**GOS- UNDP-GEF**

# MAINSTREAMING BIODIVERSITY MANAGEMENT INTO PRODUCTION SECTOR ACTIVITIES

## TO CONDUCT A RISK ASSESSMENT TO IDENTIFY THREATS TO DEMERSAL STOCKS AND STOCK ASSESSMENTS FOR KEY DEMERSAL FISH STOCKS

**FINAL MISSION REPORT**

**5th January 2015**

**Dr. Nicolás L. Gutiérrez**

Republic of Seychelles

# Table of Contents

## EXECUTIVE SUMMARY and RECOMMENDATIONS

Three SICA workshops were held in Mahe, Praslin and La Digue with the objective of qualitatively assessing the risk that fishing pose on 72 demersal fish species. Stakeholders included representatives from industry, NGOs and Governmental organizations. In general, all stakeholders agreed that fishing is the main risk cause activity to be considered. Other risks identified were climate change causing coral bleaching, use of FADs in tuna fisheries, reclamation of sea for coastal development, and dredging activities. The intensity of the Seychelles demersal fishery was concluded as high for most species, where only those with low commercial importance were identified as exploited at low intensity. Examples of fish species with a decrease trend in abundance included bormar, karang plat and madam dilo, while species potentially affected by coral bleaching included karang ledan. Example of fish species with high consequence risk score included kaptenn rouz and terez, while species for which it was concluded that the geographical distribution range has changed significantly, included vyey plat, ton ledan and madanm beri. Overall it was concluded that fishing effort is too high and pose a high risk to the productivity of the species targeted or caught as by-catch but with commercial value. Stakeholders commented that the amount of hooks and traps in the water is too high with no regulation in place to control fishing effort, as being the major cause for high fishing mortality and high risk on population abundance, catch size frequency and population geographical range.

51 species were assessed at Level 2 using the PSA analysis. While the productivity scores spanned from 1.1 to 2.7, highlighting a wide range of productivities across the species analysed, susceptibilities were all higher than 2.0 with an average of 2.6. This high susceptibility was partly due to the geographical scope and coverage of the demersal fishery fleet and the variety of fishing gears used to catch most of the species. Of all the species analysed, only 3 were considered low risk, including karang ledan, makro dou and tazar. On the other hand, of the 19 species assessed to be at high risk, 11 had at least one missing attribute, which boosted the PSA scores due to its inherent precautionary nature. The main attribute to contribute to high risk for these species, other than the unknown ones, were the old age at maturity and relatively high longevity. For those species with good information available to perform the PSA, vyey goni, vyey mashata, and bourzwa were the species at highest risks.

Data used on this report was collected and compiled by the Staff of the Seychelles Fishing Authority (SFA), where the number of records has been stable for the period 1985-2008, increasing for the period 2009-2013, with the exception of years 1996 and 2010 where the number of samples was substantially smaller. Data from 1985 to 1990 has been excluded for some analysis due to changes in the CAS. Catches have been stable (or slightly decreasing) from 1990 to 2005, increasing afterwards although with higher degree of variability, in decreasing again in recent years. However, catches sampled by the CAS for 2013 were the highest since 1985. Total effort (man*fishing days) has been stable from 1992 to 2003, but has more than doubled from 2004 to 2013. The aggregated standardized CPUE for the whole demersal fishery shows three stages: 1) from 1990 to 1998, the CPUE has slightly decreased; 2) from 1999 to 2005 where the CPUE has increased in ca. 30%; and 3) from 2006 to 2013 where CPUE has been stable or slightly decreasing. However, given the spatial structure of many of the demersal species, it is important to analyze the spatial dynamics of the fishing fleets

Catches for individual species have shown different patterns, with job, laskar and vara catches increasing from 1985/1990 to 2013, while balo, bordmar and makonde showing the opposite trend. Bourzwa catches have increased considerably during the early 2000s, decreasing in the last 10 years. These patterns can be masked by spatial fleet dynamics therefore is critical to monitor these trends at the right spatial resolution. Standardized CPUE for most species have shown a period of stability from 1990 to 1998, increasing afterwards, peaking around 2000-2002 and finally decreasing towards recent years. For bourzwa, CPUE peaked around 2005, decreasing notable towards 2013, while CPUE for vyey makonde has been relatively stable for the whole data series. This recent and constant decreasing trend for most species analyzed is alarming and requires further investigation, data collection and monitoring.

Stock assessment using surplus production models highlighted considerable uncertainty around MSY estimates due to the quality of the data available and in some cases due to the ‘uninformative’ nature of the data. Although catches for most species were around MSY levels and in some cases exceeded such levels, which may be causing a decline in CPUE, these estimates should be considered with caution. For those three species with length information, a high proportion of juveniles (between 33% and 53%) was found for 2013. Fishing immature individuals will eventually lead to recruitment overfishing. Finally, temporal analysis of species composition of the catches has shown changes in species dominance for the whole Seychelles demersal fishery. These trends could be associated to changes in species availability, in market demands, socio-cultural preferences, or a combination thereof.

In summary, consistent declining trends in CPUE for most species in the last 5 to 10 years, high proportion of juveniles in catches, and changes in species composition of the catches, are all indicators of unsustainable fishing.

General recommendations arisen from this Consultancy are:

- Information contained in the Catch Assessment Surveys needs 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.). Data should be validated through exhaustive quality controls processes.

- Measures of fishing effort should be standardized for the whole fishing fleet (e.g., man*day). The way the information is currently available difficult evaluations and stock assessments and may infer biases in CPUE indices.

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

- Although catches have been close to MSY, these estimates should be considered as a guide and not as absolute values to estimate catch quotas. Once more data becomes available, new assessments may provide more accurate estimates of sustainable catches.

- Length frequency distributions of the catches should be collected at relevant temporal and spatial scales and for most important and at higher risk species in order to elucidate trends in mean sizes.

- Data should be collected at the species level when possible or at least species grouping should be done consistently across fleets.

- Given the nature of the information, and the potential spatial structure of the demersal resources and the fishing fleets, empirical indicators are considered more appropriates than decisions made based on total catch quotas by species. Some of the empirical to be used in simple decison rules (see Gutierrez 2011) may include trends in CPUE, absolute values of mean lengths of the catch relative to length at maturity for each species, and changes in species compositions of the catches. These indicators can be monitored by collecting data at appropriate temporal and spatial scales, either through SFA enumerators but ideally through community-based data collection programs.

- 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. INTRODUCTION

## 1.1. Project objectives

The '*Mainstreaming Biodiversity Management into Production Sector Activities*" (or "*Mainstreaming Biodiversity*") Full sized Project was signed in October 2007 between the Government of Seychelles (GOS) and the United Nations Development Programme (UNDP), and is funded by a Global Environment Facility (GEF) grant of US$3,600,000. The project is part of the UNDP-GEF portfolio in Seychelles and is implemented under a Programme Coordination Unit (PCU), and headed by a Biodiversity Project Manager. The project started in February 2008, is of 6 years duration, and has the following Project Objective: "*Biodiversity conservation is integrated into key production sectors of the economy*". This Objective is to be attained through the following Outcomes:

**Outcome 1**: "*Systemic and institutional capacities for mainstreaming biodiversity management within and across sectors are strengthened*".
**Outcome 2**: "*Methods and means for integrating biodiversity and artisanal fisheries management are in place*".
**Outcome 3**: "*The tourism industry is addressing biodiversity conservation as part of good practice in business operation*".

Under **Outcome 2**, the Project is currently seeking an **international consultant** to: i) carry out a productivity-susceptibility analysis (PSA) on species taken in the plateau fishery for demersal fish resources in order to identify populations that are most vulnerable to fishing, ii) undertake stock assessment for key species and species groups identified in the PSA, and iii) formulate options for decision control rules based on a range of biological, ecological and socioeconomic objectives. The results of this consultancy will be used to update and make operational a draft management plan for the demersal fishery as part of an international consultancy which should immediately follow this one (ToR attached).

## 1.2. Context

The fisheries sector in Seychelles is critically important for ensuring both food security and economic development. The industrial marine fisheries, targeting mostly tunas, have grown considerably over the last three decades, but the artisanal fisheries also remains of great importance. Small-scale artisanal fisheries exploit a high diversity of species and habitats. Most of the small-scale artisanal fisheries are undertaken on the Mahé Plateau (55˚30'E, 4˚30'S), an area of about 41,000 km$^2$, of which the greatest part lies at depth of between 50 – 65 m. The plateau is closed to industrial fishing but is fished by about 140 whalers and schooners and at least another 500 outboard vessels and sport/recreational fishing boats. The whaler and schooner fleet undertake fishing trips lasting several days and fish the whole of the plateau away from the near shore areas. Conversely, the outboard fleet operates on a day to day basis and tends to stay close to the central granitic islands. The whalers and schooners usually fish using hand lines or hand winch often with multiple hooks whereas the outboard fleet usually fish using hand lines with single hook and traditional bamboo traps. The main species targeted by the hand line fishery are snappers, groupers and emperors whereas the trap fishery targets rabbitfish, parrotfish and emperors.

The Emperor red snapper (*Lutjanus sebae*) is the most sought after species in the plateau demersal fishery and is often used as an indicator of the general health of the demersal fish stock on the Mahé Plateau. Concerns over the status of *L. sebae* stock were raised when catches of this species began to increase dramatically in 2004. Prior to 2004, this species had been harvested at around the Maximum Sustainable Yield (MSY; 380 t) for over 10 years. In response to this dramatic increase in the catch of this species, the SFA embarked on a detailed stock assessment using rigorous and widely accepted methods. By 2007 catch of this species had reached 1077 t per annum and had more than tripled MSY. This highlighted that there were major risks from continued targeting at those levels. From 2008 to 2012 a steady decline was observed in catches and a stock assessment undertaken in 2010 concluded that the exploitation rate were still above the rate to achieve MSY and the stock status of emperor red snapper was described as **overexploited.** In 2012, the estimated catch had reduced significantly to only 209 t. Similar to emperor red-snapper the catch of groupers peaked in 2007 when a total of 158 t were caught. Between 2008 and 2012 a steady decline have been observed in annual catch with in catch was observed with only 71.6 t caught in 2012, raising concern on sustainability of stocks. This has been exacerbated in more recent years with the entrance into this fishery of a number of larger vessels which were previously targeting swordfish and tunas. These vessels are utilizing bottom-set long lines, which are increasing the catch per unit of effort (CPUE) and causing serious risk for the management of the demersal fish resources.

The Seychelles Government's vision is to develop Seychelles blue economy and ensure sustainability of fisheries resources through improvement in fisheries management. There is already a fishery co-management plan which will start implementation later this year for the area around the islands of Praslin and La Digue. It is anticipated that a similar management plan will be discussed and drafted for the coastal area around the island of Mahé. Overarching to these area/fleet based management plans, there is a need for resource-based management objectives and control rules for key demersal species that are shared among areas.

## 1.3. Specific objectives

The main objectives of this consultancy are to: i) undertake a productivity-susceptibility analysis (PSA) on species taken in the plateau fishery for demersal fish resources; ii) carry out stock assessments for key species and species group identified as part of the productivity-susceptibility analysis, iii) develop options for objectives, biological reference points and decision control rules for assessed stocks, and iv) mentor a staff selected by the Seychelles Fishing Authority (SFA) in undertaking PSAs and stock assessments. The scientific advice provided for by these activities will be made available to a consultant working in parallel who will be charged with stakeholder consultation and drafting the plan.

The consultancy will directly contributed towards the *Mainstreaming Biodiversity Project* **outcome 1** *Systemic and institutional capacities for mainstreaming biodiversity management within and across sectors are strengthened* and **outcome** 2 *Methods and means for integrating biodiversity and artisanal fisheries management are in place.*

## 1.4. Deliverables and outputs

1. A short inception report and work plan within one week of commencing the assignment.
2. A back-to-office report on completion of the first mission to Seychelles.
3. A final mission report with main issues raised and deliberations from the stakeholders workshops/meetings, consultations undertaken and problems/difficulties encountered in the undertaking of the consultancy.

# 2. ECOLOGICAL RISK ASSESSMENT

## 2.1. The Risk Assessment Methodology

The initial step in the Risk Assessment Methodology involves the development of a qualitative ecological risk assessment (ERA), which assesses the direct and indirect impacts that a fishery's activities may have on the marine ecosystem. These assessments provide the basis for any future qualitative and quantitative analysis. The process involves the following steps (Fig. 2.1):

### 2.1.1. Scoping

The fishery is profiled or characterized, including information that allows each sub-fishery to be defined based on fishing method and/or spatial coverage if this is more appropriate for assessment. At this stage, the general fishery characteristics are documented, and a list of all "units of analysis" (i.e., all species, fishing gears, fleets) is generated. Hazards and objectives for the fishery are also identified (for more detail refer to Hobday et al. 2007; Hobday et al. 2011).

### 2.1.2. Scale, Intensity, Consequence Analysis (SICA)

Level 1 is a qualitative assessment of the scale, intensity, consequence components of the fishery that identifies which hazards lead to a significant impact on any species. At this level, analyses are conducted on relevant components (target species in the present study). Level 1 is used as a rapid screening tool, where the 'worst case' scenario (i.e., the most vulnerable species) is looked at in details with relevant stakeholders. Capturing information from a broad number of stakeholders representing different sectors (fishermen, government, NGOs, etc.) is critical to the accuracy, comprehensiveness and reliability of this analysis. All information should be recorded to ensure the transparency in the process.

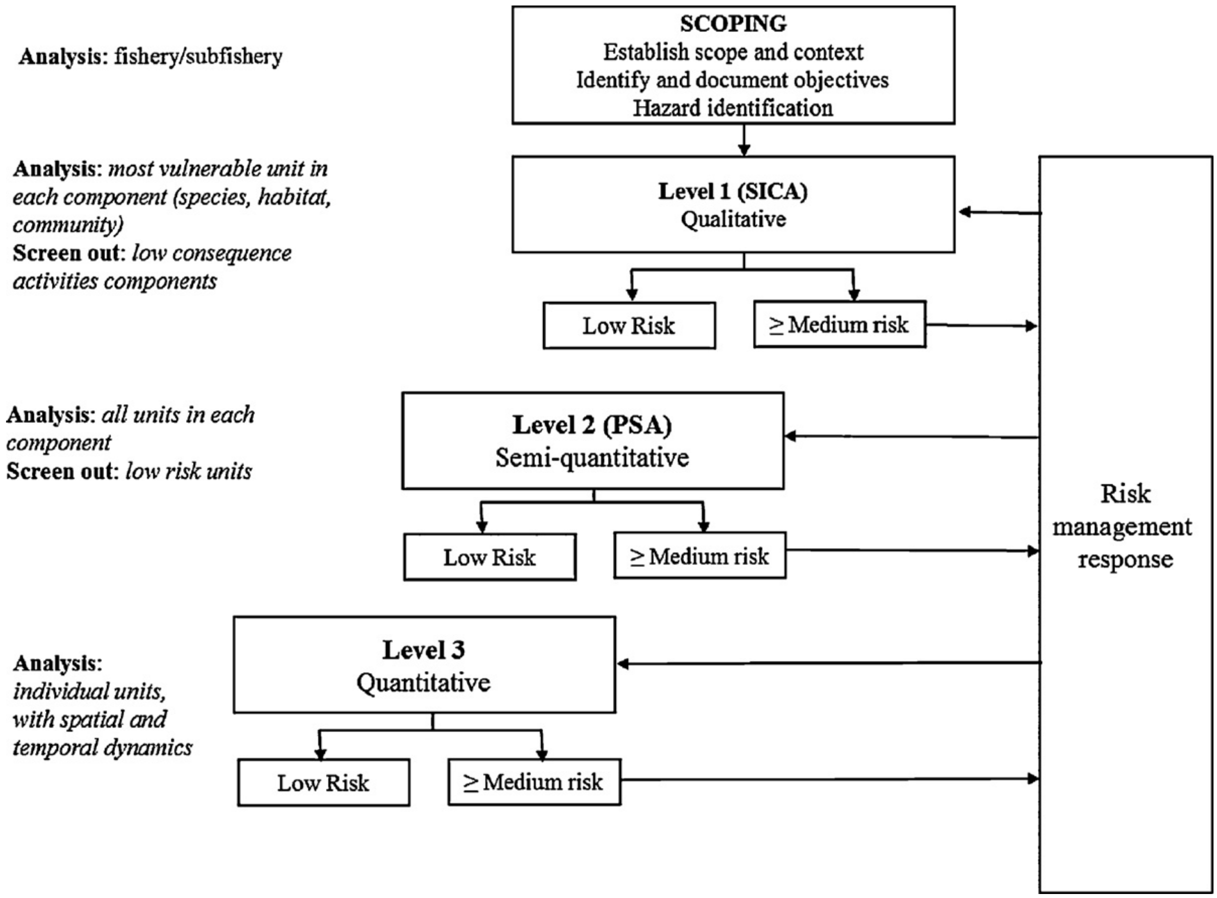



**Figure 1. Overview of the Ecological Risk Assessment highlighting each level in the hierarchy (taken from Hobday et al. 2011).**

### 2.1.3. Productivity Susceptibility Analysis (PSA)

Level 2 is a semi-quantitative analysis of the risk caused by the fishing activity to all individual species identified in the scoping stage. This PSA assesses the direct impact of fishing and is based on the assumption that risk to an species is based on two characteristics: (1) susceptibility, where the extent of the impact on the species is determined by its susceptibility to the fishing activities; and (2) productivity, which determines the rate at which the species can recover after potential depletion or damage by fishing activities. This level examines a series of each species attributes related to susceptibility and productivity and a score on a three point scale (i.e., low, medium and high) risk is determined and combined to define a relative measure of risk for each species. This analysis is precautionary in the sense that, where information on a specific productivity or susceptibility attribute for a species is not available or reliable, it is given a default score of high risk.

#### 2.1.4. Quantitative stock assessment

At the end of the Level 2 PSA assessment, a number of species may be identified as being at high risk because of the activities of the fishery and/or intrinsic characteristics of the species. This species may be subjected to a more comprehensible and quantitative assessment, which may take any form depending on the nature of the data available.

### 2.2. Stakeholder engagement

SICA workshops were held in Mahe, Praslin and La Digue on the 26th and 27th of September and $6^{th}$ of October, respectively. The objective of the SICA workshops was to qualitatively assess the risk that fishing pose on demersal fish species. Stakeholders including representatives from industry, NGOs and Governmental organizations participated in all three workshops. Two groups of stakeholders were formed and information on the Scale, Temporal and Intensity Scale of the fishery was collected to determine the consequence risk score pose by the most relevant of the species population sub-components. Seventy two species caught by the demersal fleet (i.e., pirogues, outboard, schooners and whalers) using hook gear (handline, dropline, bottom set longline), traps and nets were thoroughly analyzed.

### 2.3. SICA Results

Results from all three workshops were consistent in determining which sub-units (i.e., fleet and gear combinations) pose high risk on the productivity of Seychelles demersal species. In general, all stakeholders agreed that fishing is the main risk cause activity to be considered. However it is important to note that during the Pralin's workshop climate change causing coral bleaching was also identified as an important cause for the decrease in fish abundance. Other risks causing activities identified included: (i) the use of FADs in tuna fisheries; (ii) reclamation of sea for coastal development; and (iii) dredging activities.

SICA results were derived by identifying the most relevant sub-component that affected each of the species analysed and assigning a consequence score in the scale of 1 (low risk) to 6 (high risk). The consequence score was informed by the intensity of the fisheries (a combination of the spatial and temporal scale of the fishery operation). The intensity of the Seychelles demersal fishery was concluded as high for most species due to the broad coverage of the fishing fleets and the multi-gear nature of the operations. Only species with low commercial importance were determined as exploited at low intensity (Appendix 1).

Population abundance, population size structure and geographical range were the most relevant sub-components in determining the consequence risk. Stakeholders used catches, landings or frequency of sighting fish schools to conclude that fishing (and in some cases coral bleaching) was posing a high risk to the productivity of demersal fish species. Examples of fish species with a real and/or perceived decreasing trend in abundance included species such as bordmar (*Lutjanus coccineus*), karang plat (*Carengoides fulroguttatus*) and madanm dilo (*Epinephelus fasciatus*) among others. Kareng ledan (*Caranx ignobilis)* was identified as one of the species affected by coral bleaching. This species is often caught as bycatch but fish schools are not frequently seen since year 2000 approximately ("only few fish around" diver pers comm, Praslin workshop).

The decrease in the catch mean size of some fish species provided also an indicator of high risk. Example of fish species with high consequence risk scores included kaptenn rouz (*Epinephelus fasciatus)* and terez *(Epinephelus fasciatus)*.

There were some species for which it was concluded that the geographical distribution range has changed significantly (i.e., fish species not caught anymore in inshore waters as used to be in the past). As a result of such shift, some species, such as vyey plat (*Epinephelus fasciatus*), are low in abundance in inshore waters thus being targeted in offshore waters. Other species identified as being affected by coral bleaching and migrated to deeper water included ton ledan, (*Epinephelus fasciatus*) and madanm beri (*Epinephelus fasciatus*).

Overall it was concluded that fishing effort is too high and pose a high risk to the productivity of the species targeted or caught as by-catch but with commercial value. Main gears used include hooks gears (handline, dropline, bottom set longline), traps and nets. Stakeholders commented that the amount of hooks and traps in the water is too high with no regulation in place to control fishing effort as being the major cause for high fishing mortality and high risk on population abundance, catch size frequency and population geographical range.

One aspect of fishing in the Seychelles related to the spatial and temporal scale of fishing generally highlighted by stakeholders was the dependency of when and how fishing occur in relation to monsoon events. Fishing spatial and temporal patterns are affected by these monsoons and this should be taken into account in the implementation of management measures directed to fishing effort control.

## 2.4. PSA Results

51 species were assessed at Level 2 using the PSA analysis. Operators in the Seychelles plateau demersal fishery use different gears with different selectivity thus the PSA was run separately for hooks gears (handline, dropline, bottom set longline), traps and nets. Bibliographic references used in the PSA scoring exercise were scarce and scattered, and most attributes were taken from FishBase (Froese and Pauly 2014) for same species but generally from different geographic locations (Appendix 1). While the productivity scores spanned from 1.1 to 2.7, highlighting a wide range of productivities across the species analysed, susceptibilities were all higher than 2.0 with an average of 2.6 (Fig. 2.2). This high susceptibility was partly due to the geographical scope and coverage of the demersal fishery fleet and the variety of fishing gears used to catch most of the species, where hooks and traps were considered highly non-selective.

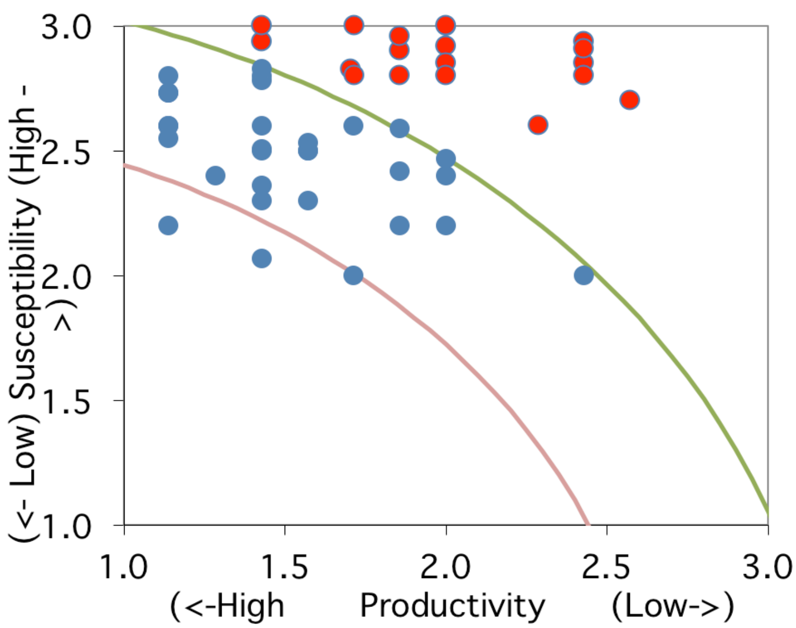



**Figure 2.2. PSA analysis of 51 fisheries caught by the demersal fishery in Seychelles. Red dots represent those species categorised at high risk.**

Of the 51 species analysed, only 3 species were considered low risk, including vyey plat (*Caranx ignobilis*), ton ledan (*Rastrelliger kanagurta*) and madanm beri (*Sphyraena barracuda*). On the other hand, of the 19 species assessed to be at high risk (Fig. 2.3; Table 2.1), 11 had at least one missing attribute and 5 have three or more missing attributes. The main attribute to contribute to high risk for these species, other than the unknown ones, were the old age at maturity and relatively high longevity (Appendix 1).

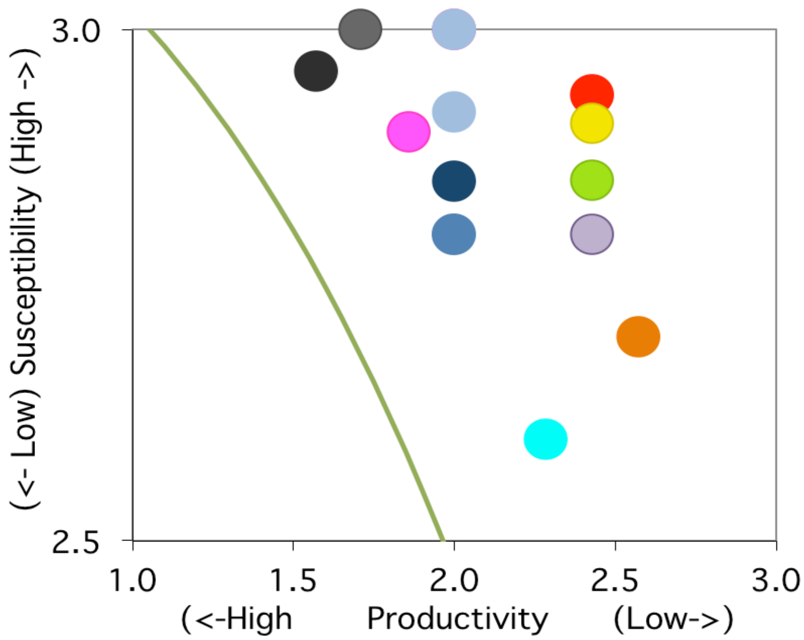



**Figure 2.3. PSA analysis of 51 fisheries caught by the demersal fishery in Seychelles. Red dots represent those species categorised at high risk.**

**Table 2.1. PSA scores for those species identified as high risks, including data quality (as the proportion of susceptibility and productivity attributes known; 1.00 = all attributes known).**

| SCIENTIFIC NAME | CREOLE NAME | SUSCEPTIBILITY | PRODUCTIVITY | PSA | DATA QUALITY | PLOT COLOR |
|---|---|---|---|---|---|---|
| *Carangoides fulvoguttatus* | Karang plat | 2.94 | 2.43 | 3.81 | 0.43 | |
| *Gymnocranius robinsoni* | Kaptenn Blan | 2.91 | 2.43 | 3.79 | 0.43 | |
| *Carangoides gymnostethus* | Karang Balo | 2.85 | 2.43 | 3.75 | 0.43 | |
| *Pristipomoides filamentosus* | Batrikan, Kalkal | 2.70 | 2.57 | 3.73 | 0.57 | |
| *Seriola spp* | Somon | 2.80 | 2.43 | 3.71 | 0.57 | |
| *Epinephelus fuscoguttatus* | Vyey Goni | 3.00 | 2.00 | 3.61 | 1.00 | |
| *Epinephelus polyphekadion* | Vyey Mashata | 3.00 | 2.00 | 3.61 | 0.71 | |
| *Epinephelus flavocaeruleus* | Vyey plat | 2.92 | 2.00 | 3.54 | 0.57 | |
| *Lutjanus sebae* | Bourzwa | 2.85 | 2.00 | 3.48 | 1.00 | |
| *Lethrinus crocineus* | Laskar | 2.60 | 2.29 | 3.49 | 0.57 | |
| *Aprion virescens* | Zob gris | 3.00 | 1.71 | 3.46 | 0.71 | |
| *Plectropomus laevis* | Vyey Babonn | 2.80 | 2.00 | 3.44 | 0.86 | |
| *Lutjanus bohar* | Vara vara | 2.90 | 1.86 | 3.44 | 0.86 | |
| *Lutjanus sanguineus* | Bordmar | 2.96 | 1.57 | 3.39 | 0.86 | |

## 2.5. Conclusions

- Most species are highly vulnerable to fishing gears (due to multi-gear operations) and spatial distribution of fishing effort (diverse fleets accessing all areas of the Mahe plateau).
- In addition to high vulnerability, some species have low productivity therefore exacerbating their risk to threats, in this case overfishing.
- Due to the precautionary nature of the SICA and PSA methods, many species were considered high risk due to lack of information to score the productivity attributes. This highlights the need for biological studies and gear selectivity studies.
- For those species with good information available to perform the PSA (data quality >0.71), vyey goni, vyey mashata, and bourzwa were the species with highest risks.
- Fishing activity has been identified as the main threat but climate change and coastal development may exacerbate impacts.

# 3. STOCK ASSESSMENT

## 3.1. 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.

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 catches, and in particular of 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, the information behind the data, 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. Surplus production models are used when only an index of abundance, such as catch per unit effort (CPUE) is available (Hilborn and Walters 1992). However, in some cases data on catch and effort is not available or not reliable or informative thus much attention has been given to developing tools and models to assess data-poor or data-limited stocks and their associate control rules, including catch-only methods (Kimura and Tagart 1984; Martell and Froese 2013, Carruthers et al. 2014).

Even when data is available and informative, considerations and uncertainties related to data errors need to be considered. Data are often missing, particularly in artisanal and recreational fisheries where monitoring and data collection is particularly difficult to gather considering limited economic and human resources or lack of monitor of private charters. 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.

## 3.2. Overall patterns in aggregated data

Data used on this report was collected and compiled by the Staff of the Seychelles Fishing Authority (SFA) Artisanal Fisheries Research Section (Table 3.1). Number of records or samples by fieldworkers was stable for the period 1985-2008, increasing for the period 2009-2013, with the exception of years 1996 and 2010 where the number of samples was substantially smaller (Fig. 3.1). Also, data from 1985 to 1990 has been exclude for some analysis due to changes in the Catch Assessment Survey and databases in 1990.

**Table 3.1. Number of records by fleet/boat type (see SFA 2005 for details and descriptions on data collection).**

| Fleet | Number of records |
|---|---|
| Small Boats | 167,661 |
| Outboard | 127,446 |
| Pirogues | 20,649 |
| Foot | 19,562 |
| Schooner | 6,923 |
| Whaler | 15,054 |

Total catches in samples were classified by species groups for both schooners and whalers and small boats (Table 3.2; Fig. 3.2). For the former (Fig. 3.2a), groups F1 (bourzwa; *Lutjanus sebae*) and F4 (zob gri; *Aprion virescens*) constituted 24% and 13% of the total long term catches for the period 1985 to 2013 respectively. For small boats (Fig. 3.2b), species representation in the catches was less skewed but still dominated by groups S2 (karang plat; *Carangoides fulvoguttatus*), S1 (karang balo; *Carangoides gymnostethus*), and F4 (zob gri; *Aprion virescens*).

A full statistical analysis of changes in species composition by time and area is recommended for proper monitoring and potentially as an empirical indicator or trigger.

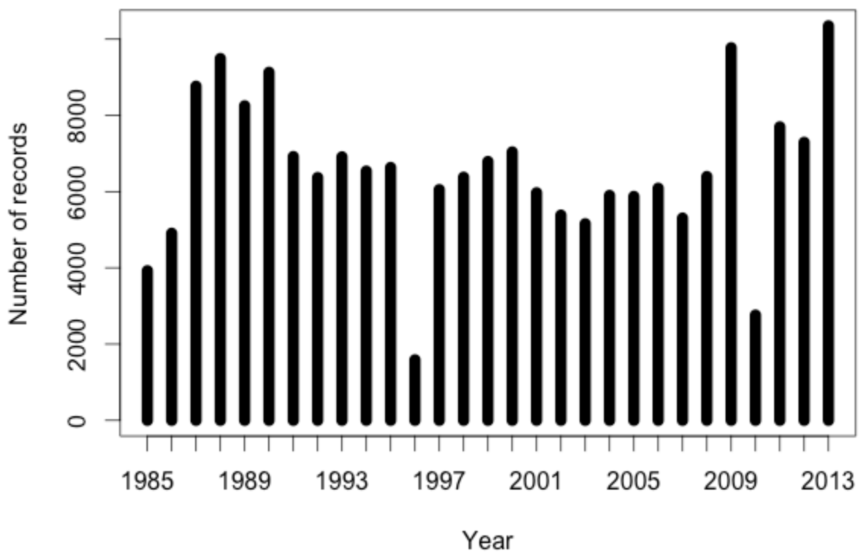



**Figure 3.1. Number of annual records or samples taken by SFA fieldworkers from 1985 to 2013.**

**Table 3.2. Creole name and code for schooners, whalers and small boats catches (from Catch Assessment Survey).**

| Species | Code | Species | Code | Species | Code | Species | Code | Species | Code | Species | Code | Species | Code | Species | Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bourgeois | F1 | Carangue | F18 | Car. Balo | S1 | YELLOWFIN | S6 | COR. LA FUME | S8 | ROU. CAPUCIN | S9 | VIE. PLATTE | S14 | OTHERS | S17 |
| Bordemar | F2 | V.Vara | F19 | Car. Platte | S2 | THON RAYE | S6 | CORDONIER | S8 | BOUETAIRE | S9 | BABONE | S14 | SARDINE | S18 |
| V.Platte | F3 | Bonite | F20 | Car. Monique | S2 | THON LES DENTS | S6 | COR. ROUGE | S8 | TAMARIN | S9 | TUKULA | S14 | BOURSE | S18 |
| J.Gris | F4 | D.Tooth | F21 | Car. A. Plume | S2 | THON BROSSE A D | S6 | ROU. LOCAL | S9 | BOURGEOIS | S10 | VIE. TUKULA | S14 | YVANO | S18 |
| J.Jaune | F5 | Becune | F22 | Car le dens | S2 | KING FISH | S6 | ROU. TACHE | S9 | BORDEMAR | S10 | VIE. GALFA | S14 | MADRAS | S18 |
| Batrican | F6 | Tazard | F23 | Saumon | S2 | SAIL FISH | S6 | ROU. ROUGE | S9 | THERESE | S10 | CAP. ROUGE | S15 | LA FLECHE | S18 |
| Tioffe | F7 | Dorade | F24 | Galate | S2 | MARLIN | S6 | CAC. BLANC | S9 | VARA VARA | S11 | LASCAR | S15 | MARMITE | S18 |
| Kingfish | F8 | Croissant | F25 | Car. Chasseur | S2 | DORADE | S6 | CAC. ROUGE | S9 | JOB GRIS | S12 | GUELE LONGUE | S15 | CARPE | S18 |
| Sailfish | F9 | V.Maconde | F26 | Car. Vert | S2 | BONITE FOLLE | S6 | CAC. BRUNO | S9 | JOB JAUNE | S12 | BACSOUS | S15 | | S18 |
| Yellowfin | F10 | O.Vieille | F27 | Car. Mimi | S2 | BECUNE | S7 | CAC. VERT | S9 | VIE. MACONDE | S13 | DAME BERRIE | S15 | | |
| C.Blanc | F11 | Sharks | F28 | Car. Gaze | S2 | BEC. VERA | S7 | CALAME | S9 | VIE. ROUGE | S14 | GUELE DE VIN | S15 | | |
| G.Longue | F12 | Others | F29 | Maq. Doux | S3 | BEC. GUEMON | S7 | MARARE | S9 | CROISANT | S14 | ECLAIR | S15 | | |
| Lascar | F13 | Crab | F30 | Maq. Canal | S4 | TAZARD | S7 | FILAMBASE | S9 | M. ANGAR | S14 | CAP. BLANC | S15 | | |
| D.Beri | F14 | Thereze | B3 | Maq. Jaune | S4 | COR. BLANC | S8 | MATONGO | S9 | CHEVAL DI BOIS | S14 | CHOUCHOUTTE | S15 | | |
| C.Rouge | F15 | Car. Balo | B19 | Maq. Blue | S4 | COR. BRISANT | S8 | CORN | S9 | VIE. ANANAS | S14 | SHARK | S16 | | |
| Bacsous | F16 | Car. Plat | B20 | Maq. Gros | S4 | COR. MARGUERITE | S8 | CAP. DU PORT | S9 | VIE. MACHATA | S14 | RAY | S16 | | |
| Saumon | F17 | Other carang | B32 | | | COR. SOULEFEMME | S8 | SURIGIEN | S9 | VIE. CHATTE | S14 | OCTOPUS | S17 | | |

Total catch, effort (in days fished and man*days) and CPUE (tons/man*days) were plotted for individual samples to identify outliers as well as temporal trends in individual samples (Fig. 3.3).

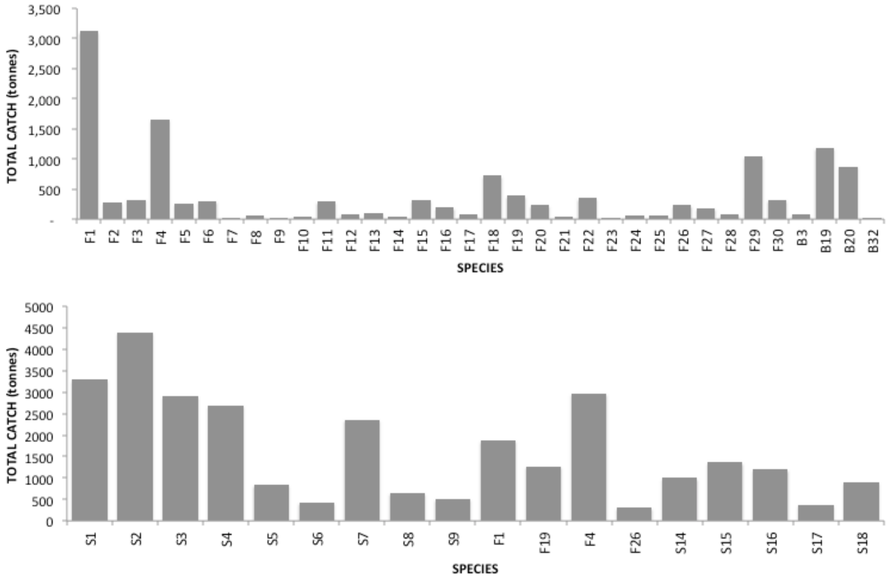



**Figure 3.2. Catch composition by species groups for (a) schooners and whalers for period 1985-2013 and (b) small boats for 1985-2013.**

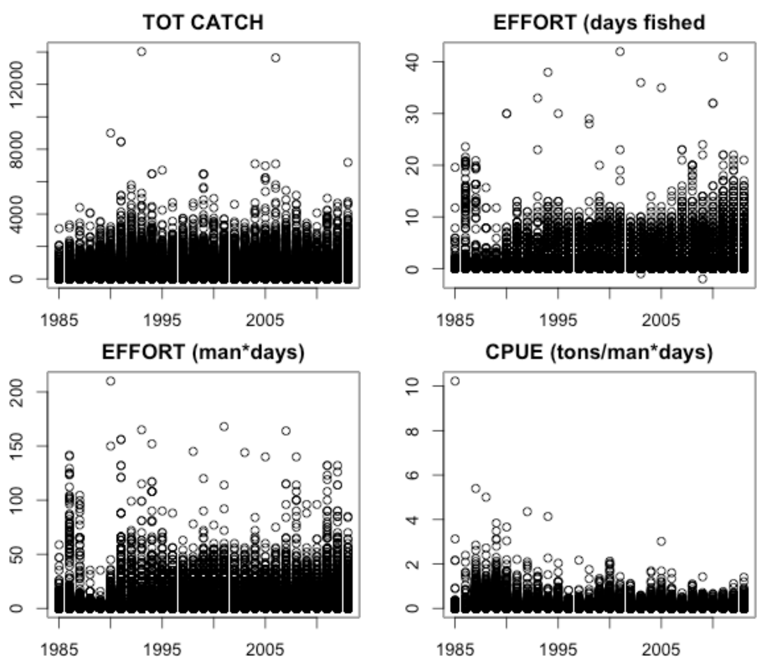



**Figure 3.3. Total catch, total effort and total CPUE for individual samples aggregated by fleet for the period 1985-2013.**

In addition, 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 (Fig. 3.4b). Due to changes in the CAS after 1990, the first 5 years of the temporal series should be treated with caution. Therefore, catches have been stable (or slightly decreasing) from 1990 to

2005, increasing afterwards although with higher degree of variability. Furthermore, catches for 2013 were the highest sampled since 1985.

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. Since the total catches may be influenced by several fishery variables, CPUE (man*days) has been standardized by fleet, gear and fishing ground (Fig. 3.4c; for detailed methodology on use of GLMs to standardize CPUE for the Seychelles fishery refer to Gutierrez, 2011). The aggregated standardized CPUE for the whole demersal fishery in Seychelles shows three periods (excluding period 1985-1990 due to changes in CAS): 1) from 1990 to 1998 the CPUE has slightly decreased; 2) from 1999 to 2005 where the CPUE has increased in ca. 30%; and 3) from 2006 to 2013 where CPUE has been stable or slightly decreased (< 5%). However, given the spatial structure of many of the demersal species, it is important to analyze the spatial dynamics of the fishing fleets. In fact, the proportion of the total catch by fishing ground as defined by the CAS (Table 3.3) has changed with time, with some grounds dominating after 2005 (Fig. 3.4d).

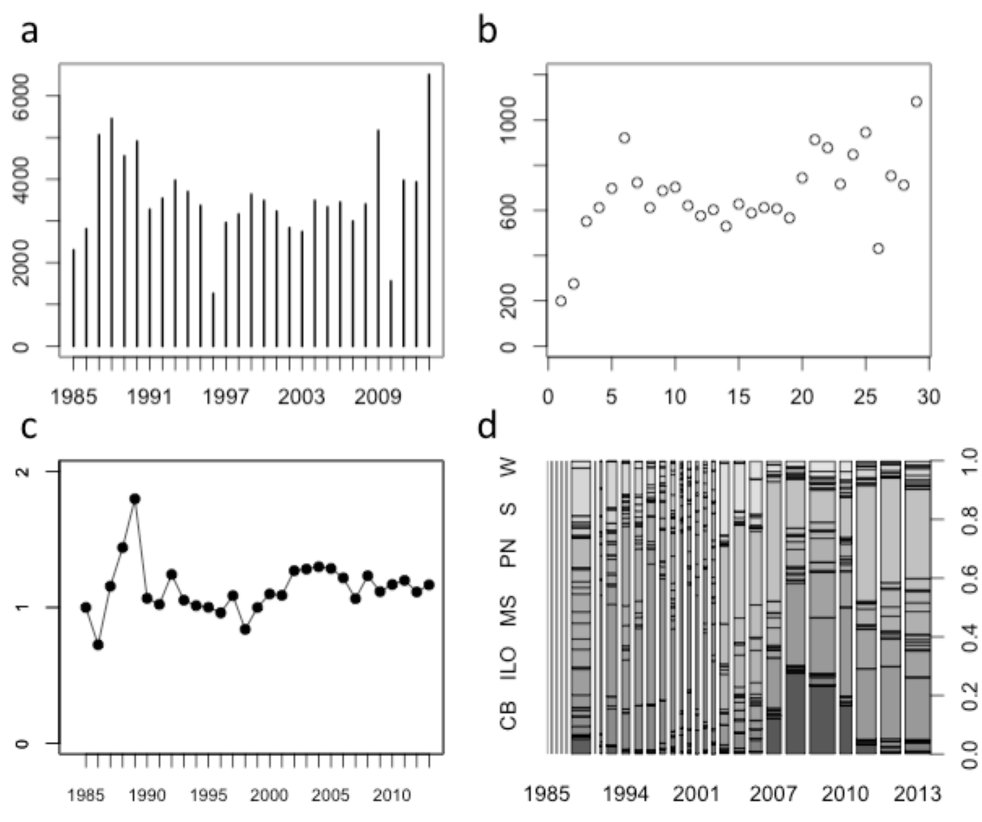



**Figure 3.4. Data from the Catch Assessment Survey (CAS) for the demersal fishery in Seychelles covering the period 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

Total effort (man*fishing days) has been stable from 1992 to 2003, but has more than doubled from 2004 to 2013 (Fig. 3.5a). In order to gain insights on the incidence of the sampling protocol and frequency, the mean catch per record was plotted by year, showing the similar three stages pattern of CPUE discussed in previous paragraph (Fig. 3.5b and c).

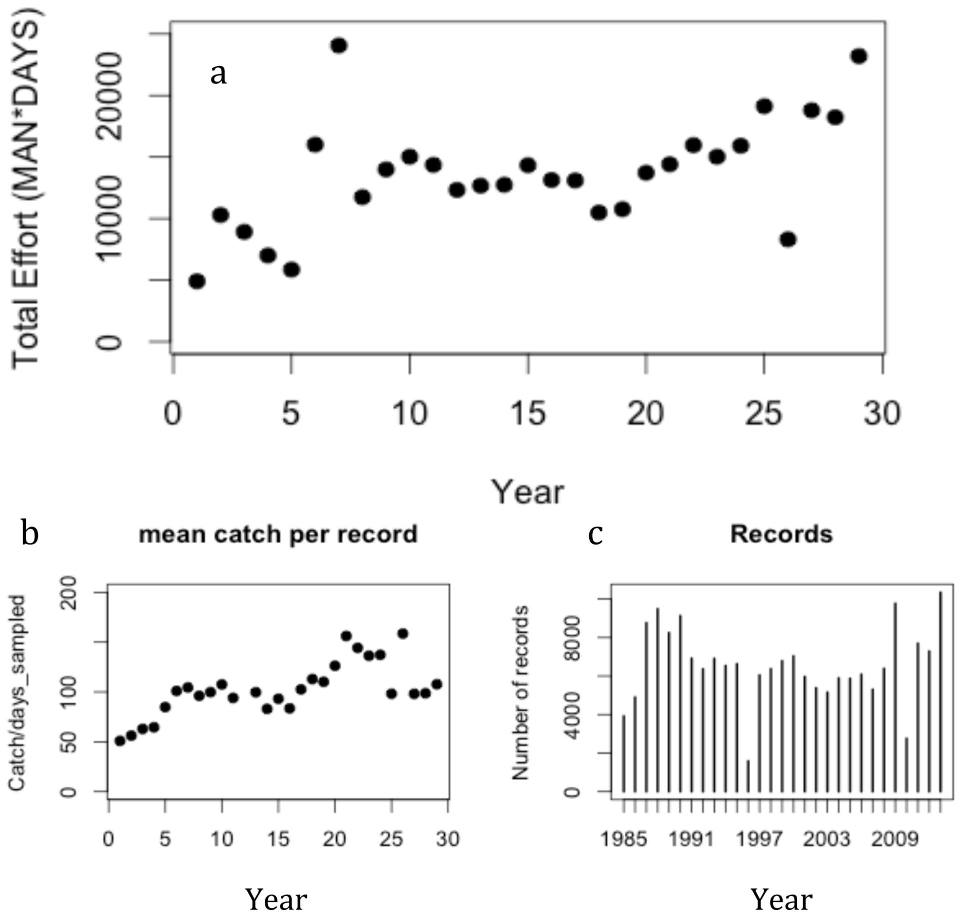



**Figure 3.5. Aggregated data for the Seychelles demersal fishery; (a) total effort in man*days; (b) annual mean catch per record; and (c) annual total number of records.**

In order to better understand patterns in catch rates, and other fishery and biological information, it is important to include the spatial component in the analyses. Although the CAS database includes information on the fishing grounds where the samples come from (Table 3.3), allowing certain degree of spatial stratification, higher spatial resolution in the sampling protocols would allow better spatial management of this fishery. Monitoring of empirical indicators at the local, fine scale level is critical to detect local depletions and to better understand the fleet spatial and temporal dynamics.

**Table 3.3. Catches of *L. sebae* for schooners and whalers by fishing ground (1990-2013).**

| FISHING GROUND | | CATCH (tonnes) |
|---|---|---|
| OUT | TEN MILES FROM MAHE PRASLIN | 2,204 |
| AMI | AMIRANTES | 1,119 |
| MAH | MAHE -UNSPECIFIED | 968 |
| N | BIRDS, DENIS, NORTH EDGE | 737 |
| SW | SOUTH WEST EDGE | 727 |
| SE | SOUTH EAST EDGE | 588 |
| NW | NORTH WEST EDGE | 587 |
| W | OWEN THOR ROBERTS BANKS | 402 |
| E | TORAZE BANK | 309 |
| NE | NORTH EAST EDGE | 301 |
| MW | MAHE WEST | 268 |
| ME | MAHE EAST | 262 |
| SIL | SILHOUETTE | 201 |
| PLA | PLATE | 187 |
| FRE | FREGATE | 133 |
| MS | MAHE SOUTH | 114 |
| MNW | MAHE NORTH WEST | 108 |

By analyzing total schooner and whalers catches (in tons) for bourzwa (*Lutjanus sebae*), clear patterns arise. Most catches (42%) of bourzwa for the period 1985-2013 came from fishing grounds OUT, AMI, and MAH (Table 3.3; Fig. 3.6). In addition, temporal patters are evident by fishing ground (Fig. 3.7). For AMI, annual catches were stable around 20 tons until 2007 were they started to increase, peak in 2009 and back to ca. 20 tons in 2011. For OUT, catches increased in 2002, peaking in 2007 and again in 2011. These spatial and temporal patterns are critical to inform proper management.

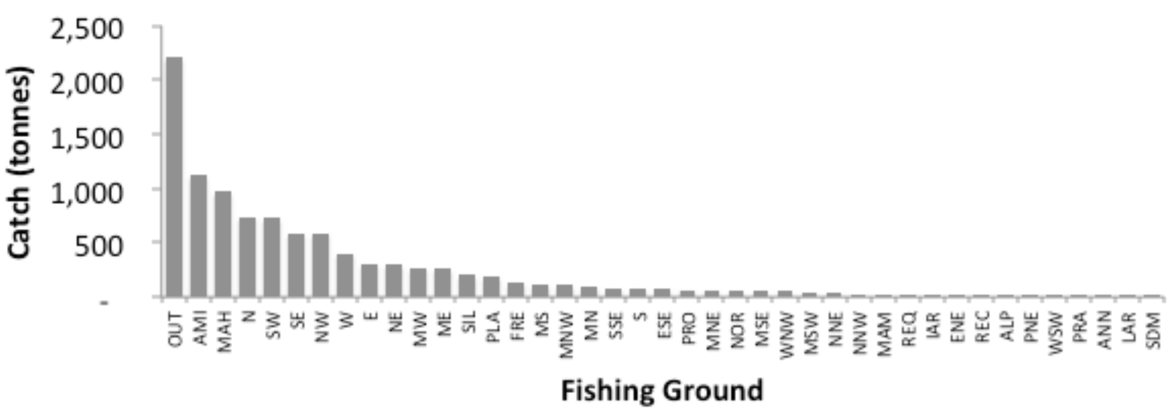



**Figure 3.6. Catches (tons) of *L. sebae* for schooners and whalers by fishing ground (1990-2013)**

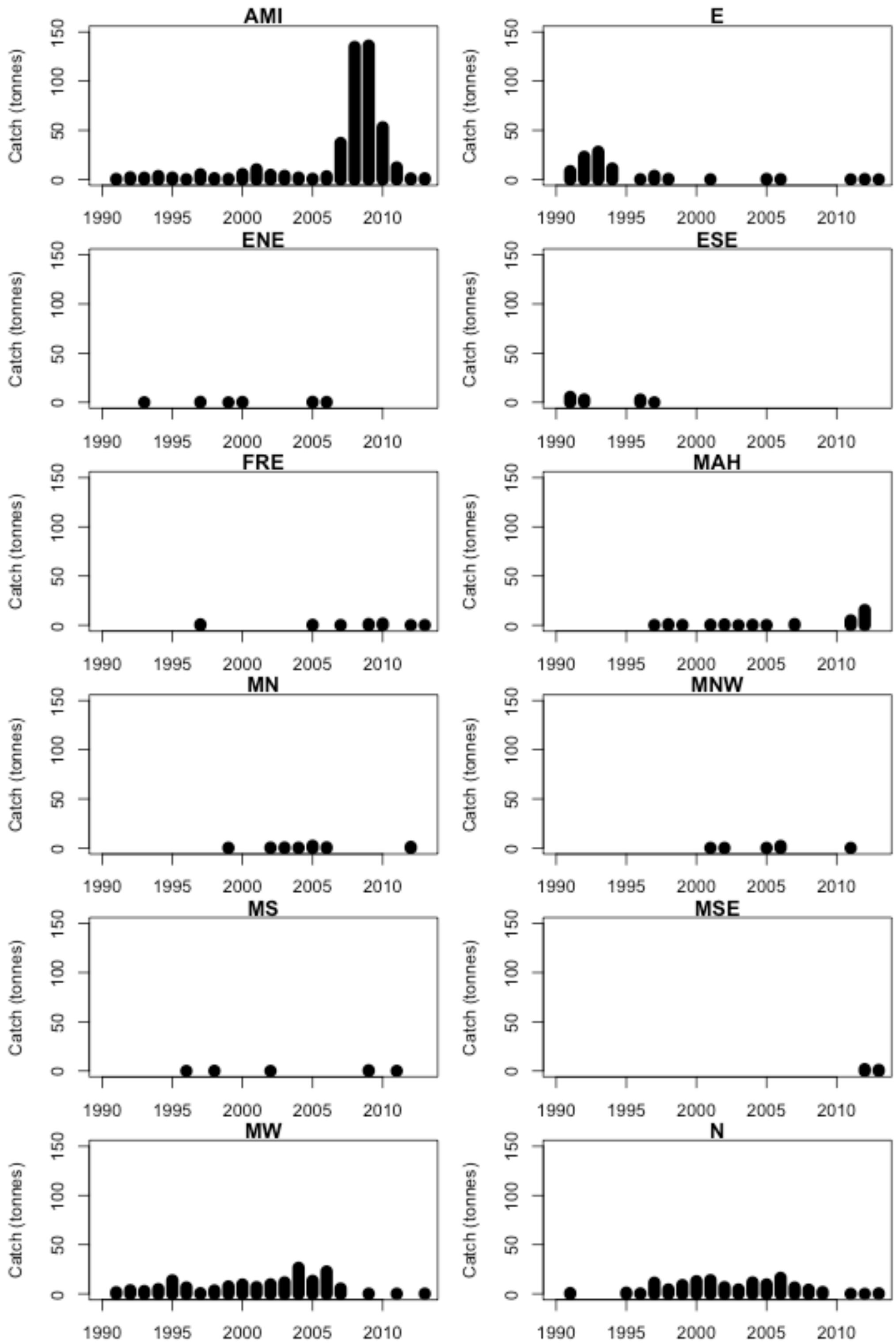



**Figure 3.7. Catch (tons) distribution of *L. sebae* for schooners and whalers by fishing ground (after CAS nomenclature) for the period 1990-2013.**

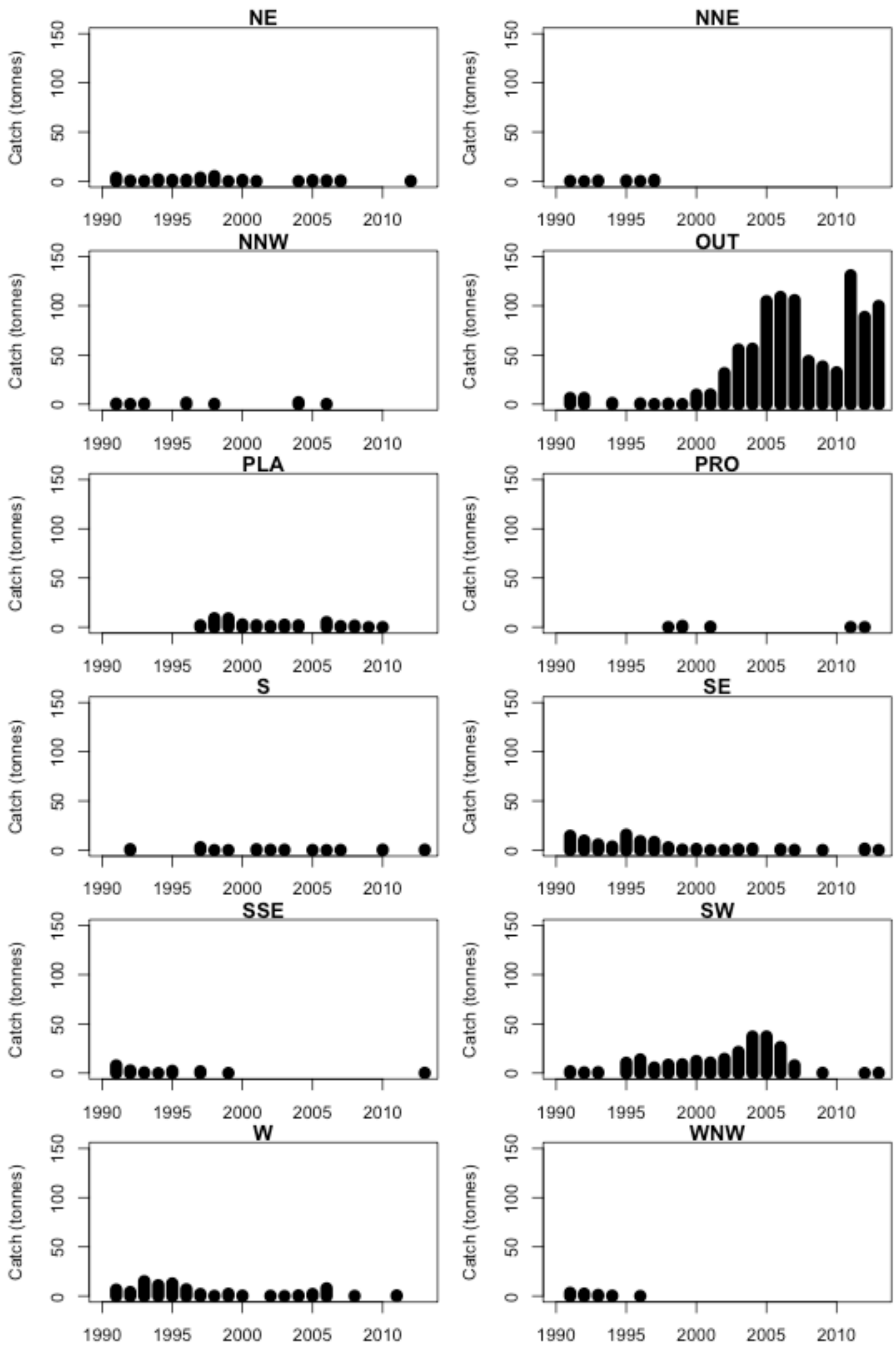



**Figure 3.7. Continued.**

## 3.3. Species specific stock assessments

One of the objectives of conducting the SICA and PSA described in Section 2, was to established those species with higher risks therefore warranting a more quantitative stock assessment. However, another critical element to consider is the nature, quantity, reliability and species resolution of the database. Although many species were identified as high risks, the data available through CAS only allowed species-specific analysis for the following species: bourzwa (red emperor; *Lutjanus sebae*), zob gri (green job; *Aprion virescens*), vyey makonde (brown spotted grouper; *Epinephelus chlorostigma),* vara vara (twospot red snapper; *Lutjanus bohar*)*,* karang balo (bludger; *Carangoides gymnostethus*); karang plat (yellowspotted trevally; *Carangoides fulvoguttatus*) and kaptenn blan (bluelined large-eye bream; *Gymnocranius robinsoni*), laskar (yellowtail emperor; *Lethrinus crocineus*) and bordmar (humphead snapper; *Lutjanus coccineus*). However, once data is collected at the species level, the same framework and approaches used for these species can be easily extended to cover the full range of species with higher socio-economic importance and high risks.

Information compiled and analyzed for each of these species included: (1) number of records per year, annual total catch, standardized CPUE (as described in Chapter 2 and in Gutierrez 2011) and proportion of the catch per fishing ground. Finally, giving the nature of the data and information available, two methodologies to assess each of these stocks were used:

1. Catch-only method. This method was developed by Martell and Froese (2013) to estimate MSY and included in DLMtools library by Carruthers (2014) to estimate overfishing limits (OFL). This method estimates stock trajectories based on catch series and intrinsic rate of increase therefore allows estimating stock depletion. OFL, which in this case is consistent with MSY, is calculated based o surplus production parameters $K$, $r$ and depletion and a Schaefer productivity curve.

2. Dynamic surplus production model. Surplus production from a stock is calculated from catch and an index of abundance. The approach used was a Schaefer logistic model using a standardized index of ln(CPUE) (for a full model description see Gutierrez 2011).

Results from both modelling approaches, including parameters and MSY calculations for the 10 species with enough information available are included in Table 3.4. Density distribution of parameters estimates are included in Appendix 2.

**Table 3.4. Model parameters and outputs for both catch-only method and surplus production model for species identified as high risk and where information was available to conduct a quantitative stock assessment.**

| Species | Bourgois | | Job | | Maconde | | Vara | | Balo | | Plat | | Kapten | | Laskar | | Bordmar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Schaefer Models** | | | | | | | | | | | | | | | | | |
| **Variable** | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **K** | 1211 | 613 | 952 | 222 | 116 | 98 | 309 | 64 | 358 | 102 | 329 | 54 | 231 | 36 | 129 | 82 | 115 | 25 |
| **r** | 0.49 | 0.28 | 0.52 | 0.29 | 0.47 | 0.29 | 0.47 | 0.29 | 0.47 | 0.29 | 0.55 | 0.28 | 0.57 | 0.26 | 0.45 | 0.30 | 0.51 | 0.26 |
| **q** | 0.082 | 0.030 | 0.062 | 0.014 | 0.017 | 0.006 | 0.057 | 0.011 | 0.174 | 0.057 | 0.125 | 0.039 | 0.093 | 0.018 | 0.021 | 0.010 | 0.090 | 0.022 |
| **Bmsy** | 605.5 | | 476 | | 58 | | 154.5 | | 179 | | 164.5 | | 115.5 | | 64.5 | | 57.5 | |
| **Fmsy** | 0.24 | | 0.26 | | 0.23 | | 0.23 | | 0.24 | | 0.28 | | 0.29 | | 0.23 | | 0.25 | |
| **MSY** | **148.0** | | **122.9** | | **13.6** | | **36.2** | | **42.1** | | **45.2** | | **33.0** | | **14.6** | | **14.5** | |
| | | | | | | | | | | | | | | | | | | |
| **Model** | **Catch-Only method** | | | | | | | | | | | | | | | | | |
| **OFL (MSY)** | **161.7** | 58 | **80.2** | 26 | **3.7** | 2 | **10.1** | 2 | **42.4** | 11 | **51.2** | 18 | **25.4** | 11 | **1.7** | 1 | **10** | 2 |

### 3.3.1. Bourzwa (*Lutjanus sebae*)

Bourza catches has been increasing since 1985, peaking in 2007 and then decreasing (Fig. 3.8b). Meanwhile, standardized CPUE has been stable from 1985 to 2001, tripling in subsequent years with a peak in 2006 and decreasing right after. However, by looking at the spatial distribution of the catches, the apparent high CPUE levels (2001 onwards) seemed to be related to the schooner and whaler fleets moving to the Outer and Amirantes fishing grounds (Fig. 3.7; Fig. 3.8d). Although CPUE has decreased since 2007, current levels seem to be above the CPUE for the period 1985 to 2001. Due to changes in the CAS and uncertainty about the spatial dynamics of the fishery and the resource, relative current levels of CPUE needs to be taken with caution while the marked decreased in CPUE from 2005 up to 2013 correspond with fishermen's observations on less availability of bourzwa in the water. In addition, catches from 2003 to 2010 have been above MSY, declining to values close to MSY for recent years (2010-2013; Fig. 3.9). Again, these values should be interpreted with caution given the considerable uncertainty observed in model outputs (Appendix 2).

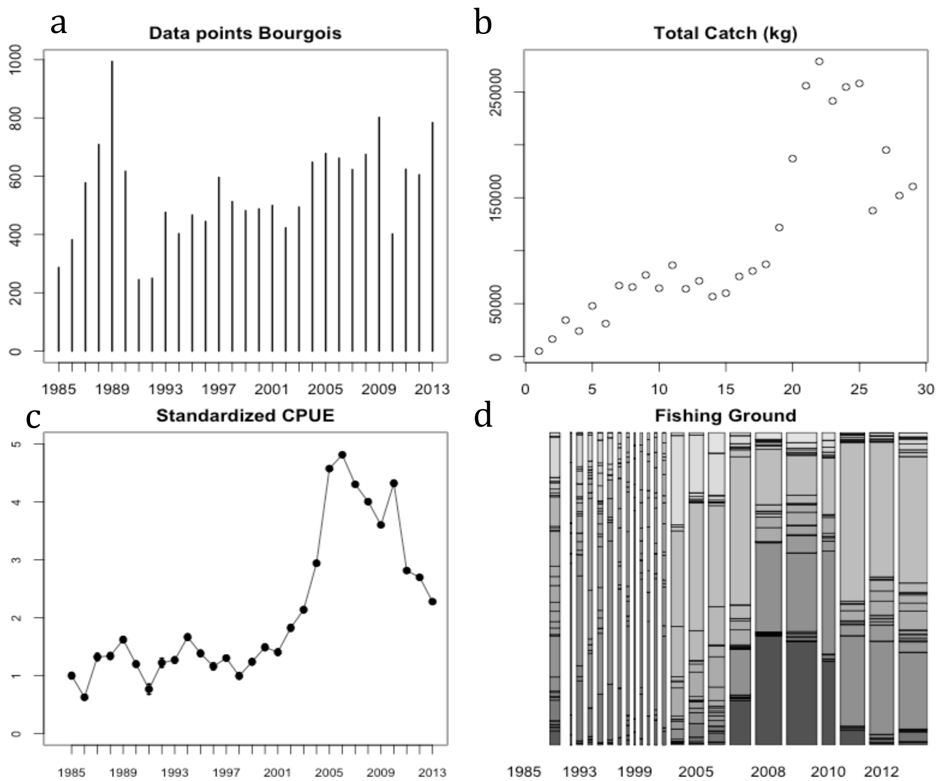



**Figure 3.8. Data for bourzwa (*L. sebae*) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

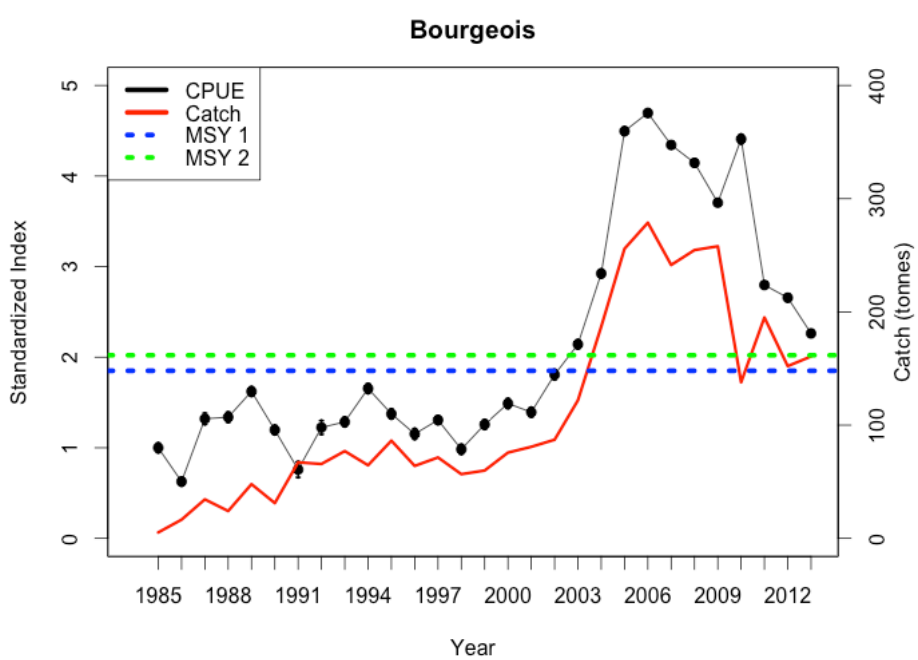



**Figure 3.9. Catch, standardized CPUE and MSY estimates for bourzwa (*L. sebae*). Green line shows MSY from the catch-only method; blue line from the Schaefer surplus method.**

### 3.3.2. Zob gri (*Aprion virescens*)

Catches of zob gri have been increasing steadily since 1985, with a higher degree of interannual variability for the period 2005-2013 (Fig. 3.10b). Standardized CPUE has also been increasing from 1985 up to 2008 where it started to decrease but still above values at the start of the data series. Again, these trends may be partially caused by changes in spatial dynamics (Fig. 3.10d). Catches have been below MSY (as estimated from Schaefer surplus method) until 2005, fluctuating around MSY afterwards (Fig. 3.11). These values should be interpreted with caution given the considerable uncertainty observed in model outputs (Appendix 2), but the decline in CPUE from 2008 onwards is alarming.

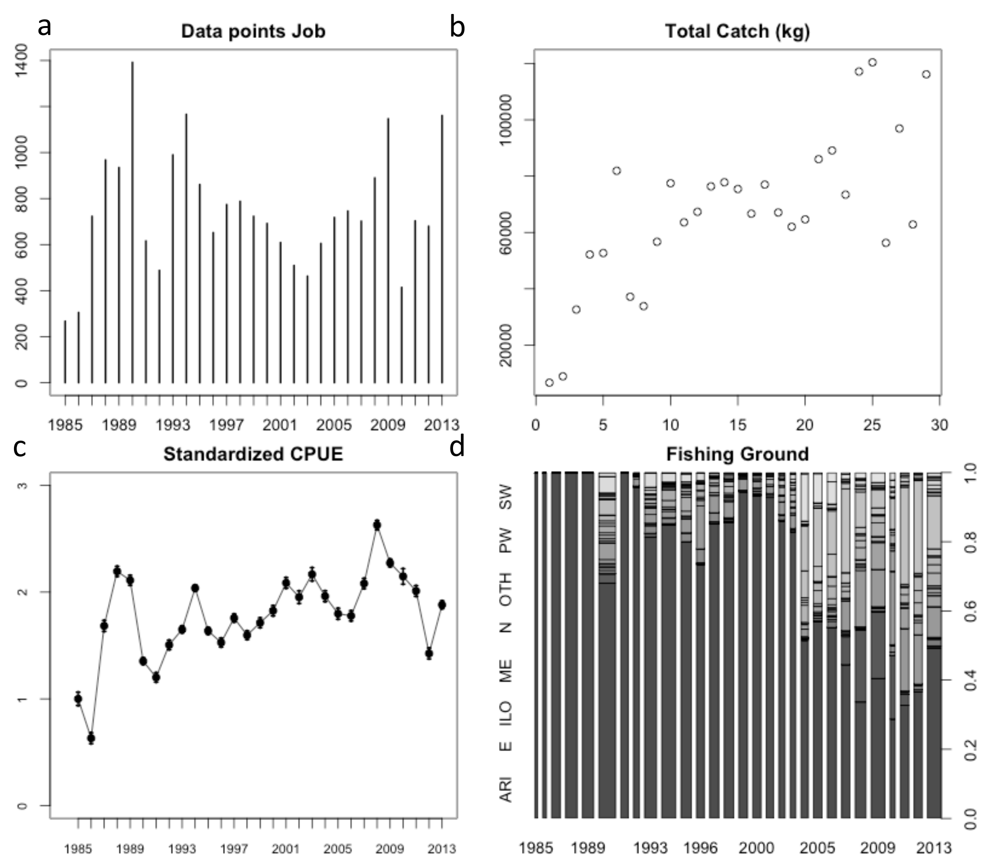



**Figure 3.10. Data for zob gri (*A. virescens* ) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

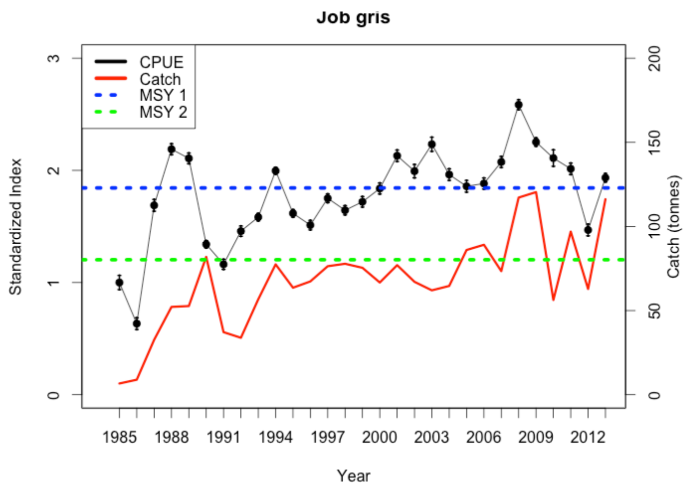



**Figure 3.11. Catch, standardized CPUE and MSY estimates for zob gri (*A. virescens*). Green line shows MSY from the catch-only method; blue line from the Schaefer surplus method.**

### 3.3.3. Vyey makonde (*Epinephelus chlorostigma*)

Catches of vyey makonde have been decreasingly steadily since 1991 reaching ca. 8 tons in 2013 (Fig. 3.12b). Standardized CPUE shows substantial interannual variability, reaching a peak in 2002 and decreasing afterward. Changes in fleet dynamics also appear to have influenced catches of this species (Fig. 3.12d). In terms of catches for the last 5 years, these have been between both estimates of MSY so it is challenging to derive conclusions based on the stock assessment. In any case, a substantial decrease in CPUE since 2002 should be considered with caution.

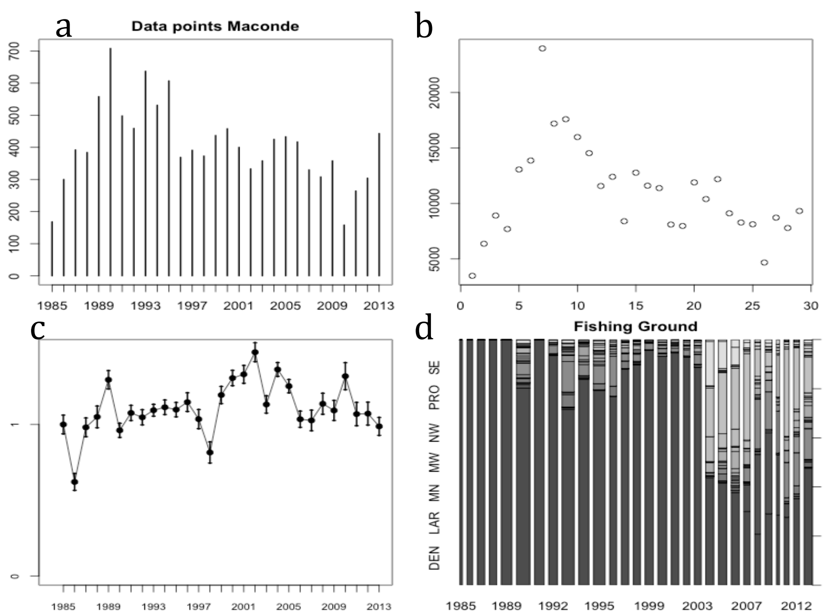



**Figure 3.12. Data for vyey makonde (*E. chlorostigma*) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

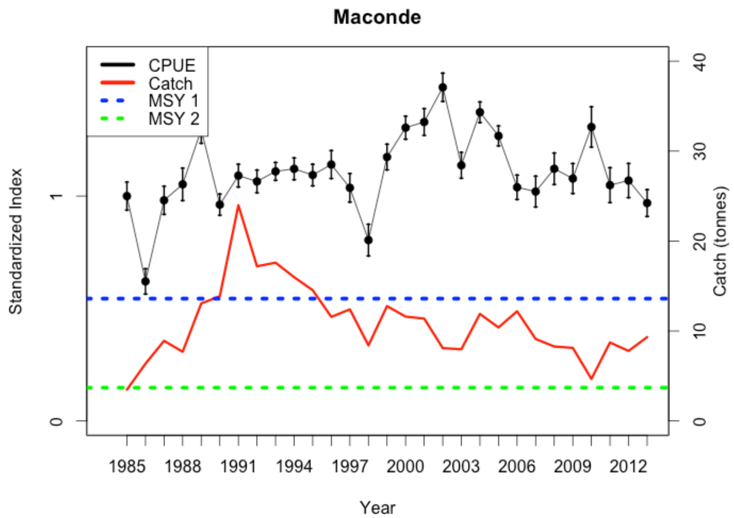



**Figure 3.13. Catch, standardized CPUE and MSY estimates for vyey makonde (*E. chlorostigma*).**

### 3.3.4. Vara vara (*Lutjanus bohar*)

Catches for this species show a high interannual variability (Fig. 3.14b) but generally increasing after 2003 (excluding 2010 where the sampling intensity was low; Fig. 3.14a). In addition, fishing fleets seem to have moved to new areas 2004 (Fig. 3.14d), which could be altering the patterns. Standardized CPUE for vara vara have increased since 1985 up to 2003 where it reached a peak and then decreased to values close to those at the start of the time series (1985). As for vyey makonde, MSY estimates are highly uncertain (Appendix 2) with substantial differences between the two methods (Fig. 3.15). Again, a marked decrease in CPUE since 2003 should be considered a warning sign.

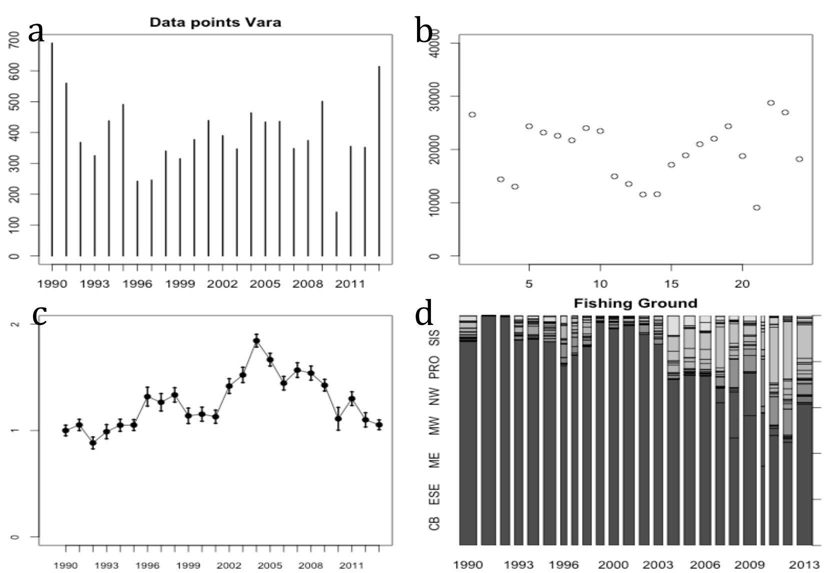



**Figure 3.14. Data for vara vara (*L. bohar*) from 1985-2013.**

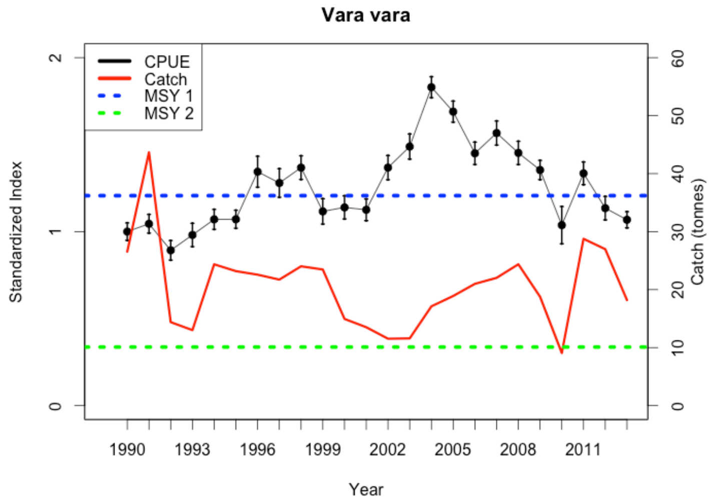



**Figure 3.15. Catch, standardized CPUE and MSY estimates for vara vara (*L. bohar*).**

### 3.3.5. Karang balo (*Carangoides gymnostethus*)

As noted for other species, data before 1990 should be either excluded from the analysis, of interpreted with caution due to changes in the CAS. Catches for karang balo have been fairly constant until 2002 where declined steadily onwards, with a few years with high catches (i.e., 2009 and 2013; Fig. 3.16b). Standardized CPUE, as for most of the other species, shows a peak around 2005 and decreasing afterwards Fig. 3.17). In this case, both stock assessment methods showed similar MSY estimates (ca. 60 tons) and catches have been generally above this level, which could explain the decrease in CPUE in recent years (Fig. 3.17).

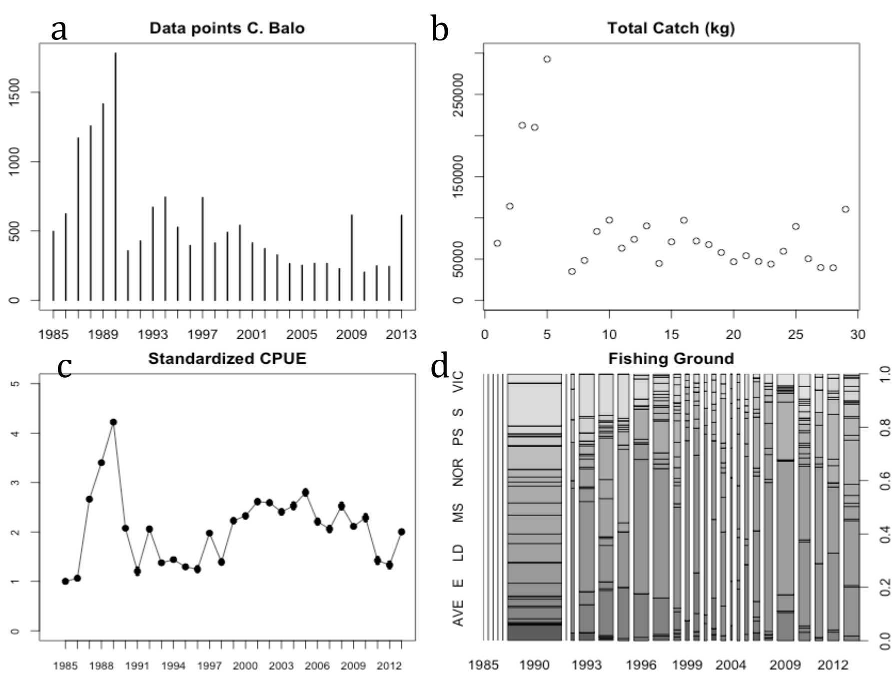



**Figure 3.16. Data for karang balo (*C. gymnostethus*) from 1985-2013.**

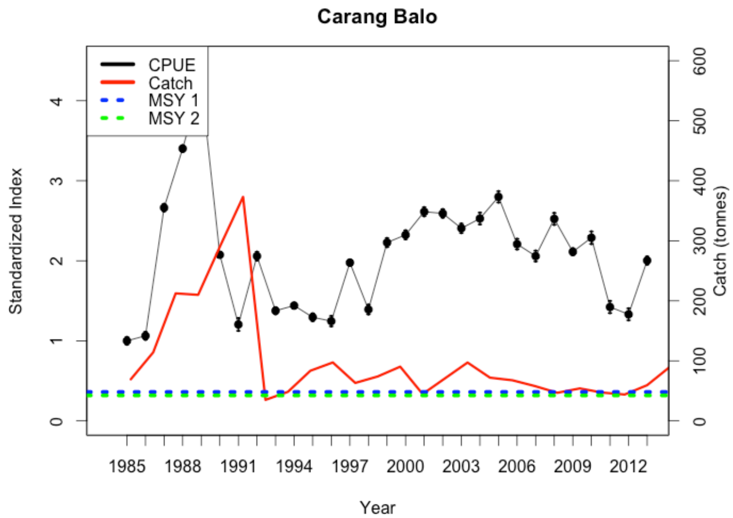



**Figure 3.17. Catch, standardized CPUE and MSY estimates for karang balo (*C. gymnostethus*).**

### 3.3.6. Karang plat (*Carangoides fulvoguttatus*)

Catches for this species also show high interannual variability (Fig. 3.18b) while standardized CPUE shows a 'low' period from 1990 to 1999 and a 'high' period from 2000 to 2004, decreasing consistently afterward (Fig. 3.18c). Catches have been slightly above MSY estimates (Fig. 3.19).

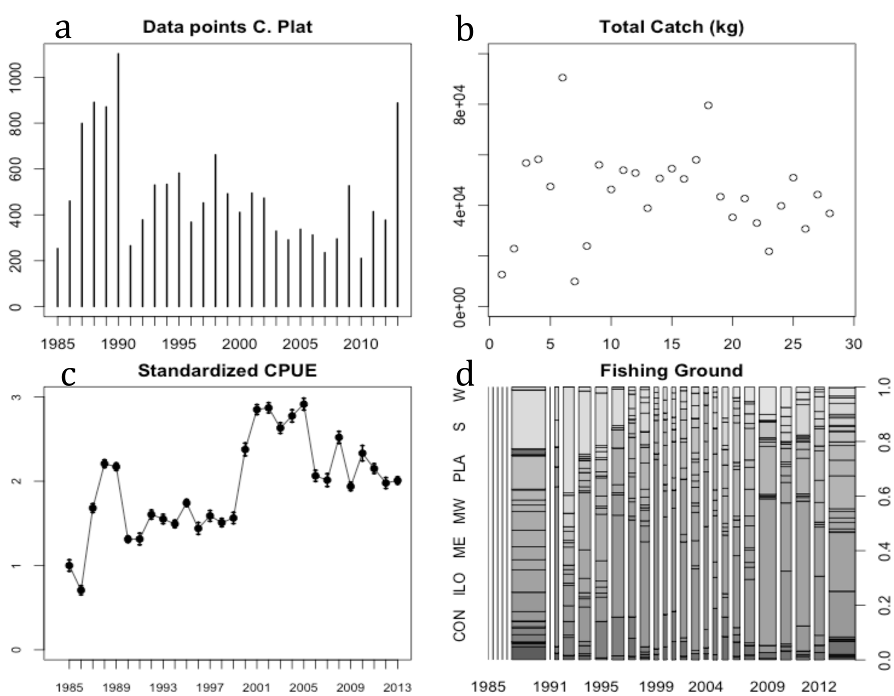



**Figure 3.18. Data for karang plat (*C. fulvoguttatus*) from 1985-2013.**

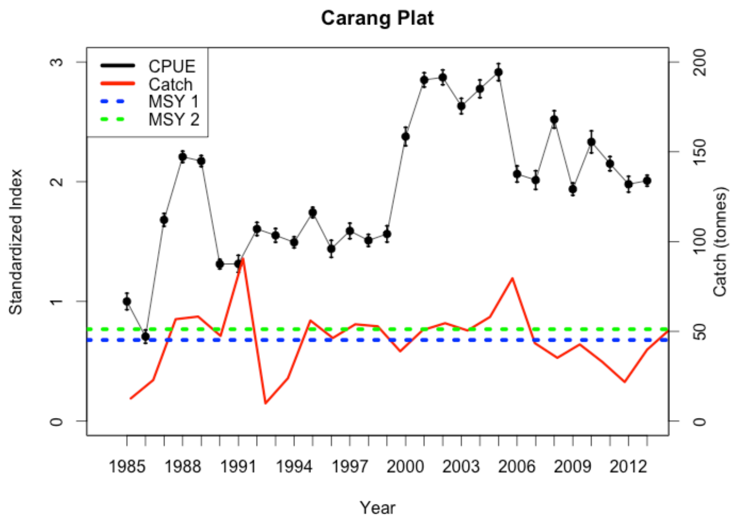



**Figure 3.19. Catch, standardized CPUE and MSY estimates for karang plat (*C. fulvoguttatus*.**

### 3.3.7. Kaptenn blan (*Gymnocranius robinsoni*)

Kaptenn blan catches have been increasing steadily since 1991 (excluding 2010 where sampling representation was low; Fig. 3.20b) while standardized CPUE has again increased since 1999, peaking in 2001 and decreasing afterwards (Fig. 3.21). Catches have been slightly above MSY estimates (Fig. 3.21) and trends in terms of spatial fleet dynamics should be better monitored.

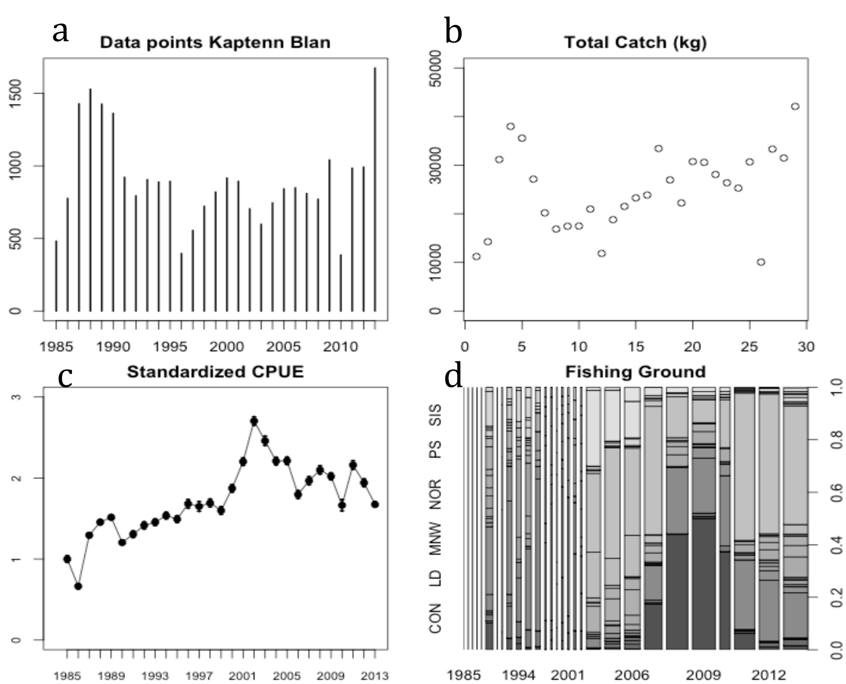



**Figure 3.20. Data for kaptenn blan (*G. robinsoni*) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

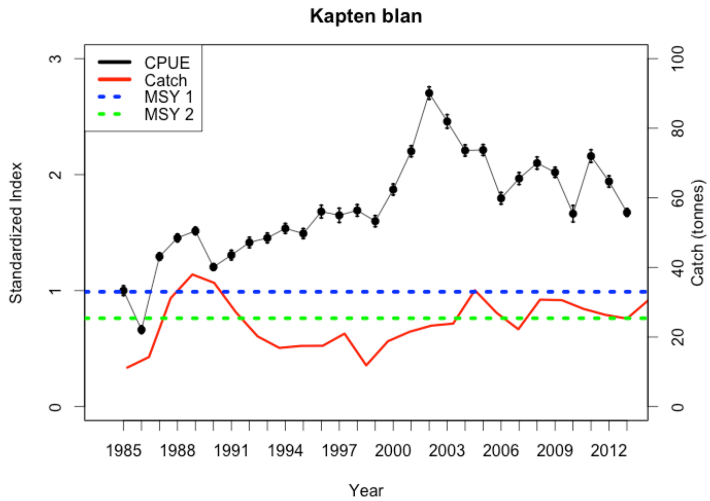



**Figure 3.21. Catch, standardized CPUE and MSY estimates for kaptenn blan (*G. robinsoni*)**

### 3.3.8. Laskar (*Lethrinus crocineus*)

Number of samples with catches of laskar has been decreasing, as well as total catches, particularly since 1992 (Fig. 3.22a,b). On the other hand, CPUE has been stable across the time series (excluding 2004) probably due to relatively low catches since 2002 when compared to MSY estimates (Fig. 3.23).

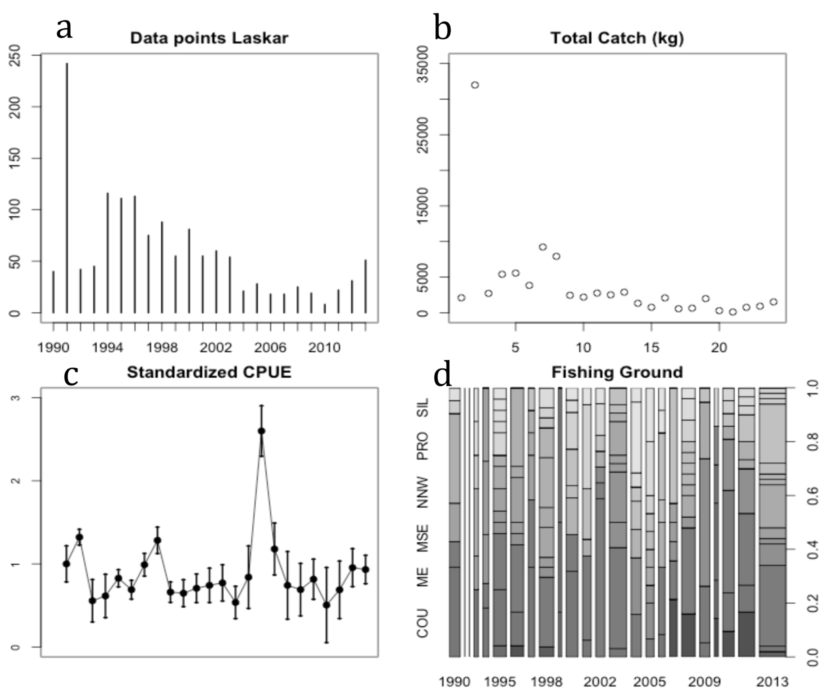



**Figure 3.22. Data for laskar (*L. crocineus*) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

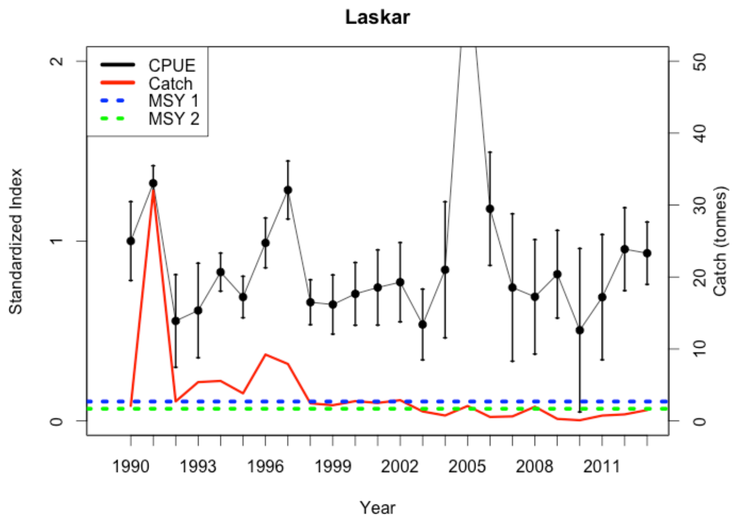



**Figure 3.23. Catch, standardized CPUE and MSY estimates for laskar (*L. crocineus*).**

### 3.3.9. Bordmar (*Lutjanus coccineus*)

Catches for bordmar show again a high interannual variability but generally higher in recent years (Fig. 3.22b) while standardized CPUE has been decreasing since 2003 (Fig. 3.22c). Catches have been generally above MSY estimates potentially causing the observed decline in CPUE (Fig. 3.23). As in previous species, MSY estimates need to be considered with caution.

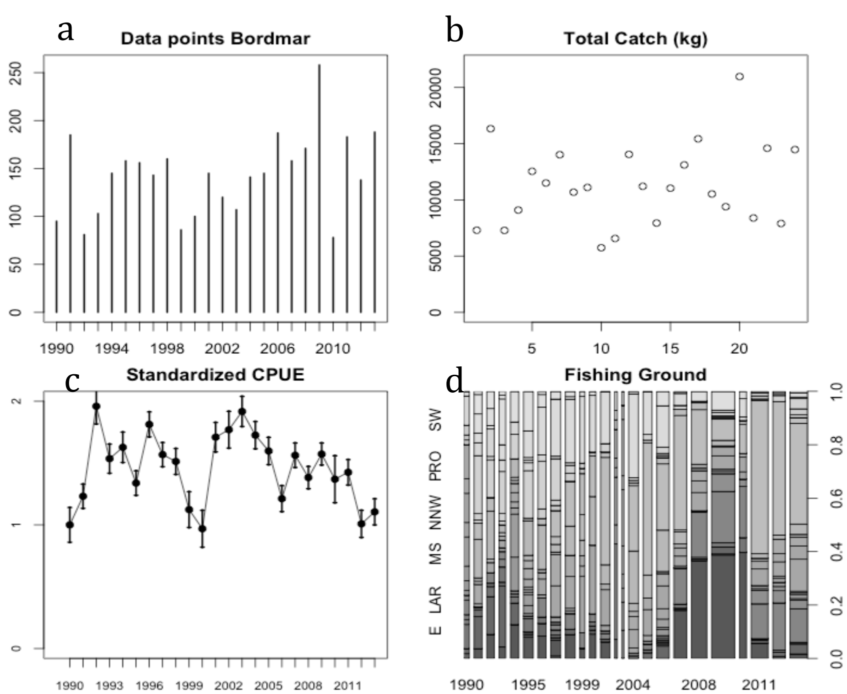



**Figure 3.22. Data for bordmar (*L. coccineus*) from 1985-2013. (a) total number of samples by year; (b) total catches per year; (c) CPUE (man*days) standardized by fleet, gear and fishing ground; and (d) proportion of catch by fishing ground as defined by CAS.**

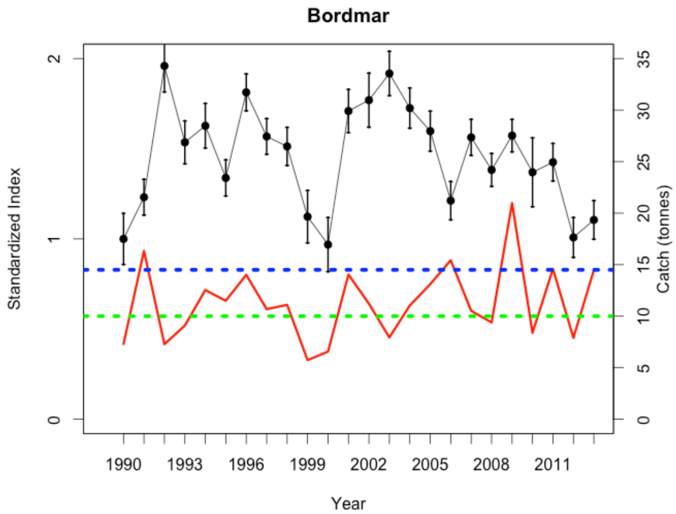


**Figure 3.23. Catch, standardized CPUE and MSY estimates for bordmar (*L. coccineus*).**

## 3.4. Length-based indicators

Fish size or length is a key factor affecting various ecological processes, and changes in length distributions may be caused by environmental factors, genetic variability in certain life histories and intra and inter-specific competitive interactions (Shin et al., 2005). Most importantly, fishing is in most cases size selective, modifying the size of length structure of fish populations with consequences in both productivity and resilience of fish stocks. Thus, length-based indicators have been identified as useful in describing the response of fish populations to fishing activities, and may also contribute to the implementation of the EAF (Garcia et al., 2003). Collecting time series of length data may be not only a cost-effective strategy to get information on the impacts of fishing in populations, but also form the basis for a suite of length-based indicators (Cope and Punt, 2009; Ault et al., 2014).

One of the most simple indicator of changes in the size structure due to, generally, fishing pressure is the mean length of the catches. By catching the oldest, biggest, fish in the population, fishing truncates the length structure and therefore decreasing the mean size of the catch (assuming closed populations, constant selectivity, etc.). Length or size structure of the catches were recorded for 3 species capture by the demersal fishery: (1) bourzwa (*L. sebae*) from 1989 to 2013; (2) zob gri (*A. virescens*) from 2003 to 2013; and (3) vyey makonde (*E. chlorostigma*) from 2003 to 2013.

Mean lengths for bourzwa have been below the mean length of maturity ($L_m$) until 2006, and slightly above afterwards (Fig. 3.24). This increasing trend in mean lengths could be interpreted as a positive indicator of stock health (i.e., there are bigger fish in the catch thus growth overfishing is not occurring). However, this slight increase in mean lengths with time may be the result of the sampling design, an artifact due to the fishing fleets moving to less exploited areas, thus where bigger fishes occur, and/or due to changes in gear selectivity or market demands. However, by looking at the length frequency distribution for the most recent year (2013), a high proportion (43%) of immature fish (i.e., lengths below $L_m$; Fig. 3.25b) are being caught. This data agrees with fishermen observations of small fish dominating the catches. In the case of bourzwa, a high demand and price for smaller fish (called mini-fish) by the tourism industry (i.e., hotels and restaurants) creates a strong incentive for fishermen to catch and retain immature fish. Moreover, length frequency distributions of the catches highlight a decrease in the occurrence of bimodal distributions, with less fish recruiting to the fishery (Fig. 1.26c). As mentioned previously, these patterns should be taking with caution until more data, at higher temporal and spatial resolution is collected and analyzed.

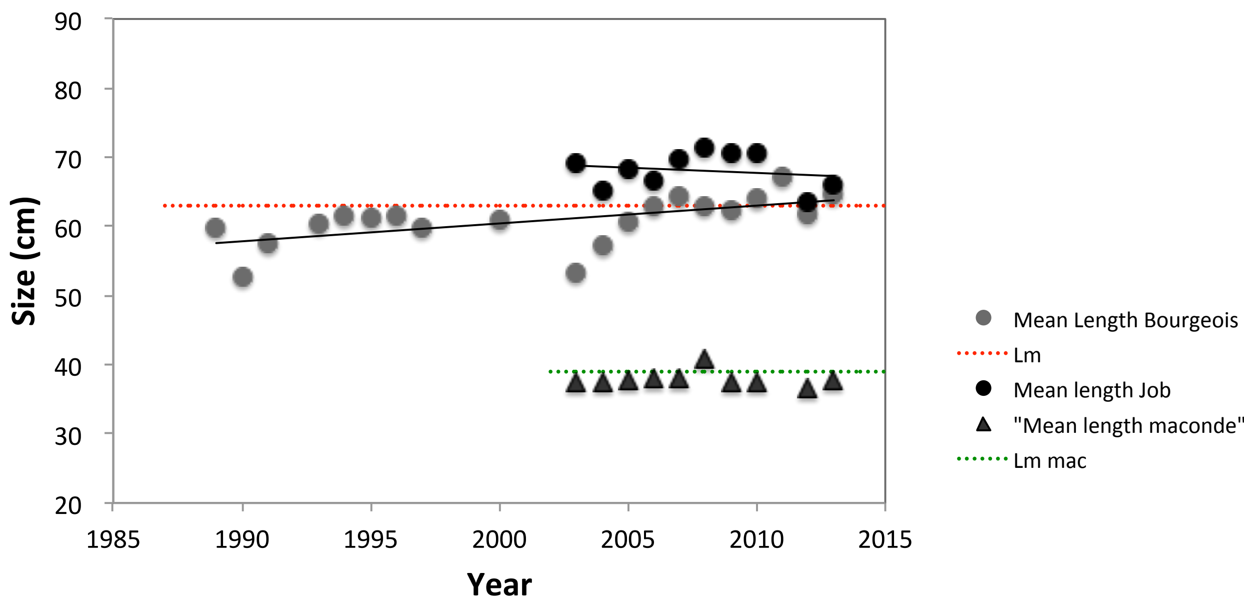



**Figure 3.24. Length/size data for three species in the Seychelles demersal fishery: (1) bourzwa (*L. sebae*) from 1989 to 2013; (2) zob gri (*A. virescens*) from 2003 to 2013; and (3) vyey makonde (*E. chlorostigma*) from 2003 to 2013. Dotted lines represent mean length at maturity for each species ($L_m$)**

On the contrary, mean lengths for zob gri have been above $L_m$ for all sampled years (except for 2012) but with a declining trend towards 2013 (Fig. 3.24). This apparent contradictory finding could be due to several factors, including data inaccuracies, poor sample representation, or uncertainty in life history parameters, particularly $L_m$. Again, length frequency distribution for 2013 shows, as for bourzwa, a high proportion (33%) of immature fish in the catches (Fig. 3.26b).

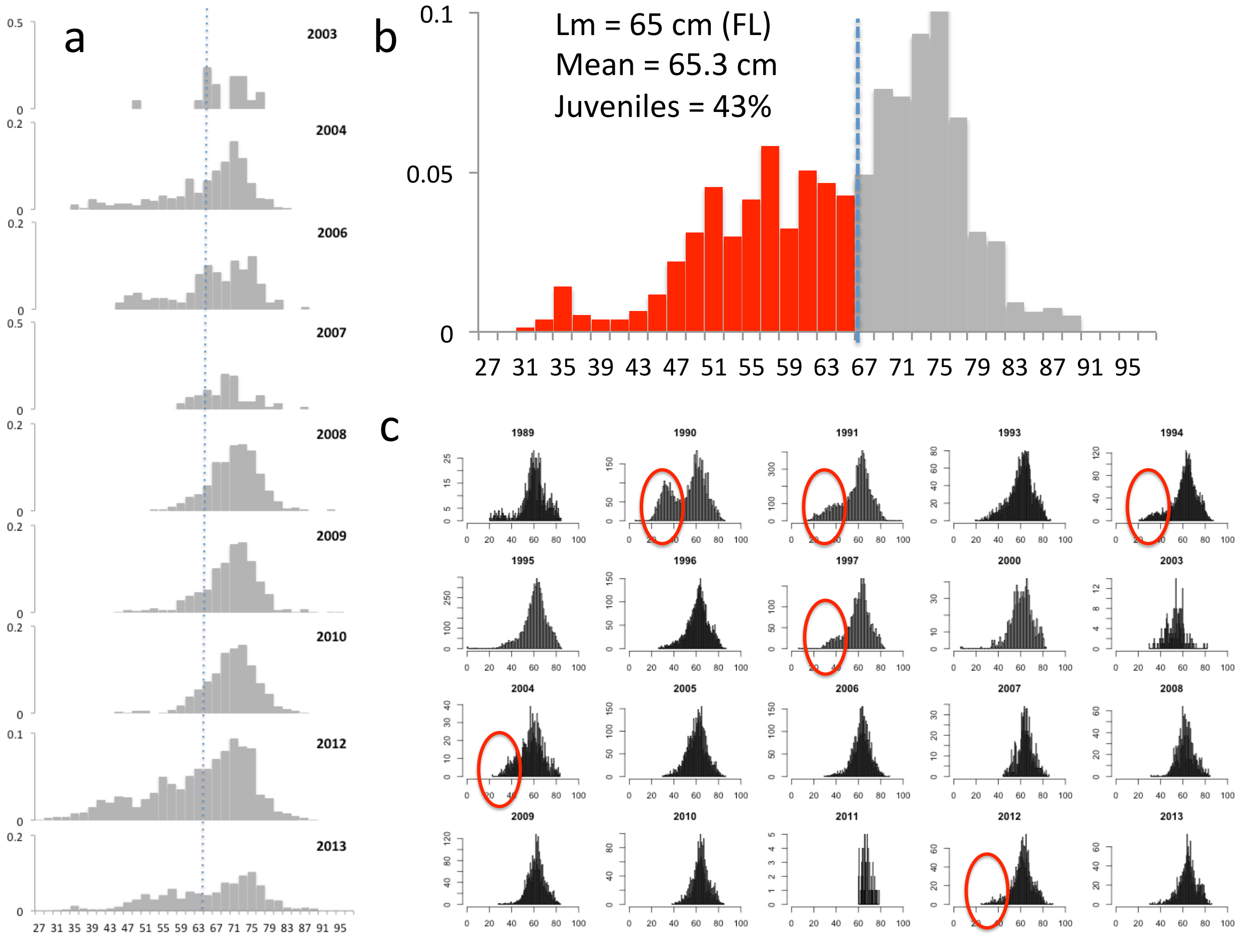



**Figure 3.25. Length frequency distribution of bourzwa (*L. sebae*) from catches; (a) from 2003 to 2013; (b) for most recent year (2013; dotted vertical line shows length at maturity and red bars represent immature individuals: $L<L_m$); and (c) for 1989 to 2013 highlighting new cohorts recruiting to the fishery (red ovals).**

Lastly, mean lengths for vyey makonde have been slight below the mean length of maturity ($L_m$), except in 2008, with no clear temporal trend (Fig. 3.24). Length frequency distribution for 2013 shows again a high proportion of immature individuals, particularly if considering $L_m$ for males (i.e., maturing a larger sizes than females; Fig. 3.27b).

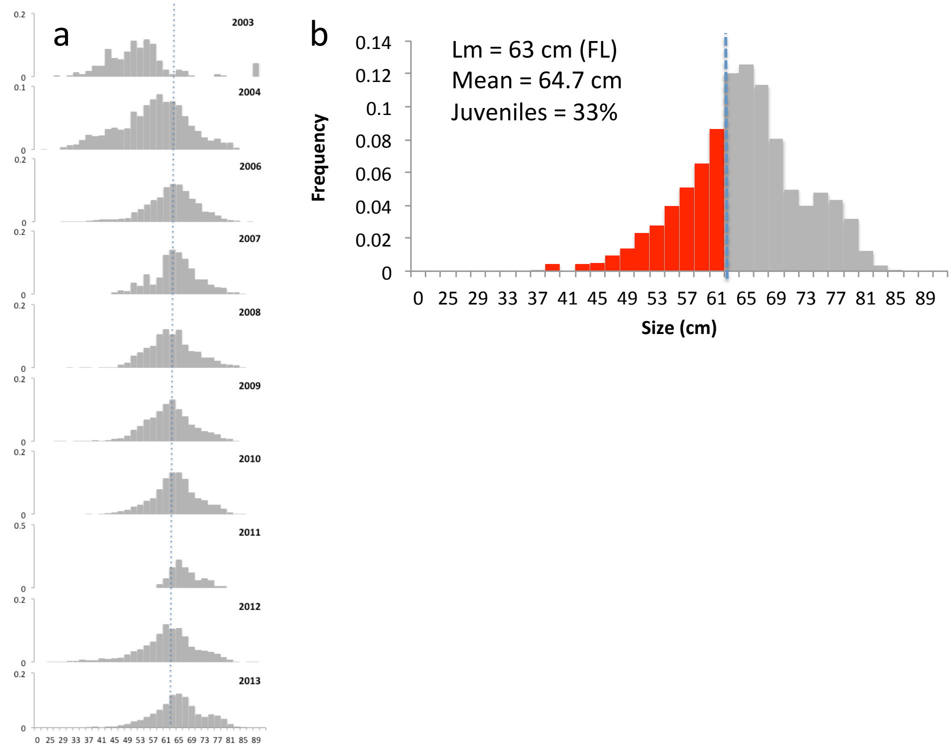



**Figure 3.26. Length frequency distribution of zob gri (*A. virescens*) from catches; (a) from 2003 to 2013; (b) for most recent year (2013; dotted vertical line shows length at maturity and red bars represent immature individuals: $L<L_m$).**

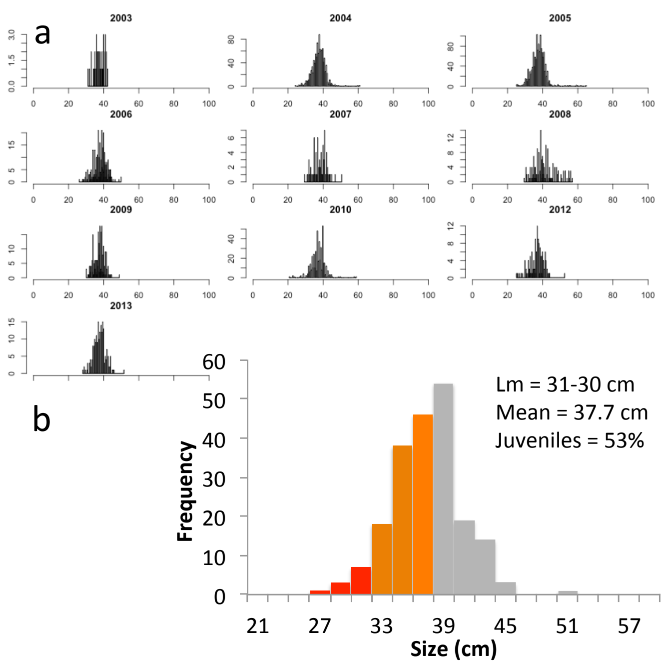



**Figure 3.27. Length frequency distribution of vyey makonde (*E. chlorostigma*) from catches; (a) from 2003 to 2013; (b) for most recent year (2013; red bars shows individuals below female $L_m$ and orange bars individuals below male $L_m$).**

### 3.5. Species composition of catches

Shifts in the catch structure in terms of species composition and numbers may be a signal of potential unsustainable practices, particularly in a multi-species fishery. For example, market or socio-cultural preferences for a particular species may shift the fishing pressure to less-preferred species once those high-value are depleted. Therefore, tracking catch species composition is critical since unsustainable fishing of a particular set of species may not be reflected in changes in the overall abundance or catches. However, these shifts in catch structure may be hidden unless sufficient spatial, temporal and species-specific data is collected. In fact, species aggregation in samples taken by the CAS may preclude the identification of such patterns and the potential depletion of some species. As an example, aggregated catches for the period 1985 to 2013 for those species capable of being differentiated by the CAS show a high variability for some species, particularly bourzwa and karang balo (Fig. 3.28).

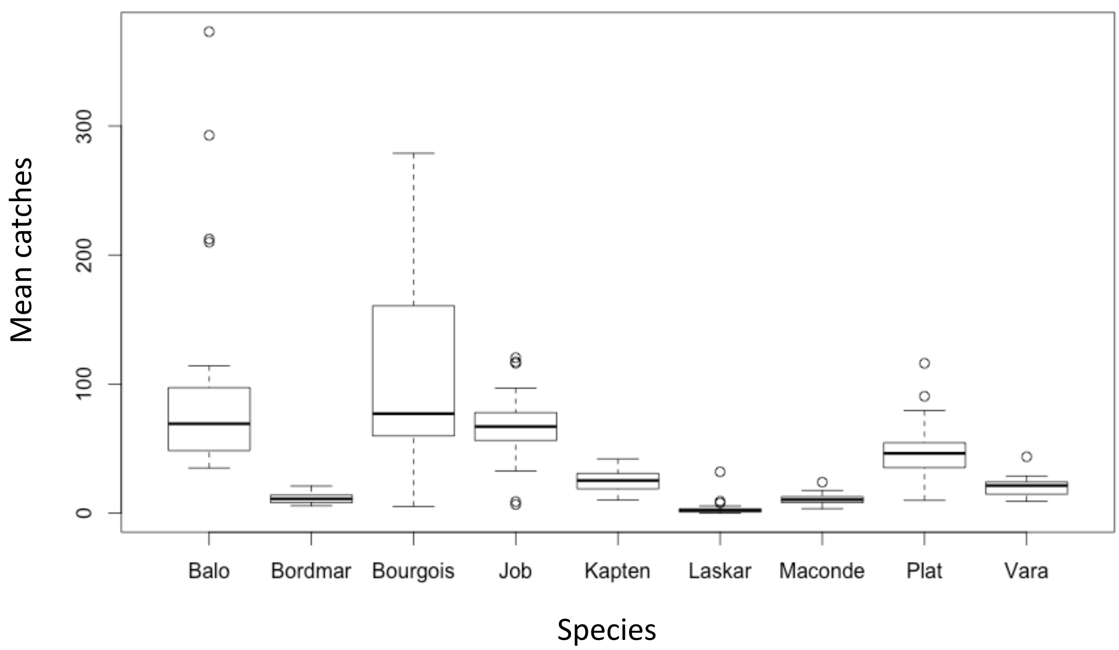



**Figure 3.28. Annual catches (in tons) for 10 species as identified by the Catch Assessment Survey from 1985 to 2013. Horizontal lines represent the median of the sample. The box shows the upper and lower quartiles. The whiskers show the range (i.e. the largest and smallest values).**

By looking at the species composition of the catches by year, some clear patterns emerge (Fig. 3.29): (1) karang balo dominates the catches in years 1985 and 1989; (2) bourzwa and zob gri, together with karang balo are the predominant species in 1993 and 1997; (3) catches of karang plat were high compared to other species for years 1993 and 2001; (4) bourzwa becomes the dominant species for years 2005 and 2009 and less dominant for year 2013.

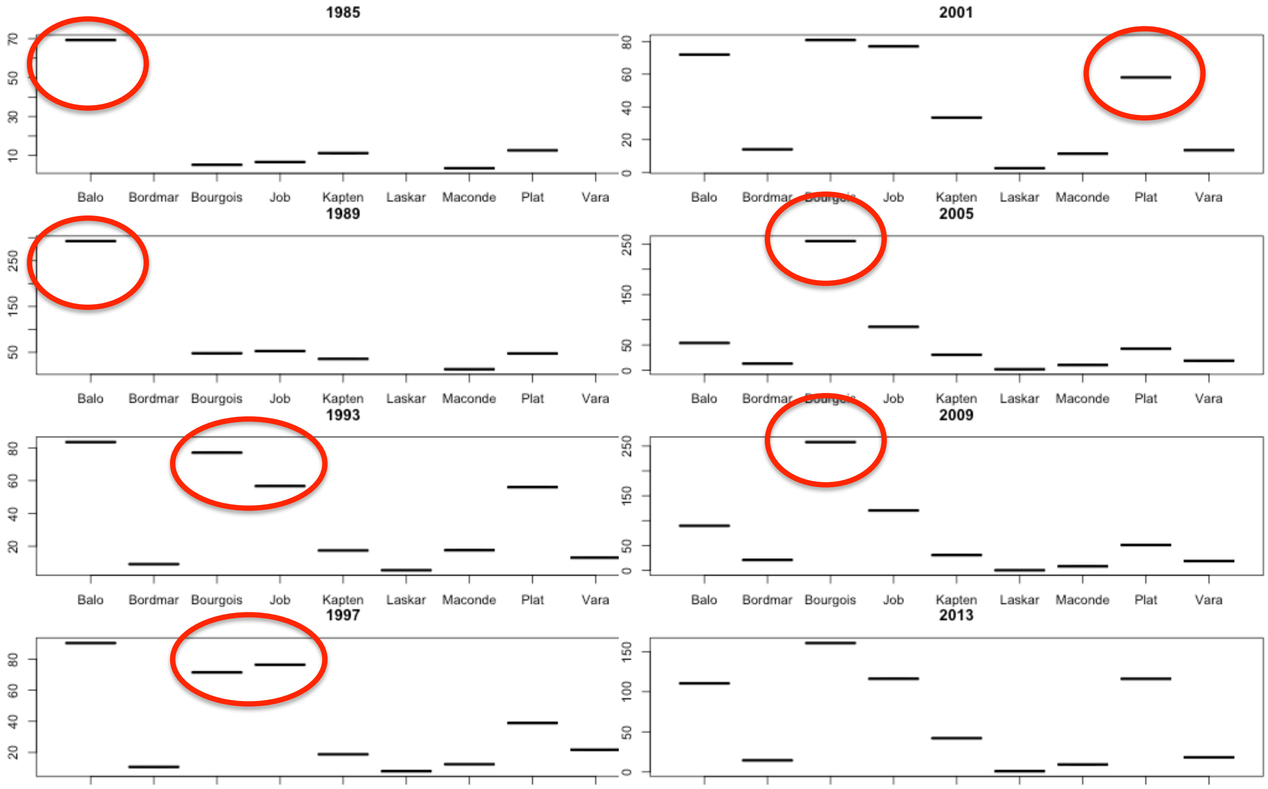



**Figure 3.29. Annual catches (in tons) for 10 species as identified by the Catch Assessment Survey from 1985 to 2013. Horizontal lines represent the median of the sample. Red ovals highlight dominant species.**

## 3.6. Conclusions

- Information contained in the Catch Assessment Surveys is rich but the database will benefit from better validation, scrutiny, documentation and clean up particularly to improve the use by external parties. In order to improve accessibility and use of the data, a series of templates could be developed, containing: catch, effort (various metrics), CPUE (various metrics) by fleet, gear, species and fishing ground. This will allow not only more efficient use of the data in future assessment, but also better internal reporting that would allow the use of empirical indicators and decision rules at the right spatial and temporal scales.

- Catches for individual species have shown different patterns (Fig. 3.30). While zob, laskar and vara have seen overall increases in catches from 1985/1990 to 2013, other species such balo, bordmar and makonde have shown the opposite trend. Bourzwa catches have increased considerably during the early 2000s, decreasing in the last 10 years. These patterns can be masked by spatial fleet dynamics (e.g., increase in catches due to fleets moving to outer fishing grounds with less exploited populations) therefore is critical to monitor these trends at the right spatial resolution.

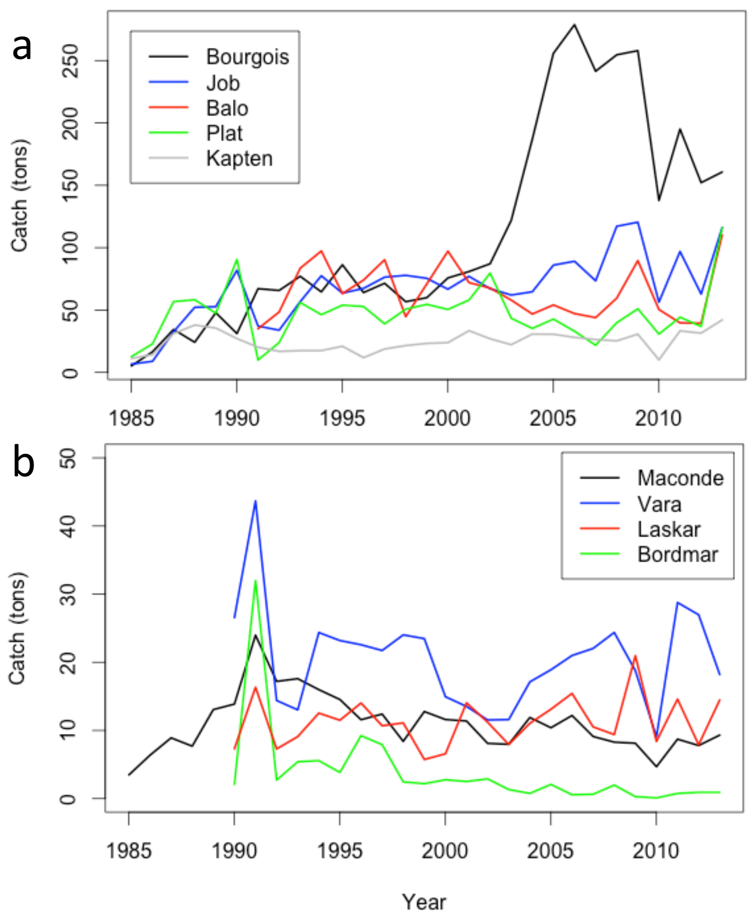



**Figure 1.30. Catches (tons) for (a) species with higher catches and (b) for species with less ctaches in the demersal fishery analyzed from 1985 to 2013.**

- Standardized CPUE has shown similar patterns for all species, excepting vyey makonde where CPUE has been relatively stable for the whole data series (Fig. 3.31). CPUE for the rest of the species analyzed have shown a period of stability from 1990 to 1998, increasing afterwards and peaking around 2000-2002 and finally decreasing towards recent years. For bourzwa, CPUE peaked around 2005, decreasing notable towards the end of the time series (2013). This recent and constant decreasing trend for all, if not most species analyzed is alarming and requires further investigation, data collection and analyses. It is important to highlight that despite this decrease in CPUE, current values are in general at or above initial CPUE levels (1985), which could indicate a fishing down process towards maximizing long-term catches. However, this initial CPUE should be considered with extreme caution given many uncertainties and poor data quality in early years of the CAS.

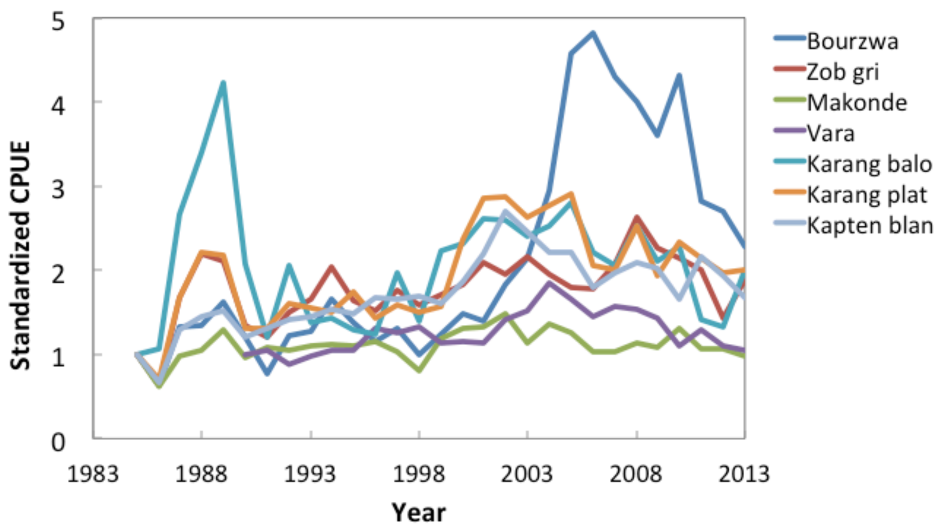



**Figure 3.31. Standardized (by fleet, gear and fishing ground) CPUE (tons*man/hours) for all species in the demersal fishery analyzed from 1985 to 2013.**

- Stock assessment using surplus production models highlighted considerable uncertainty around MSY estimates due to the quality of the data available and in some cases due to the 'uninformative' nature of the data (i.e., lack of contrast in the time series or 'one way trip'). In any case, catches for most species were around MSY levels and in some cases exceeded such levels, which may be causing a decline in CPUE. These MSY estimates should be considered with caution for the reasons above explained.

- For those three species with length information, a high proportion of juveniles (between 33% and 53%) was found for 2013. Fishing immature individuals will eventually lead to recruitment overfishing (i.e., reduction in the reproduction potential of the stock). Collection of sizes/lengths of individual fish in the catch should remain a priority and extended to other high risk species identified in the PSA work. This length information should be complemented with biological studies of length at sexual maturity to increase certainty as well as capture potential spatial structure in growth and other life history parameters. This information is considered a key step in developing length-based indicators that can be easily monitored at relevant spatial and temporal scales.

- Temporal analysis of species composition of the catches has shown changes in species dominance for the whole Seychelles demersal fishery. This trends could be associated to changes in species availability, in market demands, socio-cultural preferences, or a combination thereof. In order to better understand this patterns and use this metric as an indicator of sustainable fishing, it is important to collect this information at right spatial and temporal scales, and to clearly identify individual species (or group) in the catches. Changes in species composition of the catches can indicate unsustainable exploitation for some species with higher economic and socio-cultural interest. Thus, it is important to restructure the CAS to allow species-specific information on catches, effort and individual lengths. It is important to note that species aggregation for schooners/whalers and small boats differed (i.e., a species is in group F1 for schooners and in group B2 for small boats). Consistency in species-specific reporting is imperative.

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

## 4. REFERENCES

Ault JS, Smith SG, Bohnsack JA (2005) Evaluation of average length as an estimator of exploitation status for the Florida coral- reef fish community. ICES Journal of Marine Science 62(3): 417-423.

Carruthers TR, Punt AE, Walters KJ, MacCall A, McAllister MK, Dick EJ, Cope J. (2014) Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research 153: 48–68

Cope JM and Punt AE (2009) Length-Based Reference Points for Data -Limited Situations: Applications and Restrictions. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:169-186.

Froese R and Pauly D (2014). Editors, FishBase. World Wide Web electronic publication. www.fishbase.org

Garcia SM, Zerbi A, Aliaume C, Do Chi T, Lassarre G (2003). The ecosystem approach to fisheries, Rep. No. 443. FAO, Rome.

Gutierrez NL (2011) The establishment of baseline and development of a monitoring and assessment plan for the artisanal fishery on Praslin, Seychelles. 73 pp.

Hilborn R and Walters CJ (1992) Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

Hobday AJ, et al. (2007) Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Hobday AJ , Smith ADM, et al. (2011) Ecological Risk Assessment for the Effects of Fishing. Fisheries Research 108, 372-384

Kimura DK and Tagart JV (1982) Stock reduction analysis, another solution to the catch equations Canadian Journal of Fisheries and Aquatic Sciences 39(11): 1467–1472.

Martell S and Froese R (2013) A simple method for estimating MSY from catch and resilience. Fish and Fisheries 14(4): 504–514.

Quinn TJ II and Deriso RB (1999) Quantitative fish dynamics. Oxford University Press, New York.

Shin Y-J, Rochet MJ, Jennings S, Field JG, Gislason H (2005) Using size-based indicators to evaluate the ecosystem effects of fishing. ICES Journal of Marine Science, 62: 384-396

# 5. APPENDICES

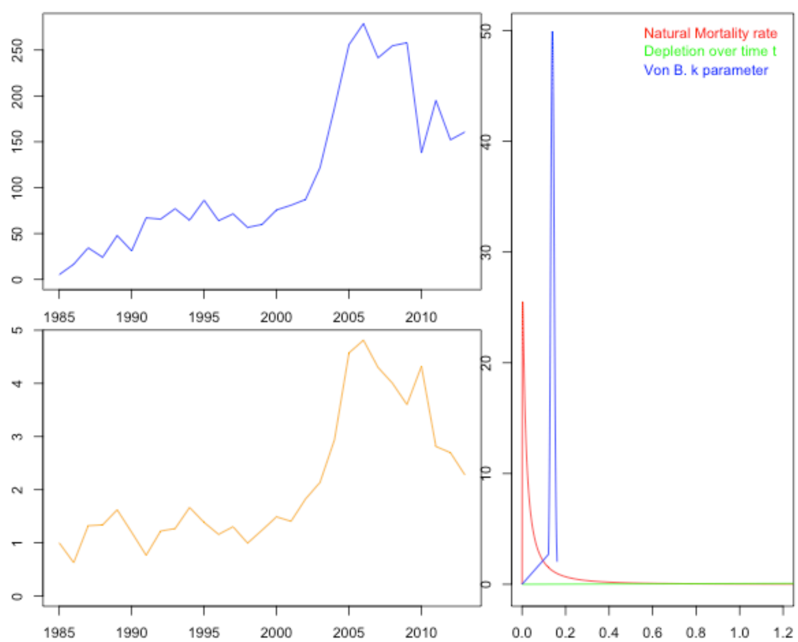
## 5.1. Appendix 1 – PSA and SICA tables

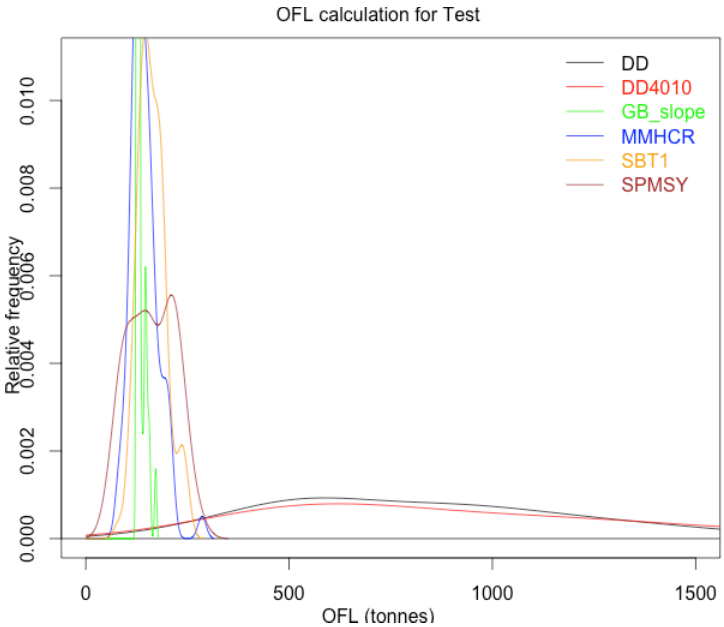
See Excel files for SICA and PSA Tables

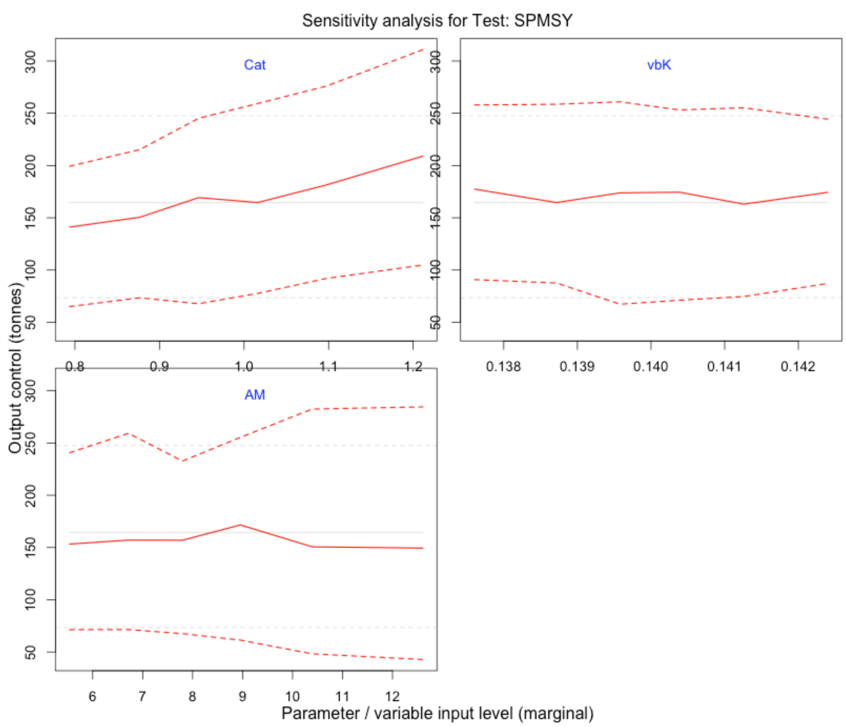
## 5.2. Appendix 2 – Assessment metrics and analyses

Figures in this Appendix show some of the exploratory sensitivity analyses derived from both surplus production models (Catch-only method implemented in DLMtool; Carruthers 2014; and Schaefer models).

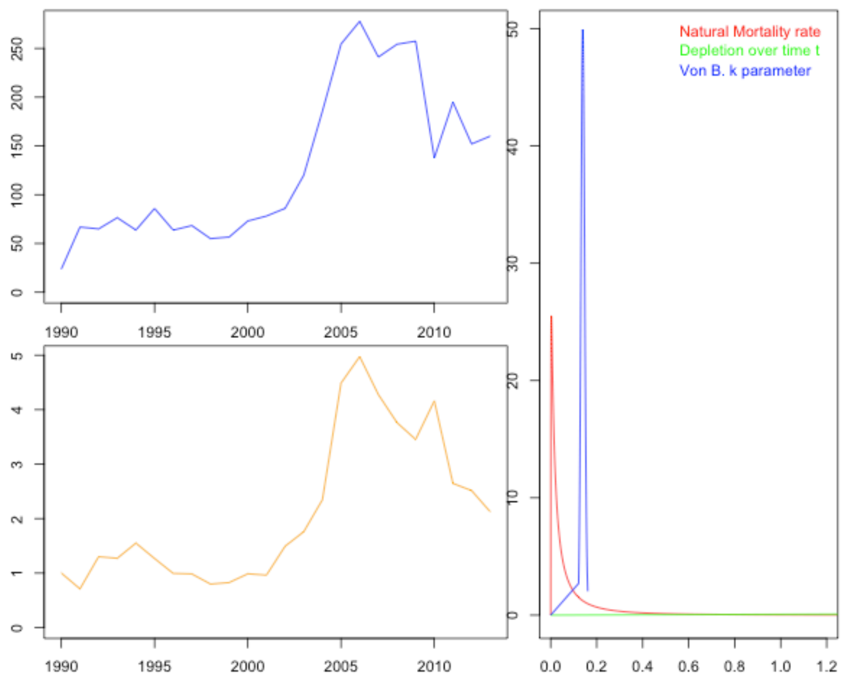
Bourzwa all fleets

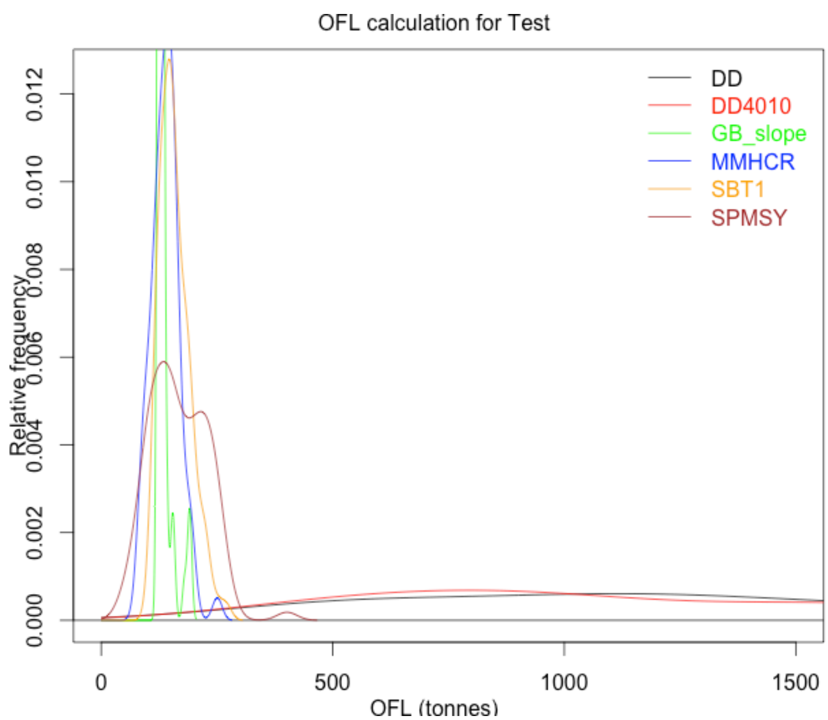


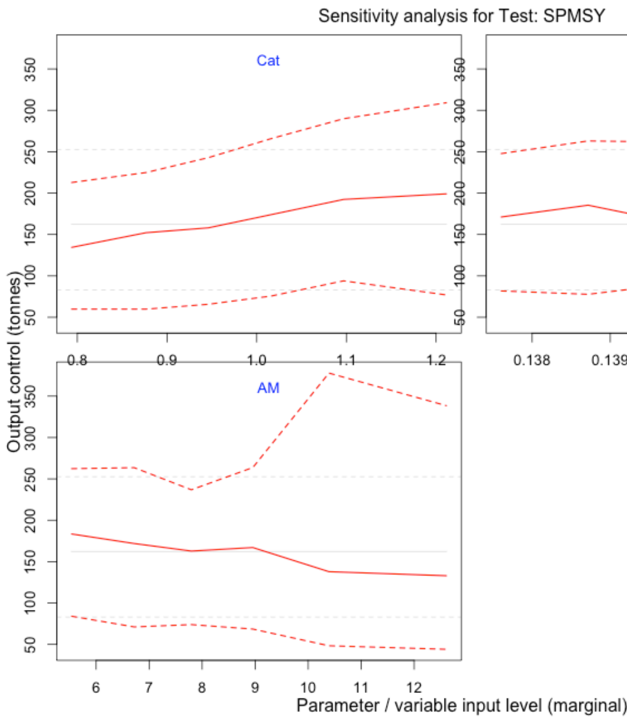


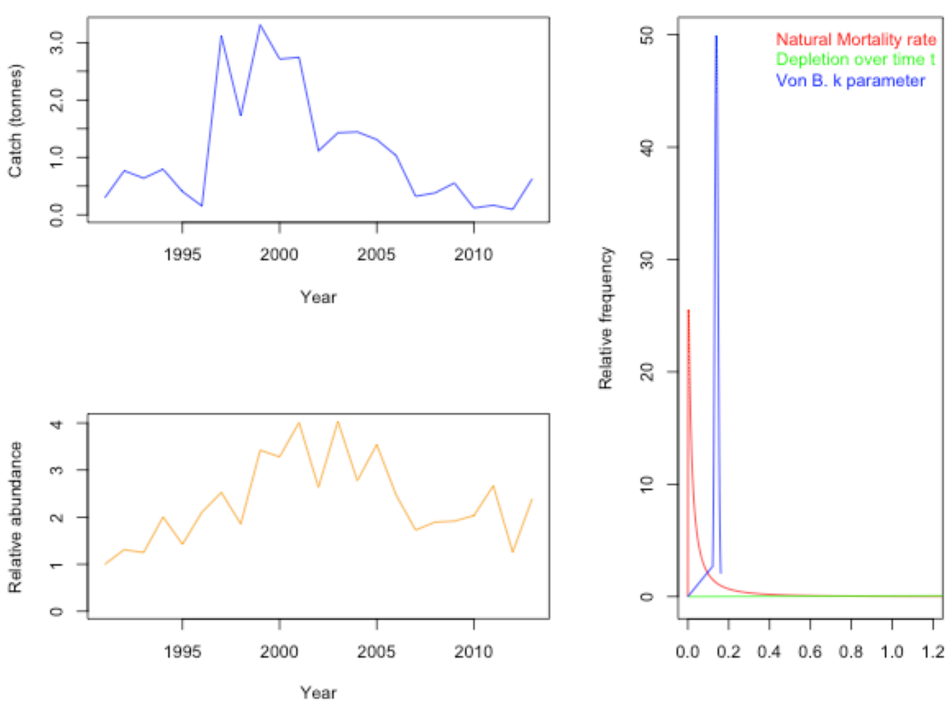

Bourzwa schooners and whalers

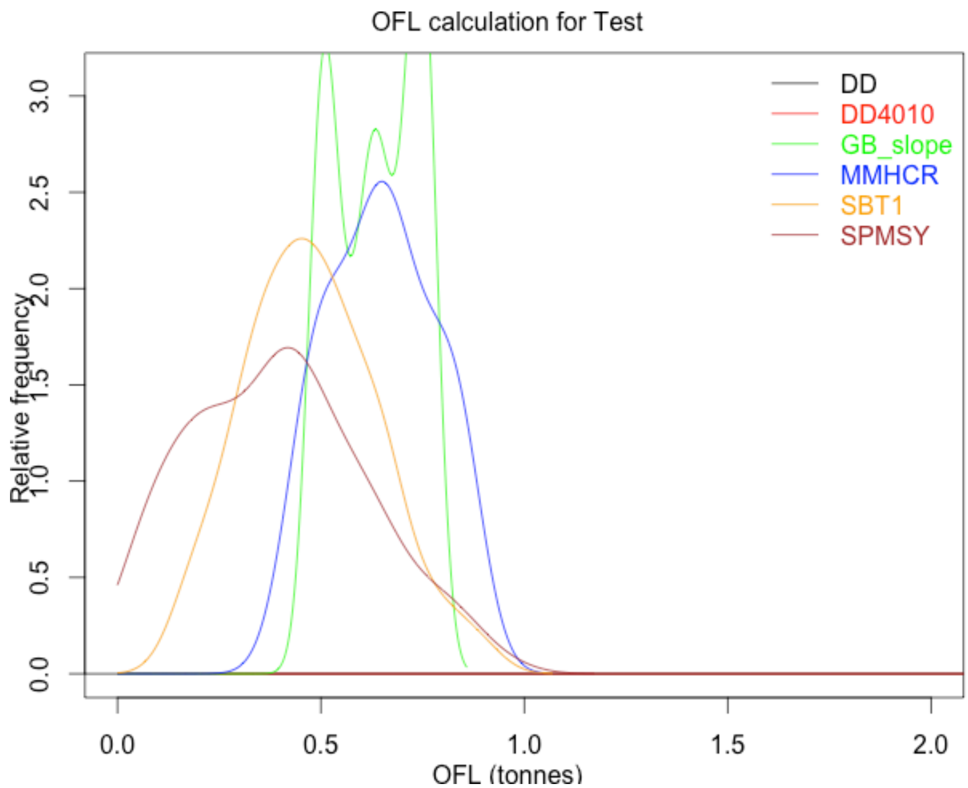

Natural Mortality rate
Depletion over time t
Von B. k parameter

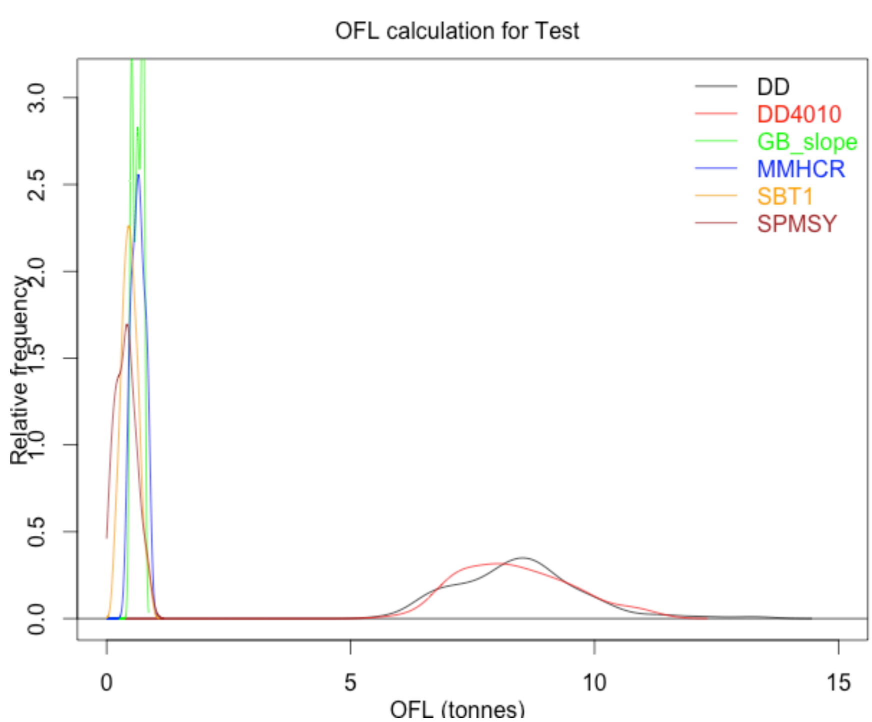

OFL calculation for Test
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
OFL (tonnes)

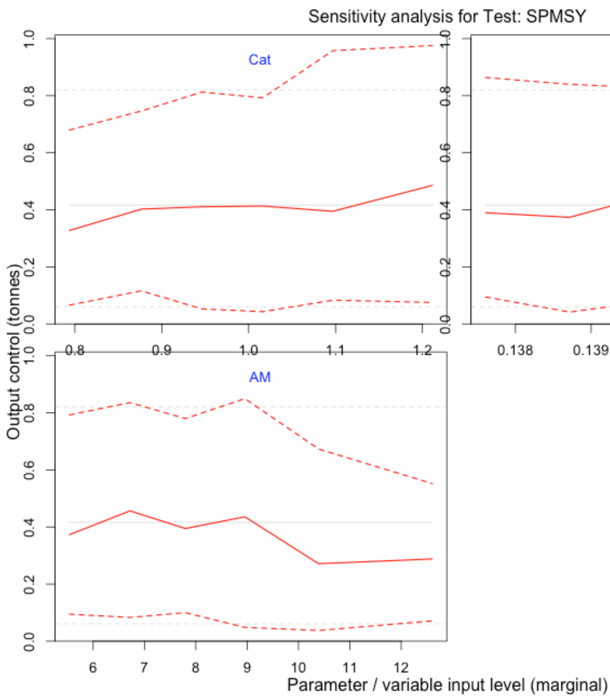



Bourzwa small boats

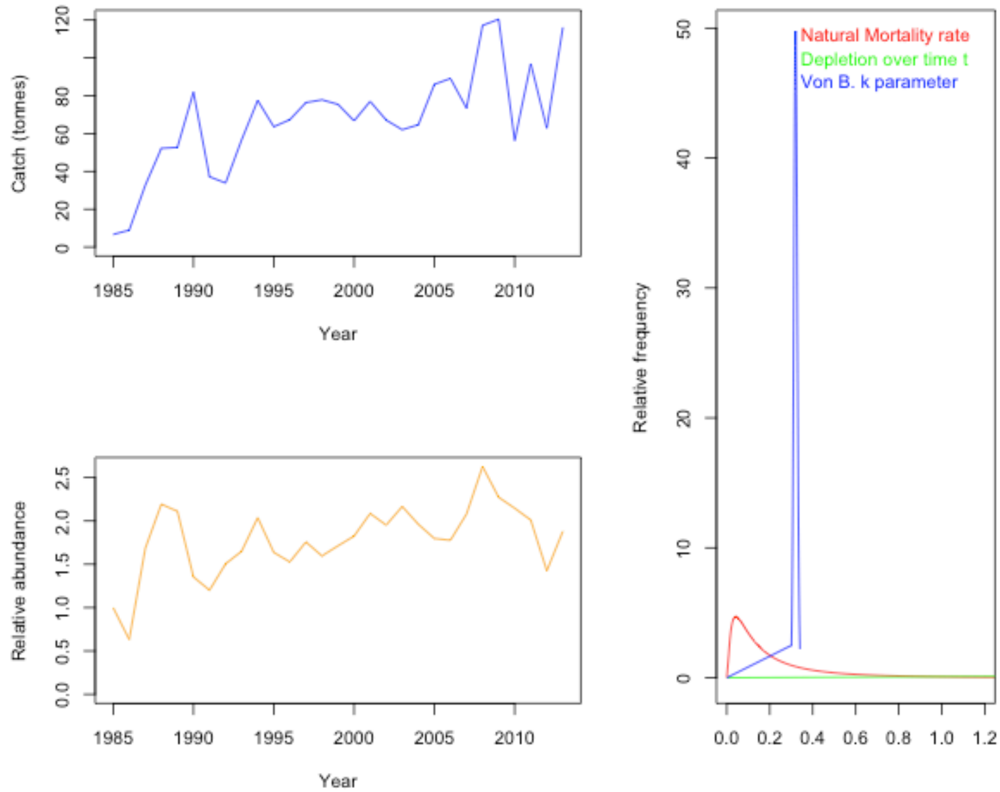


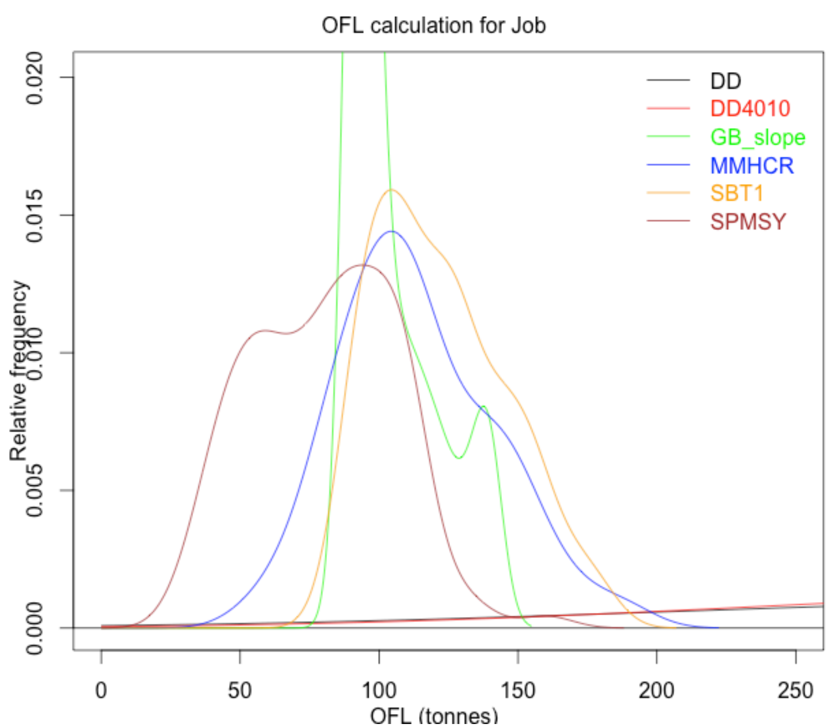

OFL calculation for Test
Relative frequency
OFL (tonnes)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY

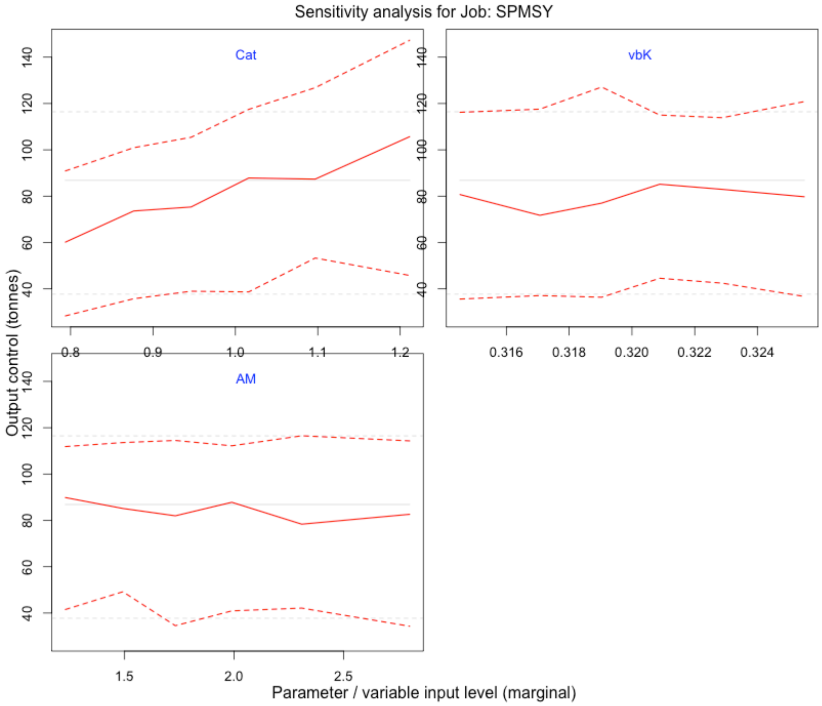

OFL calculation for Test
Relative frequency
OFL (tonnes)
0
5
10
15
0.0
0.5
1.0
1.5
2.0
2.5
3.0
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY


Sensitivity analysis for Test: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)

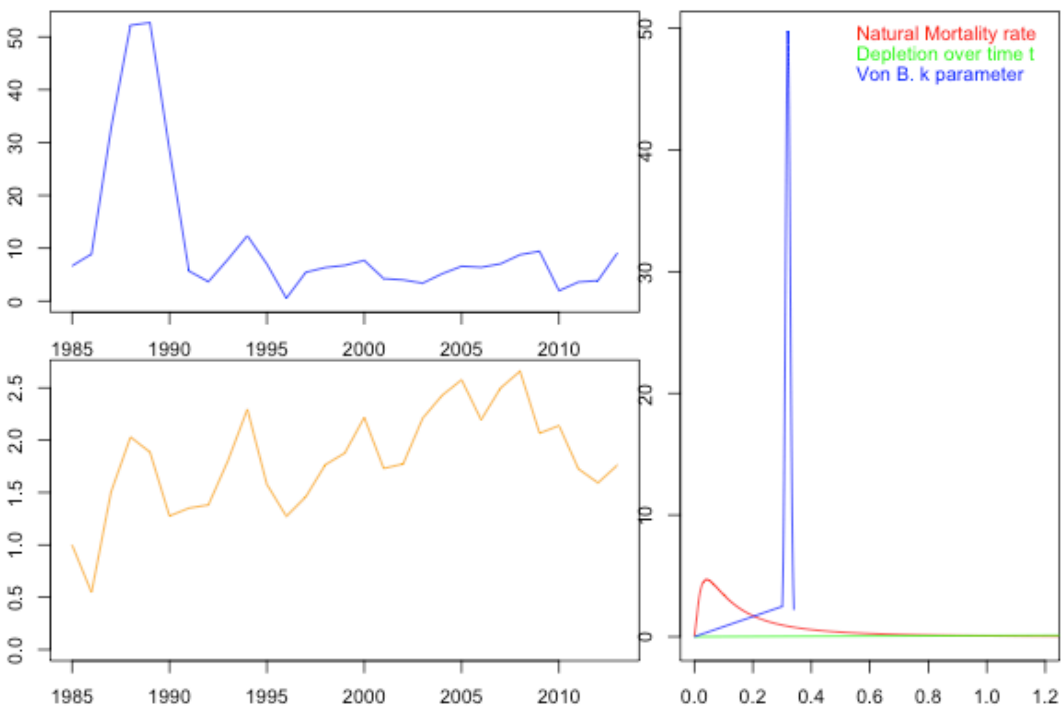

Zob gri

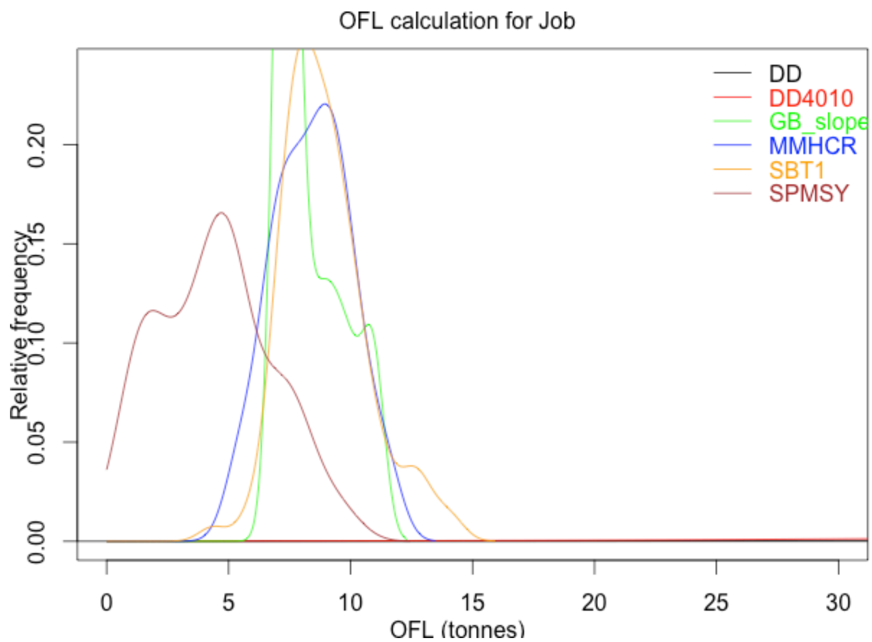

Catch (tonnes)
Year
Relative abundance
Year
Relative frequency
Natural Mortality rate
Depletion over time t
Von B. k parameter

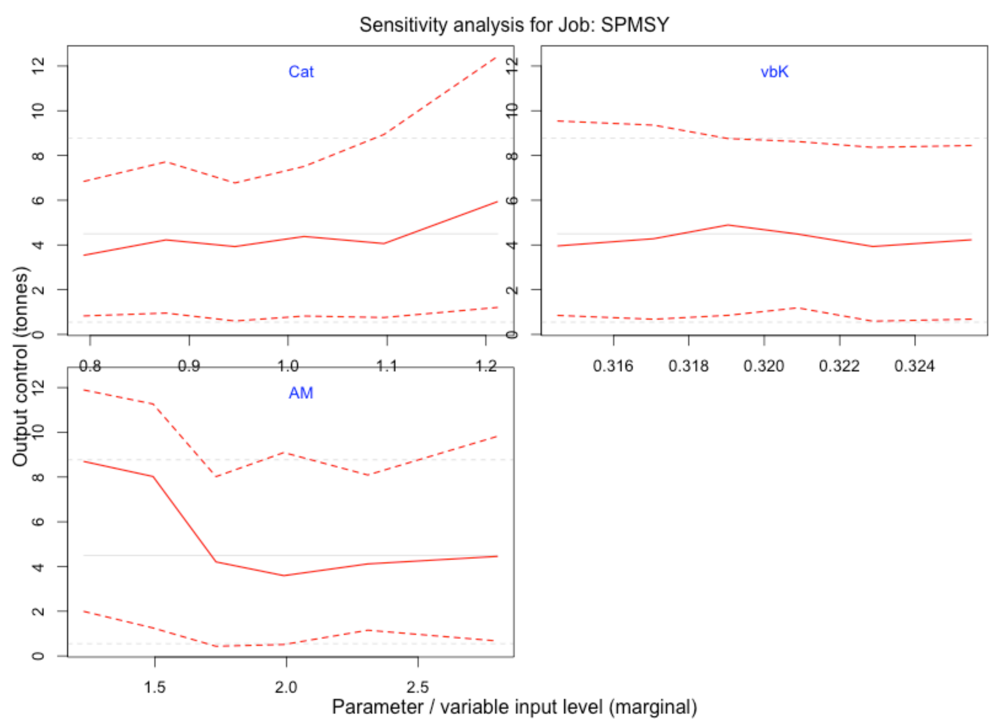

OFL calculation for Job
Relative frequency
OFL (tonnes)
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY



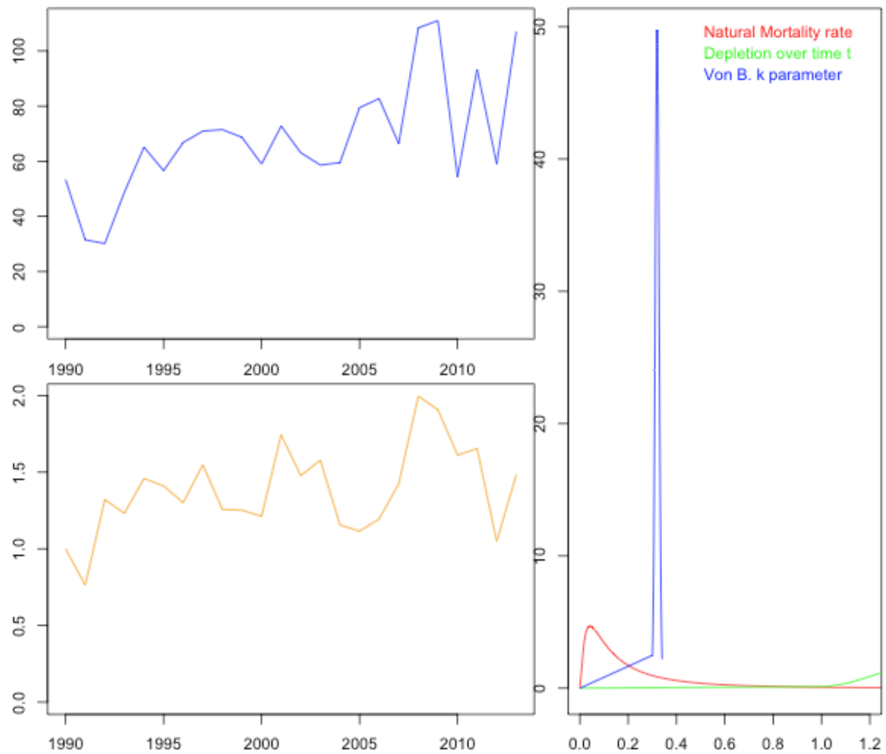

Zob gri small boats

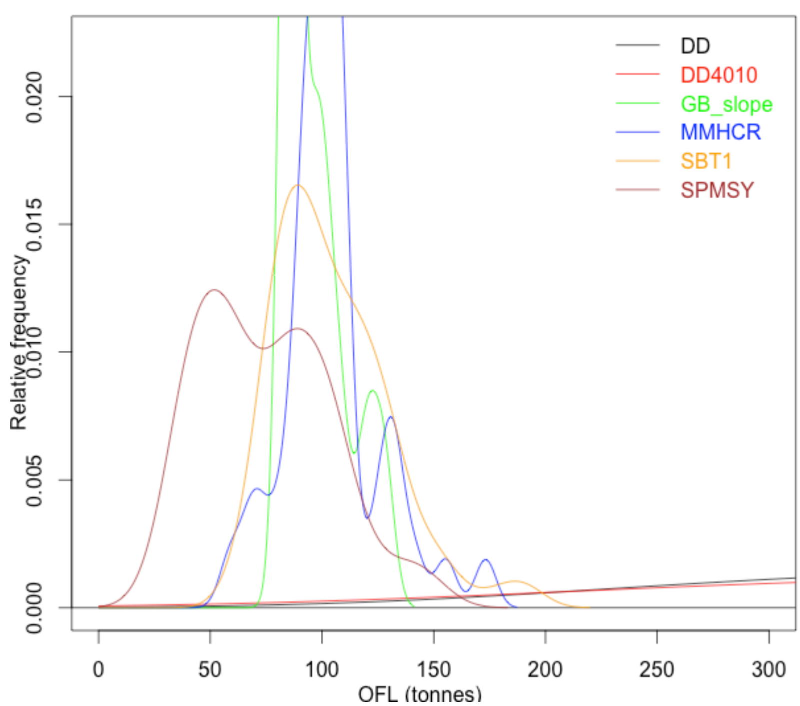



OFL calculation for Job
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
0.00
0.05
0.10
0.15
0.20
0
5
10
15
20
25
30
OFL (tonnes)

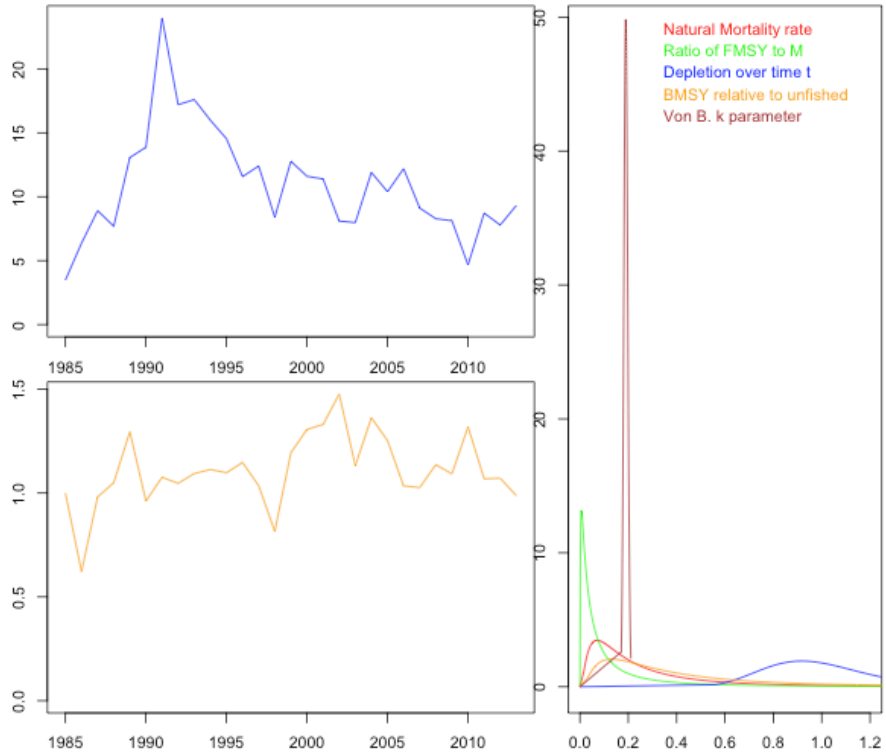

Sensitivity analysis for Job: SPMSY
Cat
vbK
AM
Output control (tonnes)
0.8
0.9
1.0
1.1
1.2
0.316
0.318
0.320
0.322
0.324
1.5
2.0
2.5
Parameter / variable input level (marginal)

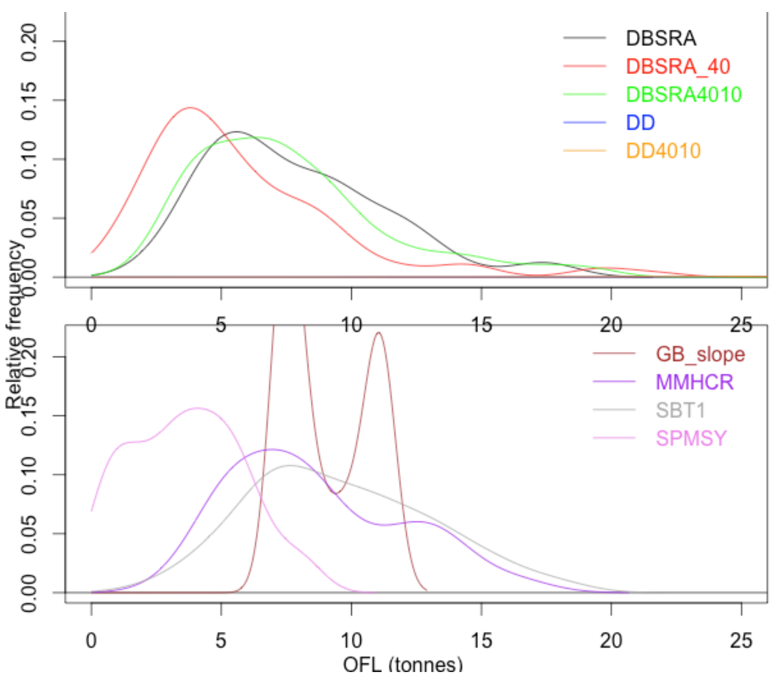
Zob gri schooners and whalers



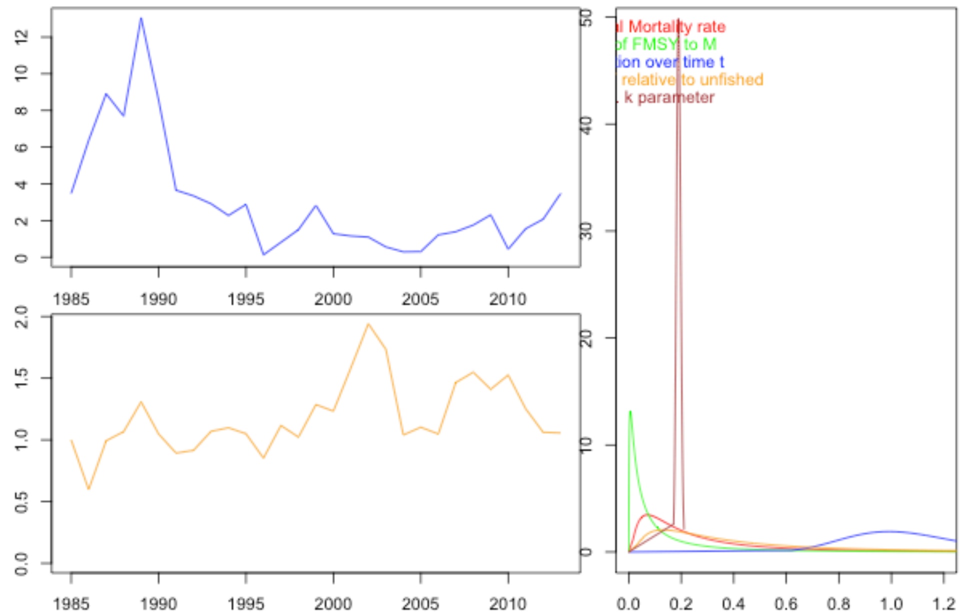



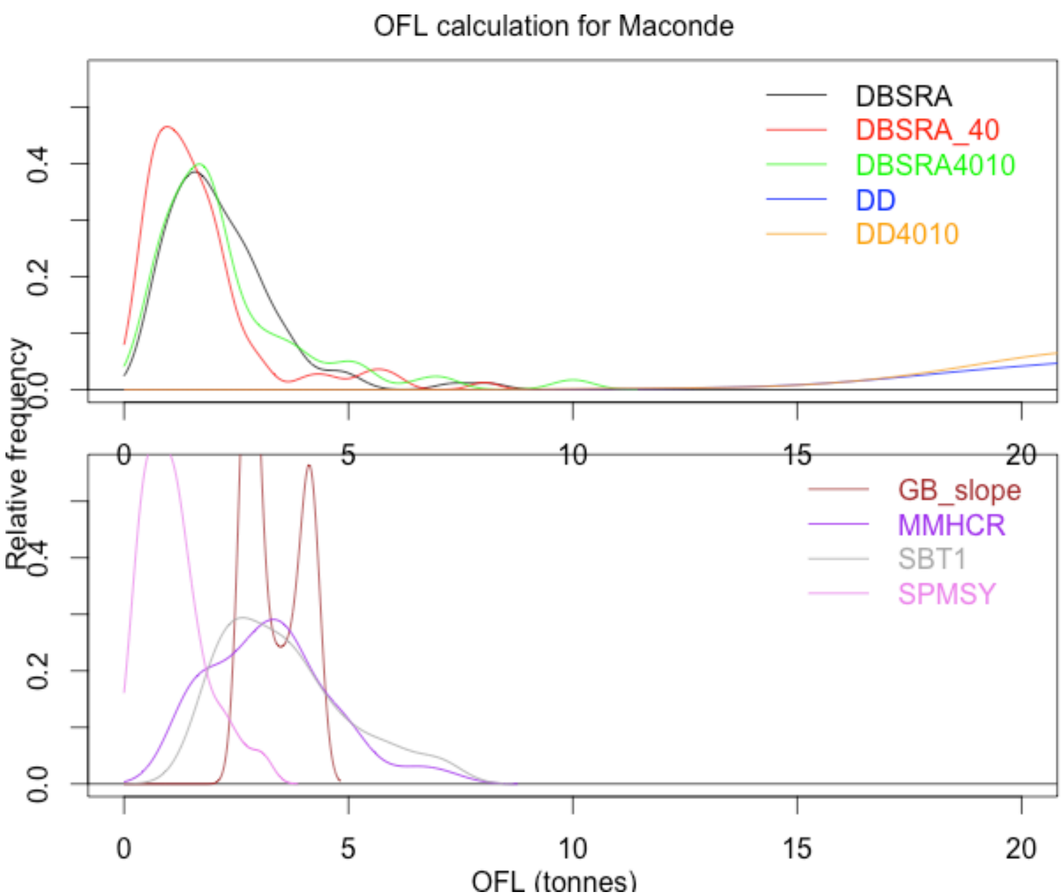
Makonde


Natural Mortality rate
Ratio of FMSY to M
Depletion over time t
BMSY relative to unfished
Von B. k parameter

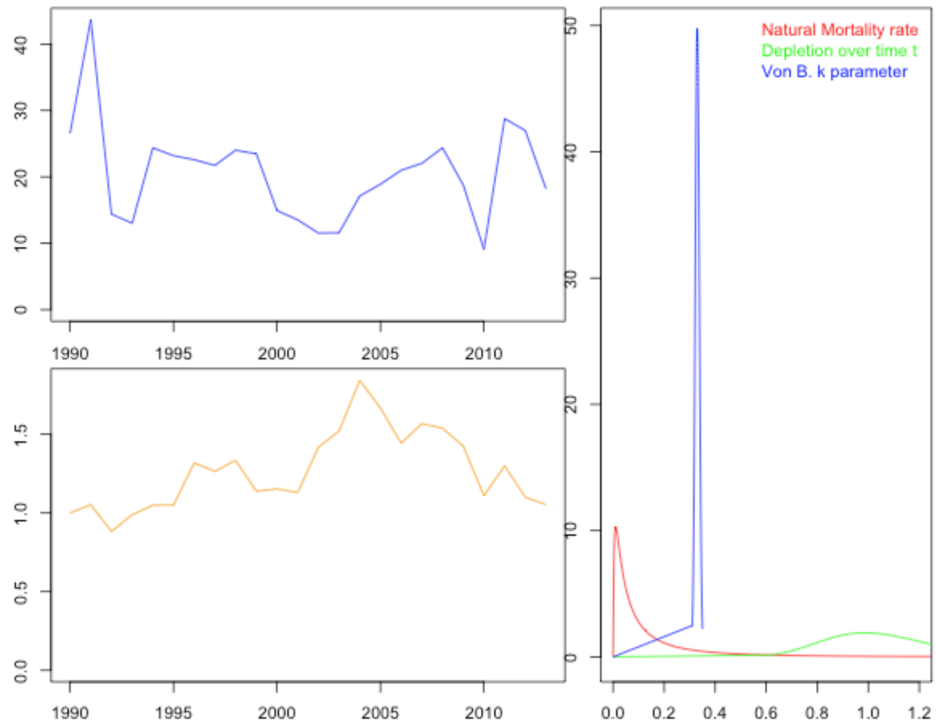

DBSRA
DBSRA_40
DBSRA4010
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
OFL (tonnes)

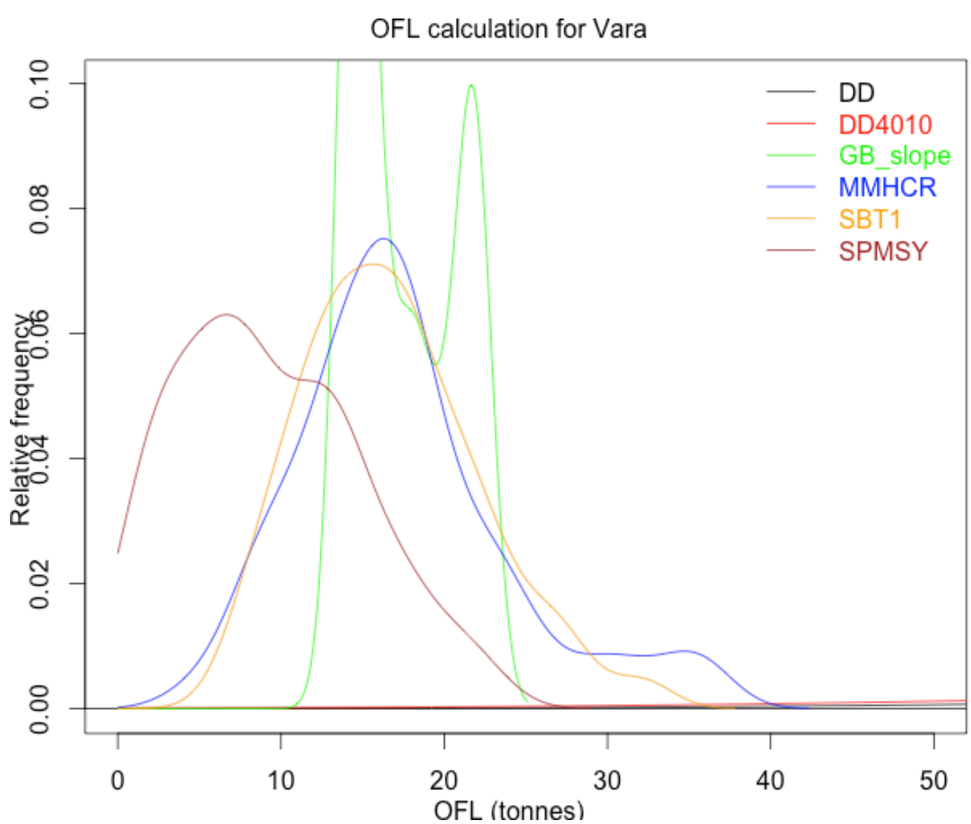
Makonde small boats

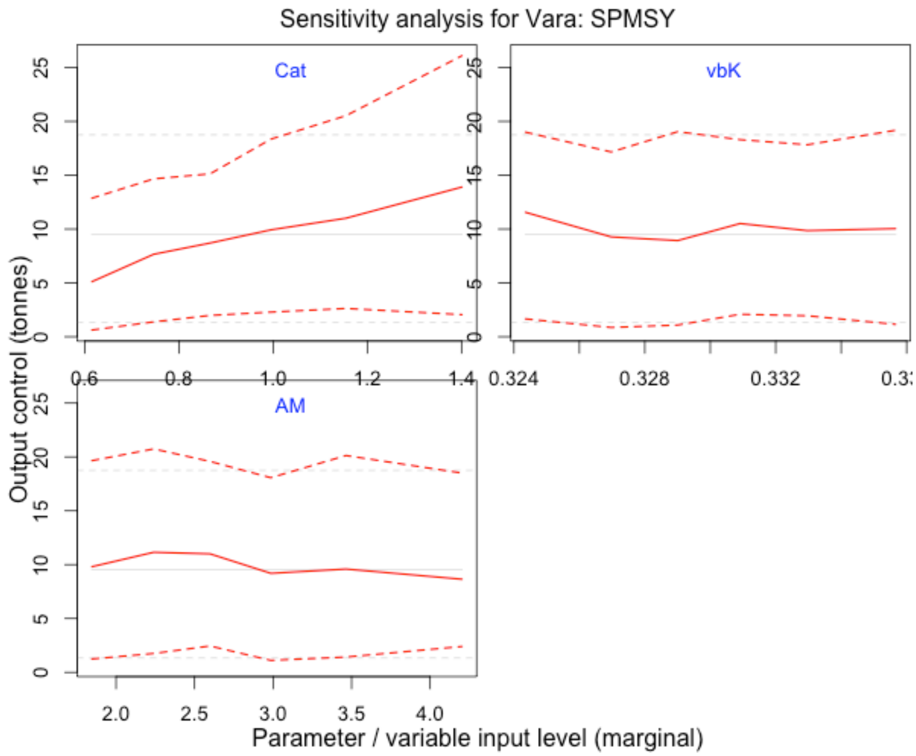


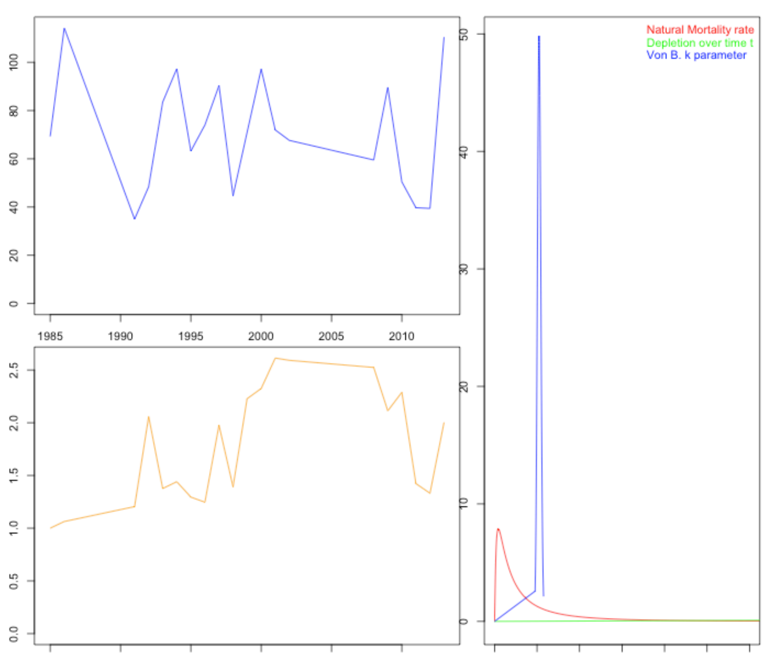
Vara vara

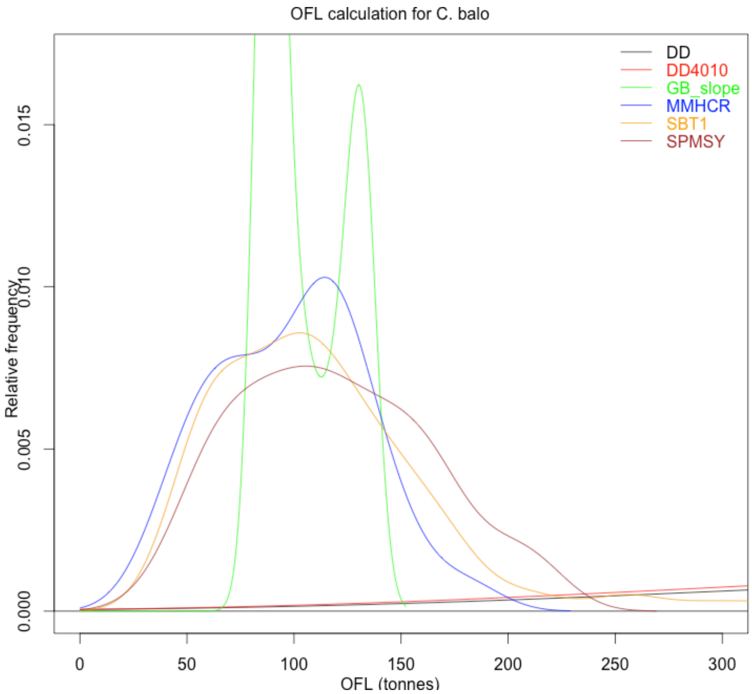

Natural Mortality rate
Depletion over time t
Von B. k parameter

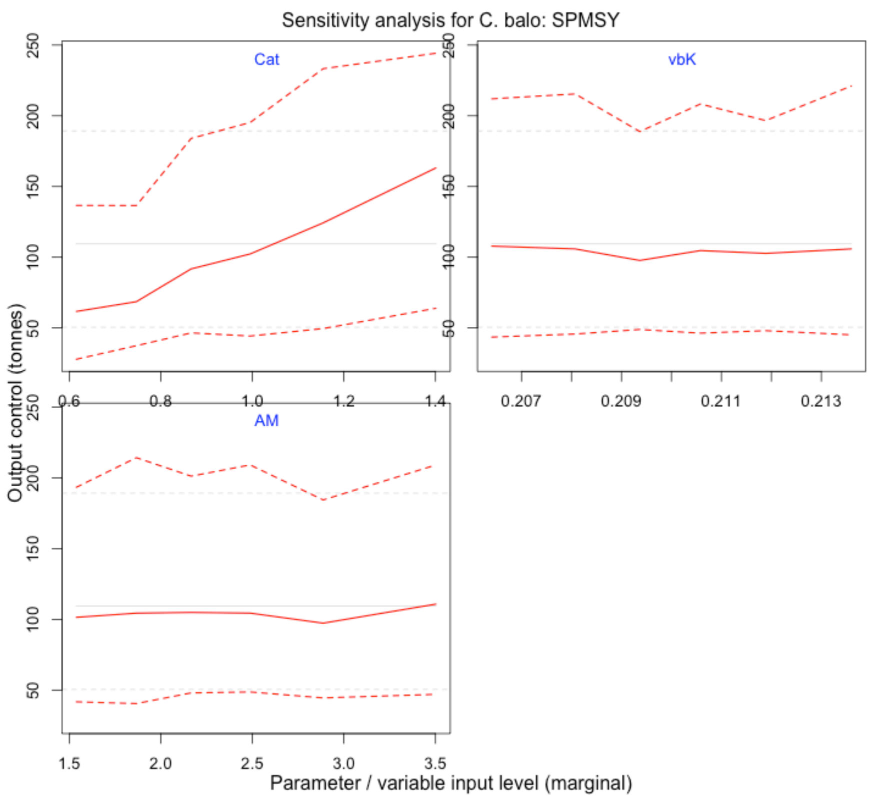

OFL calculation for Vara
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
OFL (tonnes)

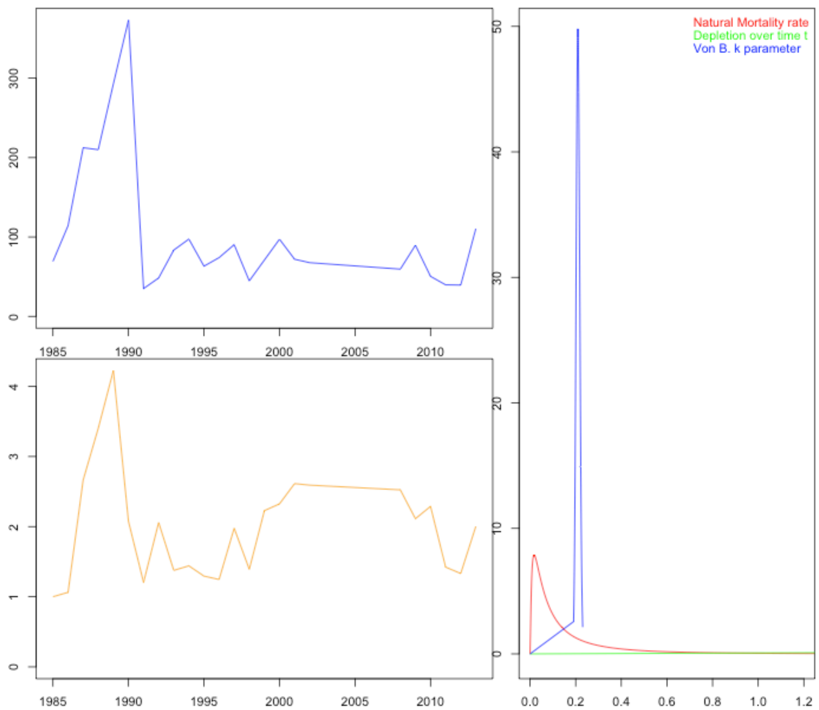


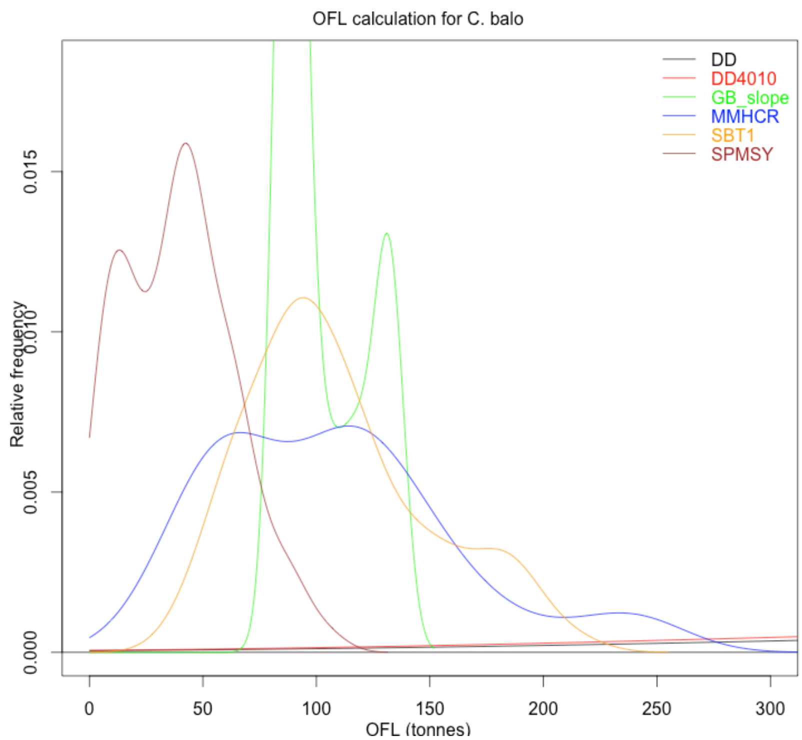

Karang balo (all years)

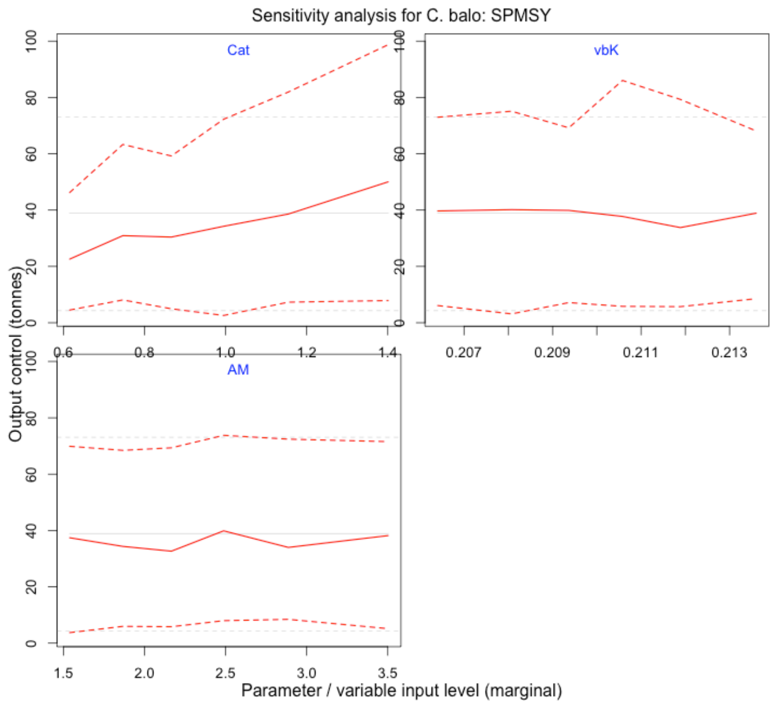



OFL calculation for C. balo
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
0.000
0.005
0.010
0.015
0
50
100
150
200
250
300
OFL (tonnes)

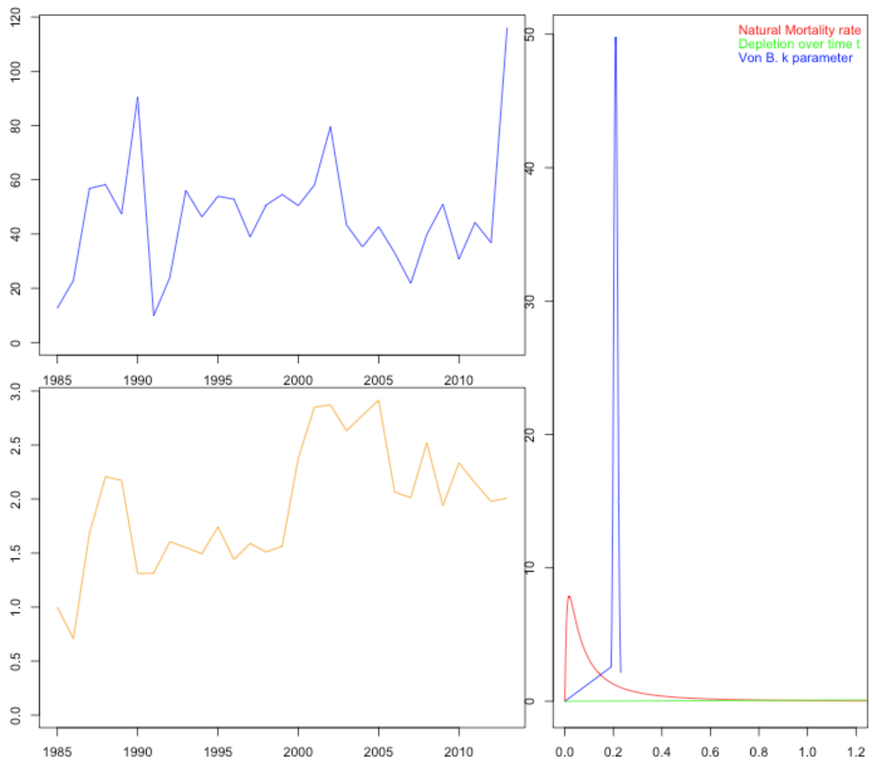

Sensitivity analysis for C. balo: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)
0.6
0.8
1.0
1.2
1.4
0.207
0.209
0.211
0.213
1.5
2.0
2.5
3.0
3.5
50
100
150
200
250

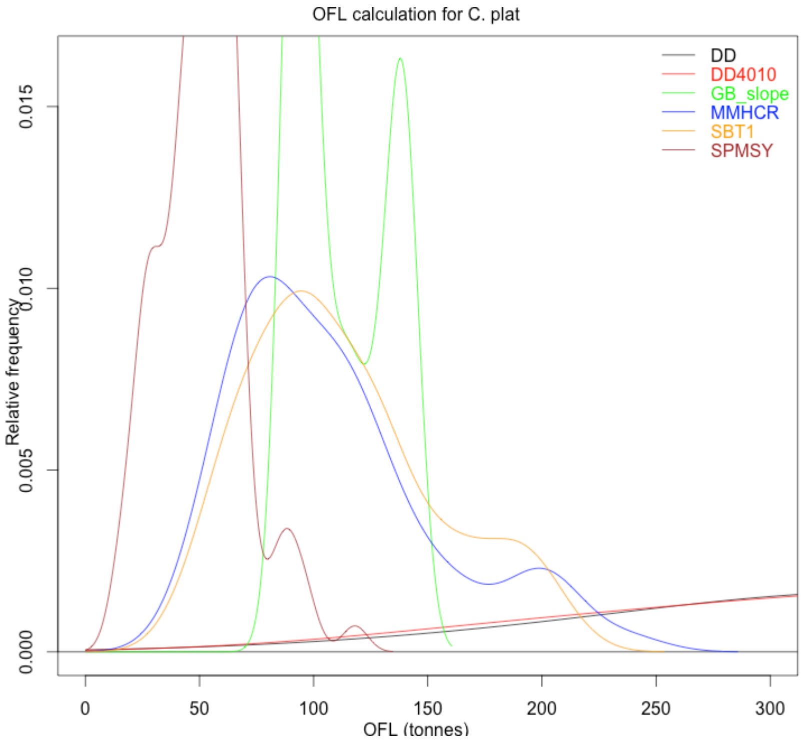

Natural Mortality rate
Depletion over time t
Von B. k parameter


OFL calculation for C. balo
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
OFL (tonnes)

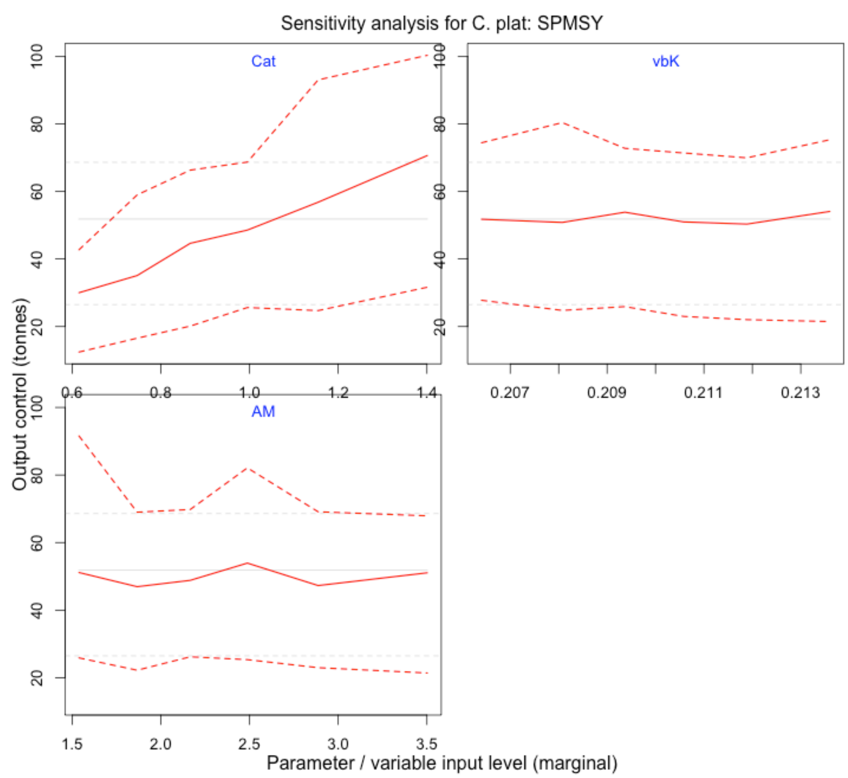

Sensitivity analysis for C. balo: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)

Karang plat


Natural Mortality rate
Depletion over time t
Von B. k parameter

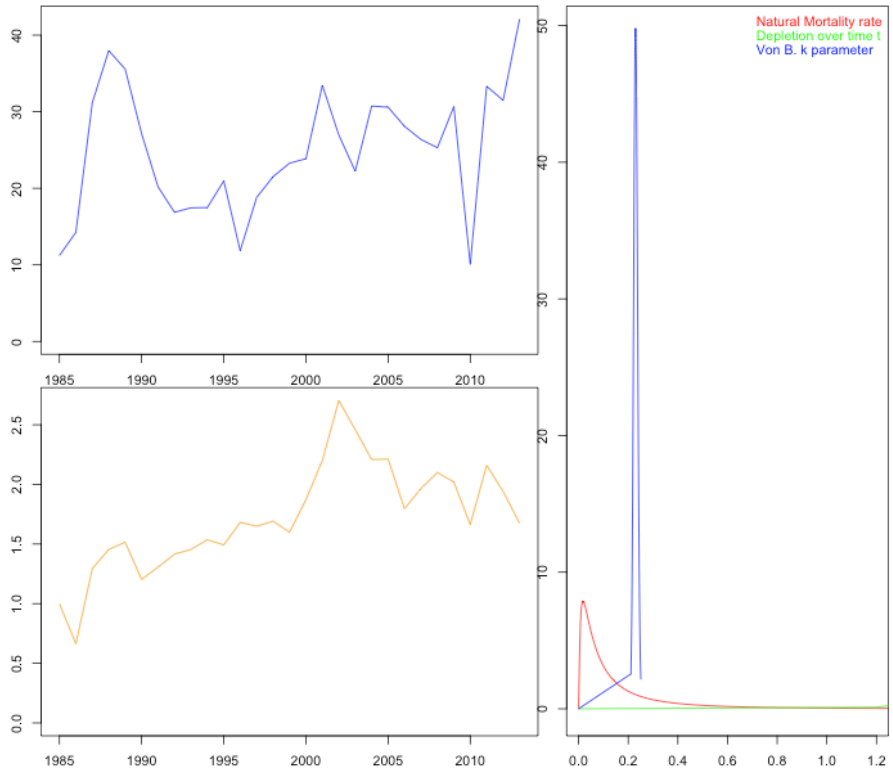


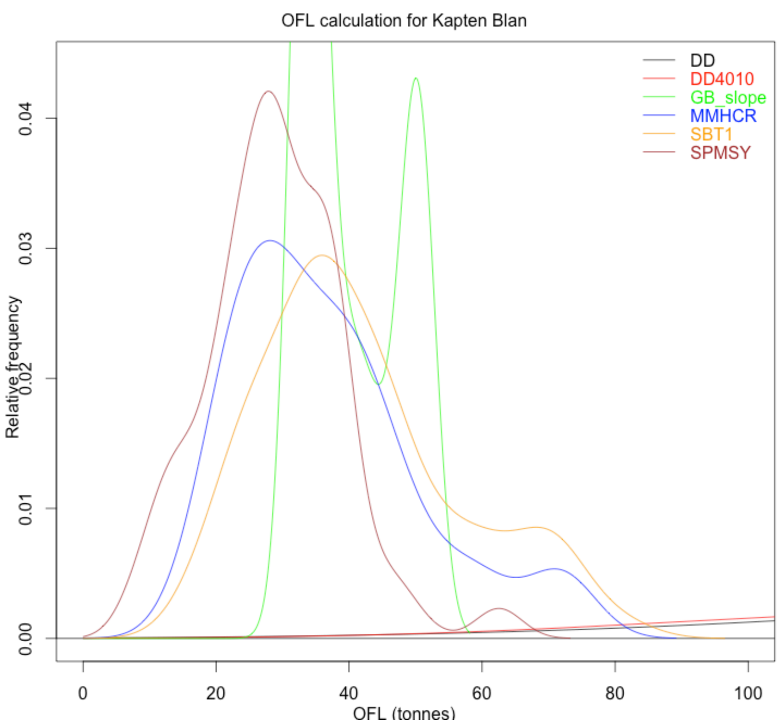
OFL calculation for C. plat
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
0.000
0.005
0.010
0.015
0
50
100
150
200
250
300
OFL (tonnes)

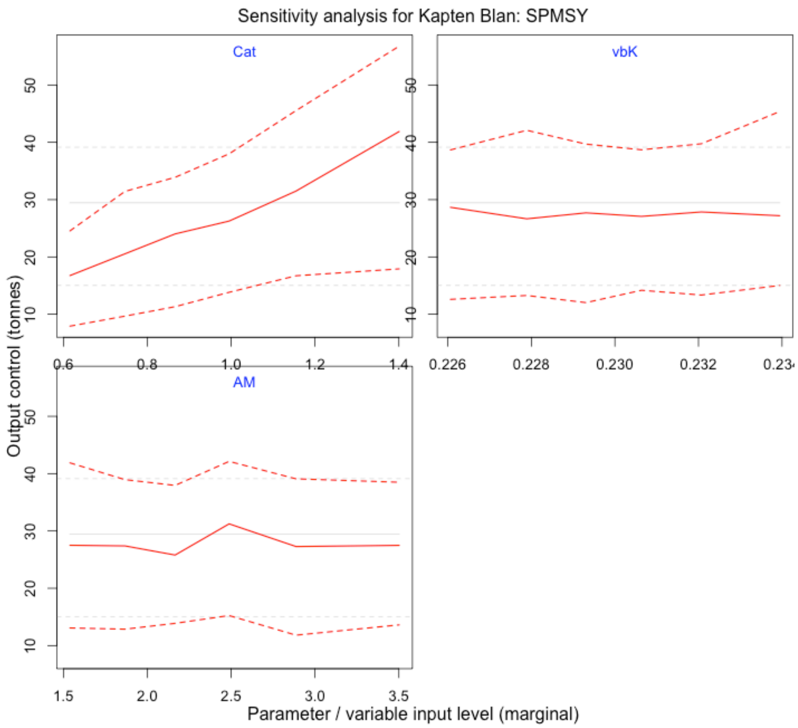



Sensitivity analysis for C. plat: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)
0.6
0.8
1.0
1.2
1.4
0.207
0.209
0.211
0.213
1.5
2.0
2.5
3.0
3.5

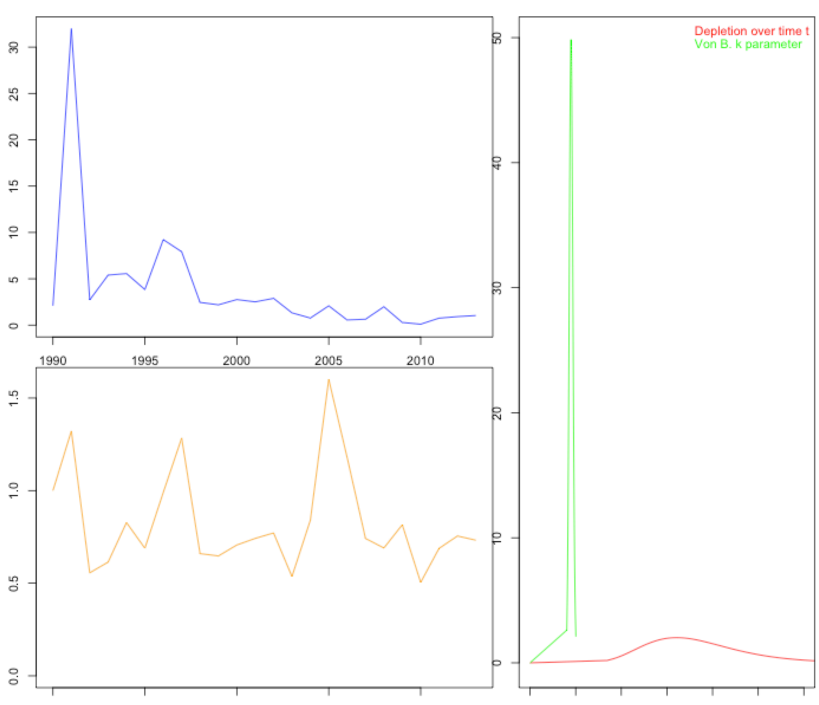
Kapten blan

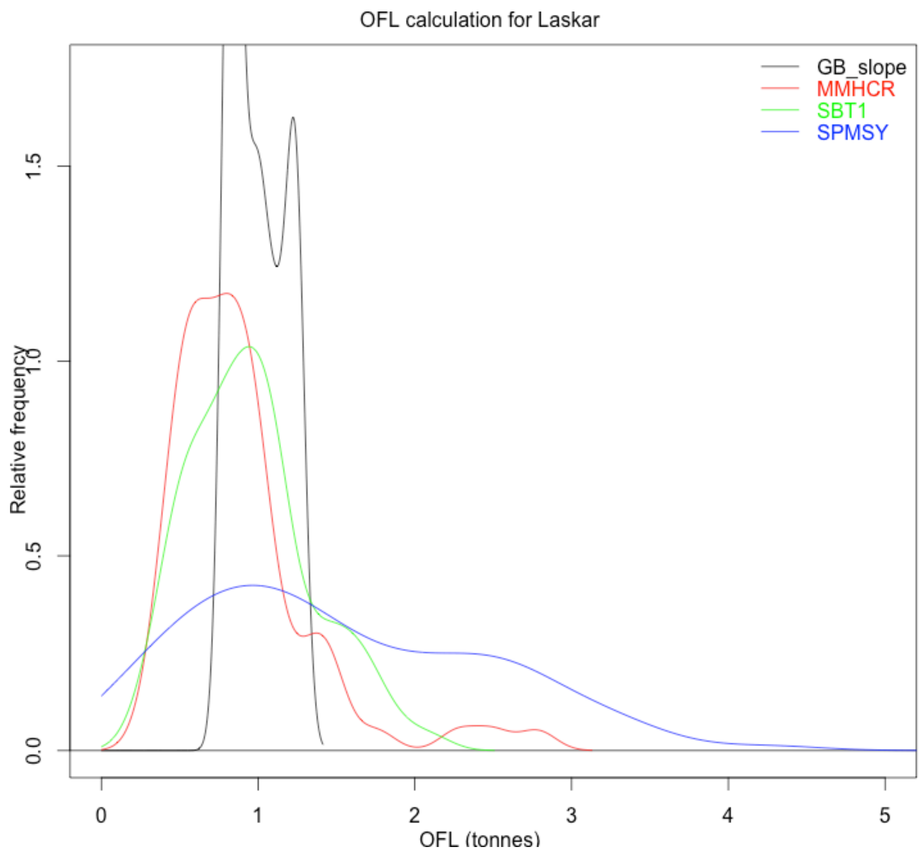

Natural Mortality rate
Depletion over time t
Von B. k parameter

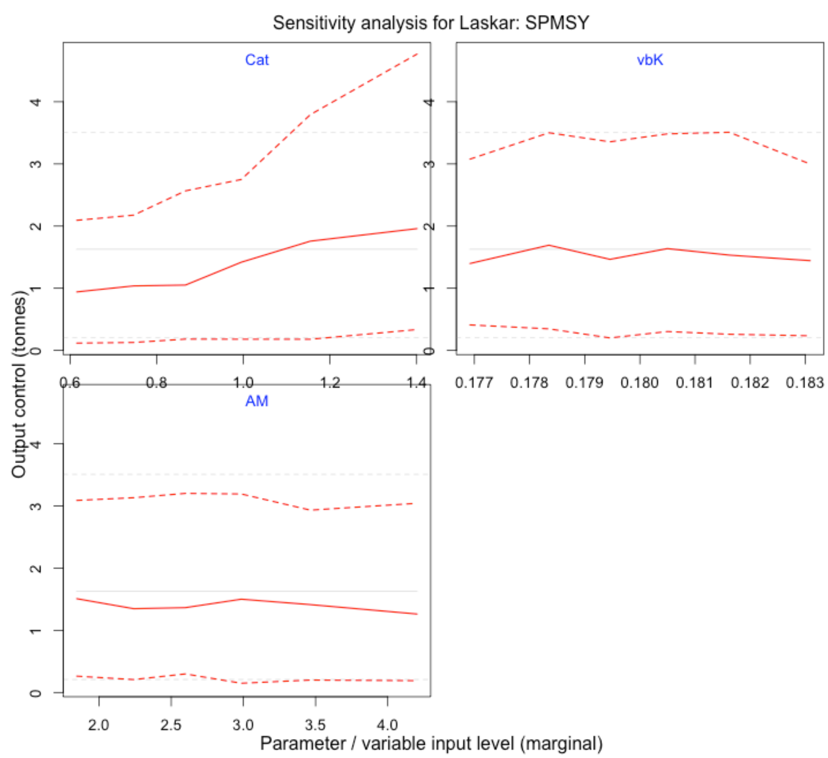

OFL calculation for Kapten Blan
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
OFL (tonnes)


Sensitivity analysis for Kapten Blan: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)

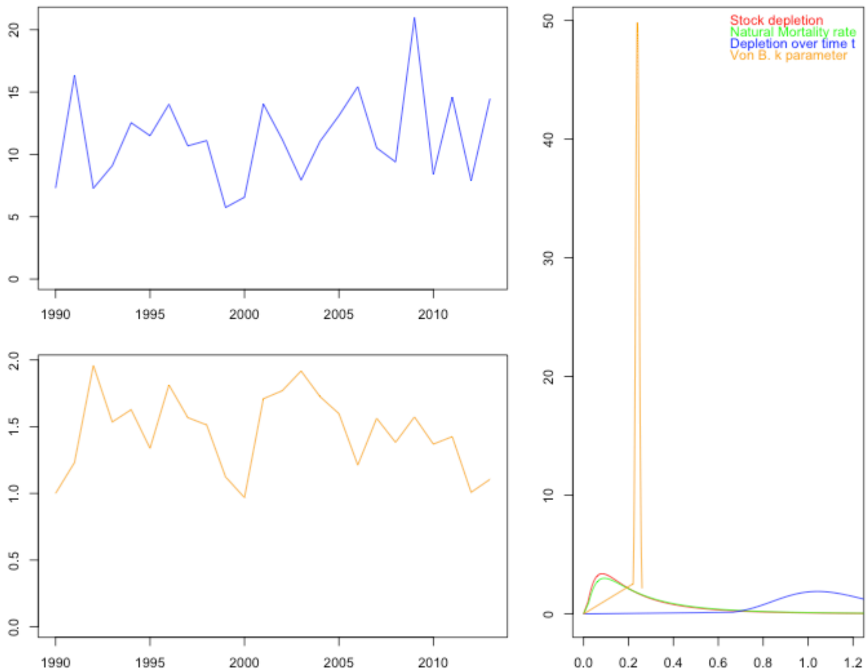
Laskar


Depletion over time t
Von B. k parameter

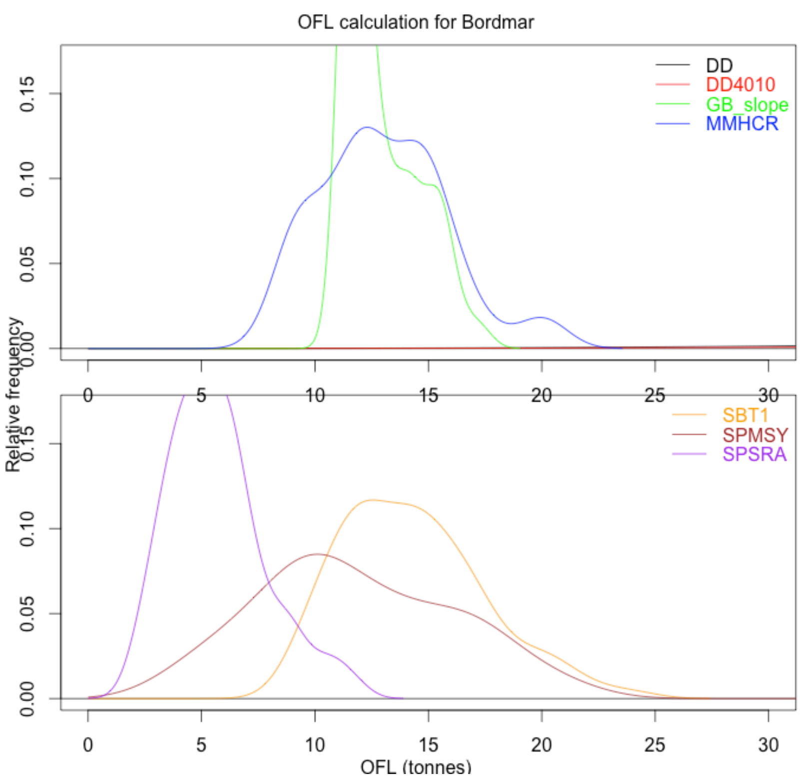

OFL calculation for Laskar
GB_slope
MMHCR
SBT1
SPMSY
Relative frequency
0.0
0.5
1.0
1.5
0
1
2
3
4
5
OFL (tonnes)


Sensitivity analysis for Laskar: SPMSY
Cat
vbK
AM
Output control (tonnes)
0.6
0.8
1.0
1.2
1.4
0.177
0.178
0.179
0.180
0.181
0.182
0.183
2.0
2.5
3.0
3.5
4.0
Parameter / variable input level (marginal)

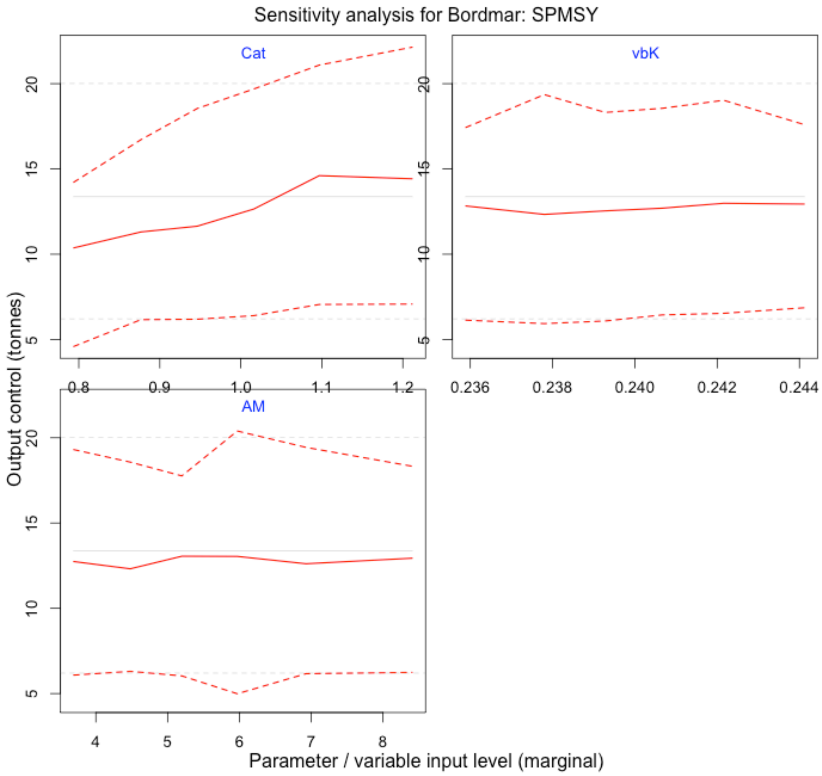
Bormar



Stock depletion
Natural Mortality rate
Depletion over time t
Von B. k parameter

OFL calculation for Bordmar
DD
DD4010
GB_slope
MMHCR
SBT1
SPMSY
SPSRA
Relative frequency
OFL (tonnes)


Sensitivity analysis for Bordmar: SPMSY
Cat
vbK
AM
Output control (tonnes)
Parameter / variable input level (marginal)
0.8
0.9
1.0
1.1
1.2
0.236
0.238
0.240
0.242
0.244
4
5
6
7
8
5
10
15
20

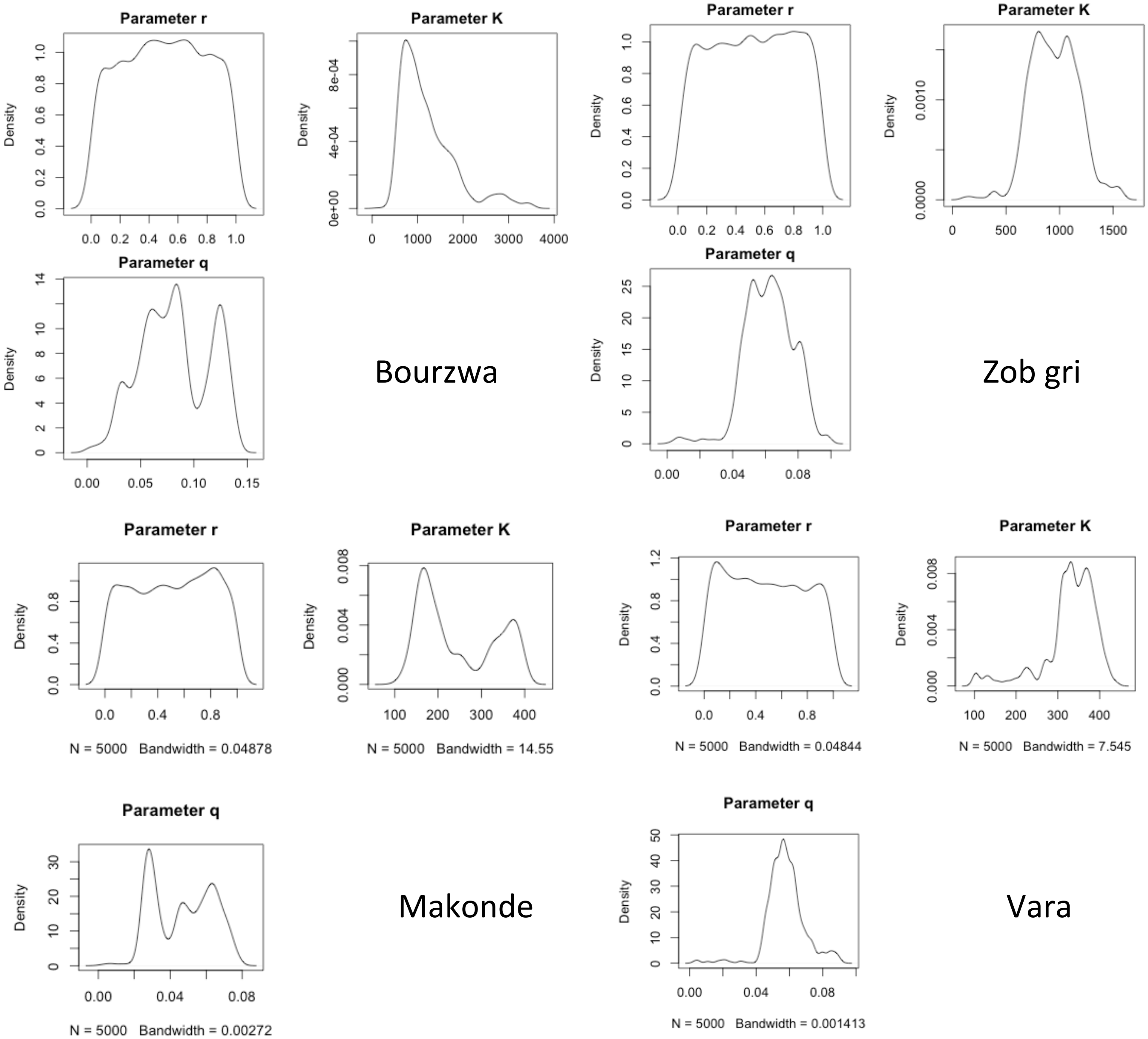



**Figure A.1. Probability density distribution for parameters *K*, *r* and *q* of the Schaefer surplus production model for species of the demersal fishery analysed in this study.**

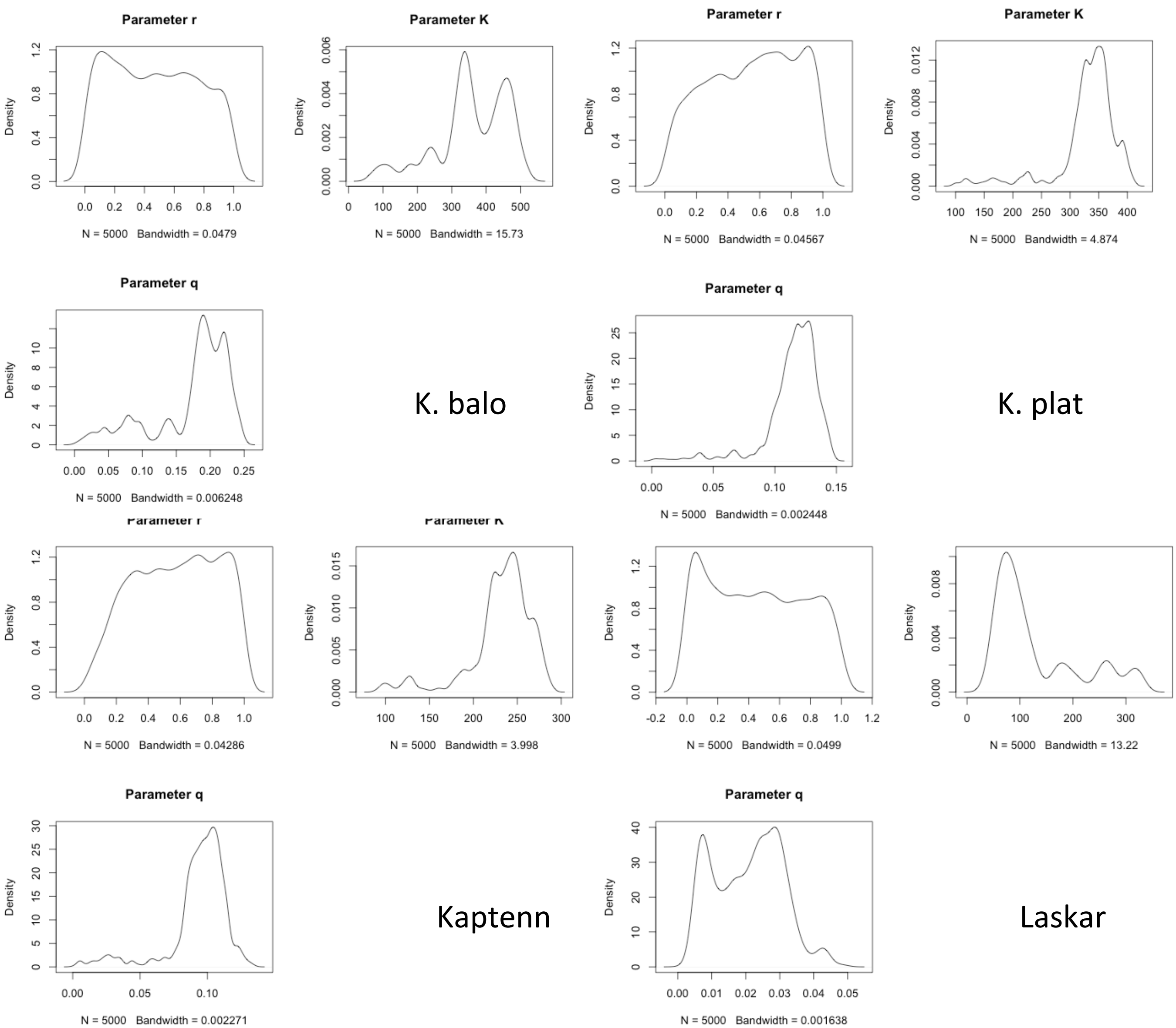



**Figure A.1 (Continued). Probability density distribution for parameters *K*, *r* and *q* of the Schaefer surplus production model for species of the demersal fishery analysed in this study.**

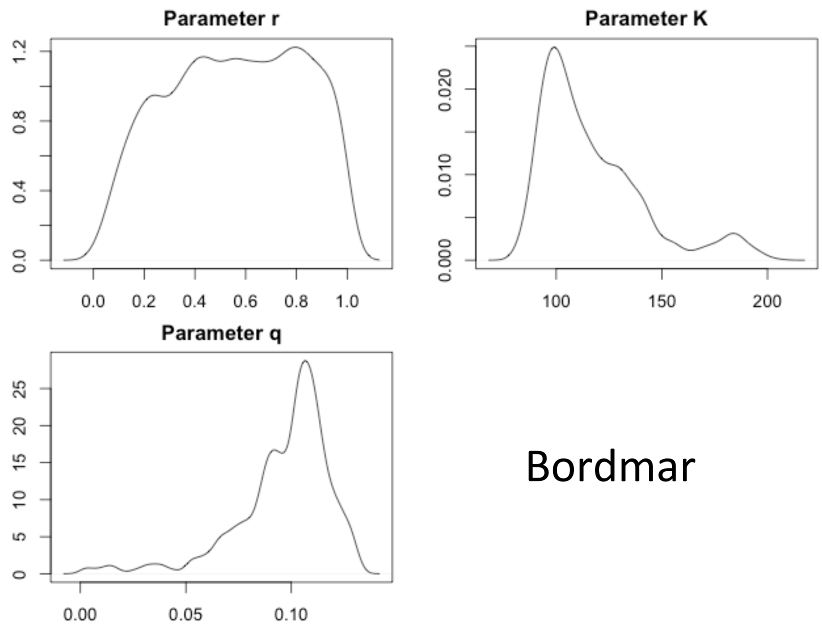



**Figure A.1 (Continued). Probability density distribution for parameters *K*, *r* and *q* of the Schaefer surplus production model for species of the demersal fishery analysed in this study.**