

# The impact of the expansion of shrimp aquaculture on livelihoods in coastal Bangladesh

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**Abstract** The area used for shrimp aquaculture in Bangladesh has increased about tenfold since 1980. This study examines how shrimp aquaculture has affected the livelihoods of people living beside the Sundarbans mangrove forest in Bangladesh. Using household survey data from 264 households in six villages in Mongla, we found that shrimp income represents 46 % of the total household income for the higher-income households, but just 26 and 8 % for middle- and lower-income households, respectively. Higher-income households were able to derive both larger absolute and relative income from the shrimp sector than the lower-income households, mainly because they had more land initially and used that to acquire ownership or access to most remaining land. This has exacerbated existing inequities so they are greater for shrimp aquaculture than for other livelihoods such as fishing or farming. The expansion of shrimp aquaculture has largely happened by converting agricultural land into shrimp farms. Often this agricultural land was acquired from the poorest people, leaving them even more vulnerable because they have been forced into poorly paid labour or the collection of wild resources from the mangrove forest (often illegal).

**Keywords** Aquaculture · Income inequality · Land use change · Land title · Mangrove forest · Shrimp

## 1 Introduction

Aquaculture is one of the fastest growing animal food-producing sectors worldwide, with annual growth averaging 6.1 % for 2002–2012 (FAO 2014a, b) and above 8 % in 12 years of the past three decades (HLPE 2014). It is likely to expand further (Duarte et al. 2007;

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Merino et al. 2012) despite concerns about its long-term sustainability (Naylor et al. 2000). In Asia, the greatest producers of food fish produced by aquaculture are China (61 % of total world market), with smaller contributions from India (6 %), Vietnam and Indonesia (4.6 % each), and Bangladesh (2.6 %) (FAO 2014b).

The area used for shrimp aquaculture in Bangladesh has expanded from about 20,000 ha in 1980 to nearly 244,000 ha in 2014 (Karim et al. 2014). The two shrimp species: *Penaeus monodon* (black tiger shrimp; local name: Bagda) and *Macrobrachium rosenbergii* (freshwater prawn; local name: Golda), have been dubbed “white gold” (in Bengali: “sada sorno”) because of their high value (Islam 2009), with about 55,000 tonnes exported in 2011/12 fetching USD 454 million<sup>1</sup> (Karim et al. 2014), making it the second largest foreign exchange earner after readymade garments. Even 10 years ago, nearly 1.2 million people were directly involved in shrimp production with another 4.8 million household members supported by the industry (USAID 2006). Of these, more than 90 % either collected shrimp fry for the farms or worked as labourers. The rest were involved in processing, hatcheries or other industries related to shrimp such as producing pharmaceuticals, selling feed and making ice (Pokrant and Reeves 2003).

One of the main factors responsible for the large-scale expansion of shrimp aquaculture has been increased funds from international donors and structural adjustment policies implemented in line with trade liberalisation and trade promotion aimed at stimulating exports (Pokrant and Bhuiyan 2001; Pokrant and Reeves 2001; Khatun 2004; Béné 2005; Paul and Vogl 2011). Other contributing factors have included a strong international market, high prices, cheap land and labour (Fleming 2004; Islam 2008a, 2009), availability of shrimp fry (Islam et al. 2004; Islam and Wahab 2005), ecological and climatic conditions of coastal areas (Chowdhury et al. 2011) and the investments made in upgrading production facilities and working conditions (Alam and Pokrant 2009).

The social research on shrimp aquaculture has largely highlighted positive impacts such as increased income, improved food security, increased employment opportunities and the number of earners in households (Hamid and Alauddin 1998; Pokrant and Reeves 2003; Sharmin and Ali 2005; Gammage et al. 2006; USAID 2006; Jahan et al. 2010; Belton et al. 2014), particularly the earning opportunities for women (Gammage et al. 2006; USAID 2006; Islam 2008b). However, as shrimp aquaculture has expanded worldwide, studies have recognised wide-ranging environmental, economic and social impacts (e.g. Ahmed et al. 2002; Hoanh et al. 2006; Ahmed et al. 2010a, b; Belton et al. 2014; Jahan et al. 2014; Paprocki and Cons 2014; Toufique and Belton 2014). These changes have implications for the sustainability of shrimp farming compared with other livelihood options, globally and in Bangladesh, a country with high population pressure and severely affected by climate change (Shahid et al. 2016).

In most parts of Bangladesh, expansion of shrimp aquaculture has caused a loss of mangroves and its associated biodiversity (Shahid and Islam 2003; Hoq 2007; Hossain et al. 2013) including by-catch from collection of shrimp fry (Hoq et al. 2001; Islam et al. 2004). In other parts, shrimp farming has mainly happened by converting agricultural land into shrimp farms (Ali 2006; Azad et al. 2009), resulting in the loss of agro-biodiversity and livestock (EJF 2004; Karim 2006) and increasing soil salinity (Wahab 2003; Ali 2006; Chowdhury et al. 2011; Rahman et al. 2011, 2013; Kabir et al. 2015). These ecological impacts are likely to be exacerbated by climate change (Islam et al. 2014; Ahmed and Diana 2015). The impacts of brackish water shrimp aquaculture in the Sundarbans region, where most shrimp aquaculture in Bangladesh takes place, have created an “ecological

<sup>1</sup> At the time of the research, 1USD = 68.9 Bangladesh Taka.

crisis” (Bala and Hossain 2010), exacerbating climate-related vulnerabilities of people living in the Sundarbans (Paprocki and Cons 2014).

From a social perspective, the expansion of shrimp aquaculture in Bangladesh has increased inequity (Manju 1996; Ito 2002; EJV 2004; Halim 2004; Samarakoon 2004; Jahan et al. 2010), diminished land security (Hossain et al. 2013) and access to share-cropping opportunities (Ito 2002; Samarakoon 2004) and exacerbated existing unequal gender and class relations (Datta 2001; Halim 2001; Belton et al. 2014). The group worst affected by the expansion of shrimp farming has been the landless as previously common land is taken for shrimp aquaculture (Halim 2004).

So far most research has addressed economic, environmental, social and management aspects of shrimp aquaculture in Bangladesh separately from each other (Ahmed et al. 2002, 2010a, b; Belton et al. 2014; Jahan et al. 2014; Paprocki and Cons 2014; Toufique and Belton 2014). Instead, a more holistic approach, such as the social-ecological or vulnerability framework (e.g. Gowing et al. 2006; Benessaiah and Sengupta 2014) is needed to understand the full impact of shrimp aquaculture on people’s livelihoods. Just as Benessaiah and Sengupta (2014) used this framework to understand vulnerability and resilience consequences of changes from common pool resources to aquaculture in Nicaragua, we investigate the vulnerabilities of people affected by the expansion of shrimp farms in Bangladesh.

To do so, we applied the vulnerability framework with vulnerability defined as the levels of exposure and sensitivity of a system and the likelihood that an individual or community will be exposed to and adversely affected by a hazard (Cutter 1996) or trends in livelihoods (Alwang et al. 2001). The latter concept is most relevant for our study, as long-term changes in the production system and livelihood sources can contribute to the level of vulnerability, both in positive and negative ways (Alwang et al. 2001; Allison and Horemans 2006). We measure vulnerability by the contribution of shrimp-based income to the overall household income portfolios of different income groups and compare the income from shrimp aquaculture in the Sundarbans with those derived from other economic activities available to people living in the region. The aims of this paper are thus to: (1) identify the socio-economic factors necessary to engage in shrimp aquaculture from the livelihood perspective; (2) assess how the growth in shrimp aquaculture has affected livelihood outcomes and the vulnerability of those pursuing them; and (3) explore inter-related impacts of the establishment of shrimp farming on access to land, productivity of adjacent agricultural land and the livelihood options available.

The paper first describes the socio-economic characteristics and shrimp ownership status among households, compares incomes of different sectors of the society from shrimp aquaculture and other sources, and the socio-economic factors that influence shrimp income. Vulnerabilities are described in the second part of the paper. We then compare the results with other studies in Bangladesh and other settings, discussing both the positive and negative outcomes of shrimp aquaculture for livelihoods.

## 2 Methods

### 2.1 Study area

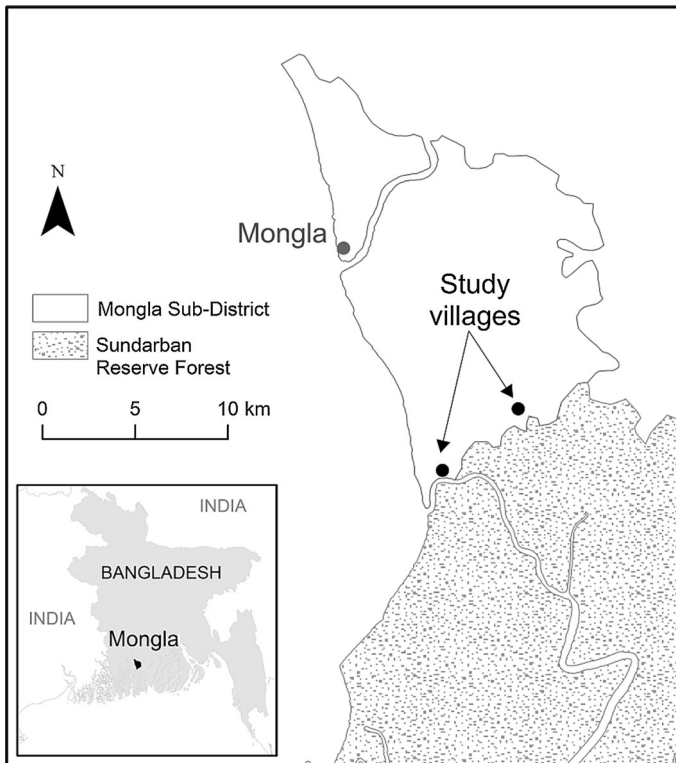
The majority of the shrimp aquaculture in Bangladesh takes place in Khulna, Satkhira and Bagerhat districts beside the Sundarbans mangrove forest (Islam and Wahab 2005). The

area includes 80 % of all shrimp farms in Bangladesh (Pokrant 2006), occupying more than 77 % of the region's agricultural land in these three districts (Hossain 2011) and covering about 180,000 ha in 2010 (Khulna Divisional Forestry Office in litt.). Our research took place in Mongla, a sub-district of Bagerhat District.

Six villages in the Mongla Sub-District, all within 200 m of the Sundarbans mangrove forests, were selected for sampling (Fig. 1). Joymony Ghol, Joymony Katakhalai and Joymony Sankirchar villages are within the Chila Union along the Passur River which enters the Bay of Bengal through the Sundarbans forest. Baiddomari, South Bashtola and Burburia, in the Sundarban Union, have no direct connection to the river and are separated by the narrow Khorma canal excavated by the forest department to create a demarcation between the forest and the villages on its periphery.

## 2.2 Quantitative data collection

Households were the unit of the vulnerability analysis, and household surveys were conducted in 264 randomly selected households from a total of 2277 households in the six villages, for the reference year September 2009–August 2010. Household assets and income were assessed using a questionnaire based on the Poverty Environment Network (PEN) (2008) quarterly household survey prototype questionnaire. The questionnaire included sections on basic household assets and household income from agricultural



**Fig. 1** Location of research villages in Mongla (sub-district of Bagerhat District), Bangladesh

production, livestock, forest resource extraction, shrimp aquaculture and non-farm activities with particular attention given to different forms of income (e.g. the different forest sources, different crops and different animals) accrued through both cash and consumption to determine the total income for each household.

### 2.3 Qualitative data collection

We carried out three focus group discussions—one with shrimp farmers, one with non-shrimp farmers and one with shrimp farm labourers, caretakers and a temporary depot owner—covering both positive and negative impacts of shrimp farming but exploring particularly any vulnerabilities created by shrimp aquaculture. The focus group discussions explored the long-term impacts of shrimp aquaculture on agriculture, sharecropping, raising of livestock, employment, land use and access to land and other environmental resources.

Semi-structured key informant interviews on the same issues were held with Fisheries Department officials, local government elected representatives, NGO workers and the owner of a large shrimp farm. In addition to personal observations of shrimp aquaculture, secondary data were collected about shrimp aquaculture from the Mongla Sub-District and Khulna Divisional Office of the Fisheries Department.

### 2.4 Calculation of farm income

Vulnerability was assessed by measuring changes in income from different sources. Shrimp farm income included all income derived from selling shrimps and other fish products obtained from shrimp farms, processing or trading of unprocessed shrimps and associated fish products, and wage labour or temporary employment on shrimp farms. We examined all income sources from shrimp aquaculture to establish their relative importance so that different sources of shrimp income could be compared. Relative shrimp income was the proportion of total income derived from shrimp-related activities.

The category of agriculture, livestock and homestead pond fisheries income was derived from the production or gathering of unprocessed crops, livestock or fish products from homestead ponds or wage labour in these sectors. The definitions of forest, forest products and income used in this study followed the PEN (2007) definitions and consisted of income derived from harvesting unprocessed forest products, processing forest products and labour in forest-based activities. Non-farm activities included income from self-owned businesses, remittances, receipts and rents, and non-farm wages including salaries and pensions for the reference period.

Income and activity reports for mangroves and shrimp aquaculture were based on a recall period of 15 days based on the spring-neap tidal cycle. The income and activity reports for salary, wage labour, and non-farm business income, income from shrimp-based enterprises, crop income, livestock income and other transfer payments were based on a recall period of 2 months.

Based on Cavendish (2002), income was calculated as follows:

$$I = \sum_{i=1}^n p_i y_i - \sum_{j=1}^m q_j v_j$$

where income ( $I$ ) is the gross value (price,  $p$ , times quantities,  $y$ , of all  $n$  products) minus the total costs (price times quantities) of all  $m$  purchased inputs (e.g. fertilisers, seeds,

tools, hired labour). Family labour and depreciation costs could not be calculated and were excluded in the cost calculation (Vedeld et al. 2004; Mamo et al. 2007; Babulo et al. 2009). For business enterprises and forest/shrimp-processing activities, incomes were estimated as gross returns minus business-related expenses, as recollected by the respondents. Salaries and wages were recorded as earnings per month, which were then multiplied by the number of months of employment in the occupation. Total household income was the sum of cash income and subsistence income—the value of products consumed directly by the household or given away to friends and relatives, computed by grossing all the available income sources. All the price values were obtained from the respondents' own reports. A market survey was conducted in the main village markets to assess the prices of goods throughout the survey periods and check these against the prices reported by the respondents. Household consumption or accumulation, rather than the cash received for self-produced crops, livestock, forestry, homestead pond fishery and shrimp products, was converted into income by multiplying by the prevailing local or the respondents' own reported values (Cavendish 2002; Fisher 2004). Per capita income was calculated by dividing by the total number of household members (PEN 2007).

Income data were analysed on the basis of terciles using the total annual income data from all the villages combined: 264 households were divided into three terciles, each of 88, based on total annual income ("lower income" USD177–796, "middle income" USD805–1,506 and "higher income" USD1509–18,963). Mean total annual incomes for the three income groups (terciles) were USD573, USD1,114 and USD4,606, respectively, all low compared to most OECD countries.

We used the covariance formula to define the Gini coefficient of income inequality (Bellu and Liberati 2006), the Gini coefficient first being calculated for total income then recalculated by removing each income source and comparing it with the total income Gini coefficient. The Gini coefficient provides a measure of the equity of income distributions within a population. Scores range between 0 and 1, with 0 representing perfect equality and 1 representing perfect inequality (Gini 1936), i.e. the lower the coefficient, the more equally income is distributed.

## 2.5 Statistical analysis

To compare continuous variables across single factors, the data were tested for normality (Shapiro–Wilk test). Having been shown to be normally distributed, a one-way ANOVA was used to determine whether differences existed among the means. If a significant difference was found at the 5 % level, pairwise multiple comparison tests were conducted to find out the confidence levels for an entire system of intervals, simultaneously, for a given variable (Campbell et al. 2002). Ordinary least squares (OLS) multiple regressions were used to model the impact of household characteristics on relative shrimp income earnings. OLS multiple regressions were used because the explanatory variables were continuous and this gives a simpler and more precise estimation of the statistics than most other methods (Shively and Luckert 2011). We used the log–log forms of OLS, whereby both the dependent and explanatory variables are converted into natural logarithms. The multi-collinearity of the regressed variables was also checked to ensure that there was no perfect collinearity among the explanatory variables. We assumed that the samples represented the whole Sundarbans region following Kar and Jacobson (2012) who used linear regression to develop a forest income prediction model for the Chittagong Hill tract regions of Bangladesh.

### 3 Results

#### 3.1 Shrimp aquaculture practice and economics

In Mongla Sub-District, almost all land for shrimp farms have been obtained by converting agricultural land and not by clearing mangrove forest. By 2010, just 1900 ha (15 %) out of a total of about 13,000 ha of cultivable agricultural land had not been converted into shrimp aquaculture (Mongla Sub-District Fishery Office 2010). Shrimp farms (“gher”) in the study area were constructed in modified rice fields surrounded by high, broad dikes. Most farms were unplanned and unregulated small-scale enterprises constructed by the farmers themselves with limited knowledge and resources. The farmers practised shrimp aquaculture from February/March to September with shrimp fry obtained either from the wild or from hatcheries. The shrimps were released into the farms at high tide and trapped inside the farms by bamboo barriers placed across entry and exit points. Partial harvesting of marketable shrimp began 3 months after initial stocking with post-larvae and was followed by cycles of partial stocking and harvesting during the remaining culture period. In 2010, in Mongla Sub-District as a whole, *P. monodon* was farmed on 10,860 ha of land and *M. rosenbergii* on just 278 ha (Mongla Sub-District Fishery Office 2010). However, in the six study villages in Mongla Sub-District there was no *M. rosenbergii* farmed even though it was the main species of fry caught in the wild for selling to farmers living further inland.

Natural fry from wild shrimp and other fin fish were allowed to enter with the tidal water and augment the farmed shrimp income. After the shrimp aquaculture season, most shrimp farms remained vacant and dry and were not used for rice cultivation. Consequently, incomes from shrimp farms were more seasonal than other sources of income (Table 1). Farmed shrimps were harvested from May to August, wild shrimp and fin fish by-catch from May to June, and income from shrimp farm labour and businesses from May to October (Table 1). In contrast, incomes were obtained throughout the year from home pond aquaculture and forest fuelwood. Other income sources were also seasonal: fishing, crab harvest and nipa leaf harvest were each restricted to a few months, and shrimp fry was collected in the forest from January to June (*Bagda* fry in Jan–Mar and *Golda* fry in Apr–June) (Table 1).

The estimated cost of production of shrimp and associated fish by-products in the study area was USD313 per hectare per season (with the average duration of shrimp aquaculture being around eight (8) months per season; Table 2). Mean yield of farmed shrimp was about 98 kg/ha per season which accounted for 45 % (98 kg/ha) of the total yield of 216 kg/ha. Wild shrimp and fin fish accounted for 17 % (36 kg/ha) and 38 % (82 kg/ha) of the total yield, respectively.

In the study area, the mean net profit from shrimp aquaculture was found to be USD367 per hectare per year. This was within the ranges of average returns reported in other studies: USD70–840 (USAID 2006), USD210–650 (Gammage et al. 2006) and USD360–540 in small- and medium-sized (1–10 ha) shrimp farms in the Khulna region (Islam et al. 2005).

#### 3.2 Shrimp aquaculture income

Household income and assets varied across income groups. While household size was similar, lower-income households owned significantly more boats and shrimp fry nets but

**Table 1** Seasonal income-generating activities near Mongla Sub-District, Bangladesh, recorded during the course of the survey (1 year)

Year of data collection	2009						2010					
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
<b>Income categories</b>												
Non-farm												
Livestock												
Crop agriculture	Rice in Jan-Feb											
Homestead pond fisheries												
Forest - shrimp & prawn fry harvest					Bagda in Jan-March			Golda in Apr-June				
Forest - other forest products	Fuelwood throughout, fishing Sept-Oct, crabs Oct-Dec, Nipa leaves Jan-March											
Shrimp farms- farmed shrimp												
Shrimp farms - fin fish <sup>1</sup>												
Shrimp farms - wild shrimp <sup>1</sup>												
Shrimp farms – labour <sup>2</sup>												
Shrimp farms – business <sup>2</sup> ( <i>Macrobrachium rosenbergii</i> )												

<sup>1</sup> Fin fish and wild shrimp are part of by-catch in shrimp farm harvest.

<sup>2</sup> Labour and business are intrinsic parts of shrimp farming.

**Table 2** Productivity, cost and net profit from shrimp aquaculture for 264 households in Mongla sub-District, Bangladesh (mean  $\pm$  SD)

	Productivity (kg/ha)	Cost (USD/ha)	Net profit (USD/ha)
Farmed shrimp <sup>a</sup>	98 $\pm$ 13.8	295 $\pm$ 53	203 $\pm$ 75
Fin <sup>b</sup> fish	82 $\pm$ 18	18 $\pm$ 11	102 $\pm$ 21
Wild shrimp <sup>c</sup>	36 $\pm$ 13	–	63 $\pm$ 22
Total	216 $\pm$ 29	313 $\pm$ 54	367 $\pm$ 84

<sup>a</sup> Farmed shrimp means shrimp cultured in shrimp farms; local name Bagda (*Penaeus monodon*)

<sup>b</sup> Fin fish grew naturally in the shrimp farm as by-products. Common fin fish species were Vetki (*Lates calcarifer*); Parsa (*Mugil parsia*); Guilla/nuna tengra (*Mystus gulio*); Carp fin fish tilapia (*Oreochromis nilotica*)

<sup>c</sup> Wild shrimp grew naturally in the shrimp farms as by-products. The common species were Horina (*Metapenaeus monocero*); Hanny (*Metapenaeus lysianassa*); Chaga chingri (*Penaeus Indicus*); Chamna Chingri (*Metapenaeus brevicornis*)

less land, often having none, and fewer large livestock, poultry or mobile phones than the middle- or higher-income households. The heads of lower-income households also tended to have had less education than those leading wealthier households. Only seven lower-income households (8 % of all the households in that category) owned shrimp farms in comparison with 56 (65 %) and 77 (88 %) of middle- and higher-income households, respectively (Table 3). The four households described as having “no possessions” had lost ownership of their shrimp farms either permanently or temporarily due to land-related



conflicts. Of the 77 higher-income households who had shrimp farms, 36 had converted their own land into shrimp farms. The establishment of shrimp farms on partly owned and partly leased land was found to be highest in higher-income households (32 households) followed by middle-income households (24 households). This study found that 12 middle- and 9 higher-income households had established shrimp farms by leasing land from other households, incurring the payment of annual rental fees.

Higher-income households depended heavily on shrimp aquaculture, earning 41 % of their income from this source and about 5 % from trading (Table 4). For the middle-income group, income from shrimp farming and trading was substantially less (26 and 3 %, respectively) with most income derived from forest resources (48 %). For lower-income households, shrimp aquaculture accounted for only 8 % of income, most of which was from selling labour (4 %) to the shrimp farms, and negligible amounts from trading.

Of the different products from the mangrove forest, shrimp fry contributed as much as 34, 22 and 12 % to the total income of the lower-, middle- and higher-income households. Members of lower-income households and some middle-income households actively collected shrimp fry with those from middle- and higher-income households operating as primary and secondary traders and distributing shrimp fry from the primary collection points to the shrimp farms. If income from shrimp fry is considered within shrimp income, then shrimp income contributed 42 % of the total income for the lower-income households compared to 47 and 51 % of the total income of the middle- and higher-income households. However, as most fry collected are *M. rosenbergii*, which is not farmed locally, we have included fry collection income with forest products not shrimp aquaculture.

### 3.3 Factors influencing shrimp income

The OLS model explained 71 % of the variation in shrimp income and showed that, as expected, shrimp farm land area was the single largest factor determining household income (Table 5). The value of boats had a significant negative relationship, suggesting that fishing and shrimp aquaculture were largely mutually exclusive, but the value of nets and livestock was positively related to shrimp income. The age and education status of the household head, amount of homestead land, number of livestock and value of mobile phones had no relationship to shrimp income.

**Table 3** Ownership of shrimp farms and land, presented as number of households in each of the three income groups in six villages in Mongla Sub-District, Bangladesh

Characteristics	Income tercile		
	Lower	Middle	Higher
<i>Shrimp farm ownership status</i>			
No shrimp farm owned	81	30	9
Lost possession of shrimp farm <sup>a</sup>	–	2	2
Owned shrimp farms	7	56	77
<i>Land used by shrimp farm-owning households</i>			
Only owned land	1	20	36
Some owned and leased land	5	24	32
Only leased land	1	12	9

<sup>a</sup> Lost possession of shrimp farm, either permanently or temporarily, due to land-related conflicts

**Table 4** Annual net income from various sources for 88 households in each of the three income groups in six villages on the edge of the Sundarbans, Mongla Sub-District, Bangladesh

Source	Income group						F value	P value
	Low		High		Medium			
	Mean	%	Mean	%	Mean	%		
Income (USD)								
Non-farm	63 <sup>a</sup>	12.7	224 <sup>a</sup>	18.7	1283	25.7	25.05	<0.001
Livestock	8 <sup>a</sup>	1.3	37 <sup>ab</sup>	3.0	65 <sup>b</sup>	1.6	8.74	<0.001
Crop agriculture	10	1.9	27	2.4	58	1.6	46.10	<0.001
Homestead pond fisheries <sup>1</sup>	15	2.7	30	2.7	76	2.0	53.70	<0.001
Forest harvesting	434 <sup>a</sup>	73.6	514 <sup>ab</sup>	47.6	757 <sup>b</sup>	23.2	5.39	<0.05
Shrimp and prawn fry <sup>2</sup>	194 <sup>a</sup>	33.8	232 <sup>ab</sup>	21.6	334 <sup>b</sup>	11.5	4.91	<0.01
Other forest products	240	39.8	282	26	423	11.7	3.03	NS
Shrimp farms	44 <sup>a</sup>	7.8	283 <sup>a</sup>	25.6	2367	45.9	46.32	<0.001
Farmed shrimp	9.6 <sup>a</sup>	1.6 <sup>1</sup>	124.8 <sup>a</sup>	11.4	1191	22.3	38.62	<0.001
Fin fish <sup>3</sup>	5.7 <sup>a</sup>	0.9 <sup>1</sup>	74.5 <sup>a</sup>	6.7	557	10.8	36.60	<0.001
Wild shrimp <sup>3</sup>	3 <sup>a</sup>	0.5 <sup>1</sup>	40.7 <sup>a</sup>	3.7	403	7.9	41.80	<0.001
Labour <sup>4</sup>	24	4.4	9.5 <sup>a</sup>	0.9	0 <sup>a</sup>	0	8.38	<0.001
Business <sup>4</sup>	2 <sup>a</sup>	0.4	33 <sup>a</sup>	2.9	216	4.9	4.93	<0.01
Total	573 <sup>a</sup>	100	1114 <sup>a</sup>	100	4606	100	96.95	<0.001

Bonferroni's test: means followed by a common superscripted letter indicates that the means are not significantly different at the 5 % significance level. NS not significant

<sup>1</sup> Homestead pond fisheries are usually fisheries traditionally in the pond of the homestead. Generally, the homestead pond is used for domestic purposes. The income from homestead pond fisheries was calculated separately in order to get a clear picture of the contribution of shrimp income to household livelihoods

<sup>2</sup> Shrimp fry was largely *M. rosenbergii*

<sup>3</sup> Fin fish and wild shrimp are part of by-catch in shrimp farm harvest

<sup>4</sup> Labour and business are intrinsic parts of shrimp farming

### 3.4 Vulnerabilities from income inequality and loss of income diversification

We found that shrimp farm income contributed most to income inequality in the study population; the lowest Gini coefficient was when shrimp farm income was excluded (0.28) compared with the Gini coefficient per capita income of 0.38 (Table 6). This was an increase in income inequality of 36 % (0.28–0.38).

Because of the conversion from agricultural land to shrimp farms, shrimp aquaculture was associated with reductions in other income-generating farming activities, resulting in smaller livestock herds, particularly cattle and less crop production and sharecropping.

Reduced livestock production was partly attributed to a lack of fodder since the establishment of shrimp farming. Focus group discussion participants described how, before shrimp aquaculture, the paddy straw and the grass of the paddy fields had been the main feed for cows, goats and buffaloes. Also, most of agricultural land was used to grow only one crop a year and so was available for common grazing for livestock for the rest of the year. However, when ponds and dikes were constructed for shrimp aquaculture, access to this fodder was lost. Further loss of grazing land occurred when shrimp aquaculture

**Table 5** Influence of socio-economic factors on shrimp income in six villages on the edge of the Sundarbans, Mongla Sub-District, Bangladesh

Variable	Coefficient	SE	<i>t</i> -ratio	<i>P</i> value
Constant	0.068	0.127	0.535	0.593
Age of head of household (years)	−0.006	0.032	−0.192	0.848
Education of head of household (years)	−0.005	0.010	−0.480	0.631
Homestead land (ha)	0.002	0.010	0.201	0.841
Shrimp farm land (ha)	0.152	0.009	16.274	<0.001
Value of boat (USD)	−0.008	0.002	−3.747	<0.001
Number of large livestock (heads)	−0.023	0.016	−1.477	0.141
Value of mobile phone (USD)	−0.001	0.003	−0.268	0.789
Value of net (USD)	0.007	0.003	2.448	0.015
Value of livestock (USD)	0.005	0.002	2.136	0.034

OLS regression,  $F = 69.72$ ,  $P < 0.001$ ,  $R^2 = 0.71$ ; Adj  $R^2 = 0.70$ ,  $N = 264$

**Table 6** Levels of income inequality in six villages on the edge of the Sundarbans, Mongla Sub-District, Bangladesh

Income considered	Gini coefficient
Total income	0.38
Without forest income	0.52
Without shrimp farm income	0.28
Without non-farm income	0.37

ponds were illegally established on state-owned land and the banks of canals. The average number of cattle per household in the research area declined from 1.43 in 1999 (Shah and Karim 2001) to just 0.31 at the time of the survey in 2009.

Reductions in poultry were also associated with shrimp farming; directly, due to increased mortality rates (as reported by focus group participants), and indirectly, due to shrimp farm owners discouraging neighbouring households from keeping ducks since they ate the shrimp larvae and their feed (according to a key informant interview with a Sub-District Livestock Officer). In the 10 years to 2009, the average number of poultry in the research area declined from 14 (Shah and Karim 2001) to nine.

The crop most affected by the expansion of shrimp farming was rice because virtually all shrimp farms were established on fields formerly used to grow rice. The agricultural land that remained had greatly reduced productivity because of increased soil and water salinity. Local non-shrimp and small shrimp farmers in the focus group discussions revealed that rice yield in the study area had fallen from 3200 to 3700 kg/ha to 460–650 kg/ha following the expansion of shrimp aquaculture due to increasing soil and water salinity. They further stated that, in the initial years of shrimp aquaculture during the mid-1980s to early 1990s, farmers used to cultivate paddy in the same land immediately after the shrimp season ended, but this gradually stopped because the lands remained under saline water for nearly 8 months of the year for shrimp aquaculture and consequently became too saline for adequate rice yields. Participants in the focus group discussions also stated that paddy cultivation was now restricted to more elevated land which was never used for shrimp aquaculture. The diversity of rice crops also declined with 10–12 varieties of paddy no longer being grown in the study area.

Other crops were also damaged by increased salinity associated with shrimp farming. The death of fruit-bearing trees such as jackfruit, mango, guava and palm as well as lower productivity in homestead vegetable and agricultural crops was attributed to increased salinity by focus group participants and key informants. They believed that increased salinity due to shrimp aquaculture was also responsible for the loss of wild vegetation that grew naturally in the region, the loss of indigenous rice varieties and the decline of vegetable and fruit species, consistent with recorded decreases in the income received from rice and vegetables in the Mongla Sub-District in the last 20 years (Shah and Karim 2001).

According to the focus group discussions with participants of study villages, sharecropping was one of the most pervasive forms of land tenure arrangement and had provided landless and marginal farmers with opportunities to participate in agricultural production until shrimp aquaculture was widely adopted in the early 1990s. Previously, a landowner and a sharecropping tenant would each receive one-third of the harvest, and the remaining one-third would be taken by the party that supplied the production inputs. This sharecropping helped many poor families achieve food security, with the households obtaining enough rice from one crop to sustain them for 1–2 years. Sharecropping ceased to be profitable when crop yields fell because of increased soil salinity.

A focus group discussion with casual labourers and shrimp farm caretakers also identified that people from landless households now had fewer opportunities to work as wage labourers than they had had in the agricultural economy. While some new jobs had been created by the shrimp sector, most were part-time, temporary or casual and were offered without employment contracts with very low wages, usually USD1–1.30 for a half-day's work and less than wages for other labour-based activities (for example, daily wages of about USD 3.50 for agricultural labour).

Many landless agricultural wage labourers who had been affected by shrimp farm development had moved into mangrove resource extraction activities. They principally caught shrimp fry to supply to the farms or went to the forest to collect other resources. Sundarbans fishermen in the focus group discussion were also concerned that shrimp fry collectors kept the shrimp fry and destroyed the fry of other fish species. As a result, and because shrimp hatcheries were starting to produce cheaper and higher-quality fry, the collection of shrimp fry had been banned,<sup>2</sup> although enforcement of the ban was patchy with some enforcement officers using the ban as a way of extracting rent from the fry collectors instead.

### 3.5 Vulnerabilities from loss of access to land and change in land tenure

Loss of access to land was attributed to shrimp aquaculture by several means. These included reducing access to sharecropping land, large shrimp farmers forcing smaller shrimp farms to lease then sell their land and instigation of other land-related social conflicts. Before shrimp farming, the poorest, usually landless families, had opportunities to sharecrop government-owned khas land along waterways. This was the intent of the Land Reform Law of 1989 which had aimed to make this land available to the landless for fishing, grazing of cattle and growing of vegetables. However, shrimp farmers reported in the focus group discussions that they gradually leased all government-owned lands except

<sup>2</sup> Section 8(1A) of Protection and Conservation of Fish Rules (MOFL 1985).

rivers, canals and their banks and then extended their control to include the land that had been sharecropped in the past, displacing the landless poor in the process. This created potential for conflict over land leasing and access to saline water and affected land sale and leasing prices.

Land leasing by powerful shrimp farmers reduced access to land by smaller farm owners and completely replaced sharecropping. However, leasing was not necessarily voluntary. In the focus group discussions, participants stated that about 20 small farmers who owned 0.4–1.2 ha of land adjoining existing shrimp farms in two of the study villages had been forced to lease their land to the wealthier shrimp farmers. The shrimp farmers then stopped paying rent and forced sale at a low price, making the previous owners landless. This land was then used as collateral to gain loans that allowed further expansion of the wealthier shrimp farmers' businesses.

A third factor of concern that came to light in the focus group discussions was that large shrimp farmers controlled access to water from the canal. In a key informant interview, the government officer in charge of fisheries acknowledged that friction between small (<2 ha) farm owners and large (>5 ha) farm owners over the use of saline water from the canals was common and, on average, his office received 20 complaints per year related to the management of saline water in shrimp aquaculture. While these disputes were resolved by "shalish", the local informal conflict management institution mediated by local government representatives, local political leaders and members of the elite, the small farmers felt they were disadvantaged in disputes with the larger farmers.

Finally, lower-income households or landless households could no longer afford to buy land because, although small shrimp farmers had been forced to sell land at low prices to more powerful farmers, the rapid expansion of shrimp aquaculture had caused a threefold increase in land prices over a four-year period, with similar increases in the cost of leasing land. This increase was driven partly by the availability of low-interest loans from government, introduced for the purpose of intensifying shrimp aquaculture. According to the manager of the local agriculture development bank, shrimp aquaculture loans totalling nearly USD 23.3 million were disbursed among the shrimp farmers from 2006 to 2009. Unexpended parts of the loans were used by the rich shrimp farmers to establish shrimp-related businesses and non-farm trading businesses and for the purchase and leasing of land, creating further inequality and landlessness. The result was that effective control of most land previously distributed among poor households had shifted to a small number of large shrimp farmers with the political connections and financial resources necessary to farm shrimp.

The land conflicts in the study area included forcible occupation and counter-occupation of land and shrimp farms, armed assault, poisoning of shrimp farms, murder and severe injuries. According to informants, parties with strong connections to the ruling political party were more likely to retain or wrest control of land for shrimp aquaculture from poorer people or members of the other party, especially after a change in ruling party. Thus, existing power dynamics were exacerbated through access to and ownership of shrimp farm land. We were told of four cases in one study village where shrimp farmers had been evicted from their farms which were then taken over by other shrimp farmers.

## 4 Discussion

### 4.1 Contribution of shrimp income to livelihoods

The information on shrimp aquaculture near Mongla is broadly similar to that in other parts of the Sundarbans hinterland both in terms of yield (Nuruzzaman et al. 2001) and costs of production (Islam et al. 2005; USAID 2006; Gammage et al. 2006). So too is the current dominance of shrimp aquaculture as a use of land: Ali (2006) calculated that 79 % of prime quality rice fields in two villages in Khulna District had been converted into shrimp farms during the period from 1985 to 2003, and overall, it has been calculated that shrimp production, together with shrimp fry collection and fry and shrimp businesses, contributed 60 % of the total household incomes in the shrimp producing areas in Bangladesh (Thomas et al. 2001). In particular, shrimp income now forms an integral part of the higher-income and some middle-income households' income generation activities. The increased demand for shrimp exports has led to a reorganisation of shrimp procurement and trade networks, which has led the higher- and middle-income households to establish shrimp depots and shrimp-related businesses in order to earn more income from shrimp activities. In addition, shrimp aquaculture helped some higher- and middle-income households to establish non-farm businesses or trading enterprises. Therefore, economic growth due to shrimp aquaculture has had a positive outcome for households with shrimp farms because shrimp aquaculture increased their income-earning opportunities.

However, just as the villages near Mongla appear to be typical in terms of the economics, so too are the negative effects of shrimp farming. In Bangladesh, income from shrimp aquaculture, though not the shrimp sector as a whole, has been highly skewed in favour of the relatively rich. Even 15 years ago, 84 % of the very poor derived no income at all from shrimp aquaculture, whereas the very rich earned 58 % of their total income from shrimp aquaculture, and the very poor earned only 8 % (Quddus et al. 2001). Hue and Scott (2008) in Vietnam and Bosma et al. (2012) in Indonesia have made similar observations of the poor, noting that those without shrimp ponds were largely dependent on mangrove resources with the rich households being the only group that earned income from trading shrimp. Similarly in the Mekong delta, shrimp aquaculture was more profitable for households with a higher investment capacity than for poorer households (Jojjre and Schmitt 2010).

Land is the primary driver of income from shrimp aquaculture. The capacity to profit from the shrimp industry is ultimately connected with the ability to own, lease or otherwise control land. Since land can be used as collateral to obtain loans from banks or other credit-providing organisations, land-owning high- and middle-income households were able to access government support for diversification through the development of shrimp aquaculture and related businesses that provided higher incomes. In contrast, lower-income households in the study area were increasingly marginalised and either driven into the mangroves to garner resources for sale or to sell their labour, often at very low rates (Swapam and Gavin 2010) because supply usually exceeds demand (Manju 1996). They can no longer share-farm idle land to grow rice, their trees and household food crops were killed by shrimp-related salinisation of the soils, and they had great difficulty obtaining water for their own small shrimp farms and were even denied access to the government-owned canals and waterways. These results are supported by another study carried out on shrimp aquaculture in the Khulna region which found that rich households controlled about 15 times more land than the poor (Quddus et al. 2001) and the 4 % of the households with

over 3 ha of land derived the majority of direct benefits from shrimp cultivation, while the 41 % of households that were landless derived just 2 % (BCAS 2001). Other studies in Bangladesh have found that reduced access to land has narrowed livelihood opportunities of the rural poor, widened the gap between rich and poor and diminished social cohesion (Deb 1998; EJF 2004; Swapan and Gavin 2010).

#### 4.2 Vulnerabilities related to shrimp aquaculture

Shrimp income is a factor causing income inequality in the study area because the economic benefits of shrimp aquaculture have not been shared fairly, and the economic activities related to shrimp aquaculture have widened the gap between the higher- and lower-income households. Inequality increases the vulnerability of the poor by constraining the options of households and individuals when faced with external shocks (Adger 1999) and by reducing the diversity of potential income sources (Ellis 1998). Thus, rather than offering a panacea to rural development in the study region, shrimp aquaculture appears to have led to greater income disparities between rich and poor (Ito 2002; EJF 2004). While the Gini coefficient without shrimp income was similar to those recorded from villages across Bangladesh with various forms of aquaculture, including two with shrimp or prawn aquaculture (range 0.21–0.29; Belton et al. 2014), it jumped to 0.38 when shrimp farm income was included. Had the Sundarbans forest resources not been available, the score would have been 0.52, underlining the importance of the natural environment to the livelihoods of the poorest people in the population (Abdullah et al. 2016a, b). Although Belton et al. (2014) reported a relatively low Gini coefficient for the prawn farming village he studied (0.25), high levels of income inequality associated with shrimp farming appear to be more typical: Abdullah et al. (2016a) found the Gini coefficient for a prawn farming site south of Khulna in south-western Bangladesh was 0.43–0.51 until a cyclone destroyed the prawn farms, when it fell to 0.27. Ahmed et al. (2002) maintained that the groups benefitting the most may include shrimp farmers, large rural landowners, absentee landlords, urban entrepreneurs, a few government officials and political elites. The distribution of benefits from shrimp across different social categories is unjust and unequal (Datta 2001). As a result, the income opportunities for the poor are reduced, while these opportunities increase for rich and medium-scale commercial farmers. There are parallels elsewhere. For example, the change from agriculture to aquaculture dependence in northern Vietnam was found to have had complex stressful effects on the levels of vulnerability in local livelihood systems (Adger 2000). As elsewhere, the promotion of export-oriented production has had detrimental consequences for both livelihoods of local populations and the environment (Rivera-Ferre 2009; Veuthey and Gerber 2012).

The loss of capacity to engage in agriculture and keep livestock because so much of the land had been converted into shrimp aquaculture ponds was one of the major causes of vulnerability for the lower-income households. These findings were similar to those of Belton et al. (2014) where commercial aquaculture expansion on land previously cultivated for paddy resulted in an inverse relationship between aquaculture employment and agriculture. In most cases, Belton et al. (2014) found that commercial aquaculture needed more hired labour per hectare than agriculture and smoothed seasonal employment cycles, but that this was not the case for shrimp farming for which the requirement for hired labour was considerably lower. The impact was particularly unfavourable for women whose labour associated with the shrimp farming was both potentially hazardous and poorly paid (Ito 2002). At our study site, poor landholders and those with no land at all had lost the little access they had to land, particularly land previously accessed for sharecropping

(BCAS 2001; Samarakoon 2004). In losing access to land, they also lost locally adapted rice varieties (Rahman et al. 2011) and had less land on which to keep livestock, one of the resources of last resort among the very poor (Karim 2006; Shah and Karim 2001). The results parallel those found in Khulna District, also near the Sundarbans, where the livelihoods of landless labourers had deteriorated both in terms of quality and security of life in shrimp producing areas (Paprocki and Cons 2014). Income from agriculture had become so low that households no longer considered agriculture as a livelihood strategy in the study area. In place of the food they would once have grown, they bought food grown elsewhere in Bangladesh. The need to buy rice, a staple food, had created a feeling of dependence and insecurity since sources of cash were so few.

The main alternative source of income for lower-income households was illegal fry collection. People who had previously worked as labourers had no choice but to move to market-oriented shrimp fry collection in order to supply the aquaculture ponds. Yet fry collection, which has become a major source of income for thousands of poor people in the Sundarbans (Multidisciplinary Action Research Centre 1997; Frankenberger 2002; Azad et al. 2007; Ahmed et al. 2010a, b), is a highly precarious source of income for lower-income households because it is illegal, even if it is poorly policed.

Shrimp aquaculture had also led to social conflicts over land tenure, leasing land arrangements and user rights between rice and shrimp farmers, between small and large shrimp farm owners and between lessor and lessee households. Households that lost control or ownership rights to their lands due to conflict had become landless and were immediately far more vulnerable to shocks. Legal challenges to settle issues arising from land conflict could take five to ten years in court to resolve, effectively discouraging recourse to the law. Similarly, there was little poor people could do about armed assault and other criminal acts that aimed to increase control of shrimp aquaculture lands by wealthier farmers—over 150 people have reportedly been killed since 1980 in clashes related to shrimp aquaculture (EJF 2004). The phenomenon is not confined to the study area. Swapan and Gavin (2010) reported 150 shrimp-related land conflicts among households in another sub-district (Koyra), and while there had been some resistance (Belton et al. 2014), many shrimp farm owners had illegally acquired leased-out land in the shrimp aquaculture areas in Khulna, rendering the original land owners landless (Begum and Alam 2000; Khatun 2009).

Shrimp aquaculture also had detrimental effects on the biophysical environment, which also affected local livelihoods. Shrimp aquaculture over the last three and a half decades in Bangladesh has been associated with increases in soil salinity in more than 1 million hectares of coastal arable land that could have yielded 2.5 million tonnes of rice, enough to meet the country's annual food deficit (Hossain 2011). Salinisation and inundation have also caused reduced agro-biodiversity (loss of rice varieties and death of tree crops in this study; Rahman et al. 2011) and a lack of fresh water in the study villages also forced people to travel long distances to collect drinking water because government-owned ponds had become salty. By-catch destruction during the collection of wild seed and broodstock has resulted in reduction in aquatic resources in the mangrove forest (Rahman et al. 2013).

### 4.3 Management options and policy implications

Management of coastal zones worldwide presents challenges to achieving sustainability for both the environment and local livelihoods (Hoanh et al. 2006). In many cases, traditional systems of access to common pool resources have been replaced by more productive, commercial practices which have excluded the poor from access to resources (e.g.



Benessaiah and Sengupta 2014). Likewise, in our study in the Sundarbans, the landless poor lost access to common land with the establishment of shrimp farms. Changes to management and access have often been associated with political interventions, for example: colonisation in West Africa (Cormier-Salem 2006) and various interventions by the State in Nicaragua such as the return to community common property management in Nicaragua (Benessaiah and Sengupta 2014) and the establishment of community stewardship (“custodias”) in Ecuador (Ocampo-Thomason 2006). In the Sundarbans of Bangladesh, planned management of coastal land has begun with zoning, but there remains the challenge of implementing equitable access to common resources and minimising detrimental impacts of intensified shrimp production (Islam 2006). Our study has highlighted that the landless poor are especially disadvantaged by the establishment of shrimp farms, and their situation needs to be incorporated into plans and regulations to achieve cooperative and equitable access to coastal resources within the population of the Sundarbans.

## 5 Conclusion

The paper examined the changes in the livelihoods structure and well-being of rural households near the Sundarbans mangrove forest in Bangladesh following the conversion of agricultural land into shrimp aquaculture. We found that livelihood strategies in the study region were being driven by shrimp aquaculture which was economically beneficial for higher- and some middle-income households, particularly those owning land, but negatively affected the livelihoods of landless and marginal farmers. The higher levels of income inequality in the study area and widening gap in household wealth had come about because of rapid changes in local land use systems, and land ownership and management practices associated with shrimp farming. The changes had weakened the income-earning opportunities of lower-income households and increased income inequality and vulnerability. The distribution of the income generated by shrimp farming was biased in favour of the groups who controlled the land and the resources necessary to participate. Unplanned shrimp aquaculture had caused the destruction of trees and plantations and reduced the area available for agricultural crops and livestock. Local manifestations of vulnerability included: land tenure arrangements that limited access to land; reduced livelihood opportunities due to the loss of access to land for agriculture and livestock, a reduction in the diversity of livelihood resources and environmental degradation (raising salinity, soil infertility); and rising prices of staple foods such as rice and vegetables that no longer were grown locally but now had to be imported from other parts of Bangladesh. Overall, we conclude that shrimp aquaculture has deepened social inequalities, increased pressure on the livelihoods of the poor and the compromised the sustainability of the Sundarbans region as a whole.

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