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A comparative study of two seasonal floodplain aquaculture systems in Bangladesh

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Abstract

This paper presents a comparative analysis of the technical and economic parameters of two community led approaches: the semi-closed water bodies and the floodplain water bodies based systems in Bangladesh. The two approaches differ in management, fish production, impact on biodiversity, capital investment and annual variable costs, share of profits and proportional benefits for the poor, and impact on allied businesses—the so-called backward and forward linkages. For the semi-closed water bodies (*beels*) the fish harvest increased from an annual average of 380 kg ha^{-1} in 2002 to 921 kg ha^{-1} by 2005. During the same period, the biodiversity measured for self-recruiting indigenous species, using the Shannon-Weiner Index (H'), increased significantly ($P < 0.05$) from 2.24 in 2002 to 2.56 in 2005. For the floodplain aquaculture system (*Pankowri* or *Daudkandi* model) annual fish production ranged from 1.5 to 1.8 t ha^{-1}. Annual net economic benefit per hectare was found to be Taka 37,710 ± 24,600 and 26,819 ± 10,780 for semi-closed and floodplain systems respectively. The net income per kg of product was found to be Taka 44.0 ± 9.0 and 13.0 ± 3.0 for semi-closed and floodplain systems, respectively. The floodplain system tends to use comparatively more feed and fertilizers per unit area that pond-based aquaculture.

Keywords: Aquaculture; Bangladesh; CBFM; Floodplains; Stocking

1. Introduction

Bangladesh is one of the world's most densely populated countries. Approximately half of its 138 million population is considered to be poor and very vulnerable to climate change. Bangladesh has extensive water bodies that have a high potential for fisheries production. Within the last 10 years, it has seen a tremendous increase in fish culture production from 192,592 tons (1989–90) to 914,752 tons (2003–04), an average increase of 51,570 tons per annum (DoF, 2005). Fish consumption for Bangladesh is estimated to average 14 kg per person per year (FIRI, 2005). Minkin *et al.* (1997) found that a rural household consumes more than 50 species of fish or prawn during the course of a year.

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Small fishes in Bangladesh are the accessible and preferred food of poor people and are good sources of micro-nutrients (Thilsted *et al.*, 1997).

In 2003 Bangladesh was estimated to be the sixth largest aquaculture producer with a total of 856,956 tons (FAO, 2005). With over 3 million aquaculture farmers, aquaculture is highly significant both in terms of food security and economic income. Also, aquaculture provides a more lucrative use of land and water than alternative activities. A hectare of land under aquaculture generates at least 43% higher income than a hectare of land under crop cultivation (Hasan & Talukder, 2004). Consequently the importance of aquaculture is growing and stakeholders are exploring alternative approaches to enhancing productivity of aquaculture systems.

This paper focuses on the comparative study of the technical and economic parameters of the two community-led approaches: the semi-closed water bodies and the floodplain water bodies based systems. The management, yield, environmental impact, financial input and equitability, and effect on the market chain vary in the two approaches studied. The comparative study was conducted during the period 2002–05.

2. Aquaculture management approach and status

2.1. Water bodies, stocking systems and their geographical distribution

There are a number of stocking systems in use in Bangladesh including: i) stocking of closed and semi-closed water bodies; ii) nursing and release into ponds, *beels* and canals; iii) nursing and release into closed floodplain areas; and iv) direct floodplain stocking of *beels*. More intensive fishery management of the semi-closed *beels* is gaining popularity in Bangladesh, whereby the closing of channels to the main floodplain encloses fish stocks and provides an opportunity for an aquaculture type management regime known as PRA, involving inputs of feed and perhaps fertilizer. Numbers of water bodies and their geographic distribution, and the management aspect of the second phase of the Community Based Fisheries Management project (CBFM-2) sites are given in Tables 1 and 2 below.

Table 1. Distribution of semi-closed *beels* and floodplain aquaculture sites.

Name of waterbody		Upazila (sub-district)	District	NGO	Remarks
Semi-closed sites under CBFM project					
1	Hamil *beel*	Kalihati	Tangail	Caritas	CBFM, deeper depressions
2	Rajdhola *beel*	Purbodhola	Netrokona	Caritas	CBFM, deeper depressions
3	Dhumnodi *beel*	Kawnia	Rangpur	BRAC	CBFM, dead river/oxbow lake
4	Ruhia Baisa *beel*	Ranpur sadar	Rangpur	BRAC	CBFM, bonded off from floodplain
5	Kafri Khal	Mithapukur	Rangpur	Caritas	CBFM, dead river
6	Tulshidanga *beel*	Mithapukur	Rangpur	Caritas	CBFM
7	Chapandaha *beel*	Pirgonj	Rangpur	BRAC	CBFM
8	Saralar *beel*	Mithapukur	Rangpur	BRAC	CBFM
Floodplain aquaculture sites					
1	Chargram	Daudkandi	Comilla	SHISUK	CBFM floodplain stocking
2	Pankouri	Daudkandi	Comilla	Do	Private, floodplain stocking
3	LKS	Daudkandi	Comilla	Do	Private, floodplain stocking
4	Khirai	Daudkandi	Comilla	Do	Private, floodplain stocking

Table 2. Water bodies and beneficiary status.

Name of water body	Lease value (Taka)	Area (ha) min-max	Registration status	*Beel* management committee (BMC) members	Total no. beneficiaries/ Share holders	
Semi-closed sites					Male	Female
Hamil *beel*	55,208	16–20	Registered (cooperative)	6 all male	138	37
Rajdhola *beel*	366,025	40–53	Registered (cooperative)	16 (14 male; 2 female)	83	37
Dhumnodi *beel*	108,272	46–58	Registered (social)	10 all male	121	0
Ruhia-Baisa *beel*	34,327	12–45	Registered (social)	6 all male	64	0
Chapandaha	83,458	2–90	Registered (cooperative)	9 all male	49	0
Saralar *beel*	42,500	6–50	Registered (cooperative)	11 all male	61	33
Kafri khal	87,916	15–70	Registered (cooperative)	9 all male	171	18
Tulshidanga	26,146	0.41–30	Registered (cooperative)	9 (7 male; 2 female)	77	39
Floodplain aquaculture sites						
Chargram		93–102	Registered, Joint Stock Co	17 executive members	459	154
Pankouri		91–91	Registered, Joint Stock Co	9 executive members	387 Share holders	
LKS		54.7–55	Registered, Joint Stock Co	15 executive members	247 Share holders	
Khirai		66.8–67	Registered, Joint Stock Co	13 executive members	245 Share holders	

2.2. Government involvement in fisheries management

The fisheries sector in Bangladesh has multiple stakeholders, of which government actors play a vital role in terms of aquatic ecological management, administration and power relations. The Ministries of Fisheries and Livestock (MoFL), Land (MoL) and Youth (MoY) play crucial roles in natural resource management. The MoL owns all lands and water bodies in Bangladesh whilst the Department of Fisheries (DoF) is the only implementing agency under the key ministry, MoFL, and authorization must come to MoFL from MoL for management of aquatic ecology. The National Fishery Policy mentions poverty alleviation as an objective, and the more recent government-approved Poverty Reduction Strategy Papers (PRSP) has emphasized the importance of this objective to the Government of Bangladesh.

2.3. Community based fisheries management project

The thrust of the Community Based Fisheries Management (CBFM) is that fishers' communities have to take charge of the responsible management and harvest of the fishes in their water bodies. This is because users must actively participate in the management process, attending meetings to decide the rules for fishing activity, patrolling or guarding water bodies and apprehending infractions. In closed and semi-closed water bodies, stocking is considered as a means of enhancing fish production through fishers' participation.

The CBFM project was designed as an action research project to test and access alternative local fishery management arrangements that might achieve greater efficiency, equity and sustainability. CBFM is a co-managed partnership project, implemented by the WorldFish Center in partnership with the Government of Bangladesh, Department of Fisheries (DoF) and local NGOs. The project has been working in the inland waters of Bangladesh to manage fisheries resources in 116 water bodies involving up to 23,000 fishing households. The project has developed a series of fisheries management approaches for ensuring sustainable fisheries resources. Most of the stocked water bodies are supported by two NGO partners (BRAC, a national level NGO established in 1972, and CARITAS, a national non-profit voluntary NGO established in 1967). In addition to semi-closed water body stocking, the fisher community of Dopi *beel* in Kishoreganj district has stocked common carp in an open *beel*, and is supported by PROSHIKA, a national non-governmental development NGO established in 1976. In addition to closed water body stocking, the community of Chargram, in the sub-district of Daudkandi, has stocked carp in converted semi-closed water bodies, and is supported by SHISUK, a development NGO and one of the project partners. It is to be noted here that the low-lying crop land area in Daudkandi has been converted into semi-closed seasonal water bodies.

CBFM approaches in stocked water bodies ensure fishers access rights and reduce the interests of diverse stakeholders. Stocking, closed season, harvesting and equity are established through coordination of *Beel* Management Committees (BMC) and locally administered. The focus on resource sustainability of the stocked water bodies has been developed by the project to ensure that CBFM successfully enhances the production and availability of small indigenous species that women and children consume.

2.4. Management of the semi-closed system

Partner NGOs have helped the fishers to develop BMCs for fishery resources management. Management committees were formed in all stocked water bodies through the election of members by participants. The BMCs in the stocked water bodies have their own resource management plans and rules. Committees have generally adopted simple conservation-based measures under the CBFM. Members follow a rotational system of sharing guard duty to prevent poaching of the stocked fish, and they also fish on rotation with jointly-owned seine nets (encircle gear). CBFM approaches integrate other management activities to protect natural resources. These include awareness, effective management and support through use of related training, regulation and enforcement. Public awareness also plays a major role in fishery management through posters, sign boards, newsletters, folk theatre, media and other types of advertisements. Ideally, communities support the sanctuary concept, which requires little need of an enforcement presence.

2.5. Management of the floodplain system

Landowners are obviously the key participants from the community to decide the establishment of a project. Communities are initially motivated to unite under an extended ‘Implementation Committee’ that provides the initial planning and finally selects a Board of Directors. The Board comprises a proportionate representation from the villages, two representatives from a partner NGO and two women as Directors. An Executive Committee is formed by the general meeting on the basis of land quotas and representatives of associate organizations. The executive committee elects a Board of Directors. Following approval by the Board, the Programme Director takes charge of management. The Managing Director and the Board of Directors approves operational plans and allocates manpower, finance and equipment. A Limited Company is legally formed and registered as a Joint Stock Company. The agreed mode of profit distribution is: 50% of profit to go to the shareholders, 27% to be distributed as land rent, 20% to be kept as a reserve fund, and the remaining 3% to be spent on social welfare. Each landowner is entitled to get shares but no individual is allowed to have more than 20 shares.

3. Materials and methods

3.1. Catch monitoring and gear survey

Catch monitoring was an observational process of the fishing effort. The gear survey involved a regular spot survey to obtain a representative of the gear in operation and the total catch from that gear. In addition, with organized fishing, the observations of fishing activity were done for four to eight days per month per site. Survey sampling covered gear census and catch monitoring (subsistence fishing) from 8 of the 12 semi-closed/floodplain water bodies. The stocking and harvest data were also collected from four floodplain water bodies. Gear census covered the number and type of gear operating in the study sites. Catch monitoring recorded species-wise catch statistics of each gear type.

An average number of gear units per day was used to estimate a total gear-wise fishing effort for that month as well as for the whole year. A mean gear-wise catch rate was used to estimate total catch for that month, as well as for the whole year. Yearly and overall species distributions were calculated from annual catch statistics data. Overall production was estimated by summing estimated total production for all gear types in each year (subsistence catch and organized production taken from BMC records). However, total production for floodplain water bodies was collected from records maintained by the organization.

3.2. Shannon-Wiener diversity index

The Shannon-Wiener Index (H') is one of several indices used to measure biodiversity. The function is defined as:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where $s =$ number of species and $p_i =$ the proportion of individuals from the ith species in the sample.

4. Results

4.1. Stocking and harvesting performance in semi-closed sites

Analysis of the result of the semi-closed *beels* under CBFM-2 shows that production varies among stocked semi-closed beels. In four old stocked semi-closed beels, the concept and technology for stocking were well known to the participants. Hence, stocking performances was better than in the newly stocked semi-closed beels. Total production as a function of stocking density during the baseline year (2002/2003) and in 2005 for project water bodies is shown in Figure 1. During 4 years of improving community management, fish production has also been improving. The study reveals that harvests from 8 semi-closed beels have increased significantly from an annual average of 380 kg ha^{-1} in 2002 to 921 kg ha^{-1} by 2005, with an average increase of 180 kg ha^{-1} $year^{-1}$ (Figure 2). Even though sites were stocked, the natural fish production trend increased from an annual average of 88 kg ha^{-1} in 2002 to 450 kg ha^{-1} by 2005. This indicates that stocking cultured species does not impact negatively on natural fish production. On the contrary, the data suggests a slight positive correlation between stocking density of cultured species and production of natural fish.

The annual variations of stocking cost during 2002–2005 in semi-closed systems changed little over time. Simultaneously, annual gross return from fishing shows a significantly increasing trend between 2002 and 2005 (Figure 3). Stocking costs in semi-closed systems was very low because of low stocking density and the involvement of participants in direct purchase of fingerling and fry, and nursing them in their nursery ponds.

Ten small indigenous self-recruited species contributed 87% and 91% on average of the total natural fish production in 2004 and 2005 respectively (Tables 3 and 4). The six most important species

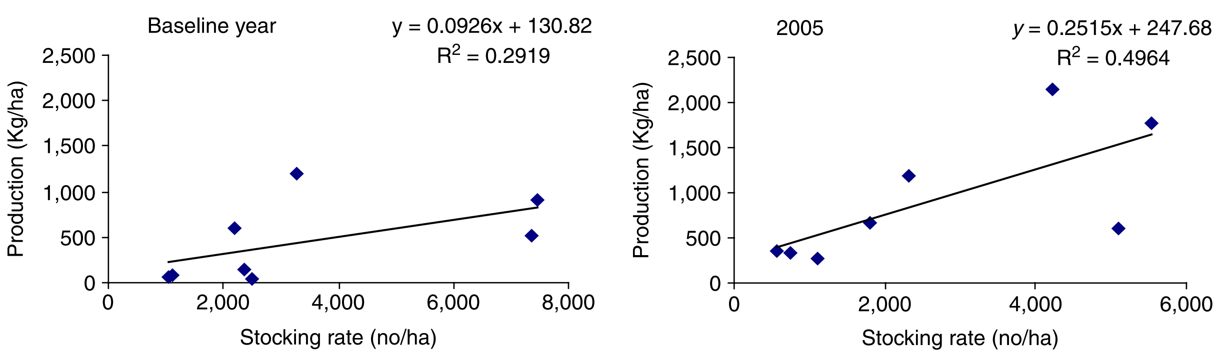

Fig. 1. Total production per ha plotted as a function of stocking density in 2002 (baseline year) and 2005 for semi-closed stocked sites.

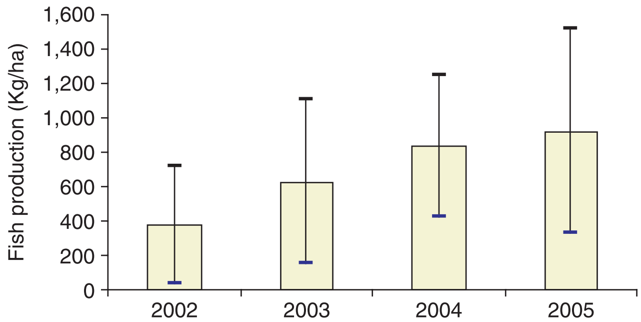

Fig. 2. Fish production trends with 95% confidence limits as a function of time (year) for semi-closed stocked sites.

(*P. sophore*, *C. punctatus*, *M. pancalus*, *G. giuris*, *N. tenuipes* and *M. tengara*) contributed more than 75% by weight, and this remained largely unchanged throughout the sampling period. Four other species (*H. fossilis*, *C. fasciatus*, *C. lala* and *X. cancila*) which appeared in the list of the ten most frequently caught fish, and which together contributed more than 10% of the total catch in 2004, were not in the list of top ten species in 2005 but were replaced by *C. batrachus*, *C. striatus*, *M. seenghala* and *W. attu*.

The production of stocked water bodies is related to a number of factors like timely stocking, size of fingerlings, stocking rate, level of compliance of the local people and effectiveness of measures to control the escape of fish.

The biodiversity of self-recruiting indigenous species using the Shannon-Weiner index (H') in the semi-closed system increased significantly ($P < 0.05$) from 2.24 in 2002 to 2.56 in 2005. A comparison of annual mean biodiversity index (H') for seven stocked sites, based on natural species proportions during 2002–2005, is shown in Figure 4.

4.2. Floodplain aquaculture

The CBFM-2 partner NGO, SHISUK, developed a floodplain aquaculture system which encloses a floodplain area using earthen embankments connected to the floodplain by sluice gates. It is one of the most successful examples of floodplain culture. Using this system, SHISUK stocked a variety of species, including native and exotic species. The catch composition reflected the stocking rates of the different species stocked and showed consistency with stocking rate and species type.

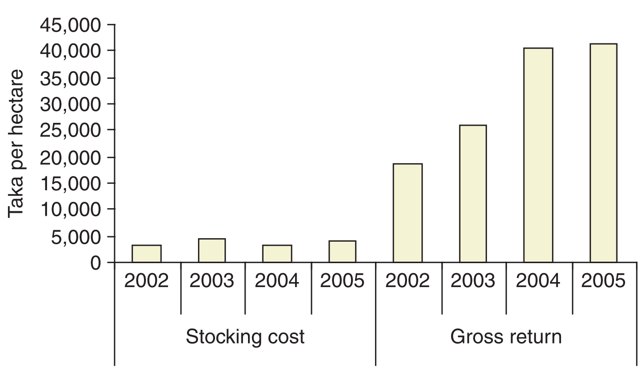

Fig. 3. Stocking cost and gross return from 2002 to 2005 for semi-close stocked sites.

Table 3. Contributions of natural fishes (% by weight) in semi-closed stocked sites in 2004.

Scientific name	Contributions (%)	Cumulative total (%)
Jat Puti (*P. sophore*)	21.92	21.92
Taki (*C. punctatus*)	13.16	35.07
Baim (*M. pancalus*)	12.89	47.97
Baila (*G. giuris*)	11.68	59.65
Guraicha (*N.tenuipes*)	9.99	69.65
Tengra (*M. tengara*)	7.47	77.12
Shing (*H. fossilis)*	2.78	79.89
Kholisha (*C.fasciatus*)	2.77	82.67
Chanda (*C. lala*)	2.51	85.17
Kaikla (*X. cancila*)	2.29	87.45

Table 4. Contributions of natural fishes (% by weight) in semi-closed stocked sites in 2005.

Scientific name	Contributions (%)	Cumulative total (%)
Taki (*C. punctatus*)	19.15	19.15
Baim (*M. pancalus*)	15.58	34.73
Jat Puti (*P. sophore*)	14.76	49.49
Tengra (*M. tengara*)	10.37	59.87
Baila (*G. giuris*)	7.80	67.67
Guraicha (*N.tenuipes*)	7.33	75.01
Magur (*C.batrachus*)	5.16	80.17
Shol (*C.striatus*)	4.17	84.34
Gujiayre (*M. seenghala*)	3.90	88.24
Boal (*W.attu*)	2.78	91.03

Data from four SHISUK project sites reveal annual fish production ranges from 1.5 to 1.8 tonnes ha^{-1} over 4 years, although at the original *Pankowri* site fish production for 2005 was found to be 2.8 tonnes ha^{-1} for the 89 hectare project site. Cultured fish production varied from 1,338 to 2,325 kg ha^{-1} and natural fish production from 165 to 263 kg ha^{-1} in 2005 (Figure 5(a)). Net income per kg of fish production ranged from Taka 9 to 16 in 2005. The net benefit (net income minus net expenditure) per hectare varies from Taka 17,917 to 41,808 among the four study sites in 2005 (Figure 5(b)).

4.3. Comparison of the two systems

Results for annual net benefit per hectare and net income per kg of product for 2005, for both the semi-closed system and floodplain aquaculture, indicate large variations between the two systems. Annual net benefit per hectare was found to be Taka 37,710 $\pm$ 24,600 and 26,819 $\pm$ 10,780 for the semi-closed and floodplain systems respectively. At the same time, net income per kg of product was found to be Taka 44.0 $\pm$ 9.0 and 13.0 $\pm$ 3.0 for the semi-closed and floodplain systems, respectively. The floodplain system tends to use comparatively more feed and fertilizers per unit area than pond-based aquaculture; by comparison, feed and fertilizers are not used in the semi-closed system. Comparative net benefit and income figures for the two systems are given in Figure 6.

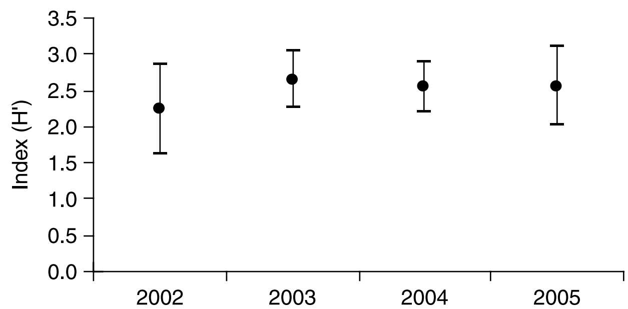

Fig. 4. Estimates of mean H' with 95% confidence limits has been plotted as a function of time, with four years' of observation.

5. Discussion

In semi-closed *beels* (the CBFM approach) participants pay for exclusive fishing rights. They also allow neighbours to fish for food following organized fishing. On the other hand, under the seasonal floodplain aquaculture system (*Pankowri or Daudkandi* model), participants do not allow any other community member to fish. There are natural relatively deeper areas in the semi-closed systems where fish can safely remain in winter. Fish can breed and survive safely in the entrapped water because community fishing is completely restricted inside the project. In contrast, when the floodplain aquaculture systems are filled with flood water from neighboring rivers or canals and water is trapped, the connectivity of water bodies is hampered and therefore the fish lifecycle is obstructed. There are also concerns with floodplain aquaculture that wild species that enter the enclosures may subsequently grow too large to escape. Whilst this may be a valuable venture by-catch, it precludes free recruitment of fish into the capture fishery and thus need for careful control of replication (Blake & Barr, 2005). There are no perennial water areas at most sites in seasonal floodplain aquaculture systems. However, a few project sites have relatively small shallow water areas where participants stocked carps fingerlings at high densities during winter.

Semi-closed water bodies are likely to generate good rates of return, and low production costs are possible through stocking by CBFM participants. However, the floodplain aquaculture system, stocking a mixture of Indian and Chinese carp along with small indigenous species, demonstrates the greatest potential for expansion in employment with high returns to labour and significant value added. Whilst it may be entirely appropriate in some areas, widespread and uncontrolled replication by enclosing

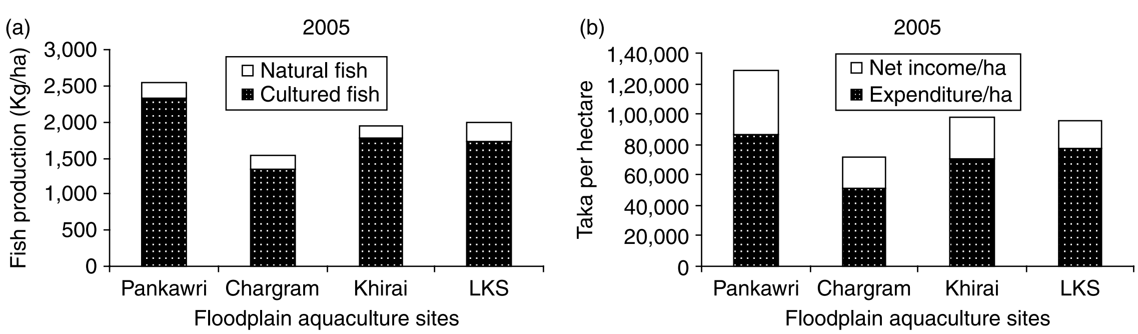

Fig. 5. (a) left and (b) right. Cultured and natural fish production, and expenses and income per hectare, from four floodplain sites in 2005.

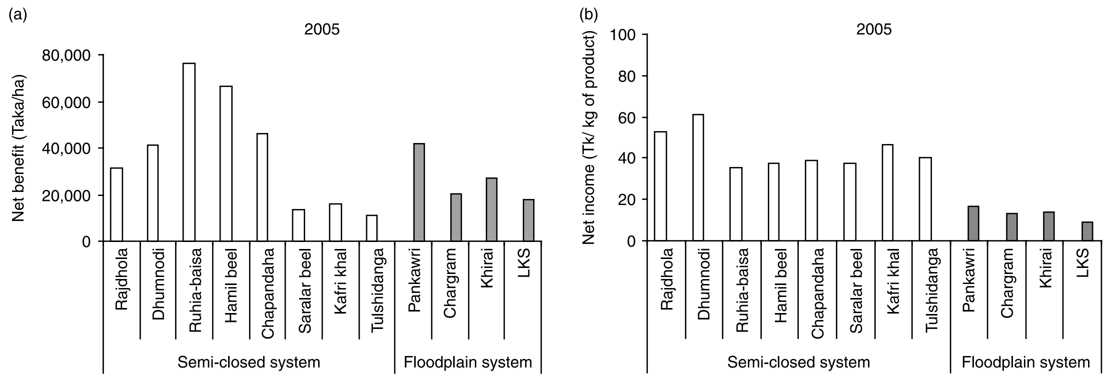

Fig. 6. Net economic benefit per hectare (a) and net income per kg of production (b) between two systems in 2005.

substantial areas of floodplain would have an adverse effect on hydrological regimes and the free movement of fish species (Blake & Barr, 2005).

The CBFM study found that single-stocking of carp (polyculture) each year with an appropriate species composition ratio does not affect the production of indigenous fishes, as assessed by comparing biodiversity levels (Mustafa & Mamun, 2005). With this evidence, the fingerling length stocked (9 cm) and the average stocking density (approx. 3,500 ha^{-1}), CBFM appears close to optimal in relation to profit maximization (Halls *et al.*, 2007). On the other hand, where there is multiple stocking of 2,000–3,000 carp fingerlings in each stocking, 4 to 5 times per annum, indigenous species are highly affected (Mustafa & Mamun, 2005). The CBFM study also found that fingerling length should be the primary factor determining stocking density decisions because profit is more sensitive to the length of the fish stocked than it is to stocking density (Halls *et al.*, 2007).

6. Conclusions and implications

The present study clearly reveals that the semi-closed stocked beels (using the CBFM approach) generated a substantial benefit to the poor fishers and participating community members. On the other hand, the floodplain aquaculture system (using the *Pankowri or Daudkandi* model), which is a costly approach, generates benefit for only certain sectors of the community (especially landowners) at the cost of bio-diversity, ecology and the livelihoods of poor people, especially fishers. However, in terms of institutionalization, the *Pankowri* or *Daudkandi* model may prove to be exceptional, but there are insufficient data and analysis to clearly demonstrate which approach best helps the poor and which if either approach is sustainable in the long term.

In semi-closed stocked *beels* managed according to a CBFM regime, the fishers have over time established appropriate stocking densities and developed empirically based effective stocking and harvesting management regimes. Account keeping has been maintained in all the water bodies, and fishers of some water bodies have made their own nursery ponds. However, planning has to be improved and should ensure timely stocking and the appropriate number of fingerlings. From the results to date of studies of stocking in semi-closed *beel* and *baor* (Oxbow lake) stocking, we may conclude that to maximize profits, villagers should maintain stocking density with 3,500 fingerlings (of approximately 9 cm) ha^{-1} $year^{-1}$. However, further research is needed to determine why the approach is more successful at semi-closed sites than in floodplain aquaculture systems.

The present study also illustrates the long-term gain that can be secured through the adoption of community-based management approaches at semi-closed and floodplain aquaculture systems. Given the cost-effectiveness of stocking as a means of increasing production and incomes, it is recommended that the CBFM approach be extended to other semi-closed and floodplain aquaculture systems and that it be adopted as a key policy for development of fisheries resources in Bangladesh.

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