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Social, economic and production characteristics of freshwater prawn, *Macrobrachium rosenbergii* (De Man, 1879) culture in West Bengal, India

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Abstract Farming of giant freshwater prawn *Macrobrachium rosenbergii*, popularly known as 'scampi,' has recently been expanding in India. The present study was conducted using questionnaire survey, Participatory Rural Appraisal (PRA), key informant interviews, and focus group discussion and to assess the present state of production of giant river prawn (*M. rosenbergii*) in South 24 Parganas District of West Bengal, India. The socio-economic and technical survey on 80 prawn farmers was conducted during May, 2014–April, 2015. Prawn culture in ponds is slowly departing from the traditional endogenously managed system to a more extensive and commercial venture in the study areas. However, use of technology and scientific knowledge has not been adopted widely. In spite of operating within a semi-traditional system, this enterprise has shown moderate productivity and higher income in the study areas. Major constraints in the large-scale culture of prawn were adequate supply of seed at required quantities across locations, disease management, and social evils such as theft and poisoning of pond. Yield of prawn culture was affected by pond condition, family labor engagement in prawn culture, and resource endowment of the farm family. Linkage with formal financial institutions, subsidized input support from fishery department and investment in human resource development of farmers might be some point of intervention to boost prawn culture in the coastal zone of West Bengal, India.

Keywords *Macrobrachium rosenbergii* · Semi-extensive system · Production constraints · India

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Introduction

The giant river prawn, *Macrobrachium rosenbergii* is native to South-East Asia, South Pacific countries, northern Oceania and western Pacific islands (New 2000, 2002). The larval stage of the species requires brackish water, so uncultivated individuals are often found in estuaries and post-larvae begin to move into freshwater 2 weeks after metamorphosis. Adults are found in most inland freshwater areas, preferring turbid conditions (New 2002). A large amount of its production has taken place in China, and there has been a rapid expansion in India and Bangladesh (Islam et al. 2000). The global production of all species of freshwater prawns reached 444,000 tons valued at US$2.2 billion (New and Nair 2012). Freshwater prawns have been cultured in many countries including Bangladesh, China, India, Indonesia, Philippines, Thailand, and Vietnam (Halwart and Gupta 2004; Pradeep et al. 2005). Despite its high economic importance, data scarcity on social, economic, and production characteristics is prevalent for the freshwater prawn farming in West Bengal.

Declining economic return from smallholder system, coupled with land fragmentation, has caused serious imbalance in rural socio-economic stability in developing nations. Alternative farm-based livelihoods, in absence of alternative employment in rural areas, have become a *sin-quo-non* for sustaining smallholder livelihoods in many of these agrarian societies. Freshwater prawn culture can be practiced by unskilled rural people on small establishments, and prawns are consumed domestically by all social classes. This differs considerably from marine shrimp farming, which is controlled by a small number of individuals and is primarily for export (New and Valenti 2000). Also, social conflict and environmental impacts are at minimum in prawn culture compared to marine shrimp farming. Prawns are produced in inland ponds which are easily integrated into the landscape, reducing competition for coastal resources (Ghosh and Sahu 2015). As a counterpoint, if individuals are to adopt this aquaculture system, they need to establish no or little environmental externalities from the current practices and must understand the link of potential pollution with the management of aquaculture.

There is a clear need to undertake socio-economic and environmental research on freshwater prawn farming for at least two reasons. First, we need to characterize the farmers in terms of their socio-economic profile and management practices to have an idea about the practicing community and identify possible technical deficiencies in their practices. Second, this information will help in finding out possible links between the prawn culture and environment and target technical interventions meaningfully. Further, identification of production constraints and factors of productivity will help in formulating appropriate extension intervention and policy framework.

The objective of this paper was to assess the socio-economic condition of the farmers, types of production systems, management strategies adopted, level of input use, level of production, and net profits of the practicing farmers. Further, the paper also examines the problems of the prawn culture and the perceived causal link of this culture with environments. Then, we identify and describe the factors which have significant influence on prawn productivity in the study areas.

Materials and methods

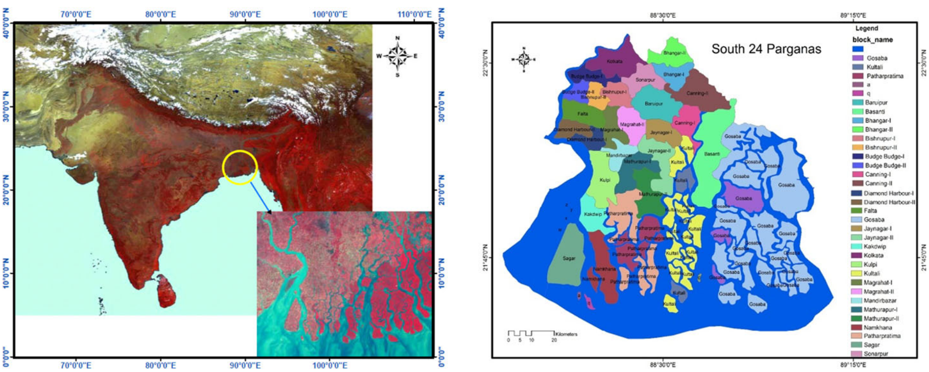
Study locations and sampling

The study was conducted in four blocks, namely, Gosaba, Basanti, Baruipur, and Kakdwip, in South 24 Parganas District of West Bengal, India, which is located in between 21°29′0″N and 22°33′45″N latitude and in between 88°3′45″E and 89°4′50″E longitudes with an average altitude of 7 m from minimum sea level (Figs. 1 and 2). Four major prawn-producing areas in South 24 Parganas District were identified based on the 2011 Survey Data on prawn production and area, collected from farmers. Three villages each from the identified areas were selected based on the suggestion of Fisheries Extension Officer and Agricultural Technology Management Agency officials. Geographical coverage, livelihood pattern, accessibility, and number of prawn farms in a village (20–30 nos) were considered for the selection of respondents. Within each village, respondents from different social groups, income groups, gender, and relation with prawn farming were included in the sample. In total, 84 respondents representing the cross-section of the communities were selected for personal interview. Four questionnaires were dropped due to data insufficiency, and data on 80 respondents were retained in the dataset. Key informants were purposively selected based on their sound knowledge of the prawn farming in the locality and their affiliation to local extension institutions.

Following Barlett et al. (2001), we had calculated the sample size for the study. It was calculated by the following formula of sample size determination for estimating population mean (the yield in t/ha) given by

$$n = \frac{z^2 \sigma^2}{e^2} \tag{1}$$

where n = sample size; z = abscissa of the normal curve cutting off an area $\alpha/2$ at the tails (1.96 in our case), "e" is the desired level of precision (±3%~0.0576 t/ha in our case), and



Figs. 1 & 2 Map of freshwater prawn surveys conducted in different selected blocks of South 24 Parganas, West Bengal, India (ERDAS, 2011 ver) σ = variance of the variable (yield of freshwater prawn) in the population (1.0 t/ha in our case). We found a sample size of 66.69~67. For securing a safe sample size, we added 20% sample (13.4) to it. Thus, a sample size of 80 was aimed at. However, in the field, we collected data on 84 respondents representing the cross-section of the communities, from which four incomplete questionnaires were dropped.

Variables and their measurements

Calculation of few important techno-managerial variables such as stocking, input use, production, and income were based on water area, excluding dykes, water storage ponds, or fish ponds. Production values represent gross production as many farmers stocked post-larvae (PL) of negligible weight; however some, stocked juveniles. Net profits were calculated for cases that included value for both water area for prawns and the entire area of the farm including dykes. All variables were calculated for a cycle period and extrapolated to yearly values. A cycle means the period of time from the beginning of pond preparation until final harvest when ponds were drained out. A list of variables used in the study, along with their descriptions, is given in Table 1.

Method of data collection:

Farmers were interviewed on their farms with a pre-tested semi-structured interview schedule. These interviews were coupled with participatory appraisal techniques and series of focus group discussions. Small-scale survey, when employed along with a variety of tools, is reported to yield cost-effective data on rural livelihoods (Ellis 1998). Therefore, a large variety of techniques and tools such as questionnaire survey, focus group discussion (Holloway 1997), Participatory Rural Appraisal (PRA) (Chambers and Conway 1992), semi-structured interviewing, and documents review (Shiyani and Pandya 1998; Goswami et al. 2014) was employed in the study.

The semi-structured socio-economic and technical survey was conducted during the period of May, 2014 through April, 2015 in different blocks of South 24 Parganas district of West Bengal. The survey instrument consisted of both closed and open-ended questions. Open-ended questions were concerned with stocking densities, feeding rates, production, and corresponding costs; these information were necessary to calculate yearly production rates and net profits. All surveys were conducted in Bengali as it was the vernacular language for the selected study area; all were simultaneously translated into English. The questionnaire was pre-tested on non-sampled respondents before the final data collection. Data collected from FGD were on aquaculture scenario, management of prawn culture, associated economics, and institutional support received in prawn culture. Modified PRA tool Problem and Solution Tree were used to identify the problems of inland prawn culture, where the trunk of the tree represents the problem, the roots its causes, and the branches its solutions. Key informant interview were recorded and later transcribed as qualitative statements. The information generated through secondary data sources kept with fishery departments, focus group discussions, PRA, and key informant interviews were used to complement the findings received from the questionnaire survey. Transcripts for key informant interviews were used to affirm the validity of the data collected through questionnaire and FGDs.

Table 1 Variables used in the study and their description

Sl. No.	Variables	Description
1	Age	Chronological age, measured in years
2	Education	Formal education received; categorized as illiterate, primary, secondary, above secondary
3	Occupation	Primary source of cash income of the household; categorized as agriculture, fishery, business, others (if any)
4	Land ownership	Legal ownership of the pond; categorized as own, leased in, corporate
5	Enterprise ownership	Managerial and ownership nature of the enterprise; categorized as manager, owner and manager
6	Training received	Institutional training on scampi farming; if received (yes)—1, otherwise (no)—0
7	Energy source	Source of energy used in the scampi farm; categorized as none, electricity, generator
8	Nature of culture	Nature of scampi culture; categorized as mutually exclusive "monoculture" and "polyculture"
9	Production system	Categorized as "grow out" and "nursing and grow out"
10	Total pond area	Area of the pond, measured in katha (1 katha = 66.67 square meter)
11	Area of nursery pond	Area of the nursery pond, measured in katha (1 katha = 66.67 square meter)
12	Family size	Number of members in the household
13	Permanent labour	Number of labor staying in the farm during a production cycle for scampi culture
14	Casual labour	Number of casual labors employed during a production cycle for scampi culture
15	Hired labour	Number of hired labors employed during a production cycle for scampi culture
16	Source of water	Water source used for scampi farming; categorized as river, lake, reservoir, dam, shallow well, deep well, rainwater, others (if any)
18	Size of prawn in nursery pond	Size of the prawn in the nursery, measured in inch
19	Price of prawn in nursing	Last season market price (Rs.) of the prawn during nursing as recalled by the farmers
20	Weight of prawn during transfer	Weight of prawn during transfer from nursery to main pond; measured in gram
21	Cycle of production	Span of a production cycle for scampi production; measured in months
22	Depth of pond	Depth of pond in feet
23	Type of soil	Texture of the soil at the bottom of the pond as reported by the farmers
24	Application of Urea	Amount of urea applied in the pond per cycle; measured in kg
25	Application of Potash	Amount of potash applied in the pond per cycle; measured in kg
26	Application of lime	Amount of lime applied in the pond per cycle; measured in kg
27	Application of organic manure	Amount of organic manure applied in the pond per cycle; measured in kg
28	Equipment use	Externally manufactured devices used in scampi farming; multiple response recorded against categories: pump, compressor, aerator, vehicles, generators, others (if any)
29	Aerator use	Type of aerator used; categorized as none, paddle wheel at surface, paddle wheel under water
30	Measure water quality	Whether water quality measured in last cycle; categorized as "yes"—1 and "no"—0
31	Cost of production	Total cost (Rs.) of production of scampi farming including input and labour cost per cycle
32	Cost of energy	Cost of energy (Rs.) in scampi farming per cycle
33	Harvesting	Technique employed in harvesting scampi; categorized as beach seine, cast net
34	Scampi production	Physical production of scampi per katha per cycle per unit area
35	Income	Cash earning (Rs.) from scampi farming in a cycle
36	Pollution impact	Perceived impact of pollution on scampi culture; categorized as no impact, moderate, severe
37	Pollution source	Sources of pollution that impact scampi culture; categorized as agriculture, industry, domestic waste, none

Data analysis

To characterize the social, economic, and techno-managerial dimensions of prawn farmers, descriptive statistics such as frequency distribution (tabular) and estimated mean with ±standard error (graph) were used. For identifying the influential factors of prawn production, a linear regression with 13 independent variables were taken up. Since high collinearity was diagnosed among these variables, a principal component analysis was used to reduce the dataset (Jolliffe 2002). Orthogonal rotation (varimax method) was employed to club smaller number of highly correlated variables under identified factors (Field 2005). Following Kaiser's criterion, factors exceeding an eigenvalue of one were retained (Kaiser 1970). After extraction of five principle components (PCs), the scores were saved in the dataset for regression analysis. The five PCs were then regressed with the prawn productivity following linear multiple regression (Çamdevýren et al. 2005).

Data were analyzed using SPSS (version 20.0) statistical software package (SPSS Inc., Chicago, USA) for generating descriptive statistics, principal component analysis, and linear regression. Surfer 8 software was used for development of maps.

Results

During the early 1990s, prawn culture started in the coastal blocks of South 24 Parganas district, mostly in a traditional way, with natural seeds and no external feed (Table 2). Household waste, cow dung, rice, or wheat bran was given as feed, and the harvest was used for household consumption only. The main problem was disease outbreak and high differential growth of prawns. Traditional and extensive monoculture was introduced during the second half of the decade. Extensive polyculture was started from 2000 in hatchery using low-cost indigenous feed. For the last few years, semi-extensive system of both mono- and polyculture was being practiced with pellet feed. During this time, span market has also expanded from household consumption to local market and from local market to export market.

Among the 80 respondents interviewed, 35 respondents were from Gosaba, 21 from Kakdwip, 14 from Basanti, and 10 from Baruipur blocks of South 24 Parganas district of West Bengal. Most of the prawn farmers had completed primary (66.3%) or secondary education (30%) (Table 2). Most of the respondents' primary occupation was fishery (50.38%) followed by agriculture (39.7%). In Kakdwip, the highest proportion of respondents (57.58%) primarily depended on fishery; in Gosaba, agriculture was the mainstay of livelihoods (50.0%). Most of the prawn rearing farmers (75%) had owned land to rear prawn, while 22% of them reared prawn in leased in land. The percentage of leasing in land was highest (33.33%) in Kakdwip. Most of the prawn growers (96.3%) initiated the business themselves and were owner manager of their farms.

Only a small percentage (13.75%) of farmers received training on fishery or prawn rearing from government or non-government organizations (Table 3). Respondents from Gosaba received more training (20%) than other blocks, and no trained respondents could be found in Basanti (Table 4). Most of the farmers (87.5%) grew Indian major carp-based polyculture and the rest of them practiced monoculture. Grow out system was prevalent (96.25%) in the study areas, where 3.75% farmers started nursing and grow out production

Table 2 Timeline on scampi farming in the study areas

Time	Culture method	Type of culture	Seeds	Feeds	Marketing	Problems
1990–1995	Traditional	Irregular	Natural	No feeds (pond productivity)	Household use only	Disease outbreak, high differential growth
1996–2000	Traditional and extensive	Monoculture	Natural	Kitchen waste	Local market	Disease outbreak, poor quality, pond water quality
2001–2005	Extensive	Polyculture	Hatchery and natural	Indigenous low cost feed	Local market	Poor quality seeds, disease outbreak
2006–2010	Extensive	Polyculture	Hatchery and natural	Indigenous low cost feed	Local market and export	Poor seeds, social problem, poaching
2011–2015	Semi-extensive	Monoculture and polyculture both practiced	Hatchery and natural	Indigenous low cost feed and pellet feed	Local market and export	Giving of poison in the pond main problem of scampi framing

Table 3 Distribution of respondents according to selected background variable

	Gosaba	Basanti	Baruipur	Kakdwip	Total	Chi square/exact test significance
Education						
Illiterate	2 (5.71)	0 (0.0)	0 (0.0)	0 (0.0)	2 (2.5)	0.57
Primary	21 (60.0)	9 (64.29)	7 (70.0)	16 (76.19)	53 (66.3)	
Secondary	12 (34.29)	5 (35.71)	2 (20.0)	5 (23.81)	24 (30.0)	
Above Secondary	0 (0.0)	0 (0.0)	1 (10.0)	0 (0.0)	1 (1.2)	
Occupation						
Agriculture	25 (48.08)[a]	14 (50.0)	5 (27.78)	8 (24.24)	52 (39.7)	0.01
Fishery	26 (50.0)	13 (46.43)	8 (44.44)	19 (57.58)	66 (50.38)	
Business	1 (1.92)	1 (3.57)	5 (27.78)	6 (18.18)	13 (9.77)	
Pond ownership						
Owned	33 (73.33)[a]	14 (82.35)	9 (69.23)	21 (66.67)	77 (74.76)	0.84
Leased in	10 (22.22)	3 (17.65)	3 (23.08)	7 (33.33)	23 (22.33)	
Corporate	2 (4.55)	0 (0.0)	1 (7.69)	0 (0.0)	3 (2.91)	
Enterprise ownership						
Manager	2 (5.71)	0 (0.0)	1 (10.0)	0 (0.0)	3 (3.7)	0.36
Owner + manager	33 (94.29)	14 (100)	9 (90.0)	21 (100)	77 (96.3)	

Figures in parentheses are percentages to the column marginal

[a] Multiple responses recorded

system recently. In fact, this number has grown rapidly in the last few years. The farmers depended mostly on rain (48.67%) as a source of water, followed by river water (18.67%). The main source of water for prawn was rain water at Gosaba, and the farmers also used river's brackish water mixed with freshwater. In Baruipur, farmers used lake water, and in Kakdwip farmers used deep well, shallow well, or dam water for their prawn pond. Higher pond size was found in Gosaba (30–40 katha average), followed by Basanti, Kakdwip, and Baruipur (Fig. 3). Average depth of pond was highest in Gosasba and Baruipur, closely followed by Basanti (Fig. 4). The range of depth was mostly 6–8 ft. Majority of soil type in ponds were either silt (60%) or clay (37.5%). At Basanti, clayey, silty, or sandy clay bottom soil was found. In Baruipur and Kakdwip, soil was more or less the same—either silty or clayey. Pump (68.95%) and generators (14.29%) are most commonly used equipments in farm, although aerators (8.05%) and compressors (5.59%) were also found. Farmers used pump set to recharge and discharge water in the prawn pond. In Baruipur and Kakdiwp, where farmers were relatively more resource-rich, farmers used generators and aerators in addition to pump sets. Among the aerators, both paddle wheels under water (10.13%) and at surface (5.06%) could be found. Most of the farmers were aware of and practiced water quality testing (77.5%). In Baruipur, block framers' monitoring of water quality varied widely—from daily, to weekly, bi-weekly, and monthly. At Basanti block, most of the farmers measured water quality monthly, and very few measured water quality daily. At Gosaba and Kakdiwp, most of the farmers measured water quality weekly and monthly. The pH of the ponds in the selected blocks of South 24 Parganas ranged from 7.1–8, although >8 and value in the range of 6–7 were also recorded. Stocking of prawn was mostly traditional (80%), and harvesting was predominantly beach seine (75.94%).

Farmers used to employ both permanent and casual labors for prawn culture. Mostly the large farmers employed permanent labors with 3500–4000 rupees monthly payment. Casual labors were employed as per the need of the farm owner. In Kakdwip, we found higher casual labor engagement (2–3), followed by Baruipur, Basanti, and Gosaba (Fig. 5).

Table 4 Distribution of respondents according to selected techno-managerial variables

	Gosaba	Basanti	Baruipur	Kakdwip	Total	Chi square/ Fisher's exact sig.
Training received						
Yes	7 (20.0)	0 (0.0)	3 (30.0)	1 (4.76)	11 (13.75)	0.06
No	28 (80.0)	14 (100)	7 (70.0)	20 (95.24)	69 (86.25)	
Nature of culture						
Monoculture	6 (17.14)	1 (7.14)	1 (10)	2 (90.48)	10 (12.5)	0.89
Polyculture	29 (82.86)	13 (92.86)	9 (90)	19 (9.52)	70 (87.5)	
Production system						
Grow out	35 (100)	13 (92.86)	9 (90)	20 (95.24)	77 (96.25)	0.19
Nursing and grow out	0 (0)	1 (7.14)	1 (10)	1 (4.76)	3 (3.75)	
Source of water						
River	20 (37.74)[a]	0 (0)	0 (0)	8 (14.82)	28 (18.67)	0.00
Lake	3 (5.66)	0 (0)	8 (34.78)	2 (3.7)	13 (8.67)	
Reservoir	0 (0)	0 (0)	1 (4.35)	3 (5.56)	4 (2.67)	
Dam	0 (0)	0 (0)	1 (4.35)	6 (11.11)	7 (4.67)	
Shallow well	0 (0)	5 (25.0)	3 (13.04)	7 (12.96)	15 (10.0)	
Deep well	0 (0)	2 (10.0)	0 (0)	8 (14.81)	10 (6.67)	
Rainwater	30 (56.6)	13 (65.0)	10 (43.48)	20 (37.04)	73 (48.67)	
Energy source						
None	0 (0)	0 (0)	1 (10.0)	0 (0)	1 (1.25)	0.04
Electricity	33 (94.29)	13 (92.86)	8 (80.0)	15 (71.43)	69 (86.25)	
Generator	2 (5.71)	1 (7.14)	1 (10.0)	6 (28.57)	10 (12.5)	
Type of soil						
Clay	8 (22.86)	8 (57.14)	5 (50.0)	9 (42.86)	30 (37.5)	0.09
Silt	26 (74.29)	6 (42.86)	4 (40.0)	12 (57.14)	48 (60.0)	
Loam	1 (2.86)	0 (0)	1 (10.0)	0 (0)	1 (2.5)	
Equipment use						
Pump	58 (74.36)[a]	15 (62.5)	12 (60.0)	26 (68.42)	111 (68.95)	0.23
Compressor	2 (2.7)	2 (8.33)	2 (10.0)	2 (5.26)	9 (5.59)	
Aerator	5 (6.76)	3 (12.5)	2 (10.0)	3 (7.9)	13 (8.05)	
Vehicles	1 (1.35)	2 (8.33)	1 (5.0)	1 (2.63)	5 (3.12)	
Generators	12 (16.23)	2 (8.33)	3 (15.0)	6 (15.79)	23 (14.29)	
Type of aerator used						
None	29 (85.29)	11 (78.57)	9 (81.82)	18 (85.71)	67 (84.81)	0.17
Paddle wheel at surface	4 (11.77)	0 (0)	0 (0)	0 (0)	4 (5.06)	
Paddle wheel under water	1 (2.94)	3 (21.43)	2 (18.18)	3 (14.29)	8 (10.13)	
Measure water quality						
Yes	28 (80.0)	12 (85.71)	7 (70.0)	15 (71.43)	62 (77.5)	0.69
No	7 (20.0)	2 (14.29)	3 (30.0)	6 (28.57)	18 (22.5)	
Stocking of prawn						
Traditional	29 (82.86)	13 (92.86)	7 (70)	15 (71.43)	64 (80.0)	0.34
Semi-intensive	6 (17.14)	1 (7.14)	3 (30)	6 (28.57)	16 (20.0)	
Harvesting						
Beach Seine	31 (88.57)	12 (85.71)	2 (20)	15 (71.43)	60 (75.94)	0.00
Cast net	4 (11.43)	2 (14.29)	8 (80)	6 (28.57)	19 (24.04)	

Figures in parentheses are percentages to the column marginal

[a] Multiple responses recorded

In Gosaba, however, higher permanent labor engagement (approx. 3 no.) could be observed, followed by Basanti, Baruipur, and Kakdwip (Fig. 6). Most of the farmers completed one cycle within 7–9 months and few of them earned extra profit by extending the cycle up to 10–12 months. It was mostly observed at Basanti and Baruipur (Fig. 7).

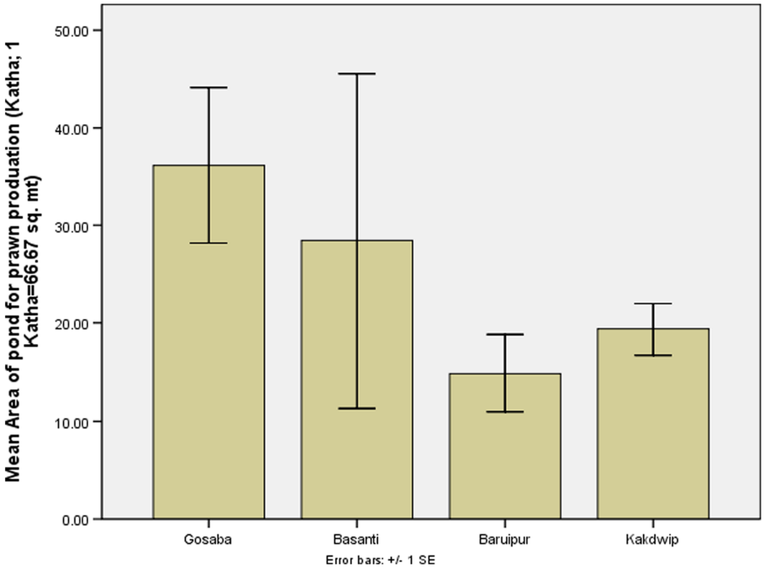


Fig. 3 Mean size of the pond for prawn production

Electricity was the major source of energy (86.25%), followed by diesel-operated generator (12.5%). Highest mean cost of energy was found in Baruipur (more than Rs.400), followed by Kakdwip (Fig. 8). Application of organic manure was highest in Kakdwip block (15–20 kg), followed by Kakdwip, Basanti, and Baruipur (Fig. 9). Urea application

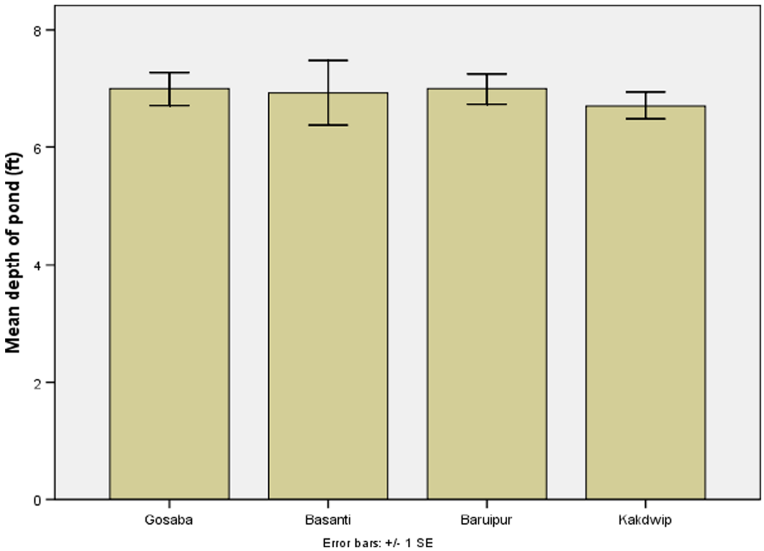


Fig. 4 Mean depth of pond

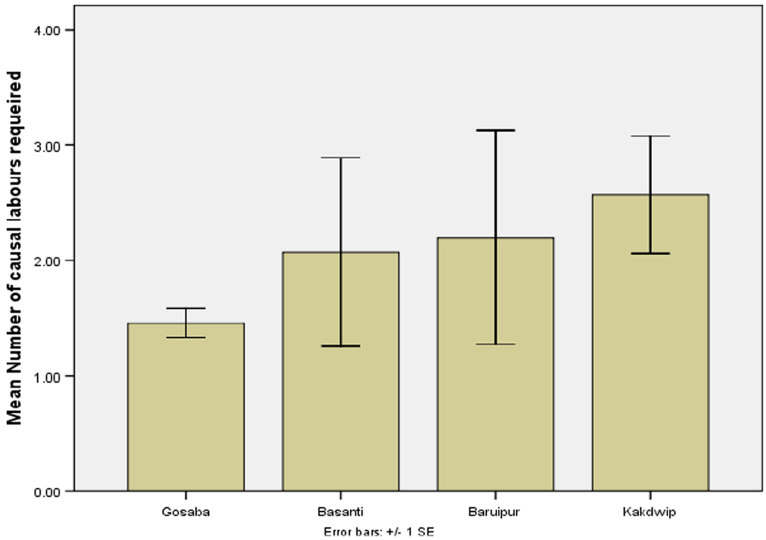


Fig. 5 Mean number of casual laborers involved in prawn production

was highest in Basanti (3–4 kg), where application of potash was highest in Kakdwip (3–4 kg) block. In Gosaba, farmers did not apply either urea or potash at all in their ponds (Figs. 10 and 11). Mean production cost of prawn culture was highest in Kakdwip (more than Rs. 20,000) followed by Gosaba (Fig. 12). Average net production of prawn per cycle was 70–150 kg/cycle depending upon the different size of the ponds. Production was highest in Kakdwip, followed by Gosaba (Fig. 13). Average net income of farmers per cycle of freshwater prawn culture was 20,000–50,000 rupees/year depending upon the size of the ponds (Fig. 14). Highest mean income was recorded in Kakdwip (more than 50,000) followed by Gosaba. In Kakdwip, most of the farmers were getting Rs. 30,000 to above 60,000 because of a steady supply of quality seeds from hatchery and 50% of the farmers had nursing prawn pond which they could sell to others blocks of the district.

Problems and solution tree, a modified PRA tool, was used to understand the problems of prawn culture at Paruldha village of Baruipur Block (Fig. 15). Since most of the seeds were female, scarcity of male seed was one of the major technical problems of prawn culture. Dependence on natural feed or kitchen waste or household waste also affected production. Very few farmers invested in artificial feeds or pelleted feed and that is why prawn was not assuming appropriate size. Another problem of prawn culture was delay in the start of culture. Since most of the farmers depended on natural seeds and natural seeds were not available all the time, farmers had to delay the commencement of culture. Lastly, and most importantly, social problems like theft and deliberate killing of prawn was found to be a menace in the study areas. Questionnaire survey also rated social problems as the most important problem (28.06%) of prawn culture, closely followed by low production (26.02%) and disease outbreak (26.02%) (Table 5). The major source of pollution in prawn culture was considered to be agriculture. But, the majority of the growers (73.75%) could not perceive its high impact on prawn culture.

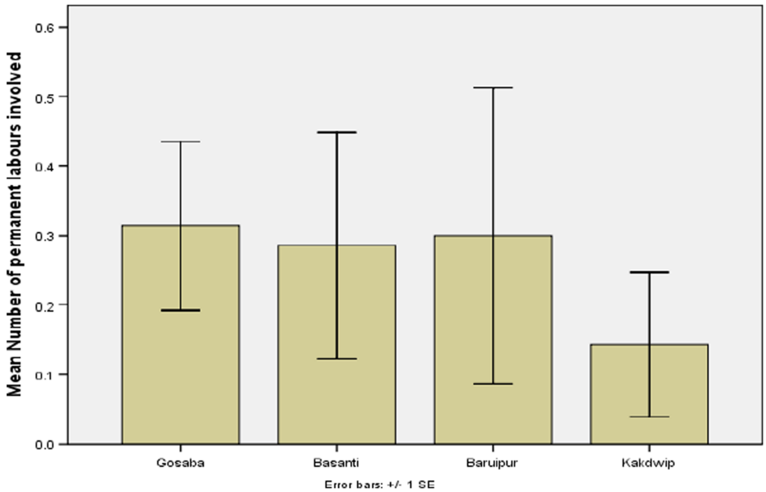


Fig. 6 Mean number of permanent labors involved in prawn production

Table 6 represents rotated factor (Varimax) matrix of 13 independent variables along with their factor loadings. The communality column shows the variance of individual variables retained in the factors. Variables with high factor loadings and high communality were considered from the rotated factor matrix. In total, 13 variables were included in PCA, of which five principal components with eigenvalues greater than 1 were retained for further analysis. These five PCs explained 67.30% of total variability in the dataset. Based on the

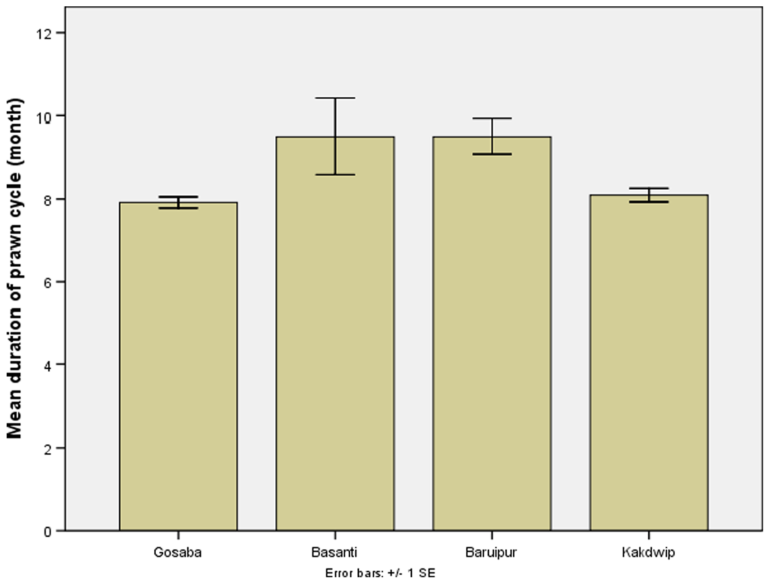


Fig. 7 Mean duration of a production cycle

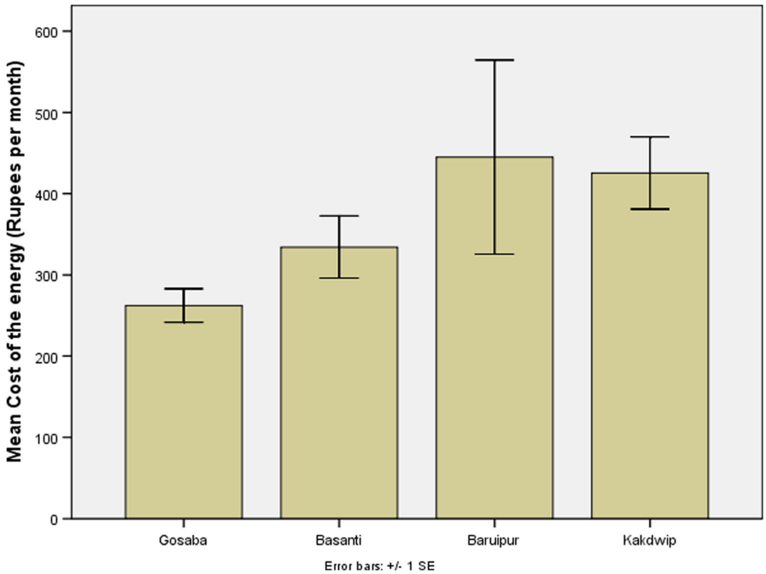


Fig. 8 Mean cost of energy in prawn production

constituent variables, the PC-1 was named as Resource Endowment. Likewise, others PCs were cycle of production (PC-2), input use (PC-3), family labor (PC-4), and pond condition (PC-5).

Table 7 represents the multiple regression coefficients of principal components in relation to prawn productivity in the studied areas. It is observed that resource endow-

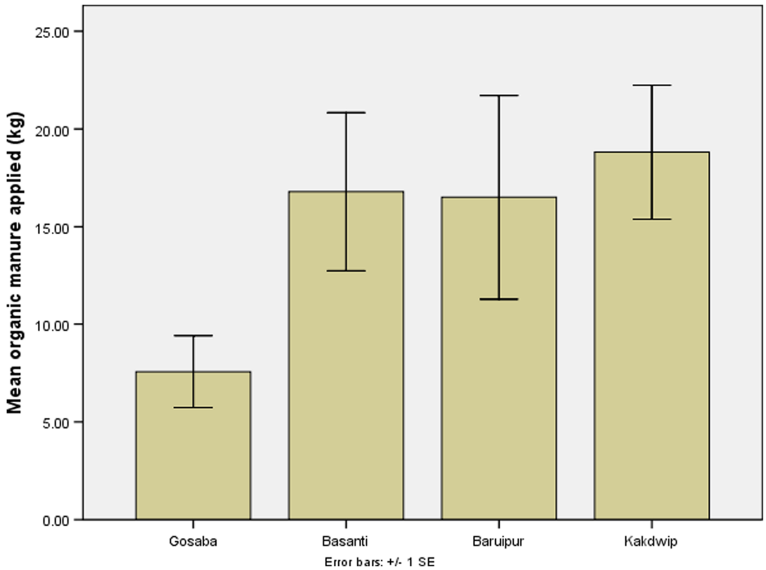


Fig. 9 Mean amount of organic manure applied in the pond

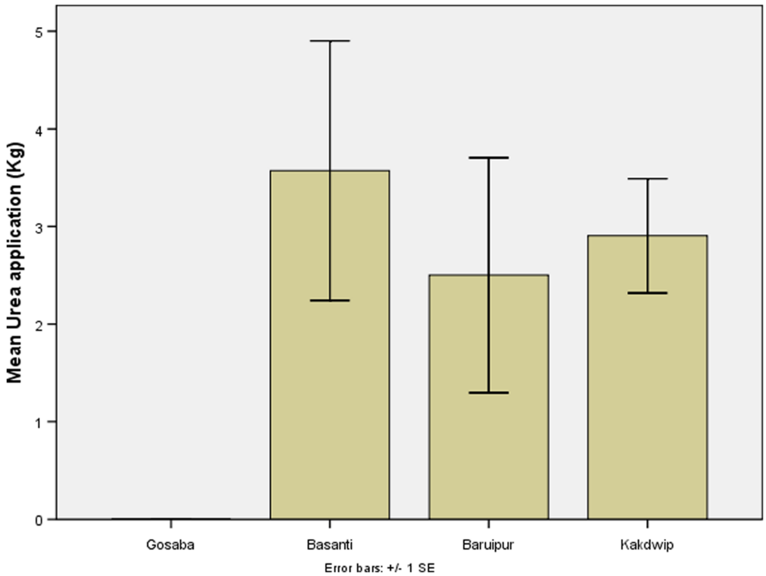


Fig. 10 Mean urea application in the pond

ment (PC-1), family labor (PC-4), and pond condition (PC-5) significantly affected the prawn productivity. These PC scores could be termed as good predictors of prawn farming in the study areas. The R^2 value of the model was $R^2 = 0.412$ suggested that five principal components jointly explained 41.2% variance of prawn productivity.

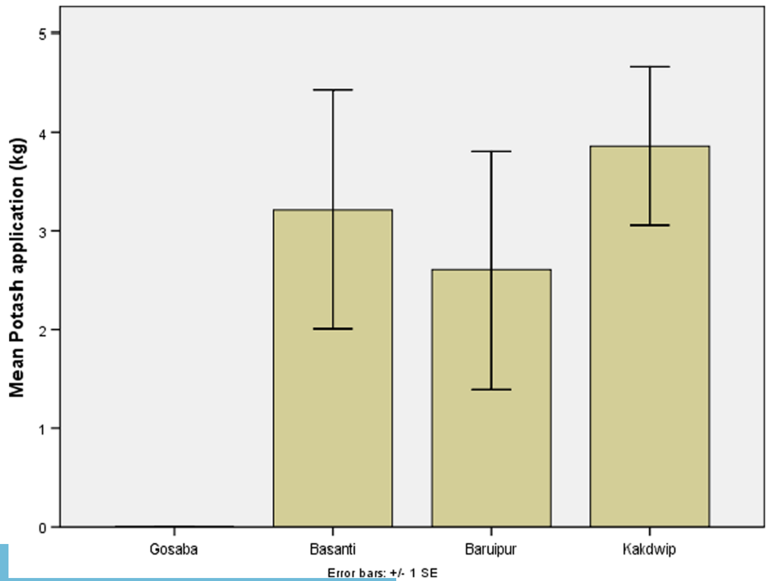


Fig. 11 Mean amount of potash application in the pond

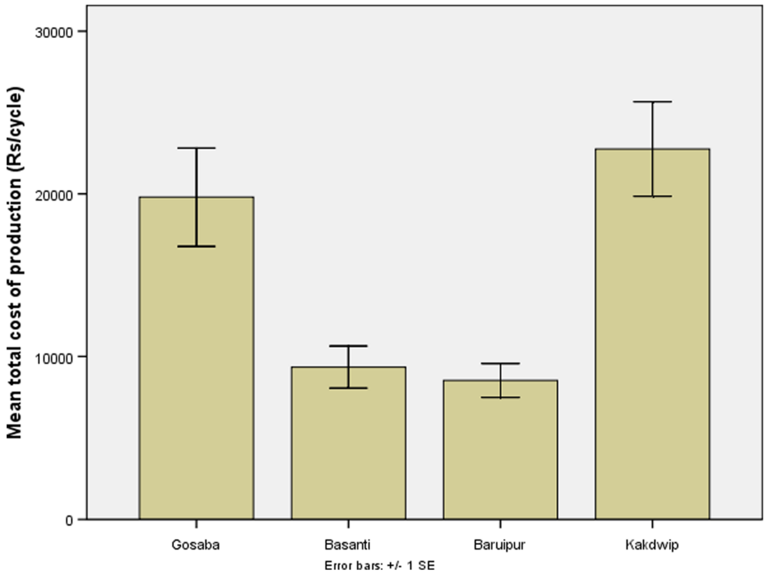


Fig. 12 Mean production cost of prawn production

Discussion

In many parts of the coastal agro-climatic zone of West Bengal, India, livelihood has diversified rapidly due to chronic bio-physical constraints in ecosystem, unprofitable nature of agriculture, poor local employment opportunity, and extreme climatic events (Mistri 2013). Prawn culture in domestic wastewater ponds began to emerge as an alternative livelihood

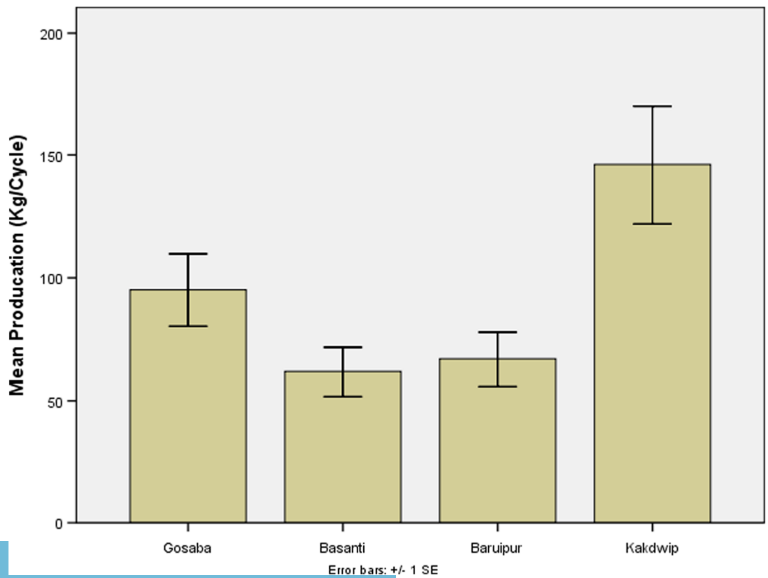


Fig. 13 Mean production of prawn in the study areas

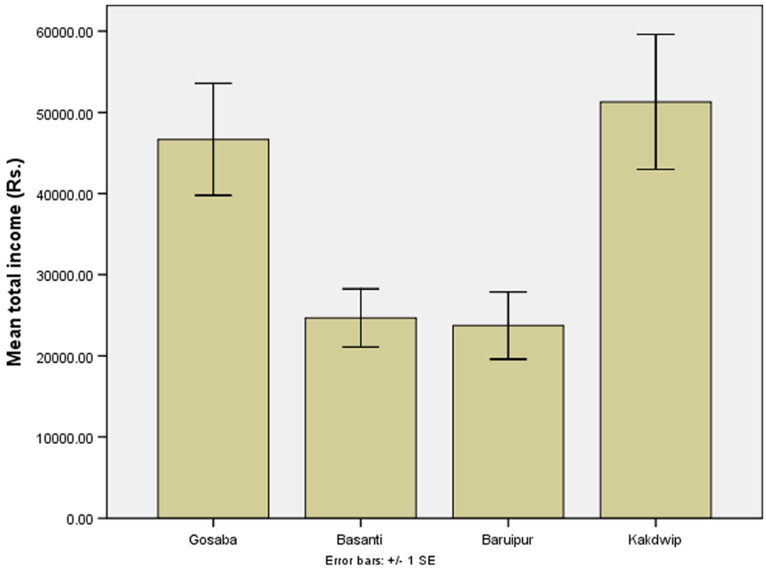


Fig. 14 Mean total income from prawn production

option for many households of the areas (New et al. 2010). The culture has also moved from a traditional internal input-supported subsistence system to a moderately commercialized semi-

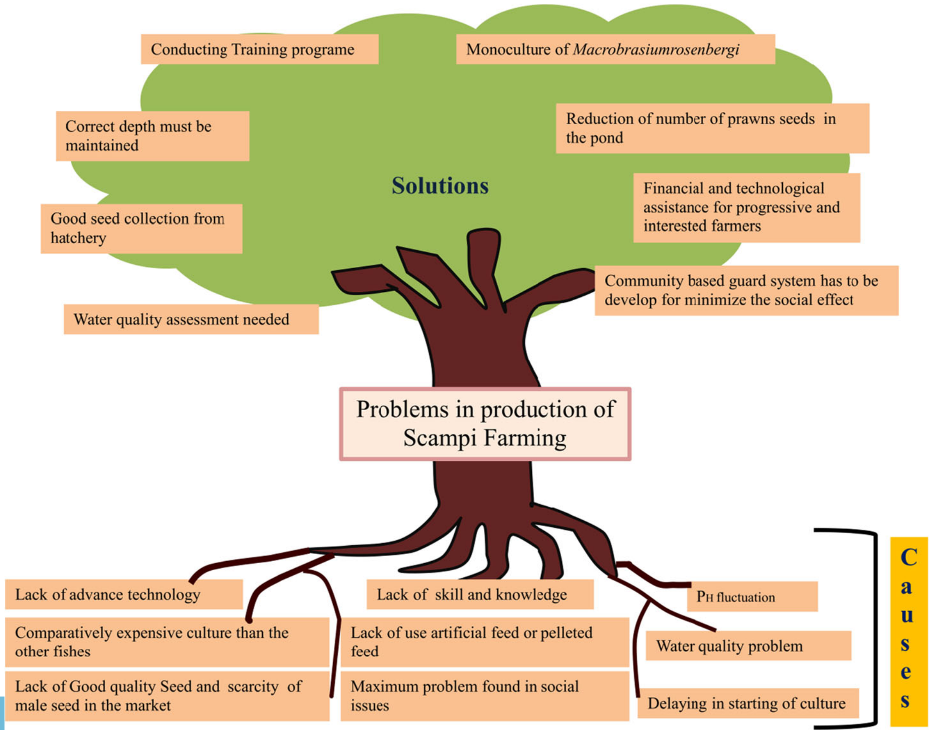


Fig. 15 Problems and solution tree in production of scampi farming

Table 5 Problems and pollution link of prawn culture in the study areas

	Gosaba	Basanti	Baruipur	Kakdwip	Total	Chi square/exact test significance
Problems						
Seed supply	9 (12.0)	5 (9.8)	1 (4.55)	3 (6.25)	18 (9.18)	0.62
Low production	19 (25.33)	11 (21.57)	5 (22.72)	16 (33.33)	51 (26.02)	
Disease outbreak	18 (24.0)	10 (19.61)	8 (36.36)	15 (31.25)	51 (26.02)	
Condition of pond	3 (4.0)	8 (15.69)	0 (0)	0 (0)	11 (5.61)	
Pollution	2 (2.67)	3 (5.88)	3 (13.63)	2 (4.17)	10 (5.1)	
Social effect	24 (32.0)	14 (27.45)	5 (22.73)	12 (25.0)	55 (28.06)	
Pollution source						
Agriculture	2 (5.71)	6 (42.9)	4 (40.0)	3 (14.29)	15 (18.75)	0.00
Industry	1 (2.86)	0 (0)	0 (0)	0 (0)	1 (1.25)	
Domestic waste	1 (2.86)	1 (7.14)	1 (10.0)	0 (0)	3 (3.75)	
None	31 (88.57)	7 (50.0)	5 (50.0)	18 (75.71)	61 (76.25)	
Pollution impact						
No impact	29 (82.86)	7 (50.0)	5 (50.0)	18 (85.71)	59 (73.75)	0.02
Moderate	6 (17.14)	6 (42.86)	3 (30.0)	3 (14.29)	18 (22.5)	
Severe	0 (0)	1 (7.14)	2 (20.0)	0 (0)	3 (3.75)	

Figures in parentheses are percentages to the column marginal; multiple responses recorded

extensive polyculture system in the last two decades. This trend is common in many developing countries due to predominance of small holdings and lack of opportunity of market integration (Nagothu et al. 2012). With increasing export of produce to external markets coupled with access to non-farm income and institutional credit, the culture is expected to assume an intensive form in near future.

The prawn growers of the study areas were inadequately trained due to absence of weak extension service in the region. The grow-out system of culture was found in all the study blocks where prawn could not be reared very intensively (New et al. 2010). Hence, the system has inherent constraints in adopting certain technology/input use and associated management practices. Source of water was extremely diverse due to the distribution of water resources in the area. This suggests location-specific technological solutions and extension support for the prawn growers of the region. Technology use in prawn culture was still skewed towards using pump sets for water management, although aerator use was on the rise in partially commercial farms. Stocking of prawn was still traditional and use of semi-intensive methods was on the rise. Due to some training programs, fortunately, water testing has become popular in the study areas. Overall, the adoption of improved management practices is low. Literature suggests low adoption in small subsistence systems and high adoption in semi-intensive system in Indian context (Srinath 2000). Keeping in view the evolution of prawn culture in this region, a move towards higher adoption of scientific culture may be expected.

Public extension record and key informant interviews with experts suggested that lower fecundity was common in pond-reared shrimp brood stock. This could be an effect of differences in shrimp size rather than its source (Cavalli et al. 2001). We recorded fecundity to be varying around 1100 eggs g^{-1} female as per government records. Cavalli et al. (1999, 2001) reported fecundity values around 1450 eggs g^{-1} female with an average weight of 26.2 ± 5.1 g. We argue that the efficiency of egg production might have decreased with increasing female size. The larger size of the females found in the current study (average 31–38 g) could thus account for the lower fecundity observed. Similar data were reported by Costa and Wanninayaka (1986) and Rao

Table 6 Five principal components derived by principal component analysis with loadings for socio-economic and techno-managerial variables and percent cumulative variance explained

Rotated component matrix[a]	Components					Communality
	1	2	3	4	5	
Age	.036	−.694	.317	−.240	.100	.652
Total pond Area	.691	−.053	−.017	.349	.202	.643
Area of nursery pond	.851	.104	−.134	−.057	−.145	.778
Family size	.197	.150	.066	.709	−.018	.569
Permanent labor in farm	.767	−.163	.091	.174	−.120	.669
Hired labor	.817	.179	−.073	.229	.095	.766
Size of the prawn in nursery pond	−.057	−.419	−.207	−.018	.700	.712
Cycle of production	.075	.788	.138	−.147	.137	.686
Depth of pond	.004	.271	.112	.000	.807	.737
Application of inorganic fertilizer	−.070	.189	.774	−.034	.029	.641
Application of lime	−.046	.351	−.568	.328	−.219	.603
Application of organic manure	−.071	−.173	.694	.300	−.222	.655
Cost of production	.233	−.116	−.034	.755	.004	.638
Cumulative variance explained	23.40	37.14	48.55	58.92	67.30	
Eigenvalues	3.04	1.79	1.48	1.35	1.09	

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization

(1991) who indicated that in wild *M. rosenbergii* populations in Sri Lanka and India, smaller females produced a higher number of eggs per unit body weight. They also argued that egg size increased with increasing body size of the spawn, resulting in fewer eggs due to differences in feeding practices, which probably also affected reproductive performance. For example, in the studies of Cavalli et al. (1999), supplementation of the brood stock diet with fatty acid resulted in improved reproductive performance. In our study, we found that a common commercial feed without any supplement was fed to the breeders. In the natural environment, *M. rosenbergii* may spawn up to four times or more per year (Ling and Merican 1961; Rao, 1991). In captive conditions, Wickins and Beard (1974) showed that one female spawned four times in 170 days. Cavalli et al. (2001) reported that one female demonstrated a capacity to breed up to five times over 180 days. This result seems to indicate that pond-reared prawns may be better than wild animals in terms of breeding frequency. Wild animals grew up under natural conditions which

Table 7 Multiple regression coefficients of principal components in relation to the productivity of scampi farming

	Unstandardized coefficients		Standardized coefficients	*t*	Sig.
	B	Std. Error	Beta		
Constant	89.934	6.813		13.201	.000
PC-1 (resource endowment)	22.714	6.858	.304	3.312	.001
PC-2 (cycle of production)	6.675	6.858	.089	.973	.334
PC-3 (input use)	2.590	6.858	.035	.378	.707
PC-4 (family labour)	39.388	6.858	.526	5.743	.000
PC-5 (pond condition)	−13.698	6.858	−.183	−1.997	.049

R square = .412; standard error 59.39. F-statistic 9.807; F-sig. 0.00

may differ from the captive conditions, and therefore, they may need some time to acclimate and adapt to the new conditions.

The absence of aeration also had a negative effect on production, and farmers who did not aerate might have had lower production due to low dissolved oxygen events in early morning. New (2000) reported that farms utilizing intensive marine farming technology that included paddle wheel aeration could attain high production (3.1 t ha^{-1} crop-^{1}). In addition to aeration, water exchange was necessary to maintain water quality when utilizing protein-rich diets, and in this survey, production was negatively linked to the number of days between water exchanges or additions. While most individuals exchanged or added water within 1 to 15 days, some waited as many as 30 to 45 days. This, combined with high feeding rates and lack of water quality monitoring, could be detrimental to prawns. By continuously exchanging a small proportion of pond water, higher water quality could be maintained (New 2002). Also, a sudden water change every 2 weeks caused most of the prawns to molt, resulting in more soft-shelled prawns at once and less losses due to cannibalism (New 2002).

Farmers who stocked directly may have had better survival rates due to lower stocking densities. In this survey, nursing densities ranged 50–250 nos m^{-2}, far below the 1000 nos m^{-2} reported by Pillay (1990). Higher densities and overcrowding can lead to cannibalism and reduce profit (New 2002). Also, many farmers who stocked directly did so with juveniles that was already 23 g and more tolerant to high pH and ammonia (New 2002). In the early stage of production, nursing ponds were probably more popular in Thailand because they more efficiently used resources, and farmers could easily count juveniles and assess their health before release into production ponds (Pillay 1990). Batch harvesting was likely to spell a positive influence on net profits because this technique reduced predator and competitor problems (New 2002). Even though it would not yield the largest and most profitable sized prawns compared to combine harvesting, more prawns could be harvested per year (New 2002). Farmers who utilized batch harvesting and stocked PL could complete up to 2.5 cycles year^{-1}, but those who directly stocked juveniles could complete up to 5 cycles year^{-1}. In this case, the increased cost of stocking juveniles was balanced by improved survival and shorter duration to marketable size (New 2002). Multiple cycles per year combined with low pond preparation and water treatment costs as well as conservative aeration and feeding would result in greater net profits.

To simplify the explanation of productivity with a handful of factors, we undertook a principal component analysis with 13 causal variables followed by a regression of prawn production with the principal component (PC) scores. We found three PCs of significant importance to explain prawn productivity—resource endowment, pond condition, and family labor use. Resource endowment such as pond size, access to water, and ability to invest in prawn culture directly affects input intensity and management practices and is causally linked to productivity of a system (New et al. 2010). Pond condition, on the other hand, influences the soil and water parameters and affects the aquatic flora and fauna, physiological activities of prawns, and microbial activities in water (Munir and Lombardi 2010). Together, pond condition determines the production environments and interacts with the management practices of the culture. Intensive use of family labor directly affects the precision of management practices, input application, and most importantly the close monitoring of the pond (Shang and Fujimura 1977; Ito 2004; Mandal et al. 2016).

Net profits in this survey were quite high compared to the average household of villagers. The most important variables positively linked to net profits were prawn production and cost of production (Armstrong et al. 1978) apart from the market value of the produce. Since the cost of cultivation was low for the farms using local seeds and household feed, and market has started to emerge steady, the profit was handsome, especially in comparison to the villagers who were engaged either in subsistence farming or were pursuing low remunerative jobs of agricultural labors. Using this data on management and market, one can conclude that higher net profits can be achieved by conservatively feeding and aerating, utilizing the batch harvest method, and establishing linkage with a steady market.

One of the major constraints in the prawn culture was adequate supply of seed at required quantities. Since in all locations majority of the seed came from hatcheries, this problem was of critical concern. Existing hatcheries were not producing up to their installed capacity due to various constraints. The low yield because of mass mortality of hatchery reared seed might have affected the productivity of prawn culture in the study areas. Although, there were other responsible factors such as brood stock management, live feed culture, and disease control as suggested by the local extension staff. Dubey et al. (2016) suggested the scarcity of seed and feed as the major constraints of semi-intensive system and associated resource and entitlement constraints with subsistence systems of prawn culture. Farmers have also found managing diseases of prawn extremely difficult because of insufficient prior experience and inadequate training on disease management. Disease prevalence in culture ponds in West Bengal is reported to be traditionally high in several studies (Bhaumik et al. 1991; Mohan and Bhatta 2002). Another major problem of prawn culture was reported to be theft and poisoning of prawn, which is widely reported in the literature in south Asian context (Ahmed et al. 2008a; Ahmed et al. 2008b).

Farmers perceived current multi-user effects on water quality in natural waterways and canals. Moreover, pollution link with agriculture, primarily through mishandling of pesticides and inorganic fertilizers, is widely reported by the respondents. However, the farmers considered impacts of external pollution from prawn culture to be either moderate or non-existent. Although it is widely reported that agriculture and aquaculture are external pollution source, farmers were not convinced with the problem perhaps due to its non-observable and long-term impact. It was also considered a cause of low production and production collapse and responsible for increased occurrence of diseases. Except for black gill, which was commonly reported by the farmers, most diseases had previously gone unnoticed on prawn farms (New 2000).

In the studied communities of South 24 Parganas, there were examples of action being taken to achieve sustainability of prawn culture and ensuring environmental welfare. For example, in Baruipur and Kakdwip, shrimp farmers used microorganisms, or probiotics, not only because of lower cost, especially when mixed with molasses, but because it was "sustainable" (Ghosh and Sahu 2014). Few shrimp farmers developed a closed farming system using lower stocking densities, less chemicals, and reserve and treatment ponds. In this survey, two respondents in Gosaba stated that they used commercial feed because "now, a day's extension staffs suggest the use of commercial feed instead of traditional feeding." The pond-reared Gangetic brood stock source, on the other hand, resulted in a lower survival and generally lowered offspring quality compared to the other domesticated sources. This might be due to the fact that they were less adapted to the conditions prevailing in the study areas.

Conclusion

Prawn culture in domestic wastewater ponds has begun to emerge as an alternative livelihood option for many households of the coastal West Bengal. The culture is slowly departing from the traditional endogenously managed system to a more extensive and commercial venture. However, use of technology and scientific knowledge has not been satisfactory and asks for critical extension support and access to working capital. In spite of operating within a semi-traditional system, this enterprise has shown moderate productivity and significantly higher income in comparison to nor-practicing farmers. Major constraints in the large-scale aquaculture of prawn were adequate supply of seed at required quantities and in all locations, disease management, and social evils such as theft and poisoning of pond. While policy should address the issue of availability of quality seeds in a decentralized manner, extension services must train farmers and provide timely advisory services to combat the disease incidence. The social evils will, however, need community participation and grassroot institutions to co-manage prawn culture in the villages. The productivity, because of mass mortality of hatchery-reared seed, was affected by factors such as pond condition (linked with bloodstock management, larviculture zoo techniques, and microbial control), family labor engagement (linked with monitoring of management practices), and resource endowment (linked with enterprise volume and ability to invest in the business). Linkage with formal financial institution, subsidized input support from fishery department, and investment in human resource development might be some point of intervention to boost prawn culture in the study coastal regions of West Bengal, India.

Community-level planning and training sessions also have potential of enhancing the sustainability of prawn culture. The canals and natural waterways used for prawn production serve as a common pool resource system which flow away the biological wastes produced by multiple users. Maintenance of the system will benefit all associated stakeholders. This tight knit community is advantageous for the dissemination of information about environmental and production issues related to their current practices. Only a quarter of farmers pursued suggested alternative culture, but the majority was interested in learning new techniques and outreach efforts along this line may normatively be welcomed. Fisheries Offices could organize community training sessions and provide a venue for local farmers to discuss environmental issues and plan water supply management within their area. Community mandated settling and/or treatment of ponds could be beneficial, and the initial steps may concentrate on implementing recycling systems in the prawn culture.

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