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Impact of the Community-Based Fisheries Management on sustainable use of inland fisheries in Bangladesh

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ABSTRACT

The Community Based Fisheries Management (CBFM) project in Bangladesh aimed to promote the sustainable use of inland capture fisheries by empowering fisher's communities to manage their own aquatic resources. This paper describes the impact of fisheries management performance using data generated under the CBFM project, funded by the Ford Foundation and the UK Government's Department for International Development (DFID).

Using quantitative indicators of catch per unit area (CPUA), catch per unit effort (CPUE), catch per fisher's day (CPD), biodiversity index (H'), fishing intensity (DPUA) and destructive fishing ratio (DFER) at up to 86 project water bodies across the country representing a variety of different habitats was compared with that of existing fisheries management (control water bodies). Estimates of the slope coefficients for each performance indicator were compared among habitat type and between CBFM and control water bodies using ANOVA (GLM). Fish production was found to have increased significantly through time at CBFM water bodies.

Trends in fish production through time were upwards at 77% of the 64 project water bodies that were monitored for at least three years without data gap. Trends in fish abundance, indicated by annual average daily catch rates by fishers, were also upwards at 72% of monitored water bodies. Changes in biodiversity index (H') with time were found to be positive and significantly greater than in control water bodies. Species assemblages are richer and more abundant at CBFM compared to control water bodies. Trends in biodiversity were also upwards at 70% of monitored water bodies. Considering all management approaches together, the score based performance indicators suggests that a fisher managed approach ensured maximum benefits, and followed by community managed and women managed approaches.

In conclusion, community-based fisheries management appears to perform significantly better than the existing management system in Bangladesh. Future projects might choose to place greater emphasis on identifying habitat-specific interventions and arrangement to meet precise management objectives. Existing information sharing networks could support experimentation and learning under future initiatives.

Key words: Community-Based Fisheries Management, Sustainable, Biodiversity,

INTRODUCTION

Bangladesh is endowed with enormous inland fishery resources and vast inland waters that are vital to millions of poor people, but production and species diversity are believed to be declining. Fishers and experts have identified potential causes for this decline including habitat degradation due to siltation and conversion to agriculture, increasing fishing pressure, destructive fishing practices and an acute shortage of dry season wetland habitat (Hughes et al. 1994).

The first phase of the Community Based Fisheries Management (CBFM) during 1994-1999 was funded by Ford Foundation grants. After an interim period of nearly two years with little or no community-based management activity, a second phase of the project (CBFM-2) began in September 2001. This ongoing 5-year follow-on phase, funded by the UK Government's Department for International Development (DFID), is being implemented jointly by the WorldFish Center and the Government of Bangladesh's Department of Fisheries, through a partnership involving 11 Non-Governmental Organizations (NGOs).

These field-based partner NGOs are responsible for organizing about 23,000 poor fishing households around 116 water bodies representing a range of different habitat types (14 closed beels, 28 floodplains, 8 haor beels, 28 open beels and 38 river sections) and located in regions throughout Bangladesh (Figure 1).

The study employed data collected from CBFM and control sites since 1997, representing a range of different habitat type and geographic location. Performance indicators relating to production, resource sustainability and biodiversity were identified together with more than 15 explanatory variables hypothesised to affect management performance.

Impacts of the CBFM were examined in two ways. Firstly, by testing for significant differences in estimates of mean values of performance indicators between CBFM and control sites (controlled comparisons) using general linear models (GLMs). Secondly by testing for significant upward or downward trends in estimates of performance indicators at CBFM sites through time (time series analysis).

For the time series analysis, significant trends in performance indicators through time were explored by testing the significance of the "slope" coefficient of regression models of performance indicators fitted using the GLM routine where time (year) was treated as the independent variable. Only sites with at least four years of observations were examined.

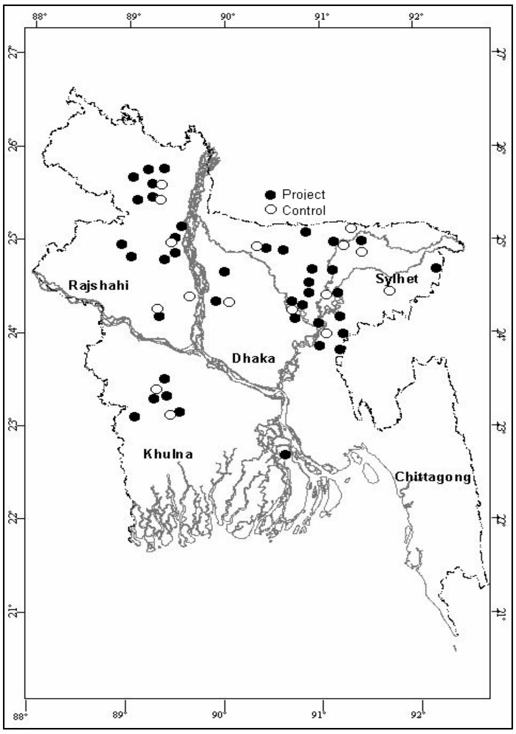

Fig. 1: Location of monitored CBFM and control sites in Bangladesh

MATERIALS AND METHODS

Monitoring of management performance variables at CBFM sites was conducted both routinely and on an ad hoc basis at both CBFM and control sites. Control sites were selected with similar topographic features and existing fishing activities to those chosen for CBFM project support. The assessment employed species-wise catch and gear-wise effort data sampled under the Project's catch assessment survey (CAS) between 1997 and 2005 from a maximum of 107 divided unequally between those under CBFM and unmanaged control sites (Table 1).

Fishing activity was observed for four to eight days per month, per site. During the first day of each two-day sampling period, a census (complete count) of gears by gear type in operation is undertaken. On the second day, randomly selected samples of landings (catch) by species and effort (gear hours) by gear are recorded for each gear type observed to be operational on the previous day. The number of samples (n) recorded for each gear type on this second day of sampling varies was typically approximately n = 7 for gillnets – the most popular gear type.

Table 1. Number of monitored CBFM and control sites by habitat type and year. CB- Closed beel; FPB-Floodplain beel; HB- haor beel; OB-Open beel; R – River section.

	CBFM					Control					Total
Split year	CB	FPB	HB	OB	R	CB	FPB	HB	OB	R	
1997-1998	2	2		2	10						16
1998-1999	5	2		2	10						19
1999-2000	4	2		2	9						17
2000-2001	2	2		2	8						14
2001-2002	2	2		2	7						13
2002-2003	9	23	6	20	16	1	4	4	4	6	93
2003-2004	12	24	6	27	19	1	4	4	4	6	107
2004-2005	12	23	6	22	20	2	4	4	4	6	103
2005-2006	11	22	7	27	19	2	4	4	4	6	106

Performance Indicators and Explanatory Variables

Management performance was quantified using indicators of production and resource sustainability. Where appropriate, differences in scale among sites were accounted for by standardizing the indicator by the mean maximum (flooded) area of the site (MaxAreas) observed during the project duration.

Annual multispecies catch per unit area (CPUA) was employed as a measure of production at each site:

$$CPUA_{s,y} = \frac{\sum_{m=June}^{m=May} \sum_{g=1}^{n} Catch_{s,y,m,g}}{MaxArea_s}$$ Equation 1

Where $Catch_{s,y,m,g}$ is the estimated multispecies catch landed by gear type g, during month m and year y at site s measured in kg ha-1 y-1.

Fish abundance indicated by multispecies catch per fisher per day or 'catch per day' (CPD) expressed as kg day-1 was employed as a measure of resource sustainability:

$$CPD_{s,y} = \frac{Catch_{s,y}}{Annual\ Fishing\ Days_{s,y}}$$

Equation 2

Where $Annual\ Fishing\ Days_{s,y}$ is the estimated total number of days spent fishing by the fishers at site s during year y, irrespective of the gear type employed.

Because of the fundamental importance of sustaining or improving fish abundance as a management objective, an alternative indicator of fish abundance that accounts for any changes in fishing power was also employed based upon observations of gillnet catch per unit effort (GNCPUE) estimates made between August and September (Equation 3):

$$GNCPUE_{i,s,y} = \frac{Catch_{8-9,i,s,y}}{NetArea_{8-9,i,s,y} \cdot Hours_{8-9,i,s,y}} .1000$$

Equation 3

Where $GNCPUE_{i,s,y}$ is the catch rate of the ith gillnet sampled at site s between August (month 8) and September (month 9) of year y. The ratio was multiplied by 1000 because units (kg m-2 hr-1) were typically very small.

Two measures of fishing effort were employed as additional (indirect) indicators of the sustainability of the fisheries. The first; annual days fished per unit area (DPUA), provided an overall measure of fishing effort (Equation 4).

$$DPUA_{s,y} = \frac{Annual\ Fishing\ Days_{s,y}}{MaxArea_s}$$

Equation 4

The second; destructive fishing effort ratio (DFER), provided an estimate of the total annual fishing effort measured in hours with (predefined) destructive gear type (dg =1 to n) as a proportion of the total annual fishing effort with any type of gear, g (Equation 5).

$$DFER_{s,y} = \frac{\sum_{dg=1}^{n} \sum_{m=June}^{m=May} Fishing\ hours_{s,y,m,dg}}{\sum_{g=1}^{n} \sum_{m=June}^{m=May} Fishing\ hours_{s,y,m,g}}$$

Equation 5

The predefined destructive gear types included monofilament gillnets, small-mesh seine nets and dewatering (see Annex 1 for a complete list).

Biodiversity, estimated using the Shannon-Weiner biodiversity Index (H') (Shannon, 1948) provided a further indicator of the sustainability of the fisheries from a conservation perspective.

RESULTS

Trends in performance indicators

Considering all trends, irrespective of their statistical significance, the presence or absence of the CBFM had a significant effect on the relative frequency of upward and downward trends in CPUA, CPD, GNCPUE and H'. Trends in DFER and DPUA were found to be independent of management. The relative frequencies of the upward and downward trends indicated that the CBFM activities have significantly ($p<0.01$) benefited production (CPUA), fish abundance (CPD) and biodiversity (H') at the majority (70-80%) of CBFM sites (Figure 2).

Virtually 57% of CBFM sites exhibited downward trends in catch per unit effort during August and September, indicated by effort standardized gillnet catch rates during the period (GNCPUE). However, these frequencies could be expected by chance. Fishing intensity (DPUA) and destructive fishing practices (DFER) both declined at more CBFM sites than they increased at but these frequencies could also be expected by chance (Table 1). At control sites, downward trends in CPUA, CPD and H' were more frequent than upward trends at but the relative frequencies could be expected by chance (Table 2). The number of downward trends in GNCPUE would not, however be expected by chance for all, and only significant, trends, indicating significant declines in the abundance of fish during August and September at control sites.

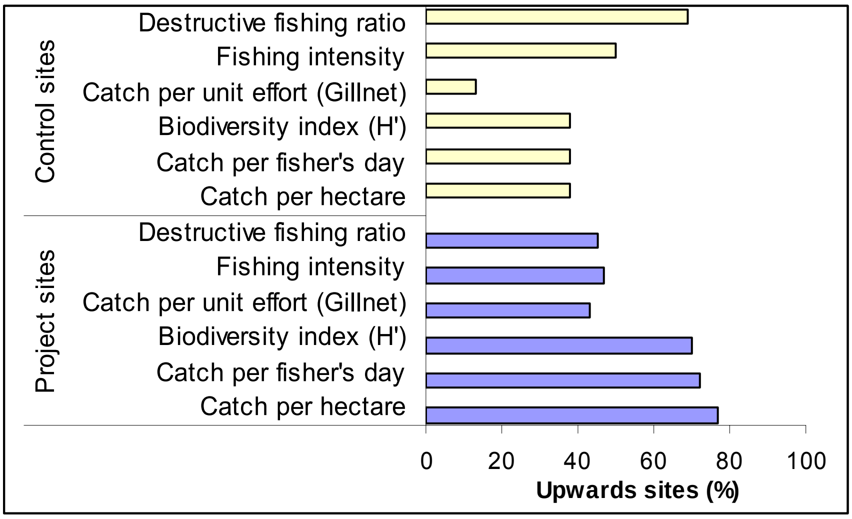

Figure 2: Comparison in the sustainability performance indicators trends for CBFM and control water bodies with at least three years of observation.

Table 2 Frequency (upward and downward) in the performance indicators.

	Performance Indicators					
	CPUA trend	CPD Trend	GNCPUE Trend	DFER Trend	DPUA Trend	H' Trend
	CBFM Sites only					
Frequency Upward	49	46	30	29	30	48
Frequency Downward	15	18	40	35	34	21
	Control Sites only					
Frequency Upward	6	6	2	11	8	6
Frequency Downward	10	10	14	5	8	10

Site Scores

Mean site score was found to vary significantly among habitat type and between CBFM and control sites. Significant differences in mean site score between CBFM and control sites were detected for closed beel ($p=0.03$, $1-\beta=0.60$, d.f.=9), open beel ($p<0.01$, $1-\beta=0.86$, d.f.=25) and river habitat ($p<0.01$, $1-\beta=0.98$, d.f.=23) (Figure 3).

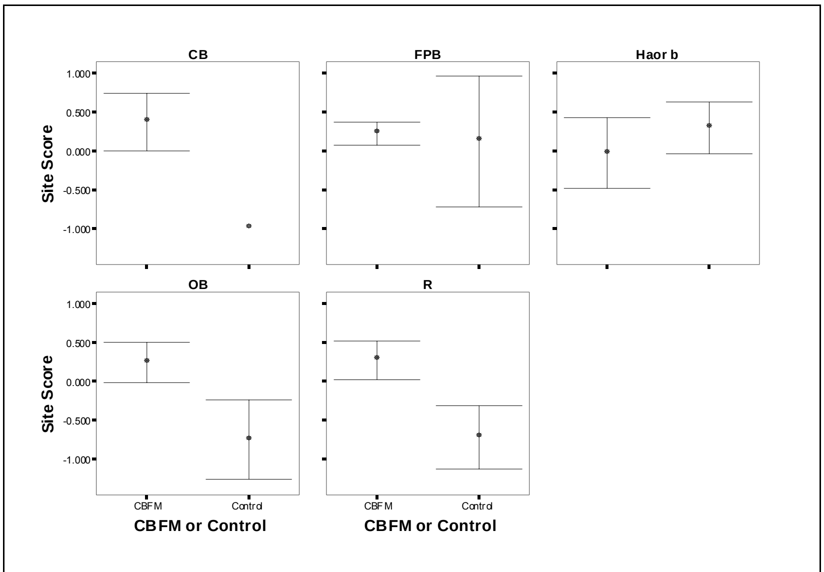

Figure 3. Mean site score with 95% CI for CBFM and control sites by habitat type.

Mean slope coefficients

Estimates of the mean CPUA slope coefficient (cpuab), representing annual rates of change in fish production, were found to vary significantly ($p<0.05$)

with habitat type, but not between CBFM and control sites suggesting that the CBFM has had no significant detectable effect on CPUA (Figure 4). However, estimates of the mean slope coefficient for CBFM sites were greater than zero for all habitat except haor beel, and significantly greater than zero (p<0.05) for closed and floodplain beel, and river habitat (Figure 4) indicating increasing production through time in these habitats. Average increases in CPUA ranged from approximately 20 to 30% per year. Estimates of the mean slope coefficient for control sites were not significantly different from zero for all habitats tested indicating no significant change in fish production (CPUA) at control sites (Figure 4).

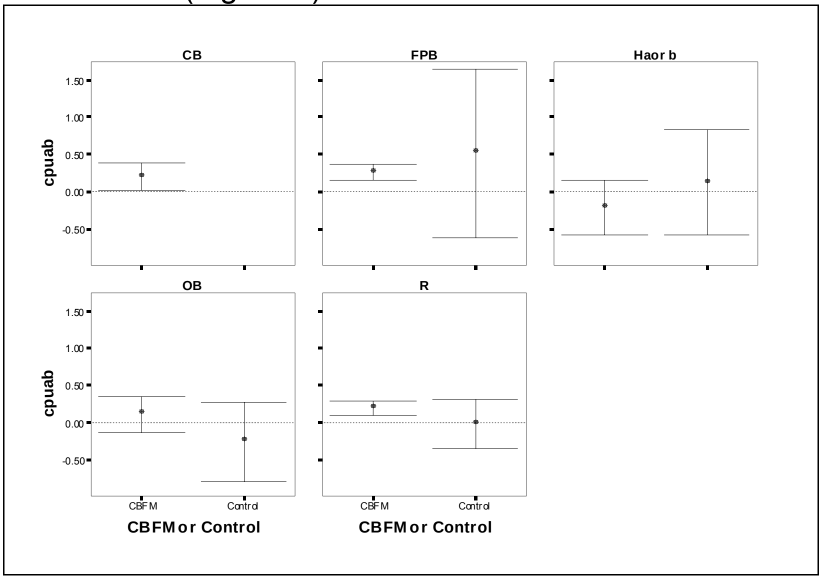

Figure 4 Mean slope coefficient estimates with 95% CI for the fish production indicator CPUA (cpuab) at CBFM and control sites for each habitat. Reference line at zero indicates no change in mean value of indicator.

Variation in fish abundance and fishing intensity, indicated by cpdb and dpuab respectively, best explained the variation in fish production (cpuab) among sites (R2=0.60; p<0.01 d.f.=77). As expected, fish production increases both with increasing fish abundance and fishing effort although these two variables are typically negatively correlated.

Two-way ANOVA tests (GLM) indicated no significant difference (p<0.05) in the estimate of the mean CPD slope coefficient among habitat type after accounting for differences between CBFM and control sites. After pooling the data across habitat, the estimate of the mean slope coefficient was significantly (p=0.03) greater for CBFM compared to control sites, and significantly (p<0.01) greater than zero (Figure 5). The estimate of the mean slope coefficient for CBFM sites translates to an increase in daily catch rates of 16% per annum. Equivalent increases by habitat ranged from 10-20% per annum. Rates of change in fish abundance at control sites were not significantly different from zero.

Estimates of the mean gillnet catch rate (GNCPUE) slope coefficient (cpueb) were found not to vary significantly across habitat type (Figure 5). After pooling the estimates across habitat, the estimate of the mean slope coefficient for CBFM sites was significantly greater ($p<0.05$) than for control sites but not significantly different from zero, indicating no significant decline in mean gillnet catch rates at CBFM sites through time (Figure 5). The estimate of the mean slope coefficient for control sites was however significantly less than zero, equivalent to a decline in catch rates (fish abundance) of approximately 30% per annum (Figure 5).

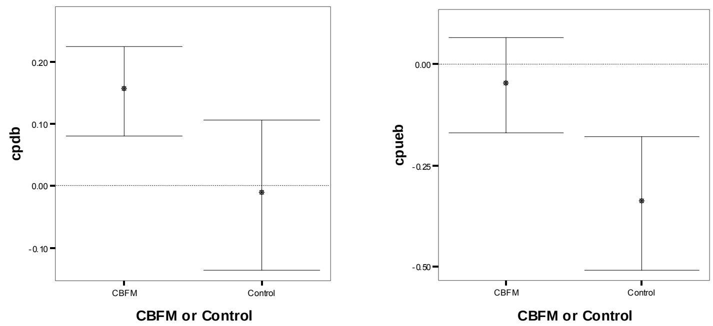

Figure 5 Mean slope coefficient estimates with 95% CI for the fish abundance indicators CPD (left) and GNCPUE (right) at CBFM and control sites for all habitat sites combined. Reference line at zero indicates no change in the value of indicator with time.

Estimates of the mean fishing intensity (DPUA) slope coefficient (dpuab) representing annual rates of change in fishing intensity were found to vary significantly ($p<0.05$) between habitat but not between CBFM and control sites (Figure 6). For CBFM sites belonging to floodplain beel habitat, mean fishing intensity increased significantly ($p<0.05$) by approximately 10% per annum, but not significantly more than at control sites. For haor beel habitat, the mean estimate for CBFM sites was significantly less than zero, equivalent to a decline in fishing intensity of more than 30% per year. This decline was not significantly different from that estimated for control sites. The remaining combinations indicated no significant change in fishing intensity through time.

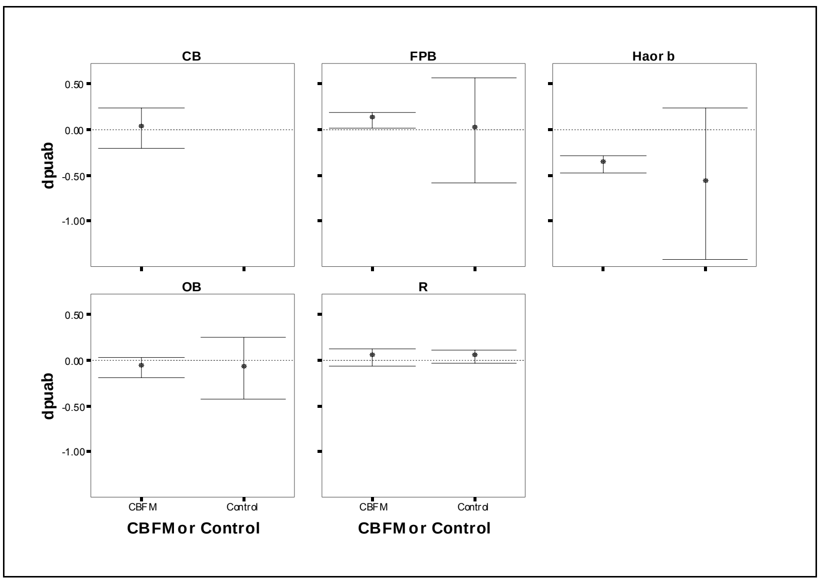

Figure 6 Mean slope coefficient estimates with 95% CI for the fishing effort indicator DPUA (dpuab) at CBFM and control sites for each habitat. Reference line at zero indicates no change in mean value of indicator.

Estimates of the mean biodiversity index (H') slope coefficient (hb) representing annual rates of change in biodiversity were found to vary significantly (p<0.05) with habitat and between CBFM and control sites (Figure 7). On average, hb was 0.19 higher at CBFM compared to control sites. Significant increases in biodiversity at CBFM sites through time (mean slope coefficient >0) were found for both closed and floodplain beel habitat equivalent to annual increases in H' of 0.12 and 0.17, respectively. Frequency distribution of (b) values for trend in biodiversity (H') with time for project water bodies are shown in figure 8. Significant improvements in H' through time were also estimated for control sites in floodplain beel habitat equivalent to 0.21 per annum. No significant (p<0.05) changes in biodiversity were detected at either CBFM or control sites in haor, open beel or river habitat. Estimates for control sites were lower than for CBFM sites for open beel and river habitat but not significantly (p>0.05). A total of 156 species of fish and prawns were recorded from all CBFM2 project water bodies during 2004-2005. Among the most dominant species, 20 species represented nearly 75% of catch (Table 3).

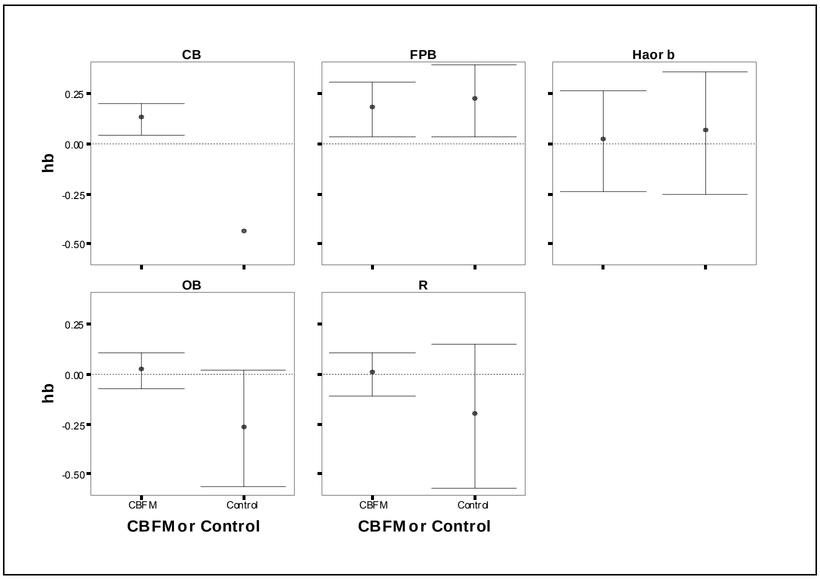

Figure 7 Mean slope coefficient estimates with 95% CI for the fish biodiversity indicator H' (hb) at CBFM and control sites for each habitat. Reference line at zero indicates no change in mean value of indicator.

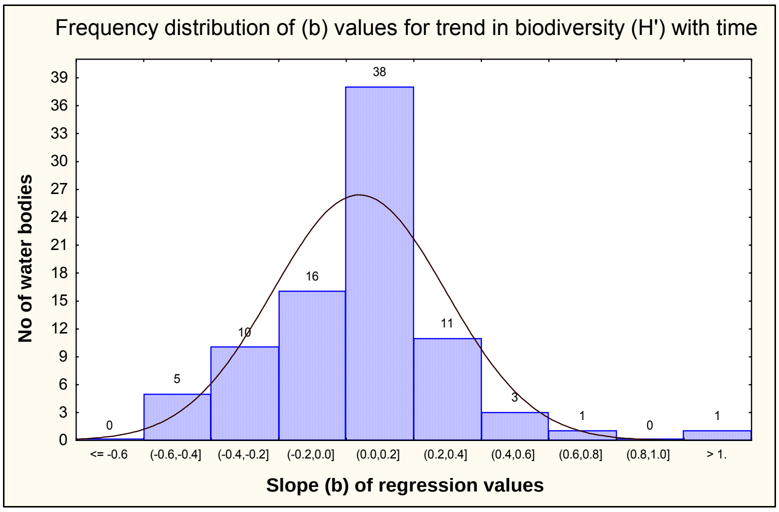

Figure 8. Frequency distribution of (b) values for trend in biodiversity (H') with time for CBFM2 project water bodies.

Table 3. Contributions of twenty dominant fish or prawn species in all CFBM2 project water bodies.

Name	Average Abundance	Average Similarity	Contribution %	Cumulative %
Puntius sophore	23.70	2.17	10.43	10.43
Channa punctatus	17.60	1.68	8.11	18.53
Nematopalaemon tenuipes	21.36	1.26	6.05	24.58
Channa striatus	18.73	1.00	4.83	29.42
Mystus tengra	13.98	0.92	4.42	33.83
Xenentodon cancila	11.50	0.91	4.38	38.21
Glossogobius giuris	12.81	0.80	3.86	42.07
Mastacembelus armatus	17.47	0.79	3.78	45.86
Nandus nandus	8.36	0.74	3.57	49.42
Wallago attu	30.16	0.64	3.09	52.51
Labeo rohita	15.94	0.61	2.96	55.46
Macrognathus aculeatus	9.21	0.57	2.74	58.21
Puntius ticto	12.13	0.56	2.72	60.92
Heteropneustes fossilis	7.65	0.54	2.62	63.54
Colisa fasciatus	8.32	0.48	2.29	65.83
Cirrhinus mrigala	15.63	0.46	2.19	68.02
Lepidocephalus guntea	6.93	0.39	1.86	69.88
Catla catla	17.46	0.35	1.70	71.58
Mastacembelus pancalus	10.70	0.35	1.68	73.26
Macrobrachium malcolmsonii	18.84	0.34	1.66	74.92

Figure 9a shows the estimates of the mean slope coefficient (b) of regressions of performance indicators with time (year) by habitat for CBFM sites. Estimates for all habitats are provided in those cases where habitat was found not to be a significant factor in determining mean slope values. Corresponding annual rates of change (%) are also showed in figure 9b.

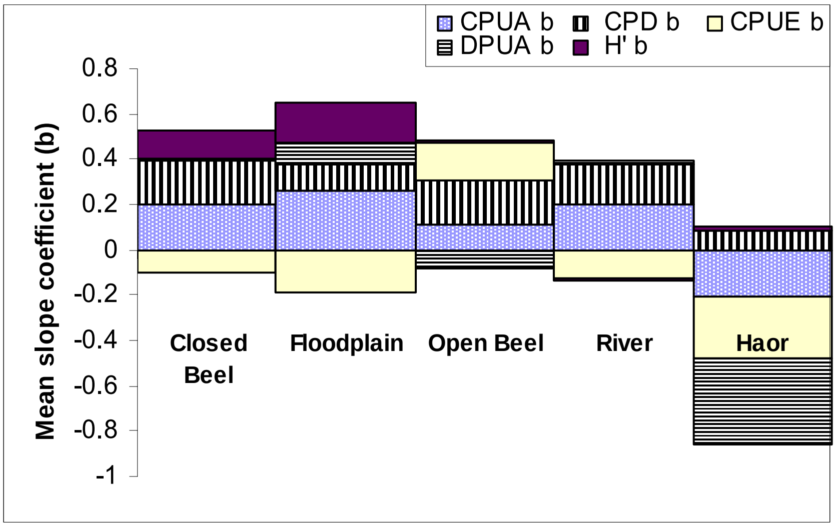

Figure 9a. Estimates of the mean slope coefficient (b) of regressions of performance indicators with time (year) by habitat for project water bodies.

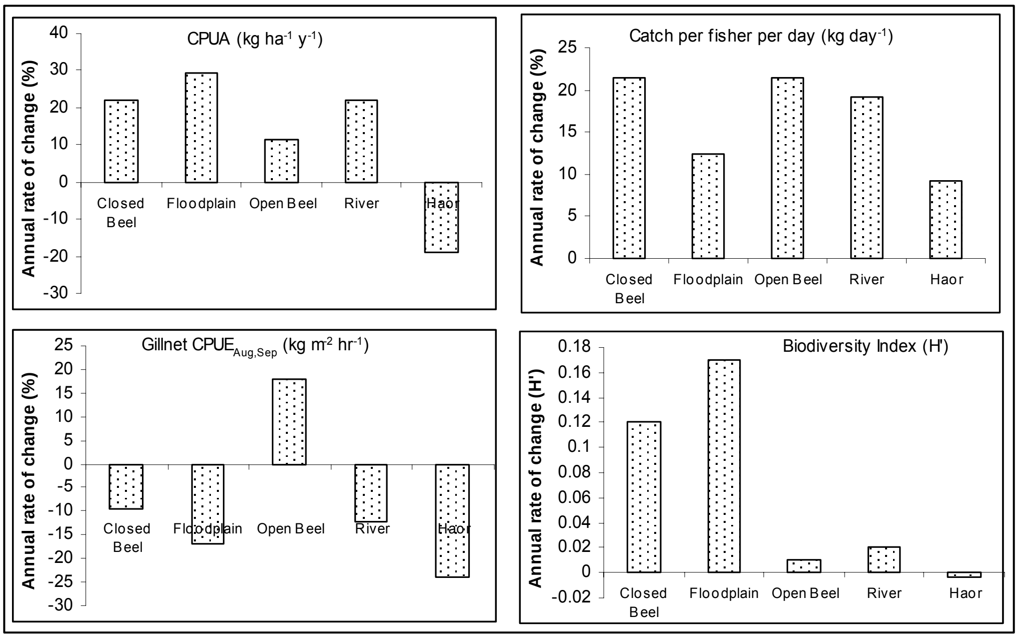

Figure 9b. Annual rates of change (%) by habitat for CBFM water bodies-based on mean slope coefficient (b) of regression. Reference line at zero indicates no change in mean value indicator.

Figure 10a shows estimates of the mean slope coefficient (b) of regressions of performance indicators with time (year) by habitat for control sites. Estimates for all habitats are provided in those cases where habitat was found not to be a significant factor in determining mean slope values. Corresponding annual rates of change (%) are also shown in figure 10b.

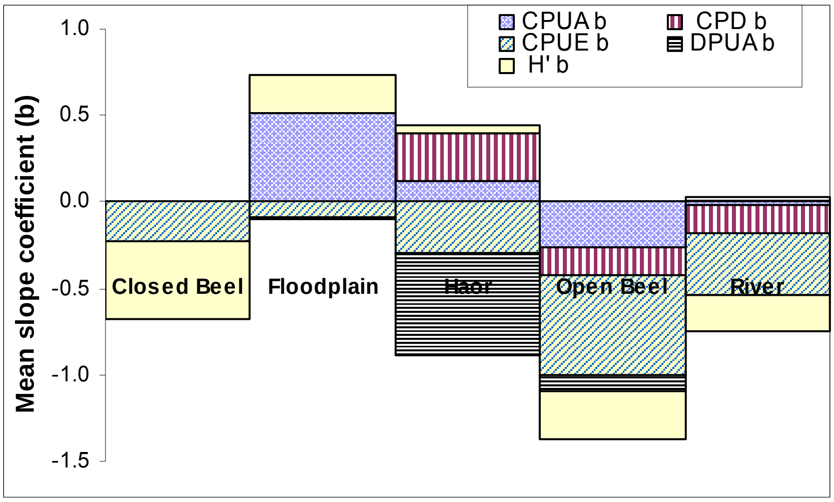

Figure 10a. Estimates of the mean slope coefficient (b) of regressions of performance indicators with time (year) by habitat for project water bodies.

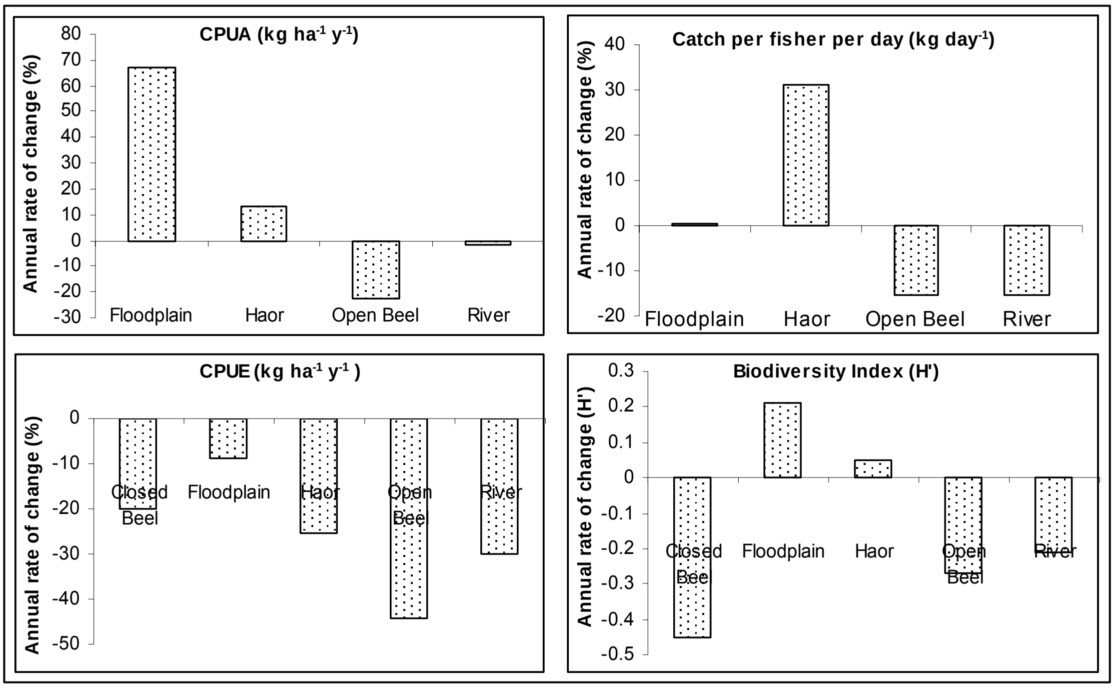

Figure 10b. Annual rates of change (%) by habitat for control water bodies-based on mean slope coefficient (b) of regression. Reference line at zero indicates no change in mean value indicator.

What Management Interventions Worked Best?

The CBFM project has provided compelling evidence to show that the fishers managed approach was effective in a wide range of different inland water body types in Bangladesh. A site score comprising the trends for all fisheries management performance indicators (CPUA, CPD, GNCPUE, DFER, DPUA and H') was calculated for each community managed water body and compared among different habitats (Figure 11). The relative frequencies of these upwards and downwards trends indicated that CBFM activities yielded benefits at 90%, 84% and 80% of the CBFM2 water bodies managed by Fishers, Community and Women respectively. However at control sites only 37% of sites had significant improvements and these were mainly in large floodplain sites. However, experimentation or adaptive approaches to management will be required to determine which are most important. In conclusion, community-based fisheries management appears to perform significantly better than the existing management regime in Bangladesh.

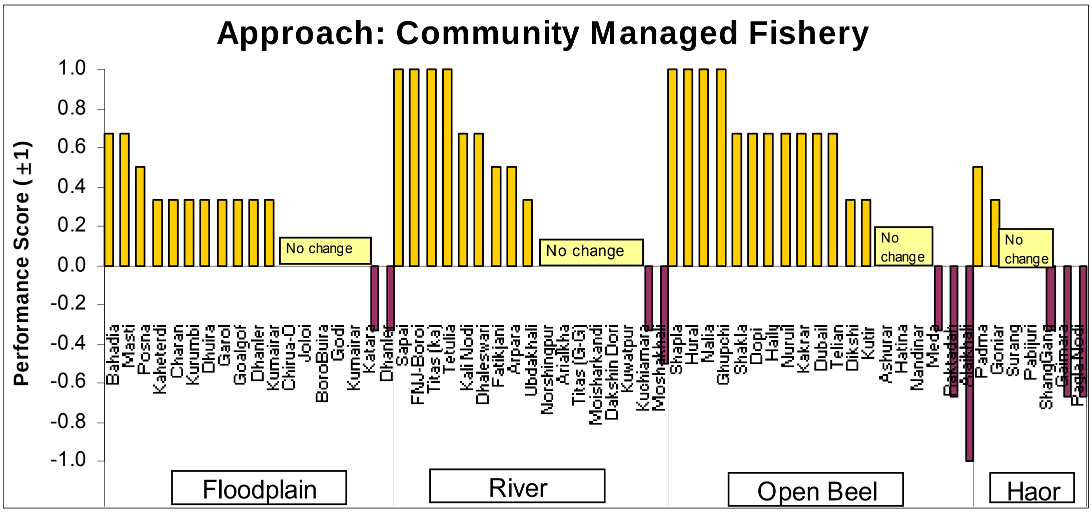

Figure 11. Plot of water bodies score comprising the trends of all fisheries management performance indicators (CPUA, CPD, GNCPUE, DFER, DPUA and H') compared among different habitat through community management approach.

DISCUSSION AND CONCLUSIONS

According to the relative frequency of upward and downward trends in performance indicators at CBFM and control sites, the CBFM Project appears to have benefited fish production (CPUA), abundance (CPD and GNCPUE) and biodiversity (H') at participating sites, but has had little or no apparent effect on destructive fishing practices (DFER) or fishing intensity (DPUA). Except for fish abundance indicated by gillnet catch rates (GNCPUE), which was found to be declining at significantly more sites than it was increasing, no significant ($p<0.05$) overall trends in management performance were detected at control sites.

The analysis of slope coefficients corresponding to these trends generated largely consistent results to those above but indicated that some of the above conclusions were habitat specific. The CBFM was found to have a significant beneficial effect on CPD, GNCPUE and H', but not CPUA or DPUA after accounting for any natural variation among habitat type and region.

Mean annual increases in fish abundance, indicated by CPD, were significantly greater at CBFM compared to control sites, particularly in river habitat (20% per annum). Furthermore, the mean change in fish abundance at control sites was not significantly different from zero. Fish abundance increased in response to a decrease in fishing intensity (DPUA) and closed seasons, but these factors explained only 15% of the total variation in fish abundance. Whilst gillnet net catches rates (GNCPUE) indicated no significant change in fish abundance at CBFM sites, a significant ($p<0.05$) decline was detected at control sites equivalent to almost 30% per annum.

The fishing power index (FPI) was found not to have increased significantly through time within any habitat suggesting that the CPD indicator is unlikely to be biased from changes in fishing power. Unlike the annual perspective of the CPD indicator, GNCPUE provides an index of fish abundance only during a two month period during the flood season when gillnets tend to target migratory whitefish species (Welcomme 1985). GNCPUE may therefore be a poor indicator of the abundance of less migratory blackfish species, and thus the entire assemblage. Therefore each indicator has advantages and disadvantages.

Irrespective of the choice of indicator, the results suggest that fish abundance does benefit from CBFM manifest either as increasing, or at least sustained, abundance.

Rates of change in biodiversity were found to vary significantly among habitat and were on average also significantly greater at CBFM compared to control sites. Improvements in biodiversity at CBFM sites through time were significant in closed and floodplain beel habitat. Significant improvements in biodiversity were also detected for control sites belonging to floodplain beel habitat.

The slope coefficient analyses also supported the conclusion that the CBFM appears overall to have had little effect on fishing intensity (DPUA) although significant declines (31% per annum) were found at CBFM sites belonging to haor beel habitat and modest (10%) but significant increases were observed in floodplain beel habitat. No significant changes in fishing intensity were detected at control sites.

Variation in the slope coefficient estimates for the individual management performance indicators at CBFM sites was significant within the majority of habitats categories but no discernable patterns were evident among the indicators to suggest that overall CBFM performance varied significantly among habitat, nor site size, geographic region or facilitating NGO (Halls et al. 2006a).

The mean composite measure of management performance (site score) was found to be greater at CBFM compared to control sites in four of the five habitats and significantly ($p<0.05$) greater in three. The size of the water body (MAXAREA), the NGO facilitating management and the ownership regime (JALMOHOL) were also found to have no detectable effects on the site score estimates among CBFM sites (Halls et al. 2006a).

Whilst co- and community-based management approaches have long been advocated as a means to addresses the failures associated with conventional 'top-down' approaches to management (Pomeroy & Williams 1994; Hoggarth et al. 1999; Wilson et al. 2003), few studies have quantitatively demonstrated their benefits. On the basis of the results presented here, it is concluded that the practices implemented under the Community Based Management (CBFM) Project in Bangladesh have improved, or at least sustained, fish abundance and biodiversity without significant loss to production compared to those at the control sites. In other words, the community-based approach adopted under the Project appears to give rise to better management performance than the existing top-down government-driven regime.

Increases in fish abundance and fishing intensity explained much (60%) of the variation in fish production. A companion paper (Halls and Mustafa 2006) describes empirical relationships between fishing intensity and production derived using data from this study to provide estimates of maximum yield and corresponding fishing effort by habitat. These estimates may help inform future CBFM programmes and provide useful starting points for experimental or adaptive management programmes in similar habitats (see below).

Greater uncertainty surrounds which factors were responsible for improvements in the remaining indicators. Closed seasons appear significant but explain less than 15% of the variation in fish abundance (CPD) after also accounting for differences in fishing intensity, and only 24% of the variation in biodiversity (Halls et al. 2006a). Halls et al. (2001) predicted that closed seasons during the rising flood period (April-July) would significantly increase floodplain fish production and abundance by improving both recruitment and yield-per-recruit. Whilst the effect of gear bans on the response of performance indicators could not be separated from those arising from closed seasons (because the two interventions were implemented together at almost all CBFM sites) the observed trends in destructive gear use (DFER) indicated that gear bans had been ineffective and therefore were unlikely to have been responsible. Hoggarth & Kirkwood (1996) predicted that gear bans do not increase overall yield, but can be an effective means of redistributing benefits to preferred gear of fisher socio-economic categories.

Reserves have been recommended as potentially effective means of controlling fishing mortality in the floodplain environment (e.g. Hoggarth et al. 1999; 2003) but studies robustly demonstrating their efficacy, and recommendations concerning minimum reserve areas, are sadly lacking. Here, reserves were found to have no detectable effect on any of the management performance indicators. Their apparent ineffectiveness here may reflect poor enforcement, inappropriate reserve location or simply that they were too small to produce any detectable effects. Seventy-five percent of the reserves occupied less than 10% of the dry season area of CBFM sites.

Up to 12 CBFM and control sites were also stocked to improve production. Estimates of fish production employed in the CPUA, CPD and GNCPUE indicators excluded landings of stocked fish although the effect of stocking activities on performance indicators was considered. A second companion paper (Halls et al. 2006b) describes a simple bio-economic model to help farmers select the most profitable and risk adverse stocking strategies based upon data collected under the CBFM Project.

Future projects or initiatives may choose to place greater emphasis on identifying effective habitat-specific management interventions and arrangements with respect to specific management objectives. For example, CBOs might be encouraged to experiment with closures to the fishery of different durations or during different months of the year (seasons), allocate different proportions of their dry season fish habitat as reserves, or control fishing effort at different levels as a means of determining the best strategy to increase fish production, abundance or biodiversity.

The CBFM Project has already demonstrated that CBOs are motivated to share and disseminate their knowledge and experiences through meetings, exchange visits and newsletters (Halls et al 2005). Consideration might therefore be given to strengthening these types of CBO networks to support experimentation and learning under future initiatives. Halls et al (ibid) describe guidelines for designing data collection and sharing systems to support this type of adaptive management approach.

Future impact studies of this type would benefit from greater consideration to the sampling design to avoid the problems encountered here arising from missing cells and an unbalanced design, and to optimize the use of project resources.

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