, guava, and banana, and timbers (goran, gewa, and sundri) have decreased significantly. Vegetable production in homestead gardens has also decreased due to salinization. The loss of livelihoods and supply problems have further increased the pressure on the Sundarbans (Hoq 2008).

Conclusions

From this study, it becomes clear that coastal fishers involved in larvae fishing belong to a most vulnerable group. It is also clear that their own fishing activity for larvae may undermine this livelihood as well as other livelihoods upon which those coastal communities depend. The large bycatch generated from the two dominating larvae fishing methods has the potential to cause negative impacts on capture fisheries and biodiversity in general. The decline of many important commercial crustacean and fish stocks may be linked to the fact that these species constitute part of the bycatch from larvae fishing. It is, however, difficult to isolate the larvae fishing effect from other factors impacting the fish stocks, such as direct overfishing, habitat destruction, and pollution. The vast numbers of both prawn larvae and other larvae being caught need to be put into perspective in terms of the number of larvae that actually enter the coastal water. The mortality of the different size classes needs to be estimated to allow for a comparison of the mortality (or capture) caused by the larvae fishery sector. This is not to say that the mortality of bycatch species caused by larvae fishing is insignificant, but rather that there is a need for more studies on how much the larvae fishery impacts targeted and nontargeted (bycatch) populations. The level of impact is probably specific to the species (or population) and can be more significant for some than for others.

Larvae fishing represents a very important livelihood for the poorest segment of the coastal community. This is true not only in Bangladesh but also in India and other countries (Islam et al. 2004). The argument behind the ban on larvae fishing is that, although larvae fishing generates significant short-term economic benefits, the risk of creating long-term cumulative environmental impacts is high. To what extent this is true we do not know, but following the precautionary principle, the ban put in place should be implemented until more in-depth studies on the link between the wild larvae fishery and the potential effects have been performed.

The lack of alternative livelihoods for poor people engaged in larvae fishing is one reason why the ban is not thoroughly implemented. Increased pressure from population expansion within the coastal zone, together with the degradation of many important resources, further reduces existing livelihood options. Thus, there is an urgent need for measures to support alternative livelihoods. An alternative to a complete ban against larvae fishing could be the introduction of periodic bans, leaving some room for larvae fishing to occur. Another alternative could be to set aside protected areas; this could decrease the pressure on both bycatch organisms and targeted species and at the same time provide a livelihood option. Fishing for larvae could be banned in certain ecologically sensitive areas, such as in the Sundarbans and important migration routes. In areas where larvae collection is seasonally allowed to continue, the scope for introducing a licensing system should be assessed to reduce fishing pressure. Training in larvae fishing and in sorting and returning the bycatch as well as environmental awareness programs could also be provided. This has been put in place by NGOs involved in the bycatch of shrimp larvae fishing in other areas. Also, practices for handling and transporting larvae should be improved.

The ban will most likely stimulate the expansion of the prawn hatchery sector over the next few years. Increased hatchery production may reduce the pressure for larvae exploitation; however, there is also an urgent need for technical support to improve the hatcheries. The hatcheries' dependence on environmental resources (including broodstock) needs to be considered when the industry expands (Ahmed 2008). Hatcheries can also consider pond-rearing broodstock, which is widely practiced in Thailand (Vicki 2007).

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Author Biographies

Nesar Ahmed is an associate professor at Bangladesh Agricultural University. He obtained a Ph.D. from the University of Stirling, UK, and a postdoctoral research fellowship at Charles Darwin University, Australia. His research focuses on socioeconomic aspects of aquatic resource management.

Max Troell is an associate professor at the Beijer Institute, Royal Swedish Academy of Sciences, and the Stockholm Resilience Centre, Stockholm University. His research focuses on sustainable aquaculture and the evaluation of ecosystem services in tropical and temperate coastal systems.