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MAINSTREAMING BIODIVERSITY MANAGEMENT INTO PRODUCTION SECTOR ACTIVITIES

THE ESTABLISHMENT OF BASELINE AND DEVELOPMENT OF A MONITORING AND ASSESSMENT PLAN FOR THE ARTISANAL FISHERY ON PRASLIN

FINAL MISSION REPORT

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Executive Summary

Several methods were used to assess the trends in abundance, CPUE and net productivity of the trap and line artisanal fishery in Praslin, Seychelles. Catch showed increasing trends from the beginning of the data series (1985), with a peak in 2005 where catches were almost double the catch registered for 1990. After 2005, catches decreased by 20%. Fishing effort has increased ca. 40% from 1985 to 1998 and maintained steady from 1998 to 2010. Standardized index of abundance (CPUE) for the Praslin trap and line fishery has been stable for the first decade of the database, consistently increasing after 1997 up to 2005 where this index was ca. 80% higher than the average CPUE for the previous period. From 2005 up to date, the CPUE has been decreasing but still ca. 20% higher than the long-term average for the first decade. The available data suggest fish populations may be healthy compared to the beginning of the data series, with a depletion phase occurring in the last 5 years. This decline in CPUE could be attributed to a higher fishing pressure due to increase in fish demand from the tourism industry, to a high proportion of juvenile fish in the catches, and to an increase in fishing pressure concentrated in nearshore areas potentially causing localized depletion of resources. However, there are obvious limitations in the data available for the assessment thus these results should be interpreted with caution until more information becomes available. It is possible, that with more years of detailed spatial data from the community-based data collection program (CDCP), much more realistic biological and stock assessment models could be developed. In addition, the CDCP would provide the data needed to monitor trends in abundance without needing to use a formal assessment model. A management strategy could be devised that is based on the data directly (using triggers or proxies for reference points) rather than using a statistical assessment model.

Chapter 1

Stock assessment of the artisanal trap and line fishery in Praslin

1.1 Introduction

The fisheries sector in Seychelles is critically important for ensuring both food security and economic development. In terms of foreign exchange earnings it surpasses tourism, and accounts for 15% of total formal employment. The industrial marine fisheries have grown considerably over the last two decades, but the artisanal fisheries also remains of great importance. Small-scale artisanal fisheries exploit a high diversity of species and habitats. Total landings for the artisanal fishery have remained fairly constant for the last 20 years, but it is believed that catch rates have declined over the last decade.

In the management of marine resources, long-term maximization of catch under sustainable yield levels is a key traditional default objective (Hilborn and Walters, 1992; Quinn and Deriso, 1999). The maximum sustainable yield (MSY) index is a simple operational principle for stock assessment and fisheries management considerations but with intrinsic biological justification and a wide set of assumptions that may restrict its use. Moreover, changes occurring during the development of a fishery offer fundamental sources of information on the dynamics of both the 2estimate sustainable catches, and in particular MSY, the level of effort required to obtain MSY (F_{MSY}), and/or the level of depletion (e.g., current biomass with respect to virgin biomass) of a particular resource. The selection of such models will depend on different factors, such data availability to be used as input, biological assumptions behind the structural nature of the model, and the objectives of the assessment. Some widely used approaches include surplus production models which consider a fish stock as homogenous ignoring age or size structure, and analytical models such as Yield per Recruit or age-structured models that require age composition data and information on biological parameters such as age-at-maturity, fecundity, growth and selectivity to the fishing gear. The first set of models is especially used when only an index of abundance, such as catch per unit effort (CPUE) is available. Most recently, much attention has been give to developing tools and models to assess data-poor or data-limited stocks and their associate control rules, including Depletion Average Corrected Catch (DCAC; McCall 2009) and density-ratios (McGilliard et. al 2011).

Spatial heterogeneity has been also increasingly considered in stock assessment and management, particularly in the analysis of catch per unit effort and for sedentary or low mobility resources with a high degree of patchiness. Understanding spatial differences in distribution and in life history processes are fundamental to both monitoring and the economic exploitation of the resource. Since coral reef fish and invertebrates usually have an extremely patchy distribution, these factors will be of fundamental importance in understanding their fisheries. However, including spatial heterogeneity into stock assessment requires information at relevant spatial and temporal scales, which are usually really difficult and expensive to collect and analyze.

Even where all these factors can be taken into account, considerations and uncertainties related to data errors need to be considered. Data are often missing, particularly in artisanal and subsistence fisheries where monitoring and data collection is particularly difficult to gather considering limited economic and human resources. Estimates of the total catch where data are absent will tend to be underestimated and data in the form of catches aggregated over a number of habitats and different depths may mask local processes (e.g., localized depletion). Identifying exactly where catches come from may be necessary for reliably estimating sustainable yields and accounting for the distribution of fishing effort. Long-term time series of aggregated catch and effort can be used to estimate sustainable yields, giving some indication of a lower bound for the potential yield of the whole stock or a particular area. In addition, when dealing with multi-species fisheries, the maximum sustainable yield is usually less than the sum of the single species MSY. Although information on inter-species interactions and ecosystem-based approaches would be more realistic, information needs often precludes the use of more holistic models in stock assessment. In conclusion, high spatial or species-specific variability in the observed catches may undermine the value of any estimate of the global average MSY, and particularly for coral reef fisheries. Thus, global averages of sustainable catches or MSY need to be considered with caution within a management plan, especially when dealing with data-limited fisheries.

1.2 Data analyses

Data used on this report was collected and compiled by the Staff of the Seychelles Fishing Authority (SFA) Artisanal Fisheries Research Section (Table 1.1). Number of records or samples by fieldworkers was stable or slightly decreasing for the whole period 1985-2010, with the exception of years 1995, 2005 and 2010 where the number of samples was substantially smaller (Figure 1.1).

Table 1.1. Variables recorded for the Artisanal fishery of Praslin (see SFA 2005 for details and descriptions on data collection).

SITE NUMBER		
	Mahe	
	Prasling/La Digue	
DATE		
BOAT		
	FOOT	By foot
	PIR	Pirogue
	IB	Inboard
	OB	Outboard
GEAR		
	FIXA	Active traps
	FIXS	Static traps
	LHPFIX	Handline and traps
	LHP	Handline
EFFORT (hours)		
NUMBER OF GEARS		
NUMBER OF SETS		
CATCH BY SPECIES GROUP		
TOTAL CATCH		

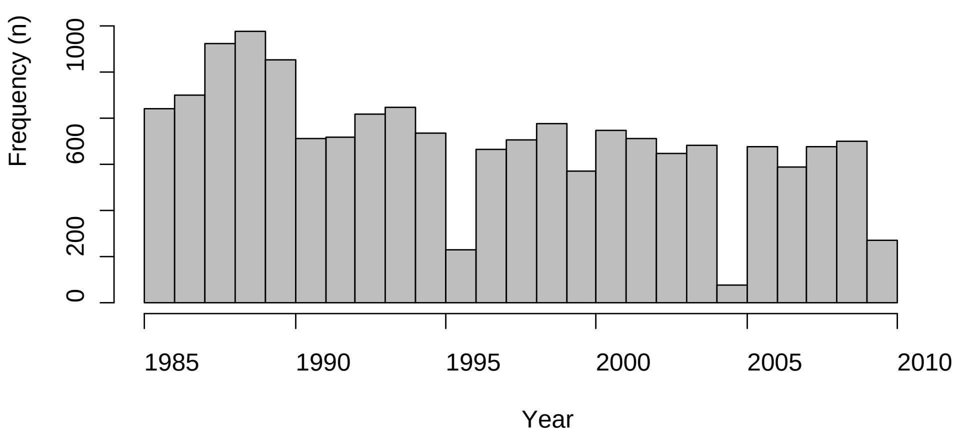

Figure 1.1. Number of annual records or samples from small boat catches taken by SFA fieldworkers from 1985 to 2010.

Total catches in samples were classified by species groups (Figure 1.2), where groups S8 (*Siganus* spp) and S9 (*Scarus* spp, *Acanthurus* spp, and other reef fish species) constituted 17% and 16% of the total long term catches for the period 1985 to 2010. In order to highlight changes in catch composition, long term trends of proportion of species groups in the total catches were analyzed (Figure 1.3). Given the fact that species groups S8 and S9 dominated the catches for the whole time series, an additional analyzes was carried out excluding those groups from the data set (Figure 1.3b). Species groups S2 (*Caranx* spp) and S12 (*Epinephelus* spp) seem to be the next group in representation of catches and S11 showing an increase (*Lutjanus sebae* or bourzwa) in total catches proportions after 2000 and particularly for the last 5 years. Although this qualitative evaluation highlights changes in catch composition, a detailed statistical analysis of the proportion of species, instead of group species, would be needed for proper monitoring (See Chapter 3).

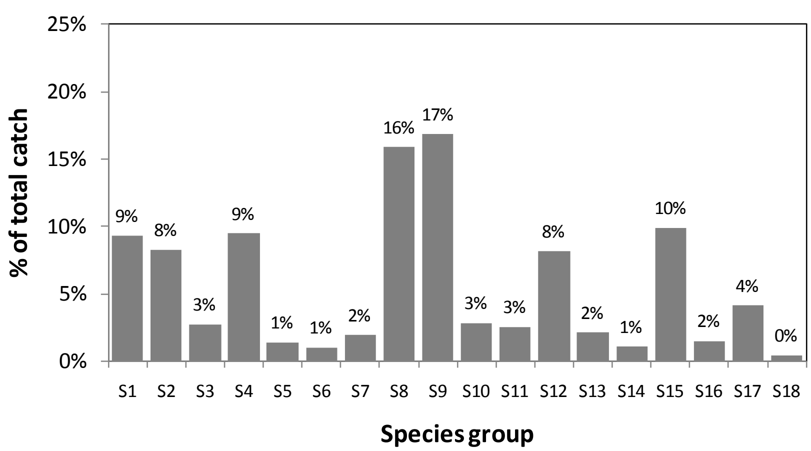

Figure 1.2. Catch composition by species groups for the trap and line fishery in Praslin from 1985 to 2010.

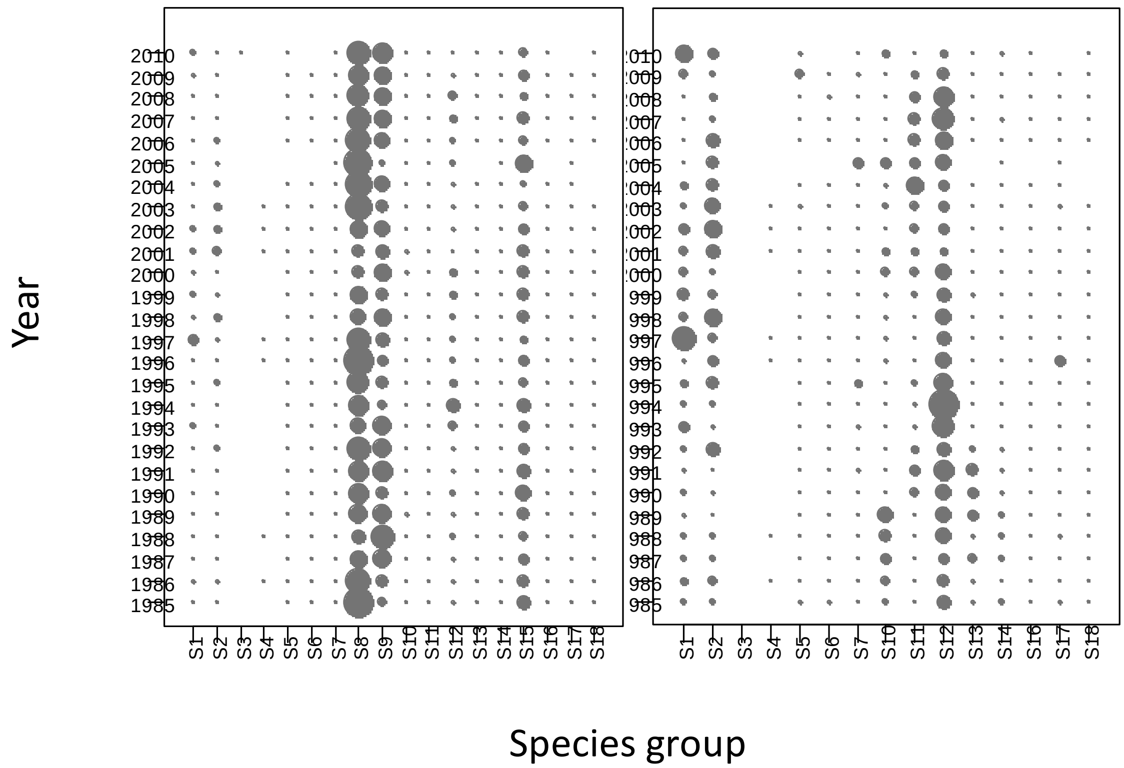

Figure 1.3. Catch composition by species groups for the trap and line fishery in Praslin from 1985 to 2010 (a) for all groups; (b) for all groups excluding S8 and S8. The size of the circle is proportional to the representation of each group (%) in the total catch.

Aggregated catch data was analyzed as the sum of the records by year to have a rough estimate of the amount of total catch taken by year as well as trends in the estimates (Figure 1.4a). In addition, given substantial inter-annual differences in the sampling effort by fieldworkers, catches were corrected by number of samples (average catch by record; Figure 1.4b). Both indices of catch showed increasing trends from the beginning of the data series, with a peak in 2005 where the catch was almost double the catch registered for 1990. After 2005, catches decreased by 20%.

Catch data was also plotted by species group (Fig. A1), where most groups showed similar increasing trends but with different degree of inter-annual variability.

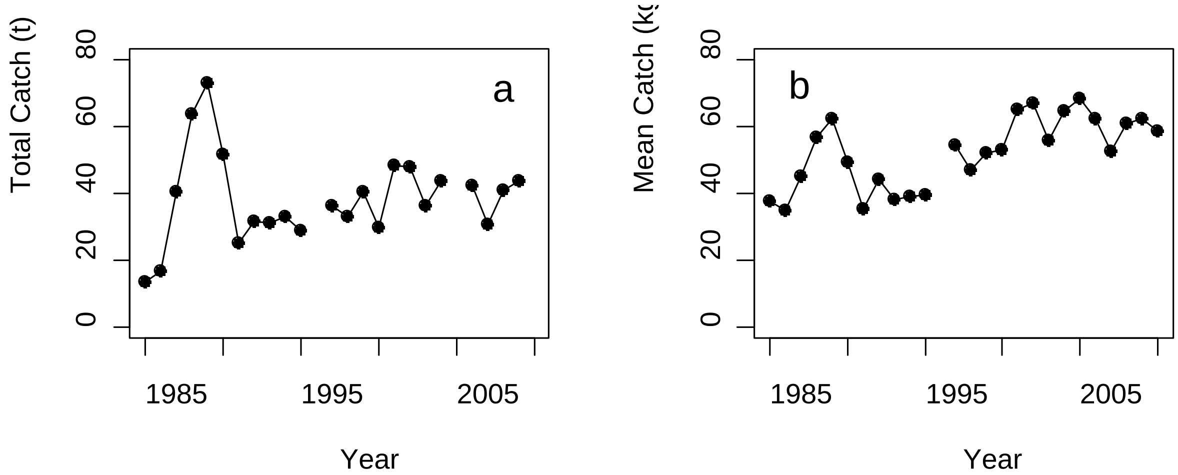

Figure 1.4. Catch from small boats in Praslin artisanal fishery from 1985 to 2010. (a) Total recorded catch in tons; (b) average catch per record (corrected by number of samples taken). Those years with low representation of samples were not plotted.

Effort was recorded (a) as number of hours fished (*H*) and (b) by number of gear multiplied by number of sets for a given day (*D*). After discussion with SFA fieldworkers, hours was considered a better indicator of actual effort (Figure 1.5). In any case, proportionality between both measures of effort was evaluated through jackknife cross-validation, where $\log(CPUE_H)$ and $\log(CPUE_D)$ were plotted and fitted to a linear regression $CPUE_H = \alpha + \beta\ CPUE_D$. Simultaneous F-test was used to test the null hypothesis of $\alpha = 0$ and $\beta = 1$ and to check for departures from a one-to-one line through the origin. Proportionality between both measures of efforts was then confirmed ($p < 0.05$; Figure 1.6). As shown in Figure 1.5, effort has increased ca. 40% from 1985 to 1998 and maintained steady from 1998 to 2010.

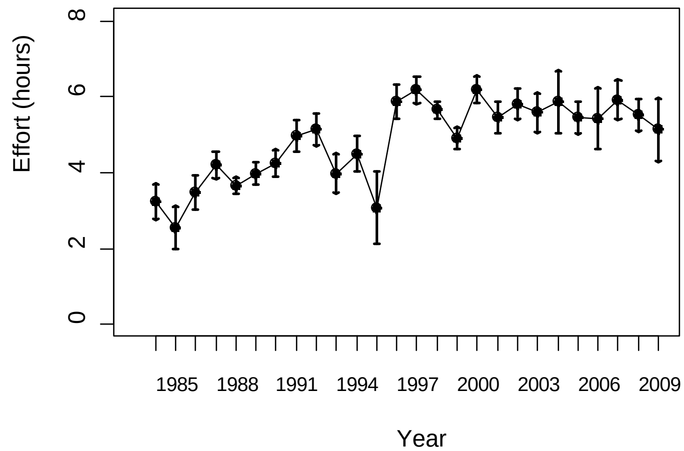

Figure 1.5. Mean (± s.e) effort in hours for the artisanal fishery in Praslin from 1985 to 2010.

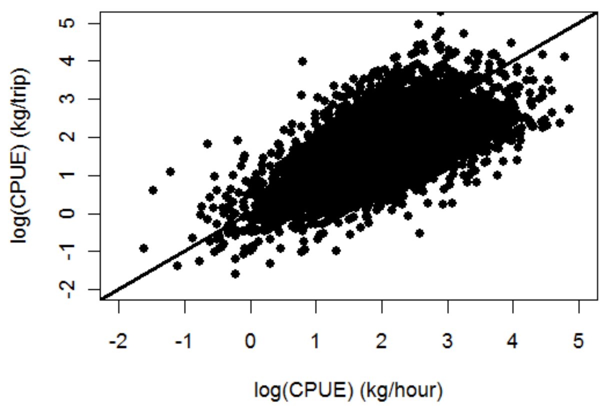

Figure 1.6. Plot of logCPUE$_H$ and log CPUE$_D$ and 1:1 line showing proportionality between both indices.

Catch rates based on fishery data, as catch per unit of effort (CPUE), are often essential for stock assessment, especially when no fishery independent data (e.g., survey biomass estimates) are available. Figure 1.7 shows the time series of raw CPUE (kg/hour) averaged for all boat types, gear, and areas (also see Table 1.2). However, catch rates may vary significantly by month, gear type, boat type and areas hence the need to standardize the CPUE to make it comparable and useful as in index of abundance. In fact, exploratory analyses of CPUE using the mentioned covariates as factors showed differences in trends for: (a) boat type (although only outboard boats are being used in Praslin after 1997); (b) gear type; and (c) interactions between gear and month (Figures A2-A10).

Table 1.2. Catch (kg) and CPUE (kg/h) for the artisanal fishery (small boats) in Praslin from 1985-2010.

	Praslin		Mahe	
Year	**Catch**	**CPUE**	**Catch**	**CPUE**
1985	13,507	8.77	125,939	13.50
1986	17,066	12.02	155,191	11.65
1987	40,801	13.90	260,447	29.40
1988	63,800	13.96	238,071	39.72
1989	73,190	17.74	215,421	41.54
1990	51,795	11.24	149,242	15.52
1991	25,289	7.84	109,921	13.33
1992	31,721	10.06	115,322	14.27
1993	31,403	8.52	78,488	11.57
1994	33,274	7.56	70,935	11.87
1995	29,109	7.48	91,803	12.61
1996	7,739	8.63	62,844	23.41
1997	36,557	11.07	85,483	14.88
1998	33,305	9.47	59,383	9.18
1999	40,687	9.82	91,241	13.00
2000	30,149	10.71	69,740	13.92
2001	48,673	14.48	73,797	13.43
2002	48,095	14.03	73,150	14.15
2003	36,276	12.72	80,165	14.86
2004	44,089	15.48	107,043	14.54
2005	5,432	15.49	110,000	12.56
2006	42,457	13.32	109,270	13.22
2007	30,811	11.52	87,063	10.41
2008	41,080	12.98	93,158	11.48
2009	43,761	13.10	173,572	12.22
2010	16,013	12.10	129,565	12.46

CPUE standardization requires the availability of relevant explanatory variables for catch and effort data (Maunder and Punt 2004) and the use of model-based techniques such as general and generalized linear models (GLM). A GLM was used to standardize catch per unit effort (CPUE) data for the Artisanal trap and line fishery in Praslin for the years 1985–2010. Data were stratified temporally by year and month and spatially by area (North East and West) using information collected by SFA. Four factors were used: Area, Month, Boat and Gear (Table 1.1). At least 12 combinations of main effects and interactions were tested for each year/area, with a 45 to 57% of the total sums of squares explained. The best models were selected by stepwise backward elimination of non-significant terms. Month and gear types were included in all models and explained the most variability.

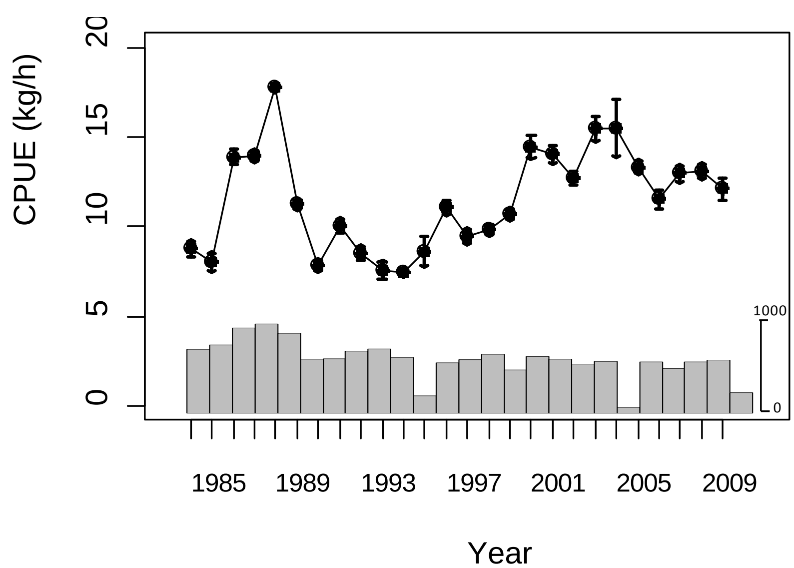

Figure 1.7. Catch per unit of effort (CPUE; mean ± s.e.) for the Praslin artisanal fishery for 1985-2010. Bars in x-axis represent number of sample sizes.

Figure 1.8 shows the standardized index of abundance (CPUE) for the Praslin trap and line fishery from 1985 to 2010. CPUE has been stable for the first decade of the database, consistently increasing after 1997 up to a 2005 where this index was ca. 80% higher than the average CPUE for the previous period. From 2005 up to date, the CPUE has been decreasing but still ca. 20% higher than the long-term average for the first decade.

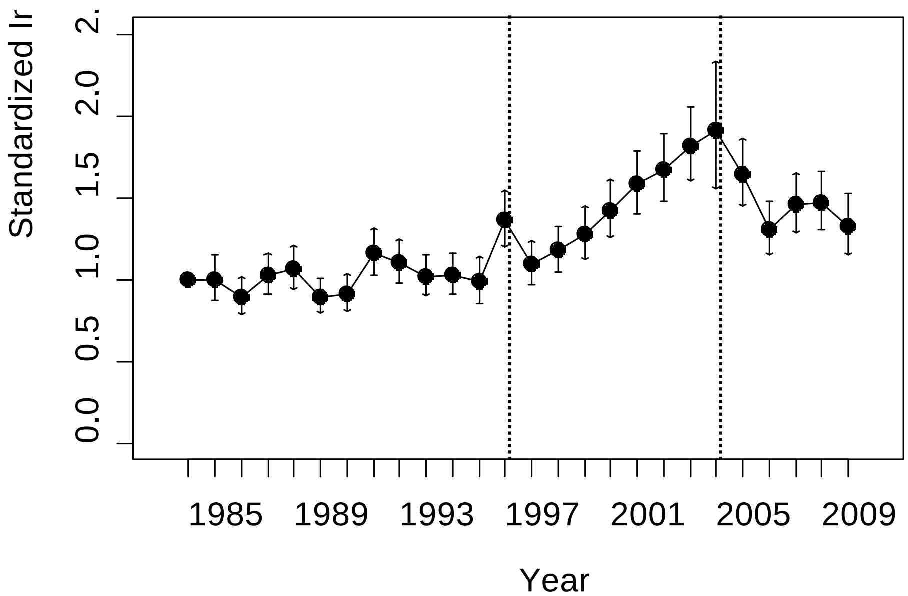

Figure 1.8. Standardized index of abundance for the artisanal trap and line fishery in Praslin (mean and 95% confidence interval). Vertical dotted lines show periods of changes in CPUE trends (for visual purposes only).

The considerable increase in CPUE from 1997 to 2005 may be related to several factors other than an increase in stock sizes: (i) mechanization of boats, switching from man powered pirogues to outboard engine boats increasing the number of hours at sea as well as the possibility of reaching outer fishing grounds; (ii) as a result of this mechanization, expansion to new and virgin fishing grounds with more abundant resources; (iii) technological advances such as global positioning systems (GPS) and fish finders increasing the efficiency and ability of fishermen to target their catches; and (iv) improved efficiency of the fishing gear, including new materials (e.g., wire traps) and alternative sources of bait (e.g., tuna-derived baits, *lamnar koko*, etc.). Although anecdotical evidence on these causes of increase in CPUE exists, social-ecological information should be analyzed to elucidate the true drivers in CPUE. In addition, an increasing tourism industry (Figure 1. 9) and higher demand for fish from the hotel industry could have been the cause for a need of higher and more efficient harvest. In fact, tourism has been stable from 1990 to 2005, showing a significant increase ($p < 0.05$) after 2005. Considering most of the catches from the Artisanal trap and line fishery goes to the domestic market in the hotel industry, this increasing trend in number of tourists could derive in higher fishing pressure on the local resources. Hence, a precautionary management plan and alternative management measures for the artisanal trap and line fishery in Praslin should be designed and implemented in the very near future.

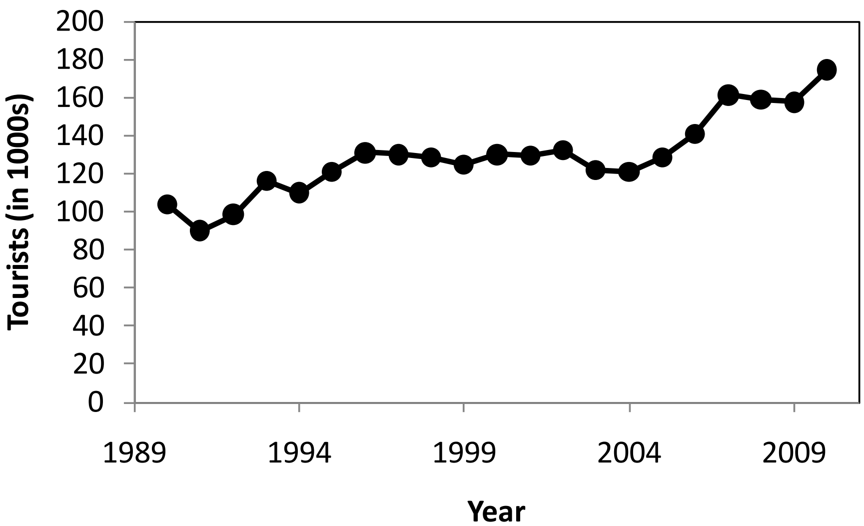

Figure 1.9. Number of tourists (in thousands) arriving in Seychelles from 1985 to 2010 (obtained from Seychelles National Bureau of Statistics 2011; http://www.nsb.gov.sc/).

When analyzing catch by area, both North East and West Praslin show similar patterns with lower values between 1991 and 1996, increasing towards 2000 and remaining stable until 2010 (Figure 1.10). Further, peaks in catches seem to be alternating in time between North East and West Praslin. These specific trends could reflect some movement of either sampling or fishing effort from one area to the other in particular years. Information about the fishermen dynamics in Praslin would be needed to further depict these patterns.

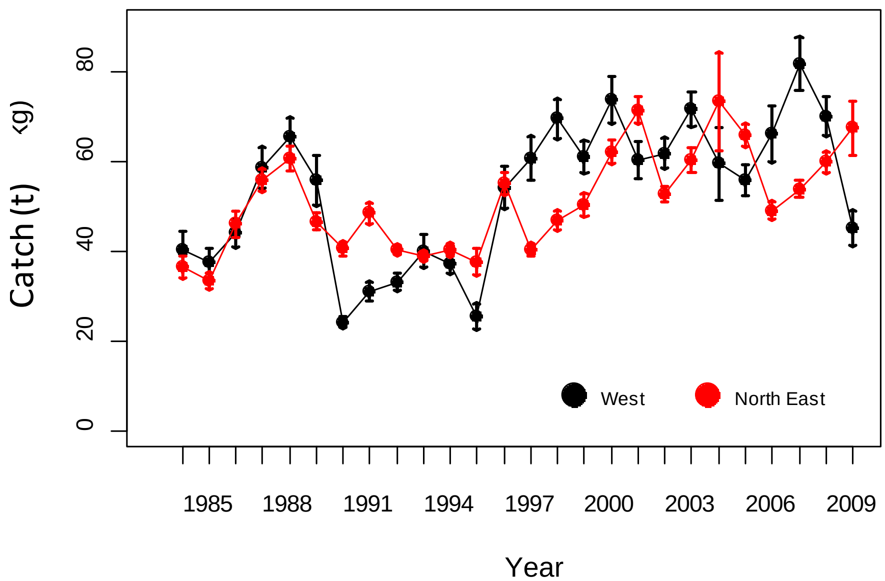

Figure 1.10. Time series of catch (in tons) for the trap and line artisanal fishery in West and North East Praslin from 1985 to 2010.

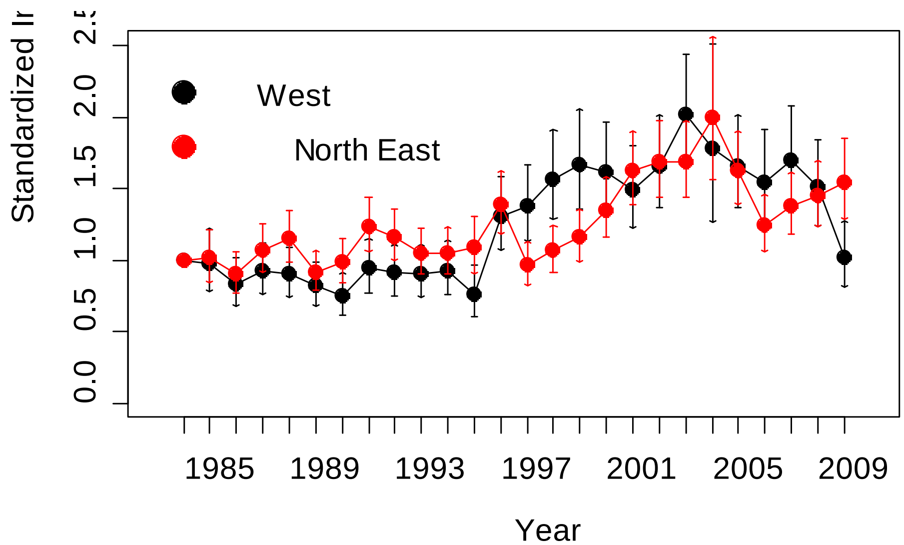

Figure 1.11. Standardized index of abundance for the artisanal trap and line fishery in West and North East Praslin (mean and 95% confidence interval).

1.3 Alternative models

The assessment of the Praslin artisanal fishery would be considered "data limited". There is a time series of catch landings and CPUE available (as mentioned in Section 1.2) which we can

treat as an index of abundance, but a time series of length frequency data and fishery-independent data at the relevant spatial scale are lacking. Catch and effort data is collected by fieldworkers at some of the landing sites hence these data is also limited. In addition, there are reasons to suppose that CPUE could be not proportional to abundance due to the searching behavior of fishermen. There are also major unknowns about basic stock biology for most species as well as virtually no research has been conducted in terms of catchability of the different gears. Thus there are some major structural uncertainties in the modeling, limited by lack of information on gear selectivity, possible misrepresentation of catches and effort, and lack of biological information. Whereas many reef fisheries assessments now routinely use a size-structured statistical catch-at-size model, this is not an option for this analysis.
The main approach was to explore three different assessment modeling framework to try to capture the extent to which the data available support alternative hypotheses about the Praslin artisanal trap and line fishery status and future productivity. The methods used imply different assumption in the biology of the stocks and present various data needs that will be discussed in following section. These three approaches are: (1) a Depletion Corrected Average Catch (DCAC) mostly used in data-poor situations; (2) a simple surplus production model using CPUE as a standardized index of abundance; and (3) an age-structured model for those species with available information.

1.3.1 Depletion Correction Average Catch (DCAC)

Unlike the classic fishery problem of estimating MSY, data-poor fishery analysis aims at estimating a yield that is likely to be sustainable. While very low yield estimates would meet the target, they are of little practical use particularly in small-scale and subsistence fisheries were communities depend on fisheries for their livelihoods. Thus, the problem is to identify a moderately high yield that is sustainable, while having a low chance that the estimated yield level substantially exceeds MSY leading to an inadvertently overfishing and potentially resource depletion before the error can be detected in the course of fishery monitoring and management.

A possible evidence for a sustainable yield could be represented by a prolonged period over which that catch has been taken without signs of a reduction in resource abundance. The estimate of sustainable yield would be comparable to the long-term average annual catch over that period (McCall 2009). However, it is rare that a resource is exploited without some change in underlying abundance. If the resource declines in abundance (which is necessarily the case for newly-developed fisheries), a fraction of the catch is derived from that one-time decline, and does not represent potential future yield supported by sustainable production. If that non-sustainable portion is mistakenly included in the averaging procedure, the average will tend to be higher than the sustainable yield (Wetzel and Punt 2011). This error has been frequently made in fishery management.

A increasingly used method is the Depletion Corrected Average Catch (DCAC; MacCall, 2009) which was developed as a means to estimate a sustainable yield for data-poor stocks. DCAC uses only catch history, the length of the catch history, a user-defined relative stock depletion status, along with biologically based parameters to calculate a yield that would likely be sustainable:

$$\text{DCAC} = \frac{\sum C_t}{n + \Delta[B_{peak}(F_{MSY}/M)M]^{-1}}$$

where C_t is the catch during year t, n is the length of the catch time series in years (i.e., 26 years), Δ is the relative stock status (i.e., $1 - B_{\text{current}}/K$), B_{peak} is the biomass that corresponds to maximum sustainable yield relative to carrying capacity (B_{MSY}/K), M is the instantaneous natural mortality rate, and F_{MSY}/M is the ratio between the fishing mortality rate that corresponds to B_{peak} and M. A Monte Carlo approach with 10,000 random draws from pre-specified prior distributions (Table 2.3; Figure 1.12) was used to account for the uncertainty regarding the four input parameters (Δ, B_{peak}, F_{MSY}/M, and M). The 3 last parameters were best guess-estimates based qualitative and anecdotical information and 4 different values of Δ corresponding to different depletion levels were included (Table 2.3).

DCAC may be comparable to a one-parameter production model that uses as input additional information on quantities such as nature mortality M and depletion. It provides an estimated yield that is likely to be sustainable, if the stock is maintained at or near the levels of abundance experienced during the historical period from which the catches were obtained (McCall 2009). The estimated yield is not necessarily maximal, but in practice could be comparable to MSY. Calculations of DCAC for the whole data series (1985-2010) are given in Table 1.3. The Monte Carlo distribution of DCAC values, ranging from 28 to 33 t, are below the current catches for the recorded Praslin trap and line fishery composed by small boats.

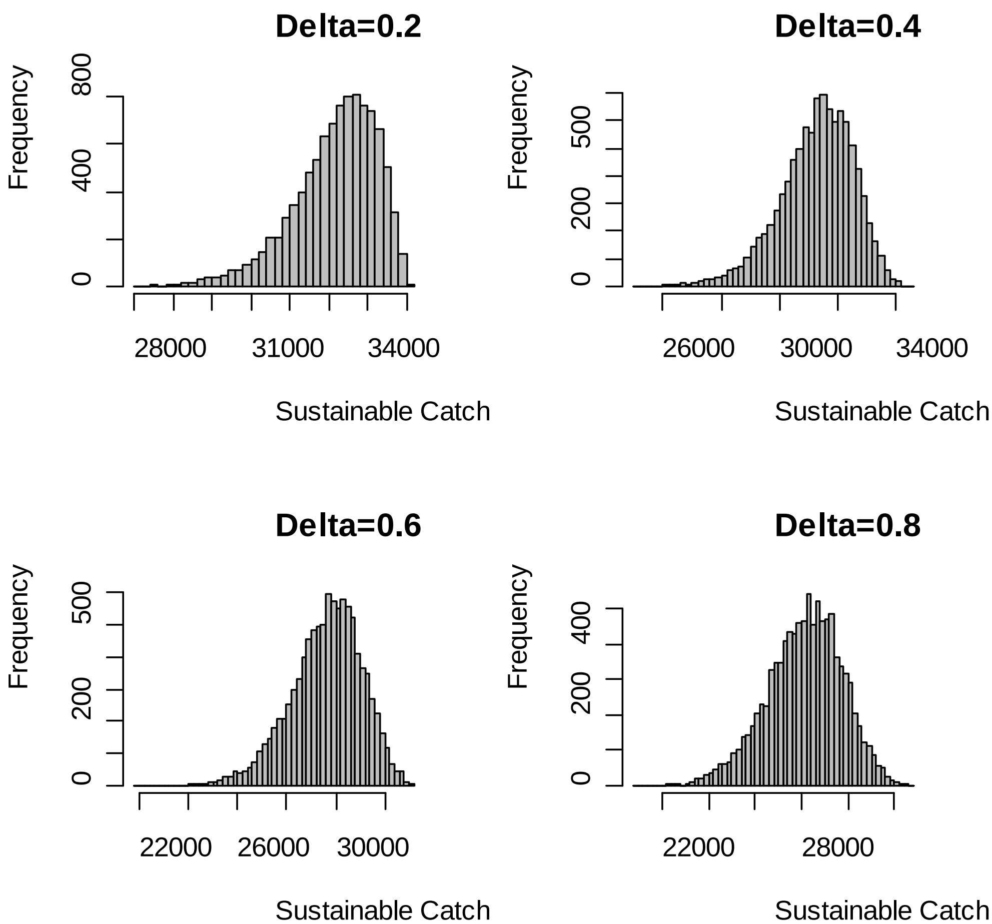

Figure 1.12. Frequency distribution of DCAC results for the artisanal trap and line fishery in Praslin based on 10,000 Monte Carlo runs of parameter values.

Table 1.3. Mean value of parameters from which random distributions (log-normal) were draw and mean and standard deviation (S.D.) for the sustainable catches (DCAC in tons) for 4 different scenarios of resource depletion.

Mortality	**F_{MSY}/M**	**Depletion**	**Sustainable catch (DCAC)**	
M		Δ	Mean (t)	S.D. (t)
0.18	1.2	0.2	33.1	1.1
		0.4	31.2	1.3
		0.6	29.6	1.5
		0.8	28.1	1.6

As mentioned before, different values of Δ represent different scenarios of depletion or changes in abundance (with Δ = 0.2 representing small changes since the development of the fishery and 0.8 substantial depletion). Trends in CPUE and anecdotical evidence suggest that stocks targeted by this fishery may present low levels of depletion thus sustainable catches would be higher or close to 30 t. Although these catches are in nature conservative and precautionary (due to the assumptions in the estimation approach), they should be considered arbitrary since we are only dealing with one component of the fishery targeting the stocks being assessed and thus should not be used as fixed reference points.

1.3.2 Surplus production model

Surplus production models are used for stock assessment purposes and the surplus production is the biomass that can be harvested each year from a population without affecting long-term abundance. The models assume population abundance will not change if the stock is harvested at the same rate as the population's capability to increase, considering fish stock as a homogeneous biomass. Surplus production from a stock could be then calculated from catch and an index of abundance (e.g. CPUE). This provides us with a method for determining if the fish stocks in Praslin in recent years have been less productive than it was when the data collection started (i.e., 1985); in other words a direct question to whether there is an indication that the stock is currently overfished and higher standing stocks of fish would result in higher surplus production.

To answer this question and determine the status of resource exploitation in the Praslin artisanal fishery, surplus production models were applied to the 1985-2010 catch and effort data to model maximum sustainable yield (MSY) and optimal exploitation rate (u_{MSY}). In the models, the artisanal multi-species and multi-gear fishery from Praslin was treated as targeting a unique stock in order to produce global estimates of MSY and u_{MSY}. In the analysis, population parameters including growth, recruitment and natural mortality were assumed to be constant. The approach used was a Schaefer (1954) logistic model and using a standardized index of ln(CPUE) and assuming different values of proportionality of this index with the stock size (e.g., hyperstability) and that increase in biomass conforms to a logistic curve where yield and effort are symmetrically related. The basic structure of the model is given by:

$$B_{y+1} = \left[B_y + rB_y \left(1 - \frac{B_y}{k} \right) - C_y \right]$$

where B_{y+1} is the biomass at time y, r is the intrinsic growth rate, and k the carrying capacity. The model is fit to the CPUE index, and a non-linear relationship between CPUE and abundance was allowed as follows:

$$\hat{I}_y = q(B_y)^{\beta}$$

The stock dynamics is assumed deterministic and the differences between the predicted and observed indices are due to observation error. Observation error is assumed multiplicative and thus the deviations are lognormal:

$$v_y = \ln\left(\frac{I_y}{\hat{I}_y}\right)$$

The normal likelihood for the deviates is the represented by:

$$L(v_y \mid \text{model parameters and data}) = \frac{1}{\sigma_v\sqrt{2\pi}}\exp\left(-\frac{(v_y)^2}{2\sigma_v^2}\right)$$

The likelihood for the entire data series is simply the product of all the individual year (1985 to 2010) likelihoods. For time series of relative abundance indices there is an analytic formula for the maximum likelihood estimate of the scaling parameter *q* when a multiplicative error is assumed. This estimate is given by:

$$q = exp\left(\frac{1}{n_y}\sum ln\left(\frac{I_y}{B_y}\right)\right)$$

Where n_y is the number of observed records of *I* (i.e, 26). Thus, from this model parameters *r, k* and β were estimated and MSY, u_{MSY}, and the current level of depletion with respect to the initial year of the data series were computed as follows:

$$MSY = \frac{r \cdot k}{4}$$

$$u_{MSY} = \frac{MSY}{B_{MSY}}$$

$$\Delta = \frac{B_{2010}}{B_{1985}}$$

The results of the estimated parameters for MSY and u_{MSY} determined using the logistic model are shown in Table 1.4 and the model fit and time series of surplus production shown in Figure 13a and 13b respectively. The model overall estimated of MSY was 58 t for the Praslin trap and line fishery composed only by small boats (i.e. mostly outboard, some inboard) and the surplus production shows a peak in 1999 and then declining towards the end of the time series. However, several caveats and considerations need to be considered regarding these estimates. A lack of contrast in the information precluded good model fits and then masking some of the peaks in CPUE. Further, it is widely accepted that in multi-species fisheries fishing effort would affect differently to all targeted species, where some could be over-exploited while others remain under-utilized (Jensen, 1981). The usefulness of the model estimations for MSY may be limited by their imprecision due to the explicit and implicit assumptions and limitations underlying the model. For example, the assumption that fishing effort is distributed fairly uniformly over the fishing grounds may not hold. If intense fishing is conducted in localized areas or certain reefs close to the shore or landing ports for long period of times, as is often the case in Praslin, it will likely produce localized overfishing, and the population will have a higher risk of depletion or even collapse in those areas of effort concentration.

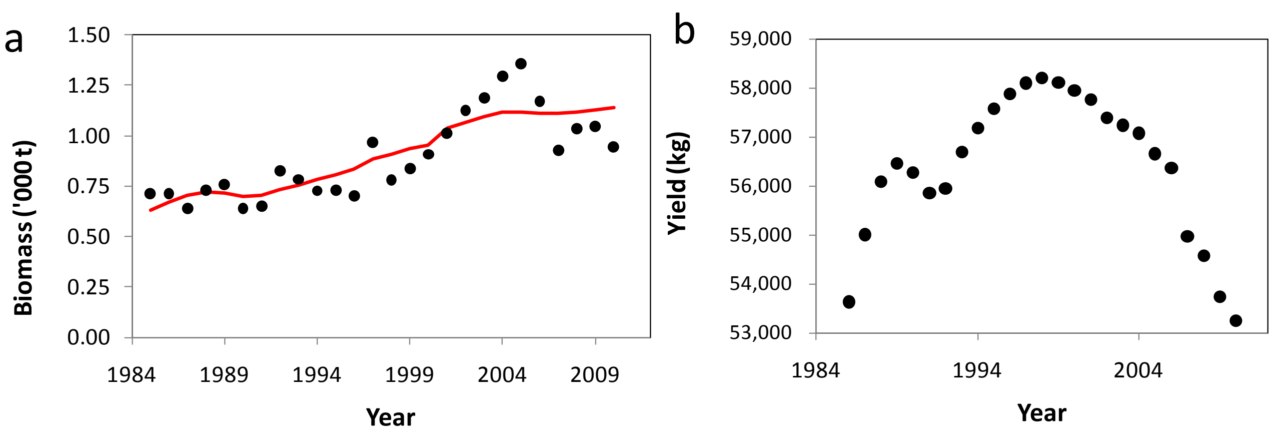

Figure 1.13. Surplus production model fit for the trap and line artisanal fishery in Praslin; (a) trends in biomass; and (b) trends in surplus production.

Table 1.4. Estimated parameters of surplus production model for the artisanal trap and line fishery in Praslin using catch and effort data from 1985 through 2010.

Parameter	Value
r	0.13
k (t)	1,749
$B_0=B_{1985}$ (t)	629
β	1.09
MSY (t)	58
u_{MSY}	0.06
Depletion (Δ)	1.81

1.3.3 Age-structure model for the Emperor red snapper (*Lutjanus sebae*) in Praslin

Emperor red snapper (*Lutjanus sebae*) or "bourzwa" as per its local Creole name is the most important commercially and culturally exploited demersal species in the Seychelles. It is caught mainly offshore on the Seychelles Bank by hook and line, although catches are also made with traditional bamboo and wire traps set in coastal waters. The average annual landings for the whole Seychelles bank has been estimated as 282.9 t during the period 1987–2003, close to its maximum sustainable yield of 380 t (Grandcourt et al. 2008). However, between 2004 and 2006, the substantial increase in annual landings to an average of 692.8 t has been associated with an increase fishing pressure by the artisanal fishery. Here, an age-structured model for the Praslin component of the Emperor red snapper is developed where the population dynamics of animals aged 1 and older is given by:

$$N_{y+1,a+1} = \begin{cases} (\tilde{B}_{y+1} / \tilde{B}_0)/\{\alpha + \beta(\tilde{B}_{y+1} / \tilde{B}_0)\} & \text{if } a = 0 \\ N_{y,a}(1-V_a F_y)S_a & \text{if } 1 \le a \le x-1 \\ N_{y,x}(1-V_x F_y)S_x + N_{y,x-1}(1-V_{x-1}F_y)S_{x-1} & \text{if } a = x \end{cases}$$

where $N_{y,a}$ is the number of animals of age a at the start of year y,

V_a is the vulnerability of a fish of age a - assumed to be a logistic function:

$$V_a = \left(1+\exp\left[-\delta(a-a_{50})\right]\right)^{-1}$$

a_{50} is the age-at-50%-vulnerability,

δ determines the slope of logistic function,

F_y is the exploitation rate during year y,

S_a is the survival rate for animals of age a,

α, β are the parameters of the stock-recruitment relationship,

$\tilde{B}_y$ is the spawner biomass at the start of year y:

$$\tilde{B}_y = \sum_{a=a_m}^{x} w_a \, N_{y,a}$$

a_m is the age-at-maturity, and

w_a is the mass of a fish of age a, defined according to a von Bertalanffy growth equation:

$$w_a = e\{\ell_\infty(1-\exp(-\kappa(a-t_0))\}^f$$

The initial conditions correspond to a population at its pre-exploitation equilibrium level:

$$N_{1985,a} = \begin{cases} R_o & \text{if } a = 0 \\ N_{1985,a-1}S_{a-1} & \text{if } 1 \le a \le x-1 \\ N_{1985,x-1}/\left(1-S_x\right) & \text{if } a = x \end{cases}$$

The catches are assumed to be removed from the vulnerable biomass:

$$F_y = C_y / B_y$$

where C_y is the catch-in-mass during year *y*,

B_y is the vulnerable biomass at the start of year *y*:

$$B_y = \sum_{a=0} w_a V_a N_{y,a}$$

The values for α and β are determined from the virgin recruitment, R_0 and the steepness of the stock-recruitment relationship. Steepness is defined as the fraction of R_0 to be expected if the spawner biomass is reduced to 20% of the virgin spawner biomass:

$$\alpha = \tilde{E}_0 \left(\frac{1-h}{4h} \right)$$

$$\beta = \frac{5h-1}{4hR_0}$$

The sums of squared is then represented by:

$$SS = \sum_Y \left(ln\, I_y + ln(qB_y) \right)^2$$

where I_y is the CPUE index for year *y*,

B_y is the predicted biomass for year *y*,

q is the catchability coefficient that relates start-year biomass to CPUE as follows

$$q = exp\left(\frac{1}{n} \sum ln\left(\frac{I_y}{B_y} \right) \right)$$

Demographic parameters for the Emperor red snapper were extracted from Grandcourt et al. 2008 and shown in Table 1.5.

Table 1.5. Demographic parameters for the Emperor red snapper (from Grandcourt et al. 2008) and estimated parameters from the age-structured model for the Praslin trap and line fishery (1985-2010).

Parameter	Value	Parameter	Value
ℓ_∞	78.7 cm	κ	0.14 yr^{-1}
t_0	-1.9 yr	e	0.02
f	3.01	S	Exp(-0.12)
a_{50}	3	δ	1
a_m	7		
R_0	8.1	h (steepness)	0.9
q	5.6 E^{-5}	B_{2010}/B_{1985}	0.46

In this basic age-structured model, CPUE is assumed to be linearly proportional to abundance (since β has been estimated close to 1 in surplus production models in Section 1.3.2.). Figure 1.14 shows the trend in the index of abundance derived from the CPUE data and the best fit. This model fit estimates the steepness parameter at 1.0, thus making recruitment constant. The total sum of squares is 1.12. Key characteristics of this fit include a continuous downward decline in abundance since 1985 followed by a "rebuilding" phase from 1997 to 2005 and another decreasing trend after that period for the last 5 years (2005-2010). Further, current estimated biomass is 51 t, corresponding to a level of depletion for the last 25 years (B_{2010}/B_{1985}) of 0.46. If we consider biomass levels in 1985 as close to virgin biomass (B_0) we can infer that the red snapper stock in Praslin is fully exploited and close to a widely used reference points of $B_{MSY} = 0.4B_0$. However, three key main points need to be considered: (i) there are considerable uncertainties in the information on catch and effort available for this stock; (ii) we are only considering catches from trap and line small boats fishery in Praslin, excluding catches from whalers and schooners which are of considerable importance; and (iii) there has been a substantial increase in catches (Grandcourt et al. 2008), decrease in mean sizes of red snapper in recent catches due to a high demand of juvenile fish by the hotel industry ("mini-fish"; Praslin Fishermen Association, pers.comm.) and a steady decline in CPUE since 2005. The level of depletion and the above mentioned considerations call for an urgent need for designing and implementing a management plan and precautionary harvest strategies for this fishery, not only in Praslin, but for the whole Seychelles bank.

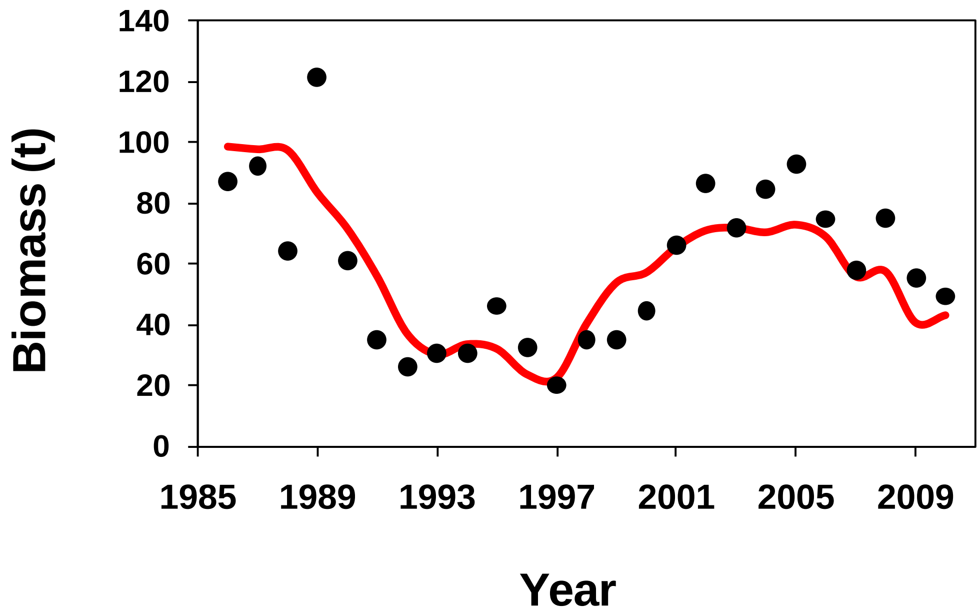

Figure 1.14. Trends in abundance and fit to CPUE data for the Emperor red snapper in Praslin (1985-2010).

1.4 Conclusions

1.4.1 Data limitations

There are obvious limitations in the data available for the assessment. The most obvious is abundance trends. I have explored the use of CPUE and corroborated this with fishermen perception in catch and CPUE trends, but it has to be recognized that none of these are probably the true trend in abundance, and it seems highly unlikely to be able to reconstruct any reliable index that truly represents changes in abundance. In addition, information in the first years of development of the Praslin fishery is not available, with important implications in the estimates of the model fits.

A widely used approach to elucidate the relationship between catch and effort in multi-species fisheries is to ignore species interactions and fit a production model to CPUE data aggregated across all species. Such an approach assumes that any species interaction effects and changes in catchability are captured in the overall relationship between yield and effort, thus any conclusions should be carefully analyzed and set in the proper context. In addition, catch and effort estimates from the Seychelles Fishing Authority are only a sample of the total catches and misreporting has been highlighted by many fishermen in the area (Praslin Fishermen Association pers. comm.). The absolute number of samples is not necessarily limiting, but obtaining a higher coverage would improve confidence in the data and potentially depict small spatial scale and localized fishery trends. Effort also needs to be standardized and better recorded for each gear type and boat. In addition, data was limited to the small boats for the artisanal trap and line fishery in Praslin, while most of the species are also extensively caught by whalers and schooner. Lastly, this is a multi-species fishery were some of the stocks would be likely shared by other fisheries (Mahe for example) or even at larger scale relevant dynamics (at the whole Seychelles bank level). Special caution should be given for those fish species with spawning aggregation behavior such as *Siganus* spp.

1.4.2 Main findings

Alternative approaches to assessing the history of stock production and current stock size and depletion levels in the Praslin trap and line fishery have been explored. All these methods depend on CPUE thus are not in any sense independent. Each of the time-dynamic methods provided estimates that surplus production in the last decades has been as large as the level early in the fishery and thus they are no major sustainability concerns for this fishery at its current level of productivity. While trends in CPUE suggest stable populations for the previous decade, a steady decline has been observed for the last 5 years. This decline in CPUE could be attributed to a higher fishing pressure due to increase in fish demand from the tourism industry and in particular due to an increase in fishing pressure concentrated in nearshore areas and potentially causing localized depletion of resources.

The models used here fail to capture other biological issues such as spawning aggregation behavior of certain species (e.g. rabbit fish) and some territorial behavior in others, and the spatial dynamics of growth and recruitment variability. It is possible, that with more years of detailed spatial data from the community-based data collection program (CDCP) detailed in Chapter 2, much more realistic biological and stock assessment models could be developed. In addition, the CDCP would provide the data needed to monitor trends in abundance without needing to use a formal assessment model. A management strategy could be devised that is based on the data directly rather than using a statistical assessment model. Certainly it would seem useful to update the kind of models used here, or to implement other approaches as soon as more data and possibly estimates of abundance become available. Such an analysis would be required to try to reconstruct the history of the fishery, but would not seem necessary to set up a sustainable ongoing management program.

In the case of the Emperor red snapper (*L. sebae*), substantial increase in catches and decline in CPUE have been observed for the last 5 years. These patterns for the Praslin fishery seem to be related to an increasing demand of this fish for the local tourism industry and specifically a demand for juvenile or “mini-fish” with potential growth overfishing consequences. Given these patterns, and the life history traits of this species (slow growth, longevity and low productivity potential) a management plan and specific harvest strategies need to be implemented in the short term to maximize its productive and minimize the risks of overfishing (see Chapter 3).

Chapter 2

Design of a community-based data collection program for the trap and line artisanal fishery in Praslin

2.1 Introduction

The involvement of fishermen and other stakeholders (e.g. processors) in fisheries management is an ongoing and iterative process that depends on (1) information gathering and sharing, (2) agreeing on common objectives and (3) developing mutually supported management strategies. Such an approach enhances support of management decisions and ensures that the agreed decisions reflect the interests of the fishing community. Most fishery managers today are faced with the challenge of fundamentally changing the traditional top-down agency-driven approach that has historically controlled access to, and use of, fish resources. They are also challenged by the need of information to design and implement a management approach that incorporates users in decision-making processes.

Fishery-dependent information on catch, effort, catch composition and size structure of exploited populations are a valuable and needed tool for stock assessment and sustainable management, especially for artisanal fisheries where fishery-independent information is hard to collect. In addition, data collection for coral reef fisheries with high levels of spatial and temporal variability may require more resources than are typically available for agencies tasked with such management. In recent years, a possible solution to this problem has been to enlist fishery members in a cooperative or community-based data collection program (CDCP). In this respect, Prince (2003, 2005) has proposed extensive use of commercial fishermen as data collectors in order to gather enough information at appropriate scales to support fine-scale management.

A CDCP involves collecting, sharing, and synthesizing essential fishery and scientific data and motivating stewardship by the fishing community. These efforts are required for developing responsible harvesting practices, collecting and distributing a high value product, and perpetuating local-level stewardship of the Praslin artisanal trap and line fishery. In Praslin, artisanal fishermen are motivated by the need for the fishery to remain sustainable and economically viable. To do so, optimizing harvest flexibility and quality requires: 1) collection of biological and fishery data to create a data-rich fishery that allows for informed management decisions, and 2) transformation of the Praslin artisanal fishery community into one that conserves the resource through best practices consistent with market demands and high quality production.

The CDCP will transform the Praslin artisanal fishery from a data-limited status to one based on good fishery-dependent and in the longer term, independent scientific data and models. In addition to focusing on collaborative research between fishery scientists at Seychelles Fishing Authority (SFA) and the fishing community, this CDCP should seek to impart an understanding of the benefits of resource stewardship and information sharing by Praslin artisanal fishermen.

To accomplish this, the Praslin Fishermen Association (PFA) and its scientific collaborators at SFA should implement the proposed system of data collection, sharing, and management. The collected data will be used to revise the stock assessment and prepare for development of a business plan for product enhancement, distribution, and marketing for Praslin Island. The data and revised stock assessment will also be useful to revise the fishery management plan (FMP) in an adaptive fashion. Successes and lessons learned will be communicated to replicate this model in other parts of the Republic of Seychelles. In sum, the proposed CDCP will use the Praslin fishery to create a replicable model for managing the artisanal fishery elsewhere in the country based on sound science, community-driven governance, and value-added markets.

There are three essential components to the CDCP aimed at creating a data-rich fishery, a sustainable fishing community, and value-driven market.

1. Governance Reform: Moving towards Community-based Management

The goal of a governance reform is to develop a system of local governance under guidelines determined by the community and the Praslin Fishermen Association and authorized by SFA and the central government. This co-management system will be developed through the sharing of information and collaborative decision-making based on an accurate determination of the status of the fishery. This component is already being developed by SFA, the Praslin Co-management

Committee (PCC), and PFA and a consultant will be hired to develop a formal community based co-management plan in the following months.

2. Data Collection and collaborative research: the Community-based Data Collection Program (CDCP)

The purpose of collaborative research is to establish data-driven management of the Praslin artisanal fishery. To do so, PFA will develop and foster participation in a data collection program in coordination with SFA to recruit and train fishermen to collect and share essential data, improve data storage and management systems, and review the existent stock assessment. The PFA shall foster the value of data gathering and sharing. To accomplish this, the PFA in collaboration with the SFA will:

- Train fishermen on how to collect information on their catches and explain the importance of data collection and information sharing.

- Investigate mechanisms to incentivize and encourage new fishermen to participate in the data collection program (for example, a certificate of "Research Fisherman", a contest of "Best Data Collector" with prizes, or even subsidies in equipment or gears for the "best collectors" if funding available, among others).

- Develop a system of decision-making centered on "cooperative conservation" in which fishermen jointly decide specific management measures (for example to cease harvesting juvenile fish or "*mini fish*"). This concept is already well grounded within the PFA, but requires education, outreach, and coordination to be effectively implemented.

This data collection and collaboration will provide an adaptive framework to improve harvest strategies in order to obtain optimum use of the resources in Praslin as well as provide the scientific guidance necessary to determine if the catches from the fishery should be reduced or could be increased. Finally, a report on the methodology and findings will be distributed for use as a template for future projects in other fisheries in Seychelles. Details on the Community-based data collection program (CDCP) are given on section 2.2 below.

3. Improved Business Conditions

This component will come at a later stage and will focus on products' diversification (e.g., educate the consumers/hotels/restaurants about underappreciated harvested species) and improved quality and distribution of the product to the consumers (e.g., refrigerated storage, initial processing on fillets, etc). PFA in collaboration with PCC and SFA will initiate programs leading to these objectives, including for example exploring means of assuring quality and developing methods of transporting and storing fish and invertebrates. Once quality, freshness, and delivery have become reliable, PFA will begin outreach and education efforts aimed at the service sector. PFA could potentially work with a financial consultant or other appropriate collaborator to run conceptual business plans using the information gained from data collection and value-added practices.

2.2 Variables of interest and data collection protocol

Fisheries data refer to information that may be of use in the management of a fishery as well as for commercial, cultural or scientific purposes. Types of data may include biological, environmental, economic and social information concerning conditions affecting the fishery.

The core data is the inventory check of fisheries variables used in fisheries statistics reports. This information can also be referred to as fisheries census, and includes the current number of fishermen, number of fishing boats, number of fishing gears by type and some socio-economic information at a sampling port scale. This information is vital as input data used in stock assessments. Another type of data collected from artisanal fisheries is the Catch Assessment Survey. These are landing surveys which are conducted at specific landing sites, including information on catch (in kg), species composition (in groups of species; see Table A1), associated effort (in hours or by trap, line, etc), and other secondary data such as number of type of boat, type of gear, number of fishermen, prices, etc. In some cases these refer to input (fishing effort) and output (catch) fisheries data. The main objectives of the Catch Assessment Survey data are (i) to supply total fish production data by weight, area and the whole country; (ii) to provide total fish production data by species group (weight caught by specific boat and gear type); and (iii) to provide catch per unit effort (CPUE; i.e., average catch per hour, fishing boat or fishing gear).

Artisanal fisheries data is collected on a sampling basis and representing only a fraction of total landings. As earlier described, catch statistics are lumped by sampling port and by species group, leading to problems of masking localized depletion (e.g., wipe out of certain reef areas) or species depletion (e.g, some species may be more vulnerable to the fishing process and their population declining without noticing). In addition, fishermen felt information taken by SFA fieldworkers is sometimes inaccurate or unreliable. Thus, improvement in data collection and analyzes is needed. This section provides a sampling procedure to be conducted by fishermen from the Praslin Fishermen Association in order to improve artisanal fisheries statistics.

The recorded information or variables will include:

- NAME(S) – Names of all fishermen onboard
- NUMBER OF FISHERMEN – Number of fishermen onboard
- DATE – the date which data is collected;
- DEPARTURE TIME – time of departure from port
- ARRIVAL TIME – time of arrival to port
- LATITUDE – Latitude in degrees of fishing site (e.g., location of traps, location of lines)
- LONGITUDE – Longitude in degrees of fishing site
- LOCATION – Location as recognized by local knowledge (when GPS not available).
- BOAT- Circle one of the options: foot, pirogue, outboard, inboard, other.
- NUMBER OF GEARS – Total number of fishing gear involved in fishing (e.g. number of trap)
- TYPE OF GEAR – Circle one of the options and specify quantities
- MATERIAL (for kazye) – Circle one of the options and specify quantities
- BAIT – Bait used if any, including use of *lamnar koko*
- SOAKING TIME START– Day and time the gear has been set
- SOAKING TIME START– Day and time the gear has been recovered
- TOTAL CATCH – Total catch for the number of gear used in weight (kg)
- NUMBER OF FISH – Number of fish caught for the number of gear used

• LANDING PORT – Landing site for that particular catch
• PRICE SOLD – Price in SR of total catch to be filled after selling the catch.
• CATCH BY GROUP- Separate catch into pre-specified groups and weight them by group

• SPECIES ID – Name or species number of the fish being sampled (as per ID Card to be provided and trained)
• WEIGHT – Weight in kg of fish being sampled
• SIZE - Size in centimeters of fish being sampled

Individual fish should be sampled, measured on a fish board to the nearest centimeter and weighted to the 0.1 kg either (i) at random from the total catch by picking them from a basket; (ii) by trap, sampling all individuals in a group of traps (for example trap 4, 8 and 12 out of 12 total traps set) or in a set of lines. Ideally, 30-50% of the total catch should be sampled.
It is expected that each sampling process will take between 30 and 45 minutes depending on the number of fish sampled. With 10 recording days/trips per month per fishermen, the expectation of getting enough data from the Praslin fishing grounds to represent the total population of boats/gears is high.

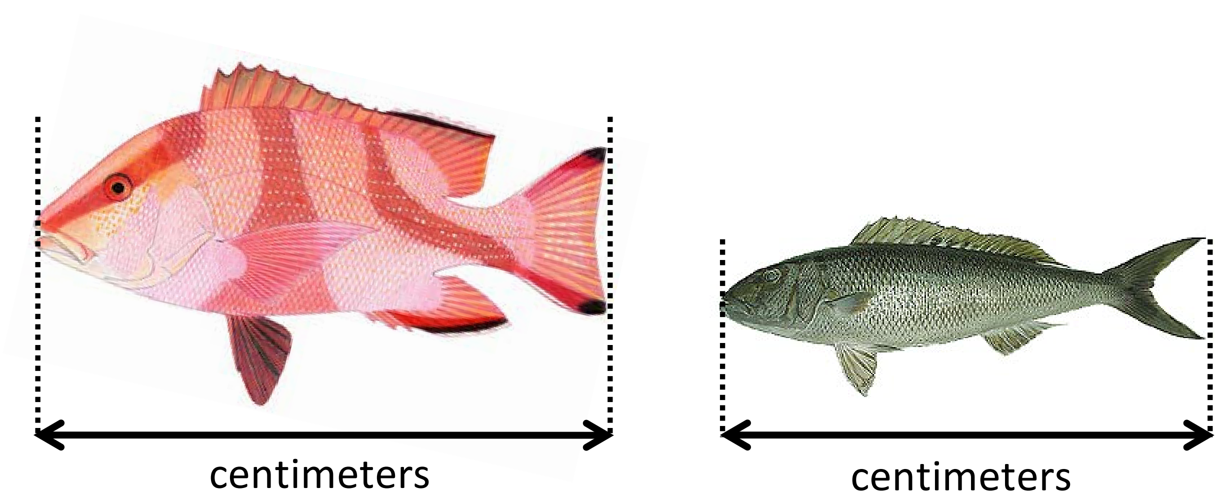

Figure 2.1. General procedure to measure fish to the nearest 0.5 centimetre (from head to fork).

Once the variables, procedures and protocols are understood, hands-on training should be done to ensure methods are routinely applied and to emphasize team work spirit. Training should be a key component of the CDCP development, where fishermen abilities to accurately identify fish to species and to estimate fish sizes and the fished location with GPS are fundamental to the robustness of the program. The following areas should be particularly stressed:

(i) Fish identification skills, by using detailed photographs or color drawings of each species, with key features useful in identification highlighted. Group discussion will allow participants to share experiences and insights relevant to fish identification. Waterproof flash cards showing a picture of each species on the front and common English and Creole names.

(ii) Fish size estimation skills could be practiced using paperboard cutouts of fish shapes in the training room.

Fishermen should be provided with the following tools in order to perform their data collection duties:

- Manual GPS
- Measuring board mounted on the boats to increase convenience and ease of handling and measuring the fish at sea (to be discussed with fishermen).
- Scale
- Species identification card
- Waterproof paper forms and pencils
- Basket to collect samples

The CDCP is developed in a two-tier system to allowed fishermen to begin collecting data at a level they selected or they feel comfortable with and then move up to the next tier when they are ready. The Tier 1 and Tier II data sheets are shown in Figure 2.1. These data sheets were discussed with the Praslin Fishermen Association and some changes were made to fit their requests and suggestions.

Lastly, fishery-dependent data should be linked to environmental information when available to depict the importance of environmental conditions such as winds, lunar phases and even climate change in affecting fishery dynamics and resources. Socio-economic information should be also gathered using interviews and other qualitative approaches.

2.3 Data accuracy and validation

Data collected by fishermen or others not trained in science are often criticized for not being scientifically sound and accurately taken, and hence not often used to inform management. Thus, checking for data accuracy and data validation are key aspects of the CDCP needed to support integration of collected data into the management process. To address data accuracy and validity, robust procedures and protocols need to be clearly defined and easily carried out by fishermen with minimal chance for individual interpretations. This may be achieved by discussion about the data collection method within the PFA (see Appendix X: Training of trainers workshop) and between PFA and SFA. Accurate data should be collected in a repeatable manner that does not vary among fishermen. It also requires discussing individual fishing operations to make sure all participants can integrate the developed procedures and protocols into their operations, especially when fishing individually (i.e., only one fisherman per boat).

Validation of the data may be accomplished through landing ports sampling and constitutes an important component of the CDCP. Total catch, catch composition by species and fish size distributions of at-sea (by fishermen) should be validated by in-port (by SFA fieldworkers) samples and then compared by means of simple statistics (e.g., Chi-square). Sampling protocols with means falling within the 95% confidence intervals of the in-port catch samples should be considered good estimators. Thus, SFA fieldworkers should coordinate port samplings with fishermen data collectors.

TIER 2

PRASLIN FISHERMEN ASSOCIATION
Community-based Data Collection Program

NAME(S): ____________________ NUMBER OF FISHERMEN 1 2 3 4

DATE: __________ DEPARTURE TIME: __________ ARRIVAL TIME: __________

LATITUDE: __________ LONGITUDE: __________ LOCATION: __________

BOAT: Outboard Inboard Other

NUMBER OF GEAR

Kazye peze	1	2	3	4	5	6	7	8	Kazye lavol	1	2	3	4	5	6	7	8
Kazye dormi	1	2	3	4	5	6	7	8	Line	1	2	3	4	5	6	7	8
Bamboo	1	2	3	4	5	6	7	8	Wire	1	2	3	4	5	6	7	8

BAIT: ____________________ LANDING SITE: ____________________

SOAKING START Date and time: __________ SOAKING END: Date and time: __________

TOTAL CATCH: Weight: __________ Number of fish: __________ Price sold: __________

CATCH BY GROUP: (weight in kg)

Kakatwa		Sirizyen		Snappers	
Kordonyen		Korn		Bekin	
Kapitenn		Vyey		Karang	

No	SPECIES ID	SIZE	WEIGHT
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

Figure 2.2. Data collection sheet for the trap and line artisanal fishery in Praslin. Red square contains Tier 1 and green square Tier 2 data collection protocol.

2.4 Data management, processing and sharing

Data entry personnel have to spend some time on checking the quality of the data recorded by community members before entering it. Data management should be done independently to SFA to overcome the stumbling block of fishermen sharing their proprietary information.

Confidential information includes the location of catch, effort, gear and baits used and prices. Fishermen may express concern about the release of these sensitive data and the potential misuse of collected data by others. To address this concern, data can be reported only in summary format (meta-data instead of raw data) and data points grouped together without identifying specific information for each fishermen. This minimizes the chance for revealing confidential information about an individual's fishing activities. In addition, sensitive information can be stored in a ‘‘confidential database’’ in which the data of concern would be coded and then placed into a ‘‘shared’’ database. However, considering the value of this information for fisheries managers, information sharing is encouraged by signing a confidentiality agreement including the following:

- Information shall not be shown on a map nor transmitted to a third party without express permission of PFA.
- Individual fishermen data shall not be published.
- A person assigned by PFA shall review all proposed reports and publications to prevent any inadvertent disclosure of the data collected by fishermen.
- In publications where PFA's intellectual property (data gathered under the PFA community-based data collection program) is utilized, the counterpart should agree to demonstrate this fact through co-authorship of the publication by a person assigned by PFA.

On a semester basis the participating fishermen should be provided with two reports. One report will consist of only their data whereas the second report will include all the data that had been submitted by all participating fishermen. These reports are useful for the fisherman's personal fishing activities and will also aid in the development of a cooperative fishery and business. In the collective reports, no maps should be shown and the area harvested is only identified as an area of 1 minute latitude unless all participants agree on making their information publicly available. The exact location of the area is known only to the Data Coordinator.

Finally, it is suggested that regular (e.g., every 6 months) meetings or "social events" are conducted to revise the data collection protocols and where fishermen can share their experiences, motivation and concerns, as well as strongly recommended to convene on a workshop a year after the commencement of the data collection program to evaluate its performance and analyze the information for trends in the fisheries statistics.

2.5 Incentives, rewards and funding

In order to enhance fishermen participation in the program and for the fishermen to perform a better job in data collection, community members who are responsible for the statistical collection should be motivated and receive assistance to compensate the time lost to their daily activities. Rewards for participation are always a good way to keep fishermen interested in data collection. For example, at the completion of 50 days of data collection an award could be given together with some rewards such as tools, instruments, or equipment.

After interviewing several fishermen from the Praslin Fishermen Association, most indicated that a primary incentive for their involvement in a community-based data collection program was the ability to acquire data, allowing for more-efficient harvesting strategies that maximize profitability and resource sustainability. Most complained about a lack of efficiency, weak coverage and misreporting of catch and effort data from fieldworkers at SFA. As in terms of keep the motivation and to include more fishermen into the program, social events such as fishing competitions and small awards and prices for those individuals collecting information seemed to be the most doable and effective approach. Some also mentioned that subsidies in terms of fishing equipment (e.g., mechanic winches, bamboo traps, etc) would be effective in keep fishermen collecting information. Confidentiality seems not to be an issue and most fishermen were willing to share the information within the PFA and eventually with SFA.

An alternative approach of having a data collection fee associated with the PFA membership was mentioned without much success, although it is an alternative that could be explored in the medium term. This fee would have to be collected and maintained in a separate fund specifically for data collection efforts, thus requiring development of new administrative processes. Further, a basic economic analysis of the costs associated with the data collection programs would be required to set the fee at a level that would adequately support the data collection efforts. This mechanism will include contributions from all participants of the fishery, whether engaged in or supportive of the data collection program or not, because everyone in the fishery would benefit from the additional data.

2.6 Expected outcomes and benefits

- Improved communication and cooperation with the Seychelles Fishing Authority
- Capacity, stewardship and enhanced feeling of "ownership" in Praslin artisanal fishery
- Data collection and improved management systems for the fishery, which can be replicated to other areas in Seychelles.
- Adaptive management using an accurate and data-rich stock assessment
- Conservation of the resource through diversification of fishing effort
- Improved market value for fishermen
- Increased availability of good quality, local fish to consumers in Praslin
- Enhanced social capital an internal level of cooperation, goodwill and good-faith among the fishing community members; community empowerment, cohesion and trust.

Community based data collection programs can provide fishery information over a large temporal time scale and at fine spatial resolution, both needed for proper management of coral reef fisheries. Once established and running, such programs will provide data as long as the fishery continues, which is highly important given the long-term changes in environmental conditions (e.g., ocean regimes and climate change) affecting marine populations. CDCPs will enable the Praslin community to become more involved in the management of their local fisheries.

The economic benefits and costs of CDCP to managing agencies and the fishing industry will be related to obtaining access to more data using the same or fewer state (i.e., SFA) resources (e.g., personnel, analyses, boats, some supplies).These data will have greater spatial and temporal coverage than could be obtained directly by the Authority through its fieldworkers program. Fishermen would bear much more of the economic burden, having to contribute time to not only collect the data but also to participate in discussions of data analyses and interpretations. Thus, an incentives or compensation scheme for fishermen should be used to sustain much of the financial burden of the program. Further, information collected by fishermen will be used, individually or at the PFA level, to increase the effectiveness of the fishing process and the business process. Lastly, by contributing their knowledge and skills to the collection of more comprehensive and current data than are presently available to fishery managers, they will realize the benefits from long-term sustainability of the fisheries they rely on for their livelihood.

Chapter 3

Recommendations for the Praslin fisheries management plan and harvest strategies

3.1 Introduction

Fish stocks for which there are limited data available from a fishery pose a considerable challenge for stock assessment. Here, we define ‘‘data limited” as meaning that there is limited data to permit application of quantitative stock assessment methods, such as statistical catch-at-age analysis and virtual population analysis, which involve fitting time-series of abundance data to estimate changes in population size over time. Many artisanal fisheries have low gross values of production (GVPs), are in developmental phases, and sometimes with only a few active operators in the fishery, although there may also be a substantial amount of latent effort. For some of these fisheries or species, quantitative stocks assessments are not available given the costs of research and monitoring, or because the collection of fishery-independent data has not been considered important in the past. However, certain degree of data richness can be achieved by developing targeted research in specific topics such as life history of the species, catchability of the different gears, and dynamics of spawning aggregations. These potential areas for research are explored in Section 3.2.

For the artisanal trap and line fishery, the multi-gear and multi-species nature makes the implementation of management measures difficult to overcome. In fact, there has never been a formal management plan and the fishery has been managed informally via fishing licenses. There are no output controls or harvest strategies and the information regarding the different species/stocks is limited. Consequently, the status of the fishery is rather uncertain, although it is assumed that current levels of effort may be sustainable (see Chapter 2). However, many of the exploited demersal species, such as snappers (*Lutjanidae* spp), are long lived, slow growing, late to mature, and thus with low productivity, while others like rabbitfish (*Siganus* spp) are vulnerable to overfishing because they aggregate to spawn. Consequently, management measures and regulations should be implemented and harvest strategies for this fishery should be focused on detecting impacts of increases or changes in effort and catches. Section 3.3 highlights some management regulations to be explored within a formal management plan.

Under most fisheries management policies, the status of a fish stock, depletion level, reference points that delineate overfished and overfishing limits, and sustainable annual catch limits must be specified. Yet, determining stock status requires a decision about what the level of depletion was at the start of the data series, what would be the optimal depletion level (for example, MSY level), and how far below the optimal depletion level the limit should be agreed. In some cases, the resource may have been depleted for much of the time-series or still in the developing phase so there is little contrast in the spawning biomass and MSY references points are highly uncertain or inaccurate as is the case for the artisanal trap and line fishery in Praslin (Section 2). In all these situations, proxies are often employed in place of the true MSY level (Restrepo and Powers, 1999). Common proxies are based on productivity such as a percentage of spawning potential ratio (SPR) or average biomass level or based on rates of fishing mortality (e.g., $F_{0.1}$). But these proxies also require considerable amount of information, as well as the technical and scientific capacity to develop and update them. Thus, alternative approaches to help managers and fishermen to choose appropriate management systems and alternative harvest strategies are introduced in section 3.4.

3.2 Research recommendations

In addition of the information to be gathered by the community-based data collection program, the management plan would benefit from the following research activities:

1. Biological studies for the main species, particularly growth, age at maturity and fecundity. Gaining insights on these aspects will allow to develop more accurate biological models for stock assessment, as well as to design fisheries regulations such as minimum mesh size and minimum landing sizes. When possible, these studies should be conducted at the relevant spatial scale to capture fine scale patterns in life history (especially for reef fish).

2. Gear catchability and selectivity, especially for the trap fishery. The Praslin artisanal trap and line fishery involves 4 different types of gear: pole and line, *kazye dormi*, *kazye peze*, and *kazye lavol*. At the same time, traps or *kazye* can be made of bamboo or wire. These different types of gears and materials may significantly affect the catchability and selectivity of the gears, as well as their impact in the substrate and the ecosystem as a whole. Thus, these important aspects affecting gear catchability and hence catch and effort data should be investigated through a robust experimental design with several treatments if possible, such as different gears, different materials, different substrate types, and different seasons. The area of the influence of the trap could be computed by different methods (for example the Effective Fishing Area, EFA, approach; Eggers et al. 1982; Gutierrez et al. 2011), the catchability as the number of fish caught in each treatments and the selectivity by measuring the individuals caught.

3.3 Management regulations recommendations

This section arises from interviews with fishermen and SFA personal but by any means represents a comprehensive and final list of recommended management regulations. Additionally, it is vital to discuss the design, implementation and enforcement of any management regulations with fishermen (PFA) and other stakeholders.

1. Use of wire traps should be discouraged. The number of trap loses in Praslin has been identify by fishermen as high, and such type of durable traps are thought to increase considerably ghost fishing. This occurs when fish are caught and retained inside the derelict trap without being recovered. The replacement of bamboo by wire resulted in more durable traps with a longer ghost fishing period. Traditionally, bamboo hexagonal mesh traps have dominated the fishery, but now smaller mesh size wire traps have become popular in Praslin and other areas. These traps are constructed of a heavier gauge wire and may lead to higher rates of ghost fishing mortality, longer ghost fishing periods, and greater potential for coral reef damage than bamboo traps.

2. Although mesh size regulations exist, no studies of gear catchability and vulnerability of the different species to different gear types have been conducted or updated. Although mesh size regulations may reduce catching juvenile fish and are relatively easy to enforce, they are not 100% effective when dealing with multi-species fisheries, where size at maturity differs among targeted species. Hence, a more effective measure would be to implement minimum landing sizes, especially for those commercially and/or culturally important species, and/or for those identified in the PSA protocol (see section 3.4). These species-specific minimum size regulations should be linked to size at maturity studies (see section 3.2) and should be implemented through educational workshops directed to the supply sector (e.g., fishermen) as well as to the demand sector (e.g., hotels). This measure may be enforced both at the fishermen level (by inspecting landings) and at the hotel industry level (restrictions on buying and selling *min-fish*).

3. Spatial and temporal closures have been proven effective in many fishery resources and particularly for coral reef fisheries. These operational tools should be designed to allow reef areas to recover when weather conditions allow to fish in outer areas (for example by banning fishing in certain reef areas outside the monsoon season). These spatial closures may be set within a rotational scheme to allow recovery of all reef areas around Praslin.

3.4 Monitoring and harvest strategies recommendations

A harvest strategy is a plan that sets out the management actions necessary to achieve defined ecological and sometimes economic objectives in a particular fishery. A harvest strategy should specify a process for monitoring and conducting assessments of the biological and economic conditions of the fishery as well as specific rules (i.e., harvest control rules) that control the fishing effort according to the biological and economic conditions of that fishery. In general, harvest strategies should be pragmatic (given the economic and data limitations), cost effective, transparent, easy to understand to all stakeholders, and adaptive (able to change as more information becomes available (Dowling and Smith 2007).

There are several principles for a harvest strategy that could be applied in data-limited situations and/or when resources for sophisticated quantitative stock assessments are not available (Figure 3.1): (1) identifying data-gathering protocols and subsequent simple analyses to better assess the fishery (as the community-based data collection program described in Chapter 2 and in Schroeter et al. 2009); (2) incorporating information derived from monitoring marine protected areas if available (for example using density-ratios; McGilliard et al. 2010); (3) Productivity and Sensitivity analysis (Field et al. 2010); and (4) trigger levels as proxies for reference points (Dowling et al. 2008). In the last case, there is clear trade-off between implementing conservative reference points in the face of uncertainty, against the cost associated with obtaining more information that would likely to allow higher exploitation levels. Further, the challenge is to reconcile harvest strategies and reference points against the reality of the available data and assessments and the low GVP for artisanal fisheries.

The density ratio (DR) control rule refers to the ratio of the fish density outside a marine protected area (MPA) or reserve to that the density inside it based on stratified (where strata represent inside MPA and outside MPA) random sampling (McGilliard et al. 2011). The DR is used as an indicator of stock status where the density inside an MPA is the best available representation of unfished conditions. Thus, harvest control rules may be applied when density outside the reserve is for example X% lower than the density outside the MPA. Unlike point estimates of unfished biomass from a typical stock assessment, the density inside an MPA is subject to the same fluctuations in environmental conditions as the fished portion of the stock. Fish densities inside well enforced MPA estimated through underwater visual censuses may represent a doable and easy to implement reference point for the Praslin artisanal fishery.

Once additional information is accessible (for example through community-based data collection programs and specifically on basic life history), methods like Productivity and Susceptibility Analysis (PSA) can estimate individual species vulnerability to fishing pressure, relative to other species (Field et al. 2010). By simultaneously accounting for estimated stock productivity and stock susceptibility to fishing effort, PSA produces estimates of overexploitation risk. Although the PSA approach allows identification of species potentially most at risk of becoming overfished or experiencing overfishing, it is not possible to make stock status determinations based on PSA criteria. In any case, it is not possible to implement meaningful triggers for every species captured in this fishery, so harvest strategies should be focused on species with most commercial and/or cultural species as well as high-risk species identified by the PSA (Smith et al. 2007).

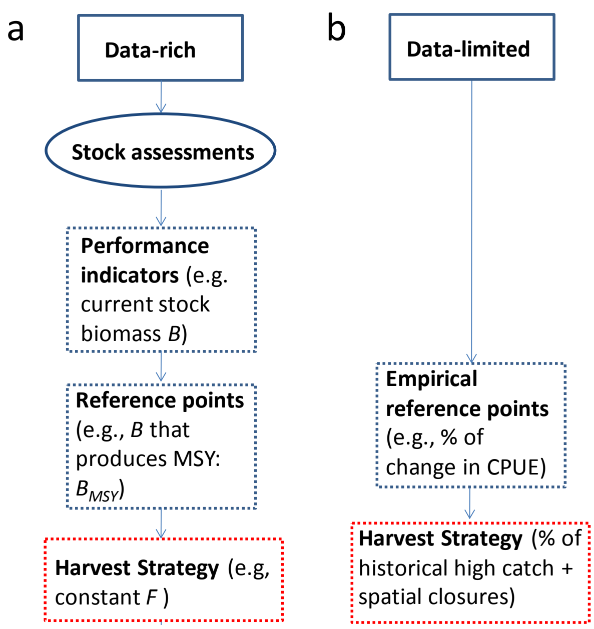

Figure 3.1. Flowchart indicating the technical process for developing a harvest strategy by (a) integrating all the available information in stock assessments to generate limit and target reference points; and (b) using the data available directly to generate proxies for reference points (trigger levels).

For small-scale, artisanal fisheries, or fisheries with low Gross Value of Production (GVP) harvest strategies are often based on triggers rather in reference points obtained through quantitative stock assessments. These approaches combine empirical reference points or trigger response levels with decision rules that aimed to improve the knowledge of the fishery by first collecting biological data and hence provide a basis to further develop the harvest strategies using more sophisticated assessments in the future (Brooks et al 2010; O'Neill et al. 2010). These harvest strategies need to consistent to the reference points, in which an extreme case could be a simply “best guess” proxy suggesting little knowledge of their relative magnitude with respect to the biomass thresholds to which they were intended to correspond. Thus, in the absence of biomass estimates, and hence biomass-based target and limit reference points, conservative trigger level proxies may be identified as reference points based on the available information (e.g., historical catch data, CPUE, mean sizes of the catch, etc.). Possible triggers may include: (i) changes in averages (e.g., X% of change in CPUE from the long-term average) or trends in CPUE (angle or slope of actual and target CPUE; Figure 3.2); (ii) changes in spatial fishing patters using geo-referenced information (especially to detect serial depletion processes); (iii) changes in species composition; (iv) changes in mean and maximum caught fish sizes; or a combination thereof. If possible, given the small scale spatial structure of some of the reef fish targeted by the Praslin artisanal fishery, these triggers should be area- or zone-specific. Additionally, each trigger should involve different response levels such that progressively higher data and analysis requirements are assigned to higher response levels to minimize the risk of overfishing associated with further fishery expansion. If a response level is reached, then the status of the fishery or a particular species will be re-assessed with a possible revision to the amount of allowable harvesting.

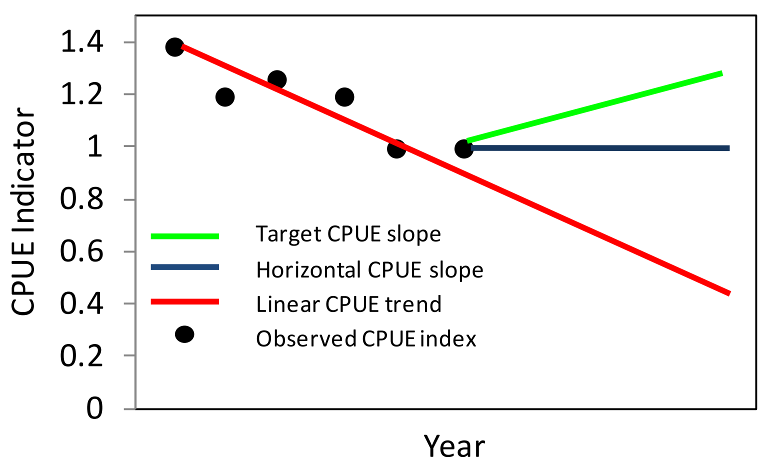

Figure 3.2. Schematic representation of different slopes to be used as harvest strategies. Red line indicates the linear regression of the observed CPUE; the blue line represents a harvest strategy to drive the CPUE constant in time; and the green line a harvest strategy to increase the slope of the CPUE in X% as an empirical target reference point.

The described approach for developing harvest strategies in data-limited fisheries should be part of an iterative process involving discussions among scientists, fishery managers and fishermen. Further, it should not only be precautionary to accommodate any uncertainties but also be directed towards more informed harvest strategies once fisheries further develop (e.g., if exporting markets are being developed or expanded). For this purpose, different response levels may be set for any trigger, with an increasingly need for information and detailed assessment to be undertaken at each of those levels (Figure 3.3).

1. Level 1 should be conservative (e.g., half its historical high catch) and may represent an early indicator of a given change in the dynamics of the fishery that deserves clarification from either a management, economic or sustainability point of view (e.g., what factors are responsible for consistently lower catches). Examples of this level of trigger may include low harvest rates and low catch volumes, in which case the fishery is unlikely to have funds available to support detailed assessments. However, low-cost exploratory analysis such as spatial and temporal CPUE trends or size frequencies of the catches should be performed, especially once the community-based data collection program gets fully implemented. Further, causes of changes should be discussed internally at the PFA, and with managers at SFA. If a reasonable justification for the observed changes can be made that does not relate to potential overfishing (e.g., catches have decreased because of a change in market demand as opposed to decreased availability), then the fishery may continue with no immediate management intervention. On the contrary, in the absence of any other explanation, precautionary management responses such as spatial or temporal closures (e.g., nearshore reef areas close after monsoon season) as well as a revision of the subsequent response level values of the trigger.

2. Level 2 should be set at a value intended to correspond to a level of exploitation that deserves a more informed and robust evaluation of stock status. This level is still intended to be conservative, although a more formal stock assessment should be undertaken on the species to justified increasing existing response level values.

3. Level 3 may be considered a proxy for a limit reference point (LRP) after which all fishing pressure on the species must finish and no further increase in catch or effort should be allowed pending expert consultation and more detailed or sophisticated stock assessments.

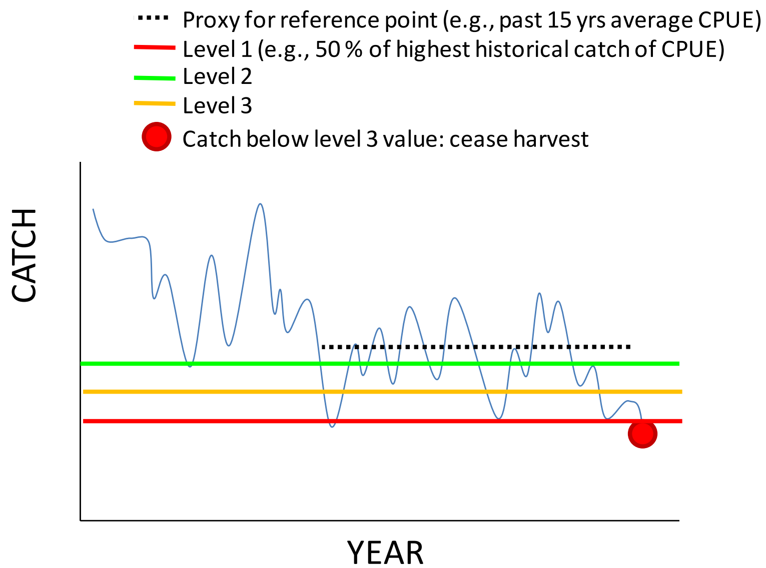

Figure 3.3. Schematic representation of a trigger or proxy for reference point (i.e., changes in current catch or CPUE with respect to the previous 15 years average or values with respect to historical high catches) with 3 different levels: (i) level 1 (most conservative) corresponding to a value equal to 50% of the historical high annual catch. Going below this point will need at least an explanation on whether changes reflect issues others than overfishing; (ii) level 2, where going below this value will require availability and analyses of relevant information and assessment of the stocks; (iii) level 3, where current catches below this level will imply a cease of the fishing activity until further stock assessments or expert consultation.

It is important that for any given fishery, more than one type of trigger is considered so that the overall strategy gets defined in terms of multiple triggers (i.e., a set of triggers). Moreover, catch quotas regulations based on trigger levels or proxies for reference points without robust point estimates of biomass or stock status should be accompanied with direct methods such as spatially-explicit management tools. Spatial management is a useful management tool in the context of data-limited fisheries and especially in coral reef fisheries. It may provide protection for at least a portion of a fished population, as well as for habitat, without a great deal of complex regulations that incur high compliance and monitoring costs. Thus, spatial management measures may be used to enhance a trigger-based harvest strategy or spatial restrictions may be part of a decision rule in response to a trigger level being reached.

The harvest strategy described above should be developed in cooperation with fishermen and other stakeholders, for example through a series of workshops with the Praslin Co-management Committee (PCCC), the Praslin Fishermen Association (PFA) and the Seychelles Fishing Authority. Again, emphasis should be given on an iterative approach via direct engagement with fishermen and other stakeholder groups (e.g., National Park authorities) at management meetings. Given the nature of the multi-species and multi-gear fishery and the paucity of data, anecdotal information from fishermen will be particularly important when identifying the key species and developing potential trigger levels. Fishermen knowledge may also assist with the identification of appropriate spatial management boundaries.

General recommendations

Chapter 1

1.1 Information contained in the Catch Assessment Surveys need to be compiled as total catches, catches by species, by areas, by gear and by boats and ready to use as inputs in future stock assessments (not currently integrated in terms of small boats, schooners, etc).

1.2 Measures of fishing efforts should be standardized not only for the artisanal boats but for the whole fishing fleet (including schooners and whalers). The way the information is available now may difficult future evaluations and stock assessments and infer biases in CPUE indices.

1.3 A stock assessment for the whole Seychelles plateau should be conducted, especially in a species by species basis when available information (for example for red snapper).

1.4 Once geo-referenced information becomes available, both stock assessments and management plans should incorporate that information in order to elucidate spatial patterns in the population and fishery dynamics.

1.5 Size frequency distribution of the catches should be obtained, both from the community-based data collection program and from fieldworkers. This would allow elucidating proportion of juvenile fish in the catch as well as trends in stock size structures.

1.6 Social and economic information should be also gathered and analyzed in order to explain trends and patterns and better design and implement management measures.

1.7 Regular consultation meetings with fishermen and other stakeholders (e.g., National Park authorities) should be implemented as part of an adaptive (co-) management plan.

Chapter 2

2.1 The community-based data collection program (CDCP) should be initialized with a hands-on training using all tools and equipment (GPS, measuring boards, etc.). Training should help fishermen to use tools and to fill out forms with real data. Social hours should follow.

2.2 SFA fieldworkers should be also trained and informed about the information collected by fishermen and a validation program (i.e., gathering the same information once fishermen land the catch) should be implemented simultaneously to the CDCP.

2.3 A data manager should be trained to enter the information into spreadsheets once it becomes available. Information should be double checked periodically.

2.4 Periodic (e.g., every 3 or 6 months) meetings should be organized in order to provide additional training to data collection and to provide an assessment of the first months of implementation. Social hours for data collection should follow.

2.5 After the first year of implementation, a comprehensive analysis of the information collected should be performed and all fishermen in the program should be provided with an individual and personalized report (trends in catches and effort, species caught, maps of areas fished, etc) of their information. Social hours should follow with “awards” and “prices” for the most dedicated data collectors.

2.6 A system of incentives should be provided, as well as a system that recognized those fishermen initially in the program but not collecting information (for example by excluding them from the program and getting all tools and equipment back after 3 months without data collection).

2.7 An agreement of confidentially and data sharing within the PFA and between PFA and SFA should be designed and implemented.

2.8 A business plan for the PFA should be designed and implemented together with the CDCP.

Chapter 3

3.1 Areas of research identified in Chapter 3 should be designed, planned and implemented in the short term.

3.2 A management plan should be designed and implemented considering, not exclusively, the management regulations mentioned in Chapter 3. Any attempt to develop a management plan should be participatory and include all stakeholders.

3.3 Harvest strategies and harvest control rules like the one described in this Chapter should be carefully designed as part of the management plan.

Appendix 1. Additional results from the data analyses and stock assessment

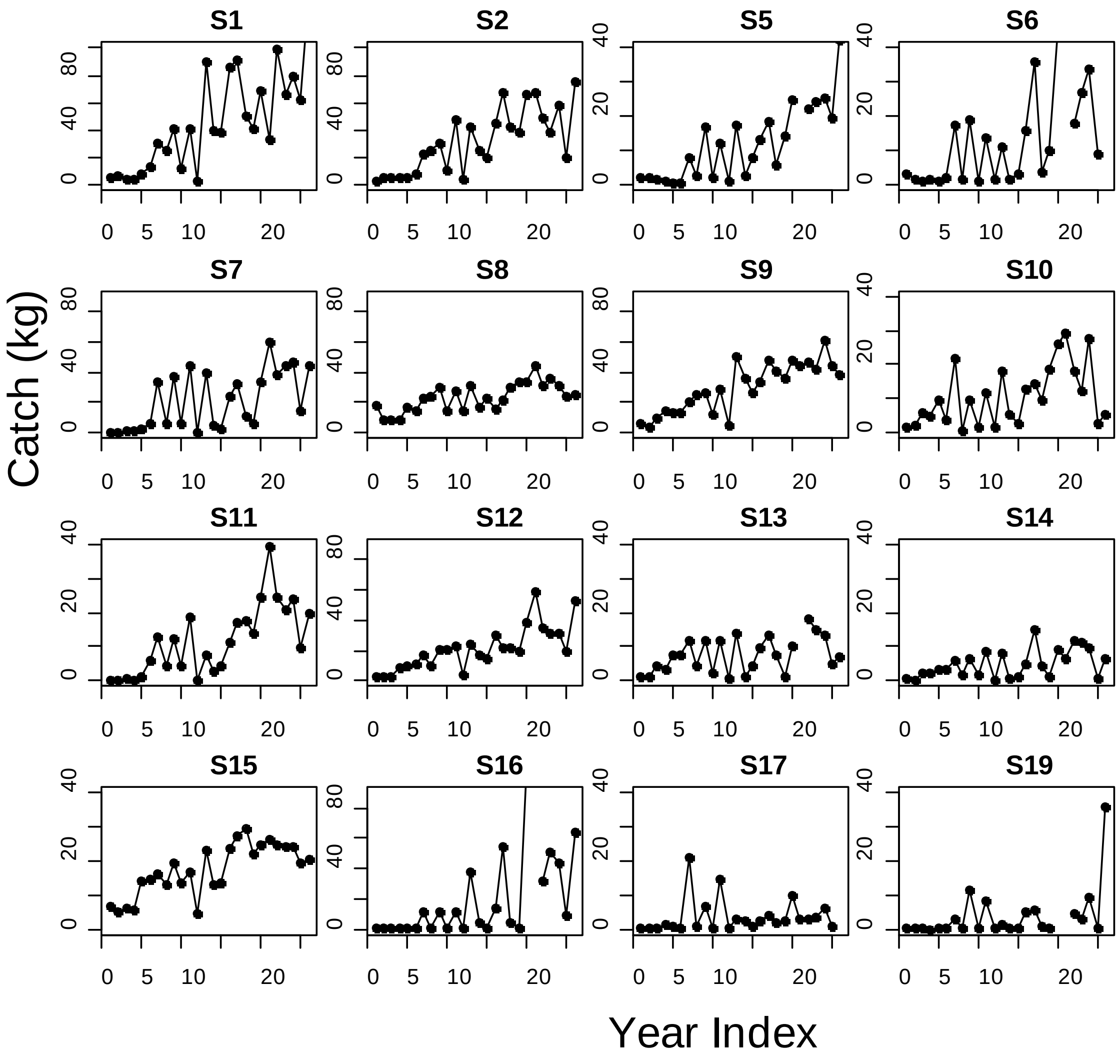

Figure A1. Catch (in kg) from small boats in the Praslin artisanal fishery and for all species groups from 1985 to 2010.

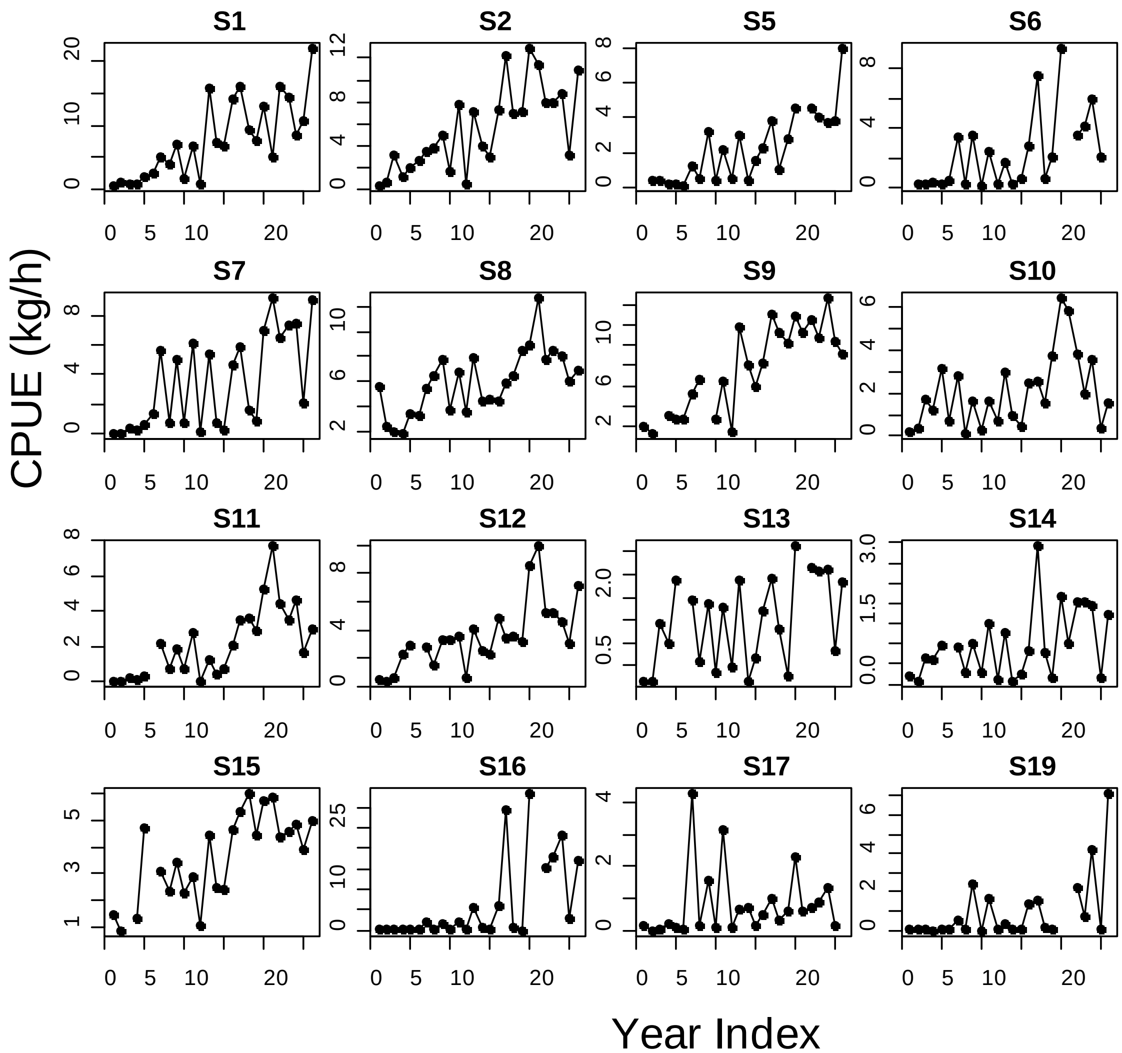

Figure A1. Catch per unit of effort (in kg per hour) from small boats in the Praslin artisanal fishery and for all species groups from 1985 to 2010.

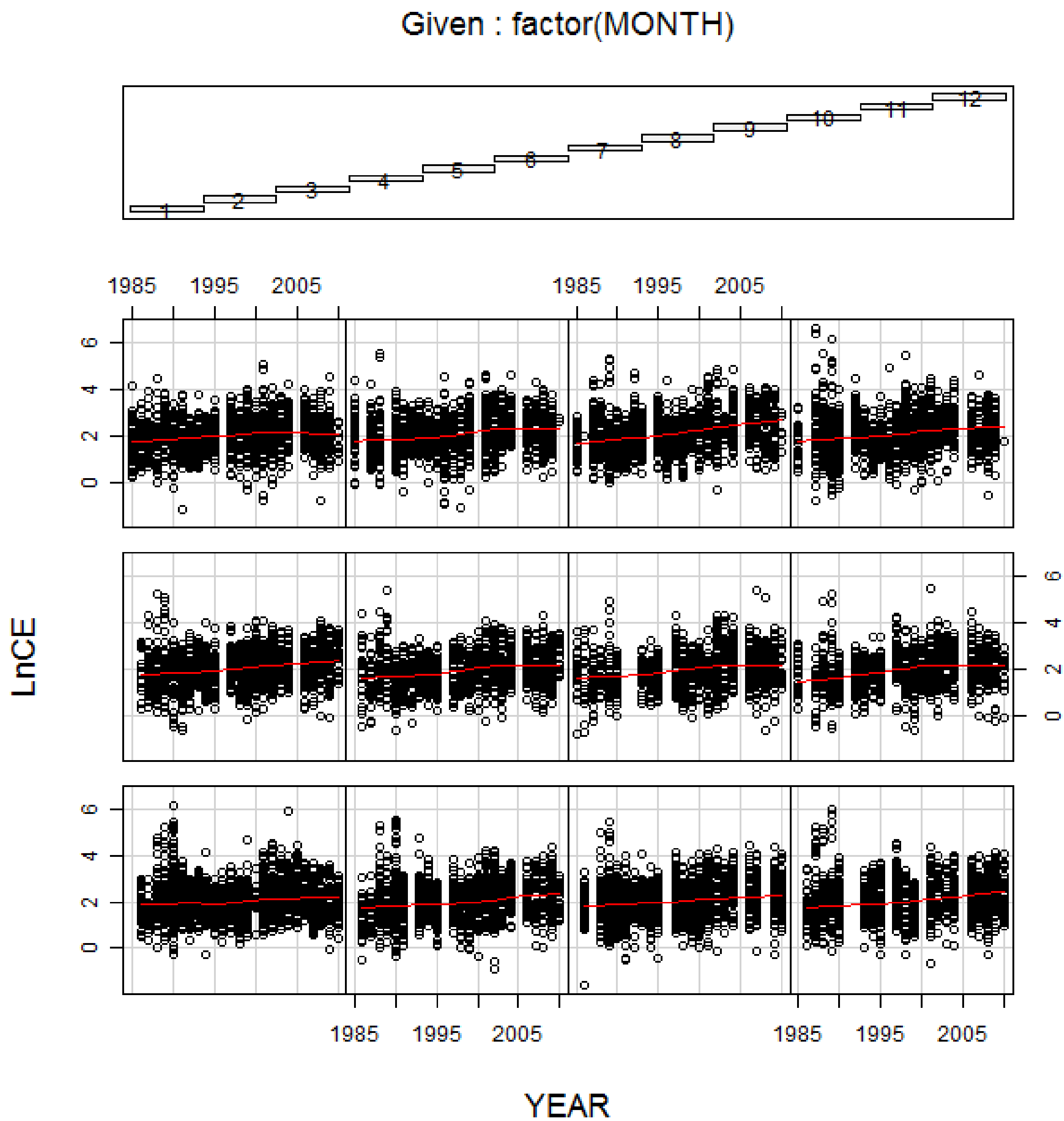

Figure A3. Plots of regression terms for general linear model for log(CPUE) using month as predictor (January to February from lower left corner to upper right corner).

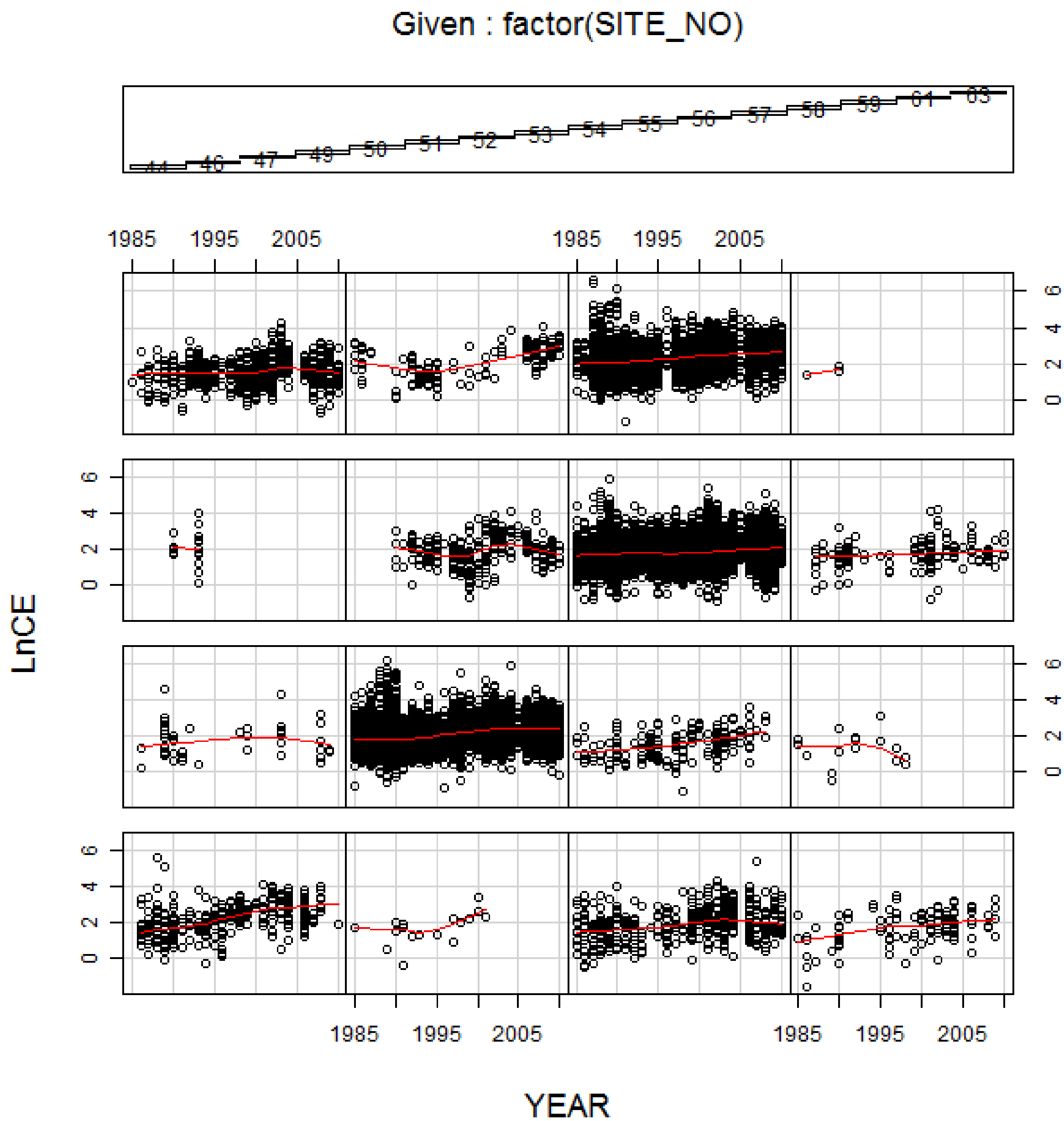

Figure A4. Plots of regression terms for general linear model for log(CPUE) using landing site as predictor. Most catches landed in sites 51, 56 and 61.

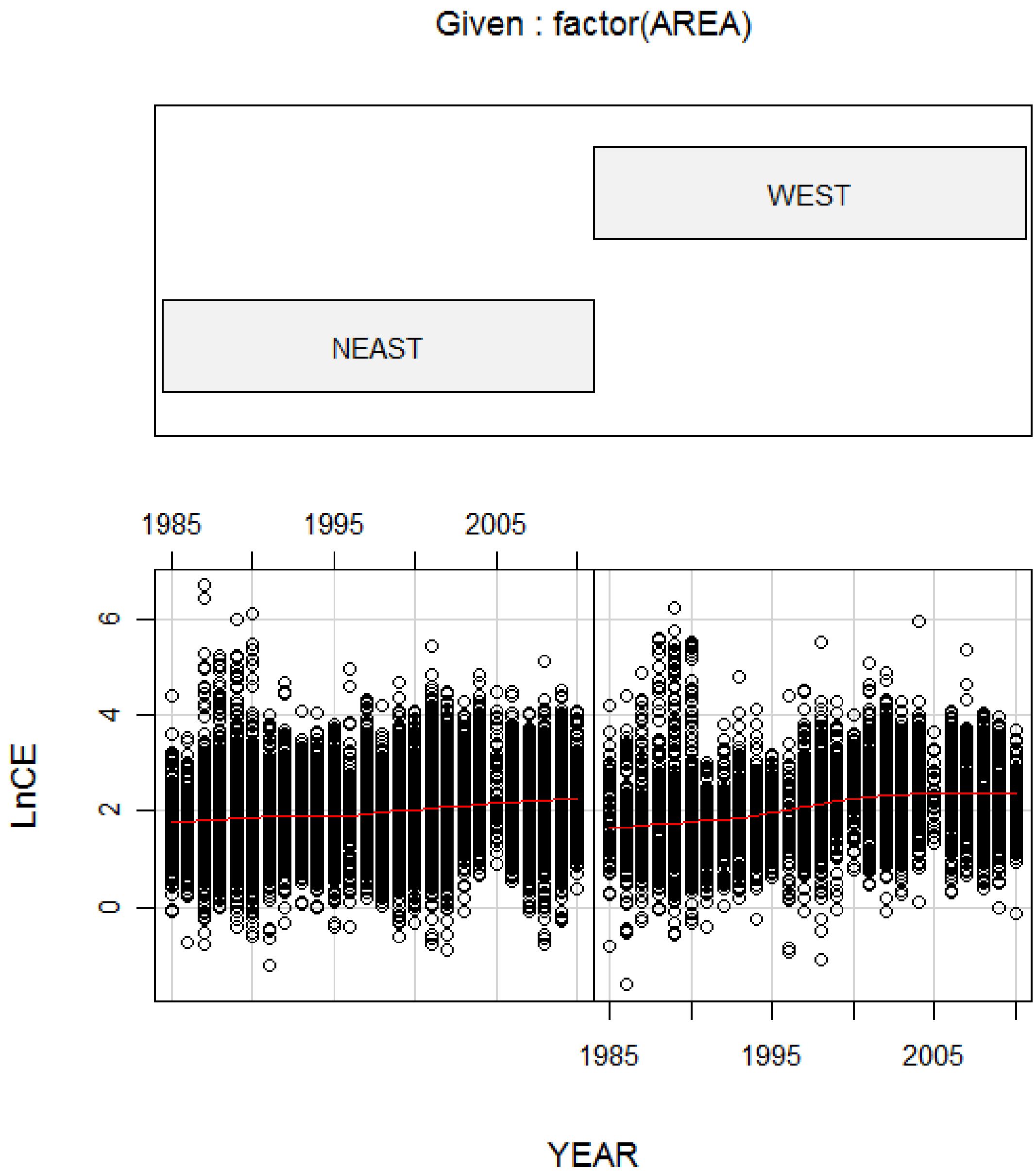

Figure A5. Plots of regression terms for general linear model for log(CPUE) using area (West and North East) as predictor. CPUE shows a higher rate of increase around 1997 for West Praslin (right panel).

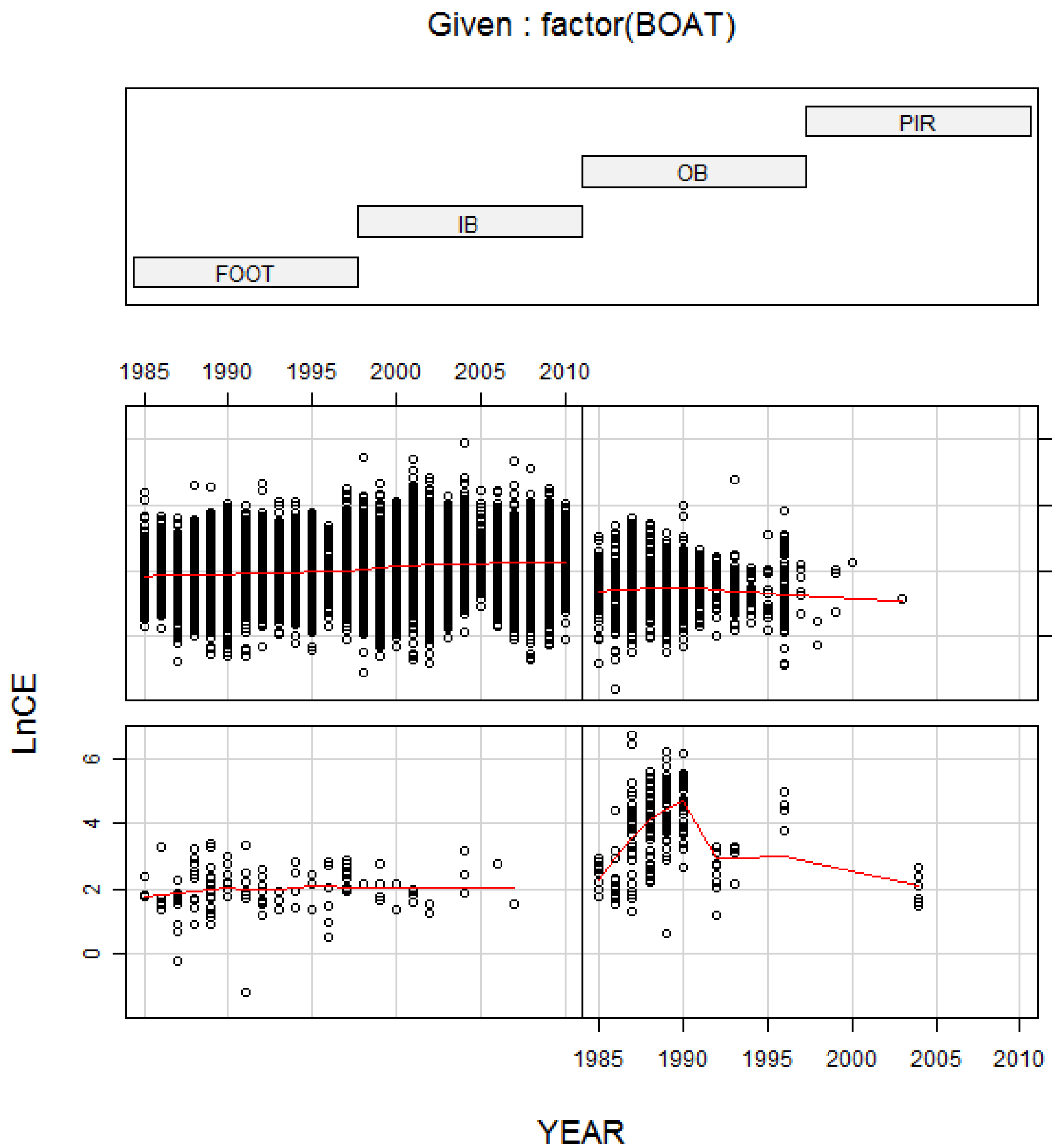

Figure A6. Plots of regression terms for general linear model for log(CPUE) using type of boat as predictor (PIR= Pirogue; OB = outboard; IB= inboard; FOOT = fishermen by food targeting octopus). Pirogues have been used only until 1995, where they have been replaced by outboard engine boats.

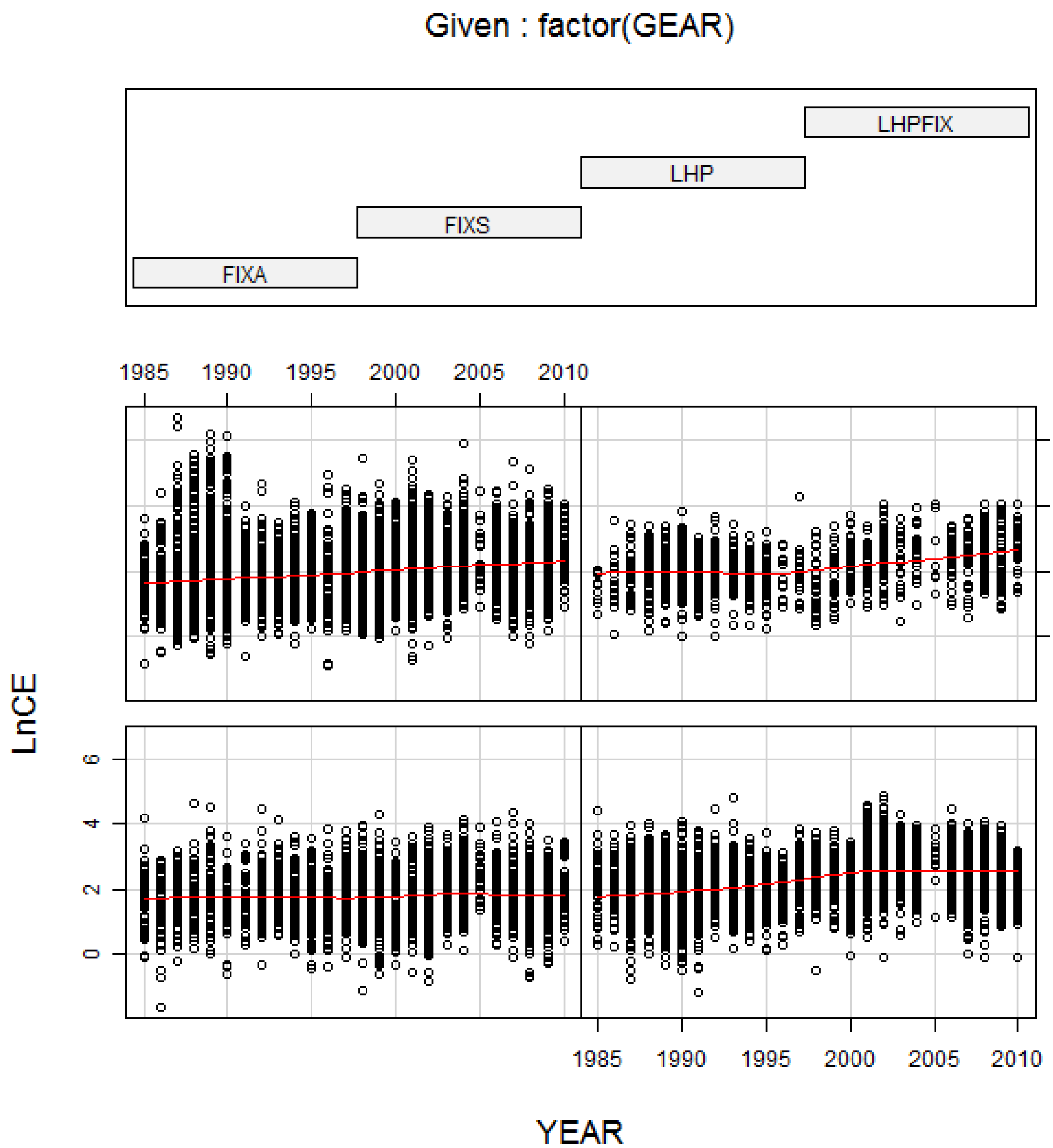

Figure A7. Plots of regression terms for general linear model for log(CPUE) using type of gear type as predictor (from upper right to lower left corners: LHPFIX = mix of pole and line and fixed traps; LHP = pole and line; FIXS = fixed passive traps; FIXA = fixed active traps). Both LHPFIX and FIXS showed a significant increase in CPUE after 1998.

Table A1. Results of GLM and ANOVA for log(CPUE) for the artisanal trap and line fishery in Praslin.

	DF	F value	Pr(>F)
Year	25	148	< 0.001
Boat	3	4107	< 0.05
Month	11	37	< 0.001
Gear	3	205	< 0.001
Month:Gear	33	11	< 0.001

Residual standard error: 0.7404 on 15419 degrees of freedom

Multiple R-squared: 0.2156, Adjusted R-squared: 0.2118

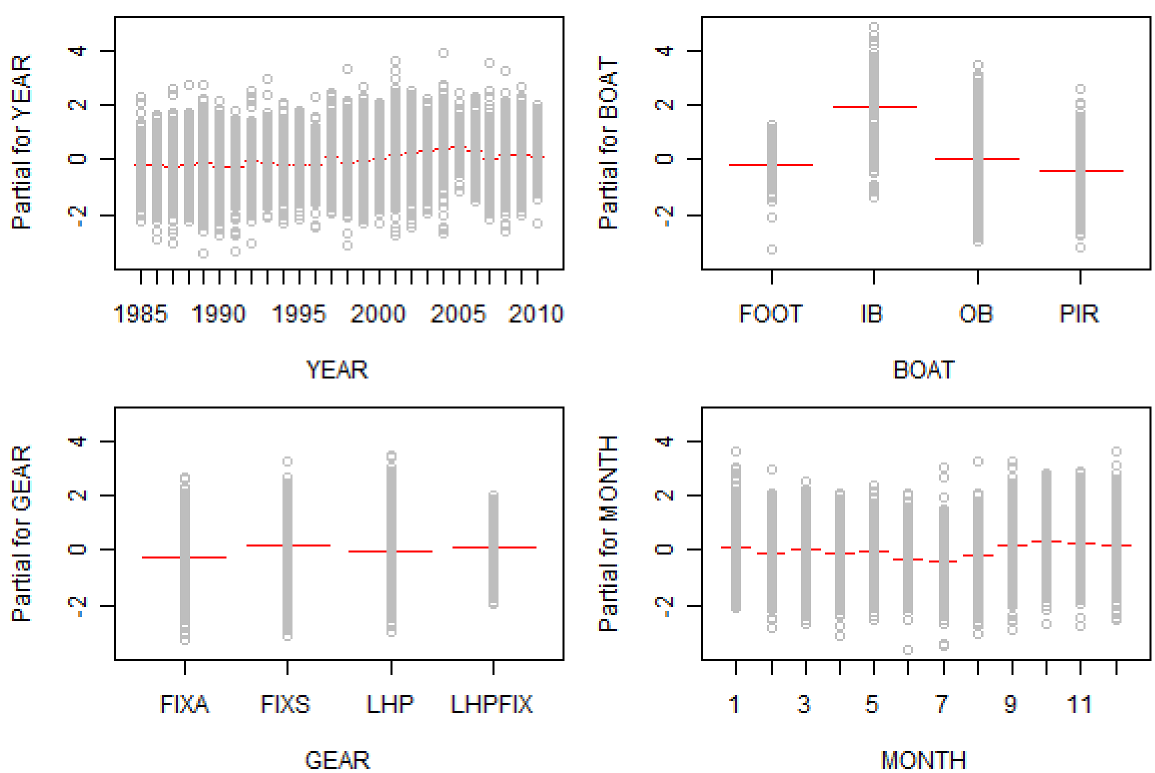

Figure A8. Partial effects for the general linear model of log(CPUE) using all data for the trap and line fishery in Praslin.

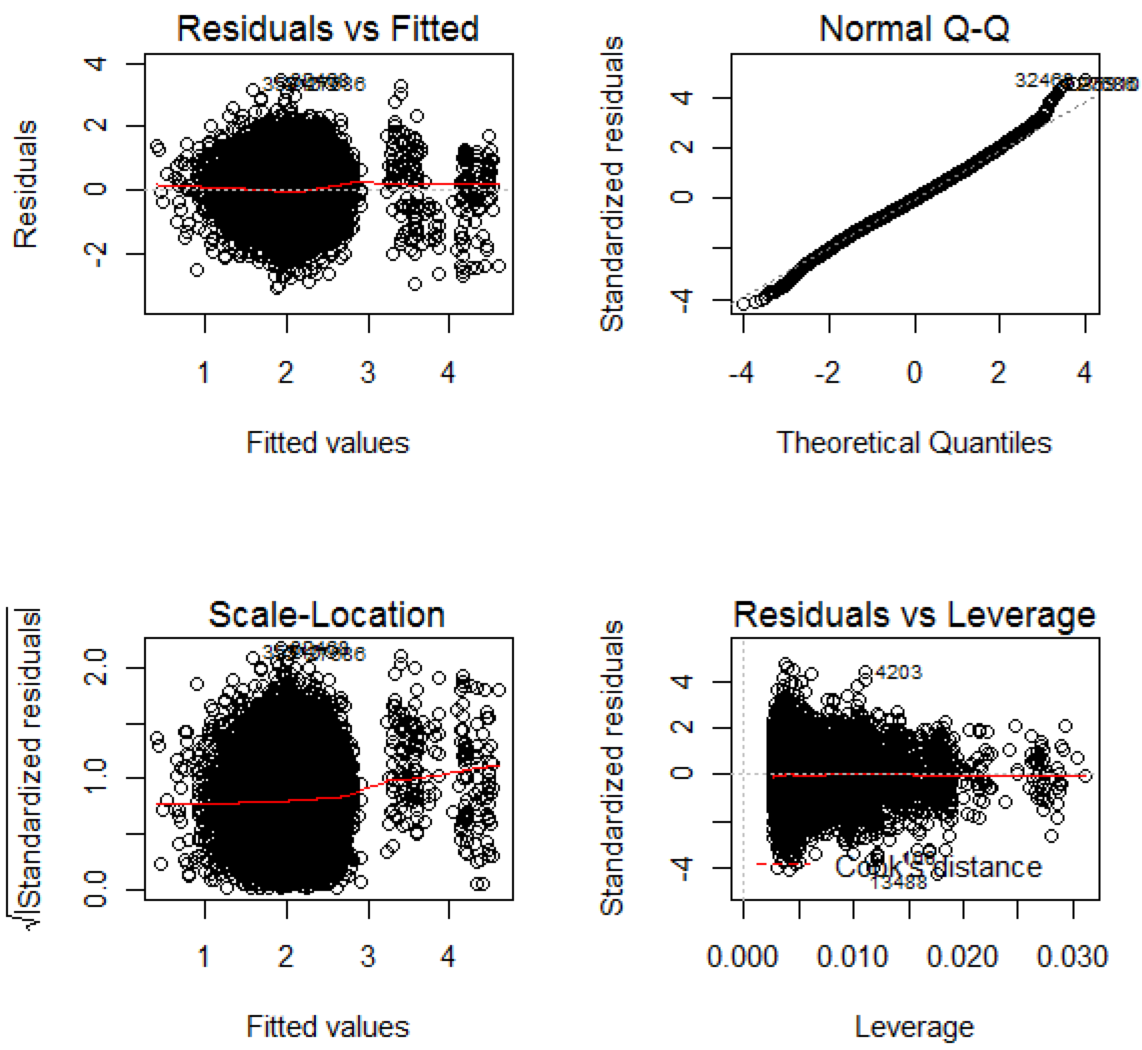

Figure A9. Residual analysis for the GLM of log(CPUE) for the artisanal trap and line fishery in Praslin.

Analysis of Variance Table

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
YEAR	25	283.06	11.32	22.1171	< 2.2e-16	***
MONTH	11	143.45	13.04	25.4730	< 2.2e-16	***
AREA	1	12.08	12.08	23.5882	1.223e-06	***
GEAR	3	76.77	25.59	49.9881	< 2.2e-16	***
AREA:GEAR	3	37.00	12.33	24.0941	1.699e-15	***
MONTH:GEAR	23	48.95	2.13	4.1576	9.937e-11	***
Residuals	6173	3160.19	0.51			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7155 on 6173 degrees of freedom
Multiple R-squared: 0.1599, Adjusted R-squared: 0.1509
F-statistic: 17.8 on 66 and 6173 DF, p-value: < 2.2e-16

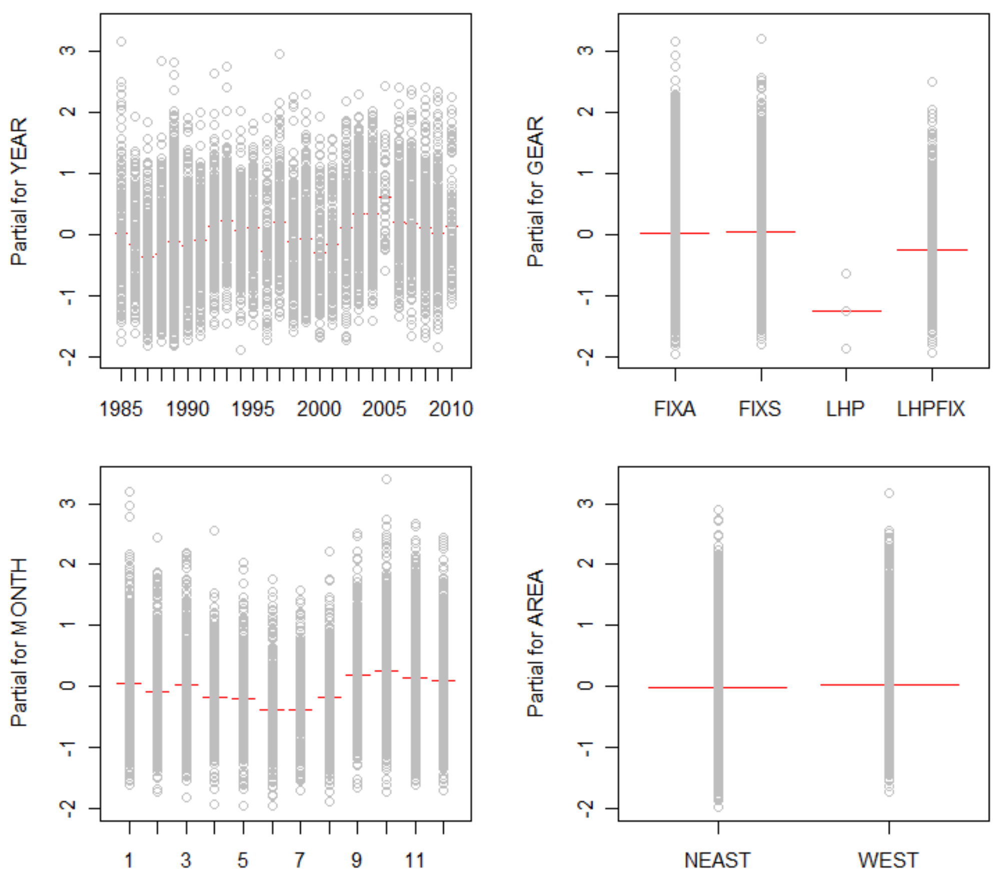

Figure A10. GLM and ANOVA results for log(CPUE) for species group S8 (*Siganus* spp)

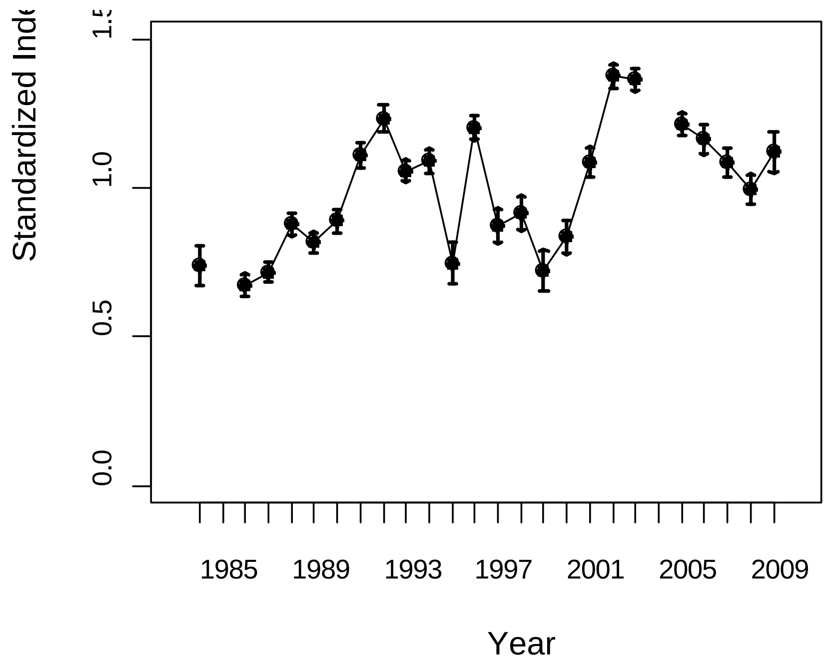

Figure A11. Standardized index of CPUE for species group S8 (*Siganus* spp). Missing year (2005) is due to a low sample size.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
YEAR	25	426.56	17.06	17.8410	< 2.2e-16	***
MONTH	11	23.77	2.16	2.2595	0.009990	**
AREA	1	4.97	4.97	5.1979	0.022749	*
GEAR	3	22.40	7.47	7.8082	3.571e-05	***
AREA:GEAR	3	14.93	4.98	5.2034	0.001411	**
Residuals	1543	1475.65	0.96			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9779 on 1543 degrees of freedom
Multiple R-squared: 0.2503,   Adjusted R-squared: 0.2294
F-statistic: 11.98 on 43 and 1543 DF, p-value: < 2.2e-1

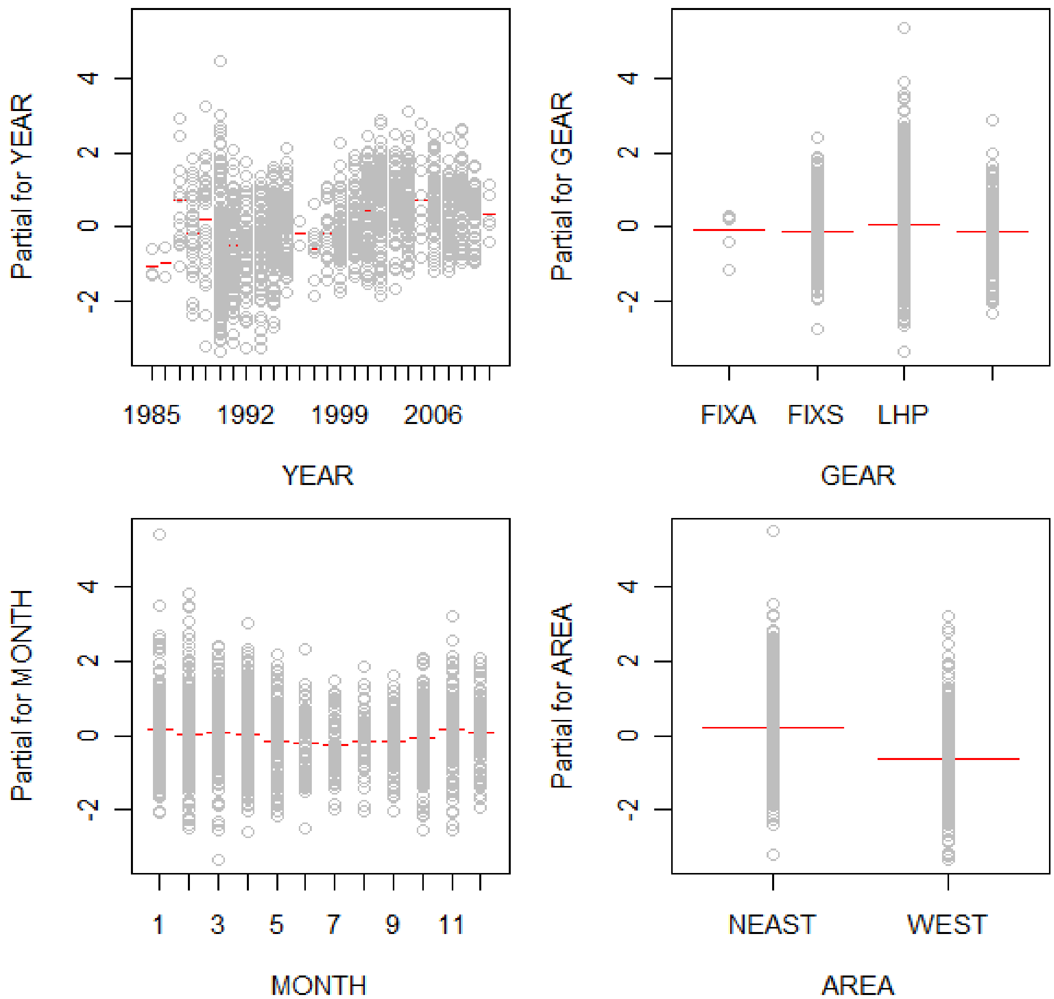

Figure A12. GLM and ANOVA results for log(CPUE) for red Emperor (*Lutjanus sebae*)

Appendix II. Minutes from Workshops

CO-MANAGEMENT COMMITTEE – Wednesday 2nd August 2011

STOCK ASSESSMENT WORSHOP - Saturday 6th August

The Chair needs to be involved and have knowledge of the Praslin AND Mahe fisheries sector.

Darril was selected as chairman; Louis as the Vice-Chair. Secretary of the Committee (Jude Bijoux).

Other members: SFA (Jan Robinson); PFA (4 members); Seychelles National Park Authority; Cousin Island; Cousine Island;

Who should be invited to be a member? What about Aride Reserve. Good but we need then another representative from the Fishing sector (to have a balance between fisheries and conservation group).

Recommendation: Include a Mahe representative as an observer

La Digue needs to be more comprehensively included in the TOR for the co-management work. Bring La Digue on board.

Needs commitment from the SFA to do what they say they will do. Better mechanism to deal and link between SFA and PFA. Commitment is there from the inception of the UNDP project, but needs to be stronger and continuous.

What do we want to educate the fishermen to do within the co-management plan?

Recommendation: gather information, stick to regulations, market timing coordination (fishermen look for hotel occupancy to see how much they should fish).

Co-management plan needs to include objectives (do we want to include benefits for the fishermen? Do we want better conditions?), what to do (what management regulations) and specific outcomes.

Do the Committee has any say on what SFA is deciding? Real voice in what the regulations should be? The Co-management Committee does not represent fishermen, but all stakeholders. PFA yes would have a say on what to decide regulation wise and what to do in terms of management.

Recommendation: Chair and Vice-Chair for the co-management committee shall not be the same people than the President and Secretary of the Praslin Fishermen Association.

Before the co-management plan, we need to agree on the management measures activities that need to be implemented and enforced. Also, co-management needs to be monitored, specific outcomes and timelines (adaptive co-management).

Who's allowed to use the fishing traps? Measures to protect licenses of Praslin fishermen and control effort (control number of traps, control mesh size, discards and landings (small fish), number of licenses, quotas for each species (if we see declining species, reduce the quota and offer some different species to the restaurants).

Other recommendations:

- Cooperatives: if you are not registered with the PFA and Co-M you won't be able to sell in the open market and hotels.
- Create a well developed and efficient system of self-enforcement (monitor, control and surveillance).
- Leaders should not be guided by self-interest. This should be closely monitored.

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