Technical Assistance to the Community-Based Fisheries Management (CBFM) Project:

Assessment of the Impact of the CBFM Project on Community-Managed Fisheries in Bangladesh

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An assessment of the Impact of the CBFM Project on Community-Managed Fisheries in Bangladesh

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1 Executive Summary

The CBFM Output to Purpose Review 2 (OPR2) Report identified a need to further examine the impact of the CBFM activities on fisheries management performance at the local level in preparation for the final phase of the Project. This study was therefore commissioned in May 2005 specifically to determine the impact of the CBFM activities on fish production, resource sustainability and fisher well-being, whilst taking account of inter and intra-annual variation in important environmental variables such as hydrology.

The study employs data collected from up to 78 CBFM and control sites since 1997, representing a range of different habitat type and geographic location. Performance indicators relating to production, resource sustainability (including biodiversity) and fisher well-being were identified in consultation with the WorldFish Centre, Bangladesh, together with more than 15 explanatory variables hypothesised to affect management performance.

Where necessary variables were expressed on a per unit area (ha^{-1}) scale to allow valid comparisons among sites and $\log_e$ or square-root transformed to ensure that the normality assumptions of the statistical methods were met.

A considerable amount of unplanned study time was required to resolve errors with the data and to prepare it in the required format for analyses. This, unfortunately, left little time for any capacity building of staff members of the WorldFish Centre, Bangladesh, in the form of training in the analytical methods employed.

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).

Controlled Comparisons

For the controlled comparisons, sources of natural variation were accounted for, either by treating these sources as fixed factors in the GLM, or by first stratifying the data by these factors. Sources of natural variation were identified in the data set as including, but not necessarily limited to, habitat type (WBTYPE), geographic region (REGION), and sampling year (YEAR). Therefore most comparisons involved a four-way analysis of variance (ANOVA).

A significant obstacle to the controlled comparisons was the extremely unbalanced sampling design adopted by the CBFM project which contained many “missing cells” ie an absence of any data for factor combinations. For example, data for control sites were absent until 2002. The south (S) and northeast (NE) regions were represented only by one site each, and many habitat types were not represented in all the regions.

Whilst multi-way factor analysis is still possible with missing cells by using a ‘Type IV sum of squares’ model, the interpretation of the results is notoriously difficult and often unreliable. The controlled comparisons were therefore repeated with subsets of the data where all levels of the factors of interest were represented in the data, albeit often in an unbalanced fashion (ie unequal sample sizes in factor combinations). This significantly reduced the number of observations overall, but improved the reliability of the results.

Multivariate comparisons using ordination techniques and permutation (Monte Carlo) tests were also used to determine the impact of the CBFM activities on species assemblages.

Of the 21 controlled comparisons made, only three significant ($P<0.05$) differences in the mean values of management performance indicators between CBFM and control sites were detected (See Section 7.1.1). These related to river fisheries production in 2004 which was found on average to be lower (149 $kg\ ha^{-1}\ y^{-1}$) at CBFM sites compared to control sites (583 $kg\ ha^{-1}\ y^{-1}$). However, these differences in production could be accounted for by significant differences in fishing intensity between the two groups of sites. The inclusion of a potentially more productive main river site in the control group might explain any remaining differences. Bi-monthly household (HH) fish consumption was significantly higher in CBFM (12 $kg\ HH^{-1}$) compared to control sites (10 $kg\ HH^{-1}$). Significant seasonal variation in fish consumption was detected. Fish consumption is greatest between October and November and lowest between April and May. Fish consumption also varies significantly among habitat type with consumption highest at river sites and lowest at floodplain beel sites.

It is very important to note that whilst most of the controlled comparisons indicated no significant differences in mean management performance indicators between CBFM and control sites, **the power of the tests performed ie the probability of detecting a true significant difference, was very low (<10%) in almost all cases**. The power of the statistical tests was low because of the small number of samples gathered in each month and the very unbalanced sampling design with many missing cells (see above).

Therefore, **there is a very high chance of drawing erroneous conclusions about the apparent non-effectiveness of the CBFM on the basis of these controlled comparisons**. In other words, the CBFM may have a positive or negative effect on many or all the performance indicators examined, but these effects remain undetectable at present. These controlled comparisons were therefore unable to answer the question: Does the CBFM work?

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. When significant slopes were detected, explanatory variables that best described the trend were then sought using the GLM after first dropping year from the model.

With the exception of fish consumption, the results of the time series analysis were equally inconclusive (see Section 7.1.2).

Whilst trends in production, measured as annual catch per unit area (CPUA) at CBFM sites were upward in all cased but one examined, these upward trends were significant in only two cases and the downward trend was also significant. Fish abundance (CPUE) trends were downward in most cases, but when considering only the significant trends, three sites exhibited upward trends and only one downward.

Trends in fishing intensity, measured in terms of fishing days per unit area (DPUA) were more consistent. Upward trends (two of which were significant) were consistent in all but one site, but this downward trend was not significant. The probability of such at outcome occurring by chance is 16% ($P=0.16$) suggesting that fishing intensity is increasing despite the implementation CBFM management interventions. No consistent trends in the destructive fishing effort ratio (DFER) were detected.

Biodiversity, measured in terms of the Shannon-Weiner Index (H’) was found to be increasing at most sites examined, but the trends were not significant.

Whilst the significance of the trends was not tested (only three years of observations), fish consumption appears to be declining at 19 or the 20 sites examined. Therefore whilst fish consumption is higher at CBFM compared to control sites (see above), there is strong evidence to indicate that fish consumption is declining overall. The downward trend may reflect increasing un-affordability of fish rather than a decline in production. Trends in income (earnings less costs) at the two sites, for which data were available, were not significant.

Recommendations
If resources permit, attempts could be made to gather more data both at existing sites and also at some additional control sites to improve the power of the controlled comparisons, at least for the fish abundance (CPUE) indicator which is based upon a monthly estimate. A variance components analysis may be required for this purpose to determine how best to allocate sampling effort between CBFM and control sites, and among habitat type and geographic region.

Consideration might also be given to multi-level modeling approaches that take better account of the hierarchical nature of the data, at least for the CPUE comparisons where individual catch rate observations are available for each site. In both cases, it is recommended that the advice of a qualified statistician be sought.

However, the alternative, and probably the most viable, option would be to focus any remaining project resources on improving the trend (time series) analyses of management indicators at individual CBFM sites. It is understood that when data for 2005 become available in the first few months of 2006, the number of sites with at least four years of data will rise from the current 14 to as many as 60 sites. The additional data will also increase the power of the trend (slope) tests for the 14 current sites. With these additional data, it should then be possible to draw clear conclusions concerning the effectiveness of the CBFM at individual sites.

More detailed recommendations for repeating the analysis and reporting the findings are provided in Section 7.4.

2 Introduction

2.1 Background

Fish from Bangladesh's vast inland waters are vital to millions of poor people, but landings 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; Ali 1979).

The practice of short term leasing small waterbodies (*jalmohals*) provides little incentive to lease holders to harvest aquatic resources in a sustainable manner and often acts as an obstacle to access by poorer members of the community (Craig *et al.* 2004).

The first phase of the Community Based Fisheries Management (CBFM) during 1994-1999 was funded by Ford Foundation grants to government and non-government partners. It aimed to promote the sustainable use of, and equitable distributions of benefits from, inland fisheries resources by empowering communities to manage their own resources.

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).

The 11 partner NGOs are Banchte Sheka (BS), Bangladesh Environmental Lawyers Association (BELA), Bangladesh Rural Advancement Committee (BRAC), Caritas, Centre for Natural Resource Studies (CNRS), Centre for Rural and Environmental Development (CRED), FemCom, PROSHIKA, Shikkha Shastha Unnayan Karzakram (SHISUK), Grassroots Health and Rural Organization for Nutrition Initiative (GHARONI), and Society Development Committee (SDC). These field-based partner NGOs are responsible for organizing about 23,000 poor fishing households around 120 waterbodies representing a range of different habitat types and located in regions throughout Bangladesh.

The principal aims of this second phase are to (i) assess the performance of the local user communities and organizations to improve their social, economic and nutritional status in a sustainable way by means of management measures that they choose to introduce.

2.2 Aims of this study

The CBFM Output to Purpose Review 2 (OPR2) Report identified a need to further examine the impact of the CBFM activities on fisheries management performance at the local level in preparation for the final phase of the Project. The review also identified the need to assess the relative importance of CBF management activities and environmental factors (particularly hydrology) in determining fisheries performance (CBFM 2, 2004).

This study aimed to address this need by specifically attempting to determine the impact of the CBFM activities on fish production, resource sustainability and fisher well-being, whilst taking account of inter and intra-annual variation in important environmental variables such as hydrology. By adopting this approach, the study attempted to answer the key question: "Does CBFM generate sustainable benefits to fisher communities or do observed changes or differences in important management performance measures simply reflect changes in fishing intensity or natural variation in flooding patterns"? Or put more simply: Does the CBFM work?

3 Materials and Methods

3.1 Monitoring Sites

3.1.1 Location

The impact of the CBFM was determined on the basis of data collected under the project's routine and *ad hoc* monitoring programmes conducted at a maximum of 78 of the total 120 project sites divided unequally between those under CBFM and control sites that are not under CBFM (Table 1). Monitoring of control sites did not begin during 2002. Most sites are located in the North and Northwest of the country, with only single sites represented in the South and North-east of the country (Table 2 and Figure 1).

Table 1 Number of monitored CBFM and control sites

	CBFM or Control	
	CBFM	Control
1997	16	
1998	19	
1999	17	
2000	14	
2001	13	
2002	52	12
2003	66	12
2004	54	13

Table 2 Number of monitored sites by region

	E	N	NE	NW	S	SW
1997	3	9		2		2
1998	3	9		4		3
1999	3	8		4		2
2000	3	5		4		2
2001	3	5		4		1
2002	14	29	1	14	1	5
2003	16	33	1	18	1	9
2004	10	30		16	1	10

Monitored CBFM and control sites represent a range of different habitat type. Open *beels* (OB), which are floodplain depressions connected to river systems, are the most common habitat type. Closed *beels* (CB) have no or limited connections to river systems. With the exception of rivers with adjacent open *beel* sites (R+OB), the monitored sites are spread fairly evenly across the range of different habitat types (Table 3).

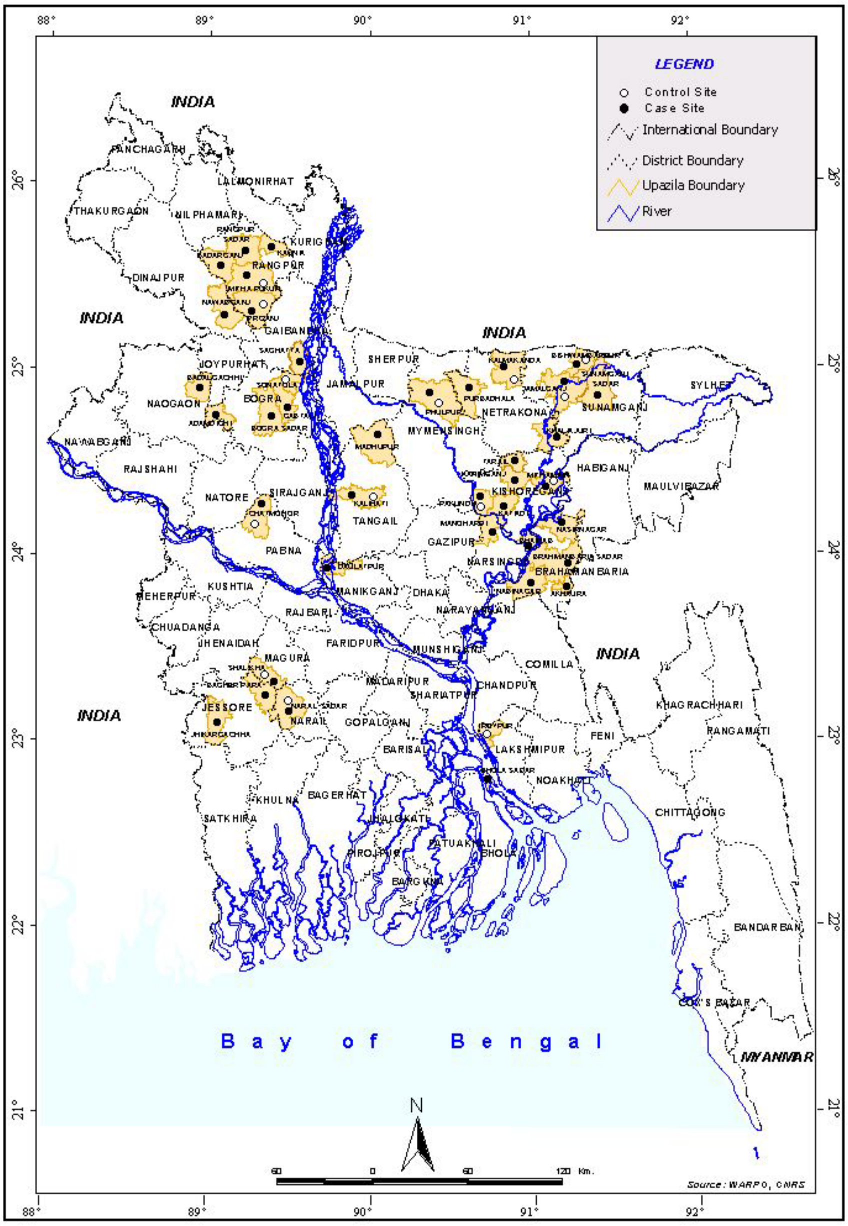

Figure 1 Distribution of monitored CBFM and control sites in Bangladesh

Table 3 Number of sites by habitat type

	CBFM or Control							
	CBFM				Control			
	CB	FPB	OB	R	CB	FPB	OB	R
1997	2	2	2	10				
1998	5	2	2	10				
1999	4	2	2	9				
2000	2	2	2	8				
2001	2	2	2	7				
2002	9	13	21	9	1	2	5	4
2003	12	14	28	12	1	2	5	4
2004	10	13	18	13	2	2	5	4

3.1.2 Management

The CBFM sites are managed either through stocking programmes, closed seasons, gear bans, or harvest reserves (sanctuaries) or a combination of these. Most monitored control sites are not managed in any way (Table 4). In those sites that are, stocking is the only form of management activity (Table 5).

Table 4 Presence of management activities at monitored CBFM and Control sites

	CBFM		Control	
	Not Managed	Managed	Not Managed	Managed
1997	13	3		
1998	8	11		
1999	1	16		
2000		14		
2001		13		
2002	13	39	11	1
2003		66	11	1
2004		54	11	2

Table 5 Monitored CBFM and control sites with stocking programmes

	CBFM		Control	
	Not Stocked	Stocked	Not Stocked	Stocked
1997	15	1		
1998	15	4		
1999	13	4		
2000	12	2		
2001	11	2		
2002	45	7	11	1
2003	56	10	11	1
2004	48	6	11	2

Following the start of monitoring activities in 1997, most CBFM sites have been managed with a combination of closed seasons and gear bans (Table 6). In 2003 and 2004, all CBFM sites were managed with at least gear bans and closed seasons. Harvest reserves (sanctuaries) have become increasingly important between 2002 and 2004.

Table 6 Management interventions employed at monitored CBFM sites

	Total CBFM sites	Closed Seasons	Gear Bans	Reserves
1997	16	2	1	1
1998	19	2	10	1
1999	17	2	16	1
2000	14	2	14	1
2001	13	3	13	2
2002	52	35	38	11
2003	66	66	66	34
2004	54	54	54	40

3.2 Monitoring Programmes

Catch monitoring sites are broadly divided into two categories i.e. individual waterbody and cluster waterbody. Monitoring of management performance variables at CBFM sites is conducted both routinely and on an *ad hoc* basis at both CBFM and control sites (since 2002). Control sites were selected to match the project waterbody types on the basis of their topographic feature and existing fishing activity which is similar to the waterbodies to be compared.

3.2.1 The Catch Assessment Survey

Species-wise landings (catch) and efforts by gear type data are collected over a two-day period twice per month corresponding to the lunar cycle. 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 is typically approximately n = 7 for gillnets – the most popular gear type.

3.2.2 Stocking and harvesting monitoring data

Log books are used by communities to record harvest weights (landings) from any stocking programmes undertaken at the site, including details of stocking density (numbers and weight stocked) and stocking sizes by species.

3.2.3 Water body areas and water heights

An ad hoc study (WorldFish Centre, 2004) was recently undertaken to provide estimates of the minimum and maximum flooded areas of each site. These estimates are used to express a number of the management performance indicators on a per unit basis for comparative purposes. Water height data is also being routinely monitored at selected sites. Currently monthly time series of water height estimates are available for only two sites for a period of only three years.

3.2.4 Fish Consumption and Income-expenditure surveys

Bi-monthly household (HH) fish consumption and income-expenditure monitoring has been ongoing since July 2002 for CBFM and control sites located in Dinajpur, Rangpur, Bogra, Tangail, Kishoreganj, Netrokona, Brahman Baria and Narail. A total of 1820 fisher households are being monitored during each bi-monthly period.

3.3 Analytical approach

The impact of the CBFM activities was determined on the basis of controlled and temporal comparisons of indicators of management performance.

3.3.1 Performance and Explanatory Variables

Performance indicators relating to production, resource sustainability (including biodiversity) and fisher well-being were identified in consultation with the WorldFish Centre, Bangladesh (Table 7). More than 15 explanatory variables hypothesised to affect management performance, were also identified. These explanatory variables are summarized in relation to the management performance indicators in the form of a hypothesis matrix (Table 8).

Transformations

It was necessary to express a number of the variables in terms of per unit area (ha^{-1}) to account for differences in the size (area) of sites. It was also necessary to $\log_e$ transform a number of the variables, including catch per unit area (CPUA) to ensure that the normality assumptions of the statistical methods were met (Figure 2). The destructive fishing effort ratio (DFER) was square-root transformed.

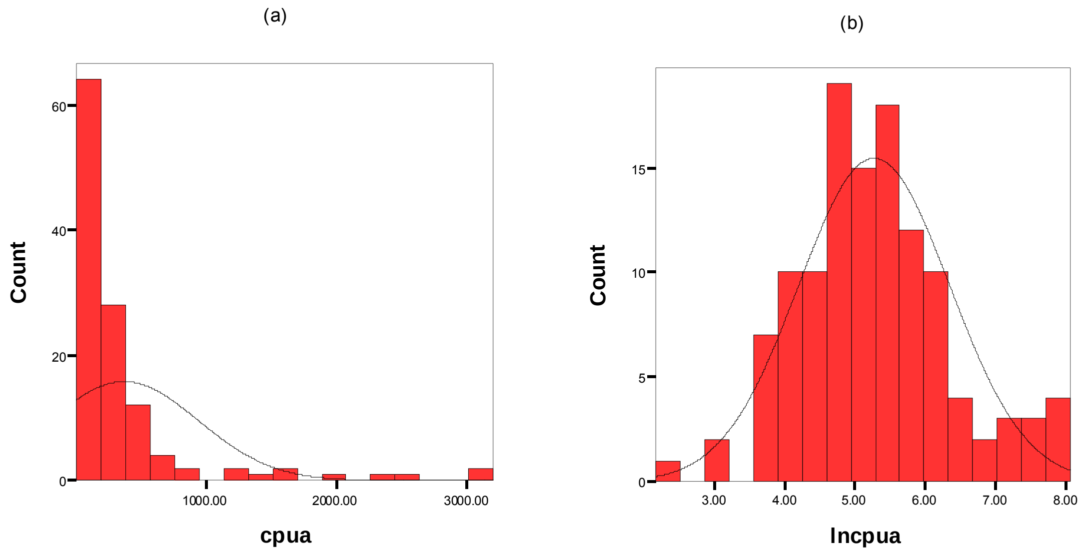

Figure 2 Distribution of (a) untransformed and (b) log$_e$ transformed CPUA estimates.

3.3.2 Analytical Procedure

3.3.2.1 Controlled Comparisons

Estimated mean site values of each performance indicator were first compared between CBFM and control sites with general linear models (GLMs) using SPSS v11.5 software. Only CBFM sites where management interventions were in place at the time of sampling were included in these comparisons since whilst sites may be classified as CBFM, management activities are often initially geared towards planning and preparation for the implementation of management interventions. Furthermore, some management interventions were not continued by some communities during the interim period (1999-2001) between the first and second phases of the project.

Whenever possible, sources of natural variation were accounted for, either by treating these sources as fixed factors in the GLM, or by first stratifying the data by these factors. Sources of natural variation were identified in the data set as including, but not necessarily limited to, habitat type (WBTYPE), geographic region (REGION), and sampling year (YEAR). Sampling year is a potentially important factor because of inter-annual variation in hydrological which can affect fish production and gear catchability (Welcomme, 1985; Welcomme & Halls 2004) [see Section 3.3.4 below]. Species assemblages can also vary significantly among habitat type and geographic region in Bangladesh (Halls *et al*. 1998; Craig *et al*. 2004) which can in turn affect production and catch rates.

To test for significant differences in the mean values of each performance between CBFM and control sites, a multi-factorial analysis of variance test was used incorporating the following factors:

Factors	**Factor Levels**
CBFM_OR	CBFM or Control site
WBTYPE	CB, OB, FPB, River
REGION	N, NE,NW, E, S, SW
YEAR	1997-2004

If WBTYPE, REGION or YEAR were found not to be significant, they were dropped and the model refitted.

3.3.2.2 Unbalanced Design and Missing Cells

The sampling design adopted by the project was extremely unbalanced with many missing cells. For example, data for control sites were absent until 2002. The south (S) and northeast (NE) regions were represented only by one site each, and many habitat types were not represented in all the regions.

Multi-way factor analysis is still possible with missing cells by using a 'Type IV sum of squares' model. The program executes a selected series of comparisons. The outcome of each comparison is then prudently combined to estimate each main effect and, where possible, each interaction. Hence, although the process is intricate, the output is interpreted in the same way as conventional ANOVAs. However, the interpretation of the results is notoriously difficult and often unreliable. Statisticians who have examined the usefulness of Type IV sums of squares have concluded that Type IV sums of squares are not up to the task for which they were developed **http://www.statsoft.com/textbook/stglm.html**.

One way to overcome the problem of missing cells is simply to select a subset of the data where all levels of the factors of interest are represented in the data, albeit possibly in an unbalanced fashion, and employ the standard Type III sum of squares model. Of course, the disadvantage with this approach is that you have to drop from the analysis some potentially useful, influential and hard won data! For the purposes of the analyses described here, this meant selecting only data for 2003 and excluding region as a fixed factor, or selecting (separately) only sites belonging to open beel (OB) and river (R) habitat in the north and northwest regions sampled between 2002 and 2004. Both approaches were adopted and results reported here.

3.3.2.3 Multivariate Comparisons of Species Assemblages

The impact of the CBFM on species assemblages was examined by comparing indices of species abundance data (small meshed seine net catch per unit effort during September 2003) between CBFM and control sites. Because of the unbalanced nature of the design, only data recorded for open beel (OB) habitat in the N and NW regions of the country could be used. Similarities in the species assemblages at CBFM and control sites were summarised in two-dimensional space using non-parametric multidimensional scaling (MDS) ordinations following a strategy proposed by Clarke (1993). The approach aims to construct a map or ordination of sites (samples) such that their placement reflects the rank similarity of their species assemblages. Sites positioned in close proximity to each other in the ordination have very similar species assemblages, whilst sites that are far apart share few common species, or have the same species but at very different levels of abundance. A "stress" measure indicates how well the ordination satisfies the (dis)similarities between sites. Stress values <0.2 indicate acceptable fits to the data. The null hypothesis [H_0: There are no differences in species assemblages between CBFM and control sites] was tested using a non-parametric permutation (analysis of similarity or ANOSIM) test based upon the difference in the average rank similarity within and between the CBFM and control site groups (*r* statistic). The significance level of the test is calculated by referring the observed value of the *r* statistic to its permutation distribution generated from randomly sampled sets of permutations of site labels.

In addition to testing the effect of CBFM on species assemblages, the effect of region was simultaneously tested by using a two-factor crossed version of the ANOSIM test. Thus, in effect, two null hypotheses were tested [H_1: There are no differences in species assemblages between CBFM and control sites (allowing for the fact that there may be differences between regions)] and [H_2: There are no differences is species assemblages among regions (allowing for the fact that there may be differences in species assemblages between CBFM and control sites)].

The MDS and ANSOSIM analyses were performed with the PRIMER (**P**lymouth **R**outines **I**n **M**ultivariate **E**cological **R**esearch) software (Clarke and Warwick, 1994) on fourth-root transformed data and employing the Bray-Curtis (Bray & Curtis, 1957) similarity coefficient as the measure of similarity between pairs of sites.

3.3.2.4 Time series (trend) analysis

Examination of changes through time (temporal comparisons) provides an alternative means to controlled comparisons of assessing the effect of CBFM activities on management performance indicators. For example, sustained or increasing values of indicators of fish abundance (CPUE) through time would suggest that the CBFM activities are sustainable or beneficial. Declines in CPUE through time would indicate that the CBFM activities are not sustainable or are significantly depleting stocks.

Significant trends in performance indicators through time were determined 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. When significant slopes were detected, explanatory variables that best described the trend were then sought using the GLM after first dropping year from the model.

3.3.2.5 Determining the effect of management interventions

Whilst not a specific objective of the study, a number of analyses were undertaken to determine the effectiveness of the community-based management interventions (ie gear bans, closed seasons, and reserves). These were treated as fixed factors in GLM models incorporating management performance indicators as dependent variables. To take account of natural variation in the dependent variable, and between-site differences in overall exploitation intensity, habitat type, region and year where also included as fixed factors (where relevant) and fishing intensity (measured in terms of numbers of fishing days per hectare per year) as a covariate.

Unimportant variables, as judged by the corresponding test of significance and partial eta-squared statistic, were dropped from the model. Dropped variables were then re-introduced in the model in different combinations in order to determine whether a particular combination of variable or factors would jointly explain a substantial component of the variation in the dependent variable. Several iterative procedures were therefore needed before it was possible to determine that the final selection was the best subset of variables.

3.3.3 CAS Survey Coverage

In some years at some sites, the CAS was not undertaken during some months for a variety of different reasons. These site-year combinations, were not included in comparisons of annual performance indicators (for example CPUA and DPUA) that are calculated by summing estimates over each calendar month.

3.3.4 Accounting for the effects of hydrology

Among site comparisons

Accounting for natural differences in hydrology when comparing fish production and abundance among sites is important, yet problematic. Modeling simulations (see Halls & Welcomme, 2004) indicate that conditions during both the flood and dry seasons are important, but that interactions also exist between these two periods. Furthermore, the response of fish populations may not be reflected in indicators of productivity and fish abundance such catch per unit area CPUA and CPUE respectively, until after one or more years, depending upon, among other factors, the age-structure of the populations present at the site.

To account for the inter-annual effects of hydrology when making among site comparisons, it was necessary to assume that CPUE and CPUA estimates made for any given year correspond to populations at equilibrium and to include, at least initially, year as a fixed factor in the model.

Among site, *s* variation in hydrological conditions in any given year, *y* was expressed in terms of the flooded area ratio (FAR) - the ratio of the dry to flood season surface area of the waterbody described by Halls & Welcomme (2004):

$$FAR_{s,y} = \frac{Dry\ season\ area_{s,y}}{Flood\ season\ area_{s,y}}$$

This indicator captures important features of the flood regime, and is comparable among sites. Exploitable biomass is predicted to increase logarithmically with this ratio (ibid) or linearly after log-transforming FAR (Halls & Welcomme 2004).

Within site comparisons (for annual time series analysis)
Flood indices (Welcomme 1985) are useful when considering within-site effects of inter-annual variation in hydrology (FI) on performance indicators. These can be estimated from the recorded water height at the site relative to some reference height, such as bank-full height:

$$FI_{s,y} = \sum_t WH_{s,t}$$

Where $FI_{s,y}$ is the flood index at site *s* during year *y* and $WH_{s,t}$ is the water height above the reference height at site *s* during year *y*. However, FI could not be included in the analysis because sufficiently long time series (>4 years) of water heights were not available for the any of the project sites.

3.3.5 Other Impact Studies.

The impact of the CBFM1 Project based upon the perceptions of stakeholders has already been reported by Thompson (2001). These perceived benefits are not re-examined here.

Table 7 Description of management performance indicators used in the analysis

Management Theme	Performance variable	Indicator	Calculation	Units	Comments
1. Production	Production per unit area (Catch per unit area, CPUA)	Annual multispecies CPUA $_{s, y}$	$\frac{\sum_{i=1}^{n}\sum_{m=Jan}^{m=Dec}\sum_{g=1}^{n} Catch_{s,y,i,m,g}}{Area_{s}}$	Kg ha^{-1} y^{-1}	Only sites monitored every month each year were included.
	Stocking yield per unit area (YPUA)	Multispecies YPUA $_{s, y}$	$\frac{Yield_{s,y}}{Area_{s}}$	Kg ha^{-1} y^{-1}	
2. Sustainability	Fish Abundance	Mean multispecies catch rate by gillnet (GN) fishers in September, CPUE $_{s, y, GN, Sept}$	$\frac{\sum_{i=1}^{n} Catch_{s,y,i,GN,Sept}}{Fishing\ Hours_{s,y,GN,Sept}}$	Kg hour^{-1}	Gillnets were selected because they are used at most sites. Comparisons were made between the same month (September) in each year because gear catchability varies through time in response to hydrological conditions. September was selected because most gillnet catch rate observations were made during this month but also because catch rate variance is also low during this month thereby helping to maximise the power of statistical comparisons.
	Fishing Intensity	Person fishing days per year per unit area, DPUA $_{s, y}$	$\frac{Person\ fishing\ days_{s,y}}{Area_{s}}$	Days y^{-1} ha^{-1}	Only sites monitored every month each year were included.
		Mean gillnet effort per unit area in September EPUA $_{s, y, GN, Sept}$	$\frac{Fishing\ Hours_{s,y,GN,Sept}}{Area_{s}}$	Hours ha^{-1}	Gillnets were selected because they are used at most sites. Selecting only observations made in September provides an explanatory variable that can be used to help interpret changes in fish abundance.
	Prevalence of destructive fishing practices	Destructive fishing effort ratio, DFER $_{s, y, dg/g}$	$\frac{\sum_{dg=1}^{n}\sum_{m=Jan}^{m=Dec} Fishing\ Hours_{s,y,m,dg}}{\sum_{g=1}^{n}\sum_{m=Jan}^{m=Dec} Fishing\ Hours_{s,y,m,g}}$	Ratio	Ratio of total annual effort with destructive gears, *dg* and non-destructive gears, *g*. Gears classified as destructive are listed in Annex 1. Only sites monitored every month each year were included.
	Biodiversity	Various univariate indicators (eg H', S) calculated from: Catch rates for each species, *i* by gillnet (GN) fishers in September, CPUE $_{s, y, i, GN, Sept}$	$\frac{Catch_{s,y,i,GN,Sept}}{Fishing\ Hours_{s,y,GN,Sept}}$	Kg hour^{-1}	See comments for fish abundance. Indicator also used for multivariate analyses (see Section 3.3.2).
3. Fisher Wellbeing	HH Net Income	Annual household income from fishing less total annual expenditure on fishing and management related activities, HHI $_{s, hh, y}$	$\sum_{m=Jan}^{m=Dec} Income_{s,hh,y,m} - \sum_{m=Jan}^{m=Dec} Expenditure_{s,hh,y,m}$	Tk y^{-1}	-
	HH Fish Consumption	Bi-monthly household fish consumption, HHFC $_{s, hh, y.}$	$\sum_{m=Jan}^{m=Dec} Quantity\ consumed_{s,hh,}$	Kg mm $^{-1}$	-

Table 8 Explanatory variables hypothesised to affect management performance

Management Theme	Performance (dependent) variable	Explanatory Variables to consider	Indicator	Units/Scoring	Comments
1. Production	Production per unit area (CPUA) (or harvest per unit area when considering the relative performance of stocking programmes)	Region	Region code	North (N); North West (NW); South (S); East (E); SouthWest (SW)	(see section 3.3.2)
		Habitat type	Habitat code	Floodplain Beel (FPB); Open Beel (OB); Closed Beel (CB); River (R).	(see section 3.3.2)
		Hydrology	Flooded Area Ratio (FAR)	Ratio	(see section 3.3.4)
			Flood Index (FI)	m days flooding	(see section 3.3.4)
		Management Type	Code	CBFM (CBFM); none (control)	
		Years under CBFM	Years	Number of years	Effect of CBFM may take several years to become detectable.
		Production potential	Secchi depth	(m)	Simple index of primary production
		Stocking intensity	Stocking density	Kg $ha^{-1}y^{-1}$ and N $ha^{-1}y^{-1}$	
			Mean length of stocked fish	cm	Natural mortality rate highly correlated with fish length
		Closed season duration	Duration of closed season	Months	Set to zero if closed seasons are not implemented.
		Gear bans	Gear bans implemented	No (0); Yes (1)	
		Harvest reserve area	Reserve area expressed as a proportion of the minimum surface area of the waterbody.	Ratio	
		Fishing intensity	Fishing days per unit area (DPUA) and Gill net effort per unit area (EPUA)	Days y^{-1} ha^{-1} or Hours ha^{-1}	(see Table 7)
		Illegal fishing/poaching	Incidence of illegal fishing/poaching	Low (0); Medium (1); High (2)	Scored by WorldFish Centre.
		Closed Season fishing	Incidence of fishing during closed season	Low (0); Medium (1); High (2)	Scored by WorldFish Centre.
		Destructive fishing	Destructive gear effort ratio (DFER)	Ratio	(see Table 7)
2. Sustainability	Fish Abundance (CPUE)	As for CPUA	As for CPUA	As for CPUA	As for CPUA
	Fishing Intensity	Stocking	See above	See above	See above
		Management type	See above	See above	See above
	Destructive fishing practices	Management type	See above	See above	See above
	Biodiversity	As for CPUA	See above	See above	See above
3. Fisher Wellbeing	HH net income	Habitat type	See above	See above	See above
		CPUA	See Table 7	See Table 7	
		Stocking	See above	See above	See above
		Control/CBFM	See above	See above	See above
	HH Fish Consumption	As for HH net income	See above	See above	See above

4 Production CPUA

4.1 Controlled comparisons

Since not every site was monitored every month during a given year, only site-year combinations that were monitored in every month were included in the analysis to avoid bias resulting from missing data. This, however, significantly reduced the number of site-year observations of CPUA available for the analysis (Table 9) [compare with Table 1].

Table 9 Number of sites by sampling year monitored for catch and effort data in every month.

	CBFM	Control
1997	8	
1998	11	
1999	8	
2000	6	
2001	10	
2002	11	
2003	33	4
2004	32	5

4.1.1 Analysis with missing cells (Type IV sum of squares)

Significant differences in production (LNCPUA) between CBFM and control sites (CBFM_OR) could not be detected even when habitat type (WBTYPE), geographic region (REGION) and sampling year (YEAR) were included as factors in the type IV model to account for natural variation (

Table 10). However, the power of the test (1-β) is low indicating that there is an 80% chance of committing a Type II error ie not rejecting the null hypothesis (CPUA is the same at CBFM and control sites) when it is false. Estimates of CPUA are approximately 200 and 320 kg ha^{-1} y^{-1} for CBFM and control sites, respectively.

Table 10 ANOVA Table for the comparison of fish production (LNCPUA) between CBFM and control sites (Type IV sum of squares).

Dependent Variable: LNCPUA

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	1.884(b)	1	1.884	1.418	.236	.219
Intercept	1014.412	1	1014.412	763.326	.000	1.000
CBFM_OR	1.884	1	1.884	1.418	.236	.219
Error	152.828	115	1.329			
Total	3470.547	117				
Corrected Total	154.712	116				

a Computed using alpha = .05
b R Squared = .012 (Adjusted R Squared = .004)

Dependent Variable: LNCPUA

CBFM or Control	Mean	Std. Deviation	N
CBFM	5.2869	1.16659	108
Control	5.7632	.94917	9
Total	5.3236	1.15487	117

Dependent Variable: LNCPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	1.884	1	1.884	1.418	.236	.219
Error	152.828	115	1.329			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

4.1.2 Analysis with no missing cells, but unbalanced design (Type III sum of squares)

Significant differences in CPUA between CBFM and control sites were also tested by selecting a subset of the data which did not have any missing cells. This corresponded to data for 2003 only but with no consideration given to sampling region as a factor (Table 11). Again, no significant differences in CPUA were detected between CBFM and control sites but the power of the test was very low, approximately 6% (Table 12).

Table 11 Number of sites with CPUA data by year and habitat type

	CBFM or Control							
	CBFM				Control			
	CB	FPB	OB	R	CB	FPB	OB	R
1997			1					
1998	2		1	4				
1999		1	1	6				
2000	1	1	2	2				
2001	1	1	2	6				
2002		2	2	7				
2003	**7**	**5**	**14**	**7**	**1**	**1**	**1**	**1**
2004	8	5	**12**	**7**			**3**	**2**

Table 12 ANOVA Table for the comparison of fish production (LNCPUA) between CBFM and control sites with no missing cells - all habitat types for 2003 (Type III sum of squares).

Dependent Variable: LNCPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.125(b)	1	.125	.068	.795	.057
Intercept	397.763	1	397.763	216.771	.000	1.000
CBFM_OR	.125	1	.125	.068	.795	.057
Error	64.223	35	1.835			
Total	1124.545	37				
Corrected Total	64.348	36				

a Computed using alpha = .05
b R Squared = .002 (Adjusted R Squared = -.027)

Estimates of Marginal Means

Dependent Variable: LNCPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	5.373	.236	4.894	5.852
Control	5.186	.677	3.811	6.561

Dependent Variable: LNCPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.125	1	.125	.068	.795	.057
Error	64.223	35	1.835			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

Finally, comparisons were made between CBFM and control sites belonging to open beel (OB) and river habitat (R) in 2004, again without regard to region. No significant differences were detected for open beel habitat (Table 13), although CPUA for river control sites was found to be significantly ($P<0.05$) higher (583 kg ha^{-1} y^{-1}) than CBFM river sites (149 kg ha^{-1} y^{-1}) (Table 14). This is likely to reflect the fact that one of the river sites within the control group is a main river type and therefore may not be strictly comparable with the other river sites belonging to the CBFM group of sites.

Table 13 ANOVA Table for the comparison of fish production (LNCPUA) between CBFM and control sites for open beel habitat in 2004 (Type III sum of squares).

Dependent Variable: LNCPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.716(b)	1	.716	.319	.582	.082
Intercept	329.173	1	329.173	146.541	.000	1.000
CBFM_OR	.716	1	.716	.319	.582	.082
Error	29.202	13	2.246			
Total	515.862	15				
Corrected Total	29.918	14				

a Computed using alpha = .05
b R Squared = .024 (Adjusted R Squared = -.051)

Estimates of marginal means

Dependent Variable: LNCPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	5.583	.433	4.648	6.517
Control	6.129	.865	4.259	7.998

Univariate Tests

Dependent Variable: LNCPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.716	1	.716	.319	.582	.082
Error	29.202	13	2.246			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

Table 14 ANOVA Table for the comparison of fish production (LNCPUA) between CBFM and control sites for river habitat in 2004 (Type III sum of squares).

Dependent Variable: LNCPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	2.895(b)	1	2.895	16.691	.005	.936
Intercept	201.254	1	201.254	1160.545	.000	1.000
CBFM_OR	2.895	1	2.895	16.691	.005	.936
Error	1.214	7	.173			
Total	257.711	9				
Corrected Total	4.108	8				

a Computed using alpha = .05
b R Squared = .705 (Adjusted R Squared = .662)

Estimates of marginal means

Dependent Variable: LNCPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	5.005	.157	4.633	5.377
Control	6.369	.294	5.673	7.066

Univariate Tests

Dependent Variable: LNCPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	2.895	1	2.895	16.691	.005	.936
Error	1.214	7	.173			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

4.2 Time Series Analysis of CBFM sites

Annual production estimates for four or more years were available for only nine CBFM sites. At eight sites, the trend in CPUA was upward, but this trend was significant (P<0.05) only for two sites (Figure 3 and Table 15). The remaining site (9) exhibited a significant (P<0.05) decline in CPUA with time. For those sites where significant increases in CPUA were detected, fishing intensity and either closed seasons or gearbans had a significant effect on CPUA (Table 16). The response was not however consistent. At site 1, CPUA declined with increasing gillnet hours, but increased with fishing days at site 3. CPUA responded positively to closed seasons and gear bans. At site 9, illegal fishing was found to have a positive effect on CPUA, that is, illegal fishing increased with time.

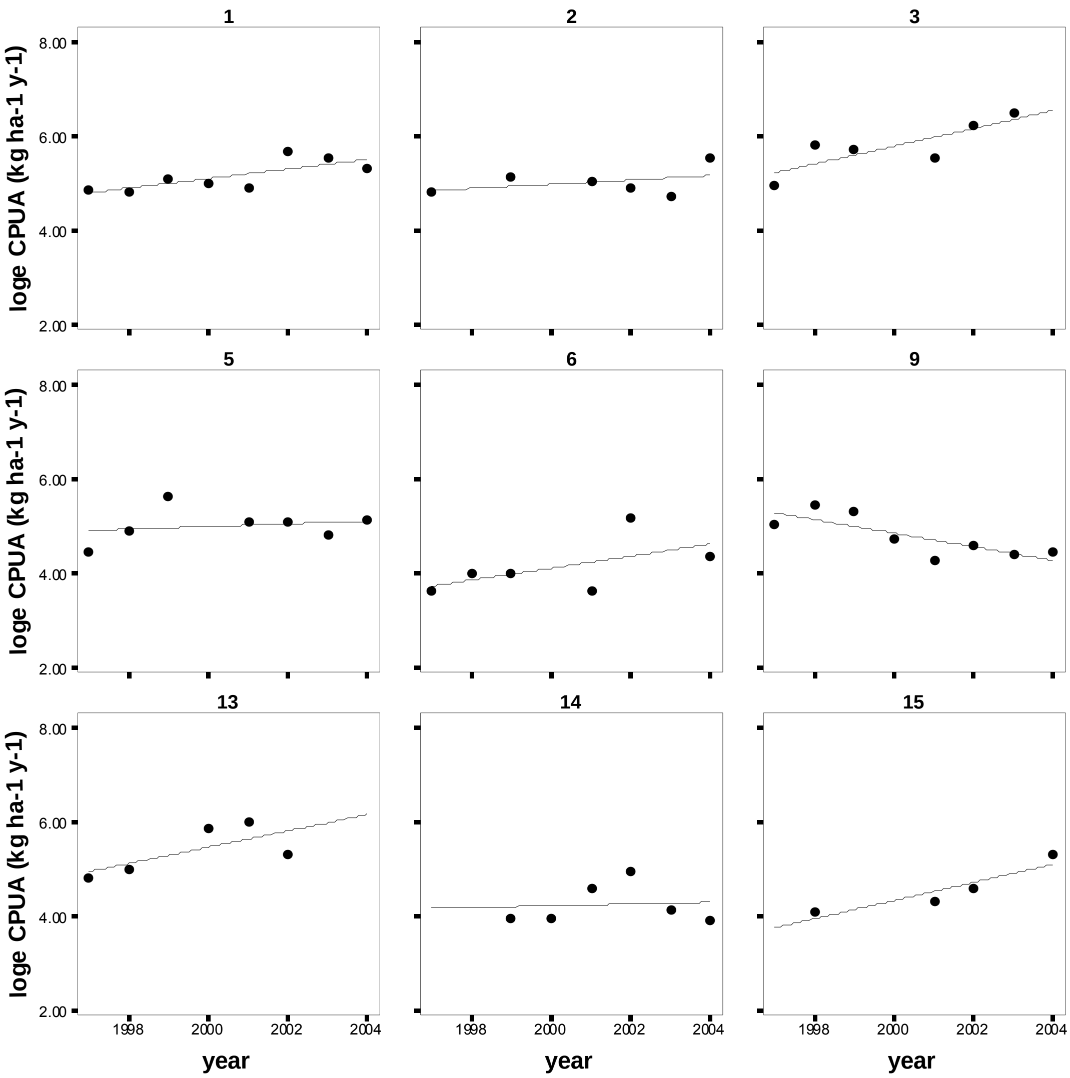

Figure 3 Estimates of mean annual fish production per unit area (CPUA) plotted as a function of time (year) for CBFM sites with at least four years of observations with fitted regression models.

Table 15 Results of regression models to test for significant changes in CPUA with time

Site Code	Habitat Type	N	Slope (b)	P	CPUA trend	Sig.	Interpretation*
1	R	8	+0.101	0.03	Up	*	Up
2	R	6	+0.046	0.43	Up		No change
3	R	6	+0.189	0.04	Up	*	Up
5	R	7	+0.029	0.64	Up		No change
6	R	6	+0.128	0.23	Up		No change
9	OB	8	-0.144	0.02	Down	*	Down
13	OB	5	+0.173	0.19	Up		No change
14	FPB	6	+0.020	0.87	Up		No change
15	R	4	+0.192	0.08	Up		No change

* at $\alpha = 0.05$.

Table 16 Best fitting model explanatory variables for sites with a significant change in fish abundance (CPUA) with time.

Dependent variable: LNCPUA

Site Code	CPUA trend	N	Variable(s)		Slope (b)	P
1	Up	8	LNGNHRPU		-.358	0.03
			MCLOSE	No	-.879	<0.01
				Yes	0(a)	
3	Up	7	LNDPUA		.794	<0.01
			GEARBANS	No	-.601	0.01
				Yes	0(a)	
9	Down	8	ILLEGALF		.780	<0.01

a This parameter is set to zero because it is redundant.

4.3 Harvest performance of stocked water bodies.

Given the prevalence of missing cells in the sampling design, it was decided that comparisons of harvest performance between CBFM and control sites would be made only for closed beel habitat between 2002 and 2004 ignoring geographic region (REGION) as a factor. Whilst this would still yield an unbalanced design, no missing cells would be included in the analysis. As well as CBFM or Control, sampling year (YEAR) was included as a fixed factor in the analysis.

	CBFM or Control		
	CBFM		Control
	CB	OB	CB
1990	1		
1991	2		
1992	2		
1993	2		
1994	2		
1995	2		
1996	1		
1997	2		
1998	5		
1999	4		
2000	4		
2001	4		
2002	**8**	1	**3**
2003	**9**	1	**3**
2004	**7**	1	**2**

No significant (P<0.05) differences in stocking programme harvest weights (LNYPUA) were detected between closed beel CBFM and control sites, although the power of the test was very low (Table 17). Year was found not to be significant and was therefore dropped from the model. Estimated mean harvest weights are 96 kg ha^{-1} for CBFM sites and 85 kg ha^{-1} for control sites but the difference is not significant (P=0.85).

Table 17 ANOVA table for GLM model comparing mean harvest per unit area (LNYPUA) between CBFM and control sites (CBFM_OR) for closed beel (CB) habitat 2002-2004.

Dependent Variable: LNYPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.081(b)	1	.081	.034	.855	.054
Intercept	481.286	1	481.286	203.313	.000	1.000
CBFM_OR	.081	1	.081	.034	.855	.054
Error	68.649	29	2.367			
Total	705.057	31				
Corrected Total	68.730	30				

a Computed using alpha = .05
b R Squared = .001 (Adjusted R Squared = -.033)

Estimates of Marginal Means

Dependent Variable: LNYPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	4.561	.321	3.905	5.217
Control	4.444	.544	3.331	5.557

Dependent Variable: LNYPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.081	1	.081	.034	.855	.054
Error	68.649	29	2.367			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

4.3.1 Stocking Performance Models

Combining data for both CBFM and control sites and across all years, the best fitting model describing 48% of the variation in stocked fish harvest yield per unit area (LNYPUA) included only stocking density expressed in terms of numbers stocked per unit area (LNNSTKPU) as a covariate (Table 18 and Figure 4).

Table 18 ANOVA table for the GLM for stocking performance

Dependent Variable: LNYPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	62.999(a)	1	62.999	56.291	.000
Intercept	.306	1	.306	.274	.603
LNNSTKPU	62.999	1	62.999	56.291	.000
Error	68.269	61	1.119		
Total	1686.046	63			
Corrected Total	131.268	62			

a R Squared = .480 (Adjusted R Squared = .471)

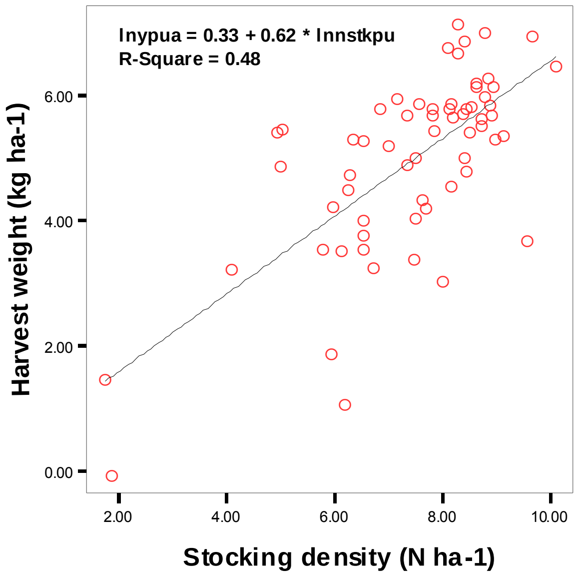

Figure 4 Harvest per unit area (YPUA) plotted as a function of stocking density. Note $\log_e$ scaling.

4.3.2 Reserves

Based upon among site comparisons across all years, reserves were found to have no significant (detectable) effect (P=0.16) on CPUA after accounting for differences in fishing intensity and habitat type (region and year were found not to be significant).

Table 19 ANOVA table for the GLM to test for the effect of reserves on CPUA (Type IV sum of squares).

Dependent Variable: LNCPUA

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	124.573(b)	8	15.572	49.225	.000	1.000
Intercept	2.913	1	2.913	9.209	.003	.853
LNDPUA	101.683	1	101.683	321.439	.000	1.000
RESERVE	.620	1	.620	1.961	.164	.284
WBTYPE	3.616	3	1.205	3.810	.012	.806
RESERVE * WBTYPE	1.107	3	.369	1.167	.325	.307
Error	37.644	119	.316			
Total	3734.730	128				
Corrected Total	162.217	127				

a Computed using alpha = .05
b R Squared = .768 (Adjusted R Squared = .752)

4.3.3 Gear bans

After accounting for differences in fishing intensity and habitat type (region and year were found not to be significant), gearbans were found to have no significant (detectable) effect on CPUA (Table 20).

Table 20 ANOVA table for the GLM to test for the effect of gear bans on CPUA (Type IV sum of squares)

Dependent Variable: LNCPUA

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	125.110(b)	8	15.639	50.152	.000	1.000
Intercept	2.444	1	2.444	7.839	.006	.793
LNDPUA	108.062	1	108.062	346.545	.000	1.000
WBTYPE	4.981	3	1.660	5.324	.002	.925
GEARBANS	.266	1	.266	.852	.358	.150
WBTYPE * GEARBANS	2.421	3	.807	2.588	.056	.624
Error	37.107	119	.312			
Total	3734.730	128				
Corrected Total	162.217	127				

a Computed using alpha = .05
b R Squared = .771 (Adjusted R Squared = .756)

4.3.4 Closed Seasons

Based upon among site comparisons, closed seasons were found to have no significant (detectable) effect (P=0.35) on CPUA after accounting for differences in fishing intensity and habitat type (region and year were found not to be significant).

Table 21 ANOVA table for the GLM to test for the effect of closed seasons on CPUA(Type IV sum of squares)

Dependent Variable: LNCPUA

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	123.975(b)	8	15.497	48.223	.000	1.000
Intercept	3.881	1	3.881	12.077	.001	.931
LNDPUA	107.103	1	107.103	333.282	.000	1.000
WBTYPE	4.192	3	1.397	4.348	.006	.860
MCLOSE	.091	1	.091	.283	.595	.083
WBTYPE * MCLOSE	1.323	3	.441	1.373	.254	.357
Error	38.242	119	.321			
Total	3734.730	128				
Corrected Total	162.217	127				

a Computed using alpha = .05
b R Squared = .764 (Adjusted R Squared = .748)

5 Sustainability

5.1 Fish abundance

5.1.1 Controlled Comparisons

Few control sites were available to test for the effects of the CBFM on sustainability indicators. Certainly too few sites were available to test the effect of geographic region (REGION) on the employed indicator of fish abundance (CPUE) (Table 22).

Table 22 Number of sites by year and habitat type for which estimates of indices of fish abundance were available.

	CBFM or Control							
	CBFM				Control			
	CB	FPB	OB	R	CB	FPB	OB	R
1997		1	1					
1998	3	2	1	4				
1999	1	2	1	6				
2000		2	2	6				
2001		2	2	6				
2002	7	4	11	7	1	1	3	2
2003	7	13	24	9	1	2	4	3
2004	4	5	15	9	1	1	5	3

5.1.2 Analysis with missing cells: All years and habitat types included [Type IV sum of squares].

Estimated mean fish abundance (CPUE) (averaged across habitat type region and year) for CBFM sites was 0.45 kg hr^{-1} compared to 0.42 kg hr^{-1} for control sites but the difference was not significant (P=0.75) (Table 23). The power of the test was, however, very low (0.06).

Table 23 ANOVA table for the GLM comparing fishing abundance (LNPUE) between CBFM and control sites (CBFM_OR) for all years and habitat types (Type IV sum of squares).

Dependent Variable: LNCPUE

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.061(b)	1	.061	.105	.746	.062
Intercept	63.885	1	63.885	110.434	.000	1.000
CBFM_OR	.061	1	.061	.105	.746	.062
Error	105.285	182	.578			
Total	227.411	184				
Corrected Total	105.346	183				

a Computed using alpha = .05
b R Squared = .001 (Adjusted R Squared = -.005)

Estimates of marginal means
Dependent Variable: LNCPUE

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	-.807	.061	-.927	-.687
Control	-.858	.146	-1.147	-.569

Univariate Tests

Dependent Variable: LNCPUE

	Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power(a)
Contrast	.061	1	.061	.105	.746	.105	.062
Error	105.285	182	.578				

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.1.3 Analysis with no missing cells, but unbalanced design: All habitat types 2002-2004 [Type III sum of squares]

The analysis was repeated but only using data for the period 2002-2004. Whilst this marginally improved the amount of variation explained by the CBFM_OR (CBFM or Control site) factor, it was still found to be not significant in determining fish abundance (Table 24). Neither sampling year (YEAR) nor habitat type (WBTYPE) were found to be significant and were therefore dropped from the model.

Table 24 ANOVA table for the GLM comparing fishing abundance (LNPUE) between CBFM and control sites (CBFM_OR) for all habitat types but only for years 2002-2004.

Dependent Variable: LNCPUE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.084(b)	1	.084	.134	.715	.065
Intercept	59.869	1	59.869	95.819	.000	1.000
CBFM_OR	.084	1	.084	.134	.715	.065
Error	87.474	140	.625			
Total	180.305	142				
Corrected Total	87.558	141				

a Computed using alpha = .05
b R Squared = .001 (Adjusted R Squared = -.006)

Estimates of marginal means

Dependent Variable: LNCPUE

CBFM or Control	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
CBFM	-.796	.074	-.942	-.651
Control	-.858	.152	-1.159	-.558

Univariate Tests

Dependent Variable: LNCPUE

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.084	1	.084	.134	.715	.065
Error	87.474	140	.625			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.1.4 Among site comparison of CPUE

The control of fishing effort remains the most fundamental form of management. Using observations for all sites and years, the response of fish abundance (CPUE) to fishing effort (fishing intensity measured in terms of gillnet hrs) was examined. The best fitting model included total annual gillnet hours per unit area (LNGNHRPU) as a covariate and habitat type (WBTYPE) as a factor (Table 25 and Figure 5). Declines in CPUE with increasing fishing effort were evident for all habitat types except rivers but significant ($P<0.05$) only for floodplain-beel habitat.

Table 25 ANOVA table for the fitted GLM model for fish abundance (LNCPUE)

Dependent Variable: LNCPUE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	15.856(a)	4	3.964	7.125	.000
Intercept	2.104	1	2.104	3.782	.053
LNGNHRPU	6.735	1	6.735	12.106	.001
WBTYPE	8.122	3	2.707	4.867	.003
Error	115.157	207	.556		
Total	281.827	212			
Corrected Total	131.013	211			

a R Squared = .121 (Adjusted R Squared = .104)

Dependent Variable: LNCPUE

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-.271	.158	-1.717	.088	-.583	.040
LNGNHRPU	-.129	.037	-3.479	.001	-.202	-.056
[WBTYPE=CB]	.050	.173	.291	.771	-.292	.392
[WBTYPE=FPB]	-.394	.149	-2.641	.009	-.688	-.100
[WBTYPE=OB]	.137	.134	1.024	.307	-.127	.401
[WBTYPE=R]	0(a)	.	.	.	.	.

a This parameter is set to zero because it is redundant.

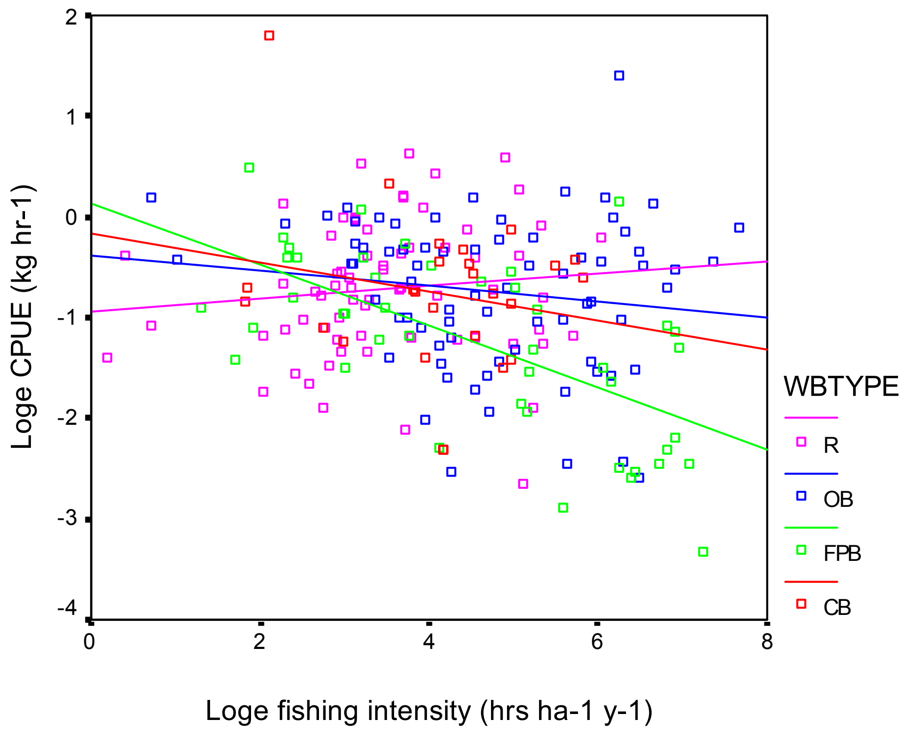

Figure 5 Fish abundance measured in terms of gillnet fisher catch rates in September plotted as a function of fishing intensity (all years combined). Note $\log_e$ scaling.

This response suggests that compensatory processes operate upon the exploited fish populations and that catches peak at some optimal level of effort. For rivers, the absence of any decline is likely to reflect the importance of external sources of recruitment (fish migrations).

Optimal levels of fishing effort were explored by plotting CPUA as a function of fishing days per year per unit area (DPUA) for each habitat type following the approach of Bayley (1988). Little evidence of an optimal level of fishing effort was detected (Figure 6).

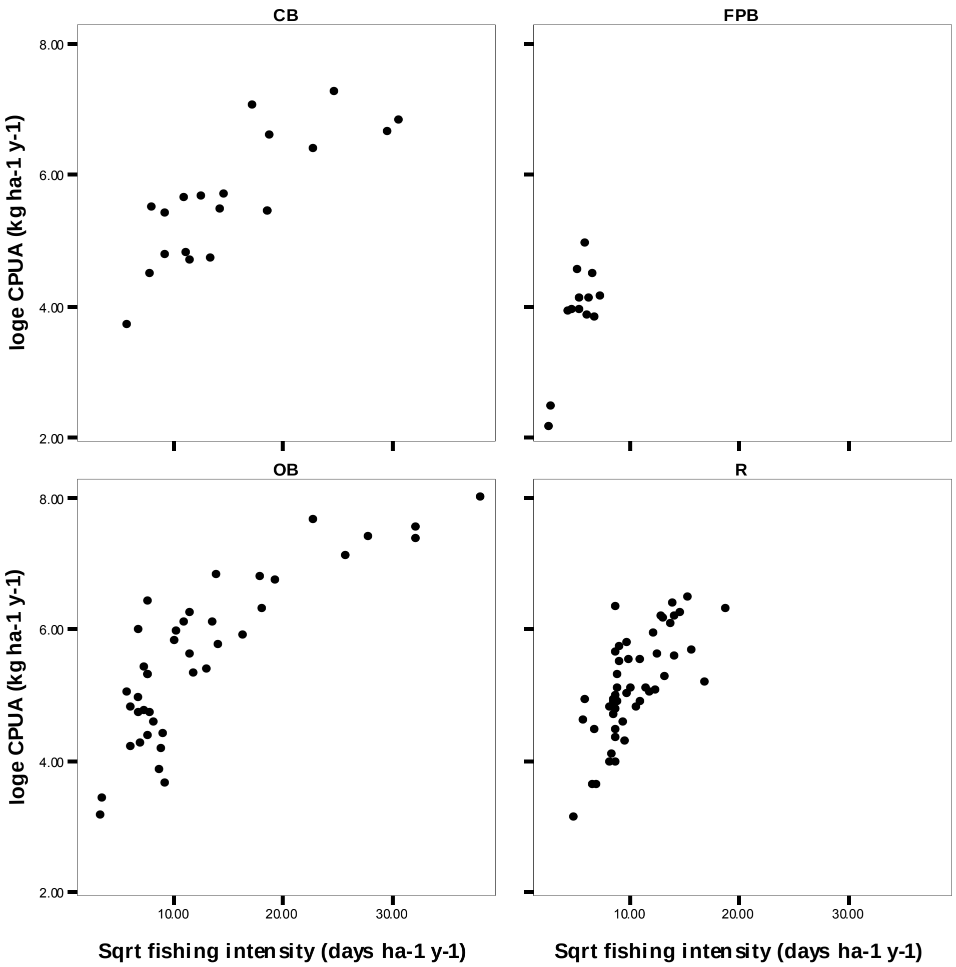

Figure 6 Annual estimates of CPUA plotted as a function of estimates of annual fishing intensity. Note $\log_e$ and square-root scaling.

5.1.5 Reserves

Based upon among site comparisons, reserves were found to have no significant detectable effect (P=0.86) on CPUE after accounting for potential differences in fishing intensity, habitat type, region and year (all found not to be significant) (Table 26).

Table 26 ANOVA table for the GLM to test for the effect of reserves on CPUE

Dependent Variable: LNCPUE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.018(b)	1	.018	.032	.858	.054
Intercept	115.517	1	115.517	202.512	.000	1.000
RESERVE	.018	1	.018	.032	.858	.054
Error	101.535	178	.570			
Total	222.394	180				
Corrected Total	101.554	179				

a Computed using alpha = .05
b R Squared = .000 (Adjusted R Squared = -.005)

5.1.6 Gear bans

Gear bans were found to have no significant (P=0.84) detectable effect on mean gillnet catch rates (CPUE) sampled during September after accounting for potential differences in fishing intensity, habitat type, region and year (only region found to be significant) (Table 27).

Table 27 ANOVA table for the GLM to test for the effect of gearbans on CPUE

Dependent Variable: LNCPUE

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	9.550(b)	7	1.364	2.507	.018	.870
Intercept	42.058	1	42.058	77.271	.000	1.000
GEARBANS	.023	1	.023	.043	.837	.055
REGION	5.530	3	1.843	3.387	.019	.758
GEARBANS * REGION	3.465	3	1.155	2.122	.099	.535
Error	95.796	176	.544			
Total	227.411	184				
Corrected Total	105.346	183				

a Computed using alpha = .05
b R Squared = .091 (Adjusted R Squared = .054)

5.1.7 Closed Seasons

Closed seasons were found to have no significant detectable effect on gillnet catch rates (CPUE) sampled during September, but the power of the test is very low. Both region (REGION) and habitat type (WBTYPE) were found to be significant (Table 28).

Table 28 ANOVA table for the GLM to test for the effect of closed seasons on CPUE

Dependent Variable: LNCPUE

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	28.959(b)	21	1.379	2.925	.000	.999
Intercept	78.749	1	78.749	167.011	.000	1.000
REGION	7.169(c)	3	2.390	5.068	.002	.914
MCLOSE	.696(c)	1	.696	1.476	.226	.227
WBTYPE	4.036(c)	3	1.345	2.853	.039	.675
REGION * MCLOSE	1.745(c)	3	.582	1.233	.299	.326
REGION * WBTYPE	8.893(c)	6	1.482	3.143	.006	.913
MCLOSE * WBTYPE	3.183(c)	3	1.061	2.250	.085	.561
REGION * MCLOSE * WBTYPE	1.298	2	.649	1.377	.255	.293
Error	76.386	162	.472			
Total	227.411	184				
Corrected Total	105.346	183				

a Computed using alpha = .05
b R Squared = .275 (Adjusted R Squared = .181)
c The Type IV testable hypothesis is not unique.

5.1.8 CPUE time series (trend) analysis

Of the 14 sites with four or more years of observations, 9 showed declines in CPUE with time but these declines were significant (P<0.05) only for site 15 (Arial-Kha River) (Figure 7 and Table 29). Of the five water bodies which showed an upward CPUE trend, three were significant (P<0.05). Therefore, no changes in CPUE were detected at 9 sites, three showed upward trends and one site showed a downward trend. Overall, there appears to be no significant trend in fish abundance with time at CBFM sites.

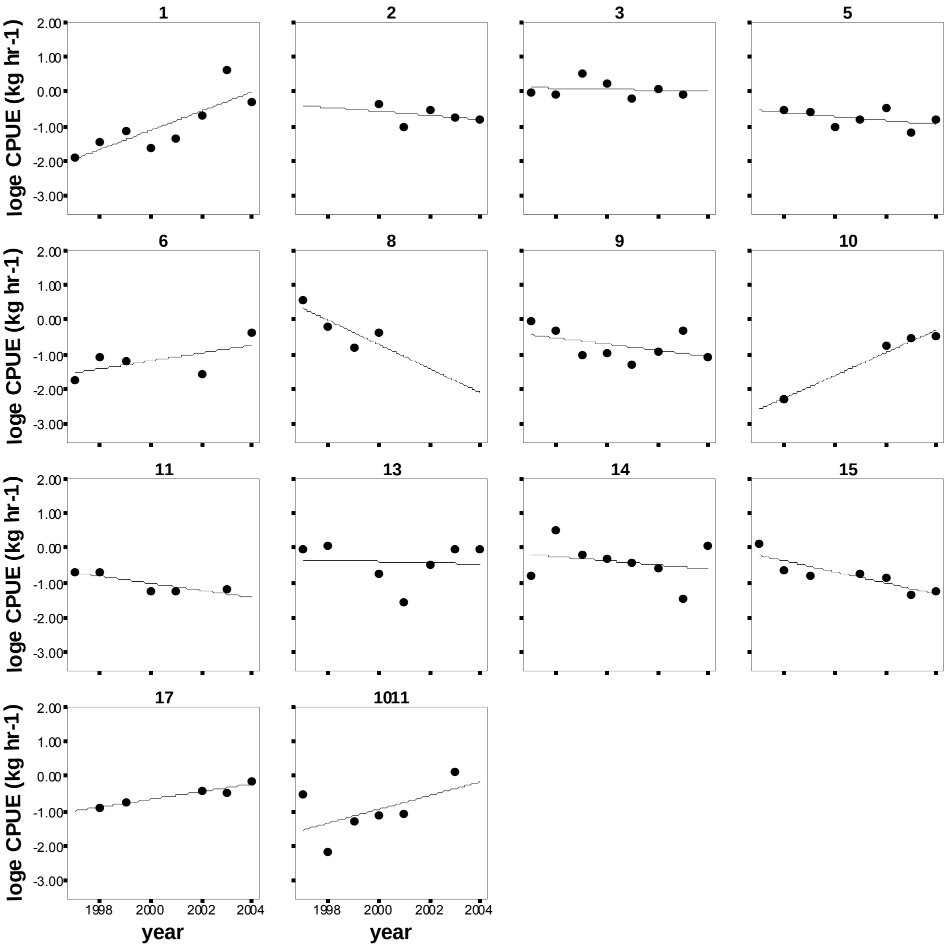

Figure 7 Estimates of mean fish abundance (CPUE) plotted as a function of time (year) for CBFM sites with at least four years of observations with fitted regression models.

Table 29 Results of regression models to test for significant changes in CPUE with time

Site Code	Habitat Type	N	Slope (b)	P	CPUE Trend	Sig.	Interpretation*
1	R	8	+ 0.28	0.01	Up	*	Up
2	R	5	-0.057	0.55	Down		No change
3	R	7	-0.016	0.76	Down		No change
5	R	8	-0.056	0.31	Down		No change
6	R	5	+0.114	0.25	Up		No change
8	R	4	-0.348	0.22	Down		No change
9	OB	8	-0.089	0.23	Down		No change
10	CB	4	+0.328	<0.01	Up	**	Up
11	R	5	-0.102	0.08	Down		No change
13	OB	7	-0.018	0.87	Down		No change
14	FPB	8	-0.060	0.55	Down		No Change
15	R	7	-0.160	0.01	Down	*	Down
17	CB	5	+0.111	0.01	Up	*	Up
1011	FPB	6	+0.199	0.26	Up		No Change

* at $\alpha = 0.05$.

For those sites where significant trends in CPUE through time were detected, explanatory variables were sought using the GLM approach. However, it was only possible to seek explanatory variables for site 1 because annual estimates of these variables including fishing effort were not available for every year because of discontinuities in the sampling programme (see Section 3.3.3). For site 1, fishing intensity measured in terms of total annual fishing days per unit area (DPUA), and the presence of closed seasons best explained the upward trend in CPUE (Table 30). Sites with closed seasons have higher CPUEs than those without. However, the positive response of CPUE to fishing effort runs counter to what would normally be expected.

Table 30 Explanatory variables for sites with a significant change in fish abundance (CPUE) with time.

Site Code	CPUE trend	N	Variable(s)		Slope (b)	P
1	Upward	8	DPUA		3.888	0.03
			MONCLOSE	Yes	0	0.02
				No	-0.890	

a This parameter is set to zero because it is redundant.

5.2 Fishing Intensity (DPUA)

5.2.1 Controlled Comparisons

5.2.1.1 Analysis with missing cells (Type IV sum of squares)

Including data from all years, regions and habitat types, mean annual fishing intensity (DPUA) was found to lower in CBFM sites (115 days y^{-1} ha^{-1}), compared to control sites (121 days y^{-1} ha^{-1}) but the difference was not significant (Table 31). Habitat type (WBTYPE), region (REGION) were found to be significant (P<0.05) factors affecting DPUA after accounting for differences between CBFM and control sites.

Table 31 ANOVA table for the comparison of $\log_e$ DPUA between CBFM and control sites (all years, regions and habitat types).

Dependent Variable: LNDPUA

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	44.969(a)	17	2.645	2.931	.000
Intercept	916.961	1	916.961	1016.102	.000
WBTYPE	10.739(b)	3	3.580	3.967	.010
CBFM_OR	.399(b)	1	.399	.442	.507
REGION	13.806(b)	3	4.602	5.100	.003
WBTYPE * CBFM_OR	1.242(b)	2	.621	.688	.505
WBTYPE * REGION	6.793(b)	5	1.359	1.505	.195
CBFM_OR * REGION	1.039(b)	2	.520	.576	.564
WBTYPE * CBFM_OR * REGION	.000	0	.	.	.
Error	89.341	99	.902		
Total	2670.912	117			
Corrected Total	134.310	116			

a R Squared = .335 (Adjusted R Squared = .221)
b The Type IV testable hypothesis is not unique.

Estimates of marginal means

Dependent Variable: LNDPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	4.743(a)	.141	4.463	5.022
Control	4.794(a)	.348	4.103	5.485

a Based on modified population marginal mean.

Univariate Tests

Dependent Variable: LNDPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.017	1	.017	.019	.891	.052
Error	89.341	99	.902			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.2.1.2 Analysis with no missing cells, but unbalanced design: All habitat types, 2003 [Type III sum of squares]

Mean total annual fishing intensity (DPUA) was found not to be significantly different (P>0.05) between CBFM and control sites when data only for 2003 were considered and region was not included as a factor. Habitat type (WBTYPE) was found not to be significant in determining fishing intensity (

Table 32). No significant differences in fishing intensity were detected between CBFM and control sites when only open beel (OB) habitat for 2004 was considered (Table 33). However, significant (P<0.05) differences were detected for river habitat for the same year (Table 34). Mean annual fishing intensity at CBFM river sites in 2004 was approximately 80 days ha^{-1} y^{-1}, compared to approximately 260 days ha^{-1} y^{-1} for control sites.

(a) Year = 2003, All habitat types, region not included as a factor.

Table 32 ANOVA table for the comparison of log_e DPUA between CBFM and control sites (2003 data only, habitat type included as a factor but not region).

Dependent Variable: LNDPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.335(b)	1	.335	.213	.647	.073
Intercept	308.663	1	308.663	196.083	.000	1.000
CBFM_OR	.335	1	.335	.213	.647	.073
Error	55.095	35	1.574			
Total	897.617	37				
Corrected Total	55.430	36				

a Computed using alpha = .05
b R Squared = .006 (Adjusted R Squared = -.022)

Estimates of marginal means
Dependent Variable: LNDPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	4.804	.218	4.361	5.247
Control	4.497	.627	3.224	5.771

Univariate Tests

Dependent Variable: LNDPUA

	Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power(a)
Contrast	.335	1	.335	.213	.647	.213	.073
Error	55.095	35	1.574				

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

(b) Year = 2004, open beel (OB) habitat type, region not included as a factor.

Table 33 ANOVA table for the comparison of log_e DPUA between CBFM and control sites (2004 data only, open beel habitat only, region not included as a factor).

Dependent Variable: LNDPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.000(b)	1	.000	.000	.993	.050
Intercept	230.259	1	230.259	135.457	.000	1.000
CBFM_OR	.000	1	.000	.000	.993	.050
Error	22.098	13	1.700			
Total	382.228	15				
Corrected Total	22.098	14				

a Computed using alpha = .05
b R Squared = .000 (Adjusted R Squared = -.077)

Estimates of marginal means

Dependent Variable: LNDPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	4.901	.376	4.088	5.715
Control	4.894	.753	3.267	6.520

Univariate Tests

Dependent Variable: LNDPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.000	1	.000	.000	.993	.050
Error	22.098	13	1.700			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

(c) Year = 2004, River (R) habitat type, region not included as a factor.

Table 34 ANOVA table for the comparison of $\log_e$ DPUA between CBFM and control sites (2004 data only, river habitat only, region not included as a factor).

Dependent Variable: LNDPUA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	2.078(b)	1	2.078	6.482	.038	.591
Intercept	153.749	1	153.749	479.522	.000	1.000
CBFM_OR	2.078	1	2.078	6.482	.038	.591
Error	2.244	7	.321			
Total	198.908	9				
Corrected Total	4.323	8				

a Computed using alpha = .05
b R Squared = .481 (Adjusted R Squared = .407)

Estimates of marginal means
Dependent Variable: LNDPUA

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	4.393	.214	3.887	4.899
Control	5.549	.400	4.602	6.496

Univariate Tests
Dependent Variable: LNDPUA

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	2.078	1	2.078	6.482	.038	.591
Error	2.244	7	.321			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.2.2 Time series analysis

At eight of the nine sites examined, the trend in fishing intensity was upward. At two of these nine sites, the trend was significant (P<0.05). The remaining site (No. 14) showed a very slight downward trend, but it was not significant (Figure 8 and

Table 35).

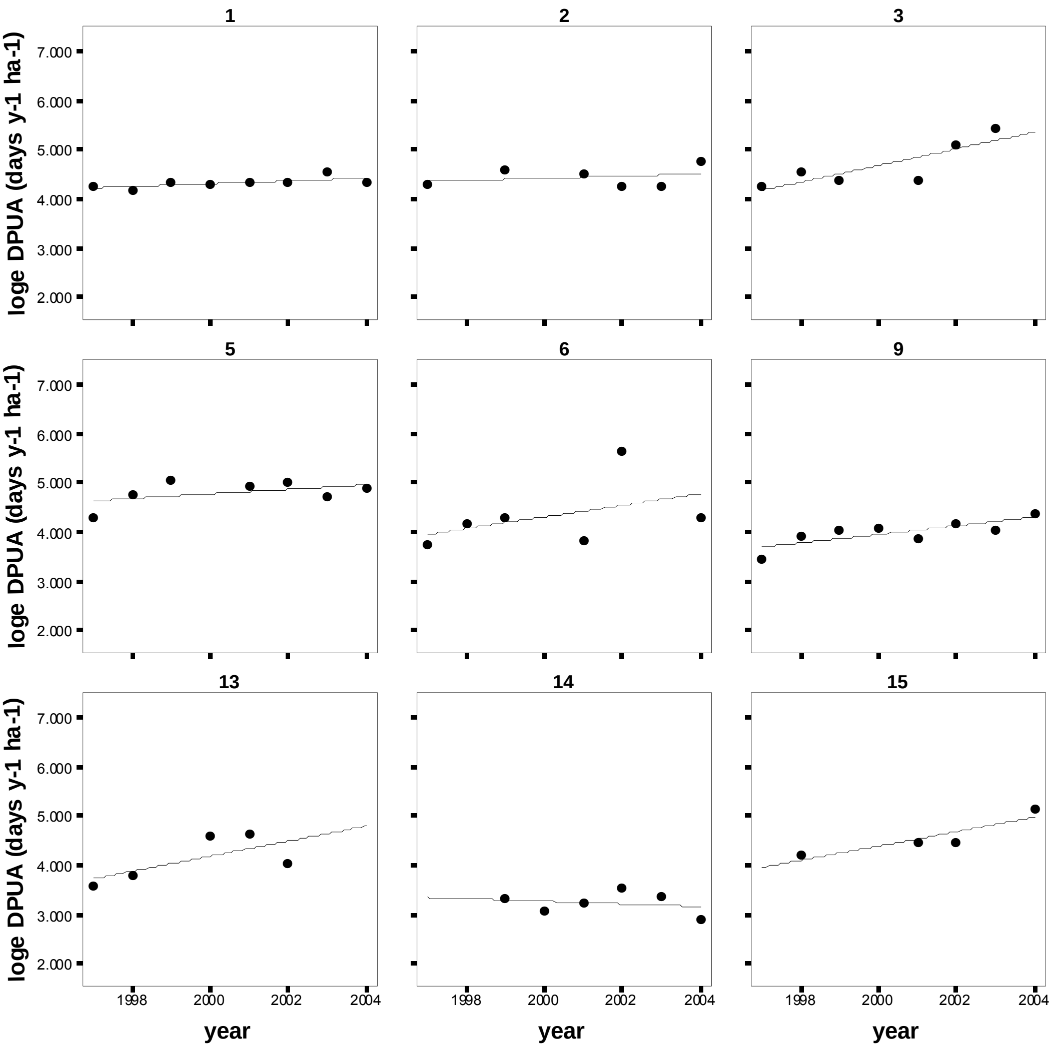

Figure 8 Estimates of mean fishing intensity (DPUA) plotted as a function of time with fitted regression models for CBFM sites with at least four years of observations.

Table 35 Results of regression models to test for significant changes in DPUA with time

Site Code	Habitat Type	N	Slope (b)	P	DPUA Trend	Sig.	Interpretation*
1	R	8	+0.029	0.09	Up		No change
2	R	6	+0.021	0.63	Up		No change
3	R	6	+0.168	0.04	Up	*	Up
5	R	7	+0.047	0.28	Up		No change
6	R	6	+0.117	0.37	Up		No change
9	OB	8	+0.086	0.02	Up	*	Up
13	OB	5	+0.152	0.22	Up		No change
14	FPB	6	-0.026	0.68	Down		No change
15	R	4	+0.146	0.10	Up		No change

* at α = 0.05.

5.3 Destructive fishing effort ratio (DFER)

5.3.1 Controlled Comparisons

5.3.1.1 Analysis with missing cells (Type IV sum of squares)

When data for all years, habitat type and regions were considered, the mean destructive fishing gear effort ratio (DFER) was found to be not significantly different between CBFM and control sites (Table 36). The mean ratio was 0.28 or 28% at both CBFM and control sites. Significant differences did exist among region (REGION). Neither habitat type nor year had a significant effect.

Table 36 ANOVA table for the comparison of DFER between CBFM and control (all years, habitat types and regions). Type IV sum of squares.

Dependent Variable: SQRTDFER

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	1.425(b)	7	.204	7.197	.000	1.000
Intercept	8.982	1	8.982	317.600	.000	1.000
CBFM_OR	.000	1	.000	.006	.940	.051
REGION	.574	3	.191	6.765	.000	.972
CBFM_OR * REGION	.155	3	.052	1.831	.146	.464
Error	3.083	109	.028			
Total	38.038	117				
Corrected Total	4.507	116				

a Computed using alpha = .05
b R Squared = .316 (Adjusted R Squared = .272)

Estimates of marginal means

Dependent Variable: SQRTDFER

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	.532	.017	.498	.566
Control	.528	.057	.415	.641

Univariate Tests

Dependent Variable: SQRTDFER

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.000	1	.000	.006	.940	.051
Error	3.083	109	.028			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.3.1.2 Analysis with no missing cells, but unbalanced design; All habitat types 2003 [Type III sum of squares]

When only data for 2003 are considered with habitat type, but not region as factors, no significant differences in the mean destructive fishing effort ratio were detected between CBFM and control sites. Habitat type was also found not to be significant and therefore was dropped from the model (Table 37). Similarly, no significant differences were detected when either only open beel (OB) or river (R) habitat were considered sampled during 2004 (Table 38 and Table 39).

(a) Year = 2003, All habitat types, region not included as a factor.

Table 37 ANOVA table for the comparison of Square-root DFER between CBFM and control sites (2003 data only, habitat type included as a factor but not region).

Dependent Variable: SQRTDFER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.007(b)	1	.007	.208	.651	.073
Intercept	3.438	1	3.438	103.475	.000	1.000
CBFM_OR	.007	1	.007	.208	.651	.073
Error	1.163	35	.033			
Total	9.469	37				
Corrected Total	1.170	36				

a Computed using alpha = .05
b R Squared = .006 (Adjusted R Squared = -.022)

Estimates of marginal means

Dependent Variable: SQRTDFER

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	.469	.032	.404	.533
Control	.513	.091	.328	.698

Univariate Tests

Dependent Variable: SQRTDFER

	Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power(a)
Contrast	.007	1	.007	.208	.651	.208	.073
Error	1.163	35	.033				

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

(b) Year = 2004, open beel (OB) habitat type, region not included as a factor.

Table 38 ANOVA table for the comparison of Sqrt DFER between CBFM and control sites (2004 data only, open beel habitat only, region not included as a factor).

Dependent Variable: SQRTDFER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	3.427E-05(b)	1	3.427E-05	.001	.978	.050
Intercept	3.722	1	3.722	87.395	.000	1.000
CBFM_OR	3.427E-05	1	3.427E-05	.001	.978	.050
Error	.554	13	.043			
Total	6.347	15				
Corrected Total	.554	14				

a Computed using alpha = .05
b R Squared = .000 (Adjusted R Squared = -.077)

Estimates of marginal means
Dependent Variable: SQRTDFER

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	.621	.060	.492	.749
Control	.625	.119	.367	.882

Univariate Tests
Dependent Variable: SQRTDFER

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	3.427E-05	1	3.427E-05	.001	.978	.050
Error	.554	13	.043			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

(c) Year = 2004, River (R) habitat type, region not included as a factor.

Table 39 ANOVA table for the comparison of Sqrt DFER between CBFM and control sites (2004 data only, river habitat only, region not included as a factor).

Dependent Variable: SQRTDFER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.032(b)	1	.032	.607	.461	.104
Intercept	1.978	1	1.978	37.851	.000	.999
CBFM_OR	.032	1	.032	.607	.461	.104
Error	.366	7	.052			
Total	3.676	9				
Corrected Total	.398	8				

a Computed using alpha = .05
b R Squared = .080 (Adjusted R Squared = -.052)

Estimates of marginal means
Dependent Variable: SQRTDFER

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	.635	.086	.431	.840
Control	.492	.162	.110	.875

Univariate Tests
Dependent Variable: SQRTDFER

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.032	1	.032	.607	.461	.104
Error	.366	7	.052			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.3.2 Time series analysis

Five of the nine sites examined exhibited a downward trend in destructive fishing gear use, whilst four showed an increase. One downward trend (site 1 – Kali Nodi River) was found to be significant at the P=0.05 level (Figure 9 and Table 40).

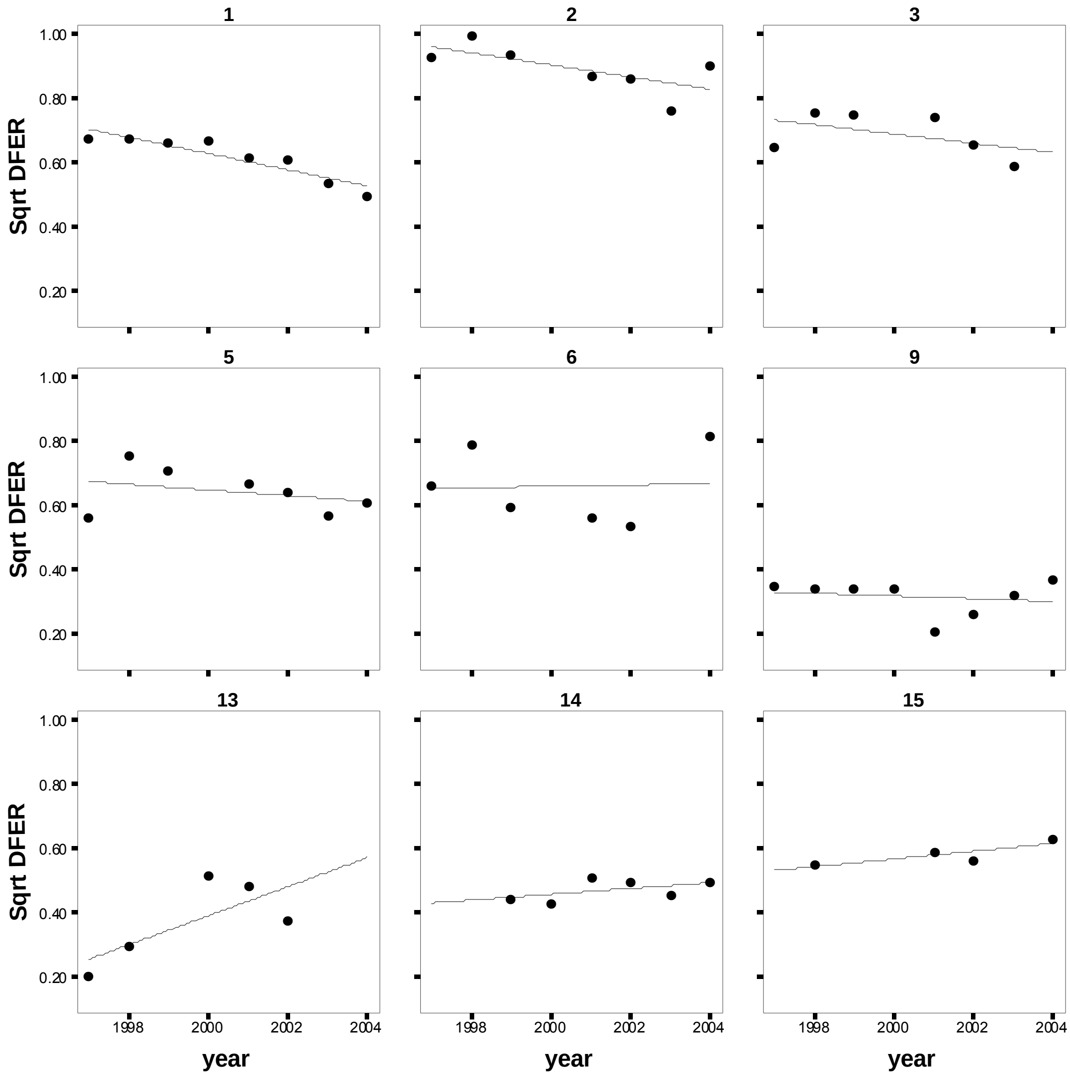

Figure 9 Estimates of mean destructive fishing gear effort ratio (DFER) plotted as a function of time (year) for CBFM sites with at least four years of observations with fitted regression models.

Table 40 Results of regression models to test for significant changes in DFER with time

Site Code	Habitat Type	N	Slope (b)	P	DFER Trend	Sig.	Interpretation*
1	R	8	-0.025	<0.01	Down	**	Down
2	R	7	-0.019	0.09	Down		No change
3	R	6	-0.015	0.32	Down		No change
5	R	7	-0.009	0.47	Down		No change
6	R	6	+0.002	0.09	Up		No change
9	OB	8	-0.004	0.65	Down		No change
13	OB	5	+0.046	0.17	Up		No change
14	FPB	6	+0.009	0.28	Up		No change
15	R	4	+0.012	0.15	Up		No change

* at $\alpha = 0.05$.

5.4 Biodiversity

5.4.1 Controlled Comparisons

5.4.1.1 Univariate Indices (H)

Few control sites were available to test for the effects of the CBFM on biodiversity indicators. Certainly too few sites were available to test the significance differences in the Shannon - Wiener diversity index (H') among geographic region (REGION) (Table 41).

Table 41 Number of sites by year and habitat type for which estimates of H' were available.

	CBFM or Control						
	CBFM				Control		
	CB	FPB	OB	R	CB	OB	R
1997		1	1				
1998	1	1	1	3			
1999			1	7			
2000		1	1	7			
2001		1	2	7			
2002	4		7	8	1	2	1
2003	5	5	15	8		5	1
2004	4		14	8	2	3	2

5.4.1.2 Analysis with missing cells (Type IV sum of squares)

The mean Shannon-Wiener diversity index (H') estimated from species wise catch rates from seine nets was marginally lower (1.8) at CBFM compared to control sites (1.9), but the difference was not significant at the P=0.05 level (

Table 42). This difference did not become significant when habitat type, year and/or region were included in the model as factors although region had a significant (P<0.05) effect on the indicator. Using gillnet catch rates to calculate the index instead of seine nets did not affect this conclusion.

Table 42 ANOVA table for the comparison of mean H' at between CBFM and control sites (all years, habitat types and regions). Type IV sum of squares.

Dependent Variable: H'

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	15.317(b)	7	2.188	5.966	.000	.999
Intercept	120.318	1	120.318	328.046	.000	1.000
CBFM_OR	.146	1	.146	.399	.529	.096
REGION	8.231	3	2.744	7.480	.000	.984
CBFM_OR * REGION	2.465	3	.822	2.240	.087	.555
Error	44.746	122	.367			
Total	597.505	130				
Corrected Total	60.063	129				

a Computed using alpha = .05
b R Squared = .255 (Adjusted R Squared = .212)

Estimates of marginal means
Dependent Variable: H'

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	1.813	.073	1.668	1.959
Control	1.944	.194	1.560	2.329

Univariate Tests
Dependent Variable: H'

	Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power(a)
Contrast	.146	1	.146	.399	.529	.399	.096
Error	44.746	122	.367				

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.4.1.3 Analysis with no missing cells, but unbalanced design (Type III sum of squares)

No significant differences in H' between CBFM and control sites were detected when the analysis was repeated for either only open beel or river habitat for the period 2002-2004 (Table 43 and Table 44).

(a) Year = 2002-2004, OB habitat type, region not included as a factor.

Table 43 ANOVA table for the comparison of mean H' at between CBFM and control sites, open beel habitat 2002-2004.

Dependent Variable: H

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.230(b)	1	.230	.551	.461	.113
Intercept	136.266	1	136.266	326.828	.000	1.000
CBFM_OR	.230	1	.230	.551	.461	.113
Error	20.847	50	.417			
Total	229.454	52				
Corrected Total	21.077	51				

a Computed using alpha = .05
b R Squared = .011 (Adjusted R Squared = -.009)

Estimates of marginal means
Dependent Variable: H

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	1.969	.100	1.769	2.169
Control	2.138	.204	1.728	2.548

Univariate Tests
Dependent Variable: H

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.230	1	.230	.551	.461	.113
Error	20.847	50	.417			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

(b) Year = 2002-2004, R habitat type, region not included as a factor.

Table 44 ANOVA table for the comparison of mean H' at between CBFM and control sites, river habitat 2002-2004.

Dependent Variable: H

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Corrected Model	.066(b)	1	.066	.164	.687	.068
Intercept	73.120	1	73.120	180.922	.000	1.000
CBFM_OR	.066	1	.066	.164	.687	.068
Error	20.208	50	.404			
Total	264.751	52				
Corrected Total	20.274	51				

a Computed using alpha = .05
b R Squared = .003 (Adjusted R Squared = -.017)

Estimates of marginal
Dependent Variable: H

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	2.158	.092	1.974	2.342
Control	2.292	.318	1.654	2.931

Univariate Tests
Dependent Variable: H

	Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
Contrast	.066	1	.066	.164	.687	.068
Error	20.208	50	.404			

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
a Computed using alpha = .05

5.4.1.4 Multivariate Comparisons

Because of the unbalanced design, comparisons of species assemblages between CBFM and control sites could only be made for open beel (OB) habitat in the N and NW regions of the country. Similarities in the species assemblages for these sites are summarised in the MDS ordinations (Figure 10). The results of the two-way ANOSIM test, indicate that no significant ($P<0.05$) differences in species assemblages exist either between CBFM and control sites or between the two regions either for seine net or gillnet landings (Table 45 and Table 46).

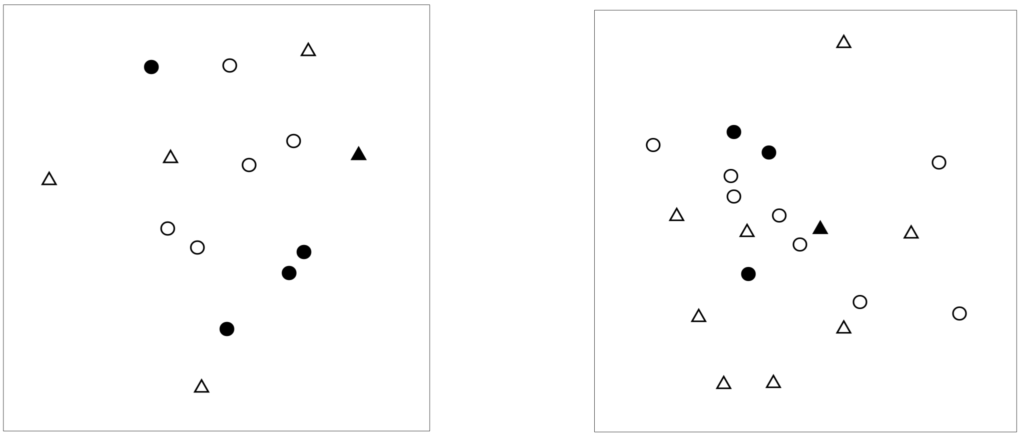

Figure 10 MDS ordinations summarising species assemblage similarities among open beel (OB) CBFM sites (open symbols) and control sites (filled symbols) in the north (circles) and northwest (triangles) regions based upon species-wise catch rate (CPUE) observations from (a) seine nets (stress = 0.19) and (b) gillnets (stress =0.14).

Table 45 Results of the two-way ANOSIM test for differences in species assemblages between CBFM and control sites and geographic region sampled from seine nets.

MANTYPE Group	REGION Group	Size	Samples
1	1	4	1,5,7,9
1	2	5	2,3,4,6,8
2	1	1	10
2	2	4	11-14

Number of samples used: 14 from a possible 14

**** **TESTS FOR DIFFERENCES BETWEEN MANTYPE GROUPS** ****
(averaged across all REGION groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): 0.141

Number of permutations: 630 (ALL POSSIBLE PERMUATIONS)
Number of permuted statistics greater than or equal to global R: 136

Significance level of sample statistic: **21.6%**
~~~~~~~~~~~

```
**** TESTS FOR DIFFERENCES BETWEEN REGION GROUPS ****
        (averaged across all MANTYPE groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R):  0.111

Number of permutations:   630  (ALL POSSIBLE PERMUATIONS)
Number of permuted statistics greater than or equal to global R:   154

Significance level of sample statistic:  24.4%
```

Table 46 Results of the two-way ANOSIM test for differences in species assemblages between CBFM and control sites and geographic region sampled from gillnets.

```
TWO-WAY CROSSED ANOSIM
                            ========================

Date:  5/ 6/2005
Similarity matrix: C:\PRIMER\DATA\WFISH\GN\GNOBNNW.SIM

  MANTYPE |  REGION  | Size | Samples
   Group  |   Group  |      |
----------+----------+------+------------------------------
     1    |     1    |   8  | 1,2,7,8,10,11,12,15
     1    |     2    |   8  | 3,4,5,6,9,13,14,19
     2    |     1    |   1  | 18
     2    |     2    |   3  | 16,17,20

Number of samples used:  20 from a possible  20


**** TESTS FOR DIFFERENCES BETWEEN MANTYPE GROUPS ****
         (averaged across all REGION groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): -0.253

Number of permutations:  1485  (ALL POSSIBLE PERMUATIONS)
Number of permuted statistics greater than or equal to global R:  1377

Significance level of sample statistic:  92.7%


**** TESTS FOR DIFFERENCES BETWEEN REGION GROUPS ****
        (averaged across all MANTYPE groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): -0.005

Number of permutations:  5000  (RANDOM SAMPLE FROM APPROX 2.574D+04)
Number of permuted statistics greater than or equal to global R:  2247

Significance level of sample statistic:  45.0%
```

5.4.2 Trend Analysis

Four the eight sites for which at least four years of data were available, six sites showed an upward trend in H' and two a downward trend. However, none of the trends were significant at the P=0.05 level (Table 47 and Figure 11).

Table 47 Results of GLM regression models to test for significant changes in H' with time.

Site Code	Habitat Type	N	Slope (b)	P	H' Trend	Sig.	Interpretation*
1	R	8	-0.041	0.11	Down		No change
2	R	8	-0.091	0.25	Down		No change
3	R	7	+0.057	0.39	Up		No change
5	R	8	+0.034	0.52	Up		No change
6	R	7	+0.134	0.20	Up		No change
9	OB	8	+0.011	0.87	Up		No change
11	R	4	+0.044	0.80	Up		No change
15	R	8	+0.076	0.36	Up		No change

* at α = 0.05.

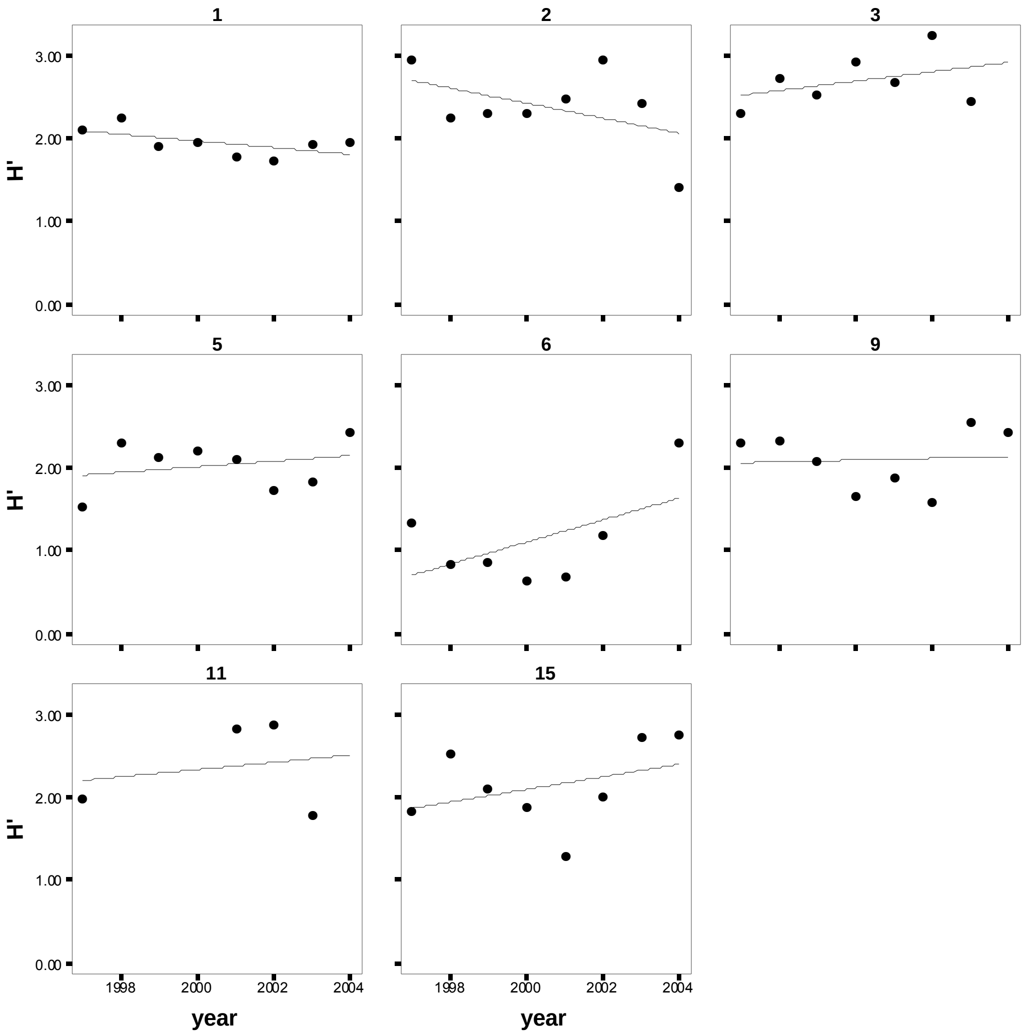

Figure 11 Estimates of mean H' plotted as a function of time with fitted regression models for CBFM sites with at least four years of observations.

6 Fisher well-being

6.1 Fish Consumption

6.1.1 Controlled comparisons

The effect of stocking on fish consumption could not be adequately assessed because only one control site was stocked. Sites with stocking programmes were therefore excluded from the comparison. For non-stocked sites, differences in household (HH) fish consumption between CBFM and control sites were tested using only data for 2003, for which bi-monthly estimates of fish consumption were available for all sites. To avoid including missing cells, closed beel CBFM sites (which were not also represented by the control sites) were not included.

Significant ($P<0.05$) differences in fish consumption were detected between CBFM and control sites taking account of significant differences in seasonality (BIMONTH) and habitat type (WBTYPE). Fish consumption is estimated to be approximately 12kg per household at CBFM sites compared to 10 kg per household at control sites. Model parameter estimates revealed that fish consumption rates vary significantly with season (BIMONTH). Fish consumption is greatest during BIMONTH 6 (October-November) and lowest during BIMONTH 3 (April-May). Fish consumption is highest at river sites and lowest at floodplain beel sites (Table 48).

Table 48 ANOVA table for the comparison of bimonthly household fish consumption between CBFM and control sites.

Dependent Variable: LNWT

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	804.041(a)	35	22.973	28.213	.000
Intercept	32570.458	1	32570.458	40000.746	.000
CBFM_OR	39.780	1	39.780	48.854	.000
WBTYPE	499.541	2	249.771	306.751	.000
BIMONTH	115.384	5	23.077	28.341	.000
CBFM_OR * WBTYPE	8.518	2	4.259	5.230	.005
CBFM_OR * BIMONTH	17.559	5	3.512	4.313	.001
WBTYPE * BIMONTH	83.607	10	8.361	10.268	.000
CBFM_OR * WBTYPE * BIMONTH	12.696	10	1.270	1.559	.112
Error	7054.630	8664	.814		
Total	61290.485	8700			
Corrected Total	7858.670	8699			

a R Squared = .102 (Adjusted R Squared = .099)

Estimates of marginal means

Dependent Variable: LNWT

CBFM or Control	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
CBFM	2.477	.015	2.449	2.506
Control	2.310	.019	2.273	2.347

Univariate Tests

Dependent Variable: LNWT

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	39.780	1	39.780	48.854	.000
Error	7054.630	8664	.814		

The F tests the effect of CBFM or Control. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Estimates of marginal means
Dependent Variable: LNWT

BIMONTH	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2.365	.029	2.308	2.422
2	2.344	.029	2.288	2.401
3	2.195	.029	2.138	2.251
4	2.325	.030	2.265	2.384
5	2.487	.030	2.429	2.545
6	2.646	.029	2.589	2.703

Estimates of marginal means

Dependent Variable: LNWT

WBTYPE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
FPB	1.978	.024	1.932	2.024
OB	2.483	.020	2.444	2.521
R	2.721	.019	2.684	2.757

6.1.2 Time Series Analysis

Mean household fish consumption was estimated on a bi-monthly basis at CBFM and control sites from June/July 2002 - Aug/September 2005. Therefore, to enable comparisons over a three year period, estimates for only the August/September bimonthly period were considered. With only three years of data, no attempt was made to fit regression models to test the significance of any trend (slope). However, visual examination of the data indicated that with the exception of site 300 (Chatol beel), there was evidence of a downward trend in fish consumption at all CBFM and control sites (Figure 12).

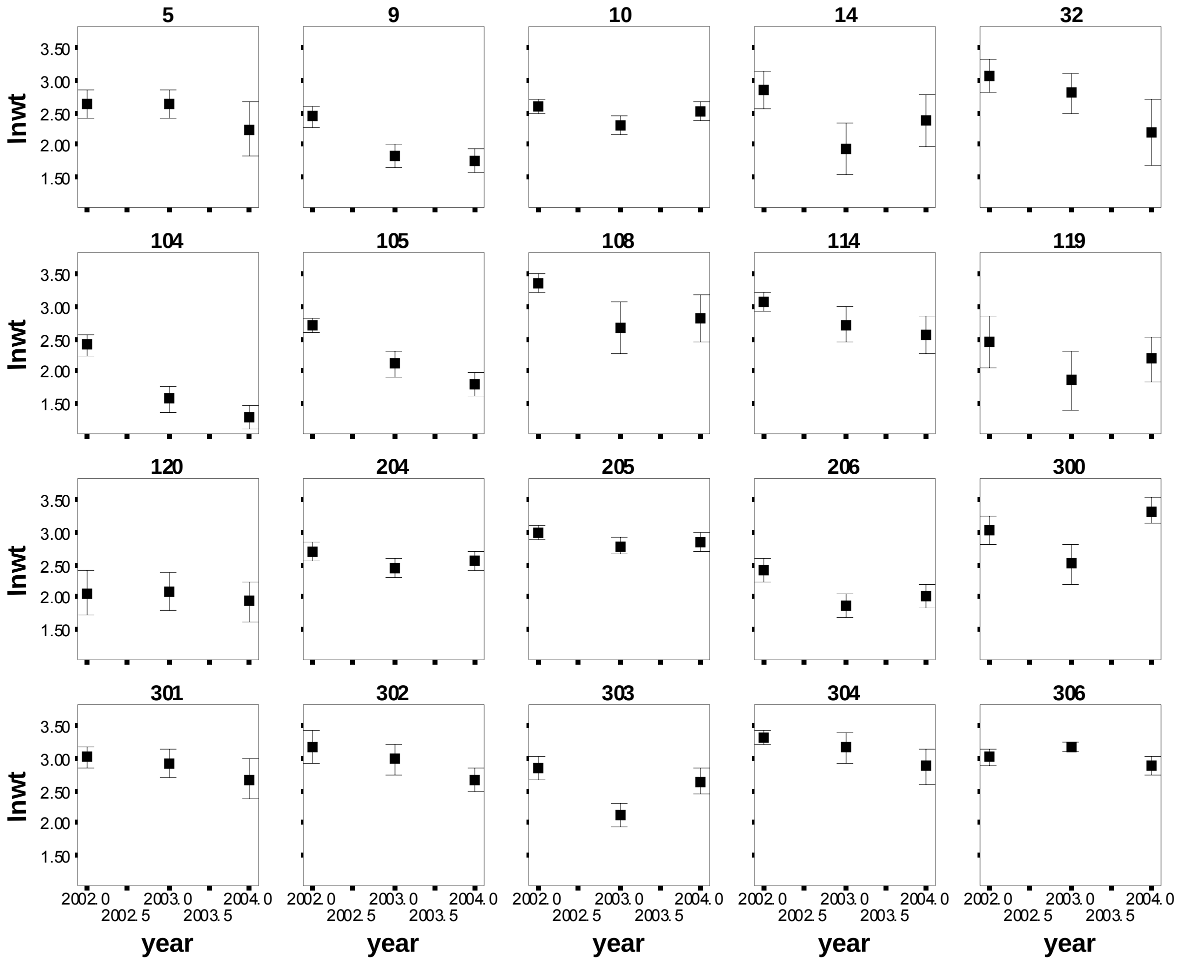

Figure 12 Estimates of mean household fish consumption for August-September with 95% confidence intervals plotted as a function of year for CBFM and control sites (Sites: 204, 205,206).

6.2 Costs and Earnings (Income).

6.2.1 Controlled Comparisons

Controlled comparisons were not possible, because annual estimates of costs and earning were available only for one control site in 2003.

6.2.2 Time series

Households at Hamil (site No.10) and Goakhola (Site No.14) beels were sampled for costs and earnings data on four occasions between 1998 and 2003 (Figure 13). Estimates of mean income for 2003 were based upon monthly samples, whereas prior to 2003, annual estimates were obtained from a single sample. Estimates for 2003 at both waterbodies are significantly lower than for the previous annual-based estimates suggesting that estimates for 2003 may be biased. **A detailed comparison of the data collection methods is required to confirm this or otherwise**. Using data prior to 2003, mean household income increases through time for Hamil beel but the trend is not significant (P=0.27). For Goakhola the trend in income was downward, but also not significant (P=0.90) (Table 49 and Table 50).

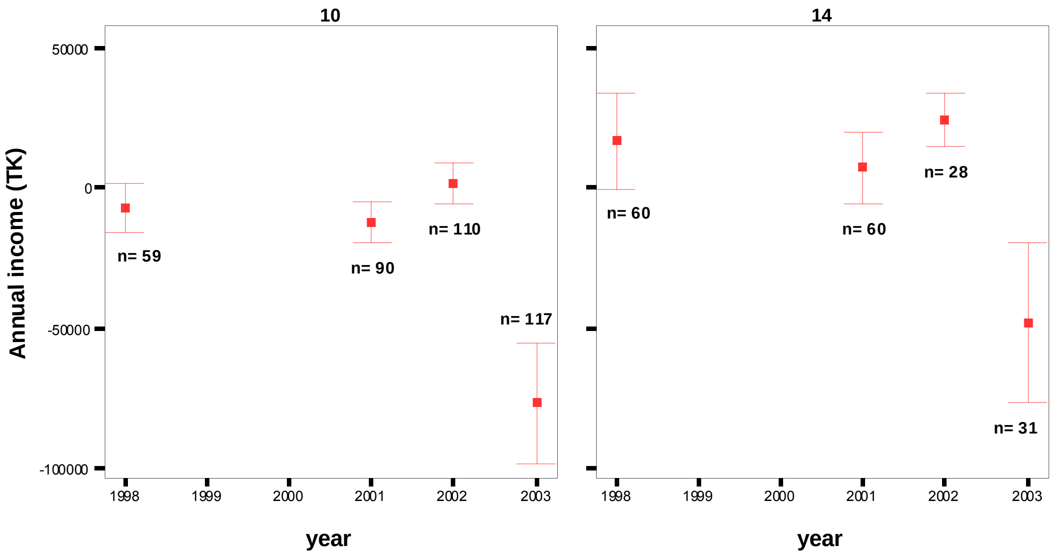

Figure 13 Estimates of mean household income (earnings-costs) with 95% confidence intervals for Hamil (10) and Goakhola (14) beels plotted as a function of sampling year.

Table 49 ANOVA table for the GLM to test the significance of the trend (slope) in mean household income with time for Hamil Beel.

Dependent Variable: INCOME

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1711328493 (a)	1	1711328493	1.240	.266
Intercept	1716655279	1	1716655279	1.244	.266
YEAR	1711328493	1	1711328493	1.240	.266
Error	354668721154	257	1380033934		
Total	363262742743	259			
Corrected Total	356380049647	258			

a R Squared = .005 (Adjusted R Squared = .001)

Parameter Estimates

Dependent Variable: INCOME

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-3319371	2976180	-1.115	.266	-9180177	2541434
YEAR	1656	1487.5	1.114	.266	-1272.8	4585.8

Table 50 ANOVA table for the GLM to test the significance of the trend (slope) in mean household income with time for Hamil Beel.

Tests of Between-Subjects Effects

Dependent Variable: INCOME

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	51652854(a)	1	51652854	.018	.895
Intercept	53769911	1	53769911	.018	.893
YEAR	51652854	1	51652854	.018	.895
Error	430658230658	146	2949713908		
Total	461265188451	148			
Corrected Total	430709883512	147			

a R Squared = .000 (Adjusted R Squared = -.007)

Parameter Estimates

Dependent Variable: INCOME

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	722607	5352080	.135	.893	-9854952	11300167
YEAR	-354	2676	-.132	.895	-5642	4934

7 Conclusions and Recommendations

7.1 Does the CBFM work?

This study sought to determine the impact of the CBFM activities on key management performance indicators of fish production, resource sustainability and fisher well-being, whilst taking account of inter and intra-annual variation in important environmental variables such as hydrology. Two approaches were adopted; firstly a controlled comparison of the performance indicators and secondly an examination of trends in the mean values of these indicators through time.

7.1.1 Controlled comparisons of key management performance indicators

Of the 21 comparisons made, only three significant ($P<0.05$) differences in the mean values of management performance indicators between CBFM and control sites were detected (Table 51). River fisheries production was found on average to be lower (149 kg ha^{-1} y^{-1}) at CBFM sites compared to control sites (583 kg ha^{-1} y^{-1}) in 2004 but mean fishing intensity during the same year was significantly higher in the control sites (256 days y^{-1} ha^{-1}) compared to the CBFM sites (80 days y^{-1} ha^{-1}). Assuming a linear relationship between catch and effort, the estimated differences in mean fishing intensity could almost account for these mean differences in production. The inclusion of a potentially more productive main river site in the control group might explain any remaining differences. Bi-monthly fish consumption was significantly higher in CBFM (12 kg HH^{-1}) compared to control sites (10 kg HH^{-1}). Seasonal variation in consumption was also found to be significant. Fish consumption is greatest between October and November and lowest between April and May. Fish consumption also varies significantly among habitat type with consumption highest at river sites and lowest at floodplain beel sites.

Table 51 Comparison of estimated marginal means of key management performance indicators between CBFM and control sites.

Indicator	Habitat	Years	Mean estimate: CBFM	Mean estimate: Control	P	Power of test
CPUA (kg ha^{-1} y^{-1})	ALL	ALL	200	320	0.24	0.22
	ALL	2003	215	179	0.80	0.06
	OB	2004	265	459	0.58	0.08
	R	2004	149	583	**<0.01**	0.94
Stocking harvests (kg ha^{-1} y^{-1})	CB	2002-2004	96	85	0.85	0.05
CPUE (kg hr^{-1})	ALL	ALL	0.44	0.42	0.75	0.06
	ALL	2002-2004	0.45	0.42	0.71	0.06
DPUA (days y^{-1} ha^{-1})	ALL	ALL	115	121	0.89	0.05
	ALL	2003	122	90	0.65	0.07
	OB	2004	134	133	0.99	0.05
	R	2004	80	256	**0.04**	0.59
DFER (%)	ALL	ALL	28	28	0.94	0.05
	ALL	2003	22	26	0.65	0.07
	OB	2004	39	39	0.98	0.05
	R	2004	40	24	0.61	0.10
H’	ALL	ALL	1.8	1.9	0.53	0.10
	OB	2002-2004	2.0	2.1	0.46	0.11
	R	2002-2004	2.2	2.3	0.69	0.07
Species assemblages (SN)	OB	2003	-	-	0.22	-
	GN	2003	-	-	0.93	-
Bi-monthly HH fish consumption (kg HH^{-1})	ALL	2002-2004	12	10	**<0.01**	1.0
Income[6]			-	-	-	-

[6]No controlled comparisons could be made. SN – sampled with seine nets; GN- sampled with gillnets

Whilst most of the comparisons indicated no significant differences in mean management performance indicators between CBFM and control sites, **it is very important to bear in mind the power of the tests performed.**

Power (1-β) can be regarded as **the probability of detecting a true significant difference**. Generally speaking, researchers aim to design tests with a power of at least 80%. For most of the controlled comparisons of performance indicators undertaken here, the power of the test was less than 10% (Table 51). **Therefore, there is a very high chance of drawing erroneous conclusions about the apparent non-effectiveness of the CBFM on the basis of these controlled comparisons.** In other words, the CBFM may have a positive or negative effect on many or all the performance indicators examined, but these effects remain undetectable at present.

The power of the statistical tests was low because of the small number of samples gathered in each month and the very unbalanced sampling design with many missing cells. Therefore, with the exception of the fish consumption, which was found to be significantly higher at CBFM compared to control sites, it is concluded that these controlled comparisons have been unable to answer the question: Does the CBFM work?

7.1.2 Trends in key management performance indicators

With the exception of fish consumption, results of the examinations of the trends in the management performance indicators at CBFM sites through time were equally inconclusive.

Whilst trends in production (CPUA) at CBFM sites were upward in all cased but one examined, these upward trends were significant in only two cases and the downward trend was also significant (

Table 52). Explanatory variables for these significant trends were not consistent among sites (see Section 4.2).

Fish abundance (CPUE) trends were downward in most cases, but when considering only the significant trends, three sites exhibited upward trends and only one downward. The presence of closed seasons best explained this significant upward trend in CPUE.

Trends in fishing intensity (DPUA) were more consistent. Upward trends (two of which were significant) were consistent in all but one site, but this down ward trend was not significant. The probability of such at outcome occurring by chance is 16% (P=0.16) suggesting that fishing intensity is increasing despite the implementation CBFM management interventions. No consistent trends in the destructive fishing effort ratio (DFER) were detected.

Biodiversity, measured in terms of H' were found to be increasing at most sites examined, but the trends were not significant.

Whilst the significance of the trends were not be tested, fish consumption appears to be declining at 19 or the 20 sites examined (see also Section 6.1.2) and all of those included in

Table 52 below. Therefore whilst fish consumption is higher at CBFM compared to control sites, there is strong evidence to indicate that fish consumption is declining overall. It should be borne in mind that these estimates include consumed fish both caught at the site and bought at the market (other sources possible). Therefore the trends should not be interpreted as changes to fish abundance at the sites. The downward trend may reflect increasing un-affordability of fish rather than a decline in production from the waterbodies but these variables are also not independent, that is, prices tend to rise with decreasing availability.

Trends in income at the two sites for which data were available, were not significant. Mean annual income estimates for 2003 at both waterbodies are significantly lower than for the previous annual-based estimates suggesting that estimates for 2003 may be biased. A detailed comparison of the data collection methods is required to confirm this or otherwise.

Table 52 Summary of the results of the trend analysis for key management indicators. Trend increasing (+); decreasing (-). Bold indicates trend is significant (P<0.05). CPUA – catch per unit area; CPUE – catch per unit effort; DPUA – fishing days per unit area; DFER – destructive fishing effort ratio. * not tested

		Trend through time							
Site Code	**Habitat Type**	**CPUA**	**CPUE**	**DPUA**	**DFER**	**H'**	**Fish consumption**	**Income**	**Site Score[1]**
1	R	**(+)**	**(+)**	(+)	**(-)**	(-)			3/5
2	R	(+)	(-)	(+)	(-)	(-)			2/5
3	R	**(+)**	(-)	**(+)**	(-)	(+)			3/5
5	R	(+)	(-)	(+)	(-)	(+)	(-)		3/6
6	R	(+)	(+)	(+)	(+)	(+)			3/5
8	R		(-)						0/1
9	OB	**(-)**	(-)	**(+)**	(-)	(+)	(-)		2/6
10	CB		**(+)**				(-)	(+)	2/3
11	R		(-)			(+)			1/2
13	OB	(+)	(-)	(+)	(+)				1/4
14	FPB	(+)	(-)	(-)	(+)		(-)	(-)	2/6
15	R	(+)	**(-)**	(+)	(+)	(+)			2/5
17	CB		**(+)**						1/1
1011	FPB		(+)						1/1
Trend	TOTAL (+)	9	5	8	4	6	0	1	
	TOTAL (-)	1	9	1	5	2	4	1	
Trend	TOTAL **(+)**	**2**	**3**	**2**	**0**	**0**	*****	**0**	
	TOTAL **(-)**	**1**	**1**	**0**	**1**	**0**	*****	**0**	
	X^2 (P)	**0.56**	**0.32**	**0.16**	**0.32**	**-**	**-**	**-**	

1 – Score 1 point for increase in CPUA, CPUE, fish consumption, income and for a decline in DFER or DPUA.

7.2 Other results

Numbers of fish stocked per hectare was found to be the best predictor of harvest weight from stocking programmes. The predictive linear model, described in Section (4.3.1), explains 48% of the variation in harvest weights.

In all habitat types, except main rivers, there is evidence (some significant at the 5% level) that fish abundance declines with increasing effort as would be expected and thus optimal levels of fishing effort (intensity) exist. These levels were sought by plotting loge transformed CPUA as a function of square-root transformed fishing intensity, following the approach of Bayley (1988). However, insufficient contrast in the data exists to determine optimal levels of fishing intensity (see Section 5.1.4).

Management interventions (gear bans, closed seasons and reserves) implemented at the CBFM sites were found to have no significant (detectable) effect on fish production (CPUA) or abundance (CPUE), but in all cases examined, the power of the tests were very low (<30%). **There is therefore a high probability (>70%) of incorrectly concluding that these interventions have no effect.**

7.3 Capacity Building

The capacity of Dr M.G. Mustafa and others was expected to be (and we believe has been) developed informally through their involvement in the data compilation, error checking and analysis process undertaken at WorldFish Centre Office, Dhaka. It would have been preferable if their involvement in this process had been greater, however, the consultant was forced to focus most of his time and attention upon completing the data analysis in a very short space of time after the late delivery of the data set which required a great deal of unplanned time for cleaning and correcting.

7.4 Recommendations

7.4.1 Publication of existing results

Up to three journal manuscripts were to form "…the main output of the technical assistance". However, given their very inconclusive nature, **it is recommended the results presented here are not published as there is a very high likelihood that they will be <u>incorrectly</u> interpreted** to mean that the CBFM has no effect. This is an erroneous conclusion. The CBFM may have a positive or negative effect, but these **effects remain undetectable at present.** This report now replaces those manuscripts as the main output of this Technical Assistance.

7.4.2 Improving the data set for further controlled comparisons

Attempts could be made to gather more data both at existing sites and also at some additional control sites to improve the power of the controlled comparisons, at least for the fish abundance (CPUE) indicator. A variance components analysis will be required for this purpose to determine how best to allocate sampling effort between CBFM and control sites and among habitat type and geographic region.

However, establishing and monitoring enough additional control sites to adequately improve the power of the tests is, in my opinion, **unlikely to be viable within the remaining duration of the CBFM Project** given the number of habitat types and regions that would need to be represented. Currently, less than 50% of the habitat-region combinations are represented by one or more control sites (Table 53).

Consideration might also be given to multi-level modeling approaches that take better account of the hierarchical nature of the data, at least for the CPUE comparisons where individual catch rate observations are available for each site. In both cases, it is recommended that the advice of a qualified statistician be sought.

7.4.3 Improving the data set for further time series analyses

The alternative, and **probably the most viable, option** would be to focus any remaining project resources **on improving the trend analyses** of management indicators at individual CBFM sites. It is understood that after data for 2005 becomes available in the first few months of 2006, the number of sites with at least four years of data will rise from the current 14 to as many as 60 sites. The additional data will also increase the power of the trend tests for the 14 sites examined here. With these additional data, it **should then be possible to draw conclusions** concerning the effectiveness of the CBFM at individual sites and therefore answer the question: "Does the CBFM work"?

Focusing upon the time series analysis also has the advantage that in-house capacity to repeat the analysis already exists, and therefore no additional training of staff would be required. However some input from an external consultant may be advisable to oversee and check the analysis (see Section 7.4.4).

Table 53 Number of sites monitored by habitat, region and year.

		Habitat	1997	1998	1999	2000	2001	2002	2003	2004
CBFM	E	CB								
		FPB								
		OB						2	7	4
		R		1	2	2	2	4	4	3
	N	CB		2				2	2	2
		FPB	1	1	1	1	1	2	11	2
		OB						5	8	5
		R		2	3	3	4	3	4	4
	NW	CB		1	1			4	3	2
		FPB								
		OB	1	1	1	2	2	4	8	5
		R								1
	SW	CB						1	2	
		FPB		1	1	1	1	2	2	3
		OB							1	1
		R		1	1	1			1	1
Control	E	CB								
		FPB								
		OB								
		R						1	1	1
	N	CB								
		FPB							1	1
		OB						1	3	3
		R							1	1
	NW	CB						1	1	1
		FPB								
		OB						2	1	2
		R								
	SW	CB								
		FPB						1	1	
		OB								
		R						1	1	1
Total			**2**	**8**	**7**	**6**	**5**	**16**	**20**	**19**

7.4.4 Repeating the analyses and further training.

The data for the time series analysis should be prepared in the same way to provide the indicators listed in Table 7. The WorldFish Centre IT team will have routines already written in SPSS to do this. The regression models should be fitted to the expanded data set, and their slopes should be tested for significance. The results can be reported in the same manner as presented here with plots of performance indicators versus time (with fitted regression models). This could be undertaken using Excel spreadsheets rather than the SPSS software if preferred. An overall results summary similar to Table 52 should be presented. For each performance indicator, a chi-square test can be used to test whether the observed frequency of positive and negative (significant) trends are significantly different to what would be expected by chance. Further guidance on regression models and Chi-square tests can be found in Zar (1984).

The WorldFish Centre may wish to consider another short-term technical assistance input from Aquae Sulis Ltd (ASL) to oversee the preparation and analysis of the data and to help report the results, possibly in the form of a journal manuscript(s).

No additional training of WorldFish Centre staff would be required to repeat these analyses. However, to repeat the controlled comparisons, including the multivariate species analysis described in this report, at least one member of staff (Dr Mustafa) would need, at a minimum, to attend courses in: (i) PRIMER at the Plymouth Marine Laboratory and (ii) General Linear Models (GLM) perhaps at Reading Statistical Services Centre (SSC).

Specific recommendations for the development of individual staff members will require some form of training needs assessment in the context of personal and institutional objectives. However, it is recommended that any member of staff involved in data analysis undertake some basic training in statistics. To design further/future surveys, a survey design course perhaps with a component on multi-level modeling component might also be necessary. Again the SSC would be able to advise you on your specific training needs. Alternatively, consideration could be given to employing an in-house statistician, perhaps with an interest in survey design who can provide continuous guidance and support to all the Centre's biologists and socio-economists. This may be the most (cost-) effective approach to ensuring the quality of future research based upon quantitative comparisons.

7.4.5 Publishing the results of repeated analyses

Before repeating the analysis and drawing conclusions concerning the efficacy of the CBFM, it is difficult to anticipate appropriate journal manuscripts titles or provide abstracts for them.

It was originally anticipated that three papers could be drafted reporting results relating to the impact of the CBFM on (i) fish production; (ii) sustainability and (iii) fisher wellbeing drawing upon the results of both the controlled comparisons and time series analyses.

Assuming now that only the time series analysis will be repeated and yield positive results, it may be more appropriate and realistic to cover all three management performance 'themes' in a single paper, perhaps under the title "Does the CBFM work"? Following the standard format, this would include some background on the CBFM and the aims of the study, a short description of the data collection and analytical methods, results, and discussion and conclusions.

7.4.6 Timetable for activities

A timetable to repeat the time series analysis after the remaining data for 2005 becomes available, and to report the results with the support from an outside agency, is summarised in the Gantt chart below.

Gantt Chart

	2005					2006											
Activity	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Enter data from existing routine monitoring programmes	■	■	■	■	■												
Complete data entry						■	■										
Data checking and formating in preparation for analysis								■									
Repeat data analysis (time series)									■								
Reporting and manuscript writing										■							

Twenty days of technical assistance is recommended beginning in April to oversee the repeated time series analysis and to help prepare either a report or a manuscript.

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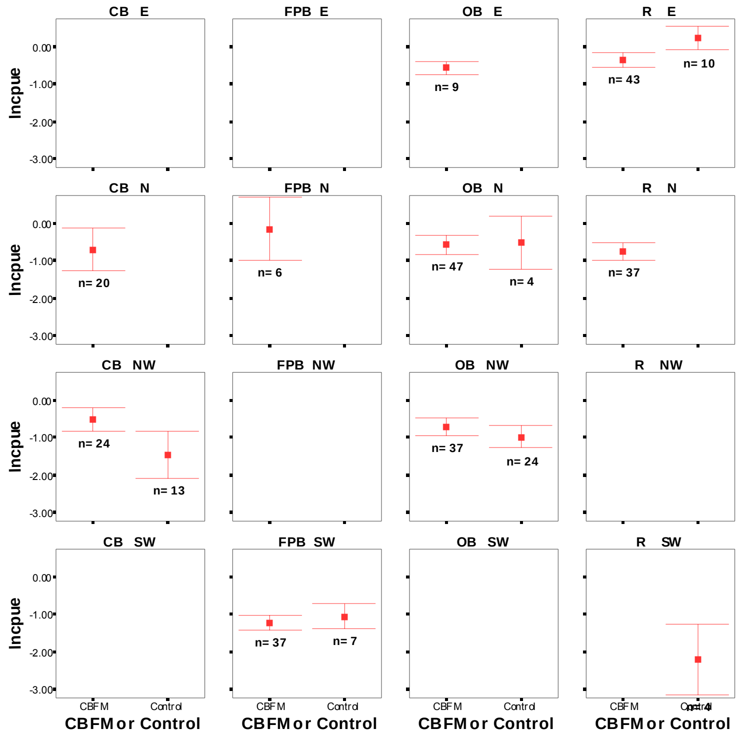
Annexes

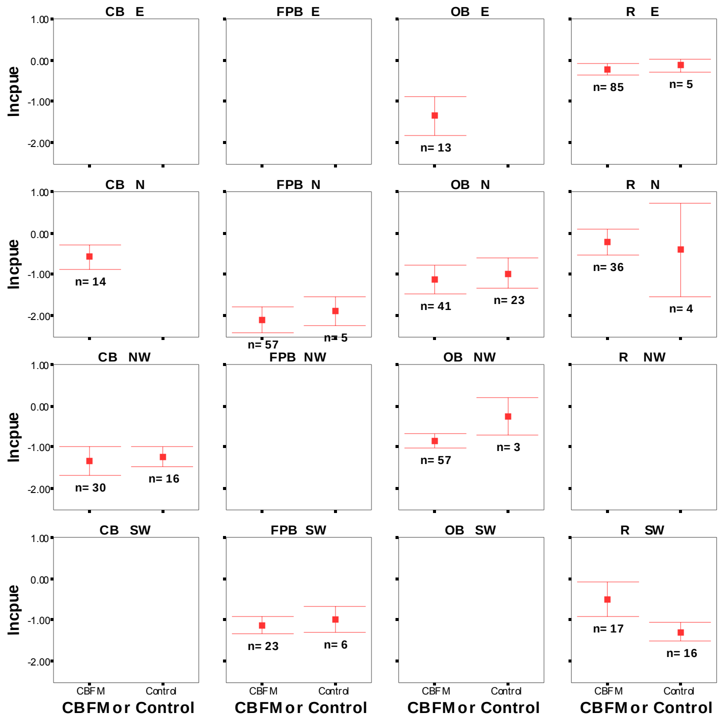
Annex 1 Destructive Gears

Gear	Code
Current jal	104
Moshari jal	201
Bhadi	201
Kawri	201
Chat jal	202
Gancha ber jal	205
Net jal	201
Bada jal	301
Beddi jal	301
Behundi jal	301
Binti jal	301
Behuti jal	301
Bhem jal	301
Bhim jal	301
Door jal	301
Baila jal / Tona jal	302
Banna/pati	1201
De-watering	1201

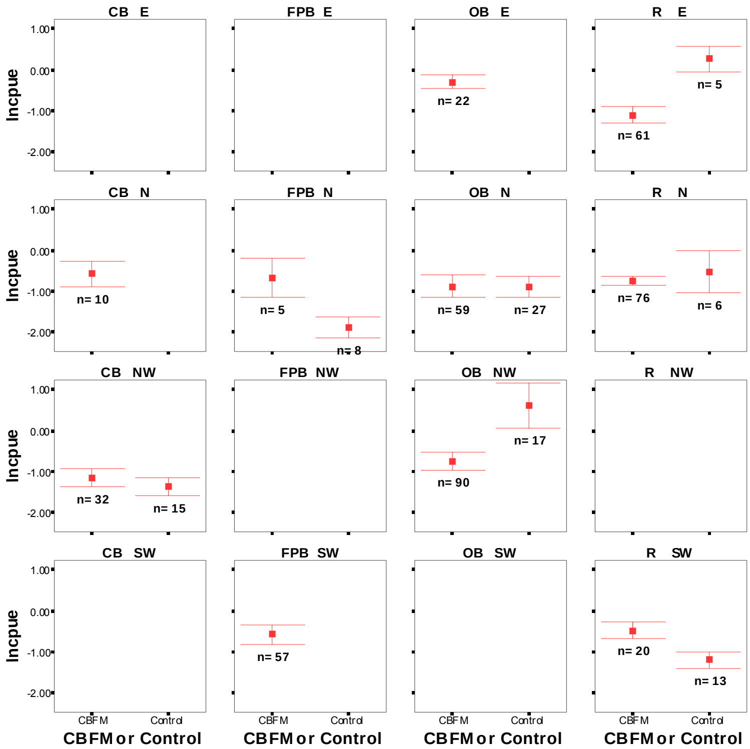
Annex 2 Estimates of mean fisher catch rates in September (ln CPUE) with 95% CI at CBFM and control sites for each habitat and region combination, 2002-2004.



Estimates of mean fisher catch rates in September (ln CPUE) with 95% CI at CBFM and control sites for each habitat and region combination for 2002.



Estimates of mean fisher catch rates in September (ln CPUE) with 95% CI at CBFM and control sites for each habitat and region combination for 2003.



Estimates of mean fisher catch rates in September (ln CPUE) with 95% CI at CBFM and control sites for each habitat and region combination for 2004.