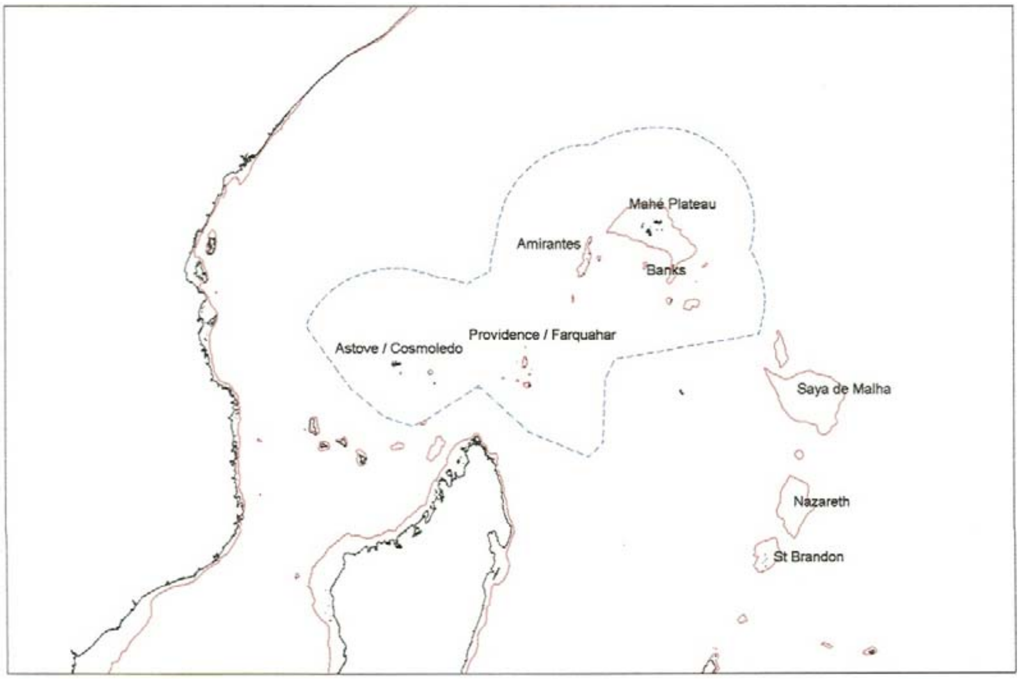
THE STATUS OF SEYCHELLES DEMERSAL FISHERY



TECHNICAL REPORT.

GOVERNMENT OF SEYCHELLES, SEYCHELLES FISHING AUTHORITY / MARINE RESOURCES ASSESSMENT GROUP LTD.

FOR

THE ODA FISH MANAGEMENT SCIENCE PROGRAMME, MANAGEMENT OF TROPICAL MULTI-SPECIES FISHERIES PROJECT, R4584

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Report Structure

This Technical Report details the results of a comprehensive analysis of catch, effort, biological and length frequency data relating to Seychelles demersal fishery. An executive summary highlights the major findings and provides some discussion. The main body of the text provides background to the demersal fishery (Sections 1, 2 and 3), indicates the methodology employed (Section 4) and presents a summary of the major results of analyses for catch and effort data (Section 5.1) and for biological and length frequency data (Section 5.2). A more detailed presentation of the analyses performed is indicated in Annexes follwing the main text (Annexes 1-11). It is suggested that the reader may find it appropriate to read the Annexes before Section 5.

Throughout this report, the following format has been adopted for the numbering of tables and figures. In the main body of the text both tables and figures are numbered sequentially. For the Annexes the numbering follows the format A.N.n where ‘A’ indicates that the table / figure is in Annex number ‘N’, and ‘n’ is the table/figure number. Within Annexes tables and figures are numbered sequentially (eg. Table A.1.2 refers to Table 2, Annex 1). Thus, where a table or figure number is not prefixed by ‘A.’ it indicates that it occurs in the main body of the text. Reference to tables and figures in the Annexes occurs throughout the main body of the text, and vice-versa.

EXECUTIVE SUMMARY

1. Management of Tropical Multi-species Fisheries is a project funded by the Overseas Development Administration of Great Britain through the Fish Management Science Programme. The project consists of a theoretical component to investigate multi-species effects, and practical (case) studies. Seychelles Fishing Authority and MRAG Ltd are collaborating on this project with respect to the plateaux and banks demersal fishery which forms a case study. The present Technical Report presents a comprehensive review and analysis of the demersal fishery. Results of the theoretical study will be presented elsewhere.

2. The fishery is described (Section 3) in relation to Seychelles geography and hydrology (Section 2). Analyses performed relate to catch and effort data (Section 5.1) and biological information (Section 5.2) for the demersal fishery. Raised total catch and effort data given in SFA Annual Statistical Reports are reproduced. For Whalers however, the accuracy of the raised catch is questioned (Annex 2). Catch rate data given in this report relate to sampled data and are considered accurate.

3. Catches are described by vessel category, location and species (5.1.1). The greatest effort relates to whalers which account for the largest proportion of demersal landings. Total demersal catches peaked at 2,280 tonnes in 1991 and by far the greatest volume was caught from the inshore grounds of the Mahe Plateau (Sector 1), although some doubt relates to specific fishing locations reported by whalers. Increasingly, whalers have fished further offshore, and this was especially true in 1994 following the relaxation of marketing restrictions. On a yield per unit area basis, the south edge of the Mahe Plateau (Sector 7) was the next most heavily fished location. Catch and effort at all other locations was light. Dominant species in the catch were *Bourgeois* (*Lutjanus sebae*), *Job Gris* (*Aprion virescens*), *Batrican* (*Pristipomoides filamentosus*), *Vara vara* (*Lutjanus bohar*), *Maconde* (*Epinephelus chlorostigma*) and *Capitaine Rouge* (*Lethrinus nebulosus*). With the exception of *Vara vara* these were the key species for biological study. Species composition varies with location.

4. Catch rates by boat category and location are described (5.1.2). Changes in catch rate within boat categories could be attributed to the introduction of new vessel designs and improved gear technology. This also accounted for some observed changes in species composition (eg. schooners targeting deeper water species; shift from schooners to whalers predominantly fishing in an area, eg. sector 3; sector 7 in 1994). Seasonal and depth effects were also apparent. It was thus necessary to stratify data by boat and gear type, and to standardise catch rates for seasonal (and depth) effects. Assuming constant catchability, standardised catch rates are an index of abundance of the demersal resource.

5. For time series data by location, no long term declines in catch rate were observed at the level of the fishing sector, suggesting that resources at locations around the edge of the Mahe Plateau and distant from it are lightly exploited and that the biomass has apparently remained constant. No consistent species composition changes were observed, although the serranid, *E. chlorostigma* had apparently decreased in abundance at the level of the sector. Evidence from the mother-ship dory fishing venture, indicated that short and long term local depletion has occurred. Locally

depleted areas in some cases had not recovered over periods of 2 years and this highlights the need for more location specific data collection than the present 'sector'. The rate of recovery of depleted areas was assessed.

6. Despite the high level of fishing pressure in Sector 1 there was no evidence of depletion or multispecies effects from time series data over the period 1989-1994 (except, for the guild ‘ other lutjanids’ which declined). However, catch rates fluctuated considerably. Species composition and catch rates are a function of prior fishing activity which is known to have occurred for a considerable period in this location. It was concluded that the present catch rates and species composition may be an unstable equilibrium different from that originally, but that the time series was insufficient to have detected these changes. The fluctuations in catch rate presently observed may be explained by a number of factors : market pressure; technological and fishing practice changes; environmental influences resulting in strong recruitment in certain years.

7. The failure of long-term time series data to indicate depletion or multi-species effects does not necessarily mean that fishing has had no effect. Rather, these analyses indicate the difficulty of using commercial catch and effort data. Apart from the problem of lack of fine definition in spatial data, the principle problem is lack of homogeneity (spatial and temporal patchiness) in commercial data. Next, especially for the lightly fished locations, the number of variables that need to be accounted for (climatic and seasonal events, technological changes, fishing depth, night vs day fishing) and scattered nature of the information mean that data are inadequate to obtain statistically valid results. At the heavily fished sector 1 the time series simply was not long enough, and it is probable that any changes to the species composition in this location occurred prior to the data available.

8. Spatial analyses indicated differences in catch rate by location which were significantly negatively correlated to prior fishing activity. Examination of gross species composition by family guild indicated no change in the catch rate of lutjanids and lethrinids, whilst that of serranids was significantly negatively correlated with fishing effort. Spatial comparisons have the dissadvantage that environmental variation must be acoounted for. Whilst present catch rates showed the strongest correlation to prior fishing catch and effort, winter primary productivity and substrate type were also significant. The latter was based on scanty data and may be an aretefact, but nevertheless this limits the applicability of the spatial approach to examine fishing effects. In particular, the change in composition of serranids, whilst apparently correlated to fishing pressure, may in fact be related to local environmental conditions, and species composition is known to vary with latitude also.

9. Time series data failed to indicate depletion with the possible exception of the guild ‘other lutjanids’ and stock assessments using the Fox biomass dynamic production model were not valid. Stock asessment using the spatial data was achieved with the Thompson and Munro plot. However, results obtained were lower than expected and did not compare well with previous assessments derived using other metods. It was concluded that due to variability in the data the spatial analyses were inadequate for accurate assessment of sustainable yield.

10. Available biological data related to key species of fish exploited by schooners and research vessels. None of the data related to the heavily fished sector 1 and thus population demographic variables derived for the key species relate to lightly exploited stocks. Population structure (minimum and maximum lengths and sex ratio), and length weight relationships are described (5.2.1; 5.2.5). Reproductive parameters are assessed (length at maturity) and seasonality of reproductive events is established (5.2.2). The highest catch rates in fact coincide with the period of greatest reproductive activity,

March-May. Gear selectivity parameters are described (5.2.3). Lc_{50} for handlines, the length at which there is 50% probability of all fish at that length being caught, was similar to Lm_{50}, the length at which 50% of female fish reach maturity, for *A. virescens, L. sebae* and *L. nebulosus*. For *P. filamentosus* fish are caught considerably smaller than Lm_{50} indicating a danger of recruitment over fishing. Gear type also affects Lc_{50} and gill nets and traps caught smaller fish than handlines. Particularly for *P. filamentosus* this could have serious consequences.

11. Growth was assessed using length based methods (5.4). As was the case with catch and effort data, spatial and temporal variation in biological and length frequency data limited their usefulness. Stratification of the data was employed to improve the derivation of growth parameters. However, as is typical with long lived slow growing species, clear modal progression was not evident for any species and frequently the data indicated a number of possible parameter combinations. Whilst the 'best' fit could be selected for each sub set of data examined, the confidence in the output was not sufficient that these data could be used to infer the effects of fishing pressure on growth, or to make spatial comparisons. The low degree of confidence in the estimate of growth parameters has significant implications. A number of other parameters are derived using growth parameter estimates as inputs (eg length at capture, natural mortality, total mortality). Sensitivity analyses were performed where appropriate to indicate the variation in parameter estimates that might be expected given uncertainty in the estimates of growth.

12. Mortality parameters were derived principally by catch curve analysis, which requires growth parameters as inputs, and by the Powell-Wetherall method which does not (the latter gives the ratio Z/K). Estimates were derived for each species (*P. filamentosus, A. virescens*, and *L. sebae* - data for *E. chlorostigma* were inadequate) by location per annum and were compared to catch. Generally total mortality derived from catch curve analysis followed the expected pattern compared to catches better than the ratio Z/K.Spatial differences in fishing pressure were reflected well in the mortality estimates derived from annually aggregated data for shallow water species (*A. virescens* and *L. sebae*), but not so clearly for individual years. Mortality estimates for the principle species caught at intermediate depths, P. filamentosus, did not follow the expected trends in relation to fishing pressure. Thus it may be seen that to a limited extent, the data describe the effect of fishing on total and fishing mortality (it increases), although results are not consistent. However, it was not possible to separate out the effects of fishing on natural mortality from these data.

13. Specific recommendations arising from this report are :

- New boats entering the fishery such as the Cygnus vessels and the 22m La Digue schooners should not be classed together with the existing schooner fleet. They fish differently and have a different fishing power and this will lead to errors when sampled data is raised to estimate total catches. New statistical categories should be established.

- Details relating to specific fishing location are critical. Attempts should be made to improve location specific details obtaining more detailed information than fishing sector. Particularly for the new vessels with satellite navigation systems location should be recorded as latitude and longitude. For boats without this technology, a detailed map with coded grid-squares should be prepared in order that knowledge of fishing location with a sector is gained.

- Although there will be a number of different statistical boat categories, as far as possible the same data collection form should be used enabling a fully integrated fisheries information system. Data from different categories will thus be more easily compared.

- Gear specific information must also be collected for each trip in order to monitor changes occurring with time. Thus hook size and mesh size information should be recorded as a matter of routine. Equipment fitted to vessels should be noted (fish finders, GPS, echo sounder etc) and a database of changes maintained. This should be integrated with catch and effort information such that the timing of specific events in the fishery may be determined. In the specific case of the mothership dory venture, area fished around the mothervessel would be a useful additional input.

- Biological and length frequency data should be related to a specific vessel trip. In this way total catch, effort and location specific information will be known. The biological and catch effort databases should be fully integrated.

- Biological and length frequency information should be collected from the heavily exploited sector 1.

- Management policies for the inshore whaler fishery and the offshore fishery targeting *Pristipomoides filamentosus* require urgent attention. *P. filamentosus* is of particular importance since it forms the major part of the catch from intermediate depths and is the target of the new vessels entering the fishery. As such special reference is made to certain points. Firstly, the total catch of this species presented in this report may in fact be an under-estimate : catches are derived from published SFA statistics which raise sampled catches to estimate the total. The vessels exploiting this species are classed as schooners, but most schooners will not fish in the same way or at the same depths, thus, when raised, catches may be estimated incorrectly (see Annex 1 which compares the relative fishing power of different boat types). Next, the data indicate that mesh size and gear type significantly affect size at first capture with serious management implications. Preliminary analyses indicate that at the present small size at first capture in relation to length at maturity, the stock could be eliminated at relatively low levels of fishing effort.

1 INTRODUCTION

The Management of Multi-species Tropical Marine Fisheries (MTMF) is a project implemented through the British Overseas Development Administration (ODA) Fisheries Management Science Programme (FMSP). The project addresses the problems of managing multi-species fisheries in developing countries where resources for data collection for stock assessment and management purposes may be limited. It aims to examine the influence of fishing pressure on the dynamics of interacting multi-species fish stocks, to identify minimum data requirements enabling sensible analysis and management of such resources, and to highlight possible management measures to enhance yields and ensure sustainability. Case study fisheries (Seychelles, Tonga, Mauritius) are examined in conjunction with a modelling exercise to explore the dynamics of these resources. MRAG have developed a Multi species Interactive Dynamic Age Structured model (MIDAS) for this purpose. MIDAS is a fully age structured simulation model which follows the mathematical structure of the dynamics of exploited fish populations described by Beverton and Holt (1957), and incorporates density dependance in the form of a stock recruitment relationship.

Of the case studies, Seychelles demersal fishery is the most complex involving the greatest number of species, a number of different fishing vessel types and a number of different gear types to exploit the resource. However, a well established data collection programme has been in operation since 1985 and some earlier information is available. There is also a considerable literature (see Bibliography). This technical report presents a review of historical information (in particular, Mees (1992b) describes the demersal fishery, parts of which are reiterated for completeness) and updates analyses relating to Seychelles demersal fishery.

2 SEYCHELLES GEOGRAPHY AND HYDROLOGY

2.1 Seychelles, General Description

The Republic of Seychelles consists of some 100 widely scattered islands (land area, 453 km^2) between 5° and 10°S and 45° and 56°E in the Western Indian Ocean. The Exclusive Economic Zone encompasses 1,374,000 km^2 of which only 48,019 km^2 of ocean cover depths of less than 200 m, the remainder is over depths of 1,000 - 1,500 m. The shallow areas are composed of plateaux and banks (Fig 1, Table 1).

All the plateaux are steep sided rising rapidly from around 1000 m. The Mahe Plateau is encompassed by an incomplete shallow rim at around 10 - 20 m which surrounds a central area of about 50 - 65 m with subsurface granite and coral outcrops forming small banks. Two coral islands occur on the north of the rim and within the plateau are granitic islands. The majority of the population of 72,000 live on the three main granitic islands (Mahe, Praslin and La Digue) whilst the coralline islands on this and the other plateaux are sparsely inhabited.

Figure 1 The region of the Indian Ocean encompassed by Seychelles EEZ, indicating the location of the main banks and plateaux.

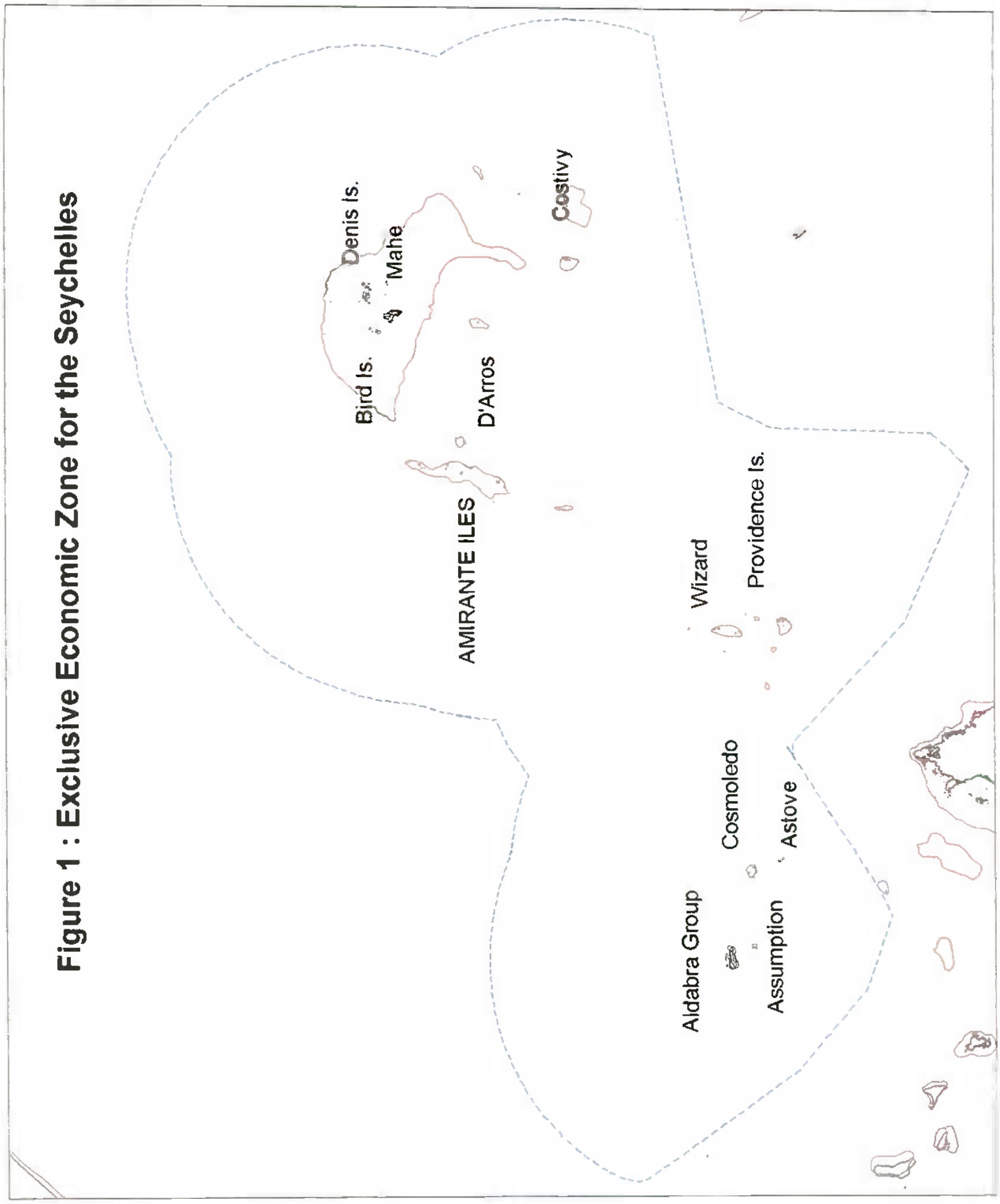


Table 1 : The total and fishable areas (km^2) of Seychelles banks and plateaux at shallow (0-75m) and intermediate (75-150m) depth strata, and the length (km) of the 100 m depth contour.

LOCATION / STRATA	SHALLOW STRATA		INTERMEDIATE STRATA	
	TOTAL	FISHABLE	LENGTH	AREA
MAHE PLATEAU				
- Inshore		6000.0		
- Offshore		6500.0		
- Trawlable		14000.0		
TOTAL	**41338.0**	**26500.0**	**998.0**	**374.0**
OUTLYING ISLANDS, PLATEAUX AND BANKS				
Banks S of MP, including Platte	2198.6	1619.6	542.6	135.3
Amirantes Plateau inc. Desroches	3999.0	2399.4	455.6	135.8
Alphonse	190.0	114.0	55.6	13.8
Providence / Farquhar	1621.1	927.7	549.5	131.7
Astove / Cosmoledo	398.1	238.9	129.5	32.4
TOTAL	**8406.8**	**5299.6**	**1732.8**	**449.0**
GRAND TOTAL	49744.8	31799.6	2730.8	823.0

The remaining islands and plateaux to the south and west of the Mahe plateau are all coralline in nature and include the Amirantes plateau, the Alphonse group, the Providence and Farquhar group and the Aldabra-Cosmoledo group.

The Fortune Bank lies south of the Mahe Plateau and has no emergent features. The bank tends to be shallower and more coralline in the north dropping to about 25 m in the south where the substratum is composed of fossil coral pebbles densely covered with macrophytes, encrusting sponges and algae. There are other smaller submerged banks in this area.

2.2 Hydrological Conditions

The climate consists of : the Northwest Monsoon from mid November to mid March followed by an inter - monsoon period of light variable winds and frequent calms; the South East Trade Winds from the end of May to October which average 12 knots and frequently limit fishing activity; a second inter - monsoon period during October - November.

Air temperature varies little throughout the year (mean daily minimum, 24-25°C; maximum, 27-30°C). Rainfall may occur throughout the year but is greatest in December and January. A strong gradient exists from 1500 - 2000 mm on the eastern granitic islands to less than 1000 mm in the western coralline islands such as Aldabra.

The hydrology of the Seychelles is affected by the eastward flowing Equatorial Counter Current and the westward flowing currents to the north and south. These are modified to a certain extent by the onset of the different monsoon periods. The southern islands lie in the west flowing South Equatorial Current, the northern in the east flowing Equatorial Counter Current. For the Mahe Plateau Tarbit (1980) described the prevailing conditions which are summarised in Table 2.

Table 2 : A summary of the hydrological conditions over the Mahe Plateau (adapted from Tarbit, 1980)

DETAILS	OCTOBER	NOVEMBER	DECEMBER	MARCH	APRIL	JULY	AUG - SEP
CLIMATE	End of SE Trades	NW Monsoon begins	NW Monsoon	End of NW Monsoon	Inter-monsoon period	SE Trades (from June)	SE Trade Winds
SEA SURFACE CURRENT	Eastwards over surf-ace of Plateau	Predominantly east-wards but northern flowing components over S of Plateau	Eastward counter-current in N but NW Monsoon pushes counter current south-wards S of Plateau	Predominantly E and SE Counter Current. Clock	Whole Plateau washed by eastward Equatorial edges of the Plateau. wise circulation occurs SE of Plateau.	Mainly southerly mod-ified to SE/SW by the to the east A small clockwise circ-ulation in S Plateau	The southerly current now swings
UPWELLING/ NUTRIENTS	In S and SE nutrient rich water is carried by counter current from intensive upwelling S of Plateau	Continues along S and SE edges of Plateau. Surface water between Mahe/Amirantes Plat-eaux nutrient rich. Algal blooms occur		of Plateau.	Upwelling associated with circulation in SE occurs. Enriched water carried over S surface	Cold water with low oxygen levels leaks over southern edge of Plateau. 19°C in S	Upwelling occurs along the southern edge of the Plateau
THERMOCLINE	A dome of cold water occurs S of Plateau, Thermocline at 20 -30m	Over plateau between 18-27°C; cool water, 16°C at 75m below S edge of Plateau	~30-40m weak temp-erature gradient	Surface and bottom temperatures over Plateau similar. No definite thermocline		A well defined thermo-cline occurs at 75 - 100m W and E of Plateau and <35m S & W	Thermocline stab-ilises at 35 - 40 m
TEMPERATURE							
SURFACE	26-28°C	26.5-29°C	27-28 C	28.5-31°C	29-31°C	26°C	26°C
20-29 m		26.4°C		28.6°C		25.7°C	
30-39 m		24.3°C		28°C		25°C	
40-49 m		23.3°C		27.1°C		23.2°C	
50-59 m		21.8°C		25.8°C		23.7°C	
60-69 m		20.2°C		24.5°C		23.2°C	

3 SEYCHELLES DEMERSAL FISHERY

3.1 Fisheries policy and legislation

The relatively large area of shallow banks and plateaux in Seychelles provides the potential for an important demersal fishery which has developed to involve a number of different vessel types and means of exploitation. The fishery has been shaped also by past and existing policy and legislation, now summarised.

The objectives for the fisheries sector relevant to the demersal fishery are (Anon 1989) :

- The creation of maximum amount of work opportunities
- The maximisation of foreign exchange earnings
- The creation of optimum linkages with other sectors
- The insurance of stable development in the industry
- The conservation of marine resources in order to ensure long term viability of the industry

Seychelles Fishing Authority (SFA) is required to collect and analyse statistical and other information on fisheries and to prepare and keep under review plans for the development and management of fisheries. The legislation is in place for the Minister (of Agriculture and Fisheries) to prescribe management measures including: closed seasons, closed areas, gear specifications, fishing methods or gear types, specification of species sizes or other characteristics of aquatic organisms that it is permitted or forbidden to catch, and schemes for limited entry into the fishery (Fisheries Act, 1986).

Certain regulations are directly relevant to the demersal fishery. By law, a local fishing vessel licence is required before fishing is permitted in Seychelles waters, and except for research purposes under licence, foreign vessels are excluded from fishing within territorial limits or on the surface of, and up to 5 nautical miles beyond the edge of the plateaux (continental shelf, defined by the 200 m depth contour. Fisheries Act, 1986; SFA, 1986a). Fishing for demersal species by means of trawl nets is prohibited. Regulations specific to demersal fish species do not exist except in as much as they are included incidentally in other regulations, eg. the restriction of mesh size in the trap fishery which occasionally catches a number of demersal species.

As a consequence the demersal fishery is exploited solely by locally owned vessels, and predominantly by hooks and lines which tend to target the top predators (lutjanidae, lethrinidae and serranidae). Locally high exploitation rates in near-shore areas led to a Government policy to limit the number of outboard- and to promote inboard powered vessels capable of fishing more distant locations. The policy of distributing fishing effort more evenly and further offshore inevitably implies a requirement for more capital intensive fishing methods and larger boats and progress has been slow. To improve the situation, recent policy has also been to move away from parastatal management of the fishing fleet towards entrepreneurial ownership.

Declines in catches and the number of vessels operating, particularly further offshore, have resulted in fleet rehabilitation plans and a number of projects are outlined in the 1990-1994 National Development Plan (Anon, 1989). Particularly relevant are the fleet replacement programme, fishing boat construction, schooner fleet management, promotion of demersal fisheries in the outer islands, development of fisheries technology, fisheries extension programme, and various infrastructure development projects. These programmes have led to the introduction of new vessel designs and fishing methods.

Infrastructure to support fisheries development has been provided or is planned and includes provision of marketing facilities, ice, and outlets for fishing equipment. In line with recent policy, marketing practices have been relaxed and the state monopoly removed.

3.2 The fishing fleet : vessels and fishing gear

Seychelles was un-populated until the eighteenth century. Fishing for demersal species was confined to coastal areas near centres of population and today is concentrated around the granitic islands. The coralline islands are sparsely inhabited and local exploitation will have had minimal impact. Seychelles schooner fishery was established in 1974 when these boats were introduced to allow fishing on the offshore banks and periphery of the Mahe and Amirantes Plateaux. Foreign mothership-dory operations were licensed to fish in the Amirantes, Cosmoledo and Providence and Farquhar between 1974 - 1977 (Ratcliffe, 1975; Harris, 1980). Whalers have increasingly targeted demersal species since the mid 1980's and developments in the schooner fishery since that time have resulted in more efficient vessels with a greater range and better means of exploiting the demersal resource. Between 1991 and 1993 a Seychelles mothership-dory venture operated. Thus fishing pressure has increased only relatively recently and for the outlying islands exploitation has been sporadic.

The demersal fishery is thus prosecuted from a number of different vessel types. For statistical purposes these are defined by the following categories :

Pirogues : any fishing boat equipped with up to 15 hp outboard motor, including un-powered boats. Types include traditional wooden canoes; fibreglass boats. Fishing range limited to coastal areas.

Outboards : Boats with an outboard motor of greater than 15 hp. Types : mostly an introduced design of fibreglass hull known as the mini-mahe; some larger wooden vessels. Fishing range limited to near-shore.

Whalers : Any undecked inboard powered fishing boat (may have a small fore-deck). Types : traditional clinker built wooden hulls; introduced fibre-glass design Lekonomie and Lavenir. Fishing range limited to Mahe Plateau except in calm weather when occasionally whalers may go as far as the Amirantes. Most fishing trips are daily, but trips of 3-4 days are made.

Schooners : Fully decked inboard powered fishing boats. Types : mostly wooden hull vessels of traditional design; ADB promoted wooden vessels known as 'la Digue' boats after the boat yard of construction; converted pole and line vessel; Swedish design fibre glass vessel. Fishing range limited only by size of vessel and extreme weather conditions. Trips may last several days.

Research : The SFA research vessel 'Etelis' a pole and line vessel; newly introduced multi-purpose Cygnus fibre glass vessels (1994); other vessels in development stage prior to full incorporation into the fishery. Range and trip length as the Schooners.

Mothership: Mothership - dory fishing ventures. Fishing range unlimited, duration up to 3 months.

Mees 1989c describes the fleet structure. Schooners are discussed by Mees (1990b) and the mothership venture by Mees (1991b; 1992c; in press). Briefly, the number of outboards and pirogues had decreased with time, but the policy of promoting inboard powered vessels led to considerable increases in the number of whalers rather than schooners. This shifted fishing pressure from coastal reefs slightly but did not achieve the objective of increasing effort at more distant fishing grounds, in fact causing an increase in fishing pressure in near-shore locations. Some whalers however, are increasingly fishing the edge of the Mahe Plateau, particularly to the west and south-west close to Mahe.

The number of schooners declined up to 1989 (see Michaud, 1988; Parker, 1988; Mees, 1990b). The introduction of the new La Digue vessels was not entirely successful and the promotion of the offshore demersal fisheries fleet remains a problem. Socio-economic factors restrict the development of the fishery (Mees, 1990c;d) in addition to technological problems. The Cygnus vessels are the latest attempt to address this problem.

The mothership-dory fishing venture achieved the objectives of increasing the yield of demersal fishery resources and exploiting distant fishing locations, increasing exports, and increasing employment. However, this privately run operation was not financially viable and failed in 1993 after 7 voyages.

The predominant fishing method employed for demersal species by all boat categories is hook and line. Pirogues and outboards may also deploy fish traps but the proportion of demersal species is negligible (see Annual statistical reports : Moussac, 1987a; 1987b; 1988a; Mees, 1989b; 1990a; 1991a; Mees and Grandcourt, 1992; Grandcourt, 1993). Whalers may target either carangidae or demersal species using hook and line. Increasingly demersal species are being targeted although the carangid fishery is the traditional target of this category.

The schooners and mother-vessel target demersal species. Hooks and lines have traditionally been used, but electric fishing reels were promoted through the SFA extension programme and have successfully been taken up by a number of schooners. They were also fitted to the dories for the recent mothership operation. Catch rates are increased by up to 30 % (Bautil, 1988;

Mees, 1990b). Drop-line fishing was tested by SFA and has recently (1994) been adopted commercially. Deep bottom set gill net fishing for demersal species was developed by SFA and was employed commercially by one of the larger La Digue schooners for a short period in 1993. This technique was also being developed with the new Cygnus vessels, but since the vessels have been privatised this technique has been abandonned in favour of drop lines.

The existence of a number of different vessel types and fishing methods has significant implications both for the analysis of the data (effort must be standardised) and management of the fishery.

3.3 The fishery and fishing locations

Seychelles artisanal fishery is described by Lablache *et al* (1988) and Mees (1989a). The demersal fishery produced 20-40% of the total landings of approximately 5000 t per annum during the period 1985 -1994. Demersal species, however, constituted around 75% of all exports (Mees, 1992b). Thus this sector of the artisanal fishery is particularly important for meeting the defined objectives of the fisheries sector.

Demersal species occur in both sandy flat bottom areas suitable for trawling, and rough and coralline substrates. However, the concentration of fish is not sufficient to support a handline fishery except in the rough / coralline areas and on the drop-offs of the banks and plateaux. Fishable areas given in Table 1 are those suitable to support a handline fishery. This has been estimated for the Mahe Plateau where the fishable area is approximately 60% of the total. This proportion was applied to the other locations in estimating fishable area[1]. It should be noted that fishable areas are not uniform and include good and bad fishing zones. Also the territorial behaviour of most demersal species means that fishable areas are separate entities from which emigration and immigration will be low. They are consequently sensitive to fishing pressure and recovery from depletion may be slow. Mees (in press) has examined recovery rates, and Russ and Alcala (in Press) indicate that following depletion a reef may take up to 5 years to recover in terms of numbers of fish but at least 10 years in terms of biomass, due to the time required for growth of new recruits.

To improve analysis the banks and plateaux have been stratified into fishing sectors, and specific fishing locations within these sectors are also identified (Fig. 2; Table 3). Sub stratification by depth was as follows : shallow (0-75 m, mostly on the surface of the plateaux); intermediate (75-150 m, at the drop off of banks and plateau); deep (>150 m). The shallow stratum on the Mahe Plateau was further sub-stratified into : inshore areas (corresponding with sector I in Table 3); offshore banks and peripheral edge zone of the Plateau rim; trawlable grounds.

It must be stressed that the stratification of fishing grounds and fishing sectors is a statistical and analytical convenience. Neither the fishing grounds nor the sectors necessarily encompass a discrete population of fish. It has been stated that fishable areas are not uniform and that due to the territorial nature of most reef and demersal species adult emigration and immigration will be low. Thus these types of fishery may be regarded as consisting of meta-populations associated with specific features, or patches of habitat, interconnected through larval or other means of dispersal - whilst the fish on different patches of habitat may belong genetically to a single population, from a fisheries point of view each patch contains a single population.

The Mahe Plateau is shallow and in practice many patches of habitat will be close together. It

[1] Areas given in Table 1 derive from a number of sources including recent estimates by MRAG, and there is some variation in the estimates. Refer to Mees (1992b) for detailed explanation

may be assumed that some mixing of adult fish occurs between patches, between fishing grounds, and even between sectors on the Plateau. Since data collection is not sufficiently detailed to relate catches to a specific feature or patch of habitat it is necessary to utilise this assumption and the definition of the area encompassing a discrete fish population becomes a matter of convenience. The area chosen may or may not be valid, and this uncertainty must be understood when interpreting the results of fisheries models applied to these data. Beyond the Mahe Plateau fishing sectors are separated physically and geographically. In these cases it is not valid to assume a single population (although there may be fish of the same genetic stock).

Figure 2. Seychelles Plateaux indicating the statistical fishing sectors of the Mahe Plateau (After Lablache and Carrara, 1984)

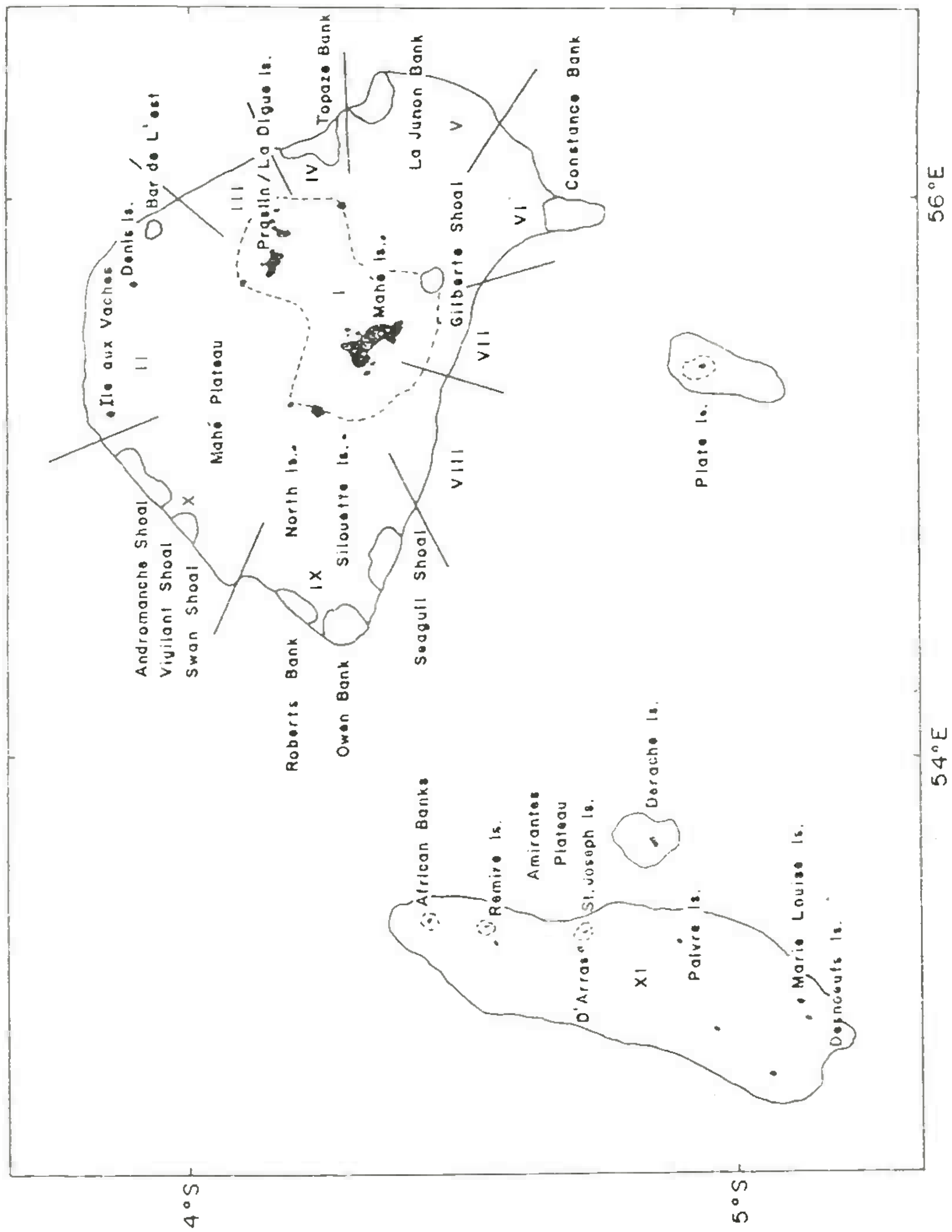


Table 3 : A description of the fishing grounds and sectors, with estimates of the areas of shallow and intermediate depth strata derived from Admiralty Charts. The area of intermediate depths were calculated from the length of the 100 m contour assuming an average 250 m width for this shelving depth band, except for the Mahe Plateau, calculated by Seychelles Lands and Survey Division (Navratsamy, pers comm).

F_GROUNDS	DESCRIPTION OF FISHING GROUNDS	SECTOR	Area, Km2 0-75 m	Length, km 100m contour	Area, km2 75-150 m
	MAHE PLATEAU AND ASSOCIATED BANKS		**41338.0**	**998.0**	**374.0**
OUT	10 MILE RADIUS OF MAHE / PRASLIN GROUP	1	4544.0		
N; NNE; NNW	BIRDS,DENIS,NORTH EDGE	2	4794.0	130.5	44.3
NE	NORTH EAST EDGE	3	1604.0	71.3	24.2
E; ENE	TOPAZE BANK	4	2913.0	89.3	30.3
ESE	LA JUNON BANK	5	8041.0	149.3	50.7
SE	SOUTH EAST EDGE	6	5405.0	235.5	79.9
S; SSE	SOUTH EDGE	7	818.0	75.0	25.5
SW	SW EDGE	8	1876.0	138.0	46.8
W; WNW; WSW	OWEN THOR ROBERTS BANKS	9	5715.0	102.8	34.9
NW	NORTH WEST EDGE	10	5628.0	110.3	37.4
	BANKS TO SOUTH OF MAHE PLATEAU		**2198.6**	**542.6**	**135.3**
ADE	Adelaide Bank	11	6.6	11.1	2.7
COE	Coetivy	11	420.0	83.3	20.8
CON	Constant	11	590.0	114.8	28.7
COR	Correira	11	17.4	33.3	8.3
FOR	Fortune	11	600.0	120.4	30.1
SAV	Bar Savat	11	48.0	50.0	12.5
SCO	Small Constant	11	170.0	55.6	13.8
M20	Seamount marked '20'	11	6.6	11.1	2.7
PLA	PLATTE	12	340.0	63.0	15.7
	OUTLYING ISLANDS AND PLATEAUX				
AMI	**AMIRANTES GROUP**	13	**3999.0**	**455.6**	**135.8**
AFR	African Banks - All Atols	13	240.2	23.8	5.9
ALP	Alphonse	13			
BIJ	Bijoutier	13			
BOU	Boudeuse	13			
DEN	Desnoeufs	13	377.3	36.8	9.2
DES	Desroches Atol	13	400.0	77.8	19.4
ETO	Etoile	13	553.9	55.5	13.8
FRA	St. Francois	13	59.3	30.8	7.7
IDS	Ile Du Sud - Near Poivre	13			
JOS	St. Joseph	13	869.3	87.0	21.8
MAR	Marie Louise	13	376.1	33.0	8.3
POI	Poivre	13	655.9	45.0	11.3
REM	Remire	13	371.1	66.0	16.5
	All others		95.9		22.0
	PROVIDENCE / FARQUHAR GROUP	14	**1621.1**	**549.5**	**131.7**
FAR	Farquhar Group - Unspecified	14	316.5	126.0	31.5
PRO	Providence Group - Unspecified (Area inc. Cerf)	14	316.5	45.5	11.4
CER	Cerf Island	14		45.5	5.7
WIZ	Wizard Reef	14	100.0	56.0	14.0
BUL	Bulldog Bank	14	285.8	73.5	18.4
MCL	Mcleod Bank	14	240.9	73.5	18.4
M17	Bank marked '17'	14	81.7	49.0	12.3
M25	Bank marked '25' between CER and FAR	14	279.7	80.5	20.1
	ASTOVE / COSMOLEDO (Exc. Aldabra)	15	**398.1**	**129.5**	**32.4**
AST	Astove	15	79.6	38.5	9.6
COS	Cosmoledo	15	318.5	91.0	22.8
	TOTAL		**49554.9**	**2675.2**	**809.2**

Demersal fish potential by hook and line at coralline banks along the Mascarene ridge in the Indian Ocean was first surveyed by Wheeler and Ommaney (1953). Fishable (ie rough grounds suitable for hand lining) and non fishable areas were first identified. Subsequently trawl surveys were conducted in the non-fishable (ie by handline) grounds. Estimates of the demersal fishery resource in Seychelles have largely been confined to the granitic Mahe Plateau based upon the swept area method applied to the trawl surveys. These estimates will tend to under-estimate fish populations in the rough grounds where greater concentrations occur, and in deeper water. For the rough (fishable) grounds, length cohort analysis has been applied to representative species in order to determine population size, and depletion assessments have also been used.

For demersal fish resources in trawlable areas, Birkett (1979) estimated the total biomass of the Mahe Plateau to be 42,000 tonnes, and Marchal et. al. (1981) estimated 75,000 tonnes. Tarbit (1980) estimates the biomass for 4176 nm^2 of the Plateau covered by trawl surveys to be 80,000 tonnes. Kunzel *et al.* (1983) estimated the total biomass for the whole of the Mahe Plateau to be 51,000 tonnes. On rough grounds, Lablache and Carrara (1988) estimate a total biomass of large demersal fish exploitable by a handline fishery of 8,400 tonnes for the offshore banks of the Mahe Plateau (1,900 nm^2). Information from these surveys has subsequently been applied to determine the potential yield of demersal species available to a handline fishery (Lablache and Moussac, 1987; Lablache et. al. 1988; Lablache and Carrara, 1988). Mees (1992b) reviewed previous estimates of biomass and yield from the demersal fishery and presented revised estimates by location and depth stratum based on analysis of new information. The basis of these estimates (shallow water biomass, 1.4 t km^{-2}, yield 0.168 t km^{-2}, fishable area equivalent to 60% of total area; intermediate depth biomass, 5.5 t km^{-2}, yield 1.375 t km^{-2}) was used with the most recent estimates of bank area (Table 3) to update the estimated yield of demersal handline caught species (Table 4). No estimate of the yield from trawlable grounds is included in Table 4, as was the case in Mees (1992b).

The yields for the offshore banks and rough ground (fishable areas) are considered to be an under-estimate. Catches are significantly below the potential yield and there is scope to more than double the present catch. Locally, however, depletion has occurred and particularly in inshore areas catches exceed potential yield (see Mees, 1992b). Potential for further development of the fishery lies in the more distant locations and intermediate and deep depth strata.

Table 4. Biomass and potential yield estimates (tonnes) available to a commercial handline fishery on demersal stocks in Seychelles.

F_GROUNDS	DESCRIPTION OF FISHING GROUNDS	SECTOR	SHALLOW STRATA Biomass	SHALLOW STRATA Yield	INTERMED. Biomass	INTERMED. Yield
	MAHE PLATEAU AND ASSOCIATED BANKS		**34723.9**	**4166.9**	**2057.0**	**514.3**
OUT	10 MILE RADIUS OF MAHE / PRASLIN GROUP	1	3817.0	458.0		
N; NNE; NNW	BIRDS, DENIS, NORTH EDGE	2	4027.0	483.2	243.7	60.9
NE	NORTH EAST EDGE	3	1347.4	161.7	133.1	33.3
E; ENE	TOPAZE BANK	4	2446.9	293.6	166.7	41.7
ESE	LA JUNON BANK	5	6754.4	810.5	278.9	69.7
SE	SOUTH EAST EDGE	6	4540.2	544.8	439.5	109.9
S; SSE	SOUTH EDGE	7	687.1	82.5	140.3	35.1
SW	SOUTH WEST EDGE	8	1575.8	189.1	257.4	64.4
W; WNW; WSW	OWEN, THOR, ROBERTS BANKS	9	4800.6	576.1	192.0	48.0
NW	NORTH WEST EDGE	10	4727.5	567.3	205.7	51.4
	BANKS TO SOUTH OF MAHE PLATEAU		**1846.8**	**221.6**	**744.2**	**186.0**
ADE	Adelaide Bank	11	5.5	0.7	14.9	3.7
COE	Coetivy	11	352.8	42.3	114.4	28.6
CON	Constant	11	495.6	59.5	157.9	39.5
COR	Correira	11	14.6	1.8	45.7	11.4
FOR	Fortune	11	504.0	60.5	165.6	41.4
SAV	Bar Savat	11	40.3	4.8	68.8	17.2
SCO	Small Constant	11	142.8	17.1	75.9	19.0
M20	Seamount marked '20'	11	5.5	0.7	14.9	3.7
PLA	PLATTE	12	285.6	34.3	86.4	21.6
	OUTLYING ISLANDS AND PLATEAUX					
AMI	**AMIRANTES GROUP**	13	**3359.2**	**403.1**	**746.9**	**186.7**
AFR	African Banks - All Atols	13	201.8	24.2	32.5	8.1
ALP	Alphonse	13				
BIJ	Bijoutier	13				
BOU	Boudeuse	13				
DEN	Desnoefs	13	316.9	38.0	50.6	12.7
DES	Desroches Atol	13	336.0	40.3	106.7	26.7
ETO	Etoile	13	465.3	55.8	75.9	19.0
FRA	St. Fancois	13	49.8	6.0	42.4	10.6
IDS	Ile du sud - near Poivre	13				
JOS	St. Joseph	13	730.2	87.6	119.9	30.0
MAR	Marie Louise	13	315.9	37.9	45.7	11.4
POI	Poivre	13	551.0	66.1	62.2	15.5
REM	Remire	13	311.7	37.4	90.8	22.7
	All others	13	80.6	9.7	121.0	30.3
	PROVIDENCE / FARQUHAR GROUP	14	**1361.7**	**163.4**	**724.4**	**181.1**
FAR	Farquhar Group - Unspecified	14	265.9	31.9	173.3	43.3
PRO	Providence Group - Unspecified (Area inc. Cerf)	14	265.9	31.9	62.7	15.7
CER	Cerf Island	14			31.4	7.8
WIZ	Wizard Reef	14	84.0	10.1	77.0	19.3
BUL	Bulldog Bank	14	240.1	28.8	101.2	25.3
MCL	Mcleod Bank	14	202.4	24.3	101.2	25.3
M17	Bank marked '17'	14	68.6	8.2	67.7	16.9
M25	Bank marked '25' between CER and FAR	14	234.9	28.2	110.6	27.6
	ASTOVE / COSMOLEDO (Exc. Aldabra)	15	**334.4**	**40.1**	**178.2**	**44.6**
AST	Astove	15	66.9	8.0	52.8	13.2
COS	Cosmoledo	15	267.5	32.1	125.4	31.4
	TOTAL		**41626.0**	**4995.1**	**4450.6**	**1112.7**

3.4 Commercially important species from the demersal fishery.

Species landed to the demersal line fishery are members of the lutjanidae, serranidae and lethrinidae (Table 5). For vessels such as the schooners and mother-ship ventures which target bottom fish these families contribute in excess of 85% of the landed catch, the remainder consisting of carangids, barracudas, pelagic species such as tuna, and sharks. The small boats and whalers may catch a smaller proportion of demersal species.

The demersal fish species exploited are commercially important, and contribute up to 77% of all fish exported from Seychelles. Around 30% of the demersal landings are exported : 40% of l red snapper (mostly *Lutjanus sebae* and *L. coccineus*); 7% of *L. bohar;* 24% of Job fish *Pristipomoides filamentosus* and *Aprion virescens*); 60% of *Epinephelus chlorostigma*; 31% of l other serranids; and 16% of all Lethrinids (Mees, 1992b). Thus it may be seen that the tjanids and serranids are more valuable than lethrinids and this may affect targeting during shing. Similarly, due to fears of ciguaterra, *L. Bohar* may be avoided and the proportion xported does not reflect the volume landed. Nevertheless, there is also a high local demand for demersal species, particularly during the SE Trade Wind period when fishing is restricted and landings are lower.

Economic value and volume of fish landed indicated the following key species from the Seychelles demersal fishery : *L. sebae, P. filamentosus, A. virescens* and *E. chlorostigma* (Mees, 1992b). *Lethrinus mahsena* is the most important lethrinid, but its common name (Lascar) is shared by several species. *Lethrinus nebulosus* is another important lethrinid.

Table 5 : Demersal species described in Seychelles catch statistics.

SEYCHELLES NAME	LATIN NAME	OTHER DETAIL/CODE
Bourgeois	*Lutjanus sebae*	BOUR
Bordemar	*Lutjanus coccineus*	BORD
Therese	*Lutjanus gibbus*	THER
Vara Vara	*Lutjanus bohar*	VARA
Job gris	*Aprion virescens*	JOBG
Job jaune	*Apharaeus rutilans*	JOBJ
Batrican	*Pristipomoides filamentosus*	BATR
Carpe	*Gaterin spp*	LUTX :other lutjanids
Madras	*Lutjanus kasmira*	LUTX :other lutjanids
Vie. Maconde	*Epinephelus chlorostigma*	MACO
Vie. Platte	*Epinephelus multinotatus*	V_PL
Tioffe	*Epinephelus morhua*	TIOF
Croisant	*Variola loutii*	CROI
Vie. Rouge	*Epinephelus fasciatus*	SERX : other serranids
Vie. Ananas	*Cephalopholis miniata*	SERX : other serranids
M. Angar	*Cephalopholis sonnerati*	SERX : other serranids
Cheval di bois	*Epinephelus corallicola*	SERX : other serranids
Vie. Machata	*Epinephelus fuscoguttatus*	SERX : other serranids
Vie. Tukula	*Epinephelus tukula*	SERX : other serranids
Vie. Galfa	*Aethalopera rogaa*	SERX : other serranids
Vie. Crab	*Epinephelus malabaricus*	SERX : other serranids
Vie. Chatte	?	SERX : other serranids
Babone	*Epinephelus tauvina*	SERX : other serranids
Tukula	*Epinephelus tukula*	SERX : other serranids
Cap. Blanc	*Gymnocranius robinsonii*	C_BL
Guele longue	*Lethrinus elongatus*	G_LO
Lascar	*Lethrinus mahsena*	LASC
Dame berrie	*Lethrinus crocineus*	D_BE
Cap. Rouge	*Lethrinus nebulosus*	C_RO
Guele de vin	*Lethrinus conchyliatus*	LETX : other lethrinids
Bacsous	*Lethrinus variegatus*	LETX : other lethrinids
Chouchoutte	*Gymnocranius griseus*	LETX : other lethrinids
Eclair	*Lethrinus lentjan*	LETX : other lethrinids

4 SAMPLING AND ANALYTICAL METHODS

Catch and effort data collection are achieved through Seychelles Catch Assessment Survey (CAS) implemented by SFA and fully described in SFA (1990). Analytical procedures are described in Mees (1990f). Briefly, a stratified sampling programme is conducted by boat category and landing site. The fishing skipper is interviewed and catch is recorded by species and weight. For whalers, a new data collection programme was introduced from July 1989. Total effort is recorded at four key sites and catches are sampled. The previous system underestimated the catch of whalers undertaking trips of greater than one day (ie for demersal species, see Mees, 1992a). For schooners the catch and effort of every boat is recorded, but frequently the catch is landed in parts : only records for which the total landed catch is known are included in the analysis. For the mother-ship - dory fishing operations an observer was placed on board the mother-ship for each voyage, and a detailed census of catch and effort information was recorded for each dory trip. The amount of detail collected (location, depth, climate, current) differs by boat category (Table 6). The number of species recorded by boat category also differs.

Table 6 : The quality of data available from the CAS for each boat category.

BOAT TYPE			QUALITY OF DATA			PERIOD
	C / F	SP. COMP	LOCATION	DEPTH	OVERALL	
SMALL BOATS	Yes	Crude	Assume all inshore	No : Assume shallow	Fair / poor	from '85
WHALERS	Yes	Crude -90 Good 90+	Some data but poor reporting	No : Assume shallow	Fair	from '85
SCHOONERS	Yes	Good	Gross location reported	Since 1991	Good	from '83
MOTHERSHIP	Yes	Good	Lat / Long	Yes	Excellent	1991-93

Length frequency and biological information was recorded for certain key species (see Section 3.5; Mees, 1992b). For length frequency, boxes of incompletely gutted fish were sampled at random. The fish were measured (fork length, to 1 mm) and where possible sexed. Length data was obtained for all key species.

Biometric samples employed whole fish encompassing the extremes of the size range observed. They were weighed (to 1 g), measured (fork length to 1 mm) and sexed. Gonads were weighed (to 0.1 g). Maturity stage was assessed for females on a scale of 1 (immature) to 5 (spent) according to criteria established by micro and macroscopic examination. A Gonadosomatic Index (GSI) - the gonad weight in grammes / whole fish weight in kilogrammes - was calculated. Biometric data was collected for *P. filamentosus* and *A. virescens*.

Sampled data by boat category, length frequency and biometric data by species form the basis of the present study. Raised estimates of catch are derived from Annual Statistical Reports published by SFA.

5 ANALYSES

5.1 CATCH AND EFFORT DATA

5.1.1 Total catch, effort and species composition per year by fishing location

Estimates of the total demersal fish catch and effort (man-days) per annum for most boat categories are available from SFA annual statistical reports (Table 7). The annual catch of all demersal species for each location was derived (Annex 1, Table 8), and species catches by location were estimated (Annex 1). The estimate of demersal catch for whalers reported in SFA statistics is thought to overestimate the true catch (see Annex 2). Re-estimation of the whaler catch by species is presented for sector 1 in Annex 2.

Table 7 : The total demersal fish catch, and the effort (man-days) applied to the demersal fishery for certain boat categories per annum. (Data available in 1985 was for the period July-December)

BOAT CATEGORY	85*	86	87	88	89	90	91	92	93	94
EFFORT - Mandays										
PLHP	5198	8138	2929	2324	3461	1659	585	126	303	717
PLHPFIXS	1161	12784	7181	2005	660	1172	2793	13	227	0
OBLHP	19555	26862	18855	17275	13482	13224	12015	975	9099	8765
OBLHPFIXS	7682	13735	8078	4145	4295	5097	6445	631	6028	2757
WHALER	23630	39705	53425	45875	34952	45639	41719	41707	44400	41478
SCHOONER	8757	11574	16238	14152	11962	10272	10429	3066	4852	5951
MV-LINES	0	0	0	0	0	0	2277	198	36	0
MV-REELS	0	0	0	0	0		1552	3953	1702	0
CATCH -mt										
SPORTS BOATS				0	0	0	0	0	0	0
SMALL BOATS	266.8	356.5	207	218.4	267.1	201.6	215.1	214.9	247.1	228.9
WHALER	296.6	824.5	672.5	600.4	672.2	1139.1	1178.4	903.8	962.1	1029.9
SCHOONER	274.1	382.9	528.8	414.7	516.7	571.7	472.3	336.2	182.4	216.2
MOTHERSHIP							419	541.2	327.5	0
TOTAL	837.5	1563.9	1408.3	1233.5	1456	1912.4	2284.9	1996.1	1719.1	1475

Table 8 : The total annual demersal fish catch by location.

SECTOR	Code	85	86	87	88	89	90	91	92	93	94
Inshore	1	442.5	846.9	605.3	574	731.3	919.5	831.3	861.9	852.4	537.7
N. Mahe Pl.	2	39.4	120.1	108.8	72.4	69.1	212.6	204.1	91.5	37.9	38.8
NE Mahe Pl.	3	36.6	46.8	68.7	25.7	28.1	52.1	42.4	37.5	15.4	55.8
Topaze Bank	4	33.5	36.9	42.6	54.7	47.6	45.2	45.4	78.7	188.3	47.1
La Junon bank	5	23.9	11.8	32.5	9	0	7.7	30.1	33.3	31	0.6
SE Mahe Pl.	6	55.5	83.8	136.5	107.8	62.4	311.5	434.7	105.9	80.4	53
S Mahe Pl.	7	42.9	114	123.6	92	114.3	83	124.4	56.6	59.9	407
SW Mahe Pl.	8	11.8	19.1	47.7	22.1	32.4	46.7	36.5	10.5	22.1	
W Mahe Pl.	9	52.8	198.7	103.3	155.3	279.6	127.8	80.4	43.8	89.7	81.3
NW Mahe Pl	10	33.5	76.1	86.8	74.2	54.6	88.3	82.4	86.7	27.8	191.2
Banks S. MP	11							201.3	50.7	18.1	3.3
Platte	12			4.2				0.7	8.2	4.5	
Amirantes	13	65	9.6	48.3	46.3	36.6	18.1	82.1	133.8	16.9	59.2
Providence / Farquahar	14							89.5	375.5	32.2	
Cosmoledo / Aldabra	15								21.6		
Saya de Mahla	99									242.4	
TOTAL		837.5	1563.9	1408.3	1233.5	1456	1912.4	2285.3	1996.1	1719.1	1474.9

Demersal species are caught during approximately 60% of all fishing trips by small boats and whalers and all trips by other vessel types. For whalers the proportion has increased slightly since 1990. It is also apparent that nearly all trips made by whalers to more distant fishing grounds target demersal species.

Demersal fish catches have fluctuated over time, reaching a peak in 1991 (Fig. 3). By boat category, whalers accounted for the approximately half the catch from 1985-1993, small boats between 10-20%, and schooners 30%. In recent years however, the proportion landed by schooners has decreased reaching 11% in 1993, and it is apparent that the volume landed by this boat category has decreased considerably since 1990. The volume landed by small boats has remained almost constant since 1985 whilst the landings by whalers have apparently increased. The mothership venture made a significant impact accounting for 18%, 27% and 19% of demersal landings from 1991-93 respectively.

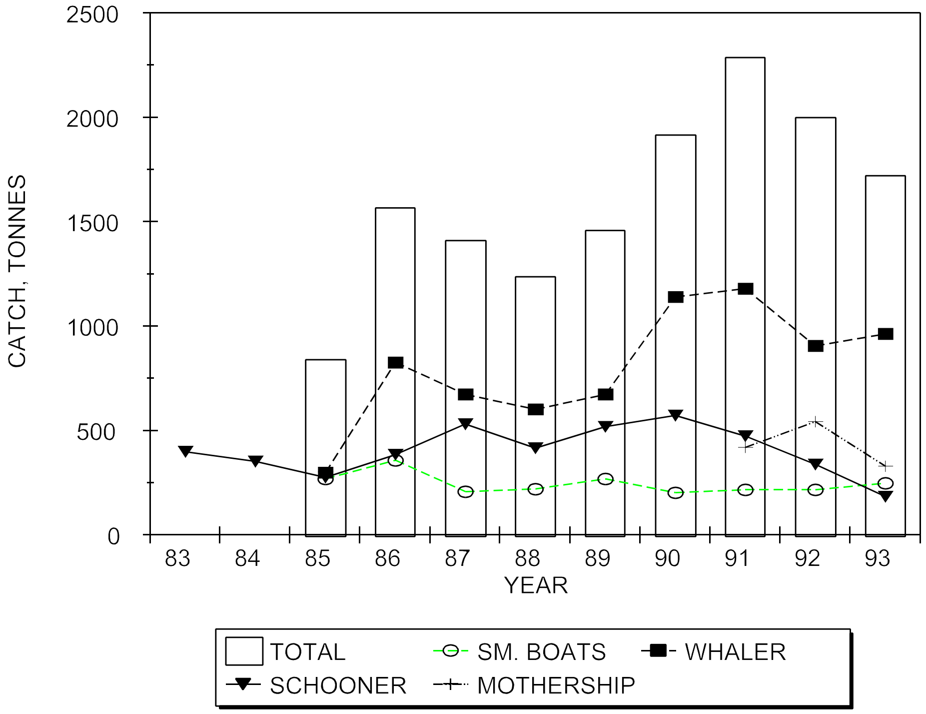


Figure 3 : Total annual demersal fish catches by boat type aggregated over all locations.

By location, around 50% of the demersal fish catch derives from inshore locations exploited by small boats and whalers (between 43% and 60% of the catch during the period 1985-1994). This sector is the most heavily exploited part of the fishery. By comparison all other locations are lightly exploited and removals with time have been intermittent (Fig 4). For example, sector 14 yielded 19% of all demersal landings in 1992 but had experienced no or very light fishing since the previous mothership venture to that location in 1976-77. Whilst total removals from distant locations have been low, yield per unit area has been relatively high intermittently, eg Sector 14 in 1991, and consistently from Sector 7, being particularly high in 1994 (not shown - scale affected, Fig. 5).

Available information indicates that locations distant from the centres of population are fished seldom by whalers, and most of the catch from these locations derived from the schooner and mothership operations (Table A1.4).

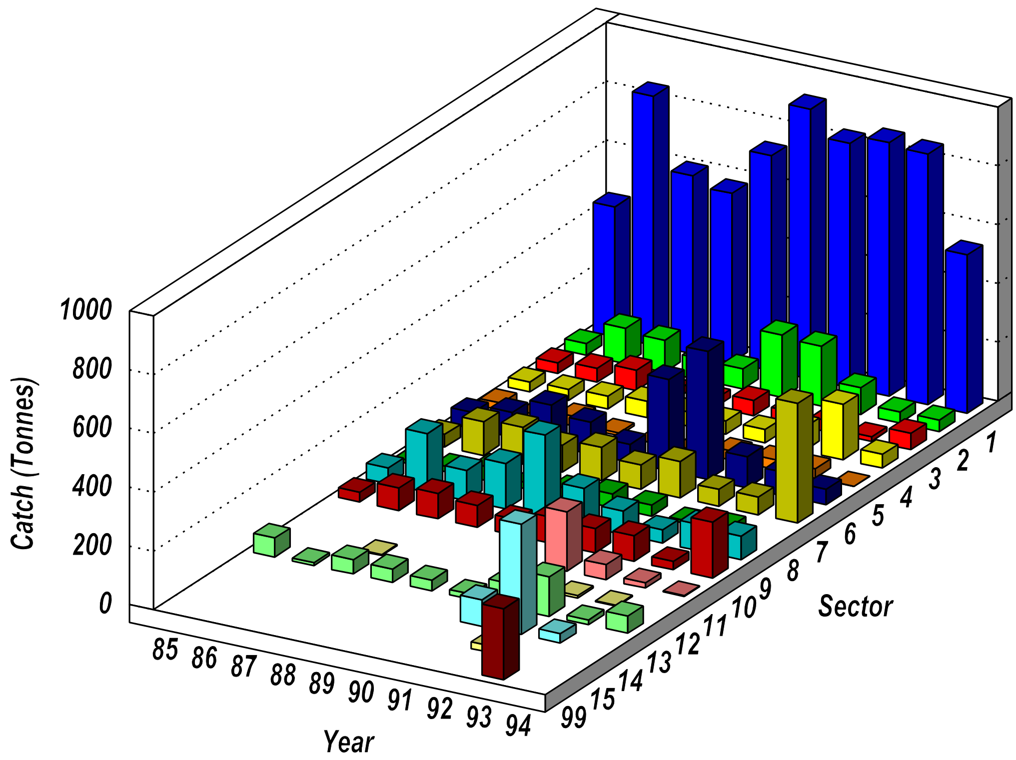


Figure 4 : Demersal fish catches by location per annum

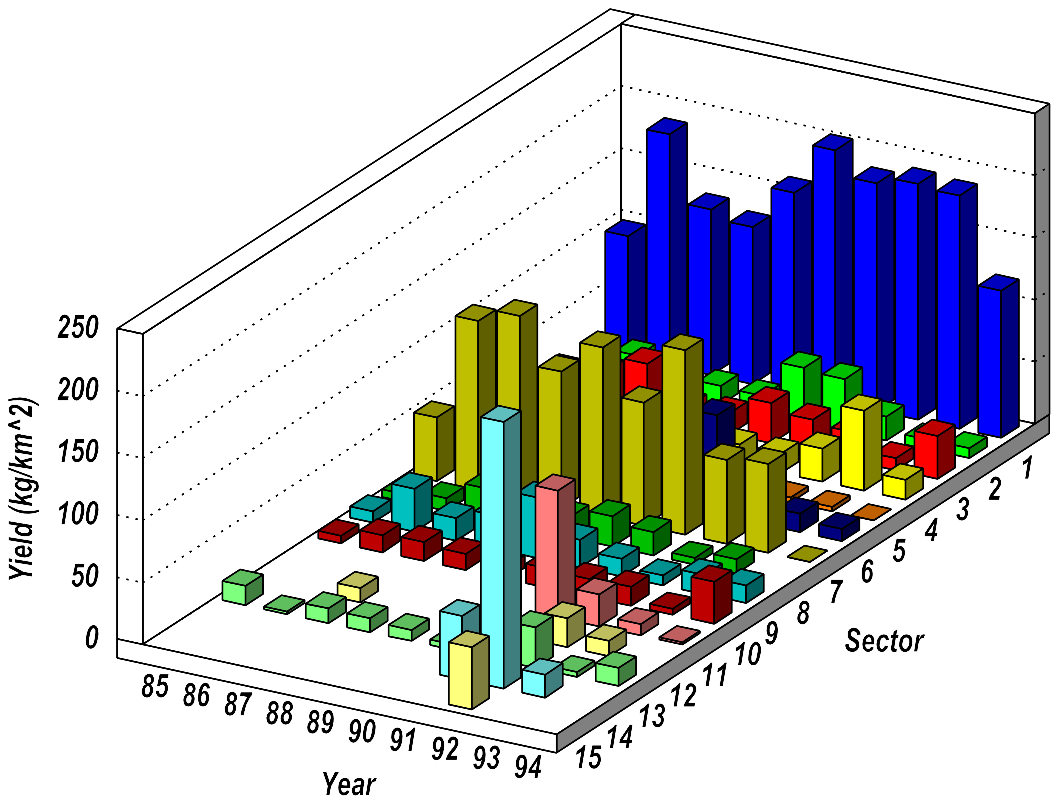


Figure 5. Yield per unit area (kgkm^{-2}) per annum by fishing sector

Species composition within Seychelles waters varies with latitude. Thus, that in the Aldabra / Cosmoledo and Providence / Farquhar groups is similar but different from that in the Amirantes 320 km to the north. Whilst the Amirantes and Mahe plateaux are at similar latitude the coralline Amirantes support a different species composition to the granitic Mahe Plateau, and in commercial terms a greater proportion of high value species occur on the latter (see Lablache and Carrara, 1984). Species composition also differs on banks within the same general location (see Mees, 1991b; 1992c), presumably related to substrate differences. Species composition may also be related to prevailing currents and other hydrological factors. Depth fished is another significant factor.

The earliest records of species composition by location within Seychelles were compiled by Ommaney and Wheeler (1953) for 1948-9 (Table 9). Recent species composition of the demersal fish catch is available for the whole fishery in SFA annual statistical reports (not reproduced). Sampled data by boat type were employed to derive the species composition by location (Annex 1 Table A1.4; Figs A1.1-16). The predominant species were Bourgeois, Job Gris, Batrican, Vara vara, Maconde, and Capitaine Rouge (ie. the key species, see 3.5). By location Bourgeois is predominantly caught in Sector 1, and is only important in catches from the Mahe Plateau (sectors 1-10). The banks (Sector 11), Platte (12) and Amirantes (13) have minor catches of Bourgeois but otherwise the species composition is similar to the Mahe Plateau with a predominance of lutjanids. By contrast Providence / Farquhar (14) and Aldabra / Cosmoledo (15) have a predominance of serranids and lethrinids (eg. 1993, Fig. 6). Some differences may be related to depth fished, and a high proportion of Batrican in the catch is an indication that fishing occurred at depths greater than 75 m.

For individual locations, the detail indicated in Table A.1.4 and Figs A.1.1-16 is summarised by species group in Figs. 7-22. Historical information from Ommaney and Wheeler (1953) and Ratcliffe (1974) and Harris (1977) is included.

Table 9 : Species composition recorded in 1948-49 by number of fish caught at different locations within Seychelles.

LOCATION SPECIES	Coetivy	Fortune	Constant	Platte	Farquhar & Providence	Aldabra	Amirantes & Desroches	Mahe Plateau
Bourgeois			4.6%				0.2%	2.0%
Bordemar								0.1%
Therese							0.4%	0.4%
Vara vara	20.0%	26.0%	4.6%	82.0%	14.0%	24.5%	67.0%	57.6%
Job gris		4.0%	1.0%		4.1%	1.0%	1.4%	2.0%
Job jaune								
Batrican	20.0%		0.8%					0.6%
Lutx						1.0%		
Maconde	10.0%					0.4%		0.7%
V. Platte		1.4%	5.4%	1.4%	70.0%	8.0%	1.6%	6.7%
Tioffe								
Croissant				4.0%		3.6%	1.4%	2.5%
Serx	10.0%				4.1%	44.2%	1.4%	0.6%
Cap. Blanc								0.7%
Guelle longue								0.7%
Lascar		56.0%	30.0%				18.7%	12.0%
Dame berrie						0.4%	0.2%	1.0%
Cap. Rouge		1.4%	21.0%	8.0%	4.1%	9.0%	2.4%	4.0%
Bacsous	33.0%	11.0%	13.0%	1.4%	4.1%	1.0%	1.0%	3.0%
Letx	10.0%					4.9%	0.8%	0.5%
Number of fish	10	73	129	74	49	273	491	1349

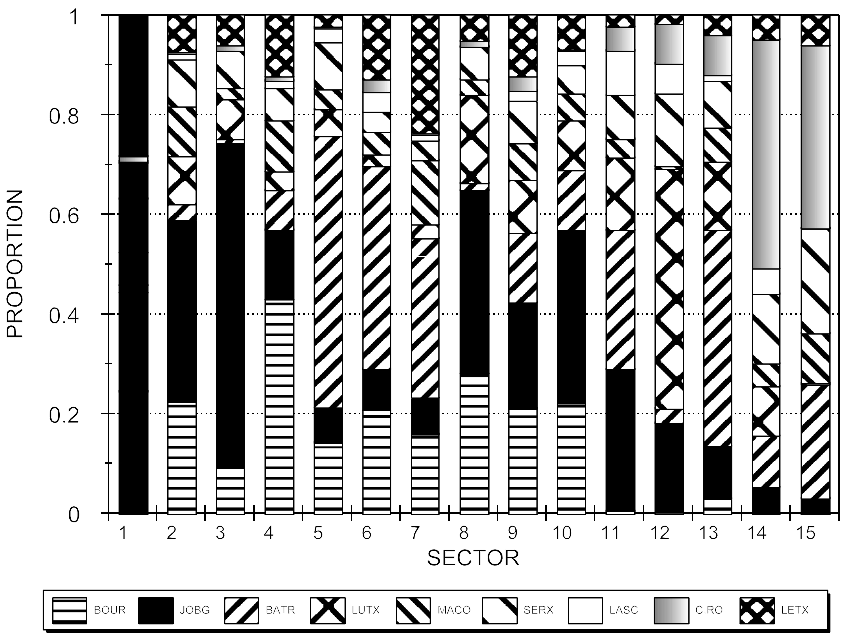


Figure 6 : The proportion of the catch by sector represented by key species and species groups in 1993.

Figures 7 - 21 : Gross species composition observed at each sector from 1948 (where available) to 1993.

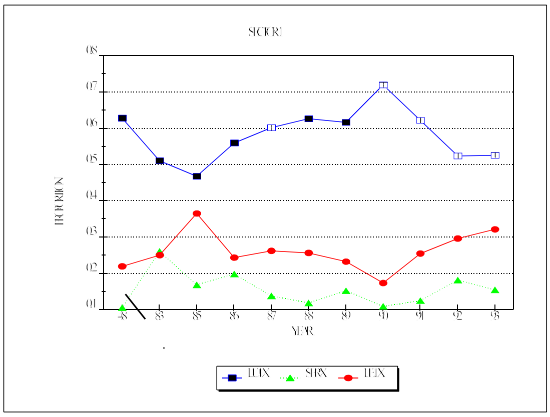


Fig. 7.

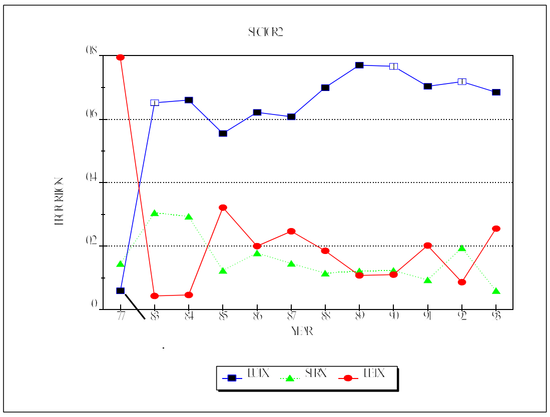


Fig. 8.

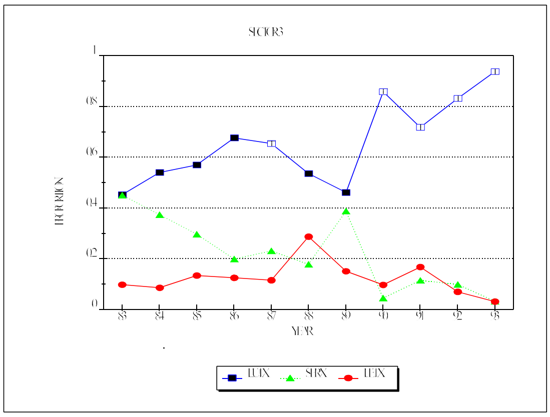


Fig. 9.

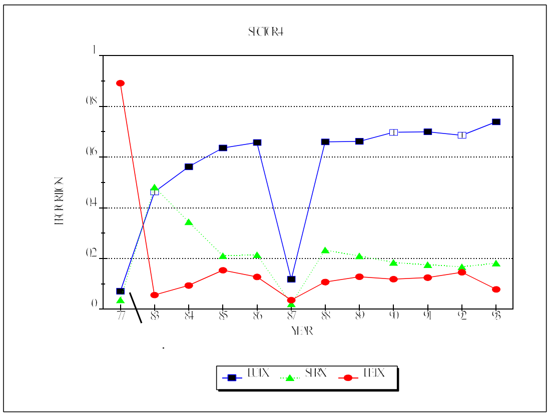


Fig. 10.

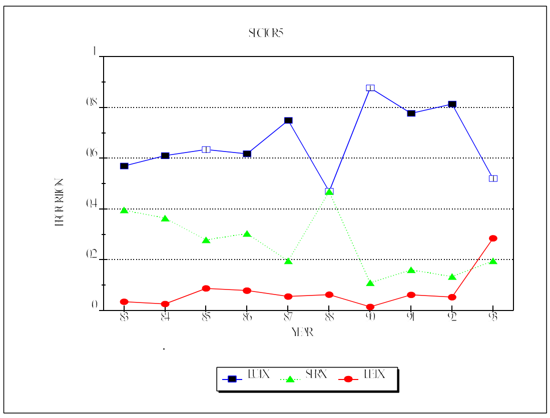


Fig. 11.

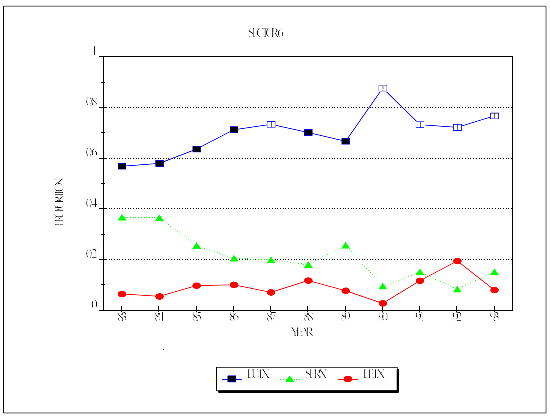


Fig. 12.

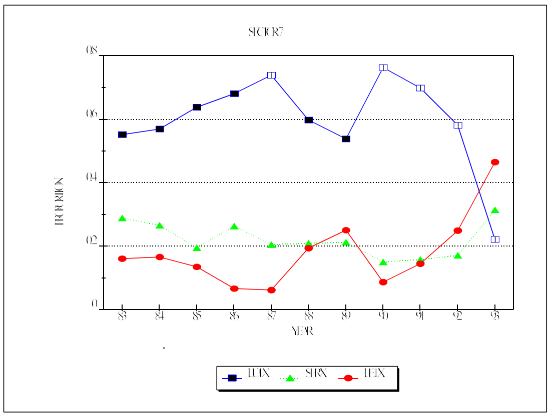


Fig. 13.

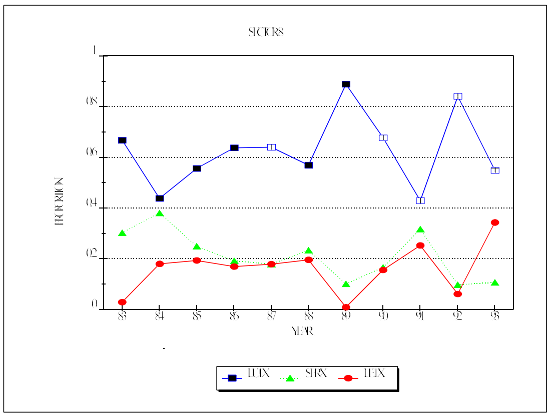


Fig. 14.

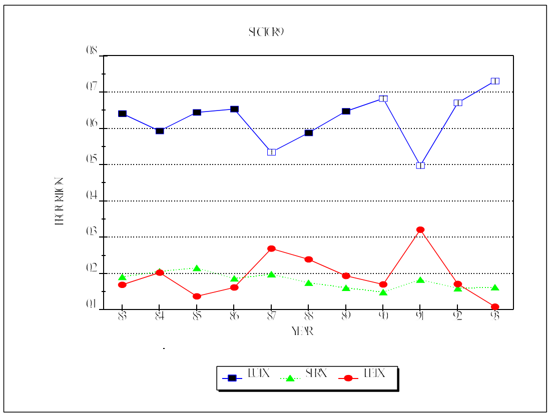


Fig. 15.

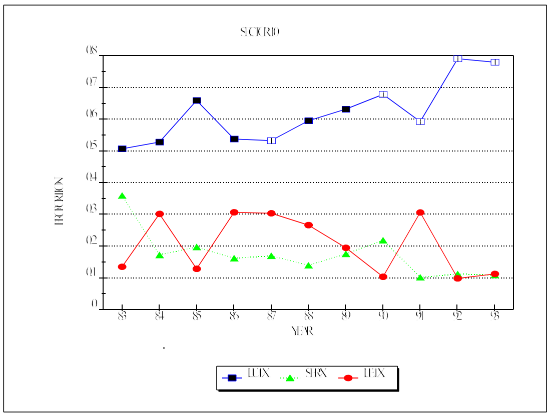


Fig. 16.

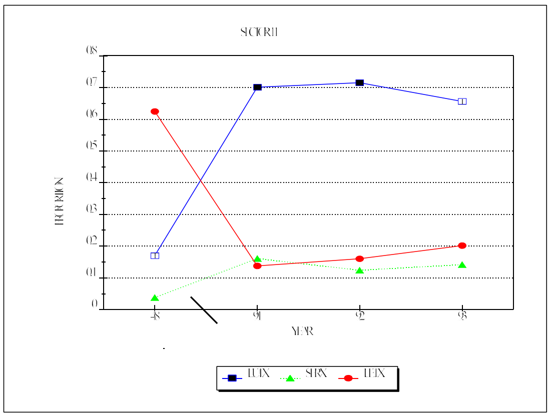


Fig. 17.

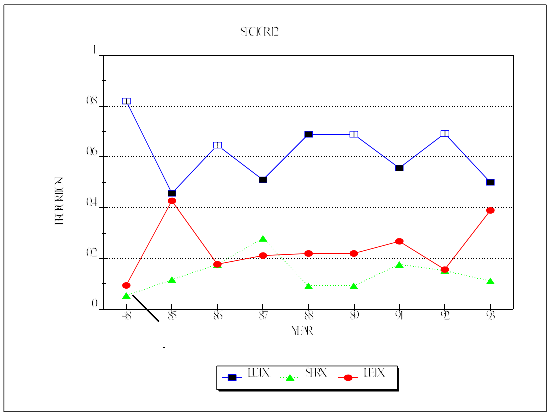


Fig. 18.

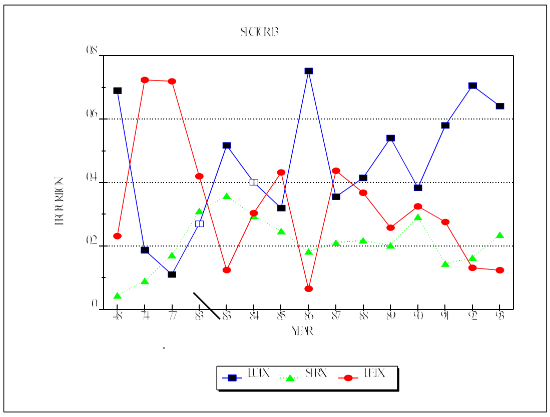


Fig. 19.

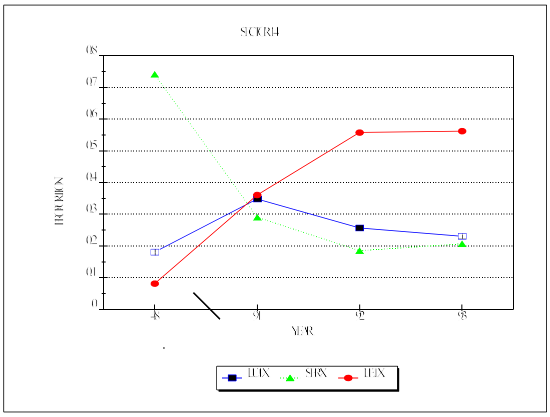


Fig. 20.

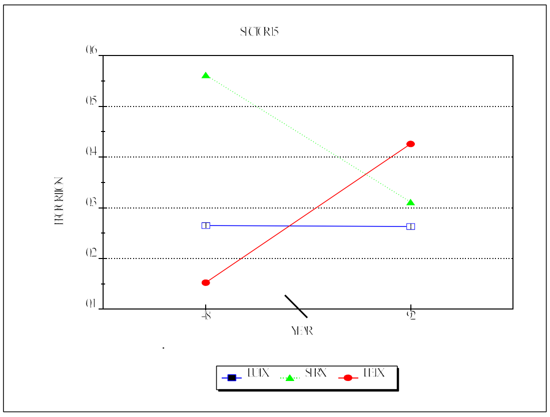


Fig. 21.

Apart from the historical data (ie before 1985), the gross species composition at each location has remained almost stable with time although a decline in the proportion of serranids is apparent (eg Sectors 3-6). No firm conclusions may be drawn in relation to the historical data since depth fished and other factors may have been different. The locations where obvious changes have occurred are :

Sector 1: in recent years the proportion of lutjanids has decreased and lethrinids increased for which there is no obvious explanation. However, the proportions have fluctuated over time and are not presently very different from 1985.

Sector 3 : lutjanids have increased and serranids decreased. Fishing by schooners at this location has decreased with time and that by whalers increased.

Sector 7 : Since 1990 there has been a dramatic decrease in lutjanids and increase in lethrinids and to a lesser extent, serranids. Catches by schooners have decreased (only 2 trips to this location were sampled in 1993) and those of whalers increased. This was especially true in 1994 (see Annex 1) when catch per unit area increased dramatically. The changes observed appear to be technologically related rather than due to fishing.

Sector 13 : Lethrinids have decreased and lutjanids increased - considerable fluctuation. Here precise location and depth fished may be important. In the latter years the mothership venture fished deeper water at the Amirantes

Whilst fishing pressure over time may have been responsible for such changes, it is necessary to consider a single representative boat category over the time period to eliminate variability arising from observations from a number of boat categories. (see 5.1.2)

5.1.2 Time series catch rate analyses (standardisation procedures, by boat type)

Assuming constant catchability, catch rate is an index of the abundance of the resource. Thus a declining catch rate over time suggests that a resource is under pressure and that biomass is decreasing. Catch rate, however, is a function of a number of variables : fishing power of the boat-type, and the gear used; annual and seasonal effects; depth effects; spatial and habitat effects both on a gross scale between fishing sectors, and on a smaller scale through the choice of fishing location (fishing grounds) with a sector. It is necessary to standardise fishing effort to account for variation in these parameters. Two approaches have been taken in this report. Where more than one boat gear type needed to be compared over several years, relative fishing power of each type was determined and effort standardised for variation in depth, season, location as appropriate (Hilborne and Walters, 1992). For single boat-gear types annual catch rates were standardised by means of a generalised linear interactive model for variation in appropriate parameters (GLIM, Francis *et al*. 1993). The latter approach was not possible for all boat-gear types due to the scattered nature of the data and few data points for certain types leading to a large number of missing data in the matrix of variables, thus limiting the reliability of model outputs.

Fishing power : 17 boat-gear combinations were identified which exploit demersal resources. The relative fishing power of each boat category was determined by means of a generalised linear model which accounted for variation in other variables, and standardised effort was calculated (Details in Annex 1; full example in Annex 4). Generally, fishing power follows the pattern mother vessel - dory >schooners > whalers > small boats (see Annex 1).

Season : Seasons correspond to the prevailing wind patterns (See 2.2). A strong seasonal variation in catch rate was demonstrated for the schooner fishery (Mees, 1990b; Annex 3) and catch rates by species varied between the low (SE Trade Wind) season and high season. For whalers at sector 1 seasonality was less pronounced but evident (see Annex 2). For the purposes of standardisation, where month was not applicable, season was taken as : 1 (North-west monsoon), December, January and February; 2 (April inter-monsoon period), March-May; 3 (SE Trade Winds), June-August; 4 (October inter-monsoon period), September - November. Such a division was selected based on aggregated monthly catch rate data from several locations for different boat types (not shown) and was considered to provide better detail than the high / low season approach previously adopted (Mees, 1990b).

Depth : 3 depth strata have been identified : shallow (0-75), intermediate (75-150 m), and deep (> 150 m, see 3.3).

Fishing location : Table 3 indicates the 15 fishing sectors and common fishing grounds within each sector. Standardisation at the level of the fishing sector was generally not performed since variation in catch rates between sectors indicates the relative abundance of demersal species in them and so is an important output.

In order to standardise annual catch rate data generalised linear interactive modelling (GLIM) was applied (Francis *et al*, 1993). This enabled both standardisation of annual data and estimation of the significance of factors contributing to variation in the catch rate. The process involves fitting a model to the data of the form:

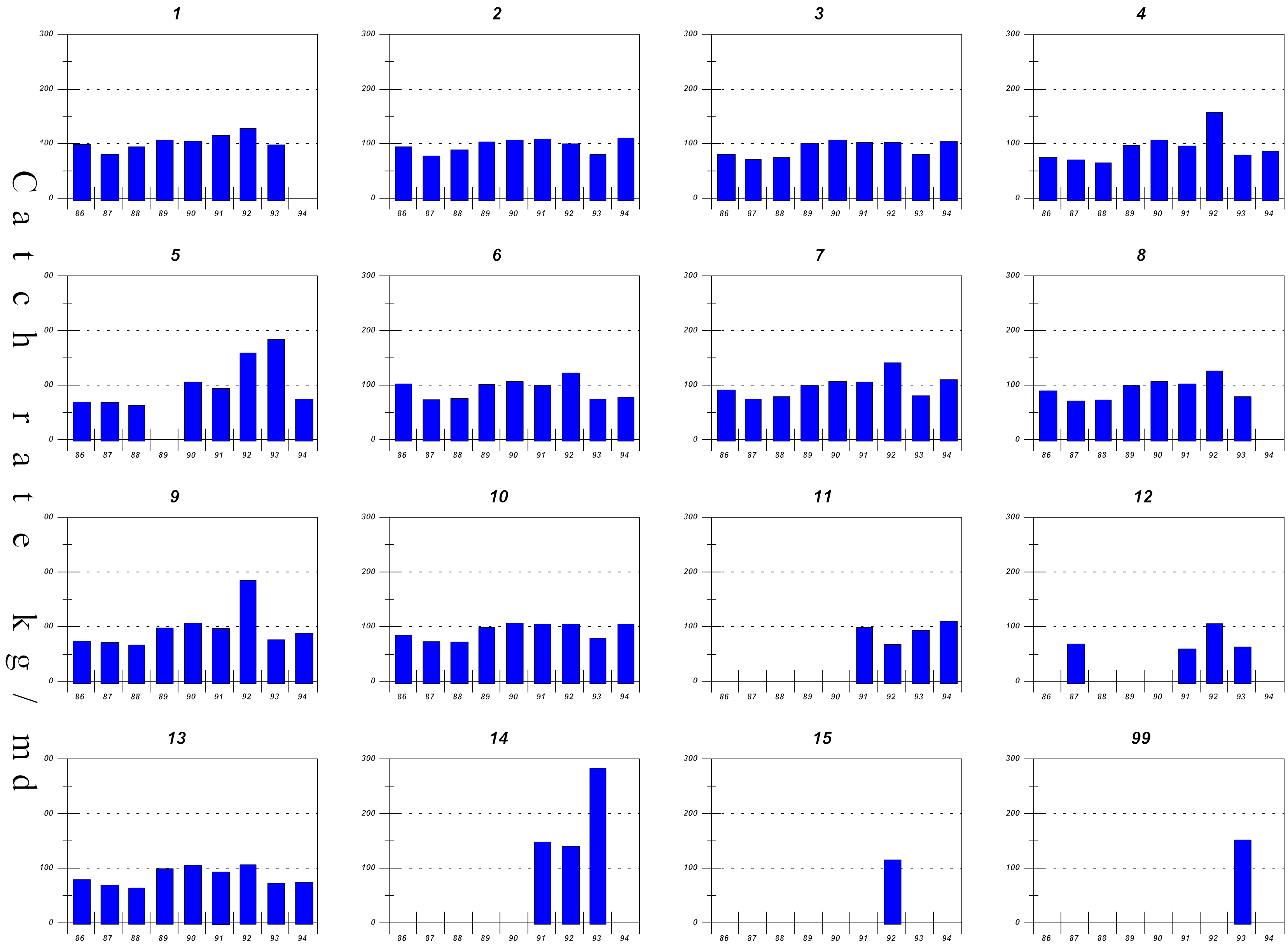
e.g. +year(y)+season(s)+location(l) + y.s + y.l + s.l + y.s.l

Two (y.s; y.l; s.l) and three factor (y.s.l) interactions are tested and if not significant may be removed simplifying the model to single factors. Each factor is tested and only retained if significant. The GLIM output will be standardised annual catch rate. That is, variation attributable to season and location will have been taken account of in the model and annual standardised catch rates are then directly comparable. Addition of other variables (depth, boat-gear type) increases the complexity of the model and interactions within the data frequently mean that simplification of the model to single factors is not possible. For this reason, whilst theoretically possible to examine all data, stratified sub-sets of data may offer the best opportunity to identify effects of fishing such as catch rate changes with time, or species composition changes.

Standardised demersal fish catch rates (kg manday^{-1}) for all boat-gear types did not indicate depletion at any sector, although some annual variation was evident (Fig. 22). Gross species composition changes discussed above could be attributed to changes in fishing patterns (vessels by location) over time. To further investigate the effect of fishing on demersal resources time series and spatial data stratified by boat - gear type and fishing sector was examined, and data for these single boat types were standardised for variation attributable to factors such as depth or seasonality. This assumes that a single boat type has fished consistently with time and that increases in fishing power have not occurred. By sector, which is a gross statistical category, fishing could have occurred at a number of locations, some of which may contain discrete populations. Ideally then, data should be stratified to as fine a level as possible. Catch rates for the mothership venture at discrete locations have been reported by Mees (1991b; 1992c; in press), but for the other boat categories such fine detail is not available. By boat category, the mothership venture is thus the most appropriate for further study, but covers a timescale of only 3 years and relates to short time periods within each year. Subsequent analyses relate to times series of data for :

- the traditional whaler fishery in sector 1 (Annex 2);
- the basic fleet of schooners fishing with handlines at a number of locations (Annex 3);
- the mothership dory venture (Annex 4);
- and to spatial data for the mothership dory venture (Annex 6).

Fig 22. Standardised catch rate (kg/manday, all demersal species) for total catch and effort (all boat-gear types) by fishing sector. (At the time of writing, complete data was not available for 1994, hence the apparent 0 catch rate at some locations)



5.1.3 Time series catch and effort analyses

The traditional whaler fishery, Sector 1. (Annex 2)

Total catch estimates by whalers reported in SFA statistics have been reproduced (Table 7 and Annex 1). The inshore fishery (Sector 1) has been shown to be the most heavily fished part of Seychelles demersal fishery, and whalers remove the largest part of this catch. The whaler fishery within sector 1 was thus examined in detail in order to evaluate the impact of sustained fishing pressure on demersal resources (Annex 2) and to determine any multi-species effects.

Traditional whalers catching at least 85% demersal species by weight from sector 1 of the Mahe Plateau were examined (Annex 2A). Season significantly affected species catch rates which were greatest during the inter-monsoon period March-May when conditions are calm. This coincides with the spawning period of many of the reef fish in Seychelles. The lowest catch rates occurred during the period of SE Trade winds. Species composition was similar during each season. Spatial differences within sector 1 were not examined and depth was not relevant for this sector (all less than 75 m). It was assumed that discrete populations of each species existed within this sector and that mixing of the population occurred (see 3.3).

Total catch by whalers from this sector was re-evaluated (Annex 2B). In order to derive an index of the abundance of demersal species in Sector 1, a stratified part of the whaler data was selected (Annex 2A) for which catch rates standardised for seasonal variation were derived by means of GLIM. To look for multi-species effects, changes in the catch rate of dominant species (Bourgeois, Job Gris, Maconde, Capitaine Blanc, Guelle Longue and Dame Berrie) over a time series of data (1989-1994) were examined. Additionally, aggregated data for the remaining lutjanids, lethrinids, and serranids, and guilds including all species in these families, and all demersal species were examined. It was found that a model of the type (year*season) resulted in a significant two factor interaction for year.season (not shown). However, in order to permit subsequent analysis it was necessary to overlook this and apply the simple model year+season (Annex 2B).

The results of analysis are discussed fully in Annex 2. In brief, no depletion or obvious multi-species effects were observed to occur despite the high fishing pressure. However, fishing pressure has been high for a considerable period of time and for the time series examined (1989-1994) it may be the case that present species composition and catch rates represent an equilibrium achieved at such levels of pressure. Data is lacking for the years during which depletion and species composition changes presumably occurred. Significant variation in annual catch rates was, however, observed. This was explained by variation in the guild lutjanidae, whilst no changes occurred for lethrinds or serranids over time. Within the guild lutjanids, most variation was explained by one species, *A. virescens*. A number of potential explanations exist. Sustained high fishing pressure may result in significant changes in abundance from year to year (eg. through a feed back mechanism such as density dependent recruitment. Note that significant variations occurred for a number of species / guilds and not *A. virescens* alone); environmental factors may have favoured strong recruitment in certain years (for *A. virescens* it was found that a large number of smaller fish recruited into the fishery in 1994); *A. virescens* forms schools and is potentially quite mobile, perhaps straying into sector 1 during certain years and invalidating the assumption that discrete populations are being studied.

The Schooner fishery (Annex 3)

Apart from sector 1 total fishing pressure (for all boat-gear types) was light at most other locations and catch rates fluctuated but did not obviously indicate a decline. Effort and yield per unit area was however, also relatively high at sector 7 (Fig 5). These locations were fished predominantly by schooners and more recently the mother-ship dory venture. For the schooner fishery, changes in vessel and gear technology resulted in increasing fishing power over time, thus potentially masking any decline in catch rate and resulting in gross species composition changes as boats with electric reels began to target fish in deeper water.

In order to examine for evidence of depletion and biomass change at the more distant fishing sectors, data stratified for the basic fleet of schooners using handlines only were employed. In fact, four categories of schooner were identified, and a number of gear combinations, but few data existed for three of the categories, particularly over the 10 year period for which data was available, although some investigation was made of 'La Digue' Schooners with reels (Annex 3; Table A.3.1). The time series of data indicated no evidence of depletion at the level of the fishing sector. Standardisation of data for the stratified boat category was not considered worthwhile (see Annex 3) and the conclusion drawn was that at the sectoral level effort was low and had little impact on demersal resources. The lack of definition in the fishing location data recorded meant that localised depletion which may have occurred was not observed (known to occur for the mothership venture). One danger of this is that within sectors catch rates may be maintained by sequentially fishing discrete areas. To avoid this, improved data collection is recommended.

The Mothership-dory fishery (Annex 4)

This fishery operated for discrete periods each year and at number of different locations. Analyses examining daily catch rates by location and species within individual voyages were presented by Mees (1991b; 1992c). Mees (in press, reproduced in Annex 4) produced a comparison of standardised catch rates from locations visited more than once over the three year period during which the vessel operated.

Within voyages, daily catch rates were generally observed to decrease at any one location. Between voyages at the same locations, catch rates frequently remained depressed and continued to fall (Figs A.4.2-3). This was particularly true for smaller banks, but less so for larger locations such as Fortune Bank (Fig A.4.4). Frequently, apparent depletion could be attributed to changes in target species or depth (Fig A.4.10-19), and of 31 locations examined only two were suitable for comparing depletion between voyages.

Time series catch rate data and stock assessment using production models

Time series data for stratified and standardised catch and effort data from both the whaler and schooner fisheries at a number of locations failed to indicate depletion. Consequently it was not possible to derive a stock assessment for demersal resources using a biomass dynamic production model (see Annex 5). The findings of this study therefore do not alter the earlier stock assessments summarised in 3.4.

Stock assessments were derived from daily catch rate data for the mother-ship dory venture at various locations (Mees, 1992c[a]; 1993[b]; Annex 4[c]) by means of a simple Leslie depletion model (Table 10). The rate of recovery of depleted resources was assessed from locations visited on more than one occasion (see Annex 4).

Table 10. A summary of stock assessments derived from the mother-ship dory fishing ventures in Seychelles waters for *Pristipomoides filamentosus, Lethrinus nebulosus* and an aggregation of all demersal species in the shallow strata (0-75m).

SPECIES	LOCATION	SECTOR	KG KM^{-1}	KG KM^{-2}	BIOMASS (Kg)	SOURCE
P. filamentosus	Small Constant	11	382.5	1,531.0	21,266	b
	Correira Bank	11	855.4	3,419.3	28,483	b
	Correira Bank	11	717.8	2,869.3	23,903	c
	Correira Bank	11	743.7	2,972.9	24,766	c
	Sea mount 20	11	1,004.3	4,010.1	11,148	b
	Poivre	13	1,505.0	6,019.8	30,099	a
	Marie Louise	13	1,414.4	5,657.4	28,287	a
	African Banks	13	505.5	2,021.8	10,109	a
L. nebulosus	Cerf	14		121.3	24,268	a
	Farquhar	14		256.1	76,819	a
	Providence	14		842.7	252,806	a
All demersal spp	Farquhar (part)	14	-	1,756-7,128	121,177	c
(Shallow stratum)	Farquhar (part)	14	-	1,198-4,863	82,684	c

The resource of *L. nebulosus* in Sector 14 was considered to be under-estimated. Whilst the abundance of *P. filamentosus* in the Amirantes (sector 13) appeared greater than that at the banks south of the Mahe Plateau (sector 11), it should be understood that fishing area was inferred from the radius of activities of the dories at the Amirantes, whilst the total bank / mount area was used for sector 11. Greater detail relating to fishing radius and actual area exploited by the dories would be useful in refining these estimates. At Farquahar, the difference in biomass shown relates to depletion following voyage 2 and a lack of recovery by the time of voyage 4.

5.1.4 Spatial analyses : Comparison of sites representing a gradient of fishing pressure. (Annex 6)

Spatial comparison of locations representing a gradient of fishing pressure can be made in order to examine the effects of fishing on catch rates and species composition. However, this approach has the added complication of the need to account for environmental variation, and the difficulty of being certain that differences observed relate to fishing pressure. Standardisation of widely different boat categories fishing in different locations will also be complicated by the fact that all boat types have not fished in all locations. However, given the lack of time series data indicating multi-species effects, spatial data for Seychelles and the Indian Ocean including Mauritian and Chagos Banks were explored (Annex 6).

Standardised catch rate data for guilds of all demersal species, lutjanids, serranids and lethrinids from 9 locations (5 in Seychelles, 3 in Mauritius, and Chagos) were correlated with prior fishing history, measured as mean annual catch and effort per square kilometre of substrate, and with various environmental parameters. Analysis by multiple regression indicated that substrate and fishing effort were the key components determining catch rate. Single regression of catch rate on fishing and environmental parameters indicated that fishing history was the most significant, but substrate was also important and a weak correlation with winter primary productivity was apparent for the demersal catch in shallow water. However, the relationship to substrate was based on a gross classification of each location, and was not considered totally reliable. The analyses showed that catch rate is most significantly affected by prior fishing history, but that environmental effects could not be discounted.

To further investigate fishing effects the Munro-Thompson Plot (Munro and Thompson, 1983; 1983a), equivalent to a Fox surplus production model for spatial rather than time-series data, was employed. This assumes that the ecological and productive characteristics of each location are similar. Whilst differences are believed to exist, correlation of catch rate to environmental parameters was weak. Fishing effects were more important. The Munro-Thompson plot examined spatial data for a single year. Applying this methodology to data for each of 1992 and 1993 failed to give significant results (Annex 6). Mean annual fishing effort (mdkm^{-2}yr^{-1}) and aggregated demersal catch rate for mother-vessels fishing in each location between 1991 and 1994 as an index of abundance (Table 11, Figs. 23-24) was therefore examined. All-vessel catch rates differed from those of the mother-vessel, but related to unstandardised historical data in the case of Mauritius, and in Seychelles where 17 boat-gear categories were identified, mother-vessel catch rates alone were considered a more reliable index of abundance.

Table 11 : Mean annual catch and effort statistics by location for the guild, 'all-demersal species', compiled from historical information, and mean mother-vessel demersal catch rates (1991-1994) as an index of abundance by location.

LOCATION	TOTAL BANK AREA	YEARS OF DATA AVAILABLE	FOR PERIOD	TOTAL CATCH AND EFFORT: CUMULATIVE DEM CATCH (KG)	CUMULATIVE EFFORT (MANDAYS)	MEAN KG DEMERSAL /KM^2/YR	MEAN MD /KM^2/YR	ALL VESSEL CPUE KG/MD	MOTHER-VESSEL DATA: FOR PERIOD	DEMERSAL CPUE	LN(CPUE)
Astove / Cosmoledo	431	16	78-93	21591	269	3.13	0.04	80.26	91-93	80.4	4.39
Providence / Farquhar	1751	16	78-93	497241	3402	17.75	0.12	146.16	91-93	87.3	4.47
Amirantes Plateau	4116	9	85-93	456671	5772	12.33	0.16	79.12	91-93	56.4	4.03
Mahe Plateau	4171	9	85-93	12906638	138207	34.38	0.37	93.39	91-93	50.2	3.92
Banks S of Mahe Pl.	2326	9	85-93	287546	3152	13.74	0.15	91.23	91-93	54.1	3.99
Saya de Mahla	4247	15	77-94	27671951	330926	43.44	0.52	83.62	92-94	46.3	3.83
Nazareth	2300	26	69-94	25452917	317832	42.56	0.53	80.08	92-94	50.3	3.92
St. Brandon	9313	12	80-94	5625729	41497	50.34	0.37	135.57	92-94	42.7	3.75
Chagos Archipelago	8853	18	77-94	1999831	48706	12.55	0.31	41.06	91-94	33	3.5

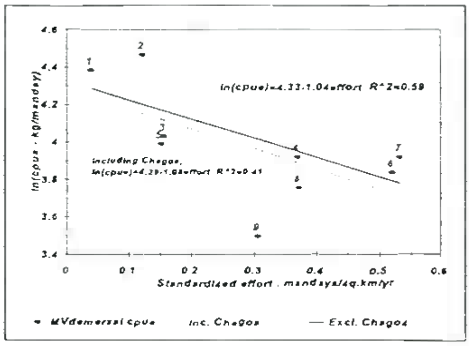


Figure 23 : Semi-logarithmic plot of demersal catch rate by location against mean annual fishing effort, and regression results with and without Chagos (9).

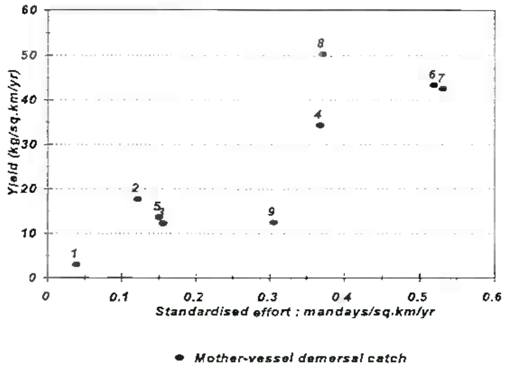


Fig. 24. Plot of mean demersal fish catch by location against mean effort per square kilometre per annum at all depths fished.

Catch rates in Chagos were less than expected relative to the level of prior fishing suggesting that either this area is less productive or that catch and effort have not been accurately reported. Primary productivity was lower around the Chagos, but catch rates were poorly correlated with this variable. Other explanations such as avoidance of potentially poisonous fish (ciguaterra) and unrecorded illegal fishing activity may be responsible for these observations (see Annex 6). The Fox surplus production model was hence fitted to these data with (P=0.064) and without (P=0.026) Chagos included. The maximum sustainable yield (MSY) was 26.9 $kgkm^{-2}yr^{-1}$ at a fishing effort, f(MSY), of 0.96 $mdkm^{-2}yr^{-1}$ (Chagos excluded, see Annex 6, Table A.6.8.). The average catch was 25.6 $kgkm^{-2}yr^{-1}$ (range 3.1-50.3 $kgkm^{-2}yr^{-1}$), and average effort, 0.28 $mdkm^{-2}yr^{-1}$ (range 0.04-0.53$mdkm^{-2}yr^{-1}$). For the single years 1992 and 1993, MSY was 43.3-99.1 $kgkm^{-2}yr^{-1}$ although neither regression was significant (Annex 6).

Similar analyses of annual mother-vessel catch rate by location against mean annual effort per square kilometre by depth band for all-demersal species and serranids (Annex 6) indicated demersal MSY in the range 15-22 $kgkm^{-2}yr^{-1}$ for all depths and 12-24 $kgkm^{-2}yr^{-1}$ at depths less than 70 m. Depth information was not available for Mauritian banks, and the lower value in each case related to the smaller data set of Seychelles only. The results were not significant for the greater depth band (MSY 1538-2589 $kgkm^{-2}yr^{-1}$). For serranids, MSY was around 2 $kgkm^{-2}yr^{-1}$ for all depths, and 108 $kgkm^{-2}yr^{-1}$ for the greater depth band at f(MSY) of 18 $mdkm^{-2}yr^{-1}$. The average yield of serranids taken by the mother-vessels was 7.5 $kgkm^{-2}yr^{-1}$ (range, 0.02-35.40 $kgkm^{-2}yr^{-1}$) for all depth strata, and 130 $kgkm^{-2}yr^{-1}$ (range 2-474 $kgkm^{-2}yr^{-1}$) for depths greater than 69 m.

Lablache and Carrara (1988) derived an estimate of the maximum sustainable yield of handline caught demersal species on the Mahe Plateau of 209 $kgkm^{-2}$.Mees (1992b) estimated the MSY of the shallow banks of the Mahe Plateau to be in the range 120-360 $kgkm^{-2}$ for fishable areas (approximately 60% of the total plateau area), and 1,300-1,500 $kgkm^{-2}$ for the intermediate depth band (75-150 m). A conservative value of 168 $kgkm^{-2}$ (MSY, Biomass = 1,400 $kgkm^{-2}$) was employed to estimate potential yield for the shallow depth strata, and 1,375 $kgkm^{-2}$ (MSY, Biomass=5,500 $kgkm^{-2}$) for the intermediate depth stratum (see Table 4). The present estimate for the shallow depth stratum, even allowing for the fact that it relates to total bank area (rather than fishable area which was not available for banks other than the Mahe Plateau) is rather low. For depths greater than 69 m the estimated MSY was similar to that previously derived, but the results were not statistically significant. Whilst these analyses have indicated broadly the effects of fishing, the variability in the data means that they are inadequate for accurate assessment of sustainable yield.

5.2 LENGTH FREQUENCY AND BIOMETRIC STUDY DATA

Biological data were collected for only a few key representatives of the multi species demersal fishery. These data enable estimation of a number of parameters required as inputs for management tools such as the age structured simulation model, MIDAS. The following are examined : population structure, reproductive parameters, gear selectivity and size at first capture, growth and mortality, and length weight relationships.

Length frequency and biometric study data were collected for *P. filamentosus, A. virescens,* and *L. nebulosus*, and a small amount of data is available from September 1994 for *L. variegatus, L. mahsena, L. bohar*, and *A. rutilans*. Length frequency data only were collected for *L. sebae* and *E. chlorostigma*. Most data was collected from schooner landings and none related to fishing sector 1 (see Annex 7). As a consequence population demographic variables derived from these data will relate to lightly exploited stocks and could differ for the heavily exploited population in sector 1. This is significant in respect to application of these parameter estimates to MIDAS. Ideally steps should be taken to obtain biological data from sector 1 and from whalers in order that biological parameters may be related to fishing pressure. The sensitivity of model outputs to variation in demographic variables arising from fishing pressure should be examined but is beyond the scope of the present project.

In utilising length frequency and biological data, different circumstances will dictate whether it is more appropriate to use aggregated data (eg. over several locations) or dis-aggregated data. In fact, Annex 7 indicated that dis-aggregation of data was inappropriate in many cases due to the small sample size. Certain analyses (eg. estimation of growth) require dis-aggregated data, whilst others (eg. estimation of reproductive status) do not. In the following sections the data set employed is clearly defined. Where dis-aggregated data was required for sector 1, in order to maintain as large a sample size as possible and to reasonably relate to this location for which data is lacking, data from all other locations on the Mahe Plateau was pooled (Sectors 2 -10).

5.2.1 Population Structure

Annex 7 details all data collected during length frequency and biometric studies, summarised in Table 12. Sex ratio given was that observed during biometric studies except for *L. sebae* for which this data was not available. Annex 7 and Table 13 indicate that length frequency and biometric data give different sex ratio values. That for biometric data, based on whole fish, is considered more accurate. Whilst differences in these parameters may occur with respect to location, sample size was frequently small for any one location and gear. Sex ratio was thus investigated for gear type only aggregated over all locations.

The Lethrinids have uneven sex ratios whilst, except for *A. virescens*, the lutjanids have equal numbers of males and females. Sex reversal (protogynous hermaphroditism) has been demonstrated in several species of lethrinds.

Table 12 : A summary of Length parameters and sex ratio observed for study species.

	Fork length Lmin	Lmax	Lmean	Sex ratio M:F
L. variegatus	23.5	39.0	30.46	1.63
L. nebulosus	18.5	79.0	48.30	0.62
L. mahsena	26.5	43.3	34.95	1.33
L. bohar	25.4	74.0	41.57	1.00
L. sebae	14.1	98.3	57.03	1.07
A. virescens	21.0	96.3	61.90	1.24
A. rutilans	38.2	92.5	76.20	1.06
P. filamentosus	21.5	87.8	48.73	1.02

Table 13 : Sex ratio observed for fish caught using different gear types; length frequency and biometric study data.

Length frequency data

L. variegatus

GEAR	N	M:F
Unknown	583	1.69
Gillnet	3	0.50
Handline	506	1.93
Reels	22	2.33
TOTAL	1114	1.79

L. nebulosus.

GEAR	N	M:F
Unknown	137	1.32
Gillnet	177	2.54
Handline	91	1.84
TOTAL	405	1.87

L. mahsena

GEAR	N	M:F

L. sebae

GEAR	N	M:F
Unknown	2583	1.09
Gillnet	48	2.20
Handline	12840	1.06
Reels	86	0.83
Traps	23	1.30
TOTAL	15580	1.07

L. bohar

GEAR	N	M:F

Biometric study data

L. variegatus GEAR

GEAR	N	M:F
Handline	150	1.63

L. nebulosus.

GEAR	N	M:F
Handline	50	0.62

L. mahsena

GEAR	N	M:F
Handline	107	1.32

L. bohar

GEAR	N	M:F
Handline	88	1.00

Table 13 Continued

Length frequency data

A. virescens

GEAR	N	M:F
Unknown	5520	1.68
Dropline	19	1.11
Gillnet	77	2.08
Handline	3344	1.96
Reels	101	1.81
TOTAL	9061	1.78

A. rutilans

GEAR	N	M:F
Unknown	481	1.69
Dropline	240	1.57
Gillnet	139	1.22
Handline	79	2.00
Reel	18	2.50
TOTAL	957	1.56

P. filamentosus

GEAR	N	M:F
Unknown	4835	1.32
Dropline	485	1.43
Gillnet	3994	1.24
Handline	8195	1.29
Reels	380	2.14
TOTAL	17889	1.30

Biometric study data

A. virescens

GEAR	N	M:F
Unknown	797	1.25
Handline	115	1.21
TOTAL	912	1.24

A. rutilans

GEAR	N	M:F
Dropline	40	1.86
Gillnet	71	0.78
TOTAL	111	1.06

P. filamentosus

GEAR	N	M:F
Unknown	1654	1.03
Gill net	78	0.73
Handline	11	1.75
TOTAL	1743	1.02

5.2.2 Reproductive Biology (Annex 8)

Biometric study data was employed in order to determine the reproductive status of *P. filamentosus, A. virescens* and *L. nebulosus*. Information relating to maturity stage and sex was also recorded from incompletely gutted fish during length frequency studies; these results are not fully reported due to the possibility of mis-identification of maturity stage and under-estimation of the number of mature fish. For *L. sebae,* however, only length frequency data was available and analyses based on this information are presented. Detailed analyses are indicated in Annex 8, summarised in Table 14. Insufficient data was available to assess reproductive status for *L. mahsena, L. variegatus, L bohar* and *A. rutilans* (September ‘94 - December ‘94 only).

Table 14 : Summary of reproductive parameters derived for key study species from Seychelles demersal fishery.

DETAILS	SPECIES			
	P. filamentosus	A. virescens	L.nebulosus	L. sebae
Min length at maturity, males GSI	31.0	34.0	38?	
Min length at maturity, females GSI	29.0	32.0	40?	
Min length at maturity, females =3+	36.6	38.0	39.8 / 69.3?	33.5
Lm25, females (biometric data)	45.0	38 or 63		60.0
Lm50, females (biometric data)	51.0	42 or 69	58?	64.0
Lm75, females (biometric data)	59.0	74.0		70.0
Spawning season, males	Feb-May & Nov	Oct -Feb & Apr - May		
Spawning season, females	All year, peak Feb-May & Oct -Dec	All year, peak Oct - Feb & Apr - May	Mar & Oct-Nov	All year

The minimum length at sexual maturity was smaller for specimens collected in the length frequency study than in the biometric study. Biometric study data is reported in Table 14 except for *L. nebulosus* where the sample size was small and length frequency study data was used. The fact that maturity occurs at small sizes for a small number of individuals in the population is apparent from interpretation of the data relating to the gonadosomatic index. The lengths shown in Table 14 relate to those at which a large proportional increase in GSI was observed, indicating gonad development at that size.

The proportion of fish in the population which are mature increases with length (and age), and from examination of Figs A.8.1, A.8.6, A.8.12 and A.8.14 maturity ogive information was derived. Sufficient biometric data was only available to achieve this for *P. filamentosus* with confidence. For *A. virescens* it appeared that half of all fish were mature at quite small lengths, but the sample size at length was small (See Table A.8.6). A range of values are reported. For *L. nebulosus* and *L. sebae* only length frequency data was available, but Lm_{50} values reported in Table 14 may be over-estimates. Estimation of this parameter from length frequency data for *P. filamentosus* (Fig A.8.3, Lm_{50}=63 cm) and *A. virescens* (Fig A.8.8, Lm_{50}=69 cm) led to higher estimates than from biometric study data.

Spawning for all species occurred throughout the entire year, but peak periods coincided with the inter-monsoon periods of March-May and October-November.

This study did not examine reproduction of *E.* chlorostigma. This serranid is a protogynous hermaphrodite (Moussac, 1986). Available data are indicated in Table 15 with those reported for the other species elsewhere.

Table 15 : Reproductive parameters estimated for Seychelles Key species reported in the literature.

GENUS	SPECIES	COUNTRY	SEX	tm	LengthMatMin	Lm	Type1	SPAWNING	SEX RATIO	RefNo.
Lethrinus	*nebulosus*	Egypt	female	5.9		45.6	TL			Sanders and Morgan, 1989
Lethrinus	*nebulosus*	Egypt	male	4.6		40	TL			Sanders and Morgan, 1989
Lethrinus	*nebulosus*	Kuwait	male	3						Carpenter and Allen, 1989
Lethrinus	*nebulosus*	Kuwait	female	4						Carpenter and Allen, 1989
Lethrinus	*nebulosus*	Kuwait	unsexed		32.5		TL			Lee and Al-Baz, 1989
Aprion	*virescens*	East Africa	female		46.5		SL	Oct - Feb		Talbot, 1960
Aprion	*virescens*	Hawaii	female		42.9	44.9	FL			Everson et al., 1989
Aprion	*virescens*	Hawaii	female		42.9		FL	May - Oct Pk 6	1:1.05	Everson et al., 1989
Aprion	*virescens*	Seychelles	female		48.7	62-64	FL	Peak 9/11+3/4	1:1.8	Mees, 1992
Lutjanus	*sebae*	Australia	female		48.5	54.2	FL			McPherson, et al., 1992
Lutjanus	*sebae*	East Africa	female		49		SL	Nov - Mar		Talbot, 1960
Lutjanus	*sebae*	Gulf Aden	female					March	1:1.04	Druzhinin and Filatova, 1981
Lutjanus	*sebae*	Seychelles	female				Trawl data		1:1.5	Tarbit in Moussac 1988
Lutjanus	*sebae*	Seychelles	female		34.6	61-63	FL	Peak 10/11+3/5	1:0.83	Mees, 1992
Lutjanus	*sebae*	Seychelles	female		62		min at spawn	Dec-Jan, Apr	1:0.66	Moussac, 1988
Pristipomoides	*filamentosus*		unsexed		35		TL			Allen, 1985
Pristipomoides	*filamentosus*	Papua N Guin	unsexed			34				Lokani et al., 1990
Pristipomoides	*filamentosus*	Andaman sea	female					March	1:0.76	Min et al., 1977
Pristipomoides	*filamentosus*	Guam	female						1:1.4	Kami, 1973
Pristipomoides	*filamentosus*	Hawaii	female					All yr pk 5-9	1:1.02	Ralston, 1981
Pristipomoides	*filamentosus*	Seychelles	female		33.2	51-53	FL, fem	All yr pk 10-4	1:1.07	Mees, 1992; 1993
Pristipomoides	*filamentosus*	Seychelles	male		40		FL, male	All yr pk 10-4		Mees, 1992; 1993
Pristipomoides	*filamentosus*	Tonga	female			38.6	50%Linf			Langi and Langi, 1987
Epinephelus	*chlorostigma*	Red sea	female		28		TL		1:0.417	Ghorab et al. 1986
Epinephelus	*chlorostigma*	Seychelles	male		39		TL	May-Jul		Sanders et al. 1988
Epinephelus	*chlorostigma*	Seychelles	female		31		TL	May-Jul	1:0.417	Moussac, 1986
Epinephelus	*chlorostigma*	Seychelles	female		23		TL			Heemstra and Randall, 1993

5.2.3 Length at first capture and Gear Selectivity (Annex 9)

Different fishing gear may exploit different size classes of the same population of fish. This is of significant importance for management - one strategy would be to exploit fish above the size at sexual maturity; an alternative gaining favour is to exploit small fish leaving larger more fecund fish to continue spawning. In the modelling phase of this project the effect of gear selectivity and of different management strategies upon the optimisation of benefits from the resource will be investigated. For the present analyses, length at first capture by different gear was investigated by pooling all data by each gear type. Only where the data indicated inter annual differences was further dis-aggregation performed. For example, in 1992 smaller fish (*P. filamentosus*) were caught in gill nets than during 1991 and 1993 (Fig A.9.5). Annex 7 indicates the number of fish measured by gear type, species and location each year. Gear selectivity parameters (see Annex 9, Table 16) are based upon the data available, and in those cases with small sample size they may change as more data become available. Thus these analyses may be regarded more as indicating length at capture rather than gear selectivity, particularly for small sample sizes.

Probabilities of capture at length were derived from length converted catch curve analysis. Growth parameter estimates are required inputs for this model, yet the accuracy of these parameter estimates is uncertain (5.2.4). Sensitivity analyses were performed to evaluate the effect of uncertainty in the growth parameters on estimation of length at capture (Annex 9). It was found that Lc_{50} was insensitive to changes in the value of K for any given value of $L\infty$, but that where $L\infty$ was less than Lmax Lc_{50} was underestimated. Lc_{50} was insensitive to changes in $L\infty$ when this value was close to or greater than Lmax. Literature values of K and $L\infty$ were thus used for this analysis where $L\infty$ approximated to Lmax.

Table 16 : To indicate gear selectivity parameters (Lc, the first fully exploited length class, and ogive parameters Lc_{25}-Lc_{75}) and the minimum and maximum length classes caught by gear type for each species. Growth parameter estimates were obtained from the literature (see Annex 9).

SPECIES	GEAR	YEAR	K	Linf	Lmin	Lmax	Lc	Lc25	Lc50	Lc75	Comments
P. filamentosus	Unknown	89, 91-93	0.288	81.7	20	86	41	31.6	36.2	39.9	
P. filamentosus	Handline	90-93	0.288	81.7	22	80	41	32.7	37.1	39.8	
P. filamentosus	Reels	92-93	0.288	81.7	24	76	43	34.9	38.6	40.6	
P. filamentosus	Dropline	91-92	0.288	81.7	24	74	45	39.2	42.4	44.5	
P. filamentosus	Gillnets	1991	0.288	81.7	20	86	49	40.4	47.0	49.7	
		1992	0.288	81.7			33	28.1	30.0	31.8	
		1993	0.288	81.7			39	37.4	38.9	40.4	Too few data
A. virescens	Unknown	91-93	0.260	104.0	20	96	67	62.1	65.2	67.3	Flat , cut off 41-67?
A. virescens	(Unknown	91-93	0.260	104.0			41	35.0	39.5	41.8	alternative cut off)
A. virescens	Handline	91-93	0.260	104.0	24	94	69	63.9	67.0	69.2	
A. virescens	Reels	91-92	0.260	104.0	40	88	69	66.3	68.0	69.9	
A. virescens	Droplines	91-92	0.260	104.0	50	78					Too few data
A. virescens	Gillnets	91-93	0.260	104.0	34	88	65	55.7	61.8	64.1	
A. virescens		91	0.260	104.0			63	51.5	60.1	62.2	Few data
A. virescens		92	0.260	104.0							Too few data
A. virescens		93	0.260	104.0			65	55.4	61.1	63.5	
L. sebae	Unknown	91-93	0.230	96.0	18	88	59	54.5	56.9	58.9	
L. sebae	Handlines	89-93	0.230	96.0	14	98	61	56.5	59.3	61.4	
L. sebae	Reels	93	0.230	96.0	32	82	61	50.7	53.7	58.7	
L. sebae	Gillnets	93	0.230	96.0	34	86	49	43.2	45.8	47.5	Flat, cut off 59?
L. sebae		(93	0.230	96.0			59	42.6	45.3	47.3	alternative cut off)
L. sebae	Traps	92	0.230	96.0	24	50	35	24.0	32.5	34.8	Few data
E. chlorostigma	Unknown	90-93	0.175	64.5	20	74	35	27.7	29.5	31.3	
E. chlorostigma	Handlines	91-93	0.175	64.5	18	80	35	27.8	29.7	31.5	
E. chlorostigma	Reels	91-93	0.175	64.5	24	62	35	28.2	29.7	31.4	
E. chlorostigma	Droplines	92-93	0.175	64.5	30	58	39	31.4	33.6	36.2	
E. chlorostigma	Gillnets	91-93	0.175	64.5	24	64	35	28.9	31.0	32.9	
E. chlorostigma	Traps	92-93	0.175	64.5	26	52	35	28.4	30.8	32.8	
L. nebulosus	Unknown	92	0.230	80.0	18	70	41	36.6	38.7	40.7	limited data
L. nebulosus	Handlines	92	0.230	80.0	30	78	53	43.1	47.3	50.7	
L. nebulosus	Gillnets	92	0.230	80.0	24	62	37	30.5	34.6	37.4	
L. variegatus	Unknown	94	0.430	39.0			25	22.9	24.4	25.9	limited data
L. variegatus	Handlines	94	0.430	39.0			25	22.5	24.0	25.6	
L variegatus	All xpt reels	94	0.430	39.0			25	22.6	24.1	25.6	
A. rutilans	Unknown	94	0.163	100.0			61	43.9	60.3	62.2	limited data
A. rutilans	Droplines	94	0.163	100.0			65	47.3	62.3	64.7	
A. rutilans	Gillnets	94	0.163	100.0			43	40.3	42.1	44.1	
A. rutilans	Handlines	94	0.163	100.0			41	38.6	39.4	40.9	
A. rutilans	All	94	0.163	100.0			63	42.9	60.5	63.6	

The relationship of the length at capture (Lc_{50}) to the length at maturity (Lm_{50}) is significant for fisheries management and traditionally the aim would be to exploit fish at or larger than length at maturity. For *P. filamentosus* Lc_{50} is less than Lm_{50} for all gear types suggesting that recruitment overfishing of this species is a potential danger. Particularly for small mesh gill nets (assumed from 1992 data), fish are caught before the onset of maturity. For *A. virescens* Lc_{50} and Lm_{50} are similar, and the different gears catch similar sizes of fish. Gear selectivities to *L. sebae* indicated that lines caught larger fish (Lc_{50} ~ 53-59cm), gillnets caught intermediate size fish (Lc_{50} ~ 45 cm) and traps caught small fish equivalent to the size at first sexual maturity (~ 33cm). Lm_{50} has not been accurately determined for this species but may be around 49 cm (0.5*Lmax, Grimes, 1987). Few data existed for *L. nebulosus*, but the evidence was that gillnets caught smaller fish than handlines and Lc_{50} was similar to Lm (39 cm, 0.5 Lmax). Large specimens of *E. chlorostigma* were not frequently captured except in gill nets, and Lc_{50} was similar for all gears.

The selectivities reported here agree with those from research cruises reported by Arthur (1993). In general, traps and gillnets exploited smaller fish than line fishing methods, and further research into mesh size and net selectivity is to be recommended given the recent developments in net fishing techniques. *P. filamentosus* appears to be the species under greatest threat since all gear types exploit this species below maturity.

5.2.4 Growth and Mortality

Growth (Annex 10)

Growth refers to the determination of body size as a function of age. For temperate water species where distinct seasons occur, age may be determined directly by counting annual rings on hard parts such as scales and otoliths. In the tropics where strong seasonality is not evident it is generally considered difficult to detect annuli on hard parts. For certain species which have distinct spawning periods, growth rings related to these life history events may be evident. Where spawning occurs more than once each year knowledge of the life history is essential in interpreting observed rings. More recently, scanning electron microscopy has been used to count daily rings on otoliths (Brother, 1979, eg. for *P. filamentosus*, Ralston and Miyamoto, 1983; Radtke, 1987) but this is expensive and time consuming so is not used as a matter of routine. Methods allowing the conversion of length frequency data into age composition have been developed, and these are most frequently applied to tropical fish species. However, their interpretation is improved if some direct age readings are available from annual or daily growth rings.

In Seychelles, a programme of length frequency data collection was initiated for the key species in the catch. Otoliths were also collected. Seasonal temperature variations occur related to the SE Trade Winds (see 2.2) and it was considered possible that seasonal or annual growth rings may occur. Characteristically, spawning occurs throughout the year, but peak periods occur during the inter-monsoon calm periods (see 5.2.2) and possibly two checks per year may relate to these periods. To investigate the utility of otoliths for ageing species from Seychelles a number of otoliths were sent for examination by an independent expert who concluded that they revealed similar structures and patterns to those observed in temperate water fish. On the basis of the small sample it was not possible to conclude that these were annuli but it was a distinct possibility (Bedford, per comm; results reported in Mees, 1992b).

An otolithometry unit was established at SFA in 1992. Otoliths from *P. filamentosus* and *A. virescens* were principally studied, and some specimens from *L. sebae* and *Carangoides gymnostethu*s were also examined. These studies, which used a number of sectioning techniques, failed to indicate consistent growth rings which could be related to annual or seasonal events. Again samples were assessed by an independent expert. It was concluded that whilst rings were evident in about 75% of otoliths studied, they lacked homogeneity, and the precision of results was low. Lunar, sub lunar and seasonal rings were evident between darker bands, possibly annuli, but were not well defined. These techniques were considered inadequate for ageing Seychelles species (Orts, pers. comm.).

During the present study the problem was further investigated, and otoliths of *P. filamentosus* were sent to the Centre for Tropical Coastal Management studies at Newcastle as the basis for study by a BSc student. By contrast, this study concluded evidence of clear annual-type banding together with what appeared to be strong monthly bands. However, the sample size was very small and establishing the time scale proved difficult. A focus in the otolith, normally related to larval life implied one year duration, longer than that believed to be the case (Polunin, pers. comm.).

These studies indicate that banding does occur in otoliths from Seychelles demersal fish species, and knowledge of the hydrology of the region would suggest that monthly, seasonal or annual ageing should be possible, as has occurred elsewhere for similar species using otoliths (eg. *A. virescen*s, Loubens, 1980; *P. filamentosus*, Ralston and Miyamoto, 1983; other species, reviewed in Manooch, 1987). However, interpretation of growth rings on otoliths from tropical species is clearly not straightforward and needs to be performed by experts in the field with considerable experience upon which to interpret their observations. Furthermore, it would seem appropriate to employ the more expensive technique of scanning electron microscopy on a few specimens to count daily rings in order to verify the periodicity of observed bands. Having calibrated readings in this way, a large number of otoliths may be studied by the cheaper methods employing light microscopy. Recent studies in Australia have also indicated a correlation between otolith weight and age, and after calibration this would result in a rapid method of age assessment (McB Williams, pers. comm.)

In the absence of reliable estimates of age based on hard parts, length frequency distribution analysis was used to determine the von Bertalanffy growth parameters for Seychelles species. These methods, however, also have their limitations and the point estimates derived should be interpreted with some care. A number of estimates were in fact derived for each species using LFDA4 (MRAG, 1995), a PC based software (Annex 10). Growth parameters were derived for *P. filamentosus, A. virescens* and *L. sebae* (Table 18). Data for *E. chlorostigma* was considered inadequate for length based methods, and an insufficient time series of information was available for other species studied.

Table 17 : Growth parameter estimates considered to best represent the available data derived for Seychelles demersal fish species. Non seasonal von Bertalanffy, and seasonal Hoenig growth curve parameter estimates are shown.

Species	K	L∞	t_0	C	t_s	Score	Method
P. filamentosus	0.244	75.80	-0.26			0.53	ELEFAN
P. filamentosus	0.240	76.24	-0.28	0.42	-0.258	0.56	HOENIG/ELEFAN
A. virescens	0.321	94.68	-0.19			37.93	SLCA
A. virescens	0.321	101.50	-0.65	0.19	0.226	0.226	HOENIG/ELEFAN
L. sebae	0.180	99.10	-0.63			0.280	ELEFAN
L. sebae	0.193	97.41	-0.35	0.64	-0.241	0.345	HOENIG/ELEFAN

Considerable variation in growth parameter estimates occurs for the same species studied by different authors around the world (Table 18). A number of factors may explain this including geographical variation, different levels of fishing pressure, sampling bias (eg, L∞ for *A. virescens* from New Caledonia is reported as 66 cm, whilst in the Maldives and Seychelles, considerably larger fish have been observed, suggesting incomplete sampling of the population in New Caledonia), or uncertainties in parameter estimation. Confidence intervals for parameter estimates are not reported.

Table 18 : Growth parameter estimates derived for *A. virescens, L. sebae, P. filamentosus,* and *E. chlorostigma* from a number of locations using a variety of techniques. Data were mostly obtained from FISHBASE (1995).

GENUS	SPECIES	COUNTRY	K	Loo	to	TYPE	METHOD GROWTH	Reference
Aprion	*virescens*	Maldives	0.348	78.0			ELEFAN	Van der Knapp et al., 1988
Aprion	*virescens*	New Caledonia	0.310	66.0		SL		Loubens, 1980
Aprion	*virescens*	Seychelles	0.290	95.0			ELEFAN males	Mees, 1992b
Aprion	*virescens*	Seychelles	0.260	104.0			ELEFAN all	Mees, 1992b
Aprion	*virescens*	Seychelles	0.140	108.0			ELEFAN females	Mees, 1992b
Lutjanus	*sebae*	Australia GBR	0.180	88.7	-0.32	FL	other method(s)	McPherson and Squire, 1990
Lutjanus	*sebae*	Australia GBR	0.210	90.0		TL		McPherson et al., 1985
Lutjanus	*sebae*	Australia GBR	0.210	72.0		SL	Non-linear regression	McPherson et al., 1985
Lutjanus	*sebae*	Australia GBR	0.130	81.7	-1.09	FL		Yeh et al., 1986
Lutjanus	*sebae*	Australia GBR	0.140	91.0		SL	Non-linear regression	McPherson et al., 1985
Lutjanus	*sebae*	Australia GBR	0.150	102.5	-0.32	FL	other method(s)	McPherson and Squire, 1990
Lutjanus	*sebae*	Australia NW	0.130	81.7	-1.09		vertebra pa	Yeh et al., 1986
Lutjanus	*sebae*	East Africa	0.157	85.1				Talbot, 1960
Lutjanus	*sebae*	Seychelles	0.307	84.0			ELEFAN all	Mees, 1992b
Lutjanus	*sebae*	Seychelles	0.380	95.1			ELEFAN males	Mees, 1992b
Lutjanus	*sebae*	Seychelles	0.270	90.0			ELEFAN fem.	Mees, 1992b
Lutjanus	*sebae*	Seychelles	0.220	98.0				Bach, 1991
Lutjanus	*sebae*	Seychelles	0.230	96.0		TL	Gulland & Holt plot	Lablache and Carrara, 1988
Lutjanus	*sebae*	Yemen Dem	0.160	85.1	-1.02	FL	scales pa	Druhzinin and Filatova, 1988

Table 18 Contd.

GENUS	SPECIES	COUNTRY	K	Loo	to	TYPE	METHOD GROWTH	POPGROWTHRefNo.
Pristipomoides	*filamentosus*	Hawaii	0.220					Ralston and Williams, 1983
Pristipomoides	*filamentosus*	Hawaii	0.310	97.1	0.02	FL		004560
Pristipomoides	*filamentosus*	Hawaii	0.164	80.5	-0.84	FL	Non-linear regression	003124
Pristipomoides	*filamentosus*	Hawaii	0.146	78.0	-1.67	FL		004560
Pristipomoides	*filamentosus*	Hawaii	0.146	78.0	-1.67		otoliths pd	FB 4560 / 4613
Pristipomoides	*filamentosus*	Hawaii FFshl	0.164	80.5	-0.84		otoliths pd	FB 3124
Pristipomoides	*filamentosus*	Hawaii NW	0.310	97.1	0.02		otoliths pd	FB 4560
Pristipomoides	*filamentosus*	N Marianas	0.289	58.0	-0.54	FL	Non-linear regression	002300
Pristipomoides	*filamentosus*	N Marianas	0.289	58.0	-0.54		otoliths pa	FB 2300
Pristipomoides	*filamentosus*	Seychelles	0.300	85.8		FL	ELEFAN males	Mees, 1993
Pristipomoides	*filamentosus*	Seychelles	0.288	81.7			ELEFAN all	Mees, 1993
Pristipomoides	*filamentosus*	Seychelles	0.275	77.6		FL	ELEFAN fem.	Mees, 1993
Pristipomoides	*filamentosus*	Tonga	0.160	77.2			K = func of Loo	Langi and Langi 1987
Pristipomoides	*filamentosus*	Tonga		80.0				Latu and Tulua 1991
Pristipomoides	*filamentosus*	Vanuatu	0.290	60.0		FL		000160
Epinephelus	*chlorostigma*	Kuwait	0.195	64.8				Mathews and Samuel, 1987
Epinephelus	*chlorostigma*	Seychelles	0.179	68.4			ELEFAN TL	Sanders et al., 1988
Epinephelus	*chlorostigma*	Seychelles	0.175	64.5			ELEFAN TL	Mees, 1992
Epinephelus	*chlorostigma*	Seychelles	0.190	62.7		TL		006975
Epinephelus	*chlorostigma*	Seychelles	0.170	66.9		TL		006975

The age structure and growth rate of fished and unfished populations of fish may be expected to vary. Gulland (1983) described how both K and L_∞ would vary with stock density, and therefore with fishing pressure. As a stock is fished the density decreases giving rise to an increase in growth rate, and to an increase in the size of individuals of a given age, thus altering the age structure of the population. For example, the mean length at age for both the yellow flounder and haddock on Georges Bank was significantly and inversely correlated with stock abundance (Ross and Nelson, 1992). In Seychelles, spatial differences in fishing pressure have been demonstrated (see Annex 6). However, insufficient time series data exist for all locations in order to permit assessment of growth. Where this is possible, uncertainties in the output (see Annex 10) mean that spatial comparisons of growth rates and inferences relating to fishing pressure based on these length frequency analyses would be somewhat dubious. Annual data at single locations do not consistently give reliable results either, and the practice of utilising a long time series of data over several years will be to establish an averaged growth rate. The question is whether such values are adequate for age based models such as MIDAS where there is the facility to vary growth parameters with time and fishing pressure, and, to what extent do such changes in populations subject to fishing pressure affect our ability to manage fish resources?

Growth parameters are also used as inputs in other models to establish total mortality or length at capture for example (eg, length converted catch curve, Jones, 1984); natural mortality if Pauly's (1980) empirical formula is used, or in the yield per recruit analysis of Beverton and Holt (1957). As a result, uncertainty in the growth parameter estimates is translated into uncertainty in other parameter estimates, and hence the need to perform sensitivity analyses for these parameters in order to establish expected ranges for them. This is especially important for fully age structured simulation models such as MIDAS which requires a large number of inter-dependent parameter estimates as inputs. In such models, it would be appropriate for other parameters dependent on K and L_∞ to vary appropriately when sensitivity of model outputs to changes in growth parameters are assessed, rather than have them as fixed values.

Mortality

Total mortality (Z) of a fish population is described by the sum of natural mortality (M), and fishing mortality (F). In previously unfished populations, an estimate of the total mortality will be equivalent to the natural mortality. For snapper and grouper populations, Ralston (1987) has reviewed mortality estimates. Natural mortality is attributed to predation, parasitism, cold water shock and red tide poisoning. Catch curves to determine Z, Z/K ratios estimates, and Pauly's empirical formula for M are the most frequently employed techniques to determine mortality in snappers and groupers. These method will be employed in this study.

The computer aided packages, FISAT (Gayanillo *et al*, 1994) and LFDA (MRAG, 1995) were used to determine Z by means of length converted catch curve analysis. Growth parameter estimates are required inputs for this model, and the sensitivity of Z to changes in these parameters was first investigated using aggregated length frequency information for *P. filamentosus* from the Mahe Plateau caught during 1990 by all gear types (Figs. 25 and 26). Natural mortality was determined empirically (Pauly, 1980; 1984; Ralston 1987) assuming a mean water temperature of 22°C. Again growth parameter estimates are required model inputs and sensitivities to Pauly's estimator were examined (Fig. 27). Fishing mortality was determined by subtraction (F=Z-M), and thus inaccuracies in the estimate of Z or M would be reflected in the estimate of F (Fig. 28). F cannot be less than zero and thus M would not be expected to be less than Z as occurred in the simulations with low L_∞ and K values. Trenkel (1993) used an enlarged data set for fish species occurring at water temperatures above 5°C to modify Pauly's (1980) original model. The FISAT version of the M estimator is also based on an extended data set (Pauly, 1984). This tends to give slightly lower values of M.

The estimate of Z derived from catch curve analysis is sensitive to variation in both K and L∞. At any given length, Z increases linearly with K. At any given value of K, Z increases with increasing L∞, and there is an inflexion point about Lmax after which the rate of change increases. Lmax for the data set studied was 78 cm and a range of values was simulated about this length. A considerable range of estimates for Z is suggested. However, in practice, as L∞ increases, the estimate of K tends to decrease (K and L∞ are negatively correlated) so Z is unlikely to vary to the extent suggested (Fig. 25). Natural mortality is sensitive to variation in values of K but not L∞. The sensitivity of resultant fishing mortality follows the pattern for Z.

The FISAT version of length converted catch curve analysis permits the estimation of mortality from length frequency distributions and growth parameter estimates with or without seasonality. Data for *P. filamentosus* caught by all gears from the Mahe Plateau in 1990 were employed to investigate the use of different growth parameter estimates which have been derived for this species (Table 19). The non seasonal growth parameter estimates derived in this report gave low mortality estimates, and M was greater than Z. This is unreasonable given that fishing for *P. filamentosus* around the Mahe Plateau had occurred prior to 1990 and was considerable in that year. Inclusion of the seasonal parameters resulted in a higher estimate of Z. Growth parameter estimates derived by Mees (1992b; 1993) for *P. filamentosus* from all of Seychelles in 1990 resulted in a higher estimate of mortality. Z was greater than M. The latter L∞ parameter estimate was closer to Lmax for this sample, and to that for the whole population sampled (87.8 cm). For further estimation of mortality by year and location, the values K=0.288, L∞=81.7 (Mees, 1992b) were used (Annex 11; Table 20), giving a more appropriate Z compared to M, and being closer to Lmax. The lack of a seasonal function means that Z may be underestimated when these parameters are employed. M may be overestimated using Pauly's model. Thus fishing mortality, F, is likely to be underestimated.

Table 19 : Estimates of Z, M and F for *P. filamentosus* from the Mahe Plateau derived with different non-seasonal and seasonal growth parameters.

Details	This report	This report	This report	Mees, 1992
Loo	75.8	76.24	76.24	81.70
K	0.244	0.24	0.24	0.288
to	-0.26	-0.28	-0.28	
C			0.42	
WP			0.242	
Z	0.47	0.47	0.58	0.77
CI Z +	0.52	0.53	0.63	0.91
CI Z -	0.4	0.41	0.53	0.63
M (@ 22 C)	0.49	0.48	0.48	0.53
F	NA	NA	0.1	0.24

This analysis of *P. filamentosus* indicated that where uncertainties exist in relation to the accuracy of growth parameter estimates, values where L∞ approximates to Lmax provide a more sensible estimate of total mortality derived by means of catch curve analysis. Given the inability to accurately determine changes in growth parameters with time or by location, a single K-L∞ pair was chosen for each species (where L∞ was close to Lmax) to investigate mortality spatially and over time (Annex 11). In addition to catch curve analysis a method developed by Powell (1979) and extended by Wetherall *et al*. (1987) was used. This allows determination of growth and mortality parameters from length frequency data and prior estimates of growth parameters are not, in this case, required model inputs. The method provides estimates of the ratio Z/K and L∞. Values of Z/K may be compared directly where no estimate of K exists in order to evaluate relative mortalities by location for example (eg. see Munro 1983). To separate Z it is possible to multiply by K, but strictly growth parameter estimates should be derived for each length frequency data set from which Z/K is estimated. Here the fixed value of K used in catch curve analysis was used to provide an indication of the approximate value of Z (Annex 11).

For snappers and groupers Ralston (1987) derived two models for the estimation of natural mortality from growth parameters: one based on linear regression (1); one based on functional regression (2). He concluded that for these fish the Pauly (1980) method underestimates M for fast growing fish, and overestimates it for slow growing fish. All three methods were used to derive natural mortality for the study species for different growth parameter estimates (Table 20. * indicates the growth parameters used for catch curve analysis). Few estimates of M exist for snappers and groupers in the literature : *P. filamentosus,* 0.25 (Hawaii, Ralston, 1981), 0.55 (Hawaii, Ralston and Williams in Ralston, 1987), 0.53 (Vanuatu, Brouard and Grandperin, 1984); *A. virescens*, 0.49 (Maldives, Van der Knapp *et al*, 1988); *L. sebae*, 0.48 (Seychelles, Lablache and Carrara, 1988).

Table 20. Empirical estimates of natural mortality derived from growth parameters for Seychelles Key species.

Species	Loo	K	T©	M Pauly	M Ralston 1	M Ralston 2	Growth Ref.
P. filamentosus	81.7	0.288	22	0.53	0.61	0.66	*Mees, 1993
P. filamentosus	76.2	0.24	22	0.48	0.51	0.54	This study
A. virescens	104	0.26	24	0.49	0.55	0.59	*Mees, 1992
A. virescens	101.5	0.321	24	0.56	0.68	0.74	This study
L. sebae	97.4	0.193	24	0.41	0.42	0.42	*This study
L. sebae	96	0.23	24	0.46	0.49	0.51	Lablache and Carrara, 1988
E. chlorostigma	64.5	0.175	24	0.43	0.38	0.37	*Mees, 1992
E. chlorostigma	68.4	0.179	24	0.43	0.39	0.38	Sanders, et al, 1988

At single locations, catch is a guide to expected fishing and total mortality if the natural mortality and number of fish are assumed to be constant with time (C=FN; Z=F+M). In order to compare locations, catch per unit area may be considered. The catch per square kilometre of substrate was thus calculated annually, and averaged over time for each location. Total mortality and Z/K were determined for *P. filamentosus, A. virescens, L. sebae* and *E. chlorostigma* by year and location (Annex 11) and as a summary of annually aggregated data by location (Table 21). It was concluded that the data for *E. chlorostigma* were inadequate for estimation of mortality using length based methods.

Comparing changes in mortality with that expected from estimates of catch removed, a number of inconsistencies were observed annually and spatially (Annex 11). Where sample size was large, inconsistencies were less apparent and it may be concluded that for aggregated data over the Mahe Plateau, the annual variation in Z estimated by catch curve analysis is a reasonable representation of total mortality. Inter location differences in mortality estimates each year, and inter annual differences at other locations with smaller sample sizes, however, may not reflect the true situation. These generalities applied to each species, but greater inconsistencies were observed for *P. filamentosus* than either *A. virescens* or *L. sebae*. If it is assumed that the results are correct, the estimate of Z for *A. virescens* from Providence in 1991 equates to natural mortality since prior fishing had been negligible: M=0.29-0.79 compared to 0.49-0.68 by empirical methods.

Comparing the two methods applied, as a general rule, the catch curve resulted in estimates which tended to follow the pattern of catches better than did the ratio Z/K which showed little annual variation. The estimate of Z derived by multiplication by K resulted in an estimate which was around half of that from the catch curve. However, this is not a true value for Z as indicated above.

Annually aggregated data reasonably reflected the expected differences in Z and Z/K by location for the shallow water species *A. virescens* (Mahe Pl>Amirantes>Providence) and *L. sebae* (Mahe Pl. > Amirantes). Whilst catch data would suggest that Z for *A. virescens* in the Providence/Farquhar group should be less than that in the Amirantes, a low level of fishing has consistently occurred at the latter location, whilst at the former, a high level of pulse fishing occurred in the year indicated following 17 years when no fishing was believed to have occurred. For the principle species caught at intermediate depths, *P. filamentosus*, the estimates of Z and Z/K were not consistent with those expected. However, comparing the most heavily fished years at each location (1990 for Mahe, 1991 for the Banks, 1992 for the Amirantes) Z was more consistent with that expected.

Table 21. A summary of averaged annual catch data, and estimated mortality rates for annually aggregated data for Seychelles key species by fishing location.

Details		Banks	Amirantes	Providence	Mahe Pl
Mean Kg/km2/yr demersal spp.	Shallow	9.3	10.0	17.4	32.7
	Intermediate	85.9	93.3	22.5	222.8
	All depths	13.7	12.3	17.7	34.4
Total mortality, catch curve, all years	*P. filamentosus*	0.88	1.04	0.81	0.7
Z/K, Powell Wetherall, all years	*P. filamentosus*	2.33	1.23	1.90	1.74
F (Zcc-MPauly)	*P. filamentosus*	0.35	0.51	0.28	0.17
F (Zcc-MRalston1)	*P. filamentosus*	0.27	0.43	0.20	0.09
Total mortality, catch curve, all years	*A. virescens*		1.01	0.79	1.57
Z/K, Powell Wetherall, all years	*A. virescens*		2.29	1.11	5.46
F (Zcc-MPauly)	*A. virescens*		0.52	0.30	1.08
F (Zcc-MRalston1)	*A. virescens*		0.46	0.24	1.02
Total mortality, catch curve, all years	*L. sebae*		0.66		0.91
Z/K, Powell Wetherall, all years	*L. sebae*		1.52		3.18
F (Zcc-MPauly)	*L. sebae*		0.25		0.50
F (Zcc-MRalston1)	*L. sebae*		0.24		0.49

5.2.5 Length - Weight Relationships

The weight of fish increases approximately in proportion to the length cubed and the length-weight relationship is :

$$W = a.L^b$$

In this report weight, W is expressed in kilogrammes and length, L, is fork length expressed in centimetres. The parameters ‘a’ and ‘b’ are derived by regression of the log transformed data.

The length weight relationship was determined by sex and location (where specified) for all key species measured (Table 22). The level of allometry (the ‘b’ parameter, equivalent to the slope of the regression) was compared for males and females and by location using the t-test. No Significant differences were found to exist by location or between males and females except for *L. variegatus* and *A. virescens* at the 10% level. Given the lack of significant differences it is considered valid to use data from all locations and both sexes in estimating the length weight parameters. These values are highlighted in Table 22.

Table 22. Length-weight relationships for key species from Seychelles demersal fishery, and comparison of the slopes of regression for males and females of each species, and all locations against fish from the Mahe Plateau only.

Local name	Scientific name	Location	Sex	Length range min	Length range max	Sample size	a	b	s.e. b	Correl. Coeff.	Sampling period from	Sampling period to	t	df	P
Baksou	***Lethrinus variegatus***	**Unspecified**	**all**	**23.5**	**39.0**	**150**	**0.00027200**	**2.217**	**0.130**	**0.66**	**22/09/94**	**19/12/94**	**m vs f**		
Baksou	*Lethrinus variegatus*	Unspecified	male	23.5	39.0	93	0.00014200	2.403	0.111	0.84	22/09/94	19/12/94	2.1936	9	<0.1>0.05
Baksou	*Lethrinus variegatus*	Unspecified	female	23.8	36.8	57	0.00070300	1.944	0.310	0.42	22/09/94	19/12/94			
Kapten	***Lethrinus nebulosus***	**Mahe Plateau**	**all**	**31.5**	**73.7**	**50**	**0.00003355**	**2.842**	**0.066**	**0.97**	**1/4/92**	**25/4/92**	**m vs f**		
Kapten	*Lethrinus nebulosus*	Mahe Plateau	male	31.5	71.1	18	0.00003162	2.860	0.111	0.98	1/4/92	25/4/92	0.3814	5	>0.5
Kapten	*Lethrinus nebulosus*	Mahe Plateau	female	37.5	73.7	29	0.00003622	2.821	0.096	0.97	1/4/92	25/4/92			
Laskar	***Lethrinus mahsena***	**Unspecified**	**all**	**26.5**	**43.3**	**107**	**0.00001749**	**3.064**	**0.183**	**0.73**	**3/10/94**	**19/12/94**	**m vs f**		
Laskar	*Lethrinus mahsena*	Unspecified	male	29.2	43.3	61	0.00005275	2.764	0.434	0.41	3/10/94	19/12/94	-0.5093	8	>0.5
Laskar	*Lethrinus mahsena*	Unspecified	female	26.5	35.4	46	0.00002665	2.936	0.113	0.94	3/10/94	19/12/94			
Vara vara	***Lutjanus bohar***	**Unspecified**	**all**	**25.4**	**74.0**	**88**	**0.00001304**	**3.127**	**0.196**	**0.75**	**25/9/94**	**19/12/94**	**m vs f**		
Vara vara	*Lutjanus bohar*	Unspecified	male	29.3	70.6	44	0.00003483	2.875	0.337	0.63	25/9/94	19/12/94	-1.1626	7	>0.2
Vara vara	*Lutjanus bohar*	Unspecified	female	25.4	74.0	44	0.00000902	3.218	0.245	0.80	25/9/94	19/12/94			
													all vs MP		
Job gris	***Aprion virescens***	**All locations**	**all**	**25.4**	**87.8**	**911**	**0.00002704**	**2.831**	**0.021**	**0.95**	**5/4/91**	**23/4/93**	**-1.4603**	**29**	**>0.1**
Job gris	*Aprion virescens*	Mahe Plateau	all	25.4	87.8	842	0.00002358	2.863	0.022	0.95	5/4/91	23/4/93	m vs f		
Job gris	*Aprion virescens*	All locations	male	25.4	84.5	502	0.00002358	2.856	0.035	0.93	5/4/91	23/4/93	1.7822	21	<0.1>0.05
Job gris	*Aprion virescens*	All locations	female	27.0	87.8	407	0.00002358	2.803	0.021	0.98	5/4/91	23/4/93			
Job jaune	***Apharaeus rutilans***	**Unspecified**	**all**	**38.2**	**92.5**	**111**	**0.00004157**	**2.723**	**0.063**	**0.95**	**26/9/94**	**12/12/94**	**m vs f**		
Job jaune	*Apharaeus rutilans*	Unspecified	male	42.6	92.5	57	0.00006973	2.609	0.123	0.89	26/9/94	12/12/94	-1.5091	7	>0.1
Job jaune	*Apharaeus rutilans*	Unspecified	female	38.2	92.0	54	0.00003499	2.758	0.065	0.97	26/9/94	12/12/94			
													all vs MP		
Batrican	***Pristipomoides filamentosus***	**All locations**	**all**	**22.5**	**74.6**	**1753**	**0.00004283**	**2.757**	**0.014**	**0.96**	**11/12/89**	**27/11/91**	**0.3788**	**40**	**>0.5**
Batrican	*Pristipomoides filamentosus*	Mahe Plateau	all	22.5	74.6	1507	0.00004379	2.751	0.015	0.96	11/12/89	27/11/91	m vs f		
Batrican	*Pristipomoides filamentosus*	All locations	male	26.3	74.6	881	0.00004379	2.748	0.016	0.97	11/12/89	27/11/91	-0.7930	29	>0.4
Batrican	*Pristipomoides filamentosus*	All locations	female	22.5	73.1	860	0.00004379	2.763	0.023	0.95	11/12/89	27/11/91			

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ANNEX 1 : Estimation of total catch, effort and species composition by boat type and location per annum.

Estimates of the total demersal fish catch and total effort, aggregated for all fishing locations by boat category, are available from SFA annual statistical reports (5.1.1; Table 7). To estimate catch and effort by boat, species and location the following steps were taken :

1. Seychelles demersal fishery is exploited by a number of vessel types using a variety of gear types. However, whilst gillnets and drop lines have recently been used on commercial vessels none of these were represented in sampled catch statistics up to 1994. Available data indicated 17 different boat-gear types which exploit demersal fish within the major categories of 'Small boats', ' Whalers', 'Schooners' and 'Mother ship ventures' (Table A1.1).

2. Small boats and whalers may target a number of fisheries, and for these the proportion of effort during which demersal species were caught was determined from sampled data, and the estimated total effort directed at the demersal fishery was calculated (not shown).

3. From sampled data, the proportion of effort relating to each boat-gear type within each category was determined and the estimated total effort by boat-gear type derived (not shown).

4. Next, effort data was standardised for boat-gear type, fishing depth and season by determining the relative fishing power of each boat-gear combination (Table A.1.1). All effort data was related to one man-day fishing by handline from a mothership-dory in the depth range 0-70 m during the period of the SE Trade Winds (June to August). Owing to the large number of variables (year, season, depth, sector, boat-gear category) and scattered nature of sampled data, it was not possible to standardise catch rates for all variables for the entire data set. Instead, using a generalised linear interactive model (GLIM, Francis, et al, 1994) with relevant sub-sets of the data, catch rate by boat-gear type was standardised for depth and season (see Hilborne and Walters, 1992). Standardised catch rates were used to calculate relative fishing power, and, assuming the same fishing power over space and time, this factor was applied to derive standardised fishing effort by boat-gear type (Table A.1.2).

   To identify the data subsets for standardisation, cross tabulation was used to investigate the number of fishing trips sampled by boat-gear category per annum (1984-1994) by sector (15 sectors), season, and depth (<70 m; >70 m[2]). With the exception of the small boats which only fished in Sector 1, it was found that data for each of these variables was only well represented for sector 6 from 1991-1993. This sub-set of data was used to standardise effort for all boat-gear categories except small boats. Data aggregated over all of the Mahe Plateau was used to standardise small boat data relative to other boat types. This was necessary since other boat types had not all fished in Sector 1. However, to reduce variability arising from sectoral differences, the aggregated data set was not used for the remainder of boat categories, although results were in-fact similar.

5. For small boats with no location specific data it was assumed that all fishing occurred inshore (Sector 1). For the other boat - gear types the number and proportion of fishing trips by location per annum was determined from sampled data, and total standardised effort by boat-gear type by sector was calculated (not shown). The sum of boat-gear

[2] Mees, 1992 defined the depth strata for Seychelles. Species such as *P. filamentosus* associated with intermediate depths are dominant in the catch at depths of around 70m and greater.

type data by sector indicates the spatial distribution of effort (Table A.1.3)

6. The total catch by boat-gear type was next estimated from the total catch by boat category given in SFA statistics (Table 7, main text) and the proportion of standardised effort by boat-gear type within each category. For the mothership dory operations, total catch was known since the venture was censused during an observer programme on every trip.

7. Assuming sampled data is representative of the fishery as a whole and that catch rates are the same at different locations[3], the total catch by boat-gear type by location per annum was then determined from total catch by boat-gear type and the respective proportion of standardised effort by location (Table A.1.4.).

8. The species composition of the sampled catch for each boat -gear type at each location each year was determined and applied to total catch derived in step 7 to determine species catches by location (Tables A.1.4). NOTE : For whalers in 1989 catch was derived from ARTFISH but species composition from the new sampling method applied from July - December 1989 when species records were improved. Note also, Sector 11 total catch and species catches are under-estimated since some schooners occasionally fish there but the location reported is usually SE or S, Sector 6 or 7.

[3] Catch rate by location does in fact differ, so the estimates of catch by location will tend to be under-estimated for distant locations and over-estimated at nearer more heavily fished locations. It was not possible to standardise for location (sector) in addition to boat, depth and season due to the large number of variables and insufficient data.

Table A1.1 : Observed catch rates (Kg man-hour^{-1}), GLIM standardised outputs (model=boat+season+depth) , and the relative fishing power (RFP) by boat-gear category for vessels coded 1-13 fishing in Sector 6 between 1991 and 1993. Small boats, were standardised using data aggregated over all of the Mahe Plateau (Mother ship-dory-handline standardised cpue was 49.9 for this data set).

Category	Boat	Gear	Code	OBS cpue	Log cpue	s.e.	STDZ cpue	RFP
Mother ship	Dory	Hand lines	1	86.2	3.919	0.152	50.4	1
	Dory	Electric reels	2	99.4	4.087	0.15	59.6	1.18
Schooner	Basic fleet, small	Hand lines	3	41	3.191	0.159	24.3	0.48
	Basic fleet, small	Electric reels	4	32.3	3.117	0.204	22.6	0.45
	Basic fleet, large	Hand lines	5	29.1	2.881	0.235	17.8	0.35
	Basic fleet, large	Electric reels	6	18.8	2.403	0.538	11.1	0.22
	'La Digue', small	Hand lines	7	33.8	3.237	0.29	25.5	0.51
	'La Digue', small	Electric reels	8	40.2	3.208	0.219	24.7	0.49
	'La Digue', large	Hand lines	9	29.6	2.8	0.197	16.4	0.33
	'La Digue', large	Electric reels	10	54.8	3.554	0.142	35	0.69
Whaler	Traditional	Hand lines	11	20.9	2.672	0.339	14.5	0..29
	'Lekonomi'	Hand lines	12	16.1	2.476	0.859	11.9	0.24
	'Lavenir'	Hand lines	13	41.4	3.264	0.371	26.2	0.52
Small boats	Out-board	Hand lines	14	17.5	2.597	0.077	13.4	0.27
	Out-board	Lines and traps	15	13.7	2.332	0.17	10.3	0.21
	Pirogue	Hand lines	16	9.3	1.931	0.818	6.9	0.14
	Pirogue	Lines and traps	17	6.9	1.529	2.947	4.6	0.09

Table A.1.2 The total standardised fishing effort (man-days) by boat-gear type per annum for all fishing sectors.

BOAT	RFP	85	86	87	88	89	90	91	92	93	94
1	1	0	0	0	0	0	0	2277	198	36	0
2	1.18	0	0	0	0	0	0	1832	4664	2008	0
3	0.48	4171	5263	6926	5368	3536	2322	2427	626	895	808
4	0.45	0	224	750	694	161	422	308	224	362	710
5	0.35	24	13	50	58	324	36	209	24	14	0
6	0.22	0	0	0	0	0	16	0	10	39	153
7	0.51	0	0	0	409	1068	0	477	146	373	250
8	0.49	0	0	0	0	0	927	427	86	79	108
9	0.33	0	24	0	46	284	0	221	11	0	14
10	0.69	0	0	0	0	0	1677	962	432	739	855
11	0.29	3060	7492	8089	6291	5581	7933	7056	7144	7134	6817
12	0.24	0	0	0	0	789	1947	1487	1255	1265	1580
13	0.52	0	0	0	0	122	765	2132	1159	3521	947
14	0.27	1222	1238	664	402	802	373	149	27	55	NA
15	0.21	185	623	339	216	136	197	0	2	28	0
16	0.14	1174	1737	1428	1436	1078	1214	1108	80	881	NA
17	0.09	404	555	341	292	330	317	401	34	375	NA
TOTAL		13653	17169	18587	15213	14210	18145	21473	16121	17804	NA

Table A.1.3 : Total standardised effort per fishing sector per annum for all boat-gear types combined (man-days)

SECTOR	85	86	87	88	89	90	91	92	93	94
1	6397	8620	7564	6073	6890	8816	7288	6751	8752	NA
2	600	1277	1410	813	670	1990	1886	920	473	352
3	708	588	969	343	279	488	416	369	191	537
4	667	494	607	839	490	425	472	501	2394	549
5	488	170	475	143	0	73	320	209	169	8
6	959	825	1843	1427	616	2934	4385	864	1074	682
7	697	1246	1648	1166	1154	782	1178	400	744	3695
8	214	214	673	306	326	438	358	83	279	
9	1008	2710	1447	2348	2862	1203	835	238	1169	926
10	596	905	1192	1035	554	827	790	829	353	1819
11							2045	751	195	30
12							11	78	71	
13	1318	121	699	721	368	171	885	1256	232	793
14							603	2686	114	
15								187		
99									1596	
TOTAL	13653	17169	18587	15213	14210	18145	21473	16121	17805	NA

Table A.1.4 : Total and species catches (tonnes) by boat-gear type and location per annum.

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
175.69	11	85	1				4.269	38.722			37.194	17.270				3.162							75.020
109.21	14	85	1					30.852			26.123	16.753				7.525							27.947
16.53	15	85	1				0.030	2.855			3.921	2.670				1.045							6.005
104.98	16	85	1				1.795	24.376			4.787	2.677				7.968							63.345
36.07	17	85	1					4.401			1.966					2.835							26.861
442.48	TOTAL	85	1				6.09	101.21			73.99	39.37				22.53							199.18
0.35	3	86	1	0.025								0.059			0.076			0.030		0.018		0.142	
1.69	9	86	1				0.285	0.259	0.322			0.142	0.040		0.017		0.048		0.407		0.169		
488.39	11	86	1				26.129	110.083			179.679	33.064				52.941							86.347
106.25	14	86	1				0.329	19.231			23.630	20.953				6.556							35.519
53.52	15	86	1				0.621	8.135			11.100	10.153				2.424							21.065
149.10	16	86	1					16.356			16.312	5.889				1.938							108.575
47.64	17	86	1					3.854			2.449	4.440				0.810							36.078
846.94	TOTAL	86	1	0.02			27.36	157.92	0.32		233.17	74.70	0.04		0.09	64.67	0.05	0.03	0.41	0.02	0.17	0.14	287.58
398.35	11	87	1				35.373	105.324			127.392	22.586				25.375							82.140
49.56	14	87	1				0.238	14.457			7.484	5.769				3.410							18.189
25.32	15	87	1				0.023	3.641			4.130	2.881				1.448							13.192
106.62	16	87	1					9.937			21.015	16.569				7.186							51.892
25.50	17	87	1				0.324	3.682			0.372	1.744				1.895							17.478
605.35	TOTAL	87	1				35.96	137.04			160.39	49.55				39.31							182.89
355.64	11	88	1				45.806	139.767			59.356	15.079				17.462							78.063
37.45	14	88	1				0.139	13.227			5.711	4.726				2.610							11.022
20.07	15	88	1				0.048	5.836			2.966	1.559				1.299							8.355
133.68	16	88	1					25.987			13.528	10.761				7.646							75.730
27.20	17	88	1					4.172			2.772	2.282				1.246							16.723
574.04	TOTAL	88	1				45.99	188.99			84.33	34.41				30.26							189.89
62.53	3	89	1	27.620	2.764		5.922	4.408	2.326			1.863	3.983		1.438	0.938	1.388	0.113	7.060	0.175	2.282	0.213	
11.33	5	89	1	4.401	0.222		0.724	0.603	2.429			0.741	0.476		0.318	0.650	0.222	0.063	0.016	0.011	0.426	0.022	
10.66	9	89	1	0.083			1.392	1.147	4.842			0.317	1.080		0.362	0.233	0.006	0.063	0.784	0.018	0.292	0.035	
316.08	11	89	1	34.295	2.845		14.571	143.405		0.032	0.316	20.039	5.847		0.853	9.482	8.471	12.074	0.695	1.675	1.707		59.613
63.56	12	89	1	18.293	1.335	0.070	0.095	11.695		0.038		12.674	0.210		0.089	2.320	1.398	4.386		0.667	2.523		7.723
91.31	14	89	1				0.475	18.965			21.960	14.290				6.967							28.635
15.50	15	89	1				0.031	2.582			4.379	1.502				0.891							6.112
122.75	16	89	1				0.037	10.311			23.040	26.379				6.236							56.735
37.54	17	89	1					3.991			6.025	6.870				2.147							18.496
731.26	TOTAL	89	1	84.69	7.17	0.07	23.25	197.11	9.60	0.07	55.72	84.68	11.60		3.06	29.87	11.49	16.70	8.55	2.55	7.23	0.27	177.31
50.33	3	90	1	24.189	1.560		2.215	5.431	0.770	0.337		2.220	4.157		0.911	2.552	1.746	0.438	1.510		2.204	0.055	
2.97	4	90	1	0.263				0.018		0.898			0.301	0.903	0.159	0.408	0.018						
6.64	10	90	1				0.215	0.453		5.197		0.460	0.195		0.006	0.061					0.051		
503.50	11	90	1	82.725	7.049	0.403	25.427	228.035		5.035	0.604	25.578	13.947		1.762	4.380	20.946	9.516	5.035	5.841	9.365		57.550
111.62	12	90	1	11.207	1.451		3.382	85.166				3.148	0.268		0.067	0.938	1.116	1.339	0.134	0.022	0.569		2.746
42.80	13	90	1	7.494	0.800	0.128	1.549	11.158		0.077	0.244	3.253	0.496		0.253	0.355		4.892	0.278	0.942			10.854
35.80	14	90	1				5.649	9.294			1.908	5.170				2.127							11.642
18.89	15	90	1				2.777	3.804			0.574	2.503				1.383							7.845
116.46	16	90	1				9.643	7.500			6.277	28.230				6.988							57.799
30.45	17	90	1				0.618	2.013			1.678	3.057				0.837							22.238
919.46	TOTAL	90	1	125.88	10.86	0.53	51.47	352.87	0.77	11.54	11.29	73.62	19.36	0.90	3.16	20.03	23.83	16.19	6.96	6.80	12.19	0.06	170.67
8.73	3	91	1	0.742	0.945		0.925	0.699	0.196			0.522	0.796		0.091	0.418	0.154		2.538	0.493	0.048	0.160	
17.52	7	91	1	9.216	0.021		0.801	0.659		0.028		1.316	1.223		0.303	0.499	0.124		1.806	0.587	0.927		
2.87	8	91	1	0.009			0.368	0.288	0.257	1.357		0.168	0.106			0.139	0.007				0.169		
375.68	11	91	1	79.682	4.546	3.607	17.432	101.960		0.075	0.488	19.310	10.744		13.975	4.395	19.686	19.085	1.878	6.499	3.607		68.599
103.15	12	91	1	16.999	1.950		2.084	60.425		0.010		6.705	0.516		0.206	1.960	1.413	3.043	1.227	0.959	1.032		4.559
108.30	13	91	1	21.779	2.047	2.437	22.093	27.335				5.155	6.790		1.408	0.866	2.231	6.032	1.051	2.632	4.105		2.274
19.34	14	91	1	3.754				4.638			0.273	3.021				1.367							6.282
0.00	15	91	1	0.001				0.001			0.000	0.000				0.000							0.002
195.76	16	91	1	7.635				4.777				30.852				3.367							149.091
831.35	TOTAL	91	1	139.82	9.51	6.04	43.70	200.78	0.45	1.47	0.76	67.05	20.18		15.98	13.01	23.62	28.16	8.50	11.17	9.89	0.16	230.81

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
5.36	3	92	1	0.455			0.708	0.959		1.963		0.230	0.422		0.016	0.220	0.034				0.287	0.063	
1.53	5	92	1					0.030		0.961		0.250	0.041		0.015	0.181					0.051		
18.63	7	92	1	9.041	0.728		0.408	2.342	0.022	1.464		0.935	1.563		0.032	0.373	0.954	0.022		0.058	0.622	0.052	
13.82	10	92	1				0.131	0.084	0.025	12.112		0.287	0.326		0.011	0.446	0.115	0.008			0.213	0.054	
530.73	11	92	1	121.113	18.629	3.450	16.718	106.836		2.017	0.106	55.674	7.855		6.740	23.989	26.961	23.140	3.980	11.676	5.254		96.168
43.16	12	92	1	16.181	3.561	0.151	0.160	7.065		0.060		4.221	0.729		0.203	1.213	0.678	3.241	0.017	1.338	0.384		3.928
33.73	13	92	1	7.849			2.793	14.008				0.374	0.759		0.681	0.283	1.838	0.519			4.611		
40.19	14	92	1	6.724				7.045			1.005	6.555				3.107							15.746
2.95	15	92	1	0.380				0.456			0.049	0.512				0.281							1.273
120.73	16	92	1	6.206				21.526				1.823				3.151							88.000
51.03	17	92	1					2.990															48.035
861.86	TOTAL	92	1	167.95	22.92	3.60	20.92	163.34	0.05	18.58	1.16	70.86	11.70		7.70	33.24	30.58	26.93	4.00	13.07	11.42	0.17	253.15
18.07	2	93	1	2.608	1.567		0.215	5.369			1.377	0.820	0.708	0.188	0.087	0.278	0.842				0.298		3.701
496.03	11	93	1	86.458	6.300	4.762	15.823	106.448		0.645		53.026	2.480		3.770	18.155	14.782	26.290	1.389	22.321	8.433		124.553
81.67	12	93	1	22.835	7.187	0.139	1.388	22.892		0.074		7.399	0.547			2.213	1.119	5.937	0.278	0.457	0.719		8.428
11.58	13	93	1	1.606			0.542	7.808				0.611	0.290		0.154	0.023	0.163	0.141		0.053			0.182
10.07	14	93	1	1.505				3.044			0.143	1.419				0.675							3.280
5.13	15	93	1	0.401				1.406			0.274	0.578				0.345							2.125
162.63	16	93	1	2.309				11.726				2.683				15.222							130.657
69.27	17	93	1					14.283								5.064							49.916
854.45	TOTAL	93	1	117.72	15.05	4.90	17.97	172.98		0.72	1.79	66.54	4.03	0.19	4.01	41.97	16.91	32.37	1.67	22.83	9.45		322.84
0.97	3	94	1	0.696			0.003	0.184		0.006		0.010	0.042			0.002	0.026						
5.38	4	94	1	0.061			0.037	0.566		4.120		0.129	0.026		0.002	0.270	0.125				0.038	0.005	
0.75	6	94	1				0.001	0.007		0.672		0.042	0.009			0.015	0.003				0.000		
4.44	10	94	1				0.204	0.228		3.499		0.133	0.060			0.170	0.084	0.004	0.016	0.014	0.019	0.007	
246.23	11	94	1	46.759	14.404	1.157	11.277	87.018		0.074		14.700	2.487		0.665	4.728	6.870	17.729	0.566	6.476	3.817		27.381
40.19	12	94	1	8.416	2.166		2.813	16.763				2.343	0.052		0.269	0.848	0.442	2.970		0.297	0.920		1.861
10.80	13	94	1	1.689	0.626	0.124		4.831				0.046	1.371				0.497	0.917	0.080	0.080	0.056		0.476
308.76	TOTAL	94	1	57.62	17.20	1.28	14.34	109.60		8.37		17.40	4.05		0.94	6.03	8.05	21.62	0.66	6.87	4.85	0.01	29.72
8.66	3	85	2	2.222	1.692		0.234	1.327	1.290			0.702	0.496				0.400	0.028			0.265		
30.76	11	85	2				0.747	6.780			6.512	3.024				0.554							13.135
39.42	TOTAL	85	2	2.22	1.69		0.98	8.11	1.29		6.51	3.73	0.50			0.55	0.40	0.03			0.26		13.13
34.63	3	86	2	4.911	1.648		4.225	8.924	0.571			2.757	1.745		1.271	0.471	1.025	0.717	3.262	0.277	0.613	2.192	
85.51	11	86	2				2.078	18.846			18.102	8.406				1.539							36.513
120.14	TOTAL	86	2	4.91	1.65		6.30	27.77	0.57		18.10	11.16	1.75		1.27	2.01	1.03	0.72	3.26	0.28	0.61	2.19	36.51
37.74	3	87	2	4.616	0.834		4.385	4.370	5.710			2.230	1.351		2.079	0.808	1.253	0.128	8.216	0.476	0.725	0.528	
1.34	4	87	2	0.228	0.095			0.143	0.613			0.059	0.159			0.016	0.027						
69.74	11	87	2				1.695	15.371			14.764	6.855				1.255							29.779
108.82	TOTAL	87	2	4.84	0.93		6.08	19.88	6.32		14.76	9.14	1.51		2.08	2.08	1.28	0.13	8.22	0.48	0.72	0.53	29.78
8.78	3	88	2	2.600	0.270		0.101	0.907	2.768			0.820	0.400		0.036	0.448	0.306	0.113			0.006		
1.34	7	88	2	0.011			0.262	0.513					0.029		0.158	0.025			0.341				
62.27	11	88	2				1.513	13.724			13.183	6.121				1.121							26.589
72.39	TOTAL	88	2	2.61	0.27		1.88	15.14	2.77		13.18	6.94	0.43		0.19	1.59	0.31	0.11	0.34		0.01		26.59
1.08	3	89	2	0.487				0.260				0.072	0.169			0.063	0.029						
2.57	7	89	2		0.620		0.142	0.689	0.558			0.077	0.276		0.044	0.021	0.006	0.022	0.076	0.034		0.005	
65.45	11	89	2	13.836	8.993	0.884	7.703	17.298		1.662	0.223	3.201	0.910		1.846	0.916	2.899	0.615	0.013	0.956	0.458		2.998
0.00	12	89	2	0.000	0.001			0.001		0.000		0.000			0.000	0.000	0.000						
69.10	TOTAL	89	2	14.32	9.61	0.88	7.85	18.25	0.56	1.66	0.22	3.35	1.35		1.89	1.00	2.93	0.64	0.09	0.99	0.46	0.00	3.00
7.83	3	90	2	2.254	1.549		0.113	1.916	0.101	0.131		0.347	0.407		0.034	0.177	0.797						
25.63	8	90	2	7.071	0.238		0.290	7.120	1.059	6.428		1.112	1.302			0.638	0.364						
116.91	11	90	2	32.466	3.507	0.748	10.709	34.149		2.046	0.105	6.898	4.127		0.526	1.368	5.319	2.443	2.490	0.397	2.455		7.085
48.37	12	90	2	7.430	2.128	0.063	2.293	23.672		1.490		4.232	3.560			0.426	0.653	0.430	0.590	0.174			1.200
13.85	13	90	2	0.470	0.240			4.187		5.820		1.242	0.422			0.364	0.835	0.100		0.165			
212.59	TOTAL	90	2	49.69	7.66	0.81	13.40	71.04	1.16	15.91	0.11	13.83	9.82		0.56	2.97	7.97	2.97	3.08	0.74	2.46		8.28
20.72	3	91	2	2.339	3.135		1.939	3.450	0.035	1.206		0.553	0.762		0.671	0.398	1.361	0.037	3.021	0.493	0.746	0.555	
2.43	8	91	2	1.061				0.437				0.443	0.391			0.084	0.013						
112.70	11	91	2	14.617	3.539	5.162	23.588	32.717		1.364		1.600	2.536		2.896	1.059	2.863	6.165	6.503	3.528	1.014		3.471
14.07	12	91	2	4.452	0.608			6.278				0.855	0.308		0.032	0.335	0.353	0.431					0.412
54.15	13	91	2	11.128	1.717	0.357	5.886	20.718				0.352	2.978			0.152	0.986	2.253	1.489	0.612	3.937		1.560
204.07	TOTAL	91	2	33.60	9.00	5.52	31.41	63.60	0.04	2.57		3.80	6.98		3.60	2.03	5.58	8.89	11.01	4.63	5.70	0.56	5.44
2.12	3	92	2	0.897			0.074	0.148		0.074		0.126	0.048		0.026	0.070			0.536	0.018	0.103		
5.87	10	92	2	0.184	0.235			1.427		2.663		0.380	0.160			0.548	0.195	0.076					
30.88	11	92	2	10.817		0.290	3.091	3.650				6.281	1.235		0.108	2.001	0.939	1.214	0.244				0.991
32.37	12	92	2	6.205			2.548	16.991				1.194	1.428			1.440		0.317	0.146				2.088
20.24	13	92	2	1.761			2.224	13.721					1.346		0.277		0.494						0.411
91.48	TOTAL	92	2	19.86	0.24	0.29	7.94	35.94		2.74		7.98	4.22		0.41	4.06	1.63	1.61	0.93	0.02	0.10		3.49

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
0.95	4	93	2	0.819			0.031					0.040	0.007			0.006	0.043				0.005		
1.54	7	93	2	0.784	0.029		0.043	0.223				0.081	0.199		0.003	0.049	0.090				0.039		
29.18	11	93	2	3.910	1.015	1.622	4.631	8.745				0.502	0.099		0.972		0.864	2.028	0.163	1.885	0.601		2.124
0.00	12	93	2					0.001															
6.24	13	93	2	0.353		0.047	0.772	3.884					0.210		0.116		0.110	0.444		0.082			0.219
37.91	TOTAL	93	2	5.87	1.04	1.67	5.48	12.85				0.62	0.52		1.09	0.05	1.11	2.47	0.16	1.97	0.65		2.34
31.57	11	94	2	4.379	4.527	0.420	5.815	10.510				0.290	1.231			0.243	0.603	2.579			0.780		0.170
0.00	12	94	2	0.000	0.000			0.000				0.000				0.000		0.000					0.000
7.20	13	94	2	3.990	1.727		0.304					0.336	0.262		0.122	0.217	0.239						
38.77	TOTAL	94	2	8.37	6.25	0.42	6.12	10.51				0.63	1.49		0.12	0.46	0.84	2.58			0.78		0.17
29.78	3	85	3	9.452	2.070		1.617	3.335	0.488	0.018		4.997	3.621		0.724	0.006	1.289	0.054	1.823		0.232	0.036	
0.94	5	85	3	0.519	0.098		0.031		0.035			0.135	0.106				0.016						
5.92	11	85	3				0.144	1.305			1.253	0.582				0.107							2.528
36.64	TOTAL	85	3	9.97	2.17		1.79	4.64	0.52	0.02	1.25	5.71	3.73		0.72	0.11	1.31	0.05	1.82		0.23	0.04	2.53
30.40	3	86	3	10.813	1.505		1.766	6.399	0.292			2.411	3.089		0.541	0.158	0.909	0.122	0.927	0.033	0.426	0.988	
16.44	11	86	3				0.399	3.623			3.480	1.616				0.296							7.020
46.84	TOTAL	86	3	10.81	1.50		2.17	10.02	0.29		3.48	4.03	3.09		0.54	0.45	0.91	0.12	0.93	0.03	0.43	0.99	7.02
46.90	3	87	3	9.943	0.704		2.326	3.630	12.625	0.009		5.262	3.147	0.009	1.168	2.157	1.299	0.718	2.190	0.202	1.177	0.295	
8.39	4	87	3	0.776	0.849		0.036	0.801	3.969			0.691	0.551		0.057	0.471	0.183						
13.41	11	87	3				0.326	2.956			2.839	1.318				0.241							5.726
68.70	TOTAL	87	3	10.72	1.55		2.69	7.39	16.59	0.01	2.84	7.27	3.70	0.01	1.22	2.87	1.48	0.72	2.19	0.20	1.18	0.30	5.73
13.74	3	88	3	2.506	0.712		0.581	1.469	1.256			1.186	0.798		0.492	0.436	0.782	0.756	1.936	0.338	0.418	0.066	
11.97	11	88	3				0.291	2.638			2.534	1.177				0.215							5.111
25.71	TOTAL	88	3	2.51	0.71		0.87	4.11	1.26		2.53	2.36	0.80		0.49	0.65	0.78	0.76	1.94	0.34	0.42	0.07	5.11
10.56	3	89	3	3.157	1.239		0.277	2.844	0.131			0.609	1.382		0.074	0.197	0.620		0.025				
17.56	11	89	3	1.043	3.610		0.235	7.779				0.597	1.306			0.388	1.565			0.148	0.023		0.855
0.00	12	89	3	0.000				0.000				0.000						0.000					
28.12	TOTAL	89	3	4.20	4.85		0.51	10.62	0.13			1.21	2.69		0.07	0.59	2.18	0.00	0.03	0.15	0.02		0.86
8.24	3	90	3	3.538	0.715		0.256	2.215	0.226			0.207	0.113		0.005	0.075	0.194	0.094			0.576	0.023	
23.91	11	90	3	2.147	0.674		0.330	14.807		1.368		1.341	0.571		0.017	1.473	0.378	0.127	0.024	0.222			0.414
14.88	12	90	3	3.817				6.259				0.336	0.772		0.086			1.922					1.681
5.04	13	90	3	1.396	1.518			2.126															
52.07	TOTAL	90	3	10.90	2.91		0.59	25.41	0.23	1.37		1.88	1.46		0.11	1.55	0.57	2.14	0.02	0.22	0.58	0.02	2.10
19.85	3	91	3	5.441	0.066		2.374	5.262	0.032	0.143		1.161	0.730		0.175	0.576	0.195	0.449	1.798	0.564	0.869		
11.27	11	91	3	4.689	0.440			2.665				0.310	0.255		0.070	0.089	0.496	1.159		0.234			0.858
4.69	12	91	3					4.690															
6.63	13	91	3	0.396	0.486		0.121	5.256					0.371										
42.44	TOTAL	91	3	10.53	0.99		2.49	17.87	0.03	0.14		1.47	1.36		0.24	0.66	0.69	1.61	1.80	0.80	0.87		0.86
3.62	3	92	3	0.766	0.884		0.130	0.830		0.002		0.134	0.256		0.010	0.102	0.241	0.047		0.015	0.132	0.069	
1.16	8	92	3	0.175	0.006		0.012	0.310		0.129		0.153	0.112		0.021	0.118	0.089			0.021		0.015	
5.79	11	92	3	0.820				3.743				0.027	0.677				0.040	0.301					0.181
0.00	12	92	3	0.000								0.000				0.000		0.000					0.000
29.68	13	92	3	0.080	0.071		0.175	28.291					0.947					0.107					
40.25	TOTAL	92	3	1.84	0.96		0.32	33.17		0.13		0.31	1.99		0.03	0.22	0.37	0.45		0.04	0.13	0.08	0.18
0.78	8	93	3	0.520	0.072			0.027		0.032		0.074	0.035				0.020						
3.89	11	93	3														3.890						
0.00	12	93	3	0.000			0.000	0.000					0.000										0.000
10.69	13	93	3					10.690															
15.36	TOTAL	93	3	0.52	0.07		0.00	10.72		0.03		0.07	0.03				3.91						0.00
4.66	3	94	3	1.490	0.258		0.249	1.110	0.637	0.048		0.272	0.199		0.151	0.092	0.122	0.020	0.009			0.001	
1.61	4	94	3	0.661				0.087		0.606		0.018	0.042		0.091	0.080	0.023						
0.91	8	94	3	0.543			0.027	0.163				0.083	0.048			0.024	0.021						
22.10	11	94	3				6.175	11.488				0.457			0.232		0.484	1.713	0.466	0.336	0.329		0.413
6.70	12	94	3					6.700															
19.80	13	94	3	1.182			2.758	12.684				0.166				0.143	0.792	0.166		1.713			0.190
55.78	TOTAL	94	3	3.88	0.26		9.21	32.23	0.64	0.65		1.00	0.29		0.47	0.34	1.44	1.90	0.48	2.05	0.33	0.00	0.60
30.92	3	85	4	7.628	2.229		2.501	5.878	0.631	1.342		3.683	2.390	0.009	0.408	0.322	1.435	0.798	0.173	0.028	0.674	0.770	
2.60	11	85	4				0.063	0.573			0.550	0.256				0.047							1.110
33.52	TOTAL	85	4	7.63	2.23		2.56	6.45	0.63	1.34	0.55	3.94	2.39	0.01	0.41	0.37	1.43	0.80	0.17	0.03	0.67	0.77	1.11
29.69	3	86	4	12.476	1.149		1.517	3.088	1.381			2.515	3.361		0.451	0.422	0.802	0.353	0.888	0.068	0.882	0.321	
7.24	11	86	4				0.176	1.596			1.533	0.712				0.130							3.091
36.93	TOTAL	86	4	12.48	1.15		1.69	4.68	1.38		1.53	3.23	3.36		0.45	0.55	0.80	0.35	0.89	0.07	0.88	0.32	3.09
CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
35.70	3	87	4	14.733	1.025		1.050	2.560	4.577			3.192	2.977		0.486	1.307	1.624	0.989	0.293	0.039	0.503	0.325	
1.01	4	87	4	0.008	0.033		0.011	0.039	0.598			0.147	0.035		0.003	0.114	0.022						
5.90	11	87	4				0.143	1.300			1.249	0.580				0.106							2.519
42.61	TOTAL	87	4	14.74	1.06		1.20	3.90	5.17		1.25	3.92	3.01		0.49	1.53	1.65	0.99	0.29	0.04	0.50	0.32	2.52
47.40	3	88	4	11.921	1.811		1.981	3.247	11.817			4.773	4.356		0.815	2.318	1.844	0.289	1.692	0.213	0.299		
2.01	7	88	4	1.065	0.029			0.030	0.476			0.096	0.176		0.009	0.025	0.103						

5.27	11	88	4				0.128	1.162			1.116	0.518			0.095							2.250
54.68	TOTAL	88	4	12.99	1.84		2.11	4.44	12.29		1.12	5.39	4.53	0.82	2.44	1.95	0.29	1.69	0.21	0.30		2.25
41.18	3	89	4	21.084	2.372		0.704	1.800	1.062			2.911	5.296	0.729	0.770	0.712		2.907		0.749	0.058	
6.39	11	89	4	0.670				4.331				0.027			0.127	0.556						0.677
0.00	12	89	4																0.000			0.001
47.57	TOTAL	89	4	21.75	2.37		0.70	6.13	1.06			2.94	5.30	0.73	0.90	1.27		2.91	0.00	0.75	0.06	0.68
19.91	3	90	4	7.269	0.906		0.167	3.602	0.111	1.300		1.240	2.083	0.139	0.494	0.661	0.159	1.766		0.006		
9.58	4	90	4	6.884	0.324		0.086	0.614		0.142		0.379	0.870		0.031	0.246						
11.96	11	90	4	0.989			1.200	0.599		6.663		0.801	0.504	0.090	0.155	0.281	0.148		0.002	0.492		0.028
3.72	12	90	4	0.685	0.039			1.642				0.279	0.034		0.120	0.046						0.873
45.17	TOTAL	90	4	15.83	1.27		1.45	6.46	0.11	8.10		2.70	3.49	0.23	0.80	1.23	0.31	1.77	0.00	0.50		0.90
30.21	3	91	4	7.133	0.039		2.033	1.390	0.692	9.311		2.281	1.347	0.375	0.807	0.643		0.462	0.169	3.504		
2.39	4	91	4	1.391	0.041			0.119				0.129	0.470		0.130	0.109						
5.84	7	91	4	4.698				0.154				0.419	0.398		0.084					0.087		
2.50	11	91	4	0.697			0.093	1.029				0.131			0.196	0.354						
4.42	13	91	4	0.394				2.879				0.278			0.158	0.710						
45.36	TOTAL	91	4	14.31	0.08		2.13	5.57	0.69	9.31		3.24	2.22	0.37	1.37	1.82		0.46	0.17	3.59		
35.17	3	92	4	16.298	1.090		0.524	2.743	0.288	4.962		2.817	1.315	0.081	0.992	1.484	1.080	1.076	0.021	0.267	0.109	
12.96	4	92	4	8.059	0.025		0.066	0.797		0.989		1.021	0.855	0.049	0.487	0.297	0.017	0.039	0.048	0.202		
5.96	7	92	4	4.348	0.171			0.461		0.101		0.406	0.283		0.059	0.130						
1.80	8	92	4	1.066	0.028		0.025	0.139		0.145		0.073	0.270	0.002	0.027	0.005	0.018					
1.93	11	92	4	0.267		0.024	0.032	0.138				0.305		0.020	0.059	0.047	0.414	0.049				0.574
10.79	12	92	4	2.225				1.306				3.487			0.254	0.144	0.704					2.668
10.12	13	92	4	1.049			0.609	8.460														
78.73	TOTAL	92	4	33.31	1.31	0.02	1.26	14.04	0.29	6.20		8.11	2.72	0.15	1.88	2.11	2.23	1.16	0.07	0.47	0.11	3.24
25.21	3	93	4	11.566	0.729		0.729	2.143		2.226		1.452	1.712	0.209	0.509	1.084	0.199	2.017	0.063	0.545	0.013	
10.49	4	93	4	5.344	0.105		0.111	0.735		1.575		0.720	1.409	0.036	0.251	0.119	0.025	0.019	0.006	0.030		
6.42	7	93	4	4.744				0.223		0.035		0.649	0.600	0.024	0.120	0.022						
3.64	10	93	4					0.155		3.218		0.076	0.040		0.115	0.036						
0.00	12	93	4	0.001								0.000										
142.56	13	93	4	82.086	3.065		1.768	8.625		6.658		16.223	8.254	0.257	4.762	2.210	1.782	1.312	0.627		4.861	
188.32	TOTAL	93	4	103.74	3.90		2.61	11.88		13.71		19.12	12.01	0.53	5.76	3.47	2.01	3.35	0.70	0.57	4.87	
14.56	3	94	4	9.385	0.189		0.009	0.546		0.151		1.836	1.270	0.032	0.316	0.716	0.052			0.028	0.019	
12.61	4	94	4	5.477	0.005		0.055	1.583		1.820		1.076	0.605	0.054	0.531	0.318	0.125	0.745	0.084	0.090	0.037	
0.97	7	94	4	0.740				0.068				0.037	0.080	0.007	0.004					0.034		
18.94	11	94	4	4.349	2.116			7.256		0.097		0.275	1.328				0.474		1.769	1.068		0.201
47.08	TOTAL	94	4	19.95	2.31		0.06	9.45		2.07		3.22	3.28	0.09	0.85	1.03	0.65	0.75	1.85	1.22	0.06	0.20
23.93	3	85	5	10.393	1.740		1.091	1.819	0.072	0.062		2.415	4.066	0.091	0.086	1.493	0.201	0.254		0.134		
11.81	3	86	5	4.863	0.592		0.890	0.797	0.148			1.151	1.892	0.209	0.337	0.279	0.458	0.106	0.015	0.065		
29.94	3	87	5	18.536	0.551		0.841	1.051	1.392			1.904	3.015	0.240	0.877	0.482	0.596	0.138	0.024	0.275		
2.60	4	87	5	1.270	0.005			0.199	0.504			0.015	0.269	0.022	0.060	0.067	0.189					
32.54	TOTAL	87	5	19.81	0.56		0.84	1.25	1.90			1.92	3.28	0.26	0.94	0.55	0.78	0.14	0.02	0.28		
9.01	3	88	5	3.314	0.378		0.060	0.223	0.251			1.397	2.136	0.060	0.624	0.114	0.423			0.023		
2.68	3	90	5		0.239		0.020	0.178		1.820		0.032			0.271	0.117						
2.97	4	90	5	1.595	0.565			0.123		0.413		0.094	0.155		0.004	0.020						
2.08	8	90	5	1.630				0.013		0.058		0.115	0.228		0.014	0.020						
7.73	TOTAL	90	5	3.23	0.80		0.02	0.31		2.29		0.24	0.38		0.29	0.16						
9.16	3	91	5	4.384	0.016		0.316	1.319	0.031	0.503		0.875	0.306	0.008	0.363	0.769	0.229			0.036		
1.74	4	91	5	0.934	0.021			0.021	0.003			0.265	0.251	0.028	0.143	0.072						
19.19	10	91	5	0.117			0.071	0.251	0.919	15.170		0.731	0.263		1.075	0.585						
30.09	TOTAL	91	5	5.44	0.04		0.39	1.59	0.95	15.67		1.87	0.82	0.04	1.58	1.43	0.23			0.04		

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
7.92	2	92	5	0.845		0.055	2.167	1.643		0.545	0.009	0.175	0.280	0.122	0.142	0.131	0.082	0.017	1.548		0.109		0.044
5.11	3	92	5	2.962			0.081	0.208		0.006		0.784	0.544		0.012	0.241	0.110	0.103		0.021		0.035	
1.26	4	92	5	0.745				0.160				0.075	0.082		0.006	0.029	0.162						
1.80	8	92	5	0.673	0.030		0.067	0.562		0.079		0.148	0.127			0.064	0.049						
0.87	9	92	5					0.011		0.851		0.002				0.005						0.001	
20.67	10	92	5				0.045	0.339	0.353	17.251		0.285	0.577			1.542	0.252		0.010		0.006	0.004	
37.63	TOTAL	92	5	5.23	0.03	0.06	2.36	2.92	0.35	18.73	0.01	1.47	1.61	0.12	0.16	2.01	0.66	0.12	1.56	0.02	0.11	0.04	0.04
27.01	2	93	5	3.754	0.986	0.016	0.562	4.497			4.214	0.845	3.530	0.303	0.216	0.389	1.215				1.372		5.091
0.58	6	94	5				0.261	0.180				0.002	0.007		0.009	0.001	0.023		0.012	0.021	0.055	0.010	
29.55	3	85	6	15.419	0.641		1.067	1.687	0.254	0.298		3.620	4.161		0.157		0.996	0.600	0.145		0.467	0.018	
25.91	11	85	6				0.630	5.711			5.485	2.547				0.466							11.064
55.46	TOTAL	85	6	15.42	0.64		1.70	7.40	0.25	0.30	5.49	6.17	4.16		0.16	0.47	1.00	0.60	0.14		0.47	0.02	11.06
11.81	3	86	6	3.622	0.502		0.253	1.039	3.252			0.781	1.324		0.089	0.404	0.327		0.026		0.188		
72.02	11	86	6				1.750	15.873			15.247	7.080				1.296							30.753
83.83	TOTAL	86	6	3.62	0.50		2.00	16.91	3.25		15.25	7.86	1.32		0.09	1.70	0.33		0.03		0.19		30.75
64.29	3	87	6	30.911	3.112		1.132	4.622	6.885			4.121	7.490		0.495	1.299	1.331	1.157	0.836	0.006	0.784	0.077	
10.07	4	87	6	4.846	0.557		0.057	0.564	1.975			0.506	0.718		0.038	0.422	0.252				0.130		
3.41	5	87	6	1.971	0.069		0.085		0.435			0.249	0.243		0.050	0.235	0.001	0.053			0.017		
58.75	11	87	6				1.428	12.949			12.437	5.775				1.058							25.086
136.52	TOTAL	87	6	37.73	3.74		2.70	18.13	9.30		12.44	10.65	8.45		0.58	3.01	1.58	1.21	0.84	0.01	0.93	0.08	25.09
35.80	3	88	6	11.055	3.039		1.525	4.196	4.031			2.295	2.309		0.777	1.153	1.428	0.147	2.345	0.405	0.745	0.333	
11.02	4	88	6	3.794	0.326			0.321	4.156			0.572	1.265		0.004	0.302	0.149	0.118			0.009		
1.83	5	88	6	1.534								0.053	0.235			0.008							
6.71	7	88	6	3.134			0.248	0.390	0.590			0.320	0.892		0.081	0.149	0.248		0.586	0.068			
52.45	11	88	6				1.275	11.560			11.104	5.156				0.944							22.396
107.81	TOTAL	88	6	19.52	3.37		3.05	16.47	8.78		11.10	8.40	4.70		0.86	2.56	1.82	0.26	2.93	0.47	0.75	0.33	22.40
2.80	3	89	6	0.578	0.059		0.815	0.340				0.361	0.199		0.054	0.064	0.126				0.033	0.170	
3.05	5	89	6	1.797			0.236	0.123				0.133	0.462			0.062	0.236						
7.08	7	89	6	4.868	0.042		0.130	0.253	0.241			0.393	0.656		0.040	0.139	0.080	0.235					
4.80	9	89	6	0.004			0.060	0.293	3.832			0.247	0.255		0.005	0.096	0.007						
44.70	11	89	6	8.189	7.219		4.702	13.164			3.871	0.675	1.484		0.201	0.098	2.128	0.809	0.045	0.027	0.009		2.061
0.00	12	89	6	0.000	0.000			0.000				0.000				0.000	0.000	0.000		0.000			0.000
62.43	TOTAL	89	6	15.44	7.32		5.94	14.17	4.07		3.87	1.81	3.06		0.30	0.46	2.58	1.04	0.04	0.03	0.04	0.17	2.06
14.32	3	90	6	7.315	0.491		0.206	1.438		2.076		0.653	1.183		0.006	0.306	0.355	0.013			0.246	0.024	
18.71	4	90	6	5.922	0.904		0.236	1.480	0.234	7.325		0.399	1.323		0.079	0.369	0.432						
1.69	6	90	6				1.272	0.002		0.096		0.024	0.007			0.250					0.035	0.004	
41.79	8	90	6	0.740	0.054		1.220	3.322	1.458	30.319		1.755	1.337		0.142	0.953	0.242		0.071		0.125	0.021	
157.15	10	90	6	0.220			14.191	10.120	7.936	109.219		7.355	2.970		0.126	2.672	0.157	0.031	0.330	0.047	1.697		
69.08	11	90	6	3.751	0.373	2.038	27.045	17.443		0.870		1.347	3.261		1.969	1.471	0.746	0.677	5.637	0.463	0.490		1.444
3.72	12	90	6	1.180	0.467		0.022	1.000			0.017	0.406			0.040			0.189		0.085			0.311
5.04	13	90	6	1.064				2.136			0.966	0.176					0.656	0.040					
311.50	TOTAL	90	6	20.19	2.29	2.04	44.19	36.94	9.63	149.91	0.98	12.12	10.08		2.36	6.02	2.59	0.95	6.04	0.60	2.59	0.05	1.75
58.44	1	91	6	7.124	0.725	0.064	2.022	6.095		26.964	0.146	1.940	1.514	1.800	0.918	0.351	0.976	0.649	2.303	0.023	4.658		0.123
84.89	2	91	6	8.761	0.441	0.433	3.820	10.408		39.440	0.993	2.462	2.428	2.716	0.968	0.560	1.723	1.919	2.360	0.331	5.051		
36.21	3	91	6	8.969	1.039		5.269	2.086	0.590	3.179		2.712	3.740		0.167	1.180	0.855	0.065	2.495	0.753	1.640	1.445	
10.64	4	91	6	2.811	0.606		0.077	0.434	1.536	2.308		0.736	1.046		0.077	0.642	0.361						
12.96	5	91	6	0.137			0.430	0.429	0.283	5.559		2.477	0.823		0.400	1.868	0.113		0.093		0.318	0.022	
8.22	7	91	6	4.305			0.155	0.204		1.683		0.776	0.748			0.211	0.135						
11.47	8	91	6	1.451	0.177		1.753	3.724	0.424	1.873		0.411	0.388		0.290	0.251	0.219		0.444	0.022	0.030	0.007	
16.07	9	91	6	0.358	0.048		1.798	0.759	1.621	9.681		0.296	0.384		0.008	0.660	0.202	0.051			0.129	0.066	
26.65	10	91	6	0.752			0.728	3.590	0.738	15.630		0.693	1.407			1.868	0.282	0.136	0.136		0.608	0.064	
147.77	11	91	6	60.911	9.443	0.207	8.039	25.446		0.754		5.069	3.901		2.379	2.438	3.768	10.610	0.163	2.896	4.167		7.462
37.51	12	91	6	13.541	0.488		0.338	1.740		0.293		9.539			0.278	1.632	1.088	4.115		0.994	0.116		3.338
450.83	TOTAL	91	6	109.12	12.97	0.70	24.43	54.91	5.19	107.36	1.14	27.11	16.38	4.52	5.48	11.66	9.72	17.54	7.99	5.02	16.72	1.60	10.92
1.68	1	92	6	0.363	0.017		0.013	0.263		0.496		0.043			0.027		0.040	0.143			0.193		0.083
13.73	2	92	6	1.785	0.549		0.180	1.287		3.645		0.332	0.159	0.232	0.177	0.069	0.934	0.314		0.003	3.719		0.335
13.84	3	92	6	7.254	0.353		0.280	1.329		1.719		1.009	0.588		0.066	0.338	0.210	0.400	0.012	0.019	0.066	0.188	
5.16	4	92	6	2.669	0.111		0.025	0.415		0.968		0.520	0.185			0.122	0.116		0.025		0.003		
1.50	6	92	6	0.966			0.106	0.154				0.104	0.059			0.035	0.059				0.016		
2.61	7	92	6	1.797	0.004			0.240				0.146	0.340			0.021	0.061						
4.24	8	92	6	1.220	0.006		0.130	0.503	0.079	1.194		0.232	0.100			0.123	0.019				0.627	0.004	
1.43	9	92	6	0.011	0.012		0.017	0.122		0.938		0.046	0.089			0.176	0.015					0.003	
28.25	10	92	6				0.105	0.206		27.038		0.138	0.201			0.438	0.113					0.003	
32.81	11	92	6	10.667	0.797		0.778	5.266				2.277	0.915		0.059	0.495	0.341	1.365	3.383	0.138			6.309
10.79	12	92	6	1.175								2.722						0.538					6.352
116.04	TOTAL	92	6	27.90	1.85		1.63	9.78	0.08	36.00		7.57	2.64	0.23	0.33	1.82	1.91	2.76	3.42	0.16	4.62	0.20	13.08

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
2.66	2	93	6	0.339				0.217		0.746	0.081	0.176	0.244	0.448		0.163	0.136	0.041			0.041		0.027
11.25	3	93	6	4.442	0.534		0.125	0.961		2.298		0.744	0.834		0.044	0.397	0.451	0.069		0.001	0.345		
3.78	4	93	6	0.512	0.259		0.019	0.417		1.927		0.213	0.121		0.008	0.187	0.112		0.002				
1.05	5	93	6				0.012	0.038		0.705		0.109	0.016		0.008	0.124	0.008			0.004	0.022	0.005	
2.87	6	93	6	0.299	0.127		0.173	0.199	0.001	1.046		0.257	0.078		0.109	0.345	0.057				0.176		
28.88	10	93	6		0.038		0.445	2.001		24.412		0.274	0.373		0.006	0.849	0.393	0.009	0.017	0.006	0.023	0.023	
5.84	11	93	6	2.510			0.155	0.388				0.845	0.333			0.157		0.502	0.036				0.911
3.40	12	93	6	0.123			0.222	1.478				0.690				0.172	0.024	0.295	0.123	0.074			0.197
23.17	13	93	6	7.843	0.468			0.938		9.338		1.844	0.440		0.049	1.425	0.716		0.032	0.060			
82.90	TOTAL	93	6	16.07	1.43		1.15	6.64	0.00	40.47	0.08	5.15	2.44	0.45	0.22	3.82	1.90	0.92	0.21	0.14	0.61	0.03	1.14
13.67	3	94	6	3.422	0.394		0.733	3.327		3.640		0.493	0.556		0.034	0.369	0.450	0.033	0.083	0.007	0.021	0.098	
4.02	4	94	6	0.278	0.003		0.107	0.972		1.940		0.094	0.218		0.007	0.124	0.208		0.003	0.003	0.063		
1.91	6	94	6				0.037	0.300		1.015		0.147	0.044		0.011	0.202	0.020		0.030	0.001	0.104		
28.89	10	94	6				4.310	1.208		18.643		0.740	0.956		0.032	0.936	0.040		0.017		1.583	0.407	
3.16	11	94	6					2.602					0.557										
3.35	12	94	6	1.939	0.608			0.322				0.084			0.181		0.025	0.119					0.070
55.00	TOTAL	94	6	5.64	1.00		5.19	8.73		25.24		1.56	2.33		0.26	1.63	0.74	0.15	0.13	0.01	1.77	0.51	0.07
15.42	3	85	7	7.443	0.706		0.386	1.391	0.948			1.769	1.753		0.083		0.378	0.015	0.234		0.308		
0.63	5	85	7	0.085				0.317										0.165				0.063	
26.86	11	85	7				0.653	5.920			5.686	2.640				0.483							11.469
42.91	TOTAL	85	7	7.53	0.71		1.04	7.63	0.95		5.69	4.41	1.75		0.08	0.48	0.38	0.18	0.23		0.31	0.06	11.47
37.27	3	86	7	17.092	0.667		1.442	3.578	2.400	0.063		3.891	6.276		0.212	0.432	0.656	0.324			0.171	0.037	
2.09	4	86	7	1.557				0.007	0.094			0.186	0.080		0.010	0.083	0.072						
74.66	11	86	7				1.814	16.455			15.806	7.339				1.344							31.880
114.02	TOTAL	86	7	18.65	0.67		3.26	20.04	2.49	0.06	15.81	11.42	6.36		0.22	1.86	0.73	0.32			0.17	0.04	31.88
54.02	3	87	7	27.183	1.810		1.874	3.452	4.732			4.030	6.380		0.621	1.540	0.999	0.713	0.065	0.005	0.562	0.022	
8.64	4	87	7	6.142	0.145			0.206	0.619			0.310	0.787		0.049	0.133	0.065	0.130			0.050		
60.89	11	87	7				1.480	13.420			12.890	5.985				1.096							26.000
123.55	TOTAL	87	7	33.33	1.95		3.35	17.08	5.35		12.89	10.33	7.17		0.67	2.77	1.06	0.84	0.06	0.01	0.61	0.02	26.00
32.09	3	88	7	9.046	1.062		2.233	2.567	1.245			2.705	2.067		1.560	1.306	1.277	0.337	3.716	0.218	2.715	0.019	
3.82	4	88	7	0.415			0.011	0.204	2.251			0.317	0.449		0.021	0.123	0.027						
1.68	7	88	7	0.810			0.246	0.138	0.195			0.034	0.171		0.006	0.049	0.029						
54.36	11	88	7				1.321	11.981			11.508	5.344				0.978							23.212
91.95	TOTAL	88	7	10.27	1.06		3.81	14.89	3.69		11.51	8.40	2.69		1.59	2.46	1.33	0.34	3.72	0.22	2.71	0.02	23.21
44.85	3	89	7	11.966	2.094		3.588	4.741	1.601			1.781	3.301		1.973	1.453	1.377	0.179	10.239	0.193	0.247	0.094	
3.48	5	89	7				0.498	0.038				1.169	0.141		0.099	1.293					0.241		
19.30	7	89	7	8.710	0.523		0.199	0.782	6.603			0.569	0.421		0.037	1.021	0.168				0.259		
39.91	11	89	7	19.456	4.406		0.407	6.621			0.028	1.672	0.052		0.192	0.786	1.505	1.301	0.020	0.231	0.635		2.570
0.00	12	89	7	0.001	0.000			0.000				0.000	0.000		0.000		0.000	0.000		0.000	0.000		0.000
6.78	13	89	7	0.477	0.201		0.054	0.562		2.332	1.231	0.629	0.395		0.049	0.277	0.492						0.076
114.32	TOTAL	89	7	40.61	7.22		4.75	12.74	8.20	2.33	1.26	5.82	4.31		2.35	4.83	3.54	1.48	10.26	0.42	1.38	0.09	2.65
13.42	3	90	7	5.612	0.454		1.295	2.577	0.238	0.718		0.529	1.002		0.024	0.164	0.707		0.081		0.012		
10.49	4	90	7	2.776	0.111		0.036	0.854	0.065	4.323		0.299	1.372		0.015	0.294	0.342						
2.71	5	90	7	0.101				0.293					0.055				0.037				2.224		
21.70	8	90	7	1.450	0.106		0.289	2.035	0.069	15.272		0.653	0.749		0.054	0.812	0.137				0.061		
13.72	10	90	7				5.428	0.258	0.296			0.285	0.582		0.250	2.254	0.003		0.100		4.076	0.184	
17.27	11	90	7	4.492	1.668			5.072				0.829	0.523		0.111	0.036	1.931	0.204		0.608	0.551		1.237
3.72	12	90	7	0.176		0.020		0.800				0.746				0.247	0.342	0.041					1.346
83.03	TOTAL	90	7	14.61	2.34	0.02	7.05	11.89	0.67	20.31		3.34	4.28		0.45	3.81	3.50	0.24	0.18	0.61	6.92	0.18	2.58
5.32	1	91	7	1.534		0.055	0.716	0.636		1.128	0.004	0.220	0.148	0.178	0.063	0.082	0.055	0.155	0.115		0.225		
10.91	3	91	7	3.154	0.190		1.281	0.822		2.413		0.635	0.240		0.206	0.603	0.927		0.299	0.050	0.082		
6.95	4	91	7	5.632	0.247			0.209		0.076		0.221	0.325			0.130	0.107						
2.59	5	91	7	0.638	0.009		0.189	0.559		0.069		0.186	0.246		0.051	0.120		0.054	0.063		0.404		
5.07	8	91	7	0.860			0.133	0.356		1.914		0.692	0.277			0.836							
85.15	11	91	7	15.829	12.730	3.099	0.724	22.429				5.228	0.204		1.243	1.201	3.210	4.181	0.060	2.980	2.733		9.230
4.69	12	91	7	3.282			0.040	0.074				0.617			0.061	0.024	0.149	0.322		0.012			0.107
4.42	13	91	7	3.926								0.348	0.145										
125.10	TOTAL	91	7	34.86	13.18	3.15	3.08	25.08		5.60	0.00	8.15	1.59	0.18	1.62	3.00	4.45	4.71	0.54	3.04	3.44		9.34
10.35	3	92	7	4.427	0.221		0.510	0.731		2.396		0.871	0.630		0.016	0.131	0.110	0.159	0.028	0.008		0.106	
1.64	4	92	7	0.040	0.164			0.124		0.983		0.092	0.025		0.005	0.158	0.046						
3.56	5	92	7	0.038			0.093	0.311		2.272		0.390	0.096	0.007	0.033	0.211	0.062		0.013		0.016	0.015	
0.55	6	92	7									0.180			0.054	0.316							
1.41	8	92	7	0.496	0.006		0.060	0.365				0.049	0.156			0.020	0.044				0.213		
15.90	10	92	7				0.122	0.291	0.105	14.526		0.181	0.076			0.350	0.215		0.014			0.013	
23.16	11	92	7	3.972	0.931			5.102				2.573				0.320	0.039	0.739	0.359		0.424		8.690
0.00	12	92	7	0.000	0.000			0.000				0.000				0.000	0.000	0.000		0.000	0.000		0.000
56.57	TOTAL	92	7	8.97	1.32		0.79	6.92	0.10	20.18		4.34	0.98	0.01	0.11	1.51	0.52	0.90	0.41	0.01	0.65	0.13	8.69
CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
1.18	3	93	7	0.026				0.075		0.917		0.059	0.019		0.007	0.064	0.005					0.008	
39.96	11	93	7	2.885		0.400	0.132	14.945				6.282			0.368	1.279	1.670	2.805					9.179
10.21	12	93	7	0.305				1.702				1.959			0.191	0.212	1.185	0.426	0.141				4.084
11.58	13	93	7	6.128	0.422			0.548		0.032		1.468	1.460		0.101	0.523	0.559	0.122		0.065		0.146	
62.93	TOTAL	93	7	9.34	0.42	0.40	0.13	17.27		0.95		9.77	1.48		0.67	2.08	3.42	3.35	0.14	0.06		0.15	13.26
0.32	3	94	7	0.016			0.005	0.010		0.278		0.003				0.007	0.002						
284.11	11	94	7	81.398	30.485	2.472	1.421	85.716		0.085		7.586	1.307		0.966	1.591	23.155	6.790	4.915	2.926	0.966		32.161

117.23	12	94	7	50.690	16.823	0.223	0.234	11.571				3.751	1.559	0.258	2.098	7.491	12.344	0.188		1.923		7.995
5.40	13	94	7	0.518		0.125	0.226	1.368				0.272	0.110			1.099	1.173					0.506
407.06	TOTAL	94	7	132.62	47.31	2.82	1.89	98.66		0.36		11.61	2.98	1.22	3.70	31.75	20.31	5.10	2.93	2.89		40.66
7.67	3	85	8	2.697	0.167		0.846	0.445	0.110			0.713	1.035	0.170		1.142	0.072	0.156		0.113		
4.14	11	85	8				0.101	0.912			0.876	0.407			0.075							1.768
11.81	TOTAL	85	8	2.70	0.17		0.95	1.36	0.11		0.88	1.12	1.04	0.17	0.07	1.14	0.07	0.16		0.11		1.77
7.58	3	86	8	2.277	0.827		0.644	0.789	0.299			0.403	0.429	0.257	0.364	0.666		0.462	0.029	0.131		
11.51	11	86	8				0.280	2.537			2.437	1.131			0.207							4.915
19.09	TOTAL	86	8	2.28	0.83		0.92	3.33	0.30		2.44	1.53	0.43	0.26	0.57	0.67		0.46	0.03	0.13		4.91
33.64	3	87	8	10.842	1.043		4.528	2.954	0.851			1.850	2.530	1.457	0.676	0.750	0.178	5.174	0.468	0.192	0.128	
1.68	4	87	8	1.331	0.051		0.020	0.041	0.082			0.034	0.085		0.023	0.012						
9.39	11	87	8				0.228	2.070			1.988	0.923			0.169							4.010
44.71	TOTAL	87	8	12.17	1.09		4.78	5.06	0.93		1.99	2.81	2.61	1.46	0.87	0.76	0.18	5.17	0.47	0.19	0.13	4.01
13.74	3	88	8	3.197	0.143		1.952	2.326	0.206			0.944	0.624	1.308	0.337	0.533		1.187	0.260	0.661	0.056	
8.38	11	88	8				0.204	1.847			1.774	0.824			0.151							3.578
22.12	TOTAL	88	8	3.20	0.14		2.16	4.17	0.21		1.77	1.77	0.62	1.31	0.49	0.53		1.19	0.26	0.66	0.06	3.58
3.67	3	89	8	2.251	0.331		0.177	0.201	0.450					0.102		0.157						
13.29	7	89	8	1.504	0.066		0.100	0.702	9.352			0.361	0.575	0.016	0.554	0.043				0.012		
6.39	11	89	8	2.350	1.349			1.314		0.466		0.215	0.477			0.217						
9.08	12	89	8	0.690	2.856			3.356				0.104				0.593				1.189		0.287
32.43	TOTAL	89	8	6.80	4.60		0.28	5.57	9.80	0.47		0.68	1.05	0.12	0.55	1.01				1.20		0.29
11.63	3	90	8	3.092	3.176		0.284	1.042	0.185	0.092		0.873	0.713	0.037	0.311	1.042	0.243		0.020	0.359	0.150	
23.91	11	90	8	1.879	2.259		0.218	15.534		0.206	0.007	0.325	0.844	0.225	0.014	1.021	0.316			0.497		0.550
11.16	12	90	8	1.928	2.704			3.705		0.055		0.381	0.171	0.007	0.720	0.624	0.100		0.055	0.685		0.018
46.70	TOTAL	90	8	6.90	8.14		0.50	20.28	0.18	0.35	0.01	1.58	1.73	0.27	1.04	2.69	0.66		0.07	1.54	0.15	0.57
8.07	3	91	8	3.019			0.745	1.930				0.316	0.085	0.082	0.613			0.282	0.113	0.462	0.420	
4.10	5	91	8				0.199	0.167	0.048	1.446		0.798	0.262	0.196	0.763	0.021				0.196		
5.19	7	91	8				0.329	0.207					0.019	0.473	0.637	0.006		3.207	0.257		0.053	
12.52	11	91	8	6.356	0.149			4.413					1.181			0.272	0.015	0.003	0.010	0.095		0.023
0.00	12	91	8	0.000				0.001				0.000										
6.63	13	91	8	2.590			0.599	1.089				0.048		0.012	0.014		0.024		0.026	2.101		0.125
36.51	TOTAL	91	8	11.97	0.15		1.87	7.81	0.05	1.45		1.16	1.55	0.76	2.03	0.30	0.04	3.49	0.41	2.85	0.47	0.15
2.87	3	92	8	0.999	0.193		0.102	1.134		0.024		0.095	0.099	0.007	0.012	0.157	0.009			0.038		
1.80	8	92	8				0.868	0.467		0.075		0.053	0.144		0.151	0.031				0.010		
5.79	11	92	8	3.873			0.142	1.114				0.544			0.009		0.046					0.060
10.46	TOTAL	92	8	4.87	0.19		1.11	2.71		0.10		0.69	0.24	0.01	0.17	0.19	0.06			0.05		0.06
3.22	3	93	8	0.412	0.210		0.408	0.606		0.327		0.080	0.061	0.143	0.120	0.271		0.551		0.030		
1.03	7	93	8	0.418				0.323	0.068			0.051	0.033		0.006	0.132						
17.82	13	93	8	3.181	0.205		0.125	0.519		2.741		0.895	0.376	0.134	0.258	1.513	0.098	6.936	0.568		0.258	
22.07	TOTAL	93	8	4.01	0.41		0.53	1.45	0.07	3.07		1.03	0.47	0.28	0.38	1.92	0.10	7.49	0.57	0.03	0.26	
42.32	3	85	9	13.894	2.302		3.089	7.533	0.550	0.131		3.991	4.549	0.614	0.059	2.357	0.449	1.625		1.121	0.021	
10.53	11	85	9				0.256	2.321			2.229	1.035			0.190							4.496
52.85	TOTAL	85	9	13.89	2.30		3.35	9.85	0.55	0.13	2.23	5.03	4.55	0.61	0.25	2.36	0.45	1.63		1.12	0.02	4.50
157.46	3	86	9	51.379	9.290		10.991	21.493	7.448			11.463	10.440	3.937	4.110	4.661	1.716	11.967	1.669	5.243	1.559	
11.03	4	86	9	6.389	0.424		0.186	1.075	0.303			0.457	0.961	0.050	0.163	0.365				0.653		
0.89	5	86	9	0.530			0.021	0.003	0.101			0.067	0.052	0.049	0.022	0.024		0.021				
29.27	11	86	9				0.711	6.451			6.196	2.877			0.527							12.498
198.65	TOTAL	86	9	58.30	9.71		11.91	29.02	7.85		6.20	14.86	11.45	4.04	4.82	5.05	1.72	11.99	1.67	5.90	1.56	12.50
71.58	3	87	9	12.183	3.371		7.852	7.731	5.698	0.036		3.586	3.701	4.216	2.935	1.883	1.489	13.922	1.016	1.188	0.716	
7.80	4	87	9	2.105	0.117		0.700	1.073	1.055			0.415	0.629	0.130	0.264	0.243		0.977	0.062	0.023		
23.87	11	87	9				0.580	5.261			5.053	2.346			0.430							10.192
103.25	TOTAL	87	9	14.29	3.49		9.13	14.06	6.75	0.04	5.05	6.35	4.33	4.35	3.63	2.13	1.49	14.90	1.08	1.21	0.72	10.19

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
112.02	3	88	9	22.270	4.974		10.205	15.604	3.943			5.310	6.004		8.715	2.352	4.783	1.031	22.382	1.434	2.263	0.683	
9.00	4	88	9	3.967	0.536		0.079	1.073	1.868			0.341	0.314			0.054	0.366		0.019		0.377		
10.06	7	88	9	3.818	0.302		0.143	1.575	0.780			0.413	0.611		0.089	0.115	0.497	0.074	1.352	0.182	0.102		
2.91	9	88	9				0.768	0.753	0.423			0.043	0.152		0.065	0.371	0.006		0.198	0.001	0.092	0.037	
21.31	11	88	9				0.518	4.697			4.511	2.095				0.384							9.099
155.30	TOTAL	88	9	30.05	5.81		11.71	23.70	7.01		4.51	8.20	7.08		8.87	3.28	5.65	1.11	23.95	1.62	2.83	0.72	9.10
125.27	3	89	9	32.796	4.635		8.280	16.874	3.445			5.399	7.103		6.439	5.023	3.721	1.178	27.898	0.626	1.528	0.251	
9.56	4	89	9	0.405			1.098	0.408	5.910			0.177	1.030		0.048	0.146	0.099				0.233		
13.29	5	89	9	0.214			2.242	0.630	4.729			1.061	0.464		0.728	1.665	0.073			0.049	1.430		
57.89	7	89	9	7.601	2.923		2.906	13.210	19.735			1.430	1.737		0.776	1.268	1.019		4.562	0.151	0.423	0.116	
11.86	9	89	9				1.955	3.366	1.968			0.278	0.428		0.528	0.533	0.008		2.743		0.050		
52.68	11	89	9	9.693	0.537		10.757	20.403			0.016	0.806	0.838		0.053	4.077	1.264	0.074		0.142			3.998
9.08	12	89	9	0.084	0.964			0.400			0.101	0.764				0.113	0.120	0.381		1.361	0.235		4.552
279.63	TOTAL	89	9	50.79	9.06		27.24	55.29	35.79		0.12	9.91	11.60		8.57	12.83	6.30	1.63	35.20	2.33	3.90	0.37	8.55
80.97	3	90	9	23.959	4.972		5.425	16.510	0.283	2.340		2.883	5.352		1.563	2.275	5.611	0.186	5.797	0.113	3.652		
6.93	8	90	9	2.979			0.090	1.988		0.835		0.262	0.578		0.007	0.104	0.074				0.010		
39.86	11	90	9	9.853	6.099		0.654	10.599		0.534	0.295	1.375	1.929		0.343	0.379	2.806	0.028		0.044	1.319		3.571
0.00	12	90	9	0.000	0.000			0.001					0.000			0.000		0.000			0.000		
127.76	TOTAL	90	9	36.79	11.07		6.17	29.10	0.28	3.71	0.29	4.52	7.86		1.91	2.76	8.49	0.21	5.80	0.16	4.98		3.57
55.41	3	91	9	11.764	2.111		4.145	6.123	0.477	0.571		3.020	2.056		2.300	2.416	2.144	0.454	13.110	0.792	2.150	1.734	
11.24	8	91	9	4.726	0.012		0.284	0.535	0.579	2.112		1.571	0.400		0.076	0.341	0.075		0.388	0.081		0.053	
13.77	11	91	9	8.550	0.281	0.182		3.301				0.463	0.080			0.074	0.165	0.391		0.085			0.191
80.42	TOTAL	91	9	25.04	2.40	0.18	4.43	9.96	1.06	2.68		5.05	2.54		2.38	2.83	2.38	0.85	13.50	0.96	2.15	1.79	0.19
27.81	3	92	9	7.261	0.904		2.837	3.649	0.058	3.215		1.719	1.933		0.345	1.171	0.873	0.592	1.137	0.111	1.082	0.904	
4.40	4	92	9	0.449	0.280		0.036	1.361	0.324	1.627		0.105	0.055		0.013	0.068	0.072				0.007		
2.11	7	92	9	0.675	0.094		0.017	0.501		0.012		0.087	0.242			0.043	0.205				0.231		
3.73	8	92	9	0.945	0.228		0.054	1.353		0.583		0.205	0.167		0.002	0.029	0.163						
5.79	11	92	9	0.355				1.366				1.306											2.762
43.84	TOTAL	92	9	9.69	1.51		2.94	8.23	0.38	5.44		3.42	2.40		0.36	1.31	1.31	0.59	1.14	0.11	1.32	0.90	2.76
13.03	3	93	9	4.639	0.240		0.077	1.459		2.708		0.524	0.375		0.134	0.278	0.396	0.026	2.104	0.027	0.007	0.029	
7.14	4	93	9	2.605	0.502		0.348	0.653		0.910		0.359	0.698		0.090	0.137	0.183	0.129	0.278		0.243		
18.24	7	93	9	8.631	1.184		0.040	2.014		1.271		1.452	1.764		0.064	0.689	1.031				0.091		
4.96	8	93	9	2.742	0.231		0.019	0.844		0.036		0.256	0.384		0.000	0.071	0.143				0.231		
46.33	13	93	9	33.876	1.751		0.241	0.973		0.023		4.485	1.978		0.111	1.274	1.293	0.139				0.167	
89.70	TOTAL	93	9	52.49	3.91		0.73	5.94		4.95		7.08	5.20		0.40	2.45	3.05	0.29	2.38	0.03	0.57	0.20	
9.25	3	94	9	1.765	0.065		0.657	2.151		1.111		0.373	0.328		0.070	0.179	0.156	0.002	2.093	0.031	0.261	0.002	
6.59	4	94	9	2.895	0.013		0.351	1.521	0.002	0.426		0.279	0.361		0.013	0.300	0.108	0.043	0.011	0.018	0.206	0.038	
1.57	6	94	9				0.144	0.327		0.861		0.064	0.032			0.102	0.009		0.003	0.002	0.023	0.004	
12.80	7	94	9	6.687	0.110		0.044	2.719		0.726		0.684	0.764		0.024	0.069	0.915				0.055		
4.74	8	94	9	2.197	0.142		0.074	0.722		0.053		0.247	0.615		0.004	0.163	0.322	0.004			0.195		
8.49	10	94	9				1.239	0.500		4.535		0.514	0.534		0.110	0.419			0.006		0.563	0.066	
37.88	11	94	9	18.887	2.996		1.428	9.436		0.265		2.224	0.981			0.098	0.958				0.500		0.087
81.32	TOTAL	94	9	32.43	3.33		3.94	17.37	0.00	7.98		4.38	3.62		0.22	1.33	2.47	0.05	2.11	0.05	1.80	0.11	0.09
20.44	3	85	10	5.960	0.717		1.474	5.233	0.613	0.121		1.876	2.263		0.110		0.799	0.125	0.311	0.049	0.713	0.059	
13.01	11	85	10				0.316	2.867			2.754	1.279				0.234							5.555
33.45	TOTAL	85	10	5.96	0.72		1.79	8.10	0.61	0.12	2.75	3.16	2.26		0.11	0.23	0.80	0.12	0.31	0.05	0.71	0.06	5.56
39.92	3	86	10	9.401	0.691		3.190	5.892	1.421			1.844	1.760		1.892	0.806	0.834	0.251	9.924	0.279	0.583	1.122	
36.18	11	86	10				0.879	7.974			7.659	3.556				0.651							15.449
76.10	TOTAL	86	10	9.40	0.69		4.07	13.87	1.42		7.66	5.40	1.76		1.89	1.46	0.83	0.25	9.92	0.28	0.58	1.12	15.45
55.47	3	87	10	7.411	1.564		5.852	8.637	4.354			2.502	2.097		4.077	0.960	2.247	0.466	12.586	0.865	1.243	0.571	
1.85	4	87	10	0.460	0.024			0.214	0.777			0.110	0.078			0.119	0.067						
29.51	11	87	10				0.717	6.504			6.247	2.901				0.531							12.601
86.83	TOTAL	87	10	7.87	1.59		6.57	15.35	5.13		6.25	5.51	2.18		4.08	1.61	2.31	0.47	12.59	0.87	1.24	0.57	12.60
32.54	3	88	10	4.084	1.396		3.215	6.759	0.774			0.823	0.524		2.821	0.628	0.693	0.172	9.176	0.478	0.592	0.387	
9.45	4	88	10	4.734	0.303		0.093	2.162	0.206			0.497	0.395		0.046	0.092	0.288	0.061	0.082		0.484		
1.83	5	88	10	1.562	0.033							0.033	0.169		0.033								
4.02	7	88	10	0.950	0.297		0.123	0.447				0.160	0.647		0.227	0.068	0.263		0.699	0.090	0.047		
26.34	11	88	10				0.640	5.805			5.576	2.589				0.474							11.247
74.18	TOTAL	88	10	11.33	2.03		4.07	15.17	0.98		5.58	4.10	1.74		3.13	1.26	1.24	0.23	9.96	0.57	1.12	0.39	11.25
33.42	3	89	10	12.940	1.250		1.838	4.532	1.019			1.688	2.309		0.648	0.715	2.206	0.267	2.650	0.070	1.063	0.204	
2.57	7	89	10	0.752			0.012	1.116					0.010			0.676		0.002				0.002	
12.77	11	89	10	1.494	0.653		1.356	6.034			0.427	0.521	0.406		0.069	0.248	0.464	0.128		0.563	0.340		0.059
0.00	12	89	10	0.000				0.000				0.000				0.000							0.000
5.81	13	89	10	1.037	0.081		0.042	1.220				0.345	0.347		0.064	0.078	0.280	2.280			0.019		0.013
54.57	TOTAL	89	10	16.22	1.98		3.25	12.90	1.02		0.43	2.55	3.07		0.78	1.72	2.95	2.68	2.65	0.63	1.42	0.21	0.07

CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
18.34	3	90	10	6.247	0.282		1.242	2.676	0.266	2.700		1.042	1.051		0.249	0.829	0.864	0.017	0.600	0.083	0.183		
1.13	5	90	10				0.413			0.075		0.156	0.009		0.052	0.347		0.008		0.012	0.055	0.002	
42.51	11	90	10	3.902	4.425	0.200	3.966	19.147		4.714		0.659	1.029		0.582	0.497	1.352	0.672		0.038	0.043		1.250
11.16	12	90	10	1.231	0.384			8.931				0.124	0.355					0.036					0.096
15.11	13	90	10	1.053			2.001	5.560					3.320		0.348		0.766				1.278		0.778
88.25	TOTAL	90	10	12.43	5.09	0.20	7.62	36.31	0.27	7.49		1.98	5.76		1.23	1.67	2.98	0.73	0.60	0.13	1.56	0.00	2.12

23.12	3	91	10	2.379	0.948		5.063	3.366	0.053	1.586		0.754	0.236		0.458	0.386	1.413		5.685	0.215	0.243	0.321	
4.19	8	91	10	0.565	0.305		0.249	1.247				0.310	0.595		0.127	0.137	0.387		0.264				
17.53	11	91	10	5.396	2.191	0.070	2.356	3.453		0.123		0.705	0.773		0.174	0.266	0.582	0.447	0.270	0.205	0.074		0.435
0.00	12	91	10	0.000	0.000		0.000	0.001				0.000						0.000		0.000			0.000
37.57	13	91	10	3.761	0.571		2.341	3.633				0.631	0.500		0.522	0.699	0.421	3.806		1.548	18.360		0.751
82.41	TOTAL	91	10	12.10	4.02	0.07	10.01	11.70	0.05	1.71		2.40	2.10		1.28	1.49	2.80	4.25	6.22	1.97	18.68	0.32	1.19
12.10	3	92	10	4.107	0.411		0.519	2.021	0.939	1.349		0.751	0.488		0.025	0.159	0.310	0.085	0.835	0.007	0.054	0.031	
2.57	8	92	10	0.299	0.071		0.079	0.188	0.182	1.203		0.178	0.133		0.006	0.151	0.026		0.012	0.020		0.019	
38.60	11	92	10	6.415	1.347	0.100	1.903	19.590		0.255		1.857	1.517		0.351	0.178	0.791	0.888	0.112	0.915	0.174		2.185
21.58	12	92	10				0.248	17.980					0.498					0.261					2.587
11.81	13	92	10	3.668	0.282		0.920	3.617				0.119	0.412		0.950	0.151	0.185	1.245		0.119			0.136
86.66	TOTAL	92	10	14.49	2.11	0.10	3.67	43.40	1.12	2.81		2.90	3.05		1.33	0.64	1.31	2.48	0.96	1.06	0.23	0.05	4.91
6.26	3	93	10	3.255	0.124		0.550	0.527		0.019		0.333	0.698		0.113	0.181	0.116	0.018	0.152	0.004	0.164	0.003	
3.89	11	93	10	1.027			1.057	1.189				0.121				0.008		0.072					0.416
3.40	12	93	10	0.594			0.749	1.572					0.012				0.073						0.399
14.26	13	93	10	1.138	0.167		0.873	8.425		1.211		0.274	0.679			0.023	0.878	0.101			0.312		0.170
27.81	TOTAL	93	10	6.01	0.29		3.23	11.71		1.23		0.73	1.39		0.11	0.21	1.07	0.19	0.15	0.00	0.48	0.00	0.98
5.07	3	94	10	2.568	0.134		0.324	0.647		0.163		0.286	0.332		0.032	0.136	0.126		0.012	0.012	0.294		
10.36	4	94	10	2.069	0.249		0.089	3.156		2.983		0.384	0.238		0.016	0.373	0.207				0.573	0.019	
2.75	7	94	10	0.789	0.179		0.496	0.278				0.052	0.211		0.097	0.118	0.056		0.267	0.006	0.199		
1.16	8	94	10	0.750	0.061		0.001	0.200				0.098	0.011		0.004	0.023	0.011						
107.33	11	94	10	31.609	11.935	2.962	16.722	30.653		0.107		2.297	2.114		0.891	0.741	1.256	3.037	0.204	0.923	1.030		0.762
3.35	12	94	10	0.230	0.442		0.027	2.222									0.428						
61.21	13	94	10	5.417	12.964		2.197	30.789		1.475		0.226			0.312	0.563	0.918	3.342	0.539	0.294	1.022		1.108
191.23	TOTAL	94	10	43.43	25.97	2.96	19.86	67.95		4.73		3.34	2.91		1.35	1.95	3.00	6.38	1.02	1.23	3.12	0.02	1.87
165.38	1	91	11	3.837		0.645	21.764	23.699		64.961	1.488	10.766	7.541	4.680	2.861	1.852	0.248	0.033	8.881	0.579	10.783		0.662
43.23	2	91	11	0.333		0.013	8.460	4.103		16.038	0.623	1.556	1.660	1.297	0.791	0.281	0.268	0.022	1.846	0.316	5.594		
208.61	TOTAL	91	11	4.17		0.66	30.22	27.80		81.00	2.11	12.32	9.20	5.98	3.65	2.13	0.52	0.05	10.73	0.89	16.38		0.66
2.80	1	92	11	0.083			0.094	0.263		1.496		0.323	0.133	0.050	0.054	0.035	0.023		0.016		0.146		0.082
80.82	2	92	11	0.420	0.234	0.065	7.411	23.680		21.676	4.364	2.853	2.699	2.643	0.873	0.695	0.259		7.629	0.226	3.807		1.237
83.62	TOTAL	92	11	0.50	0.23	0.06	7.50	23.94		23.17	4.36	3.18	2.83	2.69	0.93	0.73	0.28		7.65	0.23	3.95		1.32
31.20	2	93	11	1.454	0.175	0.006	0.140	3.794		9.943	4.967	1.866	0.761	1.129	0.306	0.346	0.509		0.677		3.026		2.081
3.35	12	94	11	0.230		0.115	1.442	0.669				0.154						0.124		0.525			0.091
4.16	3	87	12		0.052		1.226	0.682	0.077			0.154	0.018		0.358	0.709			0.346	0.295	0.242		
0.20	1	91	12			0.008		0.049				0.017			0.007				0.101		0.019		
0.97	2	91	12				0.008	0.359		0.265		0.111	0.015	0.008	0.023	0.034	0.015		0.092		0.040		
1.17	TOTAL	91	12			0.01	0.01	0.41		0.27		0.13	0.02	0.01	0.03	0.03	0.02		0.19		0.06		
1.50	3	92	12				0.460	0.244		0.087		0.021	0.021		0.154	0.260	0.006		0.181		0.065		
6.75	13	92	12	0.022			4.404	1.353									0.203				0.767		
8.25	TOTAL	92	12	0.02			4.86	1.60		0.09		0.02	0.02		0.15	0.26	0.21		0.18		0.83		
4.57	2	93	12					1.167		0.968	0.048	0.739	0.043	0.238	0.078	0.220	0.013		0.289		0.653		0.112
3.40	12	93	12	0.231				1.497				0.097			0.051		0.063						1.460
7.97	TOTAL	93	12	0.23				2.66		0.97	0.05	0.84	0.04	0.24	0.13	0.22	0.08		0.29		0.65		1.57
63.82	3	85	13	0.945			10.243	7.920	0.842	0.389		2.278	2.163		9.662	1.704	0.300		26.377	0.160	0.804		
1.18	11	85	13				0.029	0.260			0.250	0.116				0.021							0.504
65.00	TOTAL	85	13	0.94			10.27	8.18	0.84	0.39	0.25	2.39	2.16		9.66	1.73	0.30		26.38	0.16	0.80		0.50
3.88	3	86	13	0.036			2.393	0.821	0.040			0.058	0.071		0.153	0.073	0.016		0.073		0.142		
2.43	4	86	13				0.682	0.830					0.035		0.586	0.296							
3.29	11	86	13				0.080	0.725			0.696	0.323				0.059							1.405
9.60	TOTAL	86	13	0.04			3.15	2.38	0.04		0.70	0.38	0.11		0.74	0.43	0.02		0.07		0.14		1.40
37.66	3	87	13	0.128			9.016	2.772	0.226	0.034		0.444	0.633		4.323	2.429	0.045		16.544	0.697	0.207	0.136	
7.97	4	87	13	0.038			2.548	0.470	0.011			0.069	0.112		0.714	0.570			3.341	0.092			
2.68	11	87	13				0.065	0.591			0.567	0.263				0.048							1.144
48.31	TOTAL	87	13	0.17			11.63	3.83	0.24	0.03	0.57	0.78	0.74		5.04	3.05	0.05		19.89	0.79	0.21	0.14	1.14
CATCH	Boatcode	Year	Sector	BOUR	BORD	THER	VARA	JOBG	JOBJ	BATR	LUTX	MACO	V.PL	TIOF	CROI	SERX	C.BL	G.LO	LASC	D.BE	CRO	BACS	LETX
33.44	3	88	13	0.043			10.768	3.939	0.485			0.077	0.425		3.501	3.571	0.013		10.467	0.007	0.130		
10.46	4	88	13	0.022			2.382	0.933				0.010	0.005		1.336	0.796			4.972				
2.39	11	88	13				0.058	0.527			0.506	0.235				0.043							1.021
46.29	TOTAL	88	13	0.07			13.21	5.40	0.48		0.51	0.32	0.43		4.84	4.41	0.01		15.44	0.01	0.13		1.02
14.66	3	89	13	0.343	0.362		2.960	1.047	4.363			0.500	0.522		0.472	0.517	0.007		2.558		0.998		
5.95	4	89	13	0.062			1.439		2.957			0.158	0.125		0.062	0.270	0.018		0.137		0.719		
15.96	11	89	13	1.266	0.091	0.284	2.091	1.223				0.021	0.401		4.271	0.793	0.324		2.276	1.037	0.184		1.690
36.57	TOTAL	89	13	1.67	0.45	0.28	6.49	2.27	7.32			0.68	1.05		4.80	1.58	0.35		4.97	1.04	1.90		1.69
18.12	3	90	13	2.502	0.147		2.747	0.718	0.111	0.719		0.547	0.821		1.863	2.046	0.190	0.355	4.516		0.826		
0.82	1	91	13			0.024	0.167	0.066		0.292		0.074	0.031	0.031	0.035	0.007	0.005		0.073		0.017		
17.51	2	91	13	0.180		0.093	2.278	1.471		7.904		0.998	0.417	0.294	0.214	0.065	0.133	0.014	0.564	0.019	2.735		0.121
5.45	3	91	13				2.859	1.744	0.017			0.109	0.109		0.204	0.026			0.196		0.058	0.126	
7.16	4	91	13	0.322			2.131	0.560	0.387	1.052		0.144	0.819		0.007	0.313	0.125		0.040		1.257		

8.00	7	91	13	0.060			2.286	0.850	0.311	0.134		0.086	0.850		0.294	0.357	0.097		2.151	0.377	0.144		
2.87	8	91	13				0.321	0.066		0.021		0.015	0.556		0.024	0.026			0.003		1.837		
4.66	9	91	13				0.688	0.301	0.367	2.270		0.131	0.080			0.170			0.049		0.601		
26.76	10	91	13				6.377	0.634	0.241	1.798			2.213		0.268	2.352	0.083		0.393		12.208	0.177	
13.26	13	91	13				9.639	2.588					0.091		0.369		0.224		0.207	0.138			
86.49	TOTAL	91	13	0.56		0.12	26.74	8.28	1.32	13.47		1.56	5.17	0.32	1.41	3.32	0.67	0.01	3.68	0.53	18.86	0.30	0.12
10.41	1	92	13	0.051		0.012	1.383	0.550		4.756	0.150	1.182	0.278	0.404	0.182	0.363	0.073		0.141	0.017	0.428		0.432
106.83	2	92	13	2.179	0.128	0.182	9.241	7.361		54.611	0.363	8.205	3.055	3.921	0.844	2.073	1.154		1.079	0.021	8.493		3.835
15.21	3	92	13	0.700	0.373		4.376	1.667		2.158		0.400	0.653		0.163	1.054	0.205	0.116	0.794	0.085	2.359	0.099	
23.02	4	92	13	0.725	1.312		2.919	5.389	0.470	7.555		1.031	0.893		0.032	0.879	0.249		0.062		1.473	0.016	
2.11	7	92	13	0.756	0.043		0.004	0.379	0.042	0.367		0.095	0.130			0.018	0.230				0.044		
3.42	10	92	13	0.008	0.044			0.508	0.352	1.729		0.302	0.447				0.018					0.011	
161.00	TOTAL	92	13	4.42	1.90	0.19	17.92	15.85	0.86	71.18	0.51	11.21	5.46	4.32	1.22	4.39	1.93	0.12	2.08	0.12	12.80	0.13	4.27
5.08	3	93	13	0.324			0.909	0.212	0.741	0.152		0.158	0.739		0.372	0.780	0.050		0.015		0.623		
4.04	4	93	13	1.276	0.716		0.074	0.703		0.494		0.192	0.114		0.012	0.048	0.322				0.088		
7.79	10	93	13				3.024	1.637		0.809		0.005			0.340	0.814	0.375	0.053	0.263	0.076	0.353	0.036	
16.91	TOTAL	93	13	1.60	0.72		4.01	2.55	0.74	1.46		0.36	0.85		0.72	1.64	0.75	0.05	0.28	0.08	1.06	0.04	
11.82	3	94	13	1.466	0.116		2.158	1.056		0.942		0.361	0.637		0.241	1.768	0.272	0.098	1.181		1.446	0.071	
12.37	4	94	13	1.728	0.033		2.213	3.057		1.784		0.628	0.315		0.318	0.946	0.139	0.005	0.803	0.005	0.364	0.022	
6.63	6	94	13	0.065			0.290	0.618		3.264		0.951	0.267		0.122	0.602	0.056		0.023	0.011	0.316	0.040	
2.11	7	94	13	0.165			0.094	0.480				0.008			0.388	0.375			0.599				
1.25	8	94	13	0.163	0.030		0.024	0.337		0.563		0.019				0.066	0.007				0.042		
1.03	9	94	13				0.082						0.039			0.134					0.774		
23.95	10	94	13	0.115			4.656	1.126		7.343		0.525	1.851		0.989	3.456	0.062		0.084	0.053	3.389	0.287	
59.16	TOTAL	94	13	3.70	0.18		9.52	6.67		13.90		2.49	3.11		2.06	7.35	0.54	0.10	2.69	0.07	6.33	0.42	
2.05	1	91	14			0.010	0.392	0.137		0.017		0.055	0.258		0.129	0.177	0.020		0.436		0.418		
40.21	2	91	14			0.032	8.533	2.035		3.788	0.036	1.645	5.521	0.016	1.275	3.506	0.438	0.076	2.135		11.126		0.028
17.70	10	91	14		0.404		3.690	0.150	0.051			0.255				2.030				0.012	11.048	0.053	
59.96	TOTAL	91	14		0.40	0.04	12.62	2.32	0.05	3.80	0.04	1.95	5.78	0.02	1.40	5.71	0.46	0.08	2.57	0.01	22.59	0.05	0.03
7.16	1	92	14									0.505	0.099		0.002	0.018					6.304		0.231
288.94	2	92	14			0.058	13.956	15.921		31.003	15.632	12.771	27.160	0.982	3.756	9.708	0.087	0.896	14.967	0.838	129.127		11.904
5.38	10	92	14				1.269	0.066		0.178		0.007	0.133		0.051	0.784		0.032	0.016	0.009	2.832		
301.48	TOTAL	92	14			0.06	15.22	15.99		31.18	15.63	13.28	27.39	0.98	3.81	10.51	0.09	0.93	14.98	0.85	138.26		12.14
5.48	1	93	14			0.001	0.136	0.010					0.197		0.162	0.772					4.199		
12.75	2	93	14				1.219	0.746			1.600	0.643	1.200	0.020	0.200	0.572					4.938		1.607
18.23	TOTAL	93	14			0.00	1.36	0.76			1.60	0.64	1.40	0.02	0.36	1.34					9.14		1.61
20.86	2	92	15			0.042		0.676		4.723	0.044	2.082	1.992	0.010	0.277	2.126	0.002	0.002	0.006		7.618		1.250
0.32	1	93	99					0.008		0.266		0.018	0.021		0.001	0.002							0.004
225.42	2	93	99	0.271				6.131		183.176	0.744	6.650	12.015	7.822	0.586	2.592		1.037	2.863		0.068		1.330
13.55	10	93	99	0.611	0.129		1.575	0.749		6.957		0.430	1.255		0.079	1.287	0.009				0.378	0.085	
239.29	TOTAL	93	99	0.88	0.13		1.57	6.89		190.40	0.74	7.10	13.29	7.82	0.67	3.88	0.01	1.04	2.86		0.45	0.09	1.33

Figure A.1.1 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from the Mahe Plateau (Sectors 1-10).

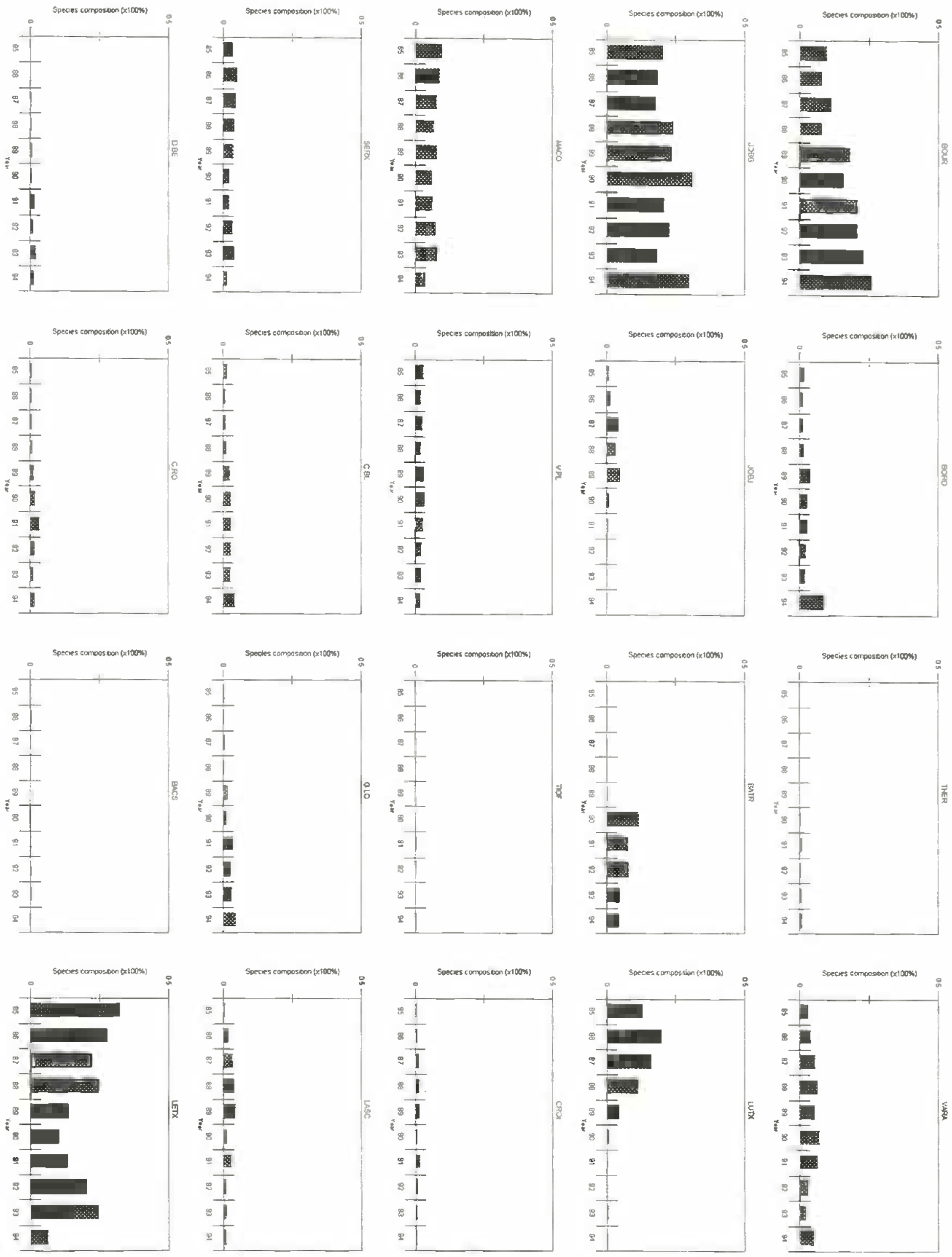


Figure A.1.2 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 1.

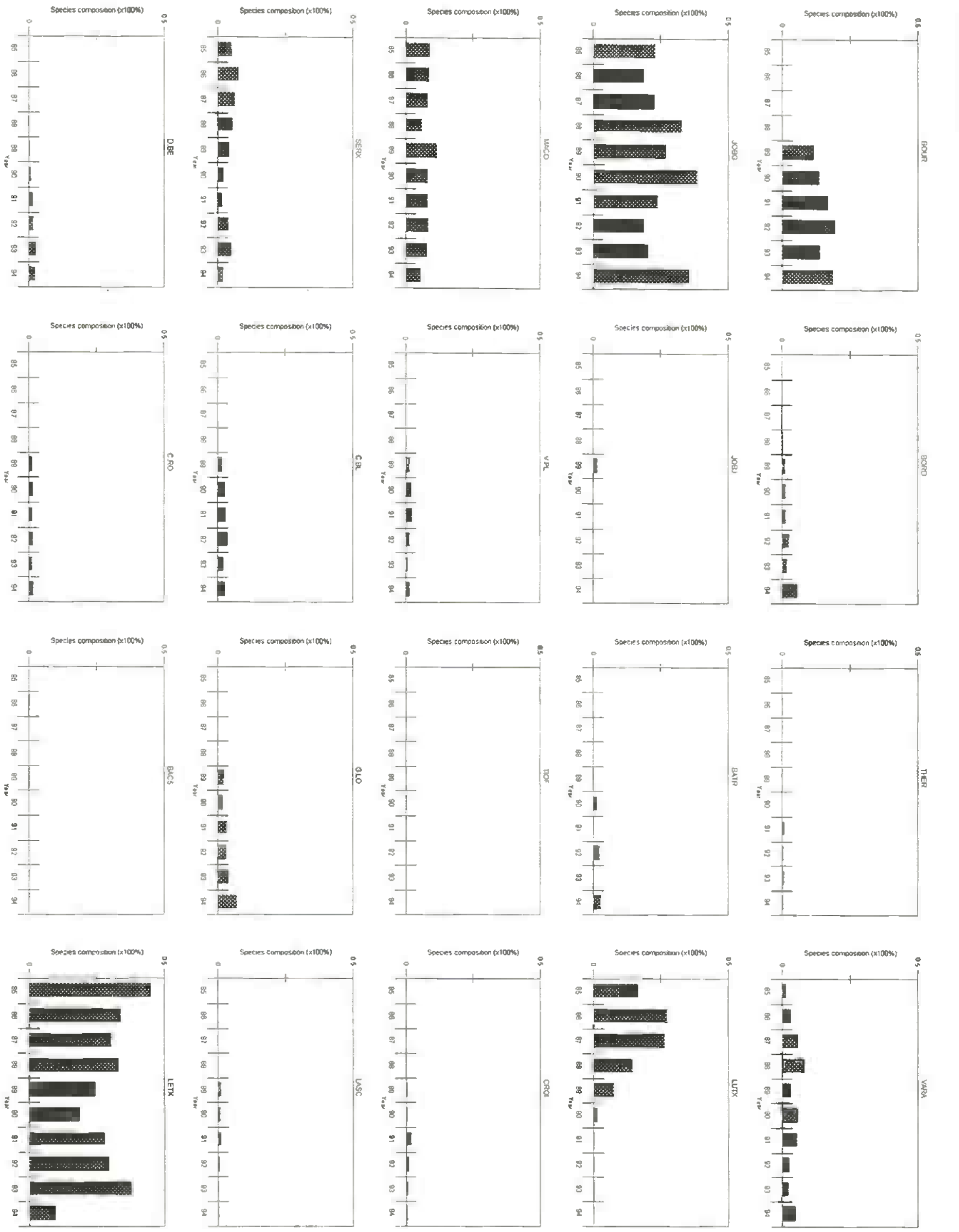


Figure A.1.3 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 2.

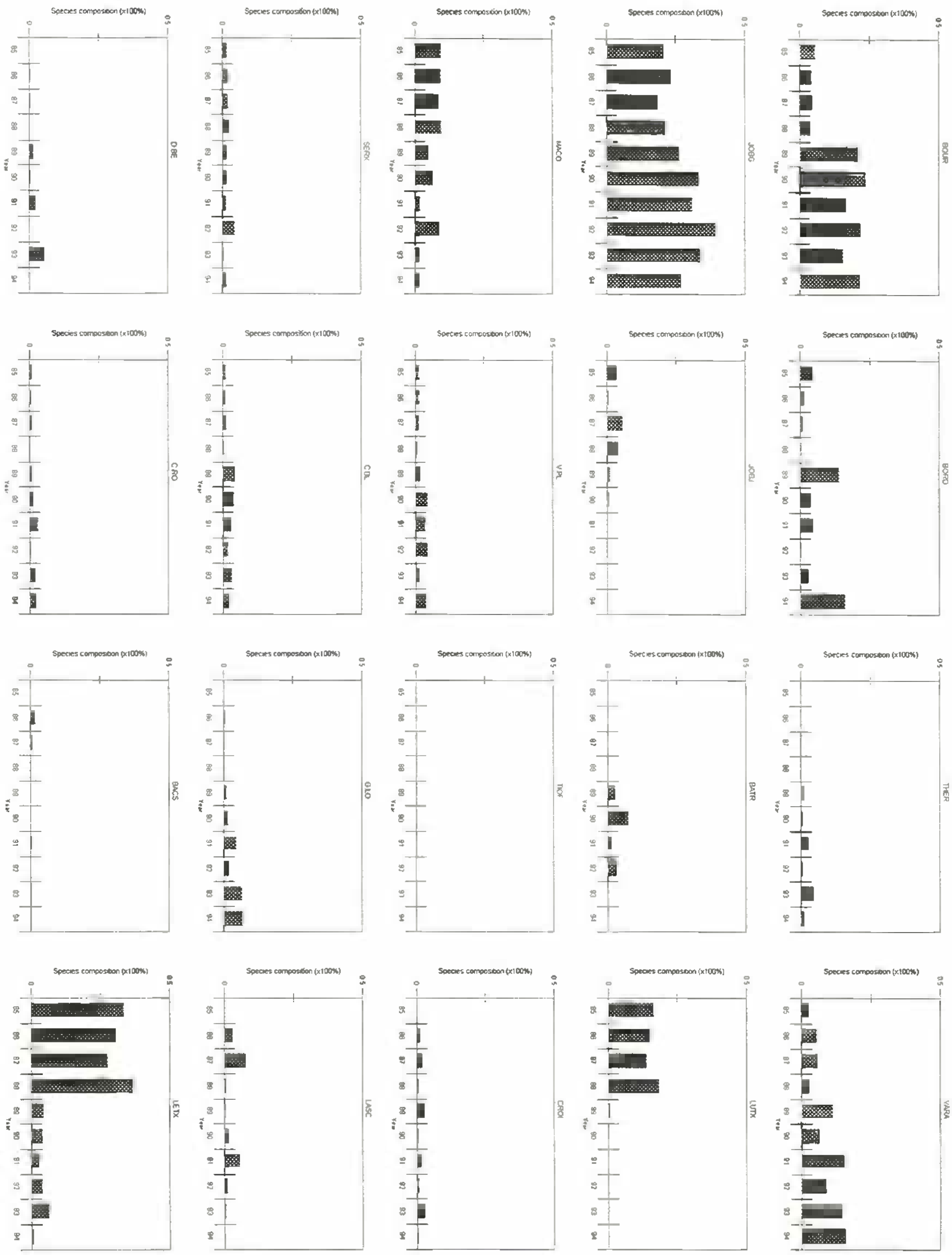


Figure A.1.4 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 3.

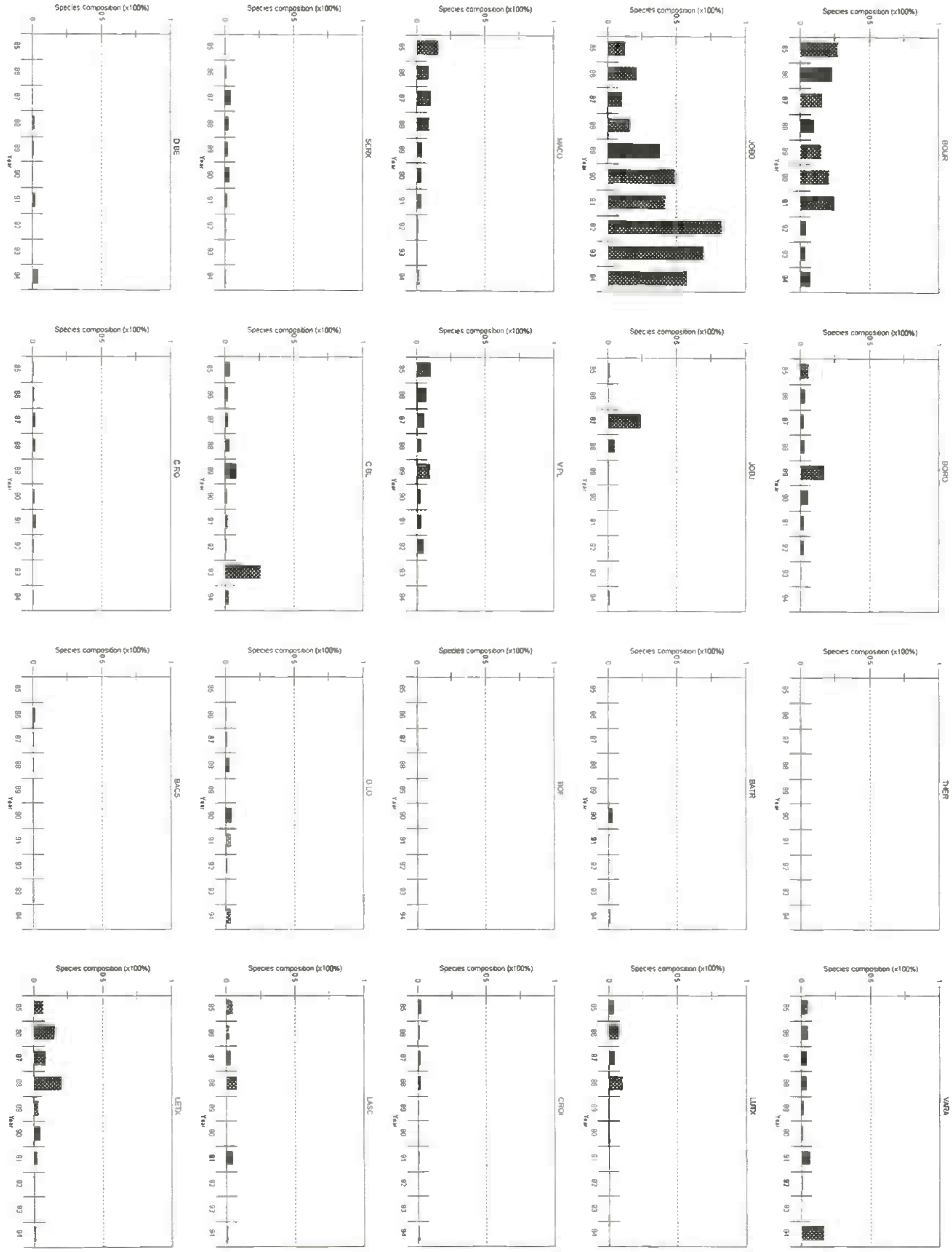


Figure A.1.5 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 4.

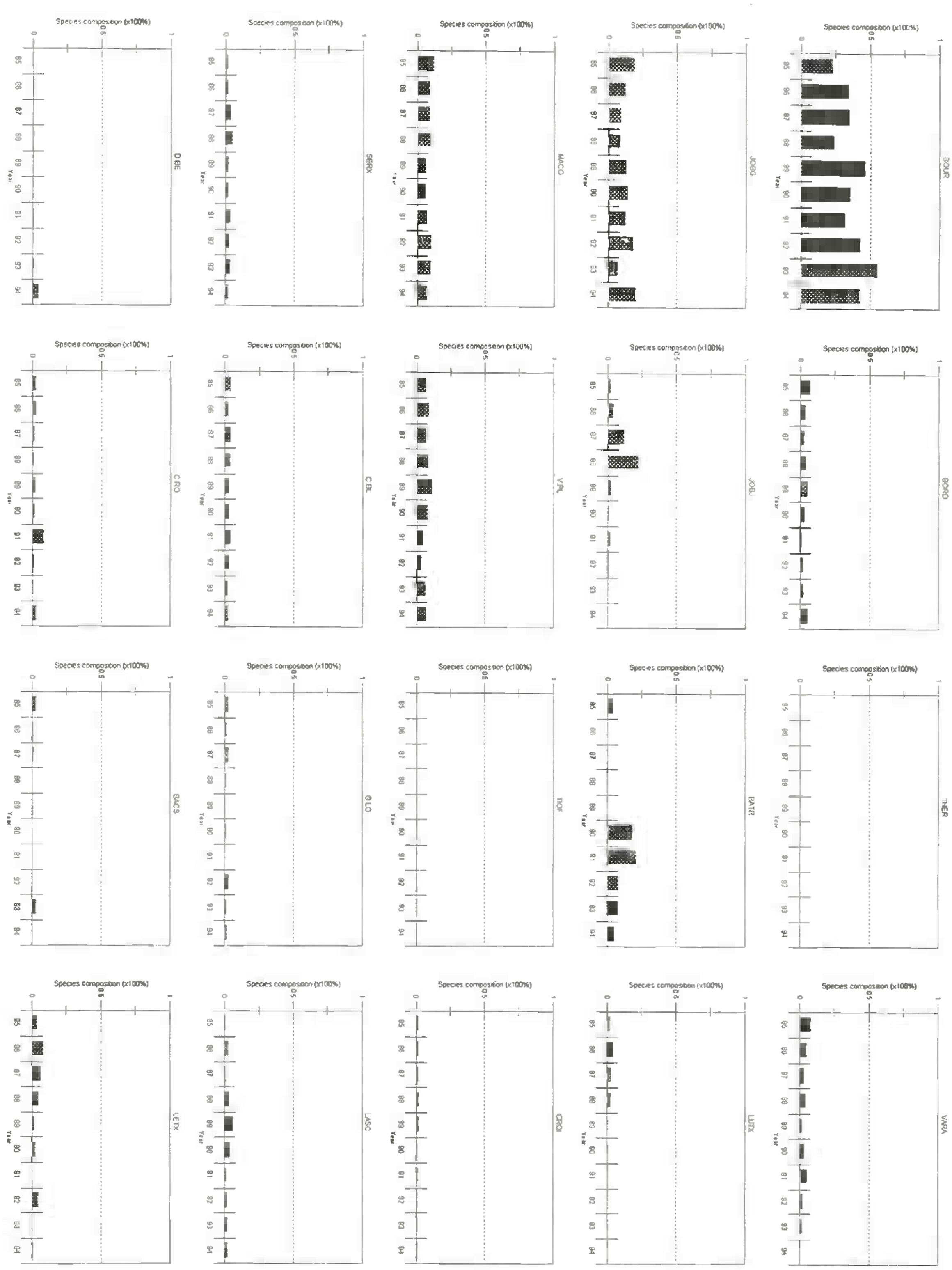


Figure A.1.6 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 5.

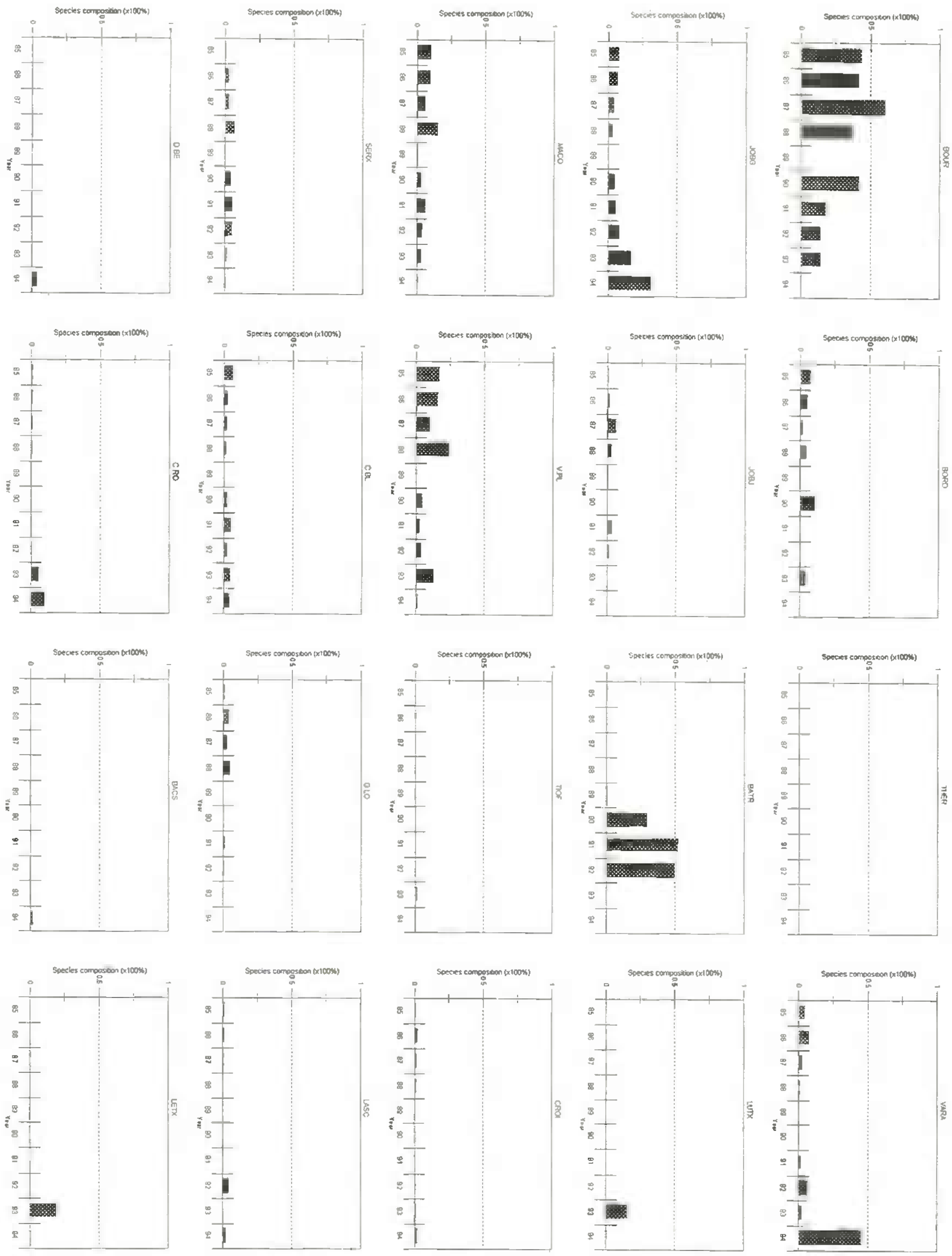


Figure A.1.7 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 6.

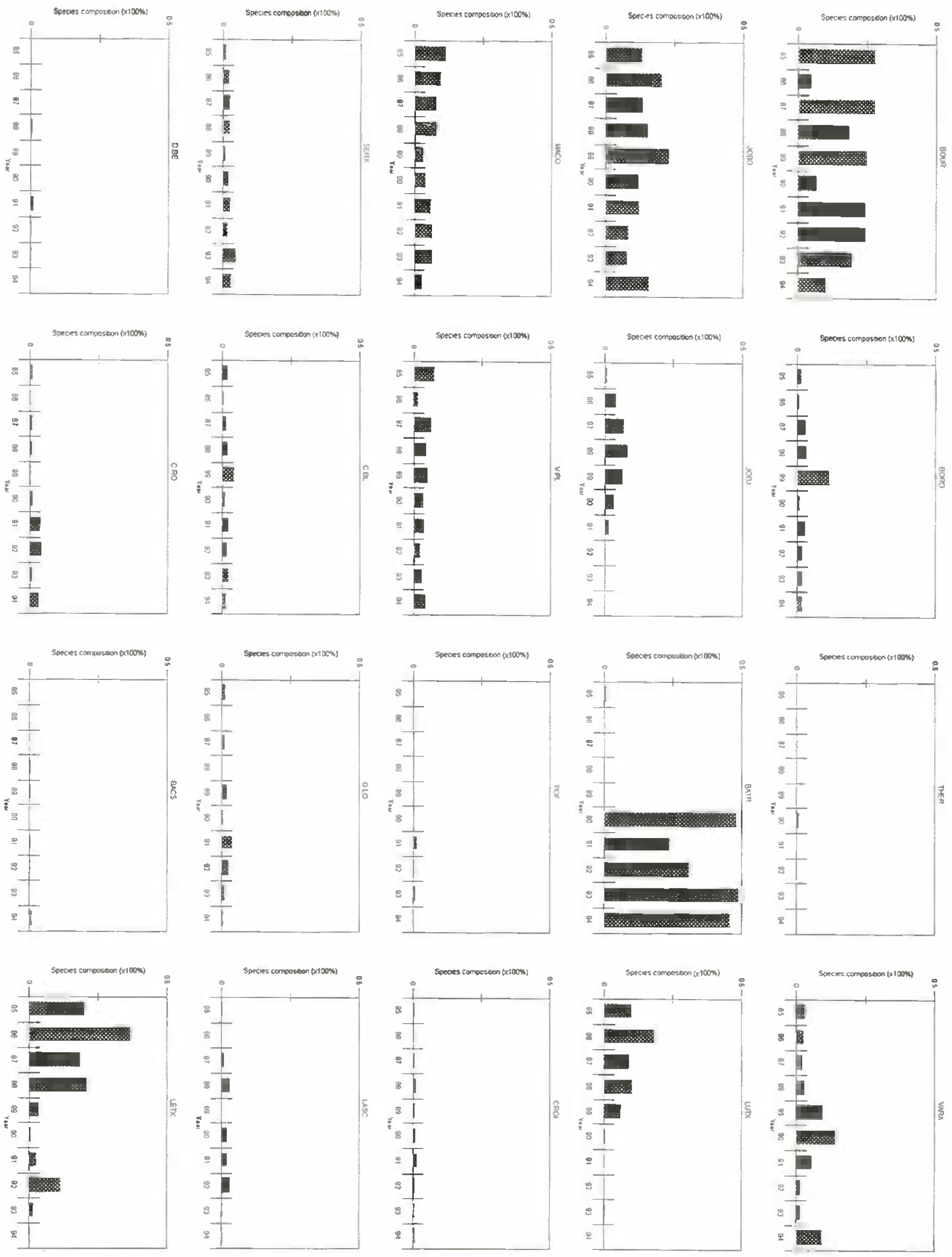


Figure A.1.8 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 7.

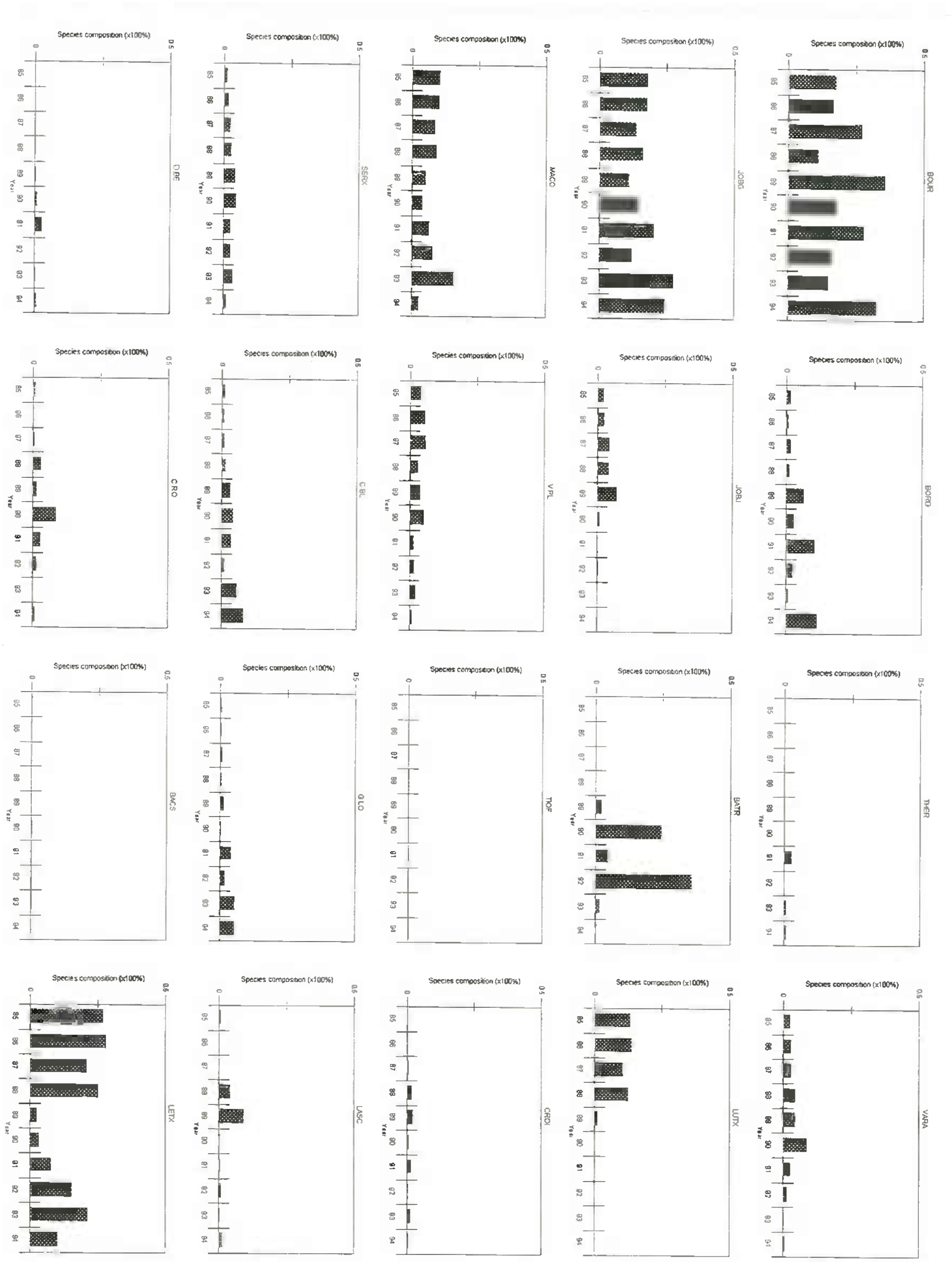


Figure A.1.9 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 8.

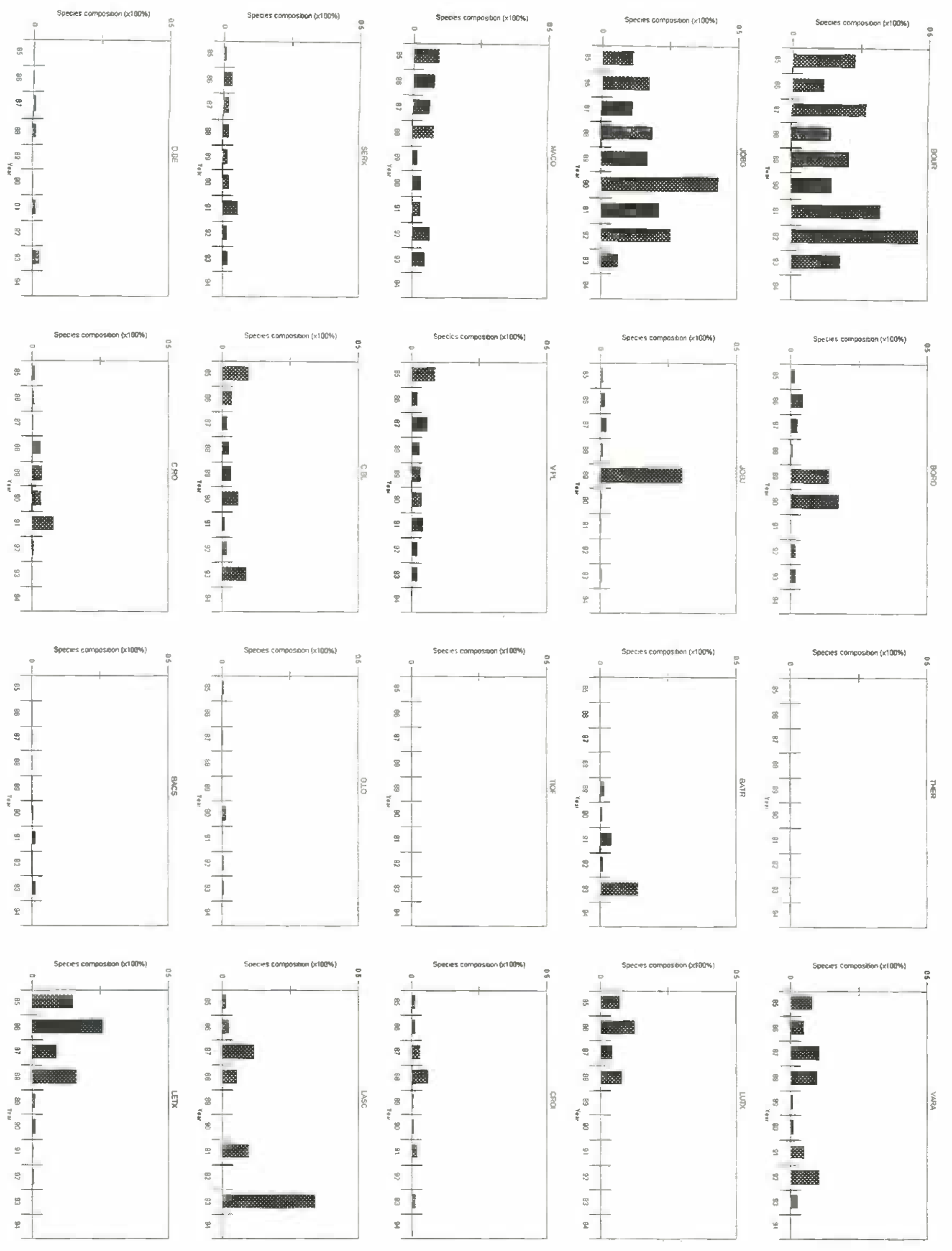


Figure A.1.10 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 9.

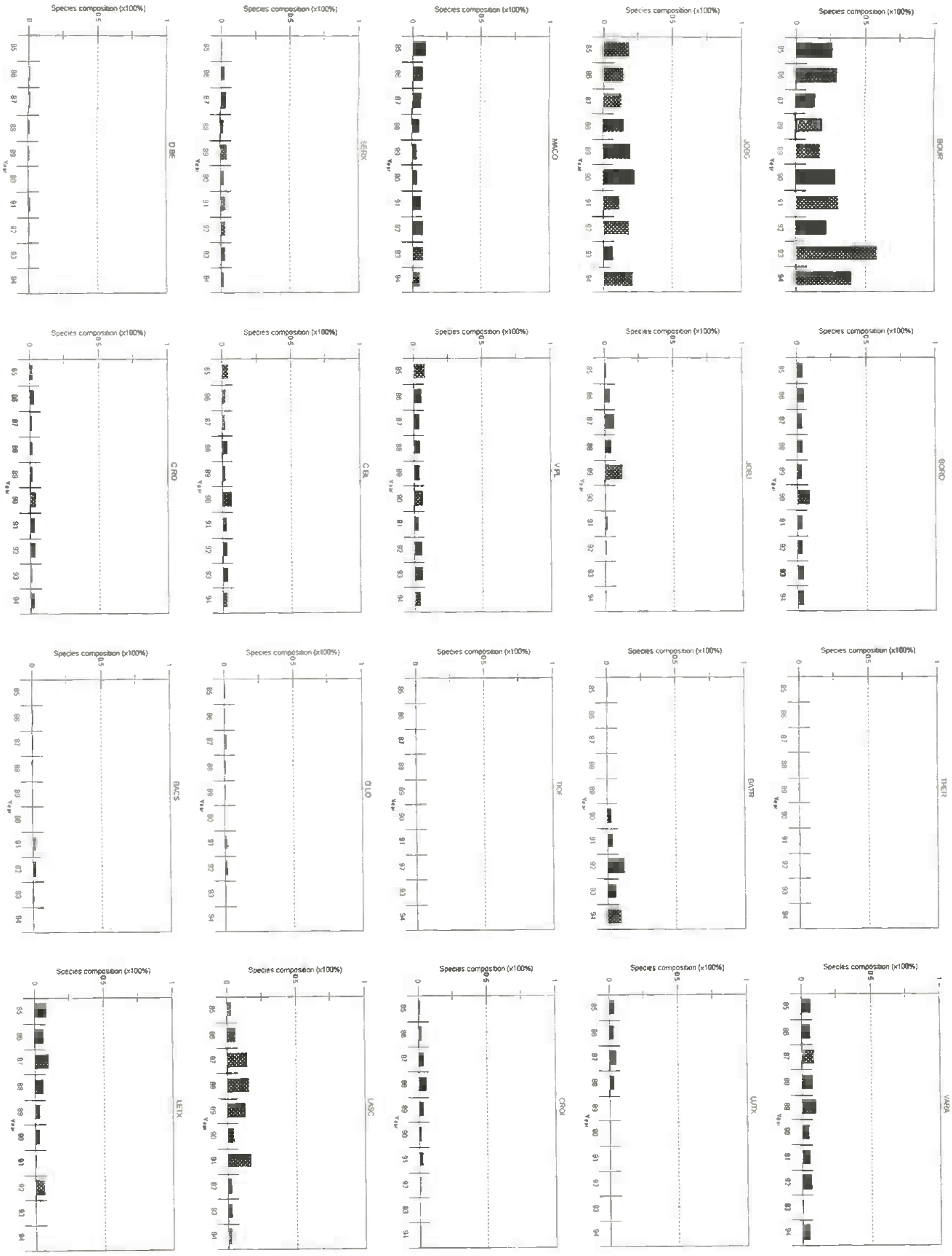


Figure A.1.11 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 10.

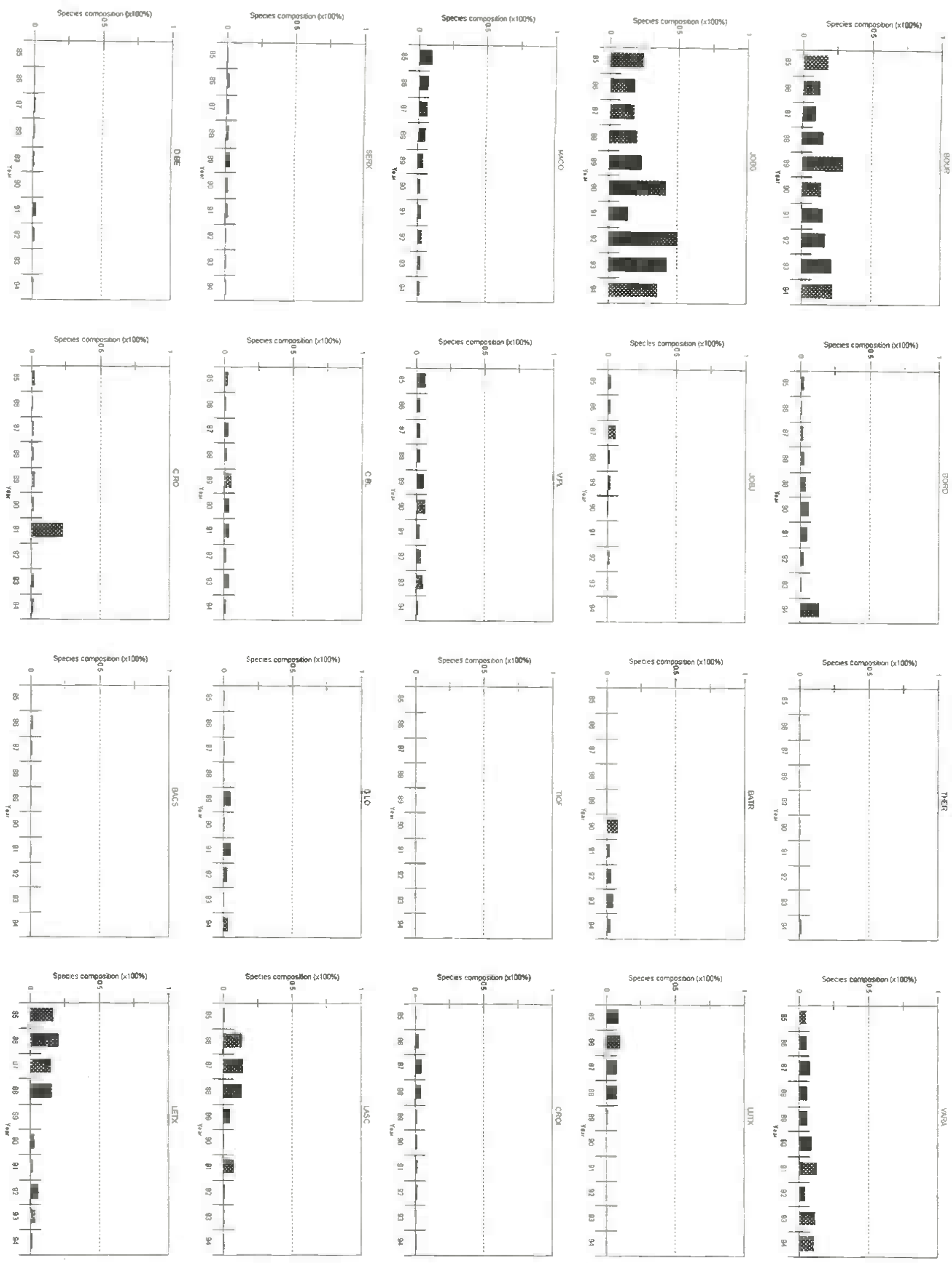


Figure A.1.12 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 11.

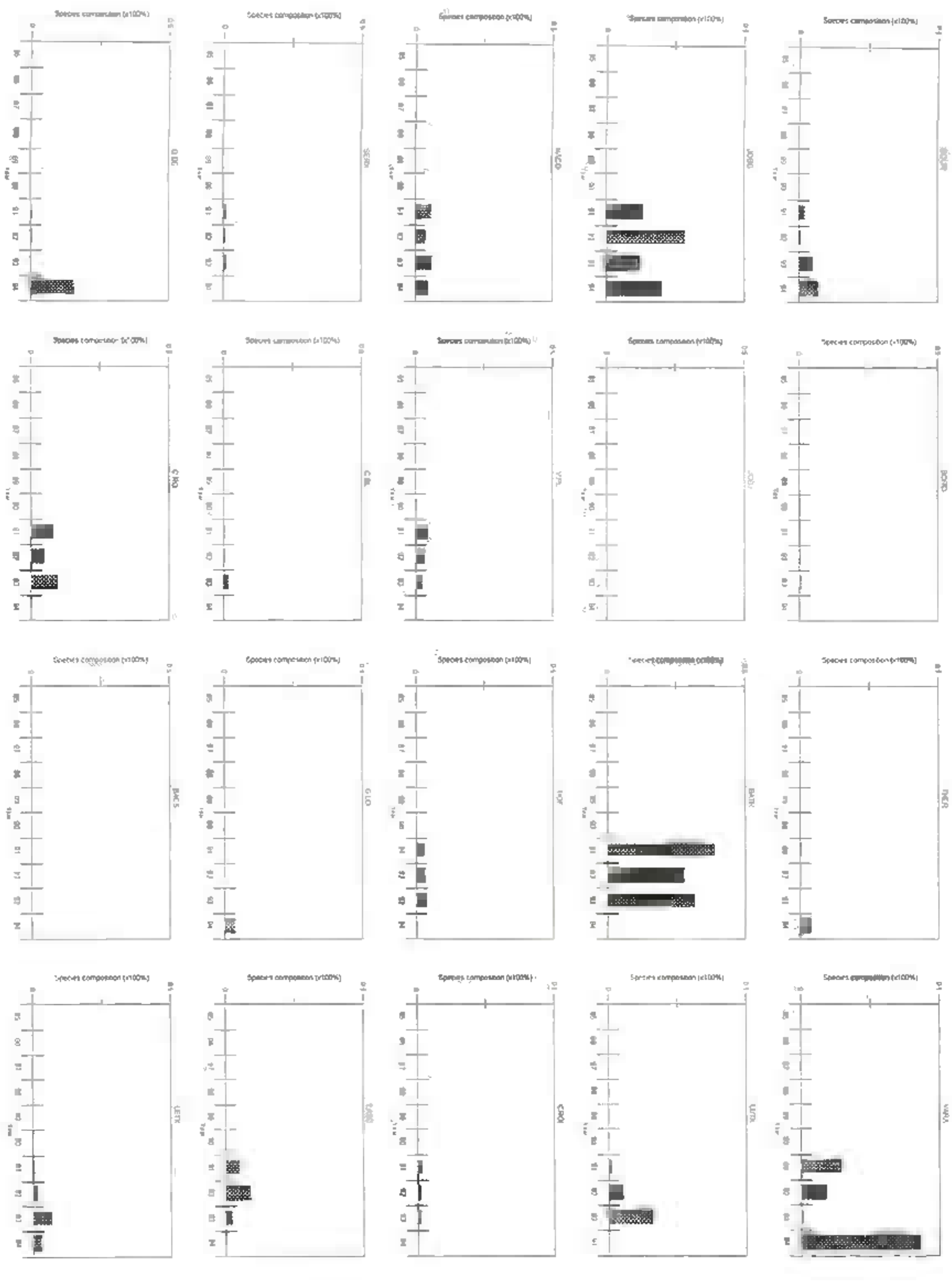


Figure A.1.13 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 12.

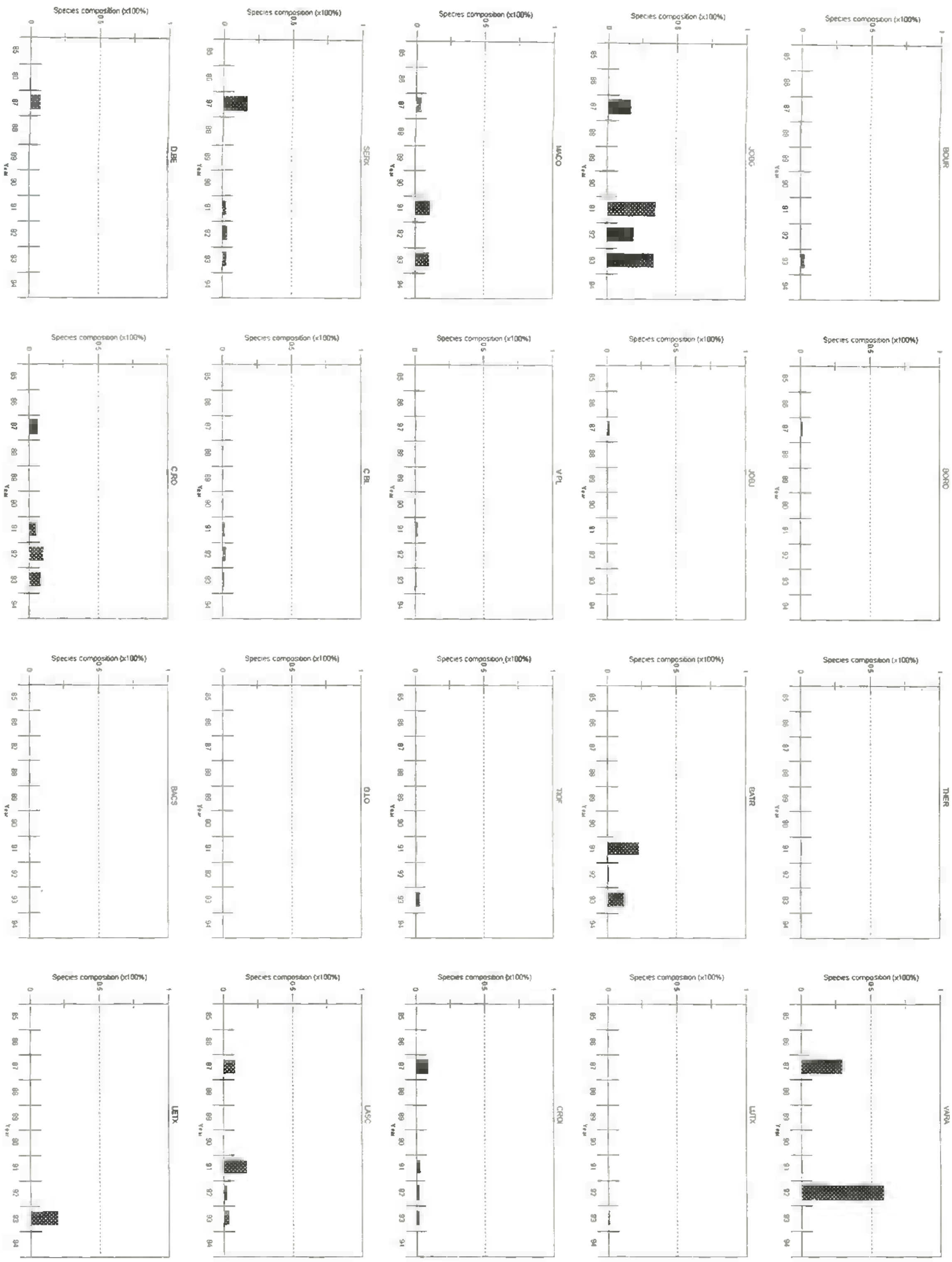


Figure A.1.14 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 13.

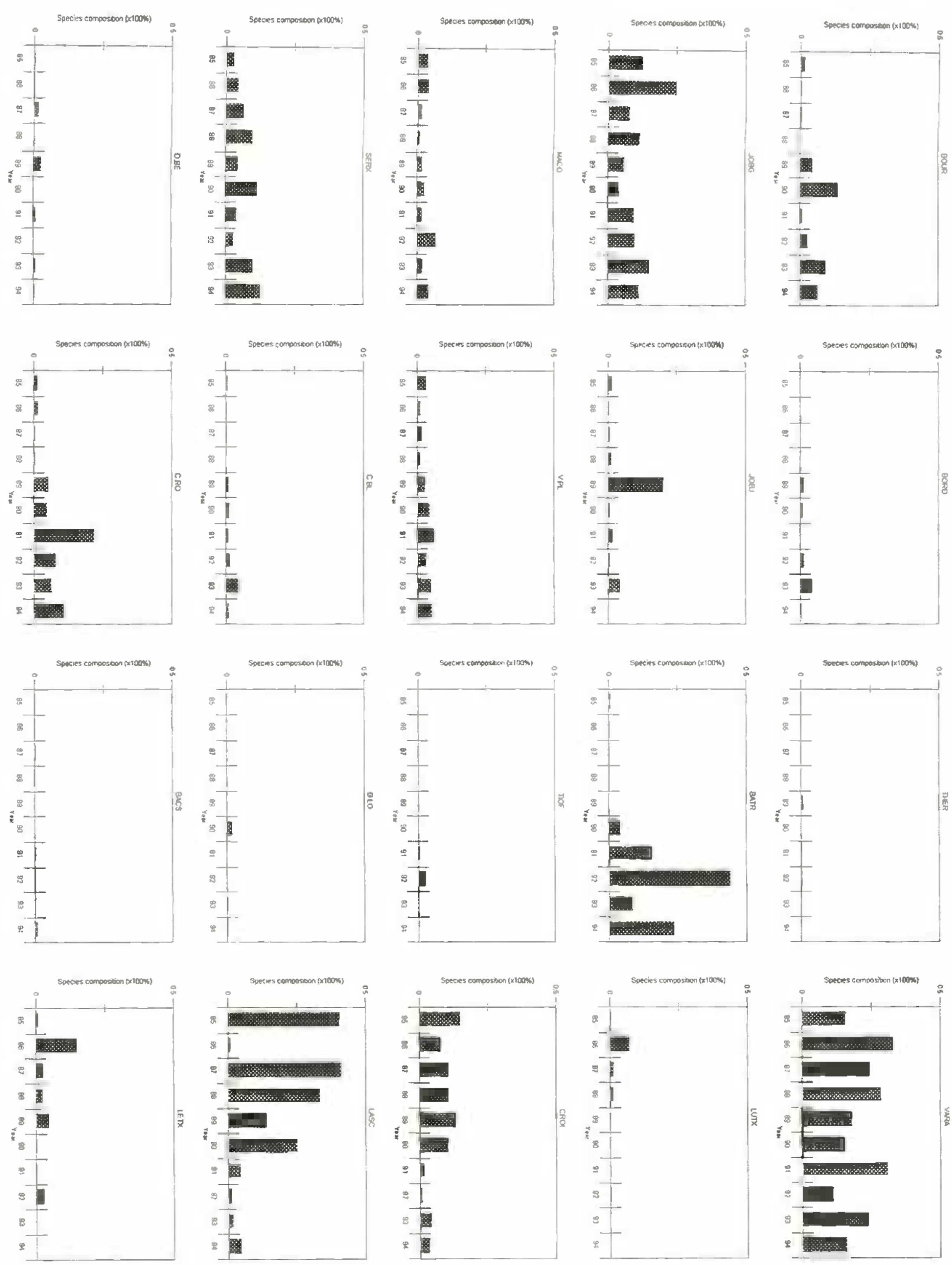


Figure A.1.15 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 14.

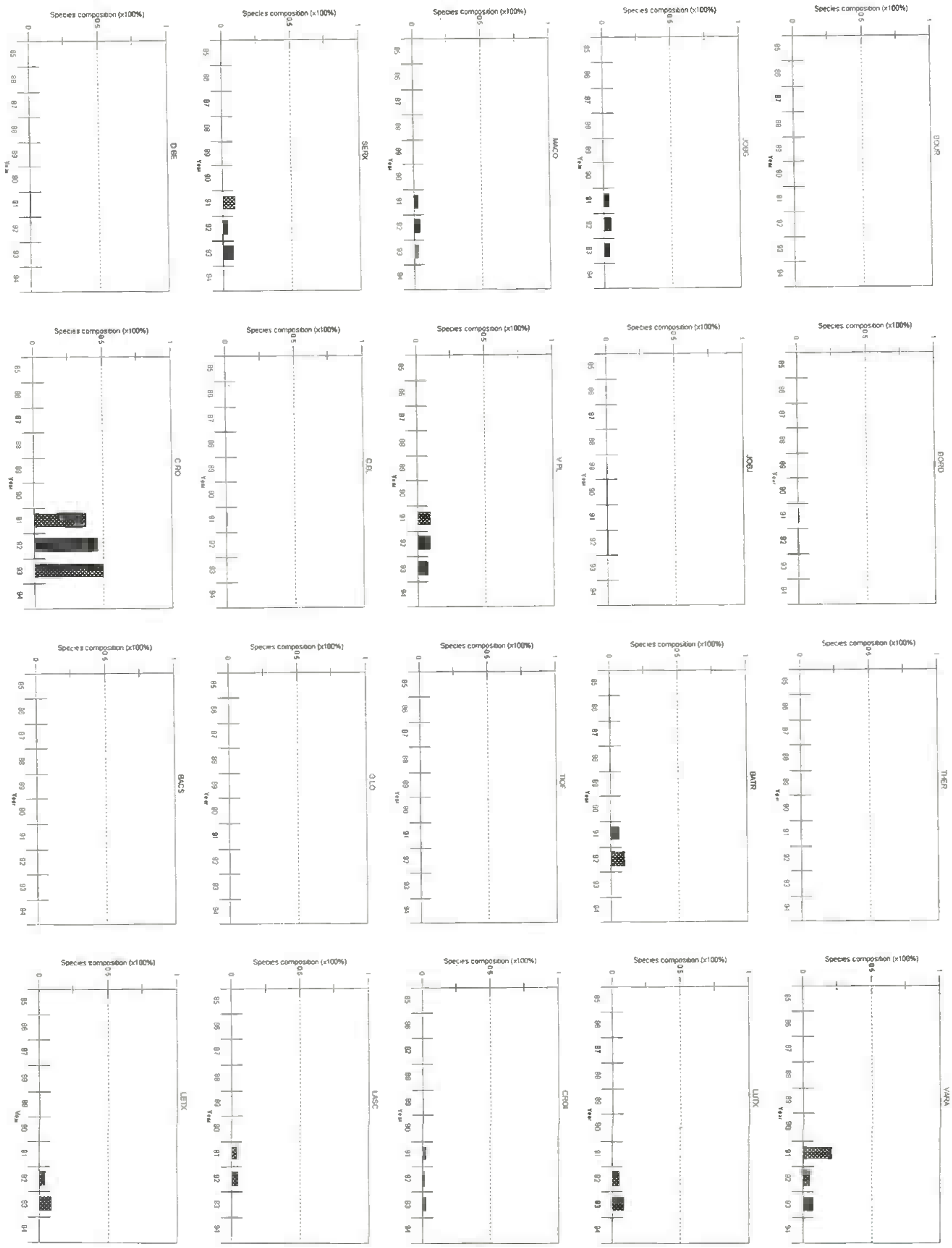
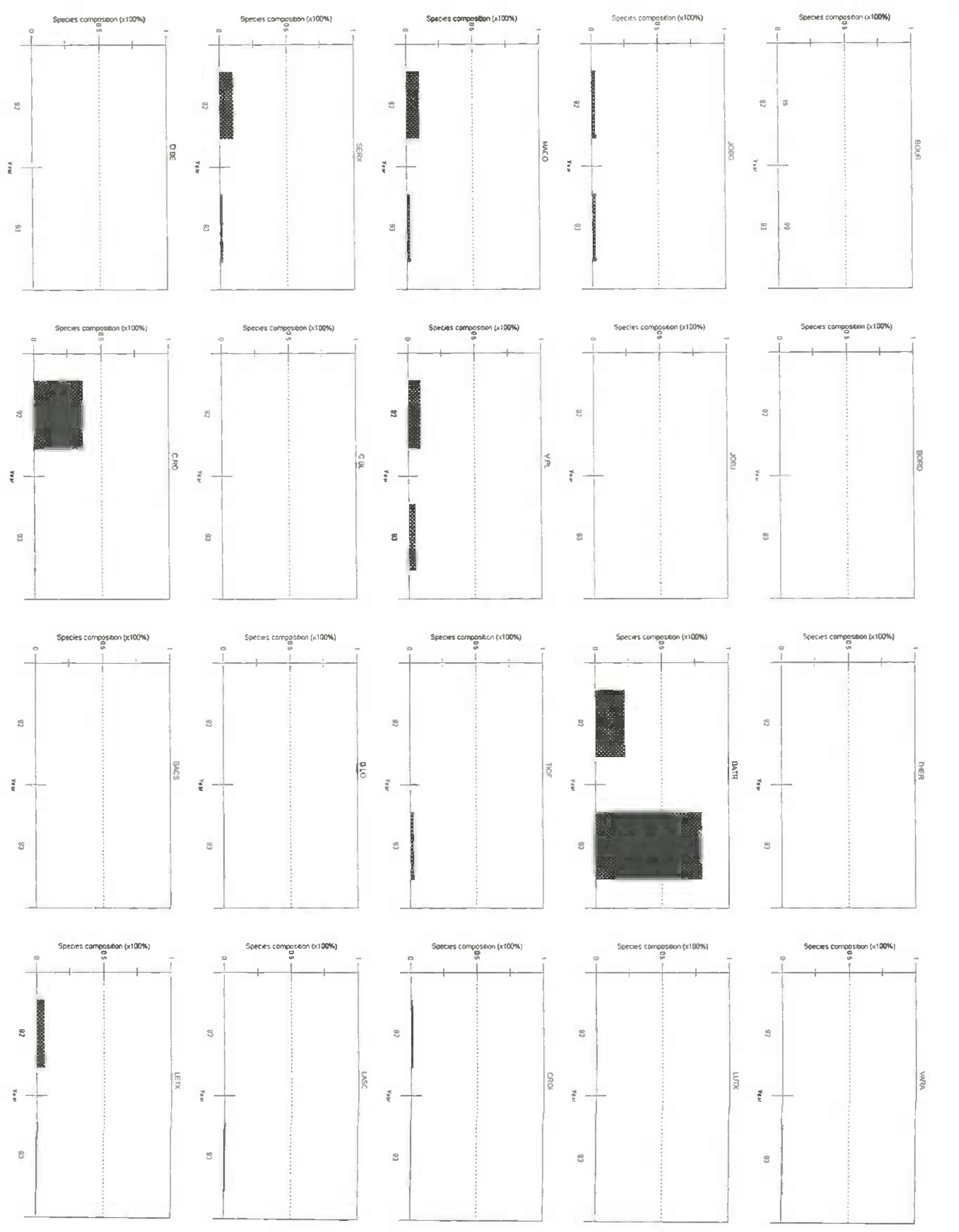


Figure A.1.16 : Species composition of the total demersal fish catch landed by all boat-gear types annually (1985-1994) from Sector 15 in 1992 and Sector 99 in 1993.



ANNEX 2 : CATCH AND EFFORT DATA FOR TRADITIONAL WHALERS IN SECTOR 1.

Sector 1, the inshore area of Mahe Plateau, was subject to the greatest fishing pressure. Schooners rarely fished in this location except during rough weather during the SE Trade Winds and consistent data was only available for small boats and whalers. Unfortunately these data sets were the least good in terms of data quality, lacking much species definition, location specific-, depth- and other details. During July 1989 an improved data collection system was introduced for the whalers, and this was incorporated fully into the SFA data collection programme in 1990. It is this data set which offers the most scope for examination of multi-species fisheries problems within sector 1, and which is now analysed in depth.

Initially data from 1989 to 1993 was analysed and apparently indicated both significant depletion and possible multi species interactions. The Fox biomass dynamic production model was applied to this data. However, the total catch and catch rate data appeared to be inconsistent - catches in 1993 remained high despite a huge decrease in catch rate, suggesting a 20 times increase in effort. This questioned the validity of the raised catch values, and indicated that perhaps misreporting of location had resulted in a greater catch being attributed to sector 1 than was the case. Next, when data for 1994 became available this was included in the analysis but an unexpected recovery of the resource was indicated. A number of explanations were investigated (change of gear, strong recruitment, shift of location, misreporting of location). On interviewing the data collectors it transpired that certain fishing area codes which combined an island and a direction had been interpreted on data entry as fishing close to that island and therefore within sector 1, whilst the data collectors intention was to indicate that fishing had occurred at the edge of the plateau, outside sector 1. This explained some of the anomalies in the analyses and a third analysis of the data was performed for data from 1989-1994 excluding all data points for which the precise location was in doubt. Only this latter analysis is presented.

ANNEX 2A: SELECTION OF DATA SET.

Boat type

There are four categories of whaler. Significantly different catch rates were observed for each category, but rather than standardise for boat type (since sample size for certain boat types was small within year and season) analyses were performed on traditional whalers only. Those boats catching 85% or more demersal species were considered to be targeting demersal fish whilst those catching no demersal species were considered to be targeting carangids (see Annex 2B below)

Fishing location :

Reporting of fishing location on catch records by whalers was poor and a large number of data have been excluded from the analysis for lack of this information. Specific locations reported relate to the nearest island, or a direction from an island within sector 1 (Table A.2.1). Those locations for which a direction was indicated may not be within sector 1 and so were excluded from the analysis. The possibility that these locations are on the edge of the Plateau is supported by the observation that mean trip length was greater for these locations than those undisputably within sector 1 (Table A.2.1).

Unstandardised (observed) catch rates by specific location are indicated in Figs. A.2.1-5. Few individual locations indicated a decline in catch rate and at the level of individual 'fishing grounds' there are few sampled data each year (frequently 1-5, Table A.2.1). Also, whilst analyses relating to specific locations are the ideal, those reported by whalers are vague and the area fished cannot be determined accurately. It is thus necessary to assume that within sector 1 full mixing of demersal species occurs and that they may be treated as single populations (see 3.3). Aggregated data may then be used for further analysis, and this is the approach adopted subsequently.

Seasonality

Data was arranged according to season (see 5.2), and scatter plots of catch rate for the subset of data analysed indicated that this factor apparently affected catch rates (Fig. A.2.6). Standardisation for seasonal effects was performed. Scatter plots of annual data are also indicated (Fig A.2.7).

Species

Species catch rates for data aggregated over all of Sector 1 for traditional whalers catching at least 85% demersal species indicated that the most important demersal species were Bourgeois and Job Gris for lutjanids, Maconde for serranids and Capitaine Blanc, Guelle Longue and Dame Berrie for lethrinids (Table A.2.3). In addition to these individual species guilds of the remaining lutjanids, lethrinids and serranids were examined. Additionally guilds of all lutjanids, all lethrinids, all serranids and all demersal species were analysed. Carangue balo was the most important of the other species.

Table A2.1 : The number of sampled fishing trips made by traditional whalers catching 85% or more demersal species, and the mean trip length (days) by location for : A. Those fishing areas definitely within sector 1, and B. Those fishing areas which may in fact be outside sector 1.

	Number of trips sampled per annum							Mean days per fishing trip						
Area	89	90	91	92	93	94	Total	89	90	91	92	93	94	Total
A.														
ANN	6	4	8	4	4	1	27	1	1	1	1	1	1	1
ARI	1	1	0	0	2	0	4	1	3			1.5		1.8
COU	1	0	0	1	0	0	2	3			1			2
FRE	0	16	5	4	14	4	43		2.8	2.6	2.3	1.4	1	2.1
IAR	0	1	4	1	1	0	7		1	1	1	1		1
ILO	0	0	1	0	0	0	1			1				1
KAR	0	0	0	1	0	0	1				1			1
LD	0	1	0	0	0	0	1		1					1
MAH	4	3	4	25	39	11	86	1	1.7	1	1.4	1	1	1.1
MAM	7	20	21	14	6	2	70	1	1	1	1	1	1	1
MAR	1	1	0	0	0	0	2	3	2					2.5
NOR	2	0	0	0	0	0	2	2						2
PRA	0	2	4	2	0	2	10		1	1	1		1	1
REC	1	0	0	6	3	0	10	1			1.2	1		1.1
REQ	0	1	0	4	1	0	6		1		1.5	1		1.2
RON	1	0	0	0	0	0	1	1						1
SIL	0	1	3	0	2	0	6		4	3.7		1		2.7
B.														
ME	1	1	0	0	0	0	2	1	4					2.5
MN	0	1	0	0	0	0	1		1					1
MNE	2	0	1	0	0	0	3	3		3				3
MNW	1	2	2	0	0	2	7	5	4.5	3			3	3.7
MS	4	1	3	0	5	7	20	1.5	1	3.3		1	1.9	1.8
MSE	5	4	15	1	4	0	29	1.8	2.8	1.8	6	1.3		2
MSW	1	1	1	0	0	0	3	4	1	1				2
MW	8	2	1	0	0	1	12	1.5	1	4			3	1.8
PNE	0	3	0	0	0	0	3		3					3
PNW	0	2	0	0	0	0	2		3					3
PS	2	2	0	0	0	0	4	1	1.5					1.3
PSE	0	1	0	0	0	0	1		1					1
PW	1	3	0	0	0	0	4	3	1					1.5
Total	49	74	73	63	81	30	370	1.6	1.9	1.6	1.3	1.1	1.4	1.5

Figures A2.1-5 : Catch rates (kg / man-day) for all demersal species by reported fishing location within sector 1 (and those indicated by a direction, possibly outside sector 1) for traditional whalers landing a catch of which 85% was demersal species. These data have not been standardised for seasonal effects (known to be significant, see below).

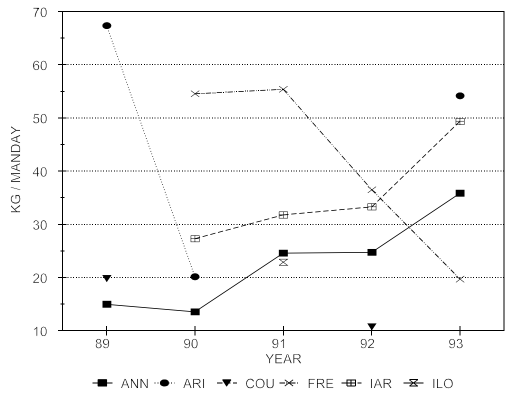


Fig. A.2.1.

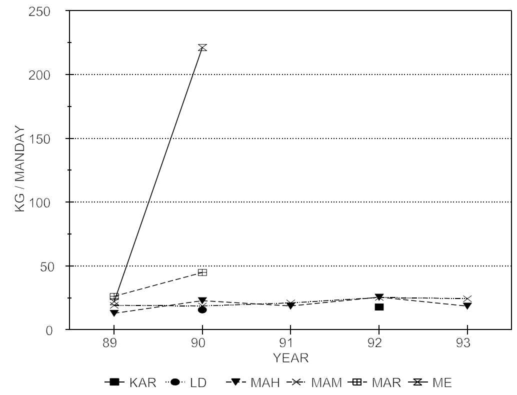


Fig. A.2.2.

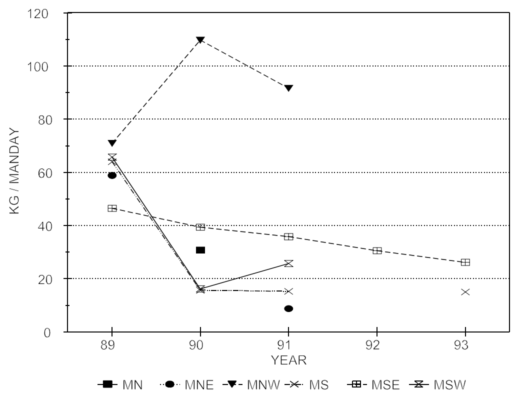


Fig A.2.3.

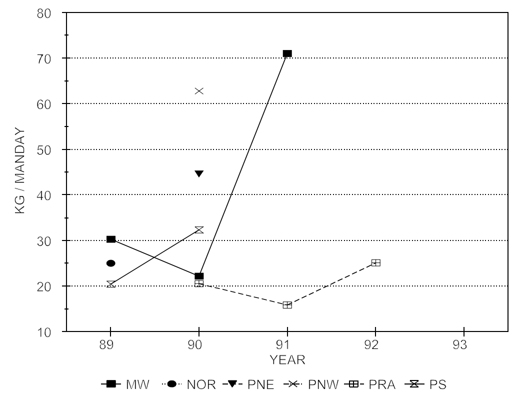


Fig. A.2.4.

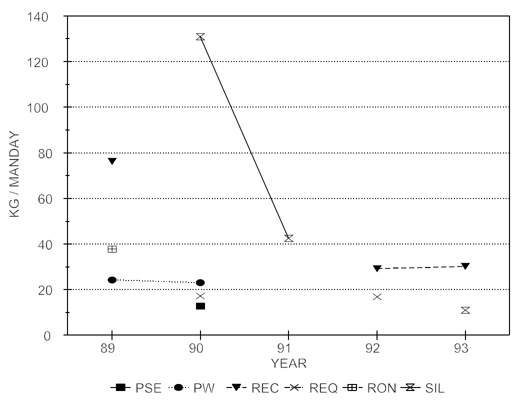


Fig. A.2.5.

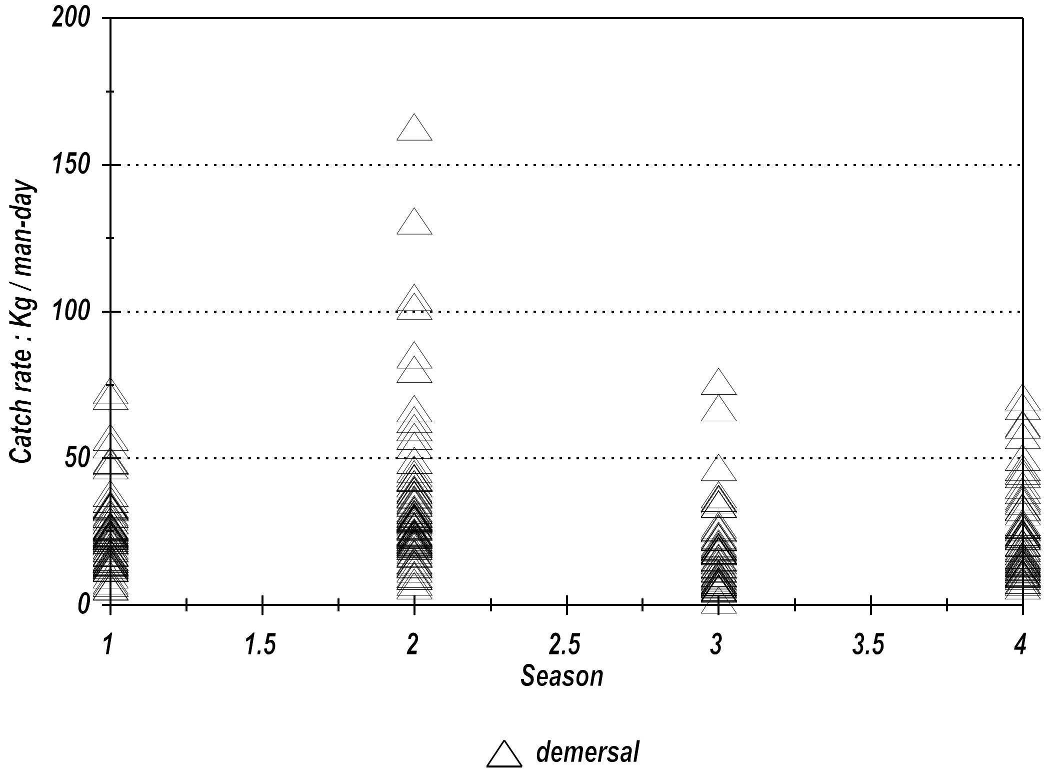


Figure A.2.7 : Scatter plot of demersal species catch rate against season for traditional whalers fishing in sector 1 and catching >84% demersal species, N=279

ANNEX 2B : SEYCHELLES 'INSHORE' WHALER FISHERY AS A CANDIDATE FOR MULTI SPECIES MODELLING

Background

Data from Seychelles multi species demersal fishery has been examined for evidence of changes in abundance, species composition and demographic variables resulting from fishing pressure. The demersal fishery is prosecuted by a number of boat categories (see 3.2) of which, data for the whaler inshore fishery (sector 1) was the only one where fishing effort was sufficiently high over the long term to potentially result in depletion and possible multi-species interactions.

Whalers target both semi-pelagic carangidae and demersal species, although not usually on the same fishing trip. Hooks and lines are used in both cases but the fishing method differs. The possibility of interactions (predation, competition for food) between carangids and the demersal lutjanidae, lethrinidae and serranidae exists, and so for the inshore fishery carangids and demersal species should be modelled. The fish consumption of two carangid species in Hawaii was calculated (Sudekum et al 1990) and found to be greater than that removed by man from heavily fished reef areas (Russ, 1991). Other non target species may also interact with these populations but data is lacking.

It is necessary to derive estimates of the catch of the important species, and an index of the abundance of carangidae and demersal species. Whaler fishing trips may be divided into those which catch some demersal species and those which catch none. The latter may be regarded as having specifically targeted carangids and this sub set of the data will be used to derive an index of the abundance of these species. Demersal species may represent an incidental catch for whalers targeting carangids. The mothership dory venture and schooner fisheries which target only demersal species generally catch 85% demersal lutjanids, lethrinids and serranids, and 15 % other species including carangidae. Thus only those whaler trips in which 85% or more demersal species were caught will be considered to have targeted demersal species, and this data sub set will be used to derive an index of the abundance of these species.

Whaler Catch and Effort Data

Estimates of the total annual catch and effort by whalers are given in Seychelles Fishing Authority annual statistical reports. Total effort is determined from records of the activity of all whalers at six key sites raised up for the total number of whalers at all sites and is considered to be accurate. Catch is determined for boats undertaking day trips and those undertaking longer trips. This was intended to address the problem of targeting and assumed that day trips were principally targeting carangids whilst longer trips targeted demersal species. However, examination of the data revealed that this is not always true. Demersal catches are believed to have been overestimated in SFA statistics due to raising catches by inappropriate effort levels (ie by trips in which no demersal species were caught). Furthermore, the raising procedure does not allow for variation in catch rates by the different whaler categories. Catch was thus re-estimated by the following procedure:

i. The number of trips sampled per annum by whaler category was determined. The proportion of sampled trips each year undertaken by category was applied to the raised total number of fishing trips in order to estimate the total number of trips by whaler category per year.

ii. The number of sampled trips for which a fishing location was reported was determined by whaler category per year, and the number for which the location was reported as sector 1. The proportion of fishing trips in sector 1 was determined and applied to the raised total number of trips to determine the number of trips in sector 1 by whaler category per annum.

iii. The number of sampled trips by boat and year in sector 1 was determined for trips where the catch of demersal species was zero and where it was greater than zero. The proportion of trips with and without demersal species was calculated and applied to the number of trips in sector 1 to determine the number of trips by boat per year in sector 1 which caught / did not catch demersal species.

iv. The mean effort (man-days per trip) was determined by boat and year for vessels which caught / did not catch demersal species and applied to the number of trips calculated in step (iii) to determine total man-days fishing effort by boat, year, demersal caught/not-, in sector 1.

v. Species catch rates (kg/man-day) were determined from sampled data by boat per year for trips in sector 1 where demersal species were caught / were not caught. The estimated total effort (man-days) derived in step (iv) was applied to estimate the total catch by species in sector 1 by boat per year.

vi. The estimated catch by species per year was calculated by summing the estimates by boat category and for trips where demersal species were / were not caught.

These analyses are not shown in full. Table A.2.2 summarises the relevant effort. Estimates of the total catch by species are given in Table A.2.3. Data for 1989 is from June to December, whilst all other years are annual data.

Table A.2.2 : The number of whaler fishing trips made each year, and the number sampled for various subsets of data : all sampled data, sampled data where fishing location was reported, sampled data where fishing location was reported as sector 1, sampled data where fishing location was reported as sector 1 and the boat type was traditional whalers. For each sub-set of data the number of trips where demersal species were caught is indicated.

LOCATION	NUMBER PER YEAR					
	6-12 /89	1990	1991	1992	1993	1994
RAISED TOTAL	4558	5992	5781	6784	6137	5625
SAMPLED DATA						
All sampled trips	876	1389	1485	965	907	1022
of which demersal species caught	524	942	963	663	682	736
All where fishing location reported	442	853	922	556	449	368
of which demersal species caught	269	566	548	371	331	248
All sampled trips to sector 1	208	506	591	443	366	177
of which demersal species caught	124	365	340	287	275	124
Sampled trips by trad. whalers to sector 1	179	301	310	338	263	116
of which demersal species caught	101	222	222	247	193	75
demersal species >= 85% of catch	24	51	50	62	72	20

Fig. A.2.8 : Whaler fishing trips : the sampling proportion, the proportion of trips where a fishing location was reported, and of these, the proportion which fished in Sector 1, and the proportion of trips in sector 1 relating to traditional whalers.

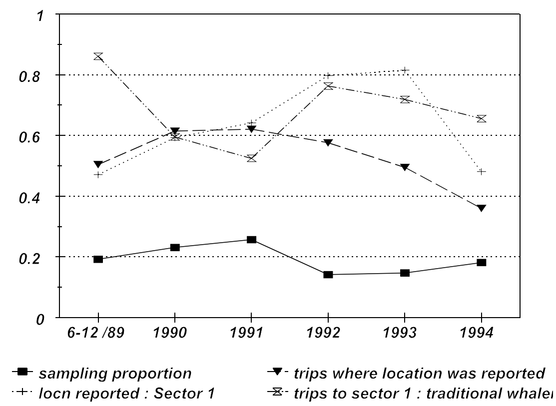


Fig. A.2.9 : The proportion of whaler fishing trips during which demersal species were caught for the data sub sets : all sampled trips, all sampled trips to reported fishing locations, all sampled trips to sector 1, traditional whaler fishing trips to sector 1.

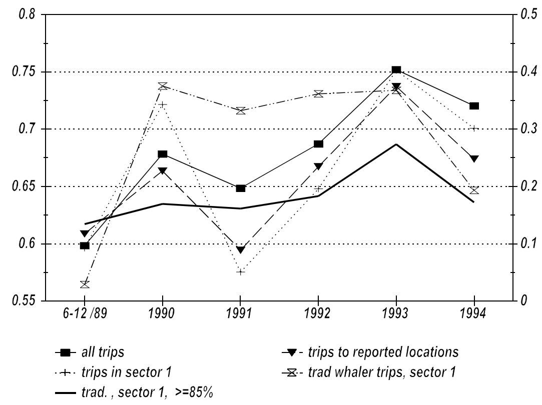


TABLE A.2.2. : Estimated total annual catch and effort from Sector 1 by species for all categories of whalers :

A.ESTIMATED TOTAL ANNUAL CATCH FROM SECTOR 1 BY SPECIES FOR ALL CATEGORIES OF WHALERS WHERE DEMERSAL SPECIES WERE REPRESENTED IN THE CATCH

ESTIMATED TOTAL VALUES					CATCH, KG BY SPECIES of demersal species only:																	
DATA FOR :		EFFORT		CATCH																		ALL DEM
YEAR	BTYPE	TRIPS	MDAYS	TONNES	BOUR	BORD	THER	VARA	JOBG	BATR	LUTJ	MACO	V_PL	CROI	SERR	C_BL	G_LO	LASC	D_BE	C_RO	LETH	-ERSALS
89	ALL	1282	8500	374.2	17080	957	27	4157	41869	25	93	11060	1736	245	3690	2939	5074	250	1662	485	21256	112604
90	ALL	2641	16252	1121.4	58740	5453	323	17928	199312	2928	449	18578	8443	1166	3353	12870	8541	3308	4411	5841	39385	391031
91	ALL	2316	14259	753.4	61434	4356	3292	23973	95483	37	262	15839	9735	8323	3607	12355	14825	2100	5315	4690	39683	305310
92	ALL	3701	20185	827.4	75478	12308	1874	9022	62874	1069	55	31380	4680	3645	13048	14491	14274	2026	6935	3810	51350	308319
93	ALL	3725	21479	817.7	67842	9401	2546	11509	96571	413	0	34931	2509	2312	11270	8882	20262	951	12083	4902	71009	357394
94	ALL	1835	9814	531	34897	10143	661	8940	73251	34	0	10138	2218	659	3367	4748	12936	340	3642	3082	16182	185238

ESTIMATED TOTAL VALUES					CATCH, KG BY SPECIES of non demersal species only:						
DATA FOR :		EFFORT		CATCH							
YEAR	BTYPE	TRIPS	MDAYS	TONNES	CABA	CAPL	CARX	PELX	BARA	ELAS	OTHX
89	ALL	1282	8500	374.2	175645	18886	10656	35516	17948	941	2002
90	ALL	2641	16252	1121.4	336732	168797	13189	62146	129947	16224	3310
91	ALL	2316	14259	753.4	174184	97090	8784	59936	76447	21865	9779
92	ALL	3701	20185	827.4	243366	110561	7793	83403	55726	8304	9959
93	ALL	3725	21479	817.7	129604	135212	7417	72462	89987	16607	8993
94	ALL	1835	9814	531	111355	100815	4757	46721	58107	18809	5239

B. ESTIMATED TOTAL ANNUAL CATCH FROM SECTOR 1 BY SPECIES FOR ALL CATEGORIES OF WHALERS WHERE DEMERSAL SPECIES WERE NOT REPRESENTED IN THE CATCH

ESTIMATED TOTAL VALUES					CATCH, KG BY SPECIES of non demersal species only:						
DATA FOR :		EFFORT		CATCH							
YEAR	BTYPE	TRIPS	MDAYS	TONNES	CABA	CAPL	CARX	PELX	BARA	ELAS	OTHX
89	ALL	869	6145	432.9	310001	29271	12632	63218	16823	802	138
90	ALL	986	5995	564.8	397400	87537	4573	48945	22013	4186	121
91	ALL	1391	7078	800.7	627805	38526	3411	95314	34428	535	696
92	ALL	1783	9316	799	542924	157148	2897	89290	4545	1711	489
93	ALL	1246	7065	266.3	138644	49842	1304	54701	19154	2612	36
94	ALL	909	4931	307.6	162266	39556	2414	43652	59024	680	0

C. ESTIMATED TOTAL ANNUAL CATCH FROM SECTOR 1 BY SPECIES FOR ALL CATEGORIES OF WHALERS

ESTIMATED TOTAL VALUES			CATCH, KG BY SPECIES of demersal species only:	
DATA FOR :	EFFORT	CATCH		ALL DEM

YEAR	BTYPE	TRIPS	MDAYS	TONNES	BOUR	BORD	THER	VARA	JOBG	BATR	LUTJ	MACO	V_PL	CROI	SERR	C_BL	G_LO	LASC	D_BE	C_RO	LETH	-ERSALS
89	ALL	2151	14645	807.1	17080	957	27	4157	41869	25	93	11060	1736	245	3690	2939	5074	250	1662	485	21256	112604
90	ALL	3627	22247	1686.2	58740	5453	323	17928	199312	2928	449	18578	8443	1166	3353	12870	8541	3308	4411	5841	39385	391031
91	ALL	3707	21337	1554.1	61434	4356	3292	23973	95483	37	262	15839	9735	8323	3607	12355	14825	2100	5315	4690	39683	305310
92	ALL	5484	29501	1626.4	75478	12308	1874	9022	62874	1069	55	31380	4680	3645	13048	14491	14274	2026	6935	3810	51350	308319
93	ALL	4971	28544	1084	67842	9401	2546	11509	96571	413	0	34931	2509	2312	11270	8882	20262	951	12083	4902	71009	357394
94	ALL	2744	14745	838.6	34897	10143	661	8940	73251	34	0	10138	2218	659	3367	4748	12936	340	3642	3082	16182	185238

ESTIMATED TOTAL VALUES

CATCH, KG BY SPECIES
of non demersal species only:

DATA FOR :		EFFORT		CATCH							
YEAR	BTYPE	TRIPS	MDAYS	TONNES	CABA	CAPL	CARX	PELX	BARA	ELAS	OTHX
89	ALL	2151	14645	807.1	485645	48156	23288	98734	34771	1743	2139
90	ALL	3627	22247	1686.2	734132	256335	17762	111091	151959	20410	3431
91	ALL	3707	21337	1554.1	801989	135615	12194	155250	110875	22400	10474
92	ALL	5484	29501	1626.4	786290	267709	10690	172693	60271	10015	10449
93	ALL	4971	28544	1084	268248	185054	8721	127163	109141	19219	9029
94	ALL	2744	14745	838.6	273620	140371	7171	90373	117130	19489	5239

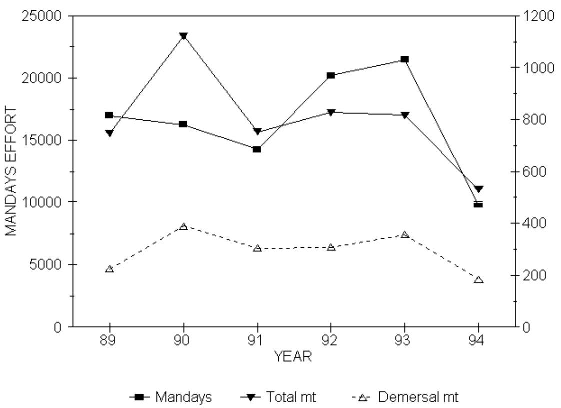


Fig A.2.10 : Total estimated catch (tonnes) and demersal catch, and the estimated fishing effort (man-days) for all whalers fishing in Sector 1 where the demersal catch was > 0. Data for 1989 has been raised to 12 months, but may nevertheless under-estimate catches that year since high catch rates are achieved in the period March-May, not sampled that year.

Examination of the pattern of fishing effort (Table A.2.2, Figs. A.2.8 and A.2.9) indicates that:

- Total fishing effort has fluctuated, peaking in 1992. Sampling frequency was less in the period 1992-1994 than previously, although the number of boats sampled remained high at around 1000 per year.

- The proportion of trips during which fishing location was reported decreased considerably, but for those trips where a location was reported the proportion fishing in sector 1 increased to 1993 and then in 1994 effort shifted to more distant locations. Between 50-80% of trips were in sector 1.

- For all boat categories the proportion of fishing trips during which demersal species were caught increased with time, suggesting increased fishing effort targeted at demersal species. The proportion of trips in which demersal species were caught was slightly less (but more erratic) in sector 1 than for all locations indicating that more targeting of carangids occurs here than at the more distant locations (Fig. A.2.9).

- For traditional whalers in sector 1 (which account for around 70% of all trips to that location) the proportion of trips in which demersal species were caught was higher than for all boat types, and remained above 70% except for 1989 (only 6 months data) and 1994. This indicates that the increased effort directed at demersal species noted above was explained by other boats in the whaler category (principally Lekonomi), and that traditional whalers in the past were more likely to target demersal species than other boat types.

- Traditional whalers catching 85% or more demersal species can be considered to have specifically targeted demersal species and the proportion is similar each year except for 1993 when it increased to 26%.

- Fishing effort directed at demersal species in 1994 does not appear to be markedly different than previous years although the proportion of trips during which demersal species were caught fell that year compared to 1993. There also appears to have been a shift of effort away from sector 1 in 1994.

Total catch (Table A.2.3) derived from sampled data was less than that from SFA annual statistics (due to the problems of mis-coding of fishing sector), and the species composition differed, particularly demersal species had been overestimated in the latter. In addition to whalers, demersal species are also exploited in sector 1 by small boats with handlines (pirogues and outboard powered skiffs) and to a small extent by the larger schooners. The total catch for selected species per annum in sector 1 derived from the above estimate for whalers and from SFA Annual statistics for other boat categories is indicated in Table A.2.4. For other species 'OTHX' the total catch has not been indicated except for whalers since a number of boat and gear types do not target or catch any demersal species, which are of principle interest. The catch of Carangue balo, is the total for all boat and gear types in each case.

TABLE A.2.4. : Total annual catch (tonnes) in Sector 1 by boat type for selected species. 1989 catch for whalers has been raised to represent 12 months.

YEAR	BOAT TYPE	SPECIES , AND GUILDS OF REMAINING SPECIES BY FAMILY									FAMILY GUILDS			ALL	
		BOUR	JOBG	LUTX	MACO	SERX	C_BL	G_LO	D_BE	LETX	LUTX	SERX	LETX	DEME	CABA
89	SMALL BOATS	0	49.7	65.7	40.2	18.7	0	0	0	92.7	115.4	58.9	92.7	267.1	284.9
89	WHALERS	34.2	83.7	10.5	22.1	11.3	5.9	10.1	3.3	44	128.4	33.5	63.3	225.2	485.6
89	SCHOONERS	25.5	5.7	22.1	2.8	9.1	1.3	0.3	0.2	8.9	53.2	11.9	10.7	75.8	1.6
89	TOTAL	59.6	139.1	98.3	65.2	39.1	7.2	10.4	3.5	145.7	297.1	104.3	166.7	568.1	772.1
90	SMALL BOATS	0	48.4	40.6	29.7	12.4	0	0	0	70.5	89	42.1	70.5	201.6	321.2
90	WHALERS	58.7	199.3	27.1	18.6	13	12.9	8.5	4.4	48.5	285.1	31.5	74.4	391	734.1
90	SCHOONERS	23.7	6.4	18.8	3.3	9.8	1.7	0.4	0	3.8	48.8	13.1	5.9	67.8	3.4
90	TOTAL	82.4	254.1	86.5	51.5	35.2	14.6	9	4.4	122.8	423	86.7	150.8	660.4	1058.7
91	SMALL BOATS	41.7	50.4	2.6	29.1	14	0	0	0	77.4	94.7	43.1	77.4	215.1	196
91	WHALERS	61.4	95.5	31.9	15.8	21.7	12.4	14.8	5.3	46.5	188.8	37.5	79	305.3	802
91	SCHOONERS	8.1	1.6	5.8	1.8	3.2	0.2	0	0.9	4.9	15.5	5	6.1	26.6	1.4
91	TOTAL	111.2	147.5	40.4	46.8	38.8	12.6	14.8	6.2	128.7	299	85.6	162.4	547	999.4
92	SMALL BOATS	34.1	36.8	5	35.1	17.2	0	0	0	86.8	75.9	52.2	86.8	214.9	1
92	WHALERS	75.5	62.9	24.3	31.4	21.4	14.5	14.3	6.9	57.2	162.7	52.8	92.9	308.3	786.3
92	SCHOONERS	6.6	2.4	13.5	1.5	2.8	0.8	0	0	1	22.6	4.4	1.8	28.8	287.3
92	TOTAL	116.2	102.1	42.9	68	41.4	15.3	14.3	7	145	261.2	109.4	181.5	552	1074.6
93	SMALL BOATS	34.6	72.4	4.7	35	16.5	0	0	0	84	111.7	51.4	84	247.1	179.6
93	WHALERS	67.8	96.6	23.9	34.9	16.1	8.9	20.3	12.1	76.9	188.3	51	118.1	357.4	268.2
93	MOTHERSHIP	2.3	4.8	2.8	0.7	1.1	0.8	0	0	3.5	9.9	1.9	4.3	16	1
93	TOTAL	104.8	173.8	31.4	70.6	33.7	9.6	20.3	12.1	164.4	309.9	104.3	206.3	620.5	448.8
94	SMALL BOATS	22	88.1	4.9	14.1	8.6	0	0	0	91.2	115	22.7	91.2	228.9	211.3
94	WHALERS	34.9	73.3	19.8	10.1	6.2	4.7	12.9	3.6	19.6	127.9	16.4	40.9	185.2	273.6
94	SCHOONERS	2	1.5	4.2	1.1	1	0.2	0	0	1.2	7.7	2.1	1.4	11.2	1
94	TOTAL	58.9	162.9	28.9	25.3	15.8	5	13	3.7	112	250.7	41.1	133.6	425.4	485.9

Catch Rate Analyses

Within sector 1 whaler catch rates may be subject to variation arising from factors such as season, whaler type (there are 4 types identified), and fishing area within the sector. In order to employ catch rate as an index of abundance it is necessary to standardise for such variation. Generalised Linear Interactive Modelling (GLIM, Francis *et al ,* 1993) was applied. It was argued that the population of fish in sector 1 is discrete for each species (see 3.3; above) and so it is inappropriate to include fishing area. Furthermore, sample size by area was insufficient (Table A.2.1), particularly within year and season. Boat type was shown to be highly significant with respect to catch rates for all species and species groups examined (not shown). However, 2 and 3 factor interactions occurred (eg. seasonal variation was not consistent by whaler type). Thus in order to avoid unnecessary complication, only traditional whalers were examined. This is appropriate since it has been shown that this category of whaler accounts for most of the effort in sector 1, and have consistently targeted demersal species. A total of 279 data points were included in the analysis relating to traditional whalers catching >84% demersal species (by weight) from sector 1 (Figs A.2.7 - A.2.8). 447 records were analysed for traditional whalers targeting carangids (no demersal species represented in the catch).

The model (year+season) was applied for key species and species groups in order to derive standardised annual catch rates where demersal species had been the target and where *C. gymnostethus* had been the target (Table A.2.5). Two factor interactions had previously been shown to exist for data up to 1993 (not shown), but were not investigated for the extended data set to 1994. Significant seasonal variation occurred for all species (groups) tested except for the group 'other lethrinidae'. Annual catch rates were significantly different except for *E. chlorostigma*, 'other lethrinidae' and 'others' indicating that their biomass did not change with time. In all other cases significant biomass changes occurred during the period 1989-1994. Observed and standardised catch rates are indicated in Figs. A.2.11-A.2.22.

Table A.2.5 : Results of GLIM analyses for the model year+season (2 factor interactions not investigated) applied to species and species group catch rate data for traditional whalers fishing in sector 1 between June 1989 and December 1994 where demersal species represented 85% or more of the catch (N=279), and for the carangid, C. gymnostethus, from traditional whalers in sector 1 where no demersal species were caught (N=447).

SPECIES	FACTOR	F	df1	df2	P	SIGNIFICANT
All demersal spp	season	20.42	3	270	<0.00001	Highly
	year	12.69	5	270	<0.00001	Highly
All lutjanids	season	22.31	3	270	<0.00001	Highly
	year	13.58	5	270	<0.00001	Highly
All serranids	season	3.947	3	270	0.0088	Yes
	year	1.633	5	270	0.1514	No
All lethrinids	season	0.9089	3	270	0.4372	No
	year	1.156	5	270	0.3312	No
L. sebae	season	10.03	3	270	<0.00001	Highly
	year	1.72	5	270	0.1313	No
A. virescens	season	21.93	3	270	<0.00001	Highly
	year	20.1	5	270	<0.00001	Highly
Lutjanidae	season	4.73	3	270	0.0031	Yes
	year	4.59	5	270	0.0005	Yes
E. chlorostigma	season	6.53	3	270	0.0003	Yes
	year	0.33	5	270	0.897	No
Serranidae	season	11.28	3	270	<0.00001	Highly
	year	11.15	5	270	<0.00001	Highly
G. robinsonii	season	5.34	3	270	0.0014	Yes
	year	8.11	5	270	<0.00001	Highly
L. elongatus	season	5.002	3	270	0.0022	Yes

	year	2.75	5	270	0.0192	Yes
L. crocineus	season	10.17	3	270	<0.00001	Highly
	year	5.419	5	270	0.0001	Yes
Lethrinidae	season	2.324	3	270	0.0753	No
	year	1.188	5	270	0.3154	No
C. gymnostethus	season	7.271	3	438	0.0001	Yes
	year	7.951	5	438	<0.00001	Highly

Figures A.2.11-A.2.22 : Observed and standardised (for seasonal variation) catch rates (Kg / man-day) for traditional whalers targeting demersal species (>=85% of the catch), and targeting carangids (demersal species = 0% of catch) in sector 1 for the dominant species in the catch and for guilds of species.

Fig A.2.11 : All demersal species.

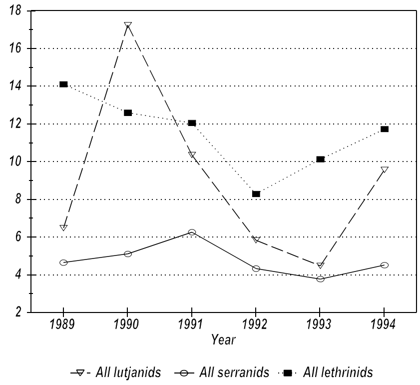


Fig. A.2 12 : Standardised catch rates for demersal family guilds.

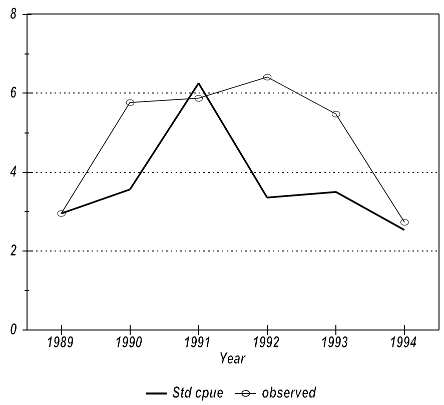


Fig. A.2.13 : *Lutjanus sebae*

Fig A.2.14 : *Aprion virescens*

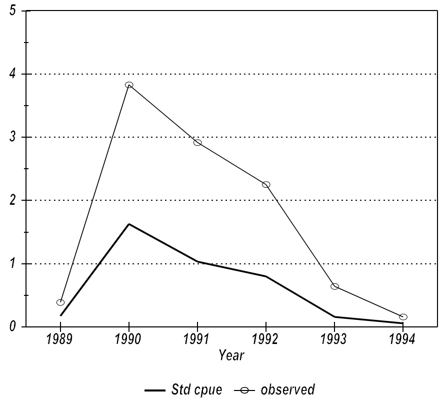


Fig A.2.15 : Remaining lutjanids

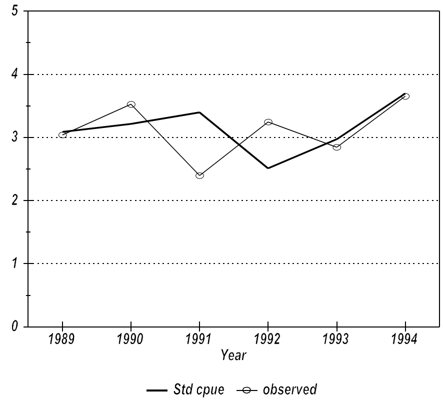


Fig. A.2.16 : *Epinephelus chlorostigma*

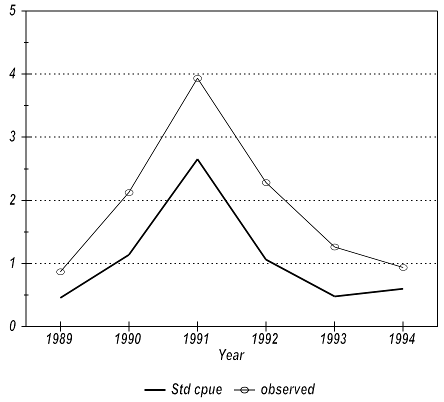


Fig. A.2.17 : Remaining serranids

Fig. A.2.18 : *Gymnocranius robinsonii*

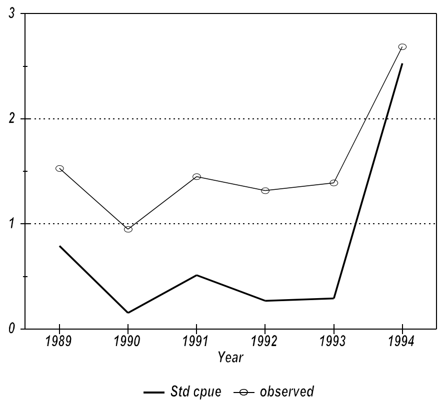


Fig. A.2.19 : *Lethrinus elongatus*

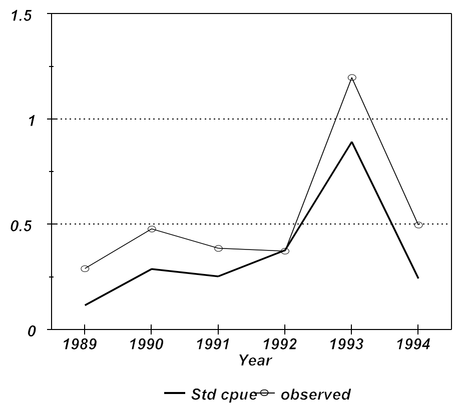


Fig A.2.20 : *Lethrinus crocineus*

Fig. A.2.21 : Remaining lethrinids.

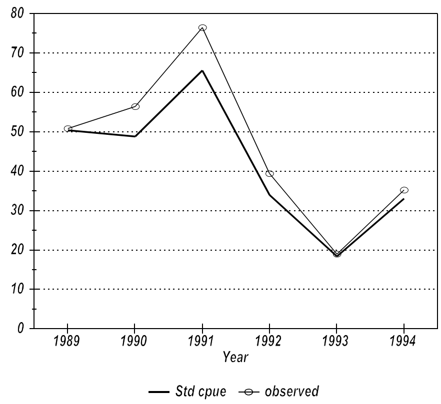


Fig A.2.22 : *Carangoides gymnostethus*

Seasonal variation in catch rates was significant for all species and guilds with the exception of lethrinids (guilds of all species, and the smaller guild excluding principal species, Table A.2.5). Annual variation was significant for the guilds of all demersal species and all lutjanids. However, no significant difference in catch rates was observed for the guilds of all serranids and all lethrinids (Table A.2.5). Thus, no change in biomass occurred for serranids and lethrinids between 1989 and 1994. The changes observed for all demersal species are thus attributable to changes in biomass of lutjanids in this period. In fact, catch rates for lutjanids and all demersal species fluctuated during the period 1989-1994[4], and did not show any consistent trend (Figs A.2.11-A.2.12). Apart from 1990, lethrinids dominated the catch of demersal species, which agrees with expectation : fishing in sector 1 occurs in shallow water (<50 m). Serranids formed the smallest part of the demersal catch (Fig A.2.12).

For individual species it may be seen that the variation in catch rates for lutjanids is principally explained by *A. virescens* which dominates the catch (Fig A.2.14). This variation is significant, as is that for remaining lutjanids which, however, form only a small part of the catch (Fig A.2.15, Table A.2.5). No significant annual variation in catch rate, and therefore biomass, was observed for *L. sebae* (Table A.2.5, Fig A.2.13). For serranids, no significant change in catch rate was observed for the principal species, *E. chlorostigma* whilst the guild of remaining species showed a significant increase in catch rate in 1991 (Figs A.2.16-17). Of the individual species of lethrinids examined all indicated significant annual variation in catch rate but no consistent increasing or decreasing trend was observed (Figs A.2.18-20). The semi pelagic *C. gymnostethus* showed a significant annual variation in catch rate the trend for which indicated depletion over the period 1989-94.

Attempts to fit catch and effort data to biomass dynamic production models were performed for those species / guilds where a significant annual variation in catch rate was indicated (Annex 5). For species guilds catch rate declined with increasing effort only for the lutjanidae (Fig A.2.23). Note that whilst the derived index of abundance for demersal species related to traditional whalers catching more than 84% demersal species indicated that lethrinids were the largest part of the catch, raised total catch estimates for all demersal catches (>0% demersal species in the catch) indicated that more lutjanids than lethrinids were removed from the fishery.

No significant depletion was found to occur for any of the demersal fish data sets examined from 1989 to 1994, and it was not possible to fit to them a biomass dynamic production model (see

4 This is in contrast to previous analyses which had indicated depletion and a reduction in catch rate and biomass by a factor of 5 between 1989 and 1993, with some recovery in 1994. This result is now considered an anomaly arising from the inclusion of data from outside sector 1 due to mis-coding.

Annex 5). If 1989 data was excluded on the grounds that it was only a seven month data set and errors could have been introduced raising the data to 12 months, then the guild 'other lutjanids' produced a good fit and indicated significant depletion. None of the other data could be fitted. The data for *C. gymnostethus* produced a poor fit, but this analysis is invalidated in that the data do not meet model requirements : a discrete population of this species does not occur within sector 1. This may also be true for *A. virescens*.

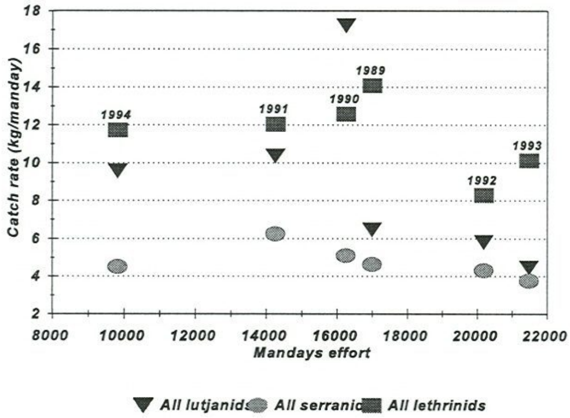


Fig A.2.23 : Standardised catch rates for family guilds caught by traditional whalers where demersal species were targeted, against total effort by all whalers in sector 1 where demersal species were represented in the catch (1989 data raised to 12 months).

Length Frequency Information

Length frequency information for fish caught within sector 1 was lacking. Consequently, aggregated length frequency data for all of the Mahe Plateau (sectors 2-10) was examined (see Annex 7) in order to infer the likely size structure of fish populations in sector 1. For *A. virescens* the size structure of the population changed in 1994. The major mode in the years 1991-1993 was around 74 cm, whilst in 1994 it was 50 cm. This suggests that a strong recruitment occurred 2 or 3 years earlier and that these fish recruited into the fishery in 1994. This may have resulted in elevated catch rates that year. Unfortunately length frequency data was not available for 1990 when catch rates for this species were also high. Other species examined and important in the catch in sector 1 (*L. sebae, E. chlorostigma*) showed no change in size structure.

Discussion

Variation in catch rates of demersal species was significant. However, despite the high fishing pressure in sector 1 there was no evidence that depletion had occurred between 1989 and 1994. Rather, catch rates had fluctuated significantly during this period, and in particular for *A. virescens*. This species is sometimes described as semi-pelagic and tends to aggregate in schools. High catch rates occurring in 1990 and 1994 could have resulted from movement of this species into sector 1 during those years. There is also evidence from length frequency information from other sectors on the Mahe Plateau that a strong recruitment of smaller fish entered the fishery in 1994 (similar data is not available for 1990, see Annex 7). Thus the fluctuating catch rates observed for lutjanids may result from fishing pressure or may have an environmental origin.

For the semi-pelagic *C. gymnostethus* a significant fluctuation in catch rate occurred and the trend indicated depletion of this resource from 1989 to 1994. However, it cannot be argued that the population of this species is confined to sector 1 and thus it is not valid to apply a depletion model to this data in order to determine abundance.

The data for whalers indicate that fishing pressure on demersal species in sector 1 increased in 1992 and 1993 but fell considerably in 1994 (Fig A.2.9). Effort was high and may be expected to have resulted in depletion and multi-species interactions. Such interactions may occur both between the targeted demersal species, and with other species such as carangids for which data exists, and potentially other non target species for which no data exists. Fishing pressure within sector 1 will have been high for a number of years prior to 1989, the start of the present data set. Hence the observed species composition and catch rates will be a result of prior fising activity and the fact that no obvious depletion or interactions occurred during the time series studied may simply reflect that an equilibrium state has been reached at the levels of fishing effort applied. This ‘equilibrium’ may not be stable and perhaps the fluctuations in biomass observed are the result of sustained high fishing pressure. Polunin and Jennings (1995) indicate that increases in fishing pressure have a greater impact on the biomass and community structure of a previously unfished community than one subject to prior exploitation. Next, it may be that ‘obvious’ interactions are not occurring, but nevertheless some interaction still occurs. For example, as a group the lethrinids showed no significant change in biomass. Individual species, however did change significantly with time (and fishing pressure), and increases in catch rate of *G. robinsonii* and *L. elongatus* in 1994 were matched by a decrease for *L. crocineus* that year. Subtle interactions are not only difficult to detect, but imply the requirement for information on a large number of species if these effects are to be modelled.

At a gross level, it could be argued that depletion of lutjanids occurred whilst the biomass of lethrinids and serranids were unaffected by increasing fishing pressure (Fig A.2.23). This however is complicated by the fact that *A. virescens* showed significant increases in 1990 and 1994 which may be environmentally related.

Other explanations for the fluctuations in catch rate were investigated through interviews with fishermen and data collectors. Whalers are increasingly being fitted with echo sounders and ice boxes and are targeting demersal species which fetch a higher price than carangids. Trip length is increasing and more trips are occurring on the edge of the Plateau rather than in sector 1. These observations are supported by the data presented. Following privatisation of marketing outlets demand for export quality demersal species has increased, and this is thought to have been important in 1994, perhaps explaining the shift of effort out of sector 1 that year. No changes in gear technology (hooks and lines) were reported but fishing at night time has apparently increased recently, and this together with increased use of echo sounders may also partly explain increases in catch rate in 1994. No data is available to test this. Non fishery related factors may also be important resulting in strong recruitment of key species in certain years.

ANNEX 3 : SCHOONER CATCH AND EFFORT DATA

Data from the schooner fishery were available from 1983 to the present, and potentially offered the greatest scope for assessment of the impact of fishing on multi-species demersal resources. Unfortunately however, this proved not to be the case : fishing effort was relatively low at any one location; few boats fished consistently throughout the entire 10 year period; adequate data on the use of echo-sounders, gear, and depth were not collected until 1990.

Mees, 1990b examined the schooner fishery in detail, and the same fleet stratification is employed in the present report (Table A.3.1). Only vessels for which complete catch details were recorded are included in the analyses.

Table A.3.1 : The number of schooner fishing trips sampled each year by boat, and stratification of the fleet. Mean catch rate aggregated over all data for each boat is indicated

BOAT	HP	YEAR											TOT	KG/
		83	84	85	86	87	88	89	90	91	92	93		MH
BASIC FLEET OF SCHOONERS (1)														
ANNA BELLE									5	33	2	5	45	46.3
AQUARIUS								1					1	64.5
BENOIT FANCHETTE							5						5	18.0
CLAYVERGE									1				1	11.3
ETOILE							1						1	10.2
KAPRISLETAN									1	7	1	1	10	52.9
LA BELLE DAYO								1	7	29	7	4	48	37.9
LA PROVIDENCE									1	3	2	3	9	27.9
LILLY									4				4	32.2
MALBAR				1		5							6	22.4
MIRELLA		6	10										16	26.7
RAYMOND BONTE								1					1	35.6
REX					1								1	19.1
SORENE							1						1	11.0
SOUMARIN II		11	8										19	20.6
STANLEY AH-KON							3						3	27.6
ST MARC		10	10										20	29.1
SZ 066								1					1	16.8
TOKOS		11	23										34	24.9
PIPON	27				1								1	38.0
SAGITAIRE	27	2			11	14	3						30	36.9
SOUMARIN I	27	9	24	19	31	35	26	17	3				164	31.7
ALERT	37	9	16	22	15	28	23	7					120	29.6
BOUDEUSE	37			2	18	12							32	18.4
CANCER (Dick)	37							5	20	40	5		70	35.4
DICK	37	9	27	17	24	24	20	9					130	26.1
FRANCOIS BONNE	37			1		11	2						14	24.7
HOPE	37			6	14	21	25						66	20.5
INNOCENT	37	3	14		16	27	19	13	10	21	4	6	133	29.2
JEFFERY DURUP I	37				3	3		2	2				10	37.3
JEFFERY DURUP II	37			3		10	10	8					31	29.8
KOUSOUPA	37			1									1	14.3
LA BELLE VIOLITA	37					4	18	20	16	28	12	14	112	42.7
LANINA	37	9	19	11									39	26.6
MAMI	37	9	12	9	12	22	14						78	30.2
PAILLE EN QUEUE	37			11	18	25	20	16	13	20	8	20	151	35.0

Table A.3.1 Continued

BOAT	HP	YEAR											TOT	KG/
		83	84	85	86	87	88	89	90	91	92	93		MH
BASIC FLEET OF SCHOONERS (1) CONTINUED.														
QUEEN	37	7	29	15	25	20	19	2					117	26.5
REEFER	37			12	18	21	18	4	8	35	12	6	134	36.3
REGIS AH-KON I	37			15	30	17	21						83	31.9
REGIS AH-KON II	37			1	24	27	2						54	38.3
REINE DES ANGES	37			8	16	12	4						40	18.1
SERRE	37	12	32	27	11	21	11	23	18	15			170	27.0
SILENCE	37			8	25	17	21		1			1	73	26.4
ST. ANDRE	37				17	29	15						61	32.0
TOUSSAINY	37	11	26	23	22	18	8						108	23.9
VALENCIA	37						6	1					7	26.1
VIGILANT	37	11	26	9	12	1							59	26.0
EDELBERT AH-KON	48			14	19	19	22	2	1				77	35.1
?	56	1		37	7						1		46	50.4
CHANTAL	56	10	29	19	23	30	26	4					141	35.7
DRAGON JAW	56			7	16	23	23	1					70	31.3
VENUS	56			3	2	25	11	1					42	28.6
LA DIGUE 12.5M SCHOONERS (2)														
ANDIAMO	76						5	1					6	14.3
DENEB	76						12	14	27	11	2	6	72	54.6
DOLPHIN (Andiamo)	76									36	14	19	69	36.7
VARIOLA	76						12	17	15	40	11		95	44.9
LA DIGUE 22.5M SCHOONERS (3)														
SCORPIO	150				3	6	5	11	17				42	50.4
TAURUS	150									17	11	7	35	44.5
VERSEAU	150									26	13	8	47	40.3
OTHER LARGE SCHOONERS (4)														
SEA GLEANER	120	5	8	3	1	8	14	13	7				59	23.0
ST MICHEL	120								4	25	13	5	47	22.8
CLARTE	150					1		3			1		5	52.6
NEW SCHOONERS ENTERING THE FISHERY SINCE 1990, EQUIVALENT TO BASIC FLEET (5)														
DE KOUZEN										9	18	9	36	50.4
DISKISYON											3		3	21.2
FAITH									2	20	7		29	25.9
LA BRINE											5	20	25	43.5
LA CYNTHIA										23	2		25	40.5
NAVAJO											7	3	10	31.2
NORTH STAR										4	3	2	9	35.1
PASYAN											4		4	37.7
REJETTA											2	4	6	36.6
ST. CROIX										24	3		27	24.5
ST GEORGES									2	30	4		36	21.1
VAINQUER										6	12	13	31	39.0
VOLOULOU										12			12	25.0
OTHERS CLASSED AS SCHOONERS, (6)														
SEYCHELLES NAVY				2									2	17.4
SWEDISH	20			1	15								16	16.8
TOTAL		145	313	307	450	536	445	198	185	514	189	156	3438	

The schooner fleet encompasses a wide variety of vessels, which have been stratified according to size and vessel design. Traditionally schooners fished with handlines. In 1986 electric fishing reels were introduced. Drop lines and gill nets were introduced in 1991/2 but have only been deployed on the large La Digue schooners (4). Echo sounders have commonly been used, but since 1992/3 GPS (global positioning satellite navigation) and fish finders have increasingly been used. Since that time some schooners have additionally fished with dories (some of the larger schooners also did this in the past). In 1990 data collection was improved to record fishing method and use of echo sounder. However, the more recent advances (GPS, fish finders, dories) have not been incorporated into the data collection programme and this needs to be addressed urgently. Furthermore, although it is known that Verseau and Taurus have fished with drop lines and gill nets, this information does not appear on the database[5]. Thus either none of these trips were sampled, or the data forms have been completed incorrectly.

Vessel-trips sampled where electric reels were used are indicated in Table A.3.2. Data prior to 1990 is assumed from knowledge of the dates on which electric fishing reels were fitted to the boats. Reported use of echo sounders is indicated in Table A.3.3. Surprisingly, only 68 vessel trips were recorded in which both electric reels and echo sounders were used. There is a possibility of mis-reporting.

Table A.3.2. Vessel trips sampled during which electric fishing reels were used

BOAT	86	87	88	89	90	91	92	93	TOT
CHANTAL	9	30	26	4	0	0	0	0	69
DE KOUZEN	0	0	0	0	0	6	17	9	32
DENEB	0	0	0	7	27	11	2	6	53
LA BELLE DAYO	0	0	0	0	0	0	0	1	1
LA BELLE VIOLITA	0	0	0	0	16	24	12	14	66
LA BRINE	0	0	0	0	0	0	0	6	6
REJETTA	0	0	0	0	0	0	0	2	2
SCORPIO	0	0	0	11	17	0	0	0	28
SEA GLEANER	0	0	0	0	1	0	0	0	1
ST MICHEL	0	0	0	0	0	3	9	4	16
TAURUS	0	0	0	0	0	0	10	7	17
VARIOLA	0	0	12	17	15	40	11	0	95
VERSEAU	0	0	0	0	0	26	12	8	46
TOTAL	9	30	38	39	76	110	73	57	432

5 These gear types occur on the length frequency data base. Unfortunately this data base is not linked to the catch and effort data : presently biological and catch- effort data are collected and treated separately. It is recommended that the computerisation of Seychelles CAS is upgraded to provide a fully integrated relational fisheries information system. Certain technical problems exist however ie. way that fish are handled through SMB meaning that biological data cannot always be related back to a particular vessel.

Table A.3.3. Vessel trips sampled during which echo sounders were used.

BOAT	90	91	92	93	TOT
	0	0	1	0	1
ANNA BELLE	5	33	2	5	45
CANCER	11	3	1	0	15
CLARTE	0	0	1	0	1
DE KOUZEN	0	9	18	9	36
DENEB	27	11	2	6	46
DISKISYON	0	0	3	0	3
DOLPHIN	0	36	14	19	69
FAITH	2	16	6	0	24
INNOCENT	3	21	4	5	33
JEFFERY DURUP I	1	0	0	0	1
KAPRISLETAN	0	4	0	1	5
LA BELLE DAYO	7	0	0	4	11
LA BELLE VIOLITA	16	28	12	14	70
LA BRINE	0	0	5	20	25
LA CYNTHIA	0	23	2	0	25
LA PROVIDENCE	1	3	2	3	9
NAVAJO	0	0	7	3	10
NORTH STAR	0	4	3	2	9
PAILLE EN QUEUE	13	16	8	19	56
PASYAN	0	0	3	0	3
REEFER	6	35	9	5	55
REJETTA	0	0	2	4	6
SCORPIO	17	0	0	0	17
SEA GLEANER	7	0	0	0	7
SERRE	1	0	0	0	1
SILENCE	0	0	0	1	1
ST MICHEL	4	25	12	5	46
ST. CROIX	0	3	1	0	4
TAURUS	0	17	10	7	34
VAINQUER	0	6	11	12	29
VARIOLA	15	40	11	0	66
VERSEAU	0	26	13	8	47
VOLOULOU	0	12	0	0	12
TOTAL	136	371	163	152	822

Given the scattered nature of the data for all schooner-gear categories, in order to investigate depletion or species composition changes due to fishing pressure over time, data stratified by boat-gear type was employed rather than attempting to standardise all boat data. Whilst ideally the data stratified by boat-gear type and sector should have been standardised for depth, fishing ground, seasonal and fishing (use of echo sounders for example) effects, data proved inadequate. Information relating to depth and use of echo sounders or fish finders was not collected until 1990. Specific fishing grounds were not recorded. Consequently, only standardisation for seasonal variation could be achieved for the whole time series from 1983, and for depth and season since 1990. As indicated above, information on the use of echo sounders appears to have been misreported so could not reliably be used.

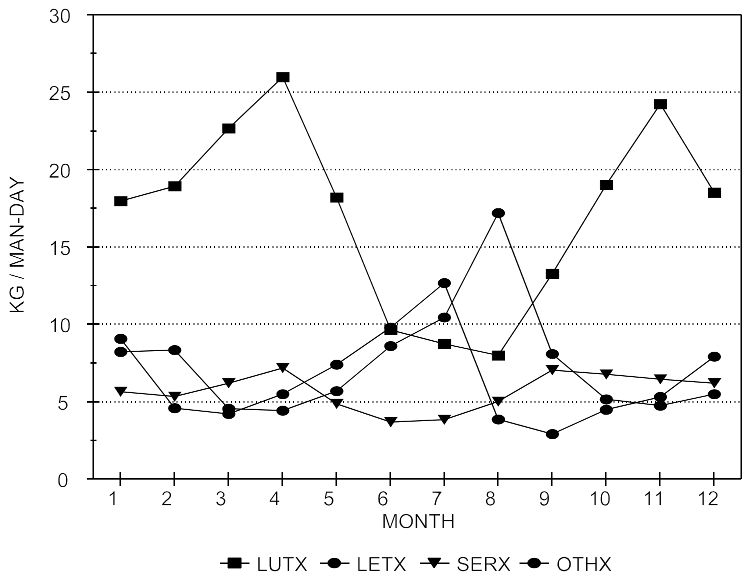
The following sub sets of the data were investigated :

- The basic schooner fleet utilising handlines only; As reported for whalers, a strong seasonal effect was observed (eg. sector 9, Fig. A.3.1). Fishing sectors 2, 4, 6, 7, 9, and 10 were examined for evidence of depletion (Figs A.3.2- A.3.13). Whilst only species guilds are illustrated, the analysis looked at individual species over the time series (not shown).

- The La Digue 12 m schooners with electric reels were examined for sector 9 (Figs A.3.14-A.3.15).

Other boat-gear-location combinations had limited data and were not investigated.

Fig. A.3.1. Monthly catch rate data aggregated over the period 1983-1993 for the family groups lutjanids, lethrinids, serranids and all others caught by basic fleet schooners using handlines only in sector 9 (Owen, Thor, Roberts Banks).



Figures A.3.2-A.3.13 : Observed catch rates for all species, demersal species and species groups lutjanidae, lethrinidae, serranidae and others for basic fleet schooners fishing with handlines only (The number of trips sampled is indicated).

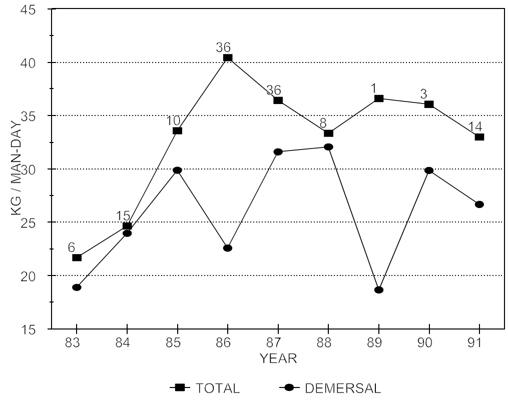


Fig. A.3.2 Sector 2

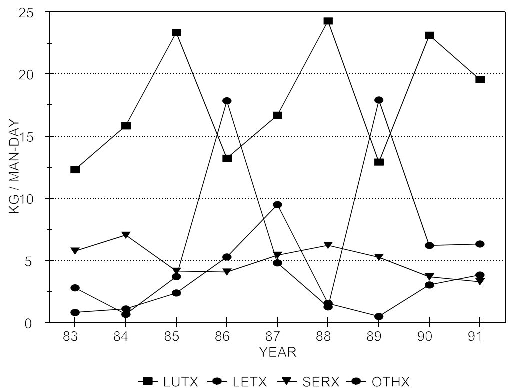


Fig. A.3.3 Sector 2

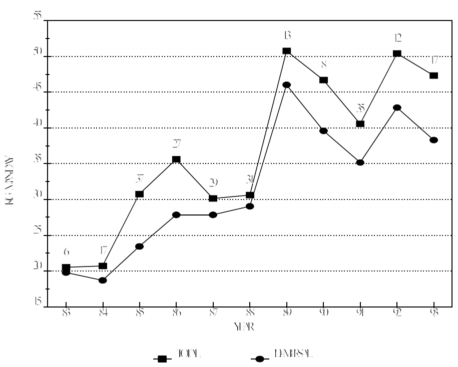


Fig. A.3.4. Sector 4

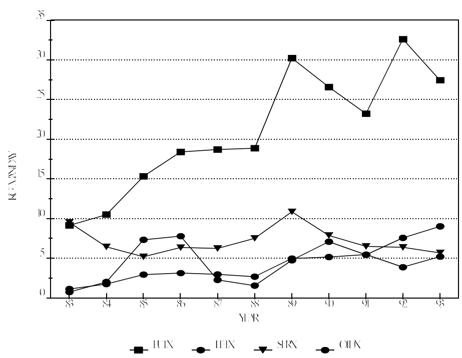


Fig. A.3.5. Sector 4

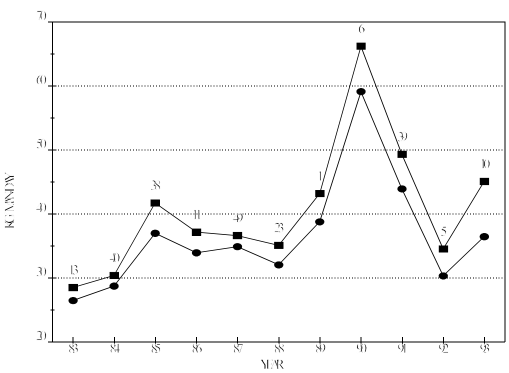


Fig. A.3.6. Sector 6

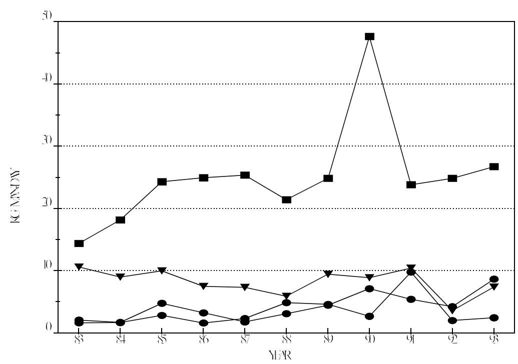


Fig A.3.7 : Sector 6

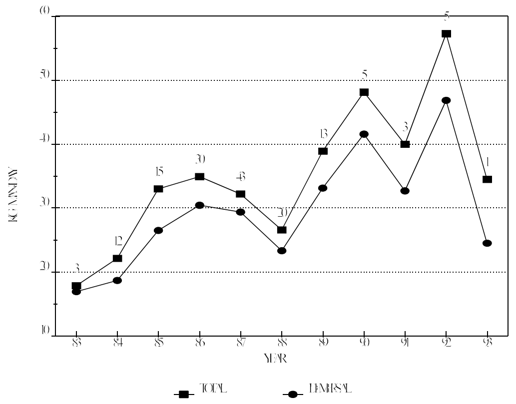


Fig A.3.8 : Sector 7

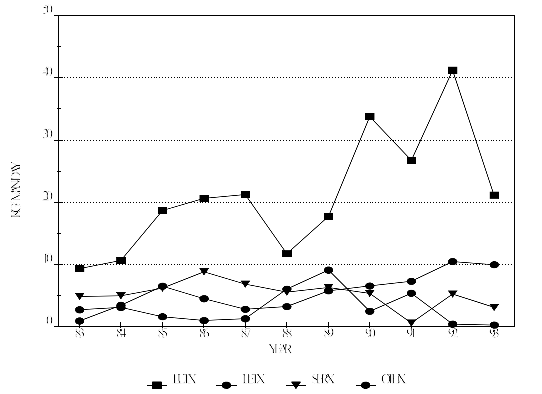


Fig A.3.9. : Sector 7

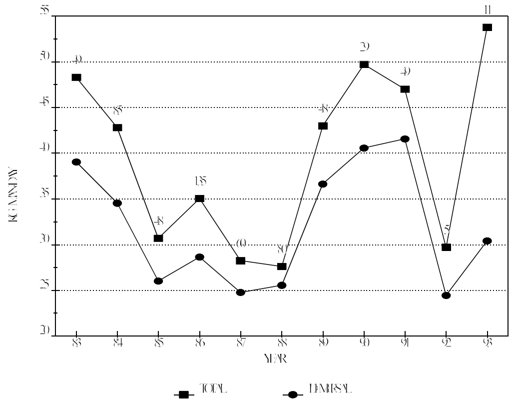


Fig A.3.10 : Sector 9

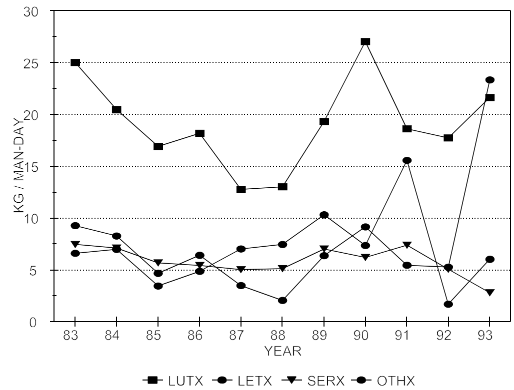


Fig A.3.11 : Sector 9

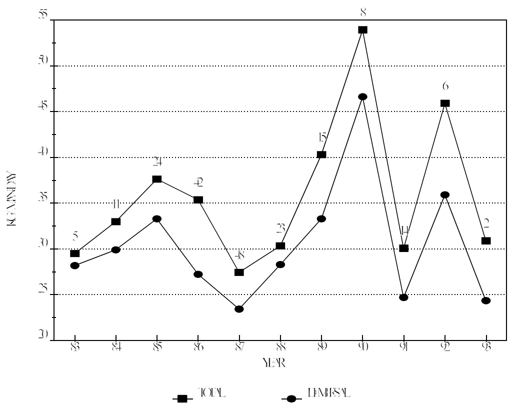


Fig A.3.12 : Sector 10

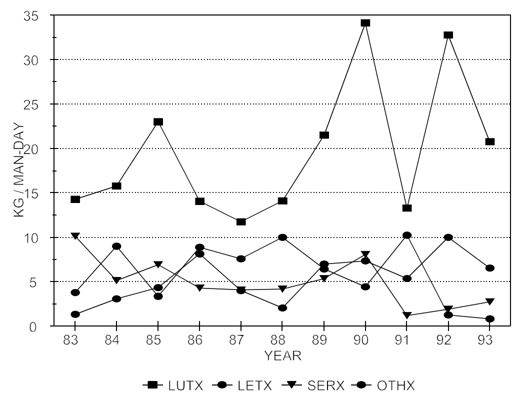


Fig A.3.13 : Sector 10

Figures A.3.14-A.3.15 : Observed catch rates for all species, demersal species and species groups lutjanidae, lethrinidae, serranidae and others for La Digue 12m schooners fishing with electric reels only, sector 9 (sample number indicated).

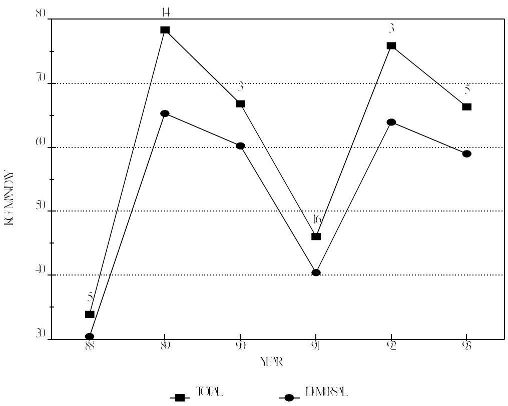


Fig. A.3.14

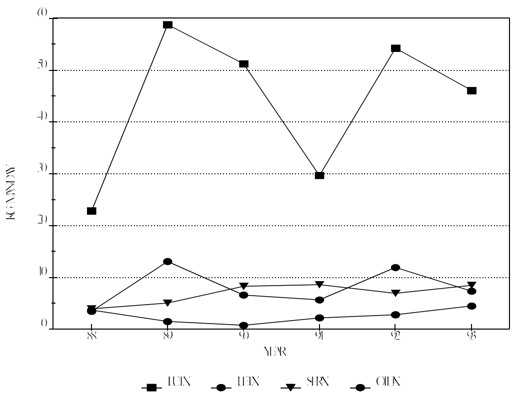


Fig A.3.15

Stratified data (Figs A.3.2-A.3.15) did not indicate evidence of depletion at any location, and catch rates apparently increased at Sector 4 and Sector 7. Increases in catch rates occurring in 1990 related to a shift of effort to deeper water (all sectors). This was evident from individual species data which showed a dramatic increase in the catch rate of *P. filamentosus* from 1990 onwards. Around this time, other boat-gear categories (principally those with electric reels) shifted their effort to deeper water, and presumably the basic fleet followed the trend adopted by vessels equipped with electric reels that year. Sector 9 indicated considerable fluctuation in catch rates, but data were inadequate to explain this variation. Individual species catch rates for all sectors (not shown) also failed to indicate any consistent pattern for any species (not attributable to changing depth), although Maconde (*E. chlorostigma*) did decrease at most locations over the period (Fig. A.3.16.).

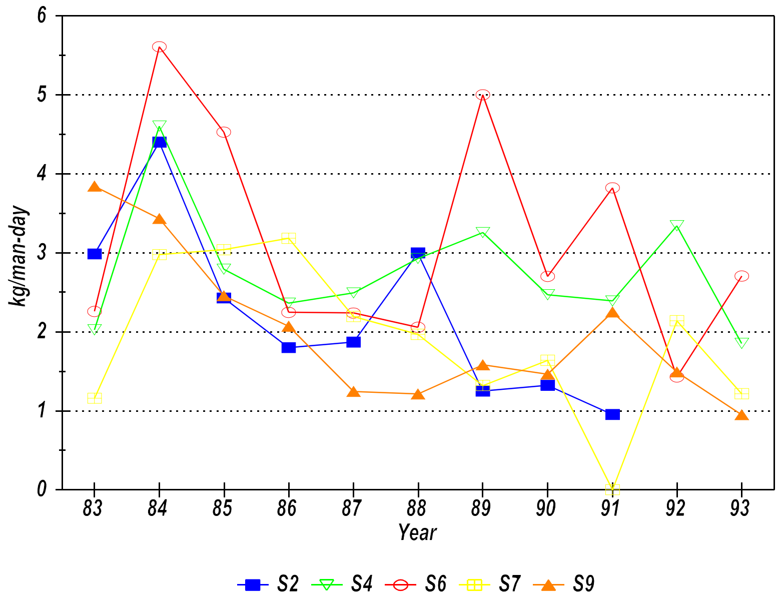


Fig. A.3.16 : Catch rates observed for *E. chlorostigma* caught by the basic schooner fleet using handlines at a number of fishing sectors.

A failure to observe depletion suggests that indeed fishing effort is low relative to the available resource and that biomass has remained relatively unchanged in the sectors examined. This could be slightly misleading in that within sectors, localised areas may have been depleted, but the definition of the data is inadequate to detect this. Furthermore, few vessels remained throughout the 10 year period, and only the better boats may have been left in 1993 thus apparently maintaining catch rates. Newer boats entering around 1989 may also have achieved better catch rates than some of the older boats - in particular this may explain the increases observed. At sector 9 the La Digue boats fishing with electric reels also indicated no depletion. There was no evidence of a consistent change in species composition which could be attributed to fishing, with the exception, perhaps, of the decrease in the serranid *E. chlorostigma* in catches since 1993, although other factors such as depth change may be partly responsible for these observations.

Stratified data thus did not indicate any location which warranted closer investigation through standardisation of catch rates and since standardisation for depth and seasonality could only be achieved for the shortened data set from 1990 onwards anyway, this was not considered worthwhile.

The conclusion to draw from these analyses is that at the level of the fishing sector, schooner fishing effort has been low and has had little impact on the demersal fishery resources. Locally (eg. within Sector 11 at a particular bank such as Small Constant) there may have been significant impact. However, the definition of the data is inadequate to detect this. Schooners simply report a general direction rather than a specific fishing location. Now that many schooners are equipped with GPS such a data collection system requires updating and latitude and longitude should be recorded. Furthermore, with the introduction of new vessels (eg. the Cygnus vessels) which fall into the statistical classification of 'Schooners' it is necessary to assess whether the schooner data collection form is adequate or whether new procedures should be devised.

ANNEX 4: Details of a paper presented at an EPOMEX/ICLARM workshop on tropical groupers and snappers, with additional details appended.

DEMERSAL FISH STOCK ASSESSMENT IN SEYCHELLES - AN ANALYSIS OF A MOTHERSHIP - CATCHER BOAT FISHERY.

Abstract

Stock assessments for certain important tropical demersal species are presented based on the analysis of commercial line fishing data collected from a mothership / catcher boat operation targeting snappers, groupers and emperors in Seychelles waters. Six fishing trips were conducted over the period March 1991 - March 1993 at a number of 'virgin' or lightly fished banks and sea mounts of varying size distant from the main centres of population.

Depletion estimates of initial population size (Biomass, B_0) are derived from daily information within single fishing voyages at specific locations. An attempt to determine production is presented utilising biomass estimates from subsequent voyages to the same locations. The limited duration spent at any one fishing location and variability in catch rates resulting from changes in fishing depth (target species) restrict the number of comparisons of site specific analyses from the present data set, but the method will be of increasing value as more information becomes available. The implications for management purposes are great: inferences may be made to the rate of recovery of depleted areas, useful in what is essentially a 'hit and run' fishery.

It is suggested that providing that adequate care is taken to account for variability in catch rates not directly attributable to fishing pressure, the application of this type of analysis to commercial data offers a cheap alternative to intensive fishing experiments during research cruises.

Introduction

The large number of fish species and information intensive requirements of most multi-species stock assessment models (for reviews see : Gulland and Garcia, 1984; Kerr and Ryder, 1989; Polovina, 1992) mean that data collection requirements for adequate stock assessment are beyond the means of many small fishery departments in tropical countries. Depletion methods of stock assessment, however, can be substantially cheaper and more effective than others (Hilborn and Walters, 1992). Polovina (1986) applied this approach to data collected during an intensive fishing experiment in the Marianas. Where commercial data can be utilized, substantial cost savings may be gained over the application of experimental fishing during planned research cruises, although at the expense of experimental design.

In this paper stock assessments are based on the analysis of commercial line fishing data collected from a mothership / catcher boat operation targeting snappers, groupers and emperors in Seychelles waters. Mees (1993) estimated the biomass of *Pristipomoides filamentosus* (Valenciennes, 1830) from data collected during a single voyage of this vessel. Here, subsequent voyages to a number of locations are presented, and enable estimates of stock production.

The study area.

Seychelles consists of four island groups in the Western Indian Ocean between 5^{o} and 10^{o}S and 45^{o} and 56^{o}E (Fig. 1). The majority of the population live on the granitic islands Mahe, Praslin and La Digue within the Mahe Plateau, whilst the coralline Amirantes, Providence / Farquhar and Aldabra / Cosmoledo groups are sparsely inhabited.

Demersal fishing effort by the artisanal fleet (mostly wooden vessels, 12 m length or smaller) is largely confined to the Mahe Plateau and its periphery, but in periods of good weather a few vessels may venture to the Amirantes group. The Providence / Farquhar and Aldabra / Cosmoledo groups may be regarded as un-fished excepting some exploitation during the 1970's by mothership - catcher boat ventures at the former group. Fishing activity at these locations, and at lightly fished banks and sea mounts south of the Mahe Plateau is examined.

Climatic conditions during the South East Trade Winds, which average 12 knots, frequently limit fishing activity from the end of May to October. It may also be affected by the north-west Monsoon between mid November and mid March. During the two inter-monsoon periods light variable winds and frequent calms occur.

Materials and methods

Between March 1991 and March 1993 an 88.4 m refrigerated cargo ship deployed up to twelve 7 m fibre-glass catcher boats during six fishing voyages to remote banks and island groups in the Seychelles. Each voyage lasted between 46 and 71 fishing days (Table 1).

Catcher boats were equipped with echo sounder and compass and usually fished within 10 miles of the mothership. Hand lines were used during the first voyage. Electric fishing reels were fitted subsequently although frequently a combination of electric reels and hand lines were used by the three man crew. One trip per boat per day was usual, although occasionally two trips were made.

Detailed catch and effort data were recorded for each catcher boat trip by an observer from the Seychelles Fishing Authority. Factors which could potentially affect catch rates and / or species composition were also recorded on the catch and effort log : depth fished, bait type, climatic conditions. These latter data are not available for all voyages and reported details for voyage 4 were considered unreliable. This information is utilised tentatively in interpretation of the results.

Total daily catch and effort data were generated by gear type (lines, reels or both) and location. In order to enable intra voyage comparisons relative fishing power was determined for gear type, month and fishing location by application of the following model to standardise fishing effort:

$$U_{tik}=U_{111}.\alpha_t.\beta_i.\gamma_k.\varepsilon_{tik} \qquad \textbf{(1)}$$

where U is the catch rate, subscript t refers to time, I to gear type and k to fishing location. U_{111} is the catch rate obtained by the first gear type in the first time period at the first location, α_t is a factor that is the abundance in month t relative to month 1, β_i is the efficiency of gear type i relative to gear type 1, γ_k is the average abundance differential in area k relative to location 1, and ε_{tik} is a factor explaining the deviation between the observed U_{tik} and the expected value for t, i and k (see Hilborn and Walters, 1992).

Taking the logarithms of both sides of equation 1, a linear statistical model is derived :

$$\log(U_{tik})=\log(U_{111})+\log(\alpha_t)+\log(\beta_i)+\log(\gamma_k)+\log(\varepsilon_{tik}) \qquad \textbf{(2)}$$

from which
the parameters α, β, ad γ may be estimated by multiple linear regression.

Fishing effort of the original catcher - boat data was standardised relative to hand-lines and to the month of January. Total daily catch and effort data were recalculated by location. These data were employed in a modification of the Leslie depletion model (Leslie and Davis, 1939) in order to determine original biomass at the start of subsequent fishing occasions (B_{01} and B_{02}), as follows :

Since each fishing occasion lasts only a few days natural mortality, growth, recruitment and immigration will be negligible and may be disregarded. B_{ti}, the biomass remaining on day t of voyage I may be expressed :

$$\begin{aligned} B_{ti} &= B_{0_i} - \sum_{s<t} C_{si} \\ &= B_{0_i} - D_{ti} \end{aligned} \qquad \textbf{(3)}$$

where C_{si} is the catch taken during day s of voyage i, and D_{ti} is the total catch taken on that voyage before day t.

The catch rate U_{ti} on day t of voyage i will be related to the biomass, B_{ti} by:

$$U_{ti} = q.B_{ti} + \omega_{ti}$$
$$= q.B_{0_i} - q.D_{ti} + \omega_{ti} \qquad \textbf{(4)}$$

where q is the catchability, and ω_{ti} explains random variability.

Whilst biomass (B_0) changes between fishing voyages due to mortality, recruitment, growth and immigration, the catchability (q) is expected to remain constant. To ensure the same estimate of q for all voyages, and to reduce estimation 'noise' due to short data series, equation 4 may be rewritten enabling simultaneous estimation of q and the B_{0i}'s by multiple regression. First, indicator variables I_{2ti} I_{3ti}........ are defined for all voyages except the first, so that I_{2ti}=1 for all data from voyage 2 and 0 for all other data, I_{3ti}=1 for all data from voyage 3, and 0 for all other data, and so on.

Consider the example of three voyages to one location. Using equation 4 we set for voyage 1:

$$U_{t1} = q.B_{0_1} - q.D_{t1} + \omega_{t1}$$
$$= q.B_{0_1} + I_{2t1}.(q.B_{0_2} - q.B_{0_1}) + I_{3t1}.(q.B_{0_3} - q.B_{0_1}) - q.D_{t1} + \omega_{t1} \qquad \textbf{(5)}$$

noting that for all observations in voyage 1 I_{2t1} = I_{3t1} = 0.
For voyage 2 (I_{2t2} = 1, I_{3t2} = 0):

$$U_{t2} = q.B_{0_2} - q.D_{t2} + \omega_{t2}$$
$$= q.B_{0_1} + I_{2t2}.(q.B_{0_2} - q.B_{0_1}) + I_{3t2}.(q.B_{0_3} - q.B_{0_1}) - q.D_{t2} + \omega_{t2} \qquad \textbf{(6)}$$

and voyage 3 (I_{2t3} = 0 I_{3t3} = 1) :

$$U_{t3} = q.B_{0_3} - q.D_{t3} + \omega_{t3}$$
$$= q.B_{0_1} + I_{2t3}.(q.B_{0_2} - q.B_{0_1}) + I_{3t3}.(q.B_{0_3} - q.B_{0_1}) - q.D_{t3} + \omega_{t3} \qquad \textbf{(7)}$$

This may be written in general form as:

$$U_{ti} = \alpha + \sum_{j=1}^{v} I_{jti}.\beta_j - q.D_{ti} + \omega_{ti} \qquad \textbf{(8)}$$

where v is the total number of voyages undertaken,

$$\alpha = q.B_{0_1} \qquad \textbf{(9)}$$

$$\beta_j = (q.B_{0_j} - \alpha) \qquad \textbf{(10)}$$

for j = 1 to v. The variables q, α and β_j may be estimated by multiple linear regression. The biomass at the start of the first voyage may then be estimated from (9):

$$\hat{B}_{0_1} = \frac{\hat{\alpha}}{\hat{q}} \qquad \textbf{(11)}$$

and subsequent voyages for j = 1 to v from (10)

$$\hat{B}_{0_j} = \frac{\hat{\alpha} + \hat{\beta}_j}{\hat{q}} \qquad \textbf{(12)}$$

Production (P) between voyages i and (i+1) to the same location can be estimated from :

$$\hat{P}_{i\rightarrow(i+1)}=\frac{\hat{B}_{0_{i+1}}-(\hat{B}_{0_i}-C_i)}{d_{i\rightarrow(i+1)}} \qquad \textbf{(13)}$$

where C_i is the total catch removed at the end of voyage i, and $d_{i\rightarrow(i+1)}$ is the time interval, in days, between fishing occasions. Production is equivalent to all gains due to growth, recruitment and immigration, less losses due to natural mortality.

Results

Factors applied to standardise the original data by month and gear type are indicated in Table 2. Throughout the six voyages fishing took place at a total of 31 different banks, sea mounts or islands. At any one location fishing duration varied between 1 and 8 days and the prevalent pattern observed was that of decreasing daily catch rates. Results relate to those locations fished during two or more voyages for greater than one day (Table 3 and Figs. 2 and 3).

In general, mean catch rates are observed to decrease from one voyage to the next. This was true for small banks and sea mounts, but not for the large banks (Constant Bank). Daily catch rates at Fortune Bank, like Constant Bank, indicate no evidence of depletion between voyages (Figure 4). For small banks, exceptions were Bulldog Bank and Sea Mount '25' in the Providence / Farquhar group : during voyage 4 strong currents depressed catch rates, not the case during voyage 5 to these locations.

Eliminating those locations at which changes in depth and target species were significant (Sea Mount '20', Wizard Reef) only 3 locations of the original 31 are suitable for the present depletion study: Correira Bank, Small Constant Bank and Farquhar (Table 4 and Figs 5-7 respectively). Small Constant Bank was eliminated from the analysis : inconsistent results which were considered unreliable (only two data points for each of voyages 2 and 3); this bank was subject to fishing by other vessels between voyages so the total catch removed was unknown. Correira Bank was unlikely to have been fished by other vessels and Farquhar had not.

At Correira Bank, no consistently decreasing trend with time occurred for the combined catch rate of all demersal species, but was observed for the target species, *P. filamentosus*. At Farquhar no trend occurred for individual species but was observed for the combined demersal catch. The biomass prececeding each voyage was estimated by regression of standardised catch rate on adjusted cumulative catch for *P. filamentosus* at Correira Bank (Fig. 8, Table 5) and all demersal species at Farquhar (Fig.9, Table 5). No attempt was made to partition effort directed at *P. filamentosus* in the case of Correira Bank. This species formed approximately 50% of the catch and at the depth range fished (> 70 m) it was the target species. Thus the total effort was assumed to be directed at this species.

In Seychelles *P. filamentosus* is caught in the depth range 75 - 150 m (Mees, 1993). The net rate of production for *P. filamentosus* at Correira Bank was 2.5 kg day^{-1} km^{-2} of the intermediate depth range (Table 5) or 0.6 kg day^{-1} km^{-1} of the 100 m isobath. For all demersal species at Farquhar, where fishing occurred in the shallow stratum, it was 0.25 kg day^{-1} km^{-2}.

Discussion

Mothership - catcher boat operations excert significant fishing pressure at localised areas over a short time period. At large banks local depletion may occur during any one voyage (as appeared to be the case during Voyage 3 at Fortune Bank, Fig. 4) but differences in precise fishing location and the relatively larger standing stock at these locations mean depressed catch rates are not observed between voyages. However, it is apparent that depletion of small isolated areas can be significant, and that catch rates remain depressed from one fishing occasion to the next indicating that insufficient time has elapsed to allow complete recovery.

The rate of recovery, or production, was estimated. At Correira Bank the stock of *P. filamentosus* had fully recovered between voyage 1 and 3. The production estimate of 2.5 kg $km^{-2}day^{-1}$ equates to 914.6 kg km^{-2} $year^{-1}$ (228.0 kg km^{-1} at 100 m isobath). Mees (1993) estimated the sustainable yield of this species to be 716.8 kg km^{-2} $year^{-1}$. Polovina and Ralston (1986) estimated the total yield of all snappers and groupers at the 200m isobath in the Marianas to be 300 kg km^{-2} $year^{-1}$ whilst Polovina *et al.* (1990) give mean estimates of 380 kg km^{-1} on reefs and 1, 460 kg km^{-1} at sea mounts for all species at the 200m isobath. Given the differences in depth, and the fact that *P. filamentosus* represented approximately 50% of the catch, the estimate of production is of the right order and sufficient to generate the estimated yield for this resource.

Incomplete recovery had occurred at Farquhar between voyages 2 and 4. Production was estimated to be 0.25 kg day^{-1} km^{-2} in the shallow stratum which is rather low. The total area of Farquhar Atoll is an inappropriate value to apply. It is not clear that fishing actually took place inside the lagoon: this is not permitted, and the maximum depth of the lagoon is 14.6m, whilst the mean fishing depth was around 50m. It is most likely that localised depletion of a smaller area has occurred. At Farquhar the anchoring positions for voyages 2 and 4 were 8 nautical miles apart. However, the catcher boats fish within a radius of approximately 10 nautical miles of the mothership and so the same area would have been exploited. Assuming a fished reef area of 10 - 20 nmi by 0.5-1 nmi (17 km^{-2} - 69 km^{-2}) the production estimate becomes 2.5 - 0.62 kg day^{-1} km^{-2}.

Polovina (1986) indicated that the catchability of subordinate species in a multispecies assemblage is inversely related to the abundance of a more dominant species, although this change in catchability may have a time lag associated with it. He also showed that the pooled estimate of abundance for three species representing 90% of the exploitable population was 71% of the estimate derived for these species individually. From this we may conclude the biomass derived for all species at Farquhar may be underestimated on each voyage, but not necessarily the production. At Correira *P. filamentosus* was dominant in the catch.

Whilst the results presented for *P. filamentosus* are of the correct order and support previous estimates of yield, there are potential sources of bias and error. During each period of fishing the model assumed a 'closed' study population due to the short time frame involved. Between fishing it was 'open'. Hilborn and Walters (1992) discuss sources of error in estimates based on closed population depletion assessments and suggest that over a short time frame catchability may decline with the removal of stupider or more aggressive fish, increasing q and depressing estimates of $B_{0.}$ Catchability was assumed to be constant for each fishing occasion although its real value may change within each fishing period in this manner. The time interval between fishing occasions (145 days at Farquhar; 302 at Correira Bank) was considered sufficiently long to negate such a change by the start of the second fishing period. In contrast to this potential bias, q may be underestimated and B_0 overestimated if errors occur in the measurement of the cumulative catch or effort. These are considered to be reliable.

It has been demonstrated that commercial data may be used for depletion estimates of stock size and production. The analyses possible were constrained by lack of replicates which under research conditions would have been contained in the experimental design : particularly depth fished; duplicate fishing trials at certain locations despite low catch rates; longer time series at each location. Nevertheless, for single voyages depletion estimates of stock size were frequently possible (see Mees, 1993, for *P. filamentosus*; Mees[6], for *P. filamentosus* and *L. nebulosus*). For estimating production between voyages it was seen that the number of site specific comparisons was limited. Additionally, depletion estimates of abundance are subject to the bias discussed. Nevertheless, it is argued that despite these limitations, valuable information has been gained at minimal cost, and that this method will be of increasing value as more data becomes available from future voyages.

References

(see references in main body of text)

[6] Mees, C. C. (unpublished) Pecheur Breton : an analysis of data relating to a mothership - dory fishing operation in Seychelles waters from March 1991 - June 1992. Seychelles Fishing Authority, SFA/R&D/023, October, 1992.

TABLE A.4.1 : Details of the Fishing Voyages undertaken between March 1991 and March 1993

Voyage	Fishing Dates	Days	Fishing Locations	Boat Days
1	03/03/91 - 02/05/91	70	Mahe Plateau (MP)	169
			Banks south of MP	547
2	23/10/91 - 16/12/91	54	Mahe Plateau	297
			Banks south of MP	142
			Platte Plateau	4
			Amirantes group	58
			Providence / Farquhar	137
3	08/01/92 - 12/03/92	64	Mahe Plateau	73
			Banks south of MP	252
			Amirantes Group	325
4	11/04/92 - 27/05/92	46	Providence / Farquhar	501
5	26/10/92 - 20/12/92	55	Amirantes group	13
			Providence / Farquhar	443
			Aldabra / Cosmoledo	79
6	10/01/93 - 22/03/93	71	Mahe Plateau	12
			Banks south of MP	60
			Platte Plateau	12
			Saya de Mahla bank	591

TABLE A.4.2 : Parameters derived by multiple linear regression for standardisation of fishing effort relative to hand-lines, January and the south-east edge of the Mahe Plateau (MP).

Parameter	Detail	Log value	Value
α_2	February	0.0417	1.0697
α_3	March	0.0421	1.5664
α_4	April	0.0467	1.7115
α_5	May	0.052	1.15
α_6	October	0.0612	1.9031
α_7	November	0.0406	1.6164
α_8	December	0.0527	1.7403
β_2	unknown (gear)	0.0829	0.0291
β_3	lines and reels	0.0291	1.0009
β_4	reels only	0.0399	1.2479
γ_2	Junon Bank	0.1665	0.9871
γ_3	South Edge MP	0.1367	1.1702
γ_4	Banks south of MP	0.0368	1.2525
γ_5	Platte Plateau	0.1342	0.9407
γ_6	Amirantes	0.0486	1.5601
γ_7	Providence/Farquhar	0.0458	2.2391
γ_8	Aldabra/Cosmoledo	0.1063	1.1974
γ_9	Saya de Mahla Bank	0.0546	2.4658

TABLE A.4.3 : Locations visited on two or more voyages for more than one day, and the fishing areas in shallow and intermediate depth strata where available.

Fishing location	Area (km^2) 0-75 m	Length of 100 m contour (km)	Area (km^2) 75-150 m
BANKS SOUTH OF THE MAHE PLATEAU			
Constant Bank	590.0	114.8	28.7
Correira Bank	17.4	33.3	8.3
Fortune Bank	600.0	120.4	30.1
Sea Mount '20'	6.6	11.1	2.7
Small Constant Bank	170.0	55.6	13.8
PROVIDENCE / FARQUHAR			
Bulldog Bank			
Farquhar	172.0[a]		
Sea Mount '25'			
Wizard Reef			

a Total area of Farquhar Atoll (UNEP/IUCN, 1988) - actual fishing area will be less than this.

TABLE A.4.4 : The anchoring position of the mothership each day at each of the locations studied showing (*) the days used in the analyses.

Location	Voyage	Dates	Position	
Correira Bank	1	24/04/91	06° 29' S 57° 10' E	*
Correira Bank	1	25-27/04/91	06° 22' S 57° 05' E	*
Correira Bank	1	10/05/91	06° 22' S 57° 05' E	
Correira Bank	3	23-25/02/92	06° 21' S 57° 06' E	*
Correira Bank	3	26/02/92	06° 30' S 57° 16' E	
Small Constant	1	01-07/04/91	06° 03' S 56° 18' E	*
Small Constant	2	07-08/11/91	06° 04' S 56° 18' E	*
Small Constant	3	21-22/02/92	06° 03' S 56° 17' E	*
Farquhar	2	09-16/12/91	10° 08' S 51° 09' E	*
Farquhar	4	09-13/05/92	10° 08' S 51° 01' E	*
Farquhar	4	17/05/91	10° 05' S 51° 10' E	
Farquhar	5	17-18/12/92	10° 08' S 51° 59' E	
Farquhar	5	19/12/92	10° 11' S 51° 11' E	

TABLE A.4.5 : Regression parameters derived for : *Pristipomoides filamentosus* at Correira Bank, and estimates of catchability, biomass, and production between voyages 1 and 3; all demersal species at Farquhar, and estimated values between voyages 2 and 4.

Parameter	Correira Bank	Farquhar
No. obs	7	13
R^2	0.9066	0.6724
α	3.017958	14.90345
β_2	0.108966	-4.73422
q	0.000126	0.000123
C_1	5426 kg	44788.0 kg
B_{01}	23903 kg	121177 kg
B_{02}	24766 kg	82684 kg
d_{1-2}	302	145
P_{1-2}	20.8 kg day^{-1}	43.4 kg day^{-1}
P_{1-2} km^{-2}	2.5 kg day^{-1} km^{-2}	0.25 kg day^{-1} km^{-2}

Figure A.4.1. Seychelles EEZ indicating the fishing locations visited by the mothership catcher vessel : Mahe Plateau, and Banks South of the Plateau, the Amirantes group, Providence / Farquhar group, and Aldabra / Cosmoledo group.

(not shown - see Figs 1 & 2 in main body of text)

Figure A.4.2. To illustrate the mean standardised catch rate (kg / man-hour) for each voyage to the banks South of the Mahe Plateau, with approximate mean fishing depth (m) per voyage shown.

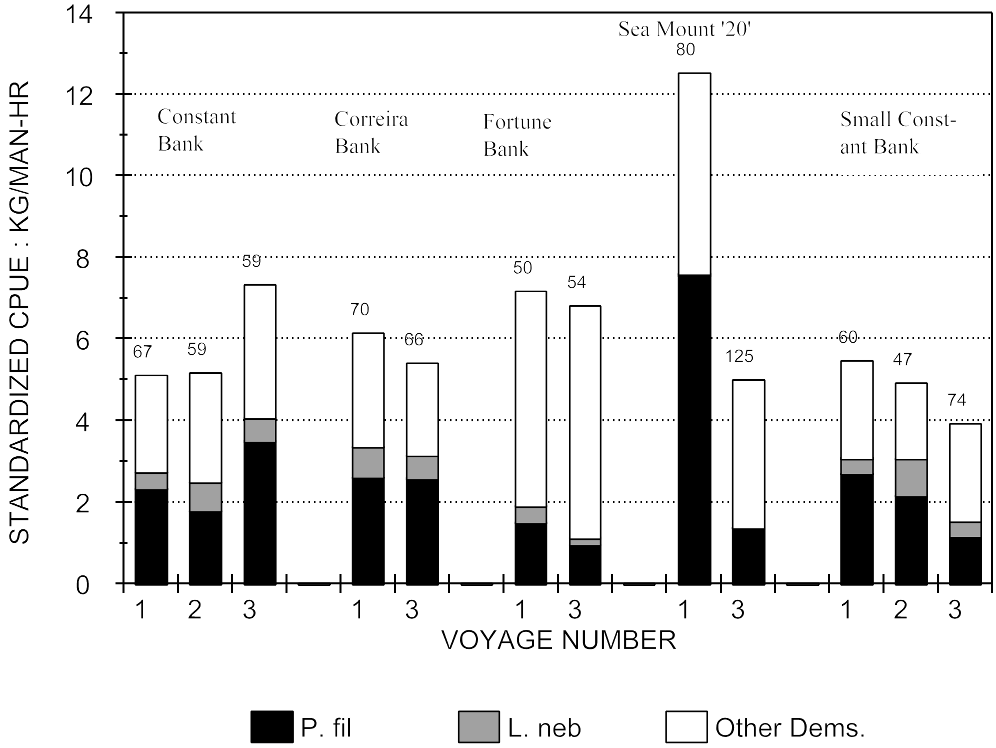


Figure A.4.3. To illustrate the mean standardised catch rate for each voyage to locations in the Providence / Farquhar group, with approximate mean fishing depth (m) per voyage shown.

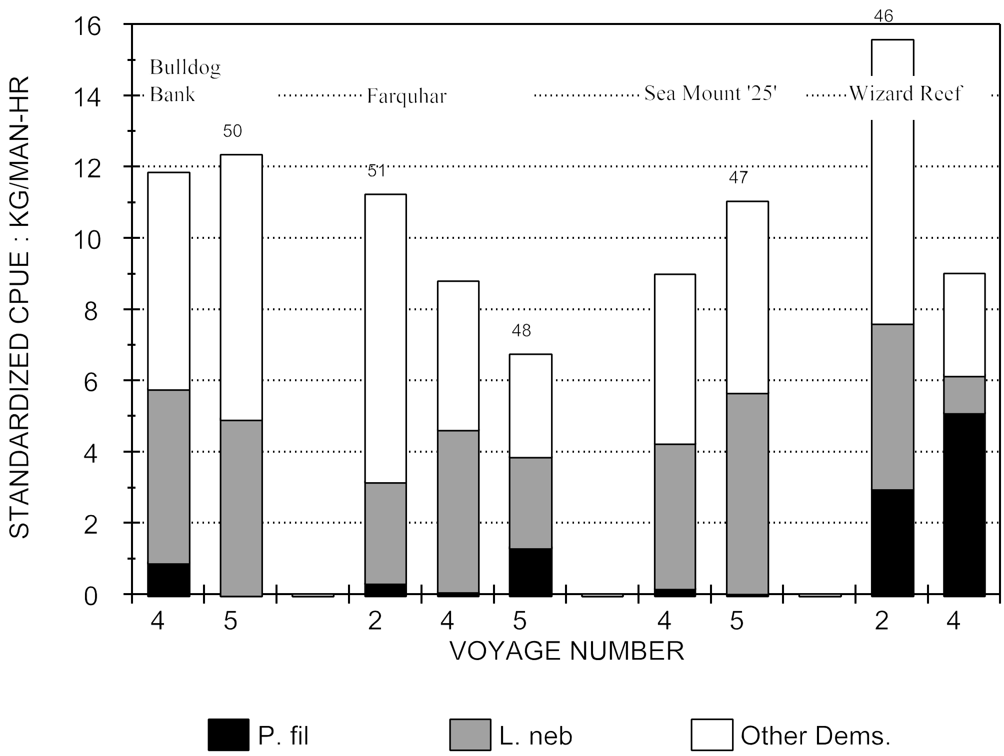


Figure A.4.4. Standardised daily catch rates at Fortune Bank. Note : in Figures 4 - 7 the X axis does not represent a linear scale. A break in the line indicates that the mothership moved location (within any voyage) or that the data relate to different voyages.

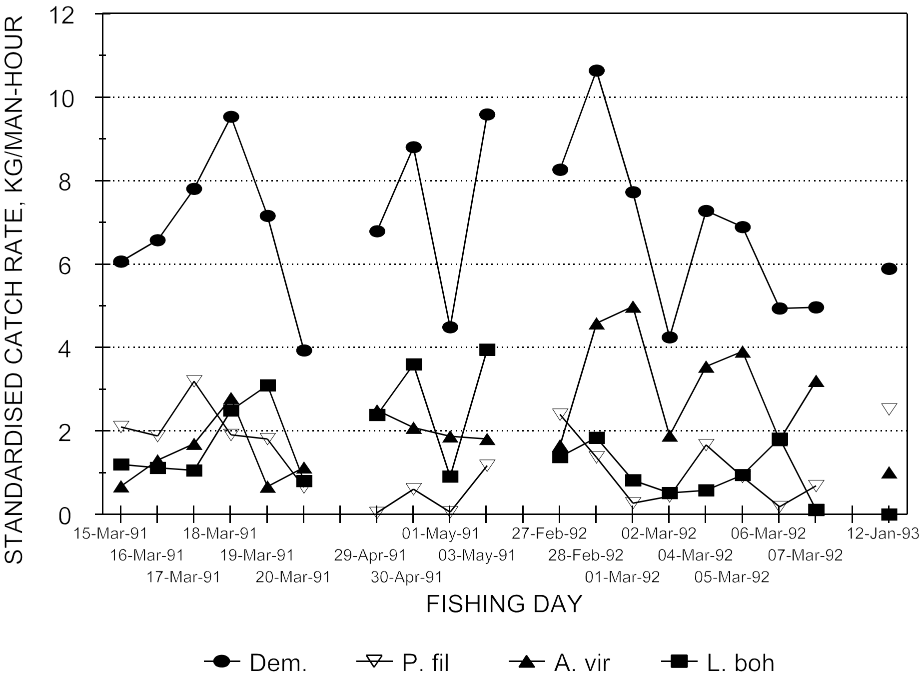


Figure A.4.5. Standardised daily catch rates at Correira Bank.

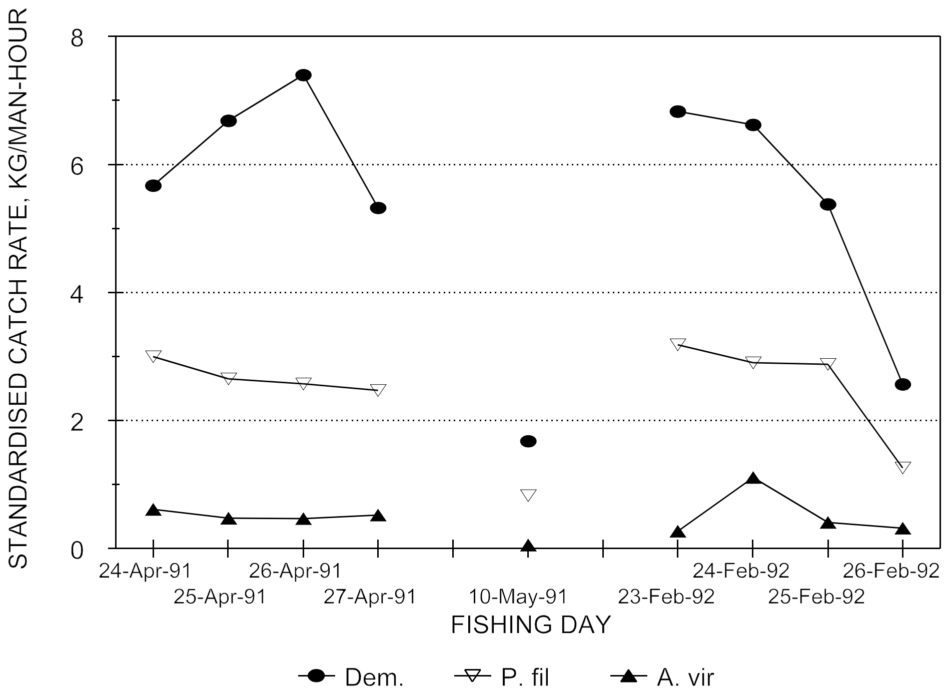


Figure A.4.6. Standardised daily catch rates at Small Constant Bank.

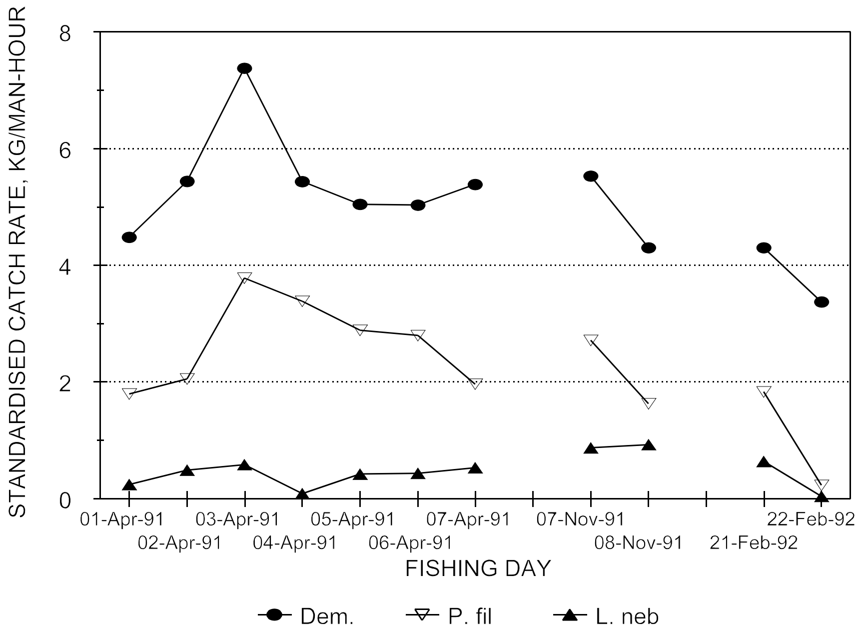


Figure A.4.7. Standardised daily catch rates at Farquhar.

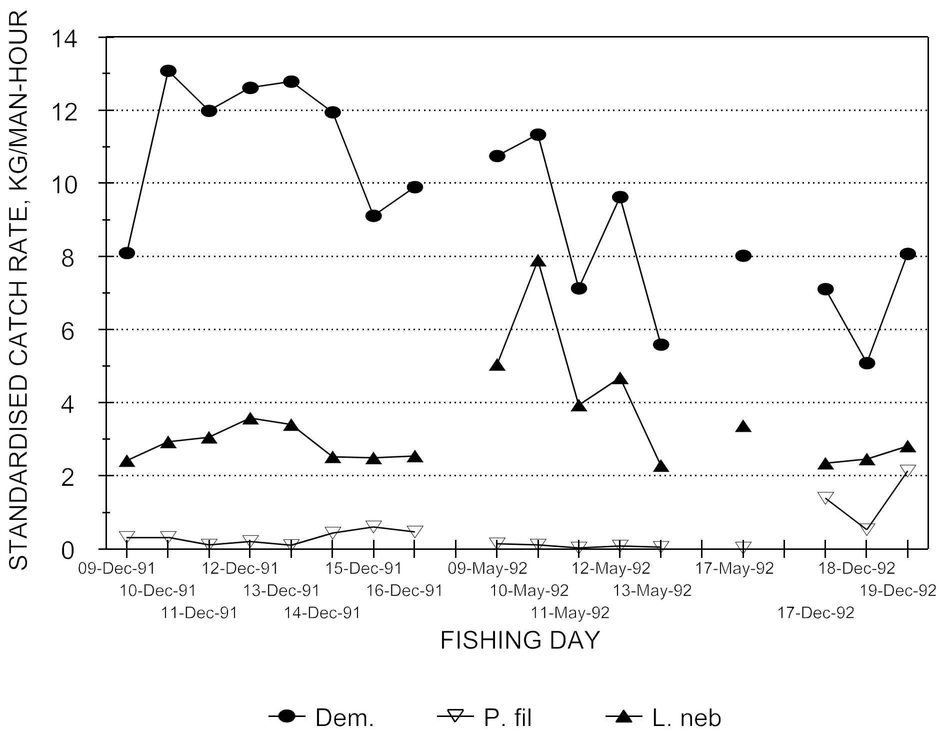


Figure A.4.8. Depletion of *Pristipomoides filamentosus* at Correira Bank during voyages 1 and 3. February 26 1992 was excluded from the analysis since the reported depth was significantly less than on the previous 3 days and the position had changed.

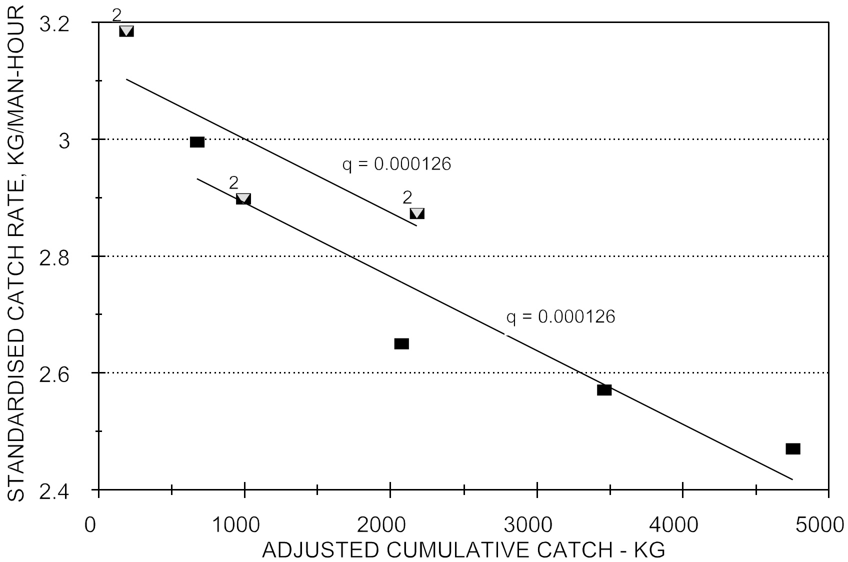
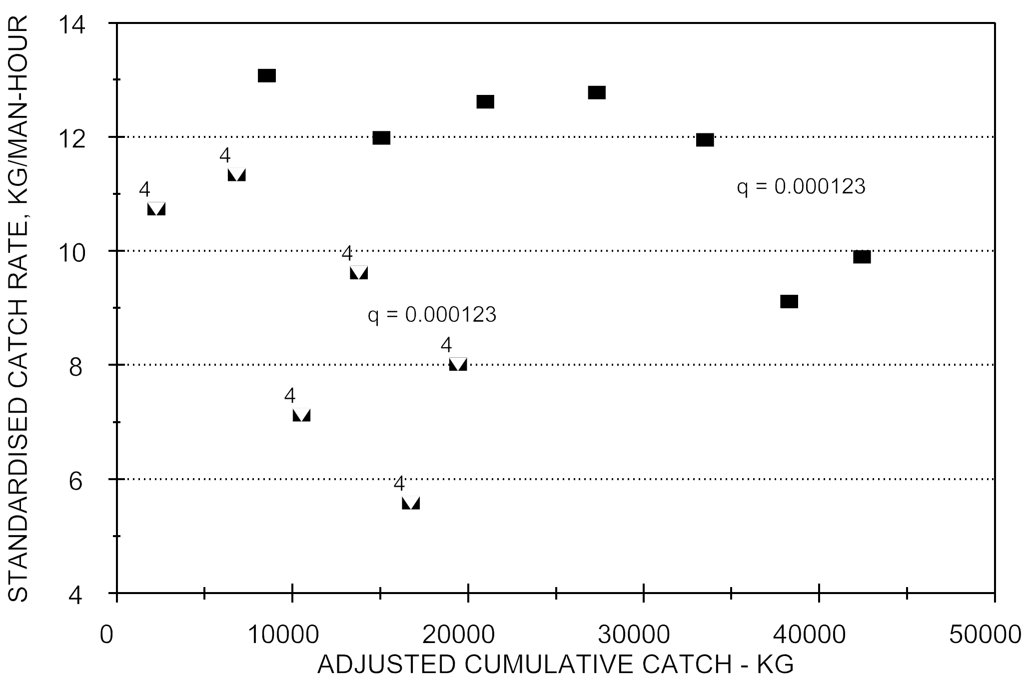


Figure A.4.9. Depletion of the total demersal species catch at Farquhar during voyages 3, 4 and 5. December 9 1991 and voyage 5 was excluded from the analysis.



ADDITIONAL INFORMATION

Mees (1991b) and Mees (1992c) presented details of analyses for individual mother-vessel voyages. It is clear that during a single trip local depletion may occur. The above paper examined locations at which fishing occurred during more than one trip and examined both depletion over a longer term and the recovery of fished reefs with time. A number of locations had been fished on more than one occasion, but because the time series was insufficient or due to changing target species or depth these locations were excluded from the analysis. The details are now presented:

Figures A.4.10 to A.4.18 Additional Information

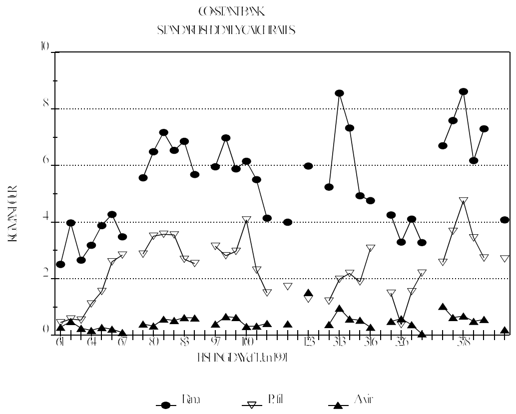


Fig A.4.10.

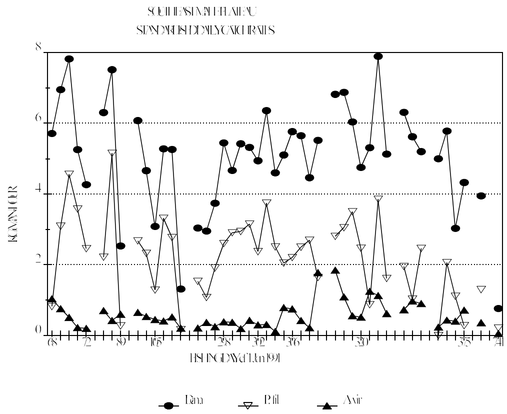


Fig A.4.11

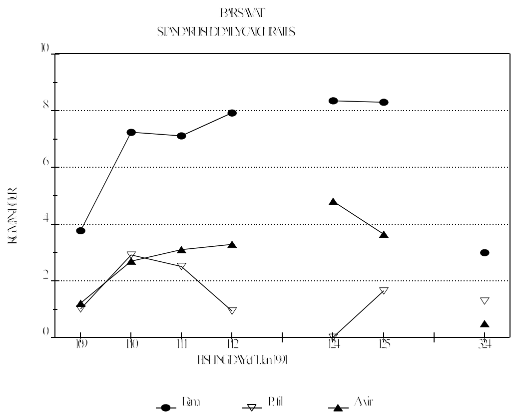


Fig. A.4.12

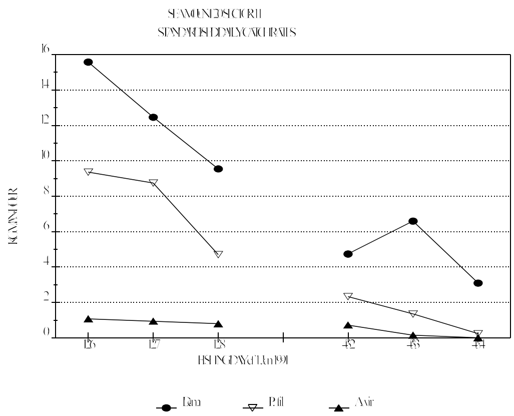


Fig A.4.13

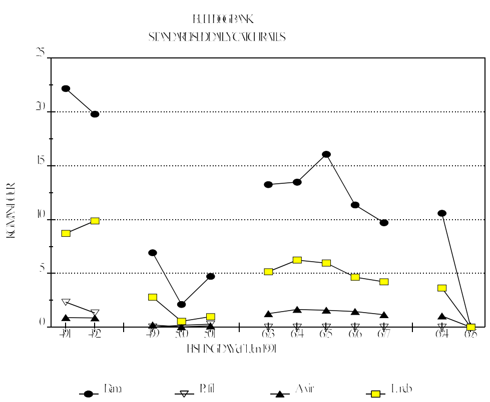


Fig A.4.14

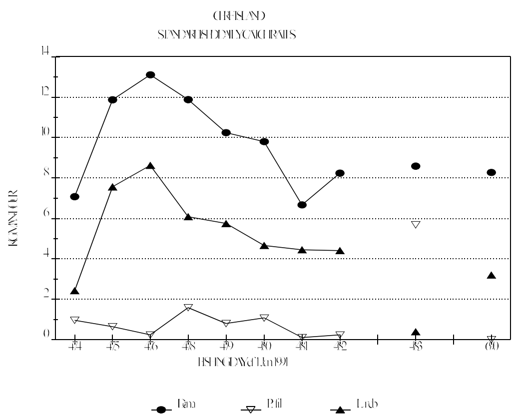


Fig. A.4.15

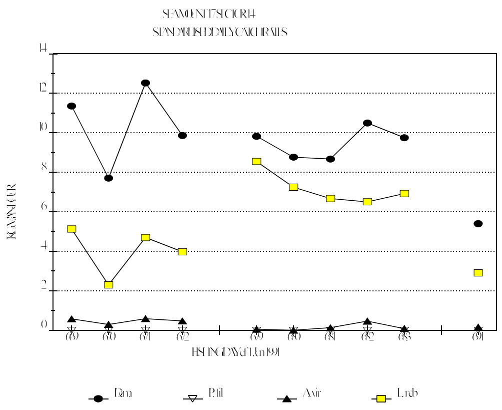


Fig. A.4.16

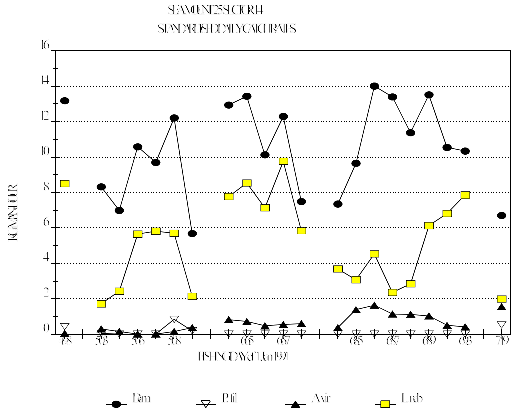


Fig. A.4.17

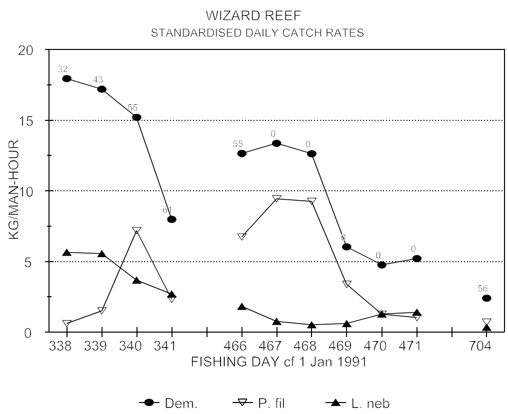


Fig A.4.18

ANNEX 5 : CEDA analyses for fishing sector 1 : estimation of exploited biomass.

Long term depletion suitable for analysis using biomass dynamic production models (Fox, Schaeffer) was not found for the lightly fished sectors. For the heavily fished sector 1 the possibility of depletion existed. The CEDA package (MRAG, 1992a) was used to investigate data from the traditional whaler fishery and sector 1. Inputs required for the model are catch and effort (or an index of abundance). In addition CEDA requires that a parameter, 'initial proportion' (In%), is entered. This reflects the degree of exploitation prior to the period covered by the data set in order to back-calculate virgin biomass. Since exploitation in sector 1 is known to have occurred for a considerable time, this parameter was set at 0.5. Additionally CEDA offers a choice of 3 error models which may be fitted to the model in order to establish the best fit. Middle timing was always selected. The CEDA manual should be consulted for further details of model fitting.

A number of vessels exploited demersal species from sector 1. Rather than standardising fishing effort for all vessels and computing a total standardised effort, inputs for the model were GLIM standardised effort values for the traditional whaler fleet in sector 1 as an index of relative abundance, together with total catch estimates from all vessels (Table A.5.1). Only those species or species guilds which indicated a significant annual variation in catch rate were examined.

In no case was a fit of data (1989-1994) to model found, (Analyses not shown, R^2 in each case was less than 0.25, and residual plots indicated no fit). Depletion was not evident. Changing the production model (Schaeffer, Fox), error model, or initial proportion did not result in significant improvements to the fit. Next 1989 data was excluded on the grounds that this information related to 7 months only and errors could have occurred in raising the estimate of catch or standardising the catch rate to a 12 month period. This improved the R^2 value and fit of residuals in some cases but with the exception of the group ‘other lutjanids’ (ie without *A. virescens* and *L. sebae,* R^2 =0.969) no fit was found (Fig A.5.1). In this case estimates of the 95% confidence intervals of K and r were inadequate. This analysis was not taken any further and the validity of the biomass estimate derived (776 tonnes) is questionable. A poor fit was indicated for *C. gymnostethus* but this is a semi pelagic highly mobile species which is not confined to sector 1. Thus CEDA analyses are inappropriate in this case.

TABLE A.5.1 : Total annual catch for selected species (groups) in sector 1 and an estimate of the index of abundance of each species (group). * indicates that significant annual variation in catch rate occurred.

DETAILS			YEAR					
			89	90	91	92	93	94
L. sebae		Total catch (mt)	102.2	82.4	111.2	116.2	104.8	58.9
		Std cpue (kg/m.day)	2.95	3.56	6.26	3.36	3.5	2.54
A. virescens	*	Total catch (mt)	238.5	254.1	147.5	102.1	173.8	162.9
		Std cpue (kg/m.day)	3.64	11.05	3.34	1.49	0.9	7.22
Lutjanids nei	*	Total catch (mt)	168.6	86.5	40.4	42.9	31.4	28.9
		Std cpue (kg/m.day)	0.17	1.63	1.03	0.8	0.16	0.06
E. chlorostigma		Total catch (mt)	111.8	51.5	46.8	68	70.6	25.3
		Std cpue (kg/m.day)	3.09	3.21	3.39	2.51	2.97	3.7
Serranids nei	*	Total catch (mt)	67	35.2	38.8	41.4	33.7	15.8
		Std cpue (kg/m.day)	0.45	1.13	2.65	1.06	0.48	0.6
G. robinsonii	*	Total catch (mt)	12.3	14.6	12.6	15.3	9.6	5
		Std cpue (kg/m.day)	0.4	1.26	1.25	0.41	0.18	0.93
L. elongatus	*	Total catch (mt)	17.9	9	14.8	14.3	20.3	13
		Std cpue (kg/m.day)	0.79	0.15	0.51	0.27	0.29	2.53
L. crocineus	*	Total catch (mt)	6	4.4	6.2	7	12.1	3.7
		Std cpue (kg/m.day)	0.11	0.29	0.25	0.38	0.89	0.24
Lethrinids nei		Total catch (mt)	249.7	122.8	128.7	145	164.4	112
		Std cpue (kg/m.day)	13.56	10.38	9.24	6.37	7.97	6.75
All lutjanids	*	Total catch (mt)	509.3	423	299	261.2	309.9	250.7
		Std cpue (kg/m.day)	6.48	17.24	10.36	5.83	4.48	9.56
All serranids		Total catch (mt)	178.8	86.7	85.6	109.4	104.3	41.1
		Std cpue (kg/m.day)	4.66	5.11	6.27	4.33	3.77	4.52
All lethrinids		Total catch (mt)	285.8	150.8	162.4	181.5	206.3	133.6
		Std cpue (kg/m.day)	14.1	12.59	12.05	8.29	10.12	11.73
All demersal species	*	Total catch (mt)	973.9	660.4	547	552	620.5	425.4
		Std cpue (kg/m.day)	24.61	36.93	29.11	17.31	17.27	27.03
C. gymnostethus	*	Total catch (mt)	1323.6	1058.7	999.4	1074.6	448.8	485.9
		Std cpue (kg/m.day)	50.35	48.81	65.56	33.95	18.34	33.02

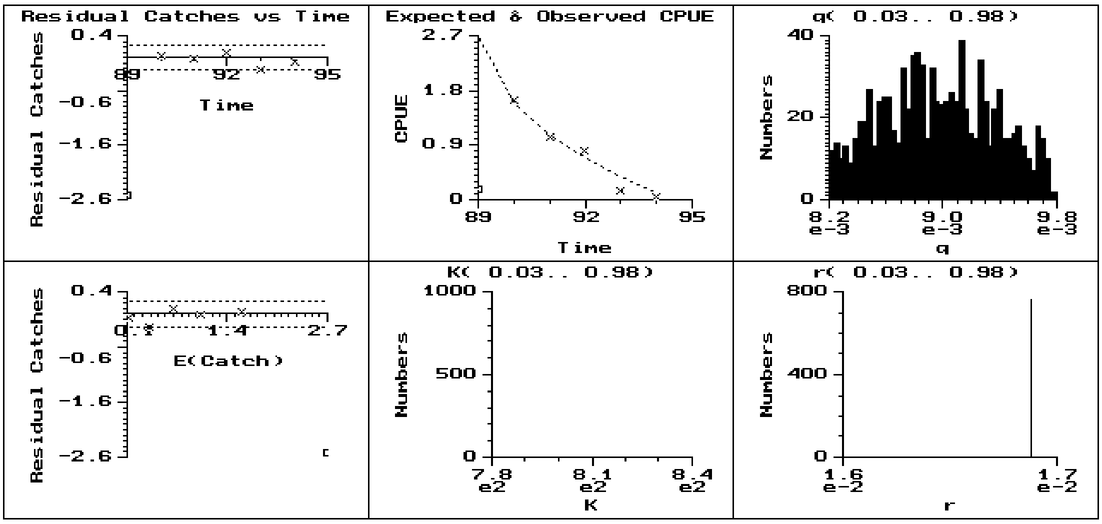


Fig. A.5.1 : The Schaefer production model applied to catch and abundance index data for the guild 'Other lutjanids' from 1990 to 1994. Error model = least squares, cpue timing = middle, initial proportion = 0.5. R^2=0.969, K=776, q = 0.00883, r=0.0169.

ANNEX 6 : Spatial analysis of fishing activity in the Indian Ocean

'A Comparison of Catch and Catch Rates from Bank Reef Fisheries in the Indian Ocean' was a poster presentation by Christopher Mees and Graham Pilling at the European meeting of the International Society for Reef Studies and the British Ecological Society : Biology and Geology of Coral Reefs, September 5-9, 1995 at the University of Newcastle. The following analysis is based on that presentation.

Indian Ocean Banks Fisheries

The banks fisheries of Mauritius and the British Indian Ocean Territories (BIOT : Chagos Archipelago) are exploited exclusively by mother-ship-dory handline fishing ventures from Mauritius (except Saya de Malha where vessels from Reunion, and recently from Seychelles have also fished). By contrast, Seychelles banks fisheries are exploited by a number of vessel types and gear types (although sample data are only available for handlines and electric fishing reels). From 1991 to 1993 a mother-ship-dory venture also operated in Seychelles.

The following Banks/Plateaux were identified :

1. Cosmoledo / Astove (Seychelles Sector 15)
2. Providence / Farquahar (Seychelles Sector 14)
3. Amirantes Plateau (Seychelles Sector 13)
4. Mahe Plateau (Seychelles Sectors 1-10)
5. Banks South of the Mahe Plateau (Seychelles Sectors 11-12)
6. Saya de Malha Bank (Mauritius / International waters)
7. Nazareth Bank (Mauritius)
8. St Brandon (including Albatross : Mauritius)
9. Chagos Archipelago (BIOT)

Effort was standardised (see Data Sources and Treatment) and historical catch and effort determined for each location where data was available. Catch rates for mother-ship dory ventures between 1991 and 1994 were compared by location (Fig A.6.1). Catch rates were also examined in relation to previous fishing history (mean catch/effort per square kilometre of bank per year), productivity, and oceanographic parameters.

Data Sources and Treatment

- Oceanographic data :

The distribution of primary production in gC/m^2/d (Figs. A.6.2 and A.6.3), and tertiary production in million tons wet weight/5^o square (estimated as an average of 1% of the primary production and 10% of the secondary production during the northwest monsoon (northern winter) and southeast trade wind period (northern summer; Figs A.6.4 and A.6.5) was illustrated (Cushing, 1971).

The distribution of both fish eggs (Fig A.6.6) and larvae (number per haul; Fig A.6.7) in the Indian Ocean during the periods April 16 to October 15 and October 16 to April 15 are presented (Cushing, 1971). Overlaid on these are the predominant current directions at these times of year.

Oceanographic information relates to the mean annual data by one degree square at a depth of 50 m (to correspond with common fishing depth), derived from the World Ocean Atlas 1994 (National Oceanographic Data Centre, Ocean Climate Laboratory, Washington, 1994) : temperature (Fig A.6.8), salinity (Fig A.6.9), dissolved oxygen (Fig. A.6.10), oxygen saturation (Fig A.6.11), available oxygen utilisation (Fig A.6.12), phosphates (Fig A.6.13), nitrates (Fig. A.6.14) and silicates (Fig A.6.15). These parameters may be influenced locally by the presence of the banks or emergent land masses, and the true values may vary somewhat from those given.

Gross substrate information was derived from UNEP/IUCN (1988). The following types were identified :

1. Coral

2. Coral and Sand
3. Granite and Sand
4. Dead coral

However, these can only be considered as gross generalisations and within each location a number of substrate types will in fact occur.

- Catch and Effort Data :

The following data were employed in the analysis :

Seychelles Banks. Catch and effort data by boat type (17 boat-gear combinations were identified) from 1985 to 1994 was analysed (Annex 1). Mother-ship dory fishing activity occurred prior to 1977 sporadically, and not again till 1991-1993.

Chagos Archipelago. British Indian Ocean Territory Inshore Fishery Logbook returns were analysed from 1991 to 1994. Prior to 1991 historical data is available in the literature and was extracted from a number of sources. Historical effort is unstandardised.

Mauritian Banks. A two year data set (1993 to 1994) was available for analysis. Prior catch and unstandardised effort data is available (as far back as 1969 for Nazareth Bank) from a number of literature sources. Depth details were not available for Mauritian vessels, but all are reported to fish predominantly in shallow water (around 50 m) on the surface of the banks.

Fishing effort data was standardised for boat-gear type, fishing depth and season using a generalised linear interactive model (see Annex 1; Table A.6.1). All effort data related to one man-day fishing by handline from a dory in the depth range 0-70 m during the period of the South-east trade winds (June to August). The relative fishing power of the Seychelles mother-ship-dory vessel was assumed to be equivalent to that of the average Mauritian vessel (direct comparison was not possible since the vessels had not fished in the same locations).

Catch data related to total catch removed by all vessel types by location. In the case of Saya de Malha it is known that a certain volume of fish have been removed by vessels from Reunion, but details were not available (Annex 1; Table A.6.2; Fig A.6.16).

Where catchability is constant, catch rate is an index of resource abundance . To compare catch rates by location, only mother-ship-dory data collected between 1991 and 1994 was utilised. Annual catch rates and mean standardised (boat, season and depth) annual catch rate by location were determined (Fig A.6.1). Additionally, standardised (boat and season) annual catch rates were determined by location and depth band (shallow, < 70 m; intermediate > 69 m)

Species Composition data was available for all except the Mauritian banks where catch is reported as ‘white' fish and total catch only. White fish are mostly lethrinids, specifically *Lethrinus mahsena* which reportedly constitutes in excess of 80% of the demersal catch (Samboo, pers. comm.). Gross species composition was determined (Fig A.6.17).

Correlation of catch rates with fishing pressure and oceanographic parameters

In order to investigate environmental and fishing effects on abundance of target demersal species, standardised catch rates by location were correlated with available production and oceanographic parameters (Figs. A.6.18 and A.6.19) and previous fishing history (Fig A.6.20). The latter was represented by mean annual catch and standardised effort per square kilometre for the number of years of available data. For Providence / Farquahar it was believed that no fishing had occurred since 1977 and the data set was considered as starting in 1978. For Cosmoledo / Astove there are no records of previous fishing, but this data was treated similarly.

Depth was recorded for the Seychelles mother-ship, but was not available for Mauritian vessels except from BIOT inshore fishery logsheets from 1993. For correlations by depth, catch rate data was determined directly for these data, and for all fishing on the Mauritian banks, the depth was assumed to be less than 70 m. Historical catch and effort, however, related to a number of vessel types for which depth was not recorded prior to 1990. Thus, in order to estimate catch by depth *P. filamentosus*, *A. rutilans* and *E. morhua* were assumed to represent the catch from the intermediate depth band, the remainder represent the shallow depth band. Effort was allocated in proportion to the sampled effort by depth band for the mother-vessel data. Catch and effort history was expressed as mean annual catch and effort per square kilometre of banks. Owing to the small area of the greater depth band, catch and effort appear high when expressed this way for this depth band.

To investigate the effect of fishing history on species composition only a gross comparison was possible given the definition of species information in the different data sets. Catch rate data by family was correlated with fishing history for lutjanidae, serranidae, and lethrinidae (Fig A.6.21). The relationship for each guild by depth band was similar to that for all depths (not shown).

Regression analyses were employed to investigate the relationship between catch rates (abundance) and fishing and environmental parameters indicated in Figs A.6.19-A.6.21. All demersal species caught at depths less than 70 m were initially studied. Single linear regression of catch rate against each parameter indicated that the relationship to mean annual catch and effort, winter primary productivity and silicates was significant at the 5% level, although the fit was poor (low R^2 : Table A.6.3a). The strongest relationships were related to fishing pressure.

Multiple regression of catch rate against all fishing and environmental parameters was not significant (not shown). That for a smaller sub model of oceanographic parameters was apparently significant (Table A.6.3b). However, none of the components of the regression were significant and the tolerance was low (< 0.1) indicating that these variables may be dropped from the model. A sub model including only those significant variables indicated above and substrate was also significant. Forward and backward stepwise iteration (to eliminate insignificant components of the model) both resulted in the same sub-model,

cpue=constant+mean annual effort +substrate

However, the relationship to substrate may be an artefact, given the loose definition of this variable and the fact that the least fished sites were both in the same category (see Fig A.6.19). Whilst previous fishing history appears to have a significant effect on catch rates (abundance), it is clear that environmental factors cannot be discounted.

Subsequent analyses (by depth band and by family) concentrated on fishing effects since this is the area of particular interest, although substrate and winter primary productivity were also investigated as the most significant environmental parameters. The poor relationship betweeen catch rates and fishing and environmental parameters has been noted. In fact, the relationship of catch rate to prior fishing was not linear, and semi-logarithmic transformation of the data improved the fit slightly. It should be noted that regression of catch rate against effort is equivalent to the Schaefer production model, and that of Ln(catch rate) against effort the Fox model (see below).

Analysis by depth band and family was restricted to locations 1-5 (Seychelles) and 9 (Chagos) due to the limited information available for Mauritius (Table A.6.4). All locations (1-9) could be included in the analysis of the shallow depth band and for lethrinids (Table A.6.5).

For all locations, fishing effects were significant for the guild ‘all demersal species’ at all depths and depths less than 70 m. The smaller data set of Seychelles and Chagos only, also indicated a significant negative correlation between all demersal species catch rate and increasing fishing pressure at all depths and depth < 70 m, but this was not true for the greater depth band. With respect to the effect of fishing on gross species composition, serranid catch rate decreased significantly with increasing fishing pressure at all depths and depths > 69 m. No correlation was observed for lutjanids or lethrinds at any depth, or for either data set.

Of the environmental parameters, substrate was generally significant whilst winter primary productivity was not, except for the complete data set (all locations). As indicated, substrate effects may in fact be an artefact of the data.

These analyses show only weak correlations of abundance (cpue) relative to fishing pressure and environmental parameters. Catch rates appear to be inversely proportional to the volume of fish removed and effort per unit area per annum. In particular, it would appear that as fishing pressure increases, the serranidae decline in abundance.

Catch rates observed for the Chagos Archipelago are less than might be expected given the annual yield removed suggesting that the reefs in BIOT may be less productive than elsewhere in the Indian Ocean. Indeed, primary productivity is low in Chagos during both winter and summer periods, and there appears to be a weak correlation between primary productivity and catch rates. However, examination of figures A.6.20 and A.6.21 indicate that Chagos catch rates are principally lower than expected in the greater depth band, and for lutjanids. Mauritius will not accept certain species due to fears of ciguatera. An alternative explanation may thus be that species avoidance or discards at sea result in the lower catch rates. Certainly it is known that *Lutjanus bohar* is avoided. Another alternative explanation is that illegal fishing activity in Chagos has depleted resources. Logbooks of Sri Lankan vessels fishing in the inshore waters examined recently by the BIOT Fisheries Protection Officer indicate that a number of illegal vessels have frequently visited the area. Consequently both mean catch and effort would be greater than indicated, and would be shifted to the right in Figs A.6.20 and A.6.21.

Application of spatial data to production models

Surplus production models examine the relationship between fishing effort and abundance (catch rate, Schaeffer; Ln(catch rate), Fox) of a resource over time. For a single year, the relationship between catch rates at a number of locations and the effort per unit area may be applied to production models. Referring to the Jamaican fishery, Munro (1977) assumed that catch rates in a multi-species community would decline exponentially in response to fishing effort. This was applied to spatial data from the fishery, plotting the natural logarithm of catch rate against effort per unit area (ie. the Fox production model), and the technique is often referred to as 'Munro and Thompson's Plot' (Munro and Thompson, 1983; 1983a). The underlying assumption is that the ecological and productive characteristics of the different locations are similar.

The present analysis has examined mean annual catch and effort and has demonstrated that the relationship between the multi-species demersal catch rate and effort ($km^{-2}yr^{-1}$) is best described best by logarithmic transformation of catch rate. This is equivalent to the Munro and Thompson Plot, but represents a modification of the method in that rather than examining data for a single year over several locations, mean annual data is employed. For the Indian Ocean Banks studied, whilst it was concluded that environmental factors could not be discounted, previous fishing history (catch and effort) was the most significant determinant of present catch rates. Chagos was apparently less productive than other areas, but only in the greater depth band. Furthermore there was reason to believe that catch and effort at this location may be underestimated, explaining this observation. Hence, it is considered justifiable to apply surplus production models to this spatial data and that Chagos may be excluded from the production model.

To illustrate the procedure, all available data for each site was aggregated (see main text : Table 11 Figs 23-24). As an index of abundance, sampled data for mother-vessel-dory operations only was used to derive standardised catch rates. All vessel catch rates differed somewhat (see Table 11) : for Mauritian vessels, historical effort available from the literature was not standardised (although the standardisation procedure related to a typical Mauritian vessel for this reason); for Seychelles 17 vessel-gear types were involved and information from a single vessel type for which good quality data were known to be available (Mother-vessel) was considered to more reliably represent abundance.

The log-linear Fox surplus production model is :

$$Ln(Y(I)/f(I)) = a + b.f(I)$$

where 'Y' is yield (catch) in year 'I' (location 'I' in this case), f(I) is fishing effort in that year (location), and the intercept 'a' and slope 'b' are constants. The Maximum sustainable yield (MSY) is :

$$MSY = -(1/b).exp(a-1)$$

at $f(MSY) = -1/b$

To investigate potential yield by depth band and family, for which data was not available from all locations, spatial and temporal data were combined following the same procedures as illustrated for the aggregated data. For demersal species at all-depths and in the shallow depth band (<70 m) it was possible to utilise data from all locations (Table A.6.6.). For serranids at each depth classification, and demersal species at depths greater than 69 m data was only available from Seychelles and Chagos (Table A.6.7.). The Fox surplus production model was not applied to data for lutjanids and lethrinids for which no significant correlation existed between the logarithm of catch rate and effort (Tables A.6.4-A.6.5).

Maximum sustainable yield was derived for the aggregated data set with and without Chagos included (Table A.6.8.). The latter was significant and indicated an MSY for all demersal handline caught banks fishery species of 26.94 $kgkm^{-2}yr^{-1}$ at an effort of 0.96 $mdkm^{-2}yr^{-1}$. The average yield was 25.6 $kgkm^{-2}yr^{-1}$ (range 3.1-50.3 $kgkm^{-2}yr^{-1}$), and average effort, 0.28 $mdkm^{-2}yr^{-1}$ (range 0.04-0.53$mdkm^{-2}yr^{-1}$). The annual data indicated demersal MSY in the range 15-22 $kgkm^{-2}yr^{-1}$ for all depths and 12-24 $kgkm^{-2}yr^{-1}$ at depths less than 70 m, the lower value in each case relating to the smaller data set of Seychelles only. The results were not significant for the greater depth band. For serranids, MSY was around 2 $kgkm^{-2}yr^{-1}$ for all depths, and 108 $kgkm^{-2}yr^{-1}$ for the greater depth band at f(MSY) of 18 $mdkm^{-2}yr^{-1}$. The average yield of serranids taken by the mother-vessels was 7.5 $kgkm^{-2}yr^{-1}$ (range, 0.02-35.40 $kgkm^{-2}yr^{-1}$) for all depth strata, and 130 $kgkm^{-2}yr^{-1}$ (range 2-474 $kgkm^{-2}yr^{-1}$) for depths greater than 69 m.

For the shallow depth stratum, these estimates of MSY based on mean annual catch and effort appear very low compared with previous estimates (see Main text). Spatial data was examined therefore for single years, 1992 and 1993 (Table A.6.9) - data were available for only 4 locations in 1991 and 1994 and were not analysed. Neither observed all-vessel catch rates or those of the mother-vessels as an index of abundance provided a significant result in either year (P=0.18-0.88). In 1992 when exceptionally high catches were taken from Providence/ Farquahar (2), the Munro-Thompson plot indicated this location was an outlier(Fig A.6.22). Excluding this data point resulted in an MSY estimate of 43.3 $kgkm^{-2}yr^{-1}$ for all handline caught demersal species from all depths. In 1993, Saya de Malha. appeared to be an outlier (Fig A.6.23), and it is known that not all catch and effort has been recorded for this location in the past. Excluding this data point MSY was estimated to be 61.9 $kgkm^{-2}yr^{-1}$ for all-vessel cpue, and 99.1 $kgkm^{-2}yr^{-1}$ for mother-vessel cpue. These estimates are more in the order expected suggesting that the use of mean annual data leads to a significant underestimation. However, none of these estimates were significant (for regression details see Figs A.6.22-A.6.23).

Table A.6.1 : Observed catch rates (Kg man-hour^{-1}), GLIM standardised outputs (model=boat+season) , and the relative fishing power (RFP) by boat for Mauritian vessels fishing Mauritian Banks between 1993 and 1994 inclusive. Fishing power was standardised relative to the 'average' performing vessel, Le Gentilly. Standardisation was not performed relative to depth : all Mauritian vessels fish at depths less than 70 m.

Mother vessel	Code	N	Observed cpue	Log cpue	Standard-ised cpue	RFP
FAKI	1	109	61.62	3.961	52.51	0.92
FAKI 1	2	70	59.96	3.918	50.30	0.88
FAKI 2	3	407	62.89	3.996	54.38	0.96
FAKI 3	4	162	65.83	3.984	53.73	0.94
GOOD HOPE	5	14	59.07	3.881	48.47	0.85
GOOD HOPE 1	6	4	38.39	3.591	36.27	0.64
HEN SIN CHAN	7	336	74.67	4.131	62.24	1.09
HOI SIONG 1	8	315	75.45	4.143	62.99	1.11
HOI SIONG 2	9	292	81.17	4.253	70.32	1.24
JABEDA	10	191	58.78	3.944	51.62	0.91
LE GENTILLY	11	271	68.69	4.041	56.88	1.00
REEF	12	184	69.13	4.03	56.26	0.99
NOOR STAR	13	170	67.33	4.003	54.76	0.96
NOOR STAR 1	14	115	66.12	4.035	56.54	0.99
NOOR STAR 2	15	279	62.95	3.957	52.30	0.92
PASIFOO	16	273	69.09	4.097	60.16	1.06
PHOENIX	17	59	74.11	4.072	58.67	1.03
PHOENIX 1	18	340	73.08	4.118	61.44	1.08
SHANDRANI	19	43	82.85	4.151	63.50	1.12
STAR HOPE	20	91	68.75	4.088	59.62	1.05
TALBOT 3	21	320	69.1	4.054	57.63	1.01
TALBOT 4	22	276	58.7	3.886	48.72	0.86

Table A.6.2. Unstandardised total fishing effort (fisherman-days), and total catch (tonnes) per annum by location for Mauritian mother-ship-dory ventures compiled from various sources (1969-1976, FAO/SWIOP, 1978; 1977-1979 reworked from Samboo, 1989, 1990; 1980-1988, FAO/UNDP, 1989; 1989-1991, Samboo, unpublished results; 1992 form AFRC 1993 Annual statistical report, 1993-1994 from original data; Chagos, 1991-1994 from original BIOT inshore logbook and observer data. * For Chagos, data prior to 1991 is reworked assuming average number of fishermen is 54; **Saya de Mahla., includes Seychelles catch and effort, but excludes that for Reunion vessels for which the details are unknown).

Fishing Effort (man-days)

Bank	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
Nazareth	8653	10978	14423	12231	12132	22130	22577	18898	17435	13022	13400	9206	8521
Saya de Mahla**									20089	17375	3720	3865	3288
St Brandon												1646	329
Chagos									667				1368

Bank	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Nazareth	8980	6320	10822	10740	10868	17347	13404				12648	20150	22947
Saya de Mahla**	15302	12897	9463	22092	27885	36383	27995				41715	44255	46198
St Brandon	210	1740	1214	2148	2163	1599	4163				4398	15041	6846
Chagos	3086	1296*	3456	3156	2604	4907	5454	6090*	2790*	5602	7893	3910	6603

Table A.6.2. Continued

Catch (Tonnes)

Bank	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Nazareth	700	850	1341	1447	1147	1920	1710	1200	1482	1198	1407	955	874
Saya de Mahla									1587	1529	372	277	378
Albatross											0	1	
St. Brandon									95	97	77	172	140
'Saint Brandon' (ALB+STB)									95	97	77	173	140
Chagos									32				81

Bank	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Nazareth	1282	920	1104	1072	1200	1475	1429	84	555	793	980	1245	1575
Saya de Mahla	1701	1245	833	2207	2767	3363	2651	2177	873	1782	2825	3069	3158
Albatross		3	0	2		2	26	130	111	161	194		
St. Brandon	43	112	283	386	533	376	720	407	499	369	446	827	406
'Saint Brandon' (ALB+STB)	43	115	283	388	533	378	746	537	610	530	640	827	406
Chagos	135	33	143	163	127	237	314	133	256	299	305	200	305

Table A.6.3. :Results of the regression of demersal catch rate data by location at depths less than 69 m against fishing and environmental parameters.

Table A.6.3a : Single regressions

DEPENDENT VARIABLE	VARIABLE	COEFF- ICIENT	STD. ERROR	STD. COEF	TOLER- ANCE	T	P (2 TAIL)	R2	SIG.
Demersal cpue < 70 m	Mean demersal catch/km2/yr < 70 m	-0.829	0.263	-0.567	1.000	-3.153	0.005	0.32	1
Demersal cpue < 70 m	Mean effort md/km2/yr < 70 m	-74.643	25.500	-0.538	1.000	-2.927	0.008	0.29	1
Demersal cpue < 70 m	Winter Primary Productivity	115.358	52.204	0.434	1.000	2.210	0.038	0.19	1
Demersal cpue < 70 m	Substrate	-14.736	7.185	-0.408	1.000	-2.051	0.053	0.17	0
Demersal cpue < 70 m	Winter Tertiary Productivity	-8.456	16.902	-0.109	1.000	-0.500	0.622	0.01	0
Demersal cpue < 70 m	Summer Tertiary Productivity	-7.241	7.565	-0.204	1.000	-0.957	0.349	0.04	0
Demersal cpue < 70 m	Available Oxygen Utilisation	-7.811	22.246	-0.076	1.000	-0.351	0.729	0.01	0
Demersal cpue < 70 m	Nitrates	4.299	4.592	0.200	1.000	0.936	0.360	0.04	0
Demersal cpue < 70 m	Oxygen	5.067	23.612	0.047	1.000	0.215	0.832	0.10	0
Demersal cpue < 70 m	Oxygen Saturation	0.254	1.118	0.050	1.000	0.227	0.822	0.00	0
Demersal cpue < 70 m	Phosphates	116.590	78.584	0.308	1.000	1.484	0.153	0.10	0
Demersal cpue < 70 m	Salinity	65.782	37.785	0.355	1.000	1.741	0.096	0.13	0
Demersal cpue < 70 m	Silicates	17.827	8.075	0.434	1.000	2.208	0.039	0.19	1
Demersal cpue < 70 m	Temperature	-17.454	12.988	-0.281	1.000	-1.344	0.193	0.08	0

Table A.6.3b : Multiple regression of catch rate against fishing and environmental parameters.

DEPENDENT VARIABLE	VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)	R2	SIG.	F	P	SIG.
Demersal cpue < 70 m	CONSTANT	61328.6	32176.4		.	1.906	0.076	0.81		9.397		1
Demersal cpue < 70 m	Available Oxygen Utilisation	-6907.6	3428.5	-67.56		-2.015	0.062					
Demersal cpue < 70 m	Nitrates	208.2	114.3	9.694		1.822	0.089					
Demersal cpue < 70 m	Oxygen	248	297.5	2.29	0.002	0.834	0.418					
Demersal cpue < 70 m	Oxygen Saturation	-339.7	161.8	-66.234		-2.1	0.053					
Demersal cpue < 70 m	Phosphates	-92.3	584.2	-0.244	0.005	-0.158	0.877					
Demersal cpue < 70 m	Salinity	-803	451	-4.335	0.002	-1.78	0.095					
Demersal cpue < 70 m	Silicates	-141.9	74.3	-3.454	0.004	-1.91	0.075					
Demersal cpue < 70 m	CONSTANT	106.1	19.2		.	5.524		0.6	1	6.861	0.002	1
Demersal cpue < 70 m	Mean effort md/km2/yr < 70 m	-78.4	41.8	-0.565	0.242	-1.876	0.077					
Demersal cpue < 70 m	Mean demersal catch/km2/yr < 70 m	-0.1	0.4	-0.055	0.285	-0.197	0.846					
Demersal cpue < 70 m	Substrate	-19.6	5.9	-0.543	0.816	-3.303	0.004		1			
Demersal cpue < 70 m	Winter Primary Productivity	28.8	46.9	0.108	0.705	0.613	0.548					
Demersal cpue < 70 m	CONSTANT	115.4	11.9		.	9.732		0.6	1	14.673		1
Demersal cpue < 70 m	Mean effort md/km2/yr < 70 m	-93.4	20.3	-0.673	0.944	-4.595			1			
Demersal cpue < 70 m	Substrate	-20.5	5.3	-0.568	0.944	-3.879	0.001		1			

Table A.6.4. Single regression of catch rate and ln(cpue)(LN) of guilds of all demersal species (DEM), lutjanids (LUT), serranids (SER), and lethrinids (LET) by depth band (all depths, AD; less than 70 m, LT; and greater than 69 m, GT) against fishing (demersal catch, KG, effort (EFF) and environmental (Substrate, SUBS, winter primary productivity PPROW parameters for locations 1-5 (Seychelles) and 9 (Chagos).

GUILDCPUE	VARIABLE	CONSTANT	COEFFICIENT	STD ERROR	T	P(2 TAIL)	R2	SIG.
DEMAD	KGDEMAD	78.88	-1.12	0.68	-1.64	0.13	0.18	0
	EFFAD	91.64	-160.28	45.53	-3.52	0.00	0.51	1
	SUBS	113.11	-27.48	7.38	-3.73	0.00	0.00	1
	PPROW	34.24	105.44	66.84	1.58	0.14	0.17	0
LUTAD	KGDEMAD	32.47	-0.07	0.40	-0.18	0.86	0.00	0
	EFFAD	38.88	-38.64	32.29	-1.20	0.25	0.11	0
	SUBS	29.66	0.84	5.70	0.15	0.89	0.00	0
	PPROW	29.94	5.45	38.61	0.14	0.89	0.00	0
SERAD	KGDEMAD	24.32	-0.60	0.23	-2.64	0.02	0.37	1
	EFFAD	25.56	-57.79	18.25	-3.17	0.01	0.46	1
	SUBS	35.30	-10.95	2.65	-4.13	0.00	0.59	1
	PPROW	3.27	44.50	24.85	1.79	0.10	0.21	0
LETAD	KGDEMAD	33.81	-0.62	0.46	-1.33	0.21	0.13	0
	EFFAD	38.76	-77.81	36.35	-2.14	0.05	0.28	0
	SUBS	62.34	-20.16	4.12	-4.90	0.00	0.67	1
	PPROW	7.58	64.68	44.59	1.45	0.17	0.15	0
DEMLT	KGDEMLT	86.30	-1.47	0.71	-2.07	0.06	0.26	0
	EFFLT	85.92	-157.20	66.78	-2.35	0.04	0.32	1
	SUBS	125.44	-31.36	7.59	-4.13	0.00	0.59	1
	PPROW	44.23	84.48	76.30	1.11	0.29	0.09	0
LUTLT	KGDEMLT	28.22	-0.16	0.37	-0.42	0.68	0.02	0
	EFFLT	33.53	-56.83	32.49	-1.75	0.11	0.20	0
	SUBS	23.99	1.02	5.32	0.19	0.85	0.00	0
	PPROW	31.86	-24.07	35.44	-0.68	0.51	0.04	0
SERLT	KGDEMLT	20.81	-0.55	0.26	-2.11	0.06	0.27	0
	EFFLT	17.99	-38.40	27.48	-1.40	0.19	0.14	0
	SUBS	33.61	-10.75	3.03	-3.55	0.00	0.51	1
	PPROW	2.67	41.55	26.84	1.55	0.15	0.17	0
LETLT	KGDEMLT	37.27	-0.77	0.47	-1.63	0.13	0.18	0
	EFFLT	34.40	-61.96	47.42	-1.31	0.22	0.13	0
	SUBS	67.84	-21.62	4.01	-5.40	0.00	0.71	1
	PPROW	9.70	67.00	46.42	1.44	0.17	0.15	0
DEMGT	KGDEMGT	87.15	-0.14	0.10	-1.37	0.20	0.14	0
	EFFGT	78.68	-1.10	1.472	-0.78	0.46	0.04	0
	SUBS	132.34	-29.93	9.96	-3.01	0.01	0.43	1
	PPROW	36.00	157.36	77.00	2.04	0.06	0.26	0
LUTGT	KGDEMGT	37.82	0.04	0.07	0.56	0.59	0.03	0
	EFFGT	39.29	0.47	0.89	0.53	0.60	0.02	0
	SUBS	44.02	-1.54	7.84	-0.20	0.85	0.00	0
	PPROW	31.65	38.25	52.06	0.74	0.48	0.04	0
SERGT	KGDEMGT	23.95	-0.09	0.02	-3.74	0.00	0.54	1
	EFFGT	19.13	-0.78	0.41	-1.93	0.08	0.24	0
	SUBS	39.59	-12.11	2.07	-5.84	0.00	0.74	1
	PPROW	5.88	42.25	24.70	1.71	0.11	0.20	0
LETGT	KGDEMGT	25.38	-0.09	0.05	-2.00	0.07	0.25	0
	EFFGT	20.26	-0.792	0.675	-1.17	0.26	0.10	0
	SUBS	48.73	-16.28	4.10	-3.97	0.00	0.57	1
	PPROW	-1.53	76.86	36.02	2.13	0.05	0.28	0

Table A.6.4 CONTINUED : Log-linear regressions

GUILD CPUE	VARIABLE	CONSTANT	COEFFICIENT	STD ERROR	T	P (2TAIL)	R2	SIG.
LNDEMAD	KGDEMAD	4.28	-0.016	0.010	-1.54	0.151	0.16	0
	EFFAD	4.51	-2.527	0.664	-3.81	0.003	0.55	1
LNLUTAD	KGDEMAD	3.23	0.003	0.019	0.15	0.880	0.00	0
	EFFAD	3.66	-1.937	1.514	-1.28	0.225	0.12	0
LNSERAD	KGDEMAD	3.17	-0.044	0.014	-3.10	0.009	0.44	1
	EFFAD	3.19	-3.871	1.198	-3.23	0.007	0.47	1
LNLETAD	KGDEMAD	3.35	-0.027	0.019	-1.47	0.168	0.15	0
	EFFAD	3.45	-2.818	1.543	-1.83	0.093	0.22	0
LNDEMLT	KGDEMLT	4.42	-0.022	0.010	-2.35	0.037	0.32	1
	EFFLT	4.41	-2.371	0.890	-2.67	0.021	0.37	1
LNLUTLT	KGDEMLT	3.08	0.000	0.018	0.02	0.987	0.00	0
	EFFLT	3.48	-2.913	1.581	-1.84	0.090	0.22	0
LNSERLT	KGDEMLT	2.86	-0.043	0.021	-2.08	0.060	0.26	0
	EFFLT	2.52	-2.149	2.255	-0.95	0.359	0.07	0
LNLETLT	KGDEMLT	3.47	-0.031	0.017	-1.76	0.104	0.21	0
	EFFLT	3.26	-1.750	1.830	-0.96	0.358	0.07	0
LNDEMGT	KGDEMGT	4.34	-0.001	0.001	-0.92	0.378	0.07	0
	EFFGT	4.25	-0.010	0.020	-0.47	0.648	0.02	0
LNLUTGT	KGDEMGT	3.33	0.002	0.002	0.90	0.385	0.06	0
	EFFGT	3.44	0.023	0.034	0.67	0.513	0.04	0
LNSERGT	KGDEMGT	3.14	-0.006	0.001	-4.96	0.000	0.67	1
	EFFGT	2.82	-0.057	0.023	-2.49	0.032	0.33	1
LNLETGT	KGDEMGT	2.89	-0.004	0.003	-1.73	0.110	0.20	0
	EFFGT	2.66	-0.042	0.036	-1.15	0.273	0.10	0

Table A.6.5. Single regression of catch rate and ln(cpue)(LN) of guilds of all demersal species (DEM),and lethrinids (LET) by depth band (all depths, AD; less than 70 m) against fishing (demersal catch, KG, effort, EFF) and environmental (substrate, SUBS, winter primary productivity, PPROW) parameters for all locations (1-9).

GUILD CPUE	VARIABLE	CONSTANT	COEFFICIENT	STD ERROR	T	P(2 TAIL)	R2	SIG.
DEMAD	KGDEMAD	73.091	-0.68	0.264	-2.57	0.018	0.24	1
	EFFAD	78.257	-83.05	24.15	-3.44	0.002	0.36	1
	SUBS	77.475	-13.72	6.39	-2.15	0.044	0.18	1
	PPROW	29.566	118.47	45.06	2.63	0.016	0.25	1
LETAD	KGDEMAD	23.472	0.17	0.219	0.79	0.438	0.03	0
	EFFAD	26.405	6.38	22.16	0.29	0.776	0	0
	SUBS	56.688	-16.77	3.679	-4.56	0	0.5	1
	PPROW	24.794	16.62	38.029	0.44	0.667	0.01	0
DEMLT	KGDEMLT	79.07	-0.83	0.263	-3.15	0.005	0.32	1
	EFFLT	75.895	-74.64	25.5	-2.93	0.008	0.29	1
	SUBS	82.135	-14.74	7.185	-2.05	0.053	0.17	0
	PPROW	33.166	115.36	52.204	2.21	0.038	0.19	1
LETLT	KGDEMLT	27.784	0.08	0.21	0.38	0.708	0.01	0
	EFFLT	26.669	12.84	19.787	0.65	0.524	0.02	0
	SUBS	58.533	-16.89	3.667	-4.61	0	0.5	1
	PPROW	24.611	25.37	37.875	0.67	0.51	0.02	0
LNDEMAD	KGDEMAD	4.2	-0.01	0.004	-2.37	0.028	0.21	1
	EFFAD	4.29	-1.254	0.375	-3.34	0.003	0.35	1
LNLETAD	KGDEMAD	2.86	0.01	0.009	1.15	0.263	0.06	0
	EFFAD	2.97	0.597	0.891	0.67	0.51	0.02	0
LNDEMLT	KGDEMLT	4.3	-0.012	0.004	-3.38	0.003	0.35	1
	EFFLT	4.25	-1.103	0.36	-3.07	0.006	0.31	1
LNLETLT	KGDEMLT	3.06	0.006	0.008	0.79	0.44	0.03	0
	EFFLT	3.01	0.861	0.723	1.19	0.247	0.06	0

Table A.6.6 : Mean annual catch and effort statistics by location for the guild, ‘all-demersal species’, compiled from historical information, and mother-vessel demersal catch rates each year as an index of abundance by location for all-depths and the depth band less than 70 m.

LOCATION	ALL VESSEL CATCH AND EFFORT					MOTHER-VESSEL DATA				
	YEARS OF AVAILABLE DATA	MEAN KG DEMERSAL /KM^2/YR (AD)	MEAN KG DEMERSAL /KM^2/YR (<70)	MEAN MD /KM^2/YR ALL DEPTHS	MEAN MD /KM^2/YR (<70 M)	FOR YEAR	DEMERSAL CPUE (AD)	LN(CPUE) ALL-DEPTHS	DEMERSAL CPUE (<70 M)	LN(CPUE) (<70 M)
1	78-92	3.34	2.7	0.03	0.01	92	80.4	4.39	82.79	4.42
2	78-91	3.65	2.47	0.02	0.02	91	129.9	4.87	144.29	4.97
2	78-92	17.7	13.39	0.13	0.07	92	80.9	4.39	92.6	4.53
2	78-93	17.75	13.26	0.12	0.11	93	92.1	4.52	94.54	4.55
3	85-91	10.62	10.18	0.15	0.1	91	53.1	3.97	54.2	3.99
3	85-92	13.36	11.56	0.17	0.04	92	57	4.04	48.41	3.88
4	85-91	34.66	32.89	0.38	0.18	91	53	3.97	49.94	3.91
4	85-92	34.55	32.74	0.37	0.26	92	31.1	3.44	27.21	3.3
4	85-93	34.46	32.71	0.37	0.33	93	48.8	3.89	54.83	4
5	85-91	12.66	7.93	0.13	0.07	91	59.1	4.08	67.61	4.21
5	85-92	14.24	10.23	0.16	0.08	92	41.4	3.72	54.46	4
5	85-93	13.74	10.11	0.15	0.06	93	48.1	3.87	50.24	3.92
6	77-92	40.91	40.91	0.44	0.44	92	51.6	3.94	51.6	3.94
6	77-93	42.37	42.37	0.48	0.48	93	36.8	3.61	36.8	3.61
6	77-94	43.76	43.76	0.52	0.52	94	35.6	3.57	35.6	3.57
7	69-92	41.77	41.77	0.5	0.5	92	55.7	4.02	55.7	4.02
7	69-93	41.94	41.94	0.51	0.51	93	49.4	3.9	49.4	3.9
7	69-94	42.56	42.56	0.53	0.53	94	49	3.89	49	3.89
8	80-92	49.16	49.16	0.21	0.21	92	42.5	3.75	42.5	3.75
8	80-93	51.55	51.55	0.34	0.34	93	43.3	3.77	43.3	3.77
8	80-94	50.34	50.34	0.37	0.37	94	41.6	3.73	41.6	3.73
9	77-93	11.82	11.53	0.28	0.26	93	35	3.55	46.43	3.84
9	77-94	12.55	11.76	0.31	0.28	94	31.8	3.46	41.83	3.73

Table A.6.7 : Mean annual effort statistics by location and depth band compiled from historical information, and mother-vessel serranid and demersal catch rates each year as an index of abundance by location.

LOCATION	ALL VESSEL EFFORT				MOTHER-VESSEL DATA								
	YEARS OF AVAILABLE DATA	MEAN MD /KM^2/YR ALL DEPTHS	MEAN MD /KM^2/YR (<70 M)	MEAN MD /KM^2/YR (>69 M)	FOR YEAR	SERRANID CPUE (AD)	LN(CPUE) ALL-DEPTHS	SERRANID CPUE (<70 M)	LN(CPUE) (<70 M)	SERRANID CPUE (>69 M)	LN(CPUE) (>69 M)	DEMERSAL CPUE (>69 M)	LN(CPUE) (>69 M)
1	78-92	0.03	0.01	0.32	92	29.06	3.37	25.11	3.22	31.9	3.46	101	4.62
2	78-91	0.02	0.02	0.06	91	41.81	3.73	43.34	3.77	35.32	3.56	123.44	4.82
2	78-92	0.13	0.07	0.79	92	17.77	2.88	16.79	2.82	19.73	2.98	100.04	4.61
2	78-93	0.12	0.11	0.12	93	20.34	3.01	19.35	2.96	32.85	3.49	146.11	4.98
3	85-91	0.15	0.1	1.64	91	7.19	1.97	6.67	1.9	8.34	2.12	73.24	4.29
3	85-92	0.17	0.04	4.36	92	12.09	2.49	9.83	2.29	12.9	2.56	76.45	4.34
4	85-91	0.38	0.18	22.88	91	6.62	1.89	5.39	1.69	7.68	2.04	68.93	4.23
4	85-92	0.37	0.26	12.54	92	2.72	1	1.99	0.69	4.39	1.48	44.24	3.79
4	85-93	0.37	0.33	3.96	93	9.62	2.26	9.83	2.29	7.6	2.03	75.43	4.32
5	85-91	0.13	0.07	1.03	91	10.77	2.38	8.86	2.18	12.8	2.55	65.94	4.19
5	85-92	0.16	0.08	1.27	92	6.36	1.85	5.17	1.64	7.69	2.04	47.32	3.86
5	85-93	0.15	0.06	1.64	93	8.15	2.1	2.17	0.77	11.7	2.46	56.99	4.04
9	77-93	0.28	0.26	0.45	93	14.75	2.69	14.61	2.68	18.95	2.94	35.15	3.56
9	77-94	0.31	0.28	0.79	94	11.39	2.43	11.01	2.4	15.55	2.74	30.26	3.41

Table A.6.8 : Results of regression of the logarithm of catch rate against mean annual effort for all aggregated mother-vessel data, and annual data for guilds of all-demersal species and serranids and estimates of MSY and f(MSY) derived by means of the Fox surplus production model.

DATASET	LOCATIONS INC.	DEPTH	GUILD CPUE	VARIABLE	CONST	COEF.	STD ERR	T	P(2 TAIL)	R2	SIG.	MSY	f(MSY)
AGGREGATED	ALL (1-9)	ALL	AGGDEMAD	EFFAD	4.29	-1.08	0.491	-2.2	0.064	0.41		24.73	0.93
AGGREGATED	ALL XPT 9	ALL	AGGDEMAD	EFFAD	4.33	-1.04	0.355	-2.92	0.026	0.59	1	26.94	0.96
ANNUAL	ALL(1-9)	ALL	DEMAD	EFFAD	4.29	-1.25	0.375	-3.34	0.003	0.35	1	21.43	0.8
ANNUAL	ALL XPT 9	ALL	DEMAD	EFFAD	4.33	-1.25	0.349	-3.58	0.002	0.4	1	22.36	0.8
ANNUAL	(1-5 AND 9)	ALL	DEMAD	EFFAD	4.51	-2.53	0.664	-3.81	0.003	0.55	1	13.22	0.4
ANNUAL	(1-5 ONLY)	ALL	DEMAD	EFFAD	4.49	-2.18	0.7	-3.12	0.011	0.49	1	15.03	0.46
ANNUAL	ALL(1-9)	<70	DEMLT	EFFLT	4.25	-1.1	0.36	-3.07	0.006	0.31	1	23.43	0.91
ANNUAL	ALL XPT 9	<70	DEMLT	EFFLT	4.27	-1.09	0.372	-2.94	0.008	0.31	1	23.98	0.91
ANNUAL	(1-5 AND 9)	<70	DEMLT	EFFLT	4.41	-2.37	0.89	-2.67	0.021	0.37	1	12.71	0.42
ANNUAL	(1-5 ONLY)	<70	DEMLT	EFFLT	4.41	-2.42	1.155	-2.09	0.063	0.31		12.49	0.41
ANNUAL	(1-5 AND 9)	>69	DEMGT	EFFGT	4.25	-0.01	0.020	-0.47	0.648	0.02		2589.4	100.0
ANNUAL	(1-5 ONLY)	>69	DEMGT	EFFGT	4.43	-0.02	0.016	-1.30	0.222	0.15		1537.7	50.0
ANNUAL	(1-5 AND 9)	ALL	SERAD	EFFAD	3.19	-3.87	1.198	-3.23	0.007	0.47	1	2.32	0.26
ANNUAL	(1-5 ONLY)	ALL	SERAD	EFFAD	3.23	-4.51	1.246	-3.62	0.005	0.57	1	2.05	0.22
ANNUAL	(1-5 AND 9)	<70	SERLT	EFFLT	2.52	-2.15	2.255	-0.95	0.359	0.07		2.13	0.47
ANNUAL	(1-5 ONLY)	<70	SERLT	EFFLT	2.62	-3.92	2.731	-1.44	0.181	0.17		1.29	0.25
ANNUAL	(1-5 AND 9)	>69	SERGT	EFFGT	2.82	-0.06	0.023	-2.43	0.032	0.33	1	107.74	17.54
ANNUAL	(1-5 ONLY)	>69	SERGT	EFFGT	2.80	-0.06	0.026	-2.14	0.058	0.32		108.03	17.86

Table A.6.9. All vessel demersal species catch and effort statistics for Indian Ocean banks fisheries in 1992 and 1993 and mother-vessel catch rates as an index of abundance.

LOCATION	Bank area	CATCH	EFFORT	CPUE	MV cpue	EFF/km2	YIELD/km2	Ln(cpue)	Ln(mvcpue)
Astove/Cosmoledo	431	21591	269	80.26	80.41	0.62	50.1	4.39	4.39
Providence / Farquhar	1751	375462	2686	139.81	82.52	1.53	214.43	4.94	4.41
Amirantes Plateau	4116	133760	1256	106.47	56.87	0.31	32.5	4.67	4.04
Mahe Plateau	41712	1406357	11162	125.99	29.27	0.27	33.72	4.84	3.38
Banks -Seychelles	2326	58893	830	70.99	44.17	0.36	25.32	4.26	3.79
Saya De Malha	42466	191558	3713	51.59	51.59	0.09	4.51	3.94	3.94
Nazareth	23001	584254	10496	55.66	55.66	0.46	25.4	4.02	4.02
St. Brandon	9313	202209	4760	42.48	42.48	0.51	21.71	3.75	3.75
Chagos	8853	305000	7893	38.64	38.64	0.89	34.45	3.65	3.65
Average 1992						0.56	49.13		

LOCATION	Bank area	CATCH	EFFORT	CPUE	MV cpue	EFF/km2	YIELD/km2	Ln(cpue)	Ln(mvcpue)
Providence / Farquhar	1751	32233	114	283.17	94.2	0.07	18.41	5.6	4.5
Mahe Plateau	41712	1404972	15598	90.07	52.26	0.37	33.68	4.5	4
Banks -Seychelles	2326	22550	266	84.92	47.27	0.11	9.69	4.4	3.9
Saya De Malha	42466	8670	236	36.8	36.8	0.01	0.2	3.6	3.6
Nazareth	23001	1164964	23604	49.35	49.35	1.03	50.65	3.9	3.9
St. Brandon	9313	731613	16908	43.27	43.27	1.82	78.56	3.8	3.8
Chagos	8853	181895	4431	41.05	44.46	0.5	20.55	3.7	3.8
Average 1993						0.56	30.25		

Fig. A.6.1 : Mothership-dory standardised catch rates for Indian Ocean banks fisheries.

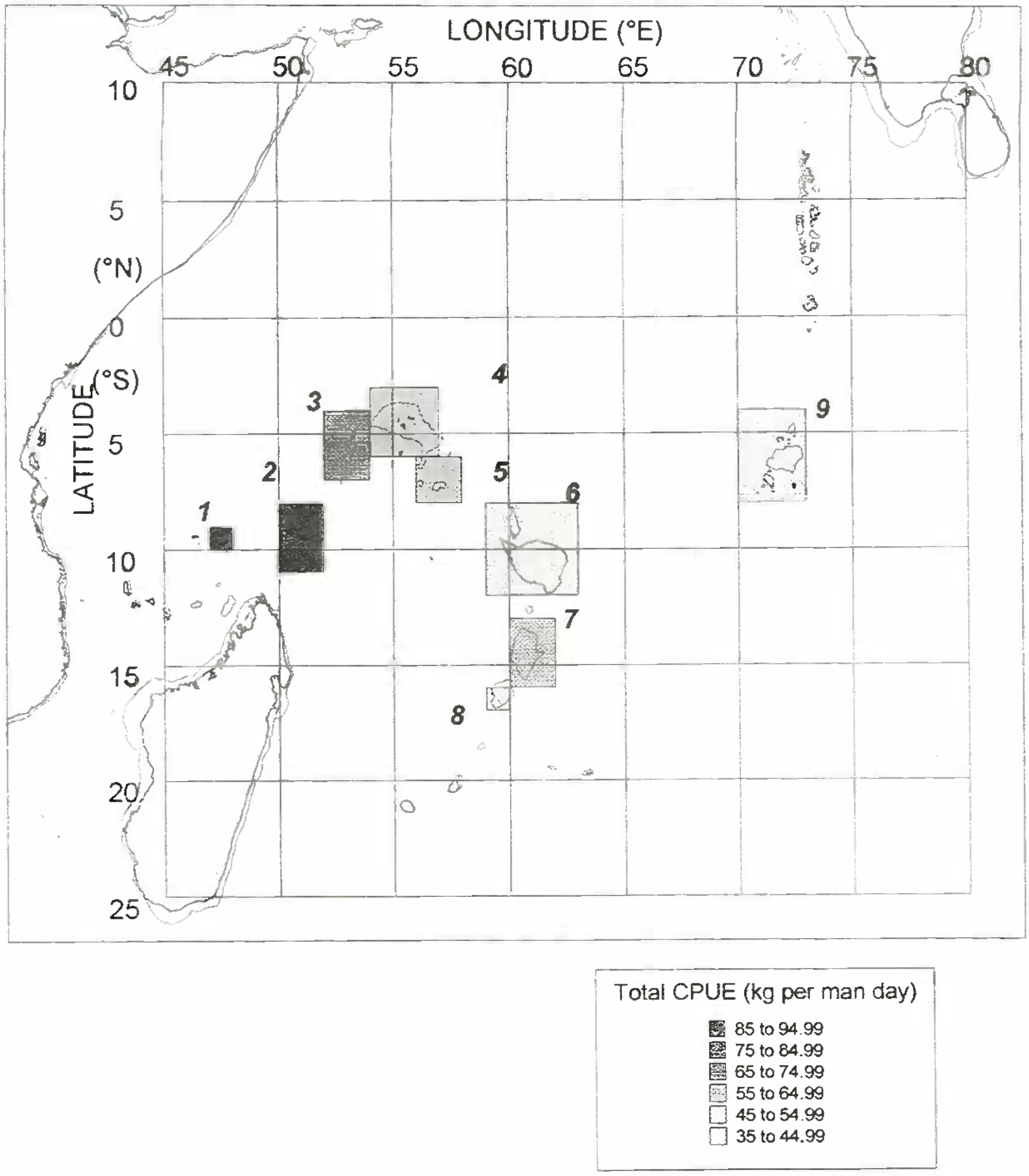


Fig. A.6.2 : The distribution of Primary productivityin the Indian Ocean during the period October - April (after Cushing, 1971)

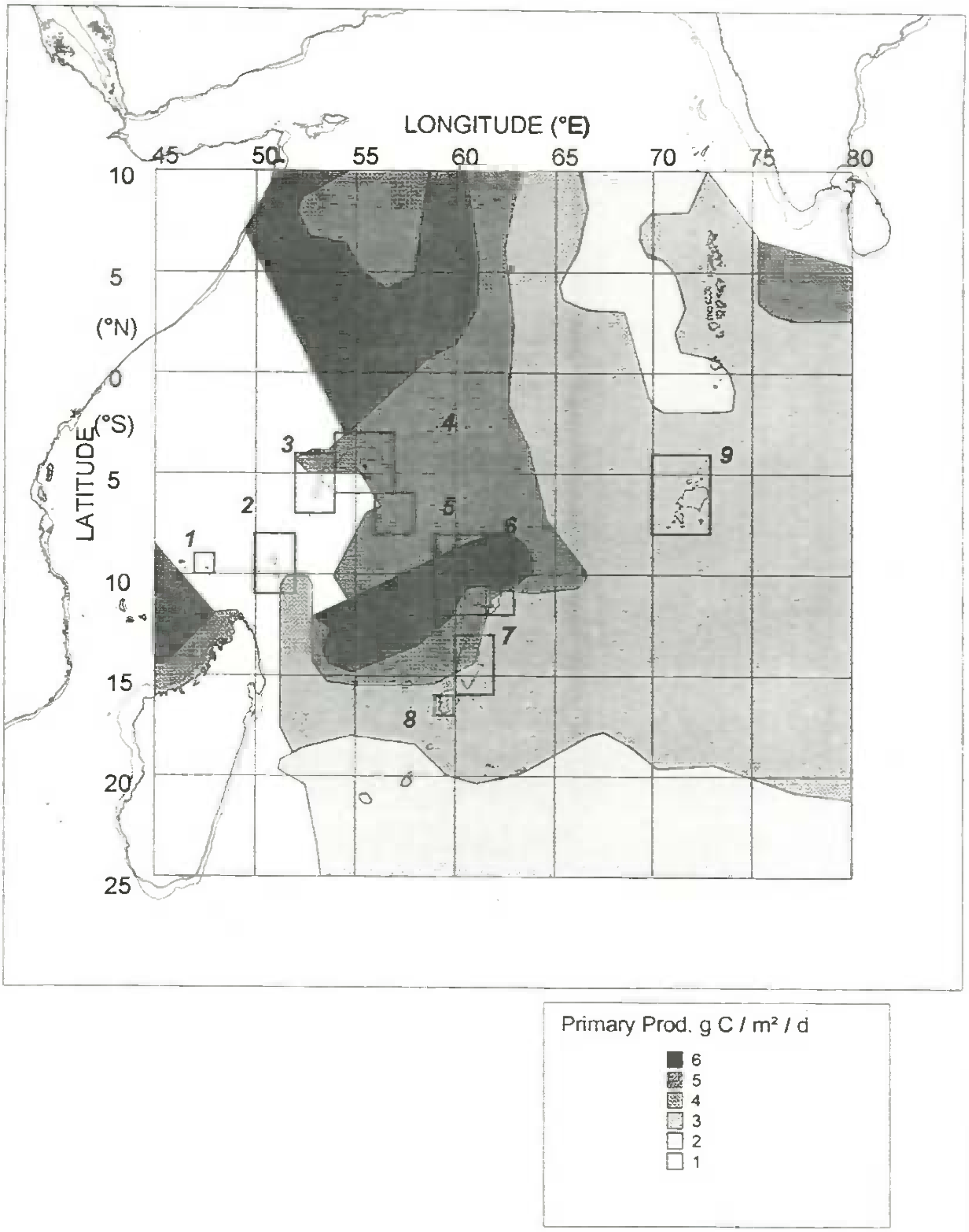


Fig A.6.3. The distribution of fish larvae during the period April 16-October 15 and the predominant direction of the currents during this time of year (after Cushing, 1971)

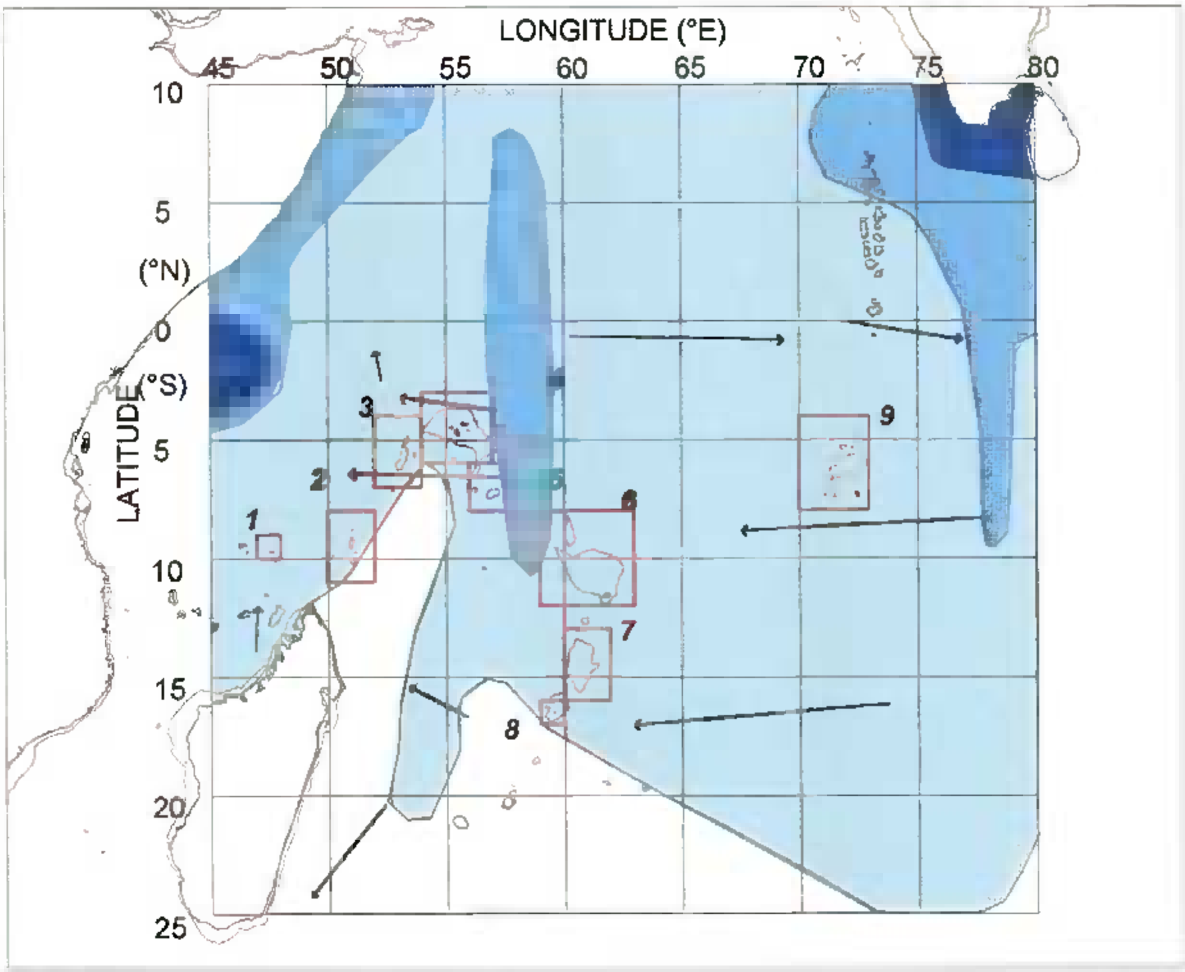


Fig A.6.4. The distribution of fish larvae during the period October 16-April 15 and the predominant direction of the currents during this time of year (after Cushing, 1971)

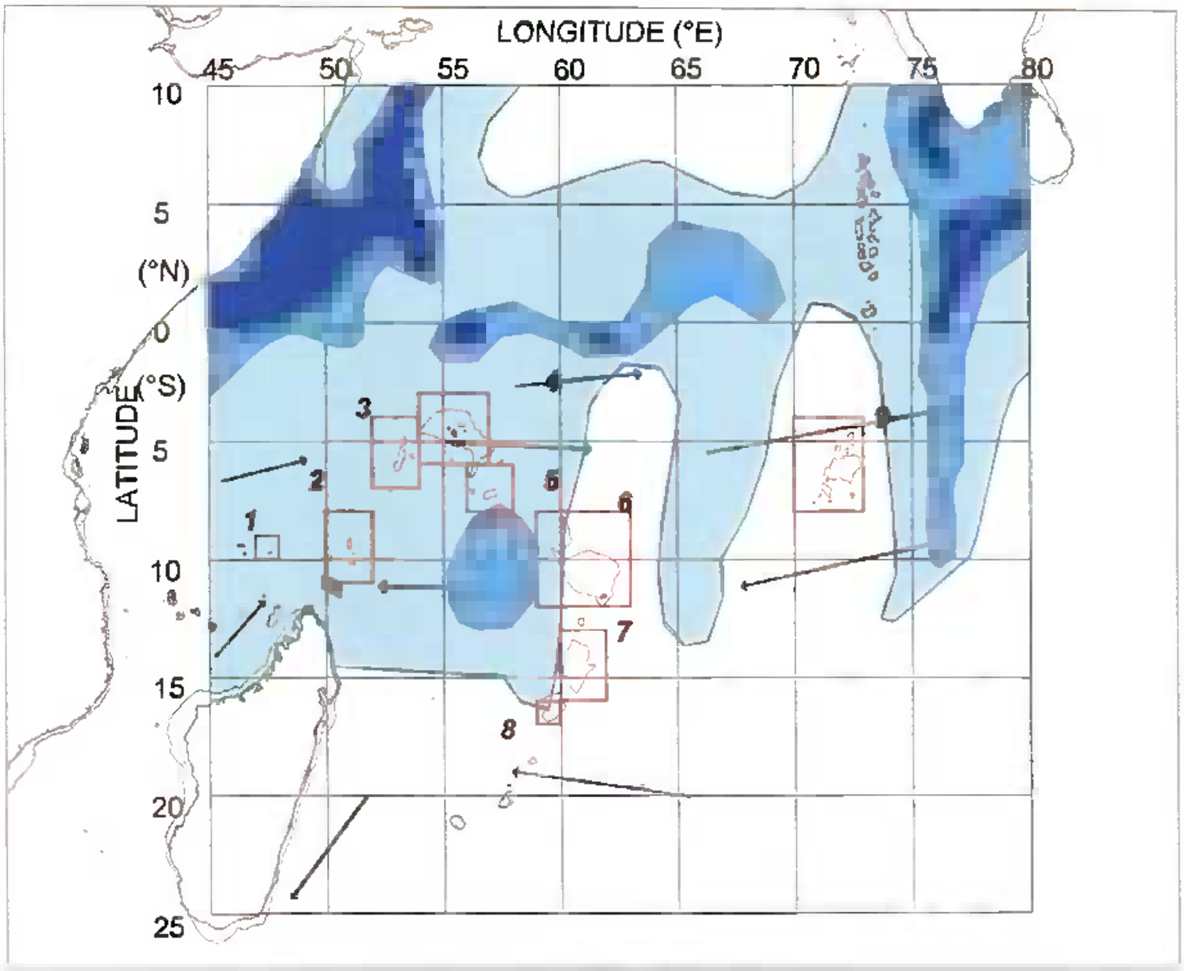
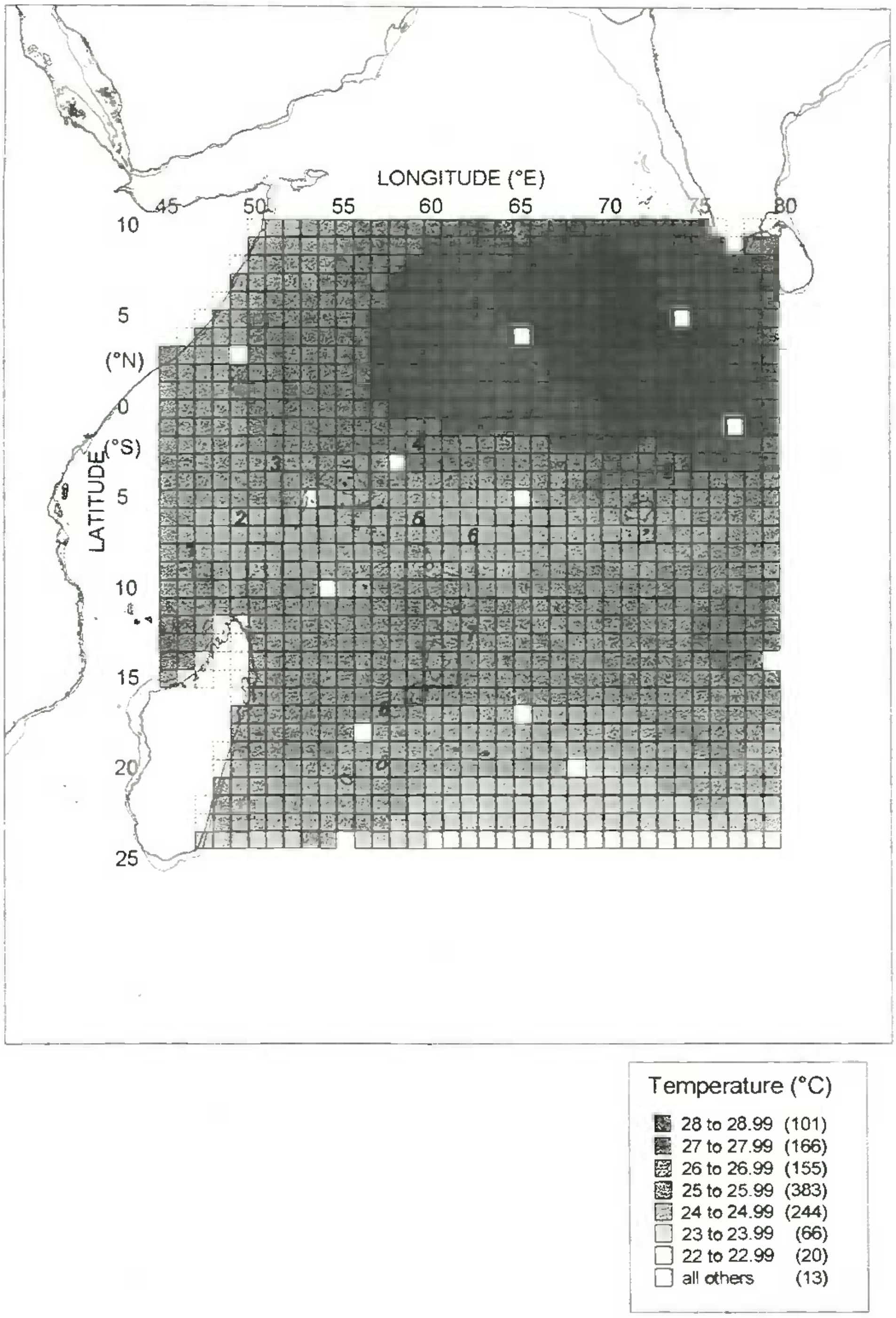


Fig.A.6.5. The variation in temperature observed throughout the Indian Ocean at a depth of 50 m (from data extracted from World Ocean Atlas, 1994)



[Figures A.6.6 - A.6.15 are missing]

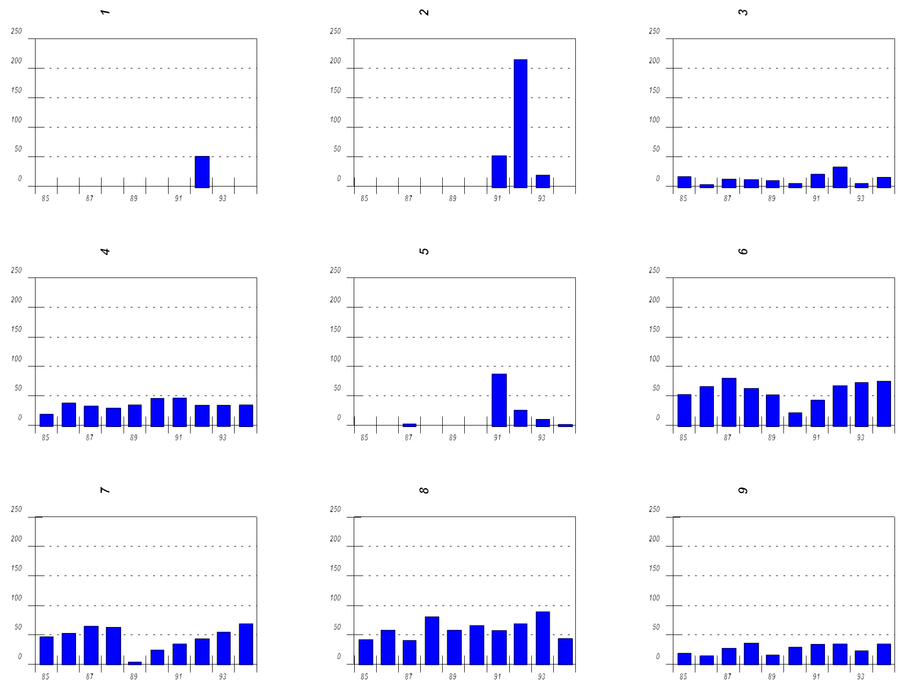


Figure A.6.16 : Annual catch (kg/km^2) by location.

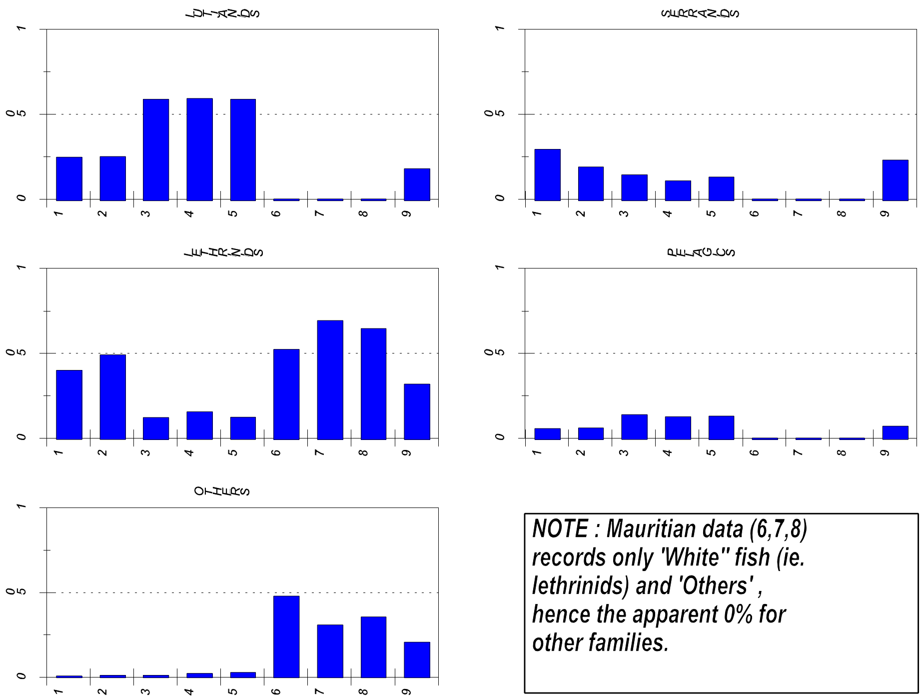


Figure A.6.17 : Gross mean species composition, 1991-94

Figs. A.6.18 Standardised demersal catch rate (kg/md) by location (1-9 indicated) related to winter and summer primary and tertiary productivity, and to substrate type for all fishing depths.

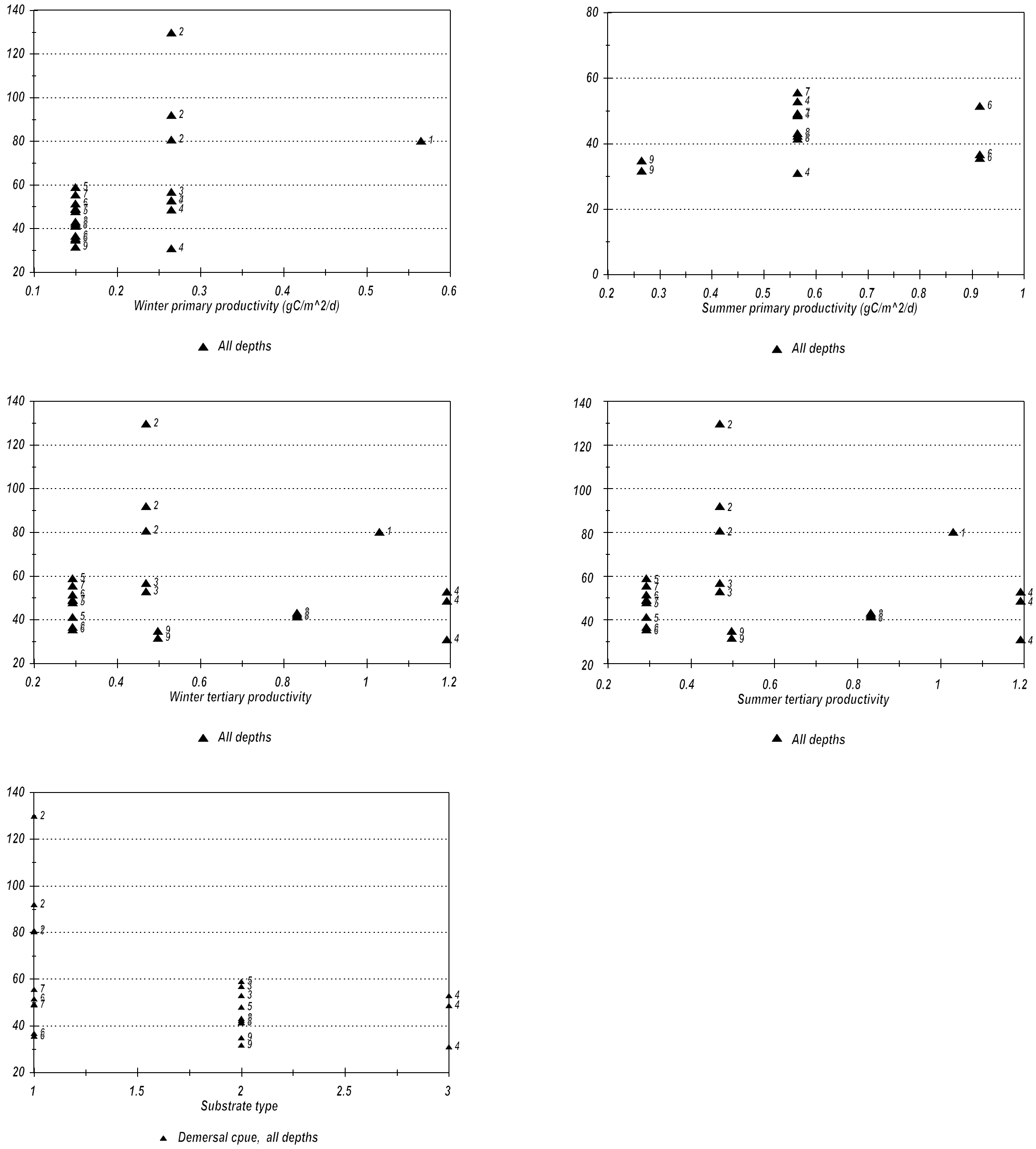


Fig. A.6.19 : Standardised demersal catch rates (kg/md over all depths) by location (1-9 indicated) in relation to oceanic parameters recorded at a depth of 50m.

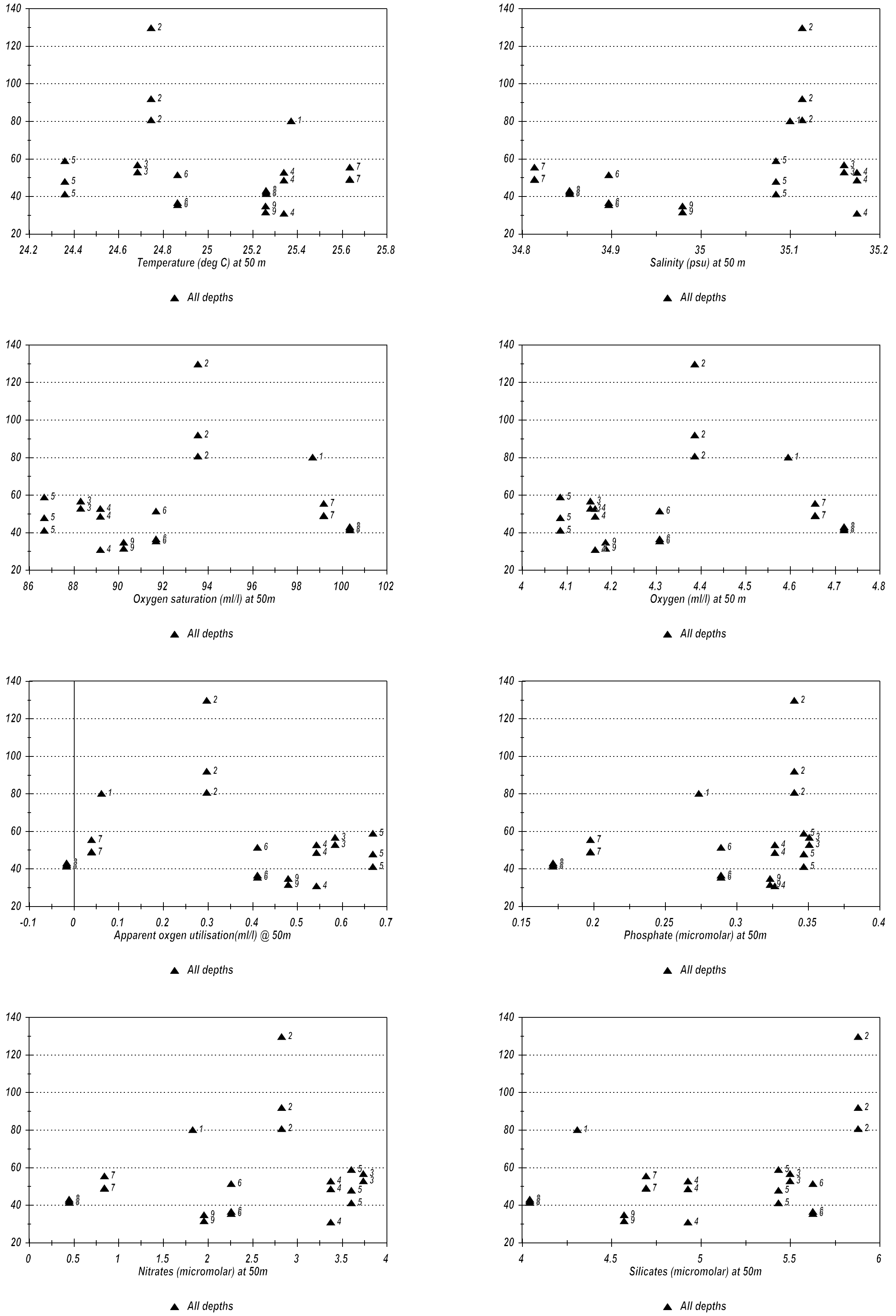


Figure A.6.20. Standardised demersal catch rates by location (1-9, indicated) related to catch and effort by depth band.

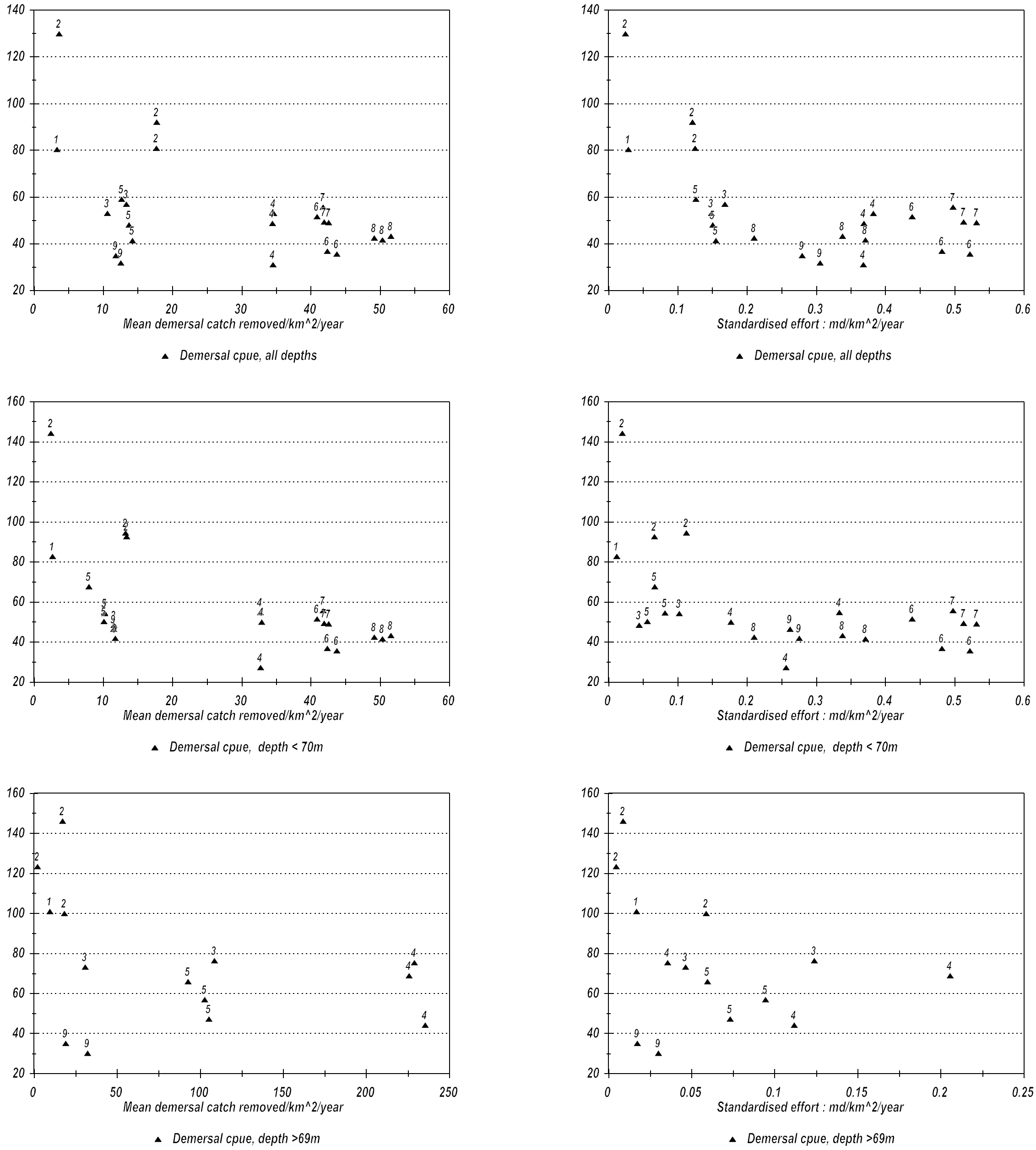
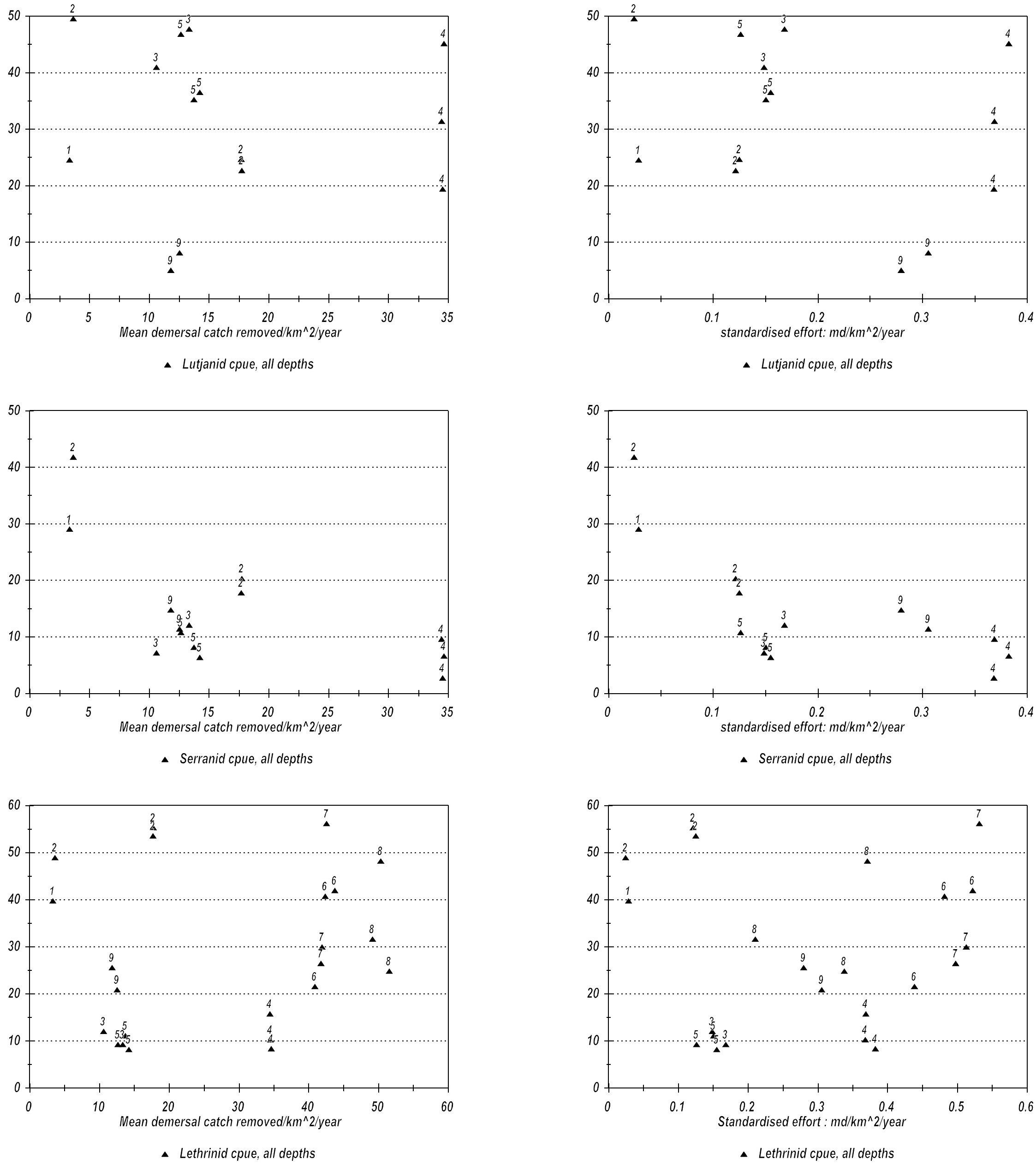


Fig A.6.21. Standardised family guild catch rates (kg/md) by location (1-9, indicated) related to catch and effort for all depths.



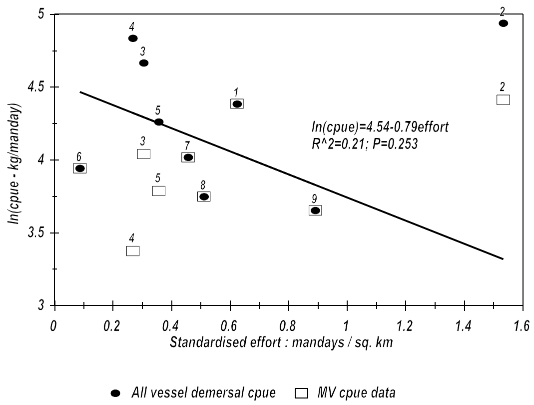


Figure A.6.22. Munro-Thompson plot of Demersal Indian Ocean Banks fisheries in 1992 for observed and mother-vessel catch rates, and regression results for observed catch rate data.

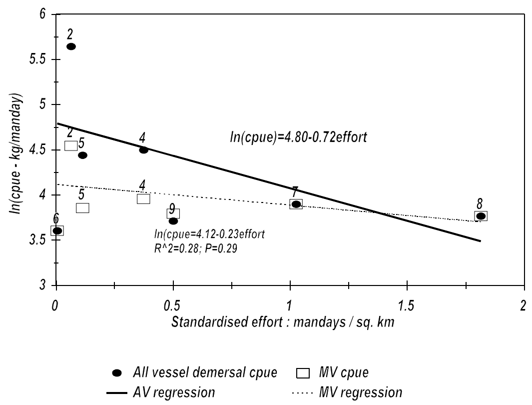


Figure A.6.23. Munro-Thompson plot of demersal Indian Ocean Banks fisheries in 1993 for observed and mother-vessel catch rates, and regression results for these data.

ANNEX 7 : Summary of length frequency and biometric data

Length frequency data was collected for *P. filamentosus, A. virescens, L. sebae, E. chlorostigma* and *L. nebulosus.* Additional information was collected during biometric studies on *P. filamentosus, A. virescens* and *L. nebulosus* (see Section 4). Data was collected mostly from schooners landing fish to Seychelles Marketing Board (SMB) at Port Victoria, and from SFA research vessels. Initially gear type and fishing location were not recorded, but where possible, this information was collected from 1990 onwards.

For each species, a summary of all data aggregated by gear type and location is given for length frequency and biometric studies, and the number of fish sampled by gear, location and year are indicated (Tables A.7.1 - A.7.15). The latter indicate that in many cases insufficient data exist to perform analyses on dis-aggregated data.

Analyses of catch and effort data indicated that effort was concentrated in Sector 1, the inshore area of the Mahe Plateau. Biological and length frequency data was collected chiefly from the schooner fishery which seldom fishes in this area. As a consequence, the biological information does not relate directly to the most heavily fished part of the population and none was recorded from Sector 1 (Tables A.7.3-4; A.7.7-8; A.7.11 A.7.13; A.7.15). In order to best indicate biological parameters in Sector 1, data for the Mahe Plateau only (Sectors 2-10) was aggregated annually by gear type (Table A.7.16, Figs. A.7.1-A.7.20).

TABLE A.7.1 : Summary of *P. filamentosus* length frequency information. All data : all gears and locations pooled

YRMON		TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
89	11	634	1.29	165	52.5	32.0	75.1	128	50.2	33.4	72.8	341	55.6	32.9	76.6
89	12	395	1.41	165	50.0	30.3	76.1	117	49.3	31.2	70.0	113	53.4	28.3	74.8
90	1	452	1.51	95	52.0	32.0	73.4	63	53.2	38.0	71.4	294	49.8	31.6	77.2
90	2	335	0.91	83	48.1	31.2	69.1	91	49.7	31.4	69.7	161	53.6	30.1	74.4
90	3	729	1.08	180	49.5	31.2	76.6	166	50.1	32.4	70.2	383	52.4	31.1	75.4
90	4	1010	1.32	250	51.6	29.1	77.6	189	47.1	6.0	70.8	571	55.3	31.7	75.0
90	5	551	1.07	171	50.6	32.6	76.7	160	49.6	31.2	71.1	220	53.6	32.5	79.5
90	6	254	1.24	92	43.7	32.6	70.8	74	44.0	33.1	64.2	88	48.1	31.5	75.7
90	7	304	0.86	103	46.7	31.6	71.0	120	46.2	31.6	71.8	81	44.5	33.1	71.4
90	8	58	1.82	31	45.4	25.6	69.5	17	45.7	34.2	64.1	10	43.3	26.1	65.6
90	9	465	1.10	201	50.9	29.6	74.0	182	50.0	29.6	70.1	82	53.0	26.0	75.0
90	10	822	1.17	329	51.1	29.2	73.1	281	50.3	28.1	77.6	212	52.4	28.7	73.8
90	11	531	1.05	208	54.0	30.3	72.8	198	52.7	30.9	71.4	125	53.7	33.9	70.3
90	12	511	1.14	198	54.7	31.8	76.3	174	51.8	29.2	74.2	139	55.5	37.9	70.6
91	1	241	1.31	85	46.3	31.8	66.7	65	45.8	30.1	67.5	91	48.2	30.7	72.0
91	2	95	1.48	40	46.7	33.4	68.3	27	43.7	33.2	58.3	28	49.7	34.7	68.1
91	3	235	2.16	106	50.9	25.1	78.8	49	52.3	35.1	78.2	80	51.4	31.5	78.3
91	4	609	1.56	259	48.9	31.4	86.6	166	47.4	29.3	78.0	184	49.2	25.2	68.6
91	5	1400	1.35	568	48.3	22.9	77.7	420	45.8	20.2	73.7	412	51.9	22.4	77.5
91	6	928	1.40	352	51.8	31.8	75.1	251	50.5	28.2	78.4	325	56.3	25.6	76.0
91	7	580	1.63	267	52.1	34.3	70.1	164	50.8	33.7	65.2	149	54.2	40.2	74.8
91	8	235	2.15	131	46.3	27.3	70.2	61	44.5	24.4	68.4	43	49.0	27.5	70.0
91	9	748	1.44	329	49.4	27.1	79.0	228	46.9	28.1	74.3	191	49.5	26.5	77.6
91	10	1473	1.75	679	50.8	23.4	78.4	388	47.4	25.6	77.9	406	50.8	25.3	78.4
91	11	1544	1.28	622	49.2	22.9	77.5	487	47.9	25.3	75.1	435	51.3	24.1	87.8
91	12	518	1.26	228	42.9	27.2	68.4	181	39.9	26.0	66.9	109	42.2	27.5	62.0
92	1	1297	2.14	543	51.3	29.5	77.0	254	49.4	29.4	72.3	500	51.7	33.3	77.5
92	2	1460	1.24	621	45.3	21.6	76.2	500	43.6	22.1	69.5	339	49.0	21.5	76.2
92	3	1384	1.37	592	43.4	25.2	74.9	432	42.2	22.0	70.0	360	45.3	23.5	75.8
92	4	1374	1.26	480	44.3	24.0	76.0	382	43.7	26.2	79.9	512	50.4	23.5	75.5
92	5	703	1.18	250	40.0	24.7	73.2	211	37.3	25.0	69.2	242	56.4	26.3	70.1
92	6	1351	0.90	425	46.0	24.9	71.0	470	39.5	23.5	71.6	456	47.1	22.8	80.0
92	7	310	1.13	128	46.6	31.4	72.3	113	40.2	31.9	66.5	69	45.5	30.9	72.3
92	8	343	1.06	148	49.8	26.6	72.5	140	50.1	30.9	73.1	55	48.8	31.5	78.0
92	9	581	1.30	236	45.0	28.9	68.9	181	45.4	28.2	69.3	164	45.0	22.0	70.4
92	10	594	0.98	259	42.9	25.5	75.0	265	42.9	26.9	68.5	70	43.1	27.2	74.2
92	11	545	1.41	161	52.8	28.5	75.0	114	51.0	29.0	72.2	270	53.9	28.5	76.1
92	12	244	1.11	73	47.4	29.9	71.3	66	43.5	28.3	64.6	105	55.8	31.0	72.0
93	9	50	1.37	26	54.3	26.2	76.0	19	57.2	36.2	76.0	5	55.8	39.2	67.4
93	10	70	3.17	19	41.8	27.5	64.5	6	41.8	34.5	49.0	45	47.7	41.0	65.0
93	11	216	1.10	74	54.6	28.5	77.0	67	54.7	33.6	71.3	75	62.1	38.0	76.6
93	12	369	1.40	146	44.4	30.5	74.0	104	43.1	29.0	69.8	119	51.9	29.0	73.5
TOTAL		26548	1.30	10118	48.3	21.6	86.6	7771	46.3	6.0	79.9	8659	51.4	21.5	87.8

Table A.7.2. Summary of *P. filamentosus* biometric study information. All data : all gears and locations pooled

YR	MON	TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
89	12	21	0.11	2	56.3	55.7	56.9	19	47.6	40.3	51.5				
90	1	95	0.86	44	50.3	31.0	69.6	51	46.1	30.1	69.2				
90	2	261	1.03	130	53.4	36.6	72.9	126	53.1	35.1	71.7	5	55.7	54.2	57.5
90	3	175	1.06	90	55.8	34.6	72.0	85	54.3	33.4	72.5				
90	4	122	1.10	64	58.0	40.0	73.6	58	51.8	38.1	71.2				
90	5	41	0.95	20	52.4	32.9	68.4	21	53.0	36.2	68.4				
90	7	45	1.25	25	51.6	43.1	69.3	20	52.5	44.9	68.0				
90	9	44	1.00	21	45.5	31.0	66.7	21	45.1	33.5	64.4	2	35.0	32.3	37.6
90	10	190	1.14	100	50.3	36.1	69.0	88	48.7	32.0	66.6	2	56.6	52.6	60.5
90	11	40	0.90	19	47.8	39.2	66.6	21	54.9	39.5	72.6				
90	12	174	1.19	94	56.7	35.4	72.0	79	56.5	36.5	73.1	1	30.5	30.5	30.5
91	1	33	2.00	22	52.2	38.2	67.0	11	58.8	48.7	65.6				
91	2	41	1.05	21	44.1	35.9	61.9	20	50.7	40.4	66.6				
91	4	81	0.93	39	53.9	43.5	71.0	42	57.6	40.7	69.5				
91	5	71	0.82	32	52.6	27.0	71.5	39	51.9	36.2	68.0				
91	6	45	2.00	30	45.6	34.7	61.6	15	41.3	30.5	56.1				
91	7	19	2.17	13	55.6	43.3	65.7	6	56.1	47.8	62.6				
91	8	95	0.84	43	46.1	26.3	72.0	51	43.5	22.5	68.4	1	23.7	23.7	23.7
91	9	56	1.00	28	50.2	41.4	71.6	28	50.2	41.4	61.8				
91	10	93	0.67	37	38.4	28.2	74.6	55	41.9	27.9	69.6	1	32.3	32.3	32.3
91	11	11	1.75	7	50.4	42.6	59.0	4	51.8	48.3	56.2				
TOTAL		1753	1.02	881	51.8	26.3	74.6	860	50.9	22.5	73.1	12	45.7	23.7	60.5

TABLE A.7.3. Number of length frequency measurements per year per sector by gear : *P. filamentosus*

UNSPECIFIED GEAR

SECTOR	89	91	92	93	TOTAL
2	0	135	1	0	136
4	0	88	1	0	89
5	0	158	0	0	158
6	0	301	0	0	301
7	0	296	1	0	297
8	0	509	0	0	509
9	0	814	0	0	814
11	0	472	0	0	472
13	0	369	0	0	369
14	0	270	0	0	270
?	1029	826	1544	194	3593
TOTAL	1029	4238	1547	194	7008

HANDLINES

SECTOR	90	91	92	93	TOTAL
2	220	23	380	0	623
3	0	5	388	0	393
4	0	0	43	0	43
5	0	313	24	0	337
6	867	277	488	0	1632
7	873	436	376	115	1800
8	136	453	1	0	590
9	305	89	93	32	519
10	58	0	278	0	336
11	510	94	0	0	604
13	221	341	0	0	562
14	250	12	0	0	262
?	2582	1041	1370	83	5076
TOTAL	6022	3084	3441	230	12777

ELECTRIC REELS

SECTOR	92	93	TOTAL
5	0	13	13
6	196	57	253
9	168	0	168
11	0	50	50
13	76	0	76
?	1	0	1
TOTAL	441	120	561

DROP LINES

SECTOR	91	92	TOT
7	78	0	78
13	110	79	189
?	0	9	9
TOTAL	188	439	627

GILL NETS

SECTOR	91	92	93	TOTAL
6	0	1204	0	1204
7	313	374	0	687
8	0	321	0	321
11	0	93	0	93
13	324	0	161	485
?	459	2326	0	2785
TOTAL	1096	4318	161	5575

TABLE A.7.4. : Number of fish measured for biometric studies per year per sector by gear : *P. filamentosus*

UNSPECIFIED GEAR

SECTOR	89	90	91	TOTAL
2	0	325	0	325
3	0	0	30	30
4	0	0	1	1
5	0	49	51	100
6	21	209	126	356
7	0	264	30	294
8	0	79	168	247
9	0	0	14	14
10	0	44	17	61
11	0	209	0	209
13	0	8	18	26
TOTAL	21	1187	455	1663

HANDLINES

SECTOR	91	TOTAL
13	11	11

GILLNETS

SECTOR	91	TOTAL
7	79	79

TABLE A.7.5 : Summary of *A. virescens* length frequency data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YR	MON	TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
91	1	450	1.68	156	57.4	28.3	83.4	93	51.9	29.5	86.5	201	58.7	23.2	84.2
91	2	623	1.41	236	59.0	29.2	81.0	167	56.9	28.8	89.9	220	59.1	31.2	88.6
91	3	895	1.51	368	56.0	28.5	85.8	243	53.4	29.4	85.8	284	63.6	28.9	87.3
91	4	1049	1.85	417	63.8	31.1	89.3	226	58.1	31.6	86.0	406	66.2	25.3	86.8
91	5	847	2.81	379	63.8	32.6	91.6	135	59.3	23.0	80.4	333	66.5	33.0	89.5
91	6	612	1.70	225	53.0	21.0	87.7	132	49.5	30.8	87.4	255	62.6	29.4	88.6
91	7	629	1.71	253	50.4	29.4	88.0	148	47.9	27.9	88.8	228	62.7	34.5	86.8
91	8	368	1.60	157	60.1	31.3	82.3	98	50.9	27.0	88.2	113	61.4	32.4	79.3
91	9	293	2.23	116	58.8	32.1	83.2	52	54.1	32.7	81.2	125	67.3	34.0	86.9
91	10	658	1.53	226	61.2	33.2	83.6	148	58.3	32.6	85.0	284	63.7	30.8	89.5
91	11	1074	1.60	419	60.9	35.3	82.2	262	60.5	38.0	86.5	393	66.1	34.8	91.5
91	12	821	1.51	344	62.3	35.7	87.4	228	62.5	40.0	94.0	249	68.0	34.3	90.0
92	1	732	1.93	284	62.5	24.3	86.8	147	63.1	27.0	88.0	301	64.9	34.5	88.4
92	2	443	2.16	175	60.4	31.0	82.0	81	59.6	33.9	87.3	187	66.7	35.2	89.2
92	3	1447	2.46	482	60.6	31.4	87.5	196	59.8	24.4	92.0	769	66.1	32.0	89.8
92	4	1007	1.99	306	60.6	34.5	84.0	154	61.5	35.0	87.5	547	66.4	37.2	94.7
92	5	697	2.20	213	64.3	28.0	84.6	97	63.1	37.7	84.5	387	69.0	37.8	93.0
92	6	107	2.92	35	59.0	40.5	76.4	12	58.3	38.2	70.5	60	69.8	47.2	94.0
92	8	4	0.00					2	86.0	81.5	90.5	2	86.0	81.8	90.1
92	9	23	3.50	7	61.7	52.3	66.4	2	74.3	64.6	84.0	14	65.1	58.5	74.5
92	10	108	1.41	45	51.0	27.3	73.5	32	55.0	25.1	86.2	31	66.2	42.5	81.5
92	11	278	4.04	97	64.0	43.0	82.0	24	60.5	43.2	74.9	157	64.7	40.1	87.5
92	12	163	3.26	62	56.9	34.5	75.1	19	55.5	43.5	72.0	82	65.4	42.2	88.0
93	1	88	1.76	37	63.0	26.5	79.8	21	67.3	31.5	84.4	30	61.6	30.6	79.0
93	2	73	2.75	11	64.5	45.5	80.5	4	73.9	60.3	82.5	58	70.2	47.6	90.5
93	3	379	1.89	85	62.2	46.1	81.8	45	65.1	40.6	96.3	249	70.3	35.8	88.4
93	4	399	1.72	93	61.2	35.2	88.8	54	64.5	42.7	90.3	252	69.0	39.4	89.0
93	5	170	1.96	55	62.8	39.9	80.3	28	59.4	37.2	86.5	87	68.9	37.0	88.0
93	6	143	3.07	43	65.8	46.0	81.4	14	60.6	43.3	73.5	86	68.9	42.3	87.0
93	7	108	1.73	38	61.7	31.3	77.3	22	58.7	39.0	77.6	48	65.5	44.6	80.2
93	9	25	2.75	11	73.4	64.5	82.5	4	69.1	63.5	78.3	10	74.4	43.5	85.3
93	10	421	1.43	140	60.4	37.2	82.0	98	62.2	28.5	92.4	183	64.8	38.5	80.7
93	11	620	1.06	216	50.0	30.4	86.2	203	46.9	32.3	84.1	201	62.5	36.7	88.3
93	12	241	1.14	74	57.6	34.5	79.3	65	54.0	33.0	75.4	102	60.7	35.5	81.7
TOTAL		15995	1.78	5805	59.8	21.0	91.6	3256	57.3	23.0	96.3	6934	65.3	23.2	94.7

TABLE A.7.6 : Summary of *A. virescens* biometric study data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YRMON		TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
91	4	80	2.81	59	65.6	43.0	78.2	21	63.9	39.0	76.5				
91	5	78	1.17	42	62.6	38.5	84.5	36	66.3	39.4	86.9				
91	6	30	0.88	14	56.5	37.4	70.3	16	61.9	37.7	76.0				
91	7	103	1.55	62	60.2	36.5	83.7	40	62.1	38.8	82.4	1	57.8	57.8	57.8
91	8	33	0.94	16	61.4	46.4	78.1	17	64.2	48.9	77.1				
91	9	33	0.94	16	74.0	70.0	77.1	17	74.6	66.3	80.8				
91	10	43	1.87	28	69.3	61.1	80.5	15	69.3	56.5	86.1				
91	11	86	1.87	56	56.8	36.9	81.9	30	59.2	35.5	76.1				
91	12	35	1.06	18	62.7	57.5	66.7	17	66.5	57.8	83.8				
92	1	15	1.14	8	70.2	62.5	75.1	7	77.2	65.1	86.1				
92	2	54	0.69	22	51.7	41.1	75.4	32	49.1	38.0	70.8				
92	3	81	1.38	47	56.9	43.2	80.3	34	61.1	46.2	79.6				
92	4	22	0.47	7	57.5	42.6	73.5	15	65.3	44.2	85.2				
92	5	63	1.52	38	66.9	49.1	80.4	25	66.9	50.2	84.0				
92	6	43	0.87	20	43.5	35.7	54.4	23	46.9	37.3	61.0				
92	11	24	1.00	12	61.6	43.5	75.2	12	69.3	54.8	79.9				
92	12	19	0.19	3	75.7	74.4	76.6	16	74.6	63.0	81.6				
93	3	51	1.43	30	31.0	25.4	39.5	21	31.3	27.0	37.8				
93	4	21	0.54	7	57.0	45.5	72.7	13	54.4	31.8	87.8	1	35.4	35.4	35.4
TOTAL		914	1.24	505	59.3	25.4	84.5	407	61.0	27.0	87.8	2	46.6	35.4	57.8

TABLE A.7.7 : Number of length frequency measurements per year per sector by gear : *A. virescens*

UNSPECIFIED GEAR

SECTOR	91	92	93	TOTAL
2	220	2	0	222
3	0	64	0	64
6	51	3	0	54
7	318	0	1	319
8	60	0	0	60
9	669	0	0	669
10	105	0	0	105
11	23	0	0	23
13	312	0	0	312
14	139	0	0	139
?	4050	1995	1111	7156
TOTAL	5947	2064	1112	9123

HANDLINES

SECTOR	91	92	93	TOTAL
2	131	17	69	217
3	18	351	63	432
4	48	177	9	234
5	141	28	33	202
6	228	345	244	817
7	153	188	205	546
9	470	822	226	1518
10	142	96	228	466
12	51	15	0	66
13	351	74	17	442
14	18	0	0	18
	546	689	206	1441
TOTAL	2297	2802	1300	6399

ELECTRIC REELS

SECTOR	92	93	TOTAL
2	0	51	51
5	0	24	24
6	0	8	8
9	27	0	27
10	0	4	4
11	0	28	28
	76	48	124
TOTAL	103	163	266

DROP LINES

SECTOR	91	92	TOTAL
13	23	9	32

GILL NETS

SECTOR	91	92	93	TOTAL
4	0	1	0	1
6	0	7	4	11
7	0	10	14	24
9	0	1	0	1
11	0	9	0	9
13	52	0	9	61
99	0	0	55	55
?	0	3	10	13
TOTAL	52	31	92	175

TABLE A.7.8. :Number of fish measured for biometric studies per year per sector by gear : *A. virescens*

UNSPECIFIED GEAR

SECTOR	91	92	TOTAL
1	10	0	10
2	67	65	132
3	94	0	94
4	40	0	40
5	11	0	11
6	14	19	33
8	5	0	5
9	176	111	287
10	60	57	117
13	0	69	69
TOTAL	477	321	798

HANDLINES

SECTOR	91	93	TOTAL
2	2	24	26
3	2	48	50
7	18	0	18
9	22	0	22
TOTAL	44	72	116

TABLE A.7.9 : Summary of *L. nebulosus* length frequency data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YRMON		TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
92	3	119	1.86	26	55.8	31.5	72.5	14	60.0	47.3	74.6	79	55.2	33.5	79.0
92	4	38	2.33	21	46.5	37.5	66.0	9	51.2	41.7	64.5	8	51.1	35.7	67.8
92	5	50	1.36	19	49.6	36.2	63.4	14	53.0	36.5	68.0	17	48.9	39.2	69.5
92	6	5	3.00	3	64.7	61.1	68.3	1	42.0	42.0	42.0	1	62.3	62.3	62.3
92	8	337	2.49	127	42.0	29.0	58.5	51	44.0	30.7	56.8	159	40.6	24.7	62.3
92	10	132	0.98	40	56.2	28.4	69.0	41	56.6	27.5	68.6	51	55.2	27.2	69.5
92	11	176	2.45	27	48.8	36.0	65.1	11	47.5	37.8	64.5	138	49.2	18.5	72.6
92	12	3	NA	1	62.3	62.3	62.3					2	55.8	45.5	66.1
TOTAL		860	1.87	264	47.5	28.4	72.5	141	50.9	27.5	74.6	455	48.0	18.5	79.0

TABLE A.7.10 : Summary of L. nebulosus biometric study data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YRMON		TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
92	4	50	0.62	18	48.5	31.5	71.1	29	49.5	37.5	73.7	3	39.1	34.5	46.1

TABLE A.7.11 : Number measurements per year per sector by gear : *L. nebulosus*

LENGTH FREQUENCY DATA
UNSPECIFIED GEAR

SECTOR	92	TOT
0	334	334

HANDLINES

SECTOR	92	TOT
6	15	15
7	6	6
9	50	50
13	107	107
0	11	11
TOTAL	189	189

GILLNETS

SECTOR	92	TOT
0	337	337

BIOMETRIC STUDY DATA
HANDLINES

SECTOR	92	TOT
9	27	27
10	23	23
TOTAL	50	50

TABLE A.7.12 : Summary of *L. sebae* length frequency data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YR	MON	TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
89	11	727	1.30	277	63.5	25.3	84.5	213	57.2	24.6	80.0	237	61.0	21.4	83.0
89	12	156	0.55	43	61.9	23.2	83.3	78	51.6	23.7	77.0	35	58.0	20.3	81.6
90	1	253	0.57	51	54.5	23.0	77.4	89	42.1	19.5	68.4	113	41.8	18.4	76.5
90	2	533	0.81	159	56.4	24.5	81.3	196	50.8	23.7	70.2	178	51.1	21.9	81.5
90	3	946	0.73	223	57.4	23.2	81.2	305	48.6	22.1	74.0	418	50.8	20.0	84.4
90	4	573	0.84	173	55.3	21.7	82.9	205	48.7	22.2	78.2	195	54.2	20.8	81.4
90	5	216	0.70	52	61.4	23.0	82.3	74	50.2	24.9	70.6	90	52.8	21.5	75.7
90	6	26	5.00	15	60.3	47.3	71.8	3	49.0	41.1	56.6	8	57.1	44.6	63.5
90	7	281	0.61	67	56.6	29.2	83.8	109	47.9	26.0	69.3	105	47.9	19.6	80.8
90	8	147	0.57	31	57.9	36.5	74.6	54	50.0	31.5	69.8	62	53.6	34.2	78.0
90	9	314	0.61	70	64.4	5.0	82.5	114	51.0	23.2	70.3	130	58.1	24.7	80.5
90	10	732	0.86	217	61.2	24.0	86.0	252	52.7	24.8	73.3	263	53.6	21.0	80.1
90	11	360	0.96	129	62.1	25.4	83.5	135	55.8	28.3	77.7	96	56.1	25.9	76.6
90	12	308	1.09	117	49.6	25.1	81.2	107	45.6	26.3	72.0	84	46.4	26.2	73.0
91	1	348	1.19	107	57.9	28.2	83.2	90	51.1	26.8	75.2	151	54.8	19.9	83.5
91	2	668	1.13	231	60.1	28.9	82.1	204	53.5	27.8	73.6	233	55.4	24.5	98.3
91	3	892	1.01	310	61.3	23.6	82.5	307	52.4	21.1	78.5	275	59.6	22.7	88.4
91	4	1133	1.12	448	62.5	25.6	84.4	400	56.7	27.8	78.2	285	58.4	20.5	80.7
91	5	1051	1.15	401	61.4	23.0	88.1	350	52.7	23.9	78.5	300	60.6	20.3	91.1
91	6	472	1.39	181	59.7	26.1	82.4	130	51.7	21.7	77.5	161	58.8	21.0	80.4
91	7	302	0.58	70	45.2	17.0	75.5	120	32.7	15.4	65.3	112	27.8	14.1	67.4
91	8	238	1.06	74	62.4	36.3	79.6	70	55.5	35.3	66.3	94	57.3	27.7	75.2
91	9	896	1.21	320	62.3	21.4	83.4	264	50.7	21.9	72.4	312	60.9	19.0	83.4
91	10	976	1.03	354	62.3	29.8	86.0	344	56.7	25.0	74.6	278	60.0	24.2	82.8
91	11	1088	1.37	447	60.4	30.5	83.9	326	54.6	27.2	70.9	315	62.5	27.5	82.0
91	12	417	1.12	138	62.6	21.6	84.2	123	51.0	20.6	75.4	156	59.1	20.9	84.6

TABLE A.7.12 : Summary of *L. sebae* length frequency data continued.

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YR	MON	TOTAL		MALE				FEMALE				UNDETERMINED			
		N	M:F	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL	N	AVG FL	MIN FL	MAX FL
92	1	500	1.14	208	59.7	24.5	83.5	182	50.5	21.5	73.2	110	55.0	21.0	76.5
92	2	1110	1.28	398	59.9	22.3	82.8	312	51.5	23.0	81.6	400	59.1	22.2	94.0
92	3	2233	1.07	717	61.7	24.4	85.3	670	54.0	24.4	77.0	846	60.8	24.2	89.0
92	4	1124	1.04	331	61.1	29.7	82.4	319	53.8	27.3	80.2	474	60.6	24.5	85.2
92	5	1136	1.24	411	60.0	24.9	86.0	332	53.2	22.6	71.9	393	59.3	24.8	81.2
92	6	173	1.07	62	42.3	21.8	75.1	58	40.4	23.0	68.0	53	48.8	18.2	79.0
92	9	10	0.50	2	33.5	32.0	35.0	4	29.4	26.1	35.0	4	23.5	22.3	24.0
92	10	137	1.00	51	55.0	23.2	77.6	51	49.3	27.0	64.1	35	51.9	22.2	80.5
92	11	95	0.94	31	51.7	29.5	78.2	33	44.2	25.3	63.9	31	52.8	23.1	74.3
92	12	70	1.13	26	55.8	25.1	77.6	23	49.1	27.2	71.0	21	59.3	47.5	69.0
93	1	153	2.48	62	64.7	47.0	82.0	25	56.5	41.0	66.3	66	61.5	39.0	76.0
93	2	260	1.87	103	61.1	28.4	81.6	55	56.6	27.1	72.6	102	62.4	32.2	83.0
93	3	646	1.14	163	63.3	29.4	83.2	143	55.1	23.7	72.0	340	62.8	20.7	86.3
93	4	474	1.08	138	59.4	32.6	86.2	128	52.9	32.4	69.5	208	59.2	30.5	83.2
93	5	188	1.17	54	63.1	32.2	83.0	46	54.5	32.2	72.8	88	61.1	32.5	80.8
93	6	33	1.11	10	63.4	37.5	73.0	9	52.7	44.5	64.2	14	57.3	34.7	74.5
93	7	19	1.67	10	70.1	52.7	81.6	6	61.7	50.2	66.7	3	61.2	53.7	69.1
93	9	222	1.60	80	67.8	42.3	86.6	50	60.5	48.9	73.2	92	65.6	45.4	84.8
93	10	577	1.07	215	59.7	27.5	80.3	201	55.9	26.2	75.0	161	57.9	28.4	81.2
93	11	532	1.19	192	65.5	27.2	83.2	162	59.3	30.3	71.2	178	59.7	19.1	81.3
93	12	216	1.19	76	66.6	33.6	83.4	64	56.8	38.1	68.8	76	63.1	31.8	81.4
TOTAL		23961	1.07	8045	60.5	5.0	88.1	7535	52.6	15.4	81.6	8381	57.7	14.1	98.3

TABLE A.7.13 : Number of length frequency measurements per year per sector by gear : *L. sebae*

UNSPECIFIED GEAR

SECTOR	91	92	93	TOTAL
6	0	62	0	62
9	0	8	0	8
?	31	2344	1525	3900
TOTAL	31	2414	1525	3970

HANDLINES

SECTOR	89	90	91	92	93	TOTAL
2	0	153	624	22	10	809
3	0	0	119	467	0	586
4	0	0	183	180	42	405
5	0	0	317	132	114	563
6	0	67	904	824	118	1913
7	0	43	358	355	129	885
8	0	149	572	207	0	928
9	0	274	1049	475	29	1827
10	0	172	244	225	0	641
11	0	23	0	0	0	23
13	0	0	345	43	0	388
14	0	0	20	0	0	20
99	0	0	0	0	51	51
?	883	3808	3715	1205	1010	10621
TOTAL	883	4689	8450	4135	1503	19660

ELECTRIC REELS

SECTOR	93	TOTAL
2	72	72
?	136	136
TOTAL	208	208

GILLNETS

SECTOR	92	93	TOTAL
13	0	65	65
?	15	19	34
TOTAL	15	84	99

TRAPS

SECTOR	92	TOTAL
?	24	24

TABLE A.7.14 : Summary of *E. chlorostigma* length frequency data

ALL DATA : ALL GEARS AND LOCATIONS POOLED

YEAR	MON	SEX UNDETERMINED			
		N	AVG FL	MIN FL	MAX FL
90	5	111	41.6	29.9	62.5
90	6	153	37.7	24.0	50.4
90	7	338	39.5	23.8	60.8
90	8	206	36.2	24.8	55.2
90	9	471	37.6	21.3	63.7
90	10	708	36.4	25.2	63.2
90	11	351	39.2	23.4	64.3
90	12	297	39.7	23.1	59.8
91	1	309	38.2	25.1	60.4
91	2	383	35.8	22.5	48.3
91	3	573	36.9	22.1	61.5
91	4	675	38.1	24.3	60.3
91	5	832	37.7	22.6	67.5
91	6	494	38.1	20.4	61.5
91	7	394	39.7	21.2	80.7
91	8	403	37.5	22.5	63.5
91	9	645	37.7	22.2	64.0
91	10	900	38.1	23.8	69.0
91	11	906	37.8	21.9	58.0
91	12	507	38.6	21.1	64.8
92	1	719	38.8	19.9	62.1
92	2	899	36.1	22.5	65.4
92	3	2019	36.4	20.4	58.7
92	4	1350	36.4	23.4	65.8
92	5	878	37.1	20.8	64.2
92	6	218	37.5	28.8	59.5
92	7	46	38.0	29.2	42.0
92	8	39	37.4	31.0	50.5
92	9	119	37.4	24.0	53.0
92	10	309	38.3	24.2	68.5
92	11	225	41.3	25.0	62.2
92	12	292	37.0	24.0	59.7
93	1	245	37.2	26.8	61.5
93	2	523	36.6	24.5	53.4
93	3	551	37.3	22.2	72.0
93	4	432	39.5	25.5	65.9
93	5	298	38.2	27.5	60.6
93	6	105	42.8	28.1	74.1
93	7	63	39.0	28.5	53.1
93	9	188	36.8	27.0	42.8
93	10	453	36.2	24.5	58.7
93	11	510	36.6	21.2	59.0
93	12	266	36.3	24.4	49.8
94	3	5	29.9	26.0	35.0
TOTAL		20408	37.5	19.9	80.7

TABLE A.7.15 : Number of length frequency measurements per year per sector by gear : *E. chlorostigma*

UNSPECIFIED GEAR

SECTOR	90	91	92	93	TOTAL
3	0	53	0	0	53
5	0	1	1	0	2
6	0	38	42	18	98
13	0	50	0	0	50
	2635	3948	2689	1173	10445
TOTAL	2635	4090	2732	1191	10648

HANDLINES

SECTOR	91	92	93	94	TOTAL
2	83	17	31	0	131
3	136	383	0	5	524
4	119	162	13	0	294
5	309	253	86	0	648
6	602	558	329	0	1489
7	25	471	326	0	822
8	164	0	0	0	164
9	238	567	149	0	954
10	33	45	100	0	178
12	0	18	0	0	18
13	138	44	5	0	187
99	0	0	41	0	41
	971	1505	756	0	3232
TOTAL	2818	4023	1836	5	8682

TRAPS

SECTOR	92	93	TOTAL
3	0	70	70
6	0	1	1
	59	0	59
TOTAL	59	71	130

ELECTRIC REELS

SECTOR	91	92	93	TOTAL
3	0	2	0	2
5	54	27	40	121
6	29	0	15	44
7	29	0	0	29
9	0	38	40	78
10	0	0	25	25
99	0	0	58	58
	0	0	110	110
TOTAL	112	67	288	467

DROPLINES

SECTOR	92	93	TOTAL
6	29	0	29
?	0	12	12
TOTAL	29	12	41

GILLNETS

SECTOR	91	92	93	TOTAL
5	1	0	0	1
6	0	0	9	9
7	0	12	27	39
11	0	83	0	83
13	0	0	28	28
99	0	0	22	22
?	0	108	150	258
TOTAL	1	203	236	440

LENGTH FREQUENCY DISTRIBUTION OBSERVED ON MAHE PLATEAU FOR EXTENDED DATA SET TO 1994.

In the absence of length frequency data from sector 1, the most heavily fished sector, annual aggregate length frequency distributions by gear type were derived for *P. filamentosus, A. virescens, L. sebae*, and *E. chlorostigma* from all fishing locations on the Mahe Plateau only (Sectors 2-10).

TABLE A.7.16 :The number of fish sampled during length frequency studies by gear type per annum from the Mahe plateau (Fishing sectors 2-10)

Aprion virescens

METHOD	90	91	92	93	94	TOTAL
Un-known	0	1423	69	1	791	2284
Drop line	0	0	0	0	14	14
Gill net	0	0	19	18	214	251
Hand line	0	1331	2024	1077	1102	5534
Electric reel	0	0	27	87	289	403
Traps	0	0	0	0	6	6
TOTAL	0	2754	2139	1183	2416	8492

Lutjanus sebae

METHOD	90	91	92	93	94	TOTAL
Un-known	0	0	70	0	0	70
Gill net	0	0	0	0	147	147
Hand line	858	4371	2887	442	1042	9600
Electric reel	0	0	0	72	483	555
TOTAL	858	4371	2957	514	1672	10372

Epinephelus chlorostigma

METHOD	90	91	92	93	94	TOTAL
Un-known	0	92	43	18	0	153
Drop line	0	0	29	0	0	29
Gill net	0	1	12	36	136	185
Hand line	0	1709	2456	1034	819	6018
Electric reel	0	112	67	120	335	634
Trap	0	0	0	71	3	74
TOTAL	0	1914	2607	1279	1293	7093

Pristipomoides filamentosus

METHOD	90	91	92	93	94	TOTAL
Un-known	0	2301	3	0	413	2717
Drop line	0	78	351	0	738	1167
Gill net	0	313	1899	0	3213	5425
Hand line	2459	1596	2071	147	793	7066
Electric reel	0	0	364	70	383	817
TOTAL	2459	4288	4688	217	5540	17192

Figure A.7.1 : Mahe Plateau only - *Aprion virescens* length frequency distribution observed for all gear types in 1991, 1992, 1993, and 1994 respectively.

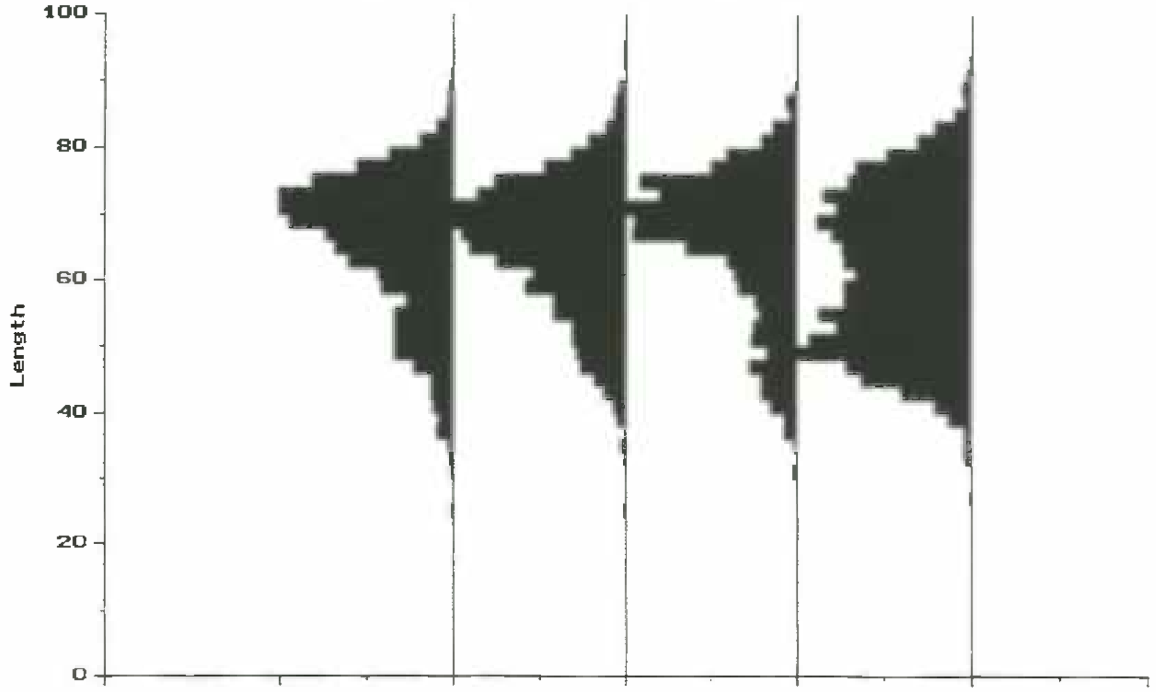


Figure A.7.2 : Mahe Plateau only - *Aprion virescens* length frequency distribution observed for unknown gear types in 1991, 1992 and 1993 respectively.

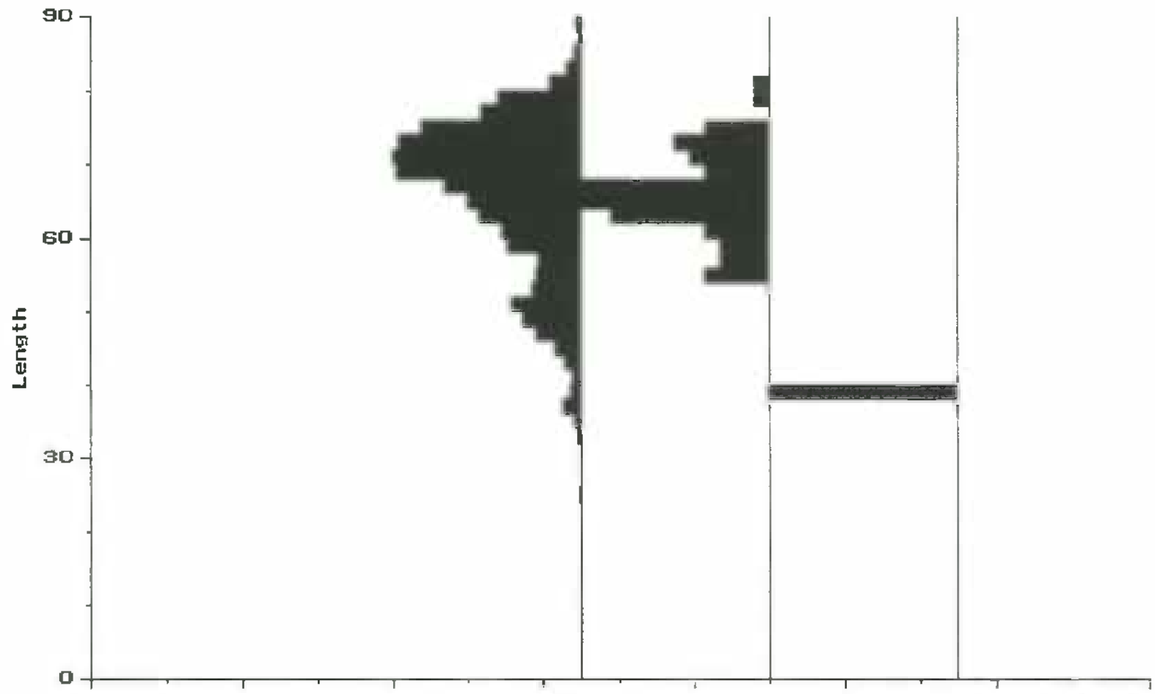


Figure A.7.3 : Mahe Plateau only - *Aprion virescens* length frequency distribution observed for hand lines in 1991, 1992, 1993, and 1994 respectively.

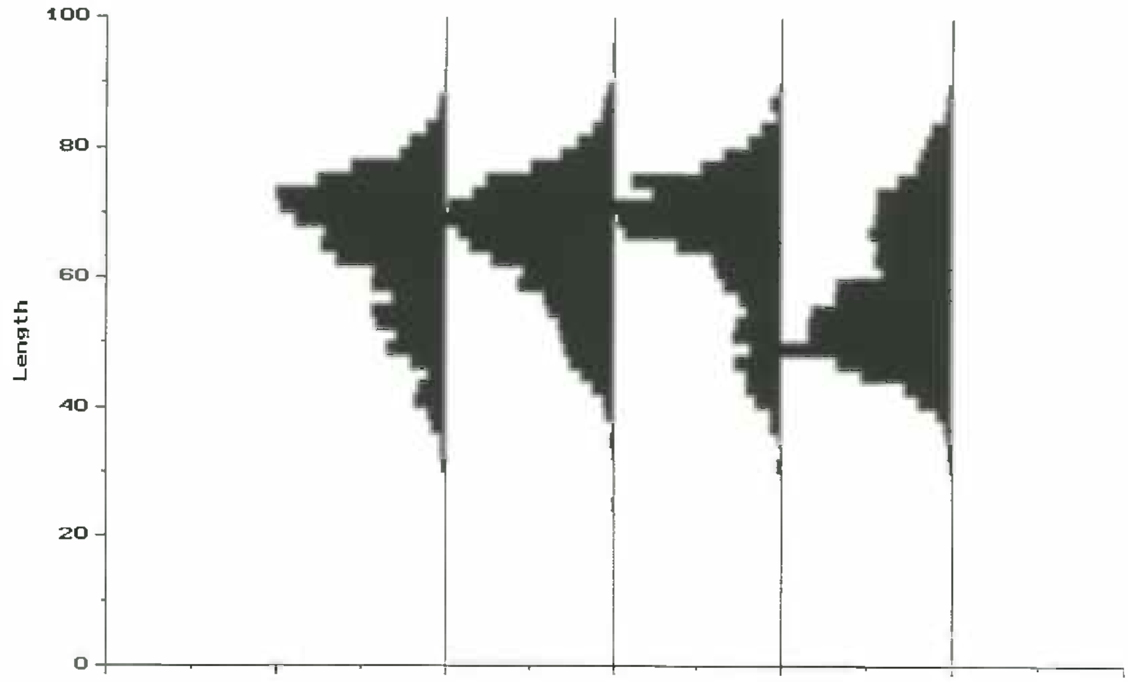


Figure A.7.4 : Mahe Plateau only - *Aprion virescens* length frequency distribution observed for electric reels in 1992, 1993, and 1994 respectively.

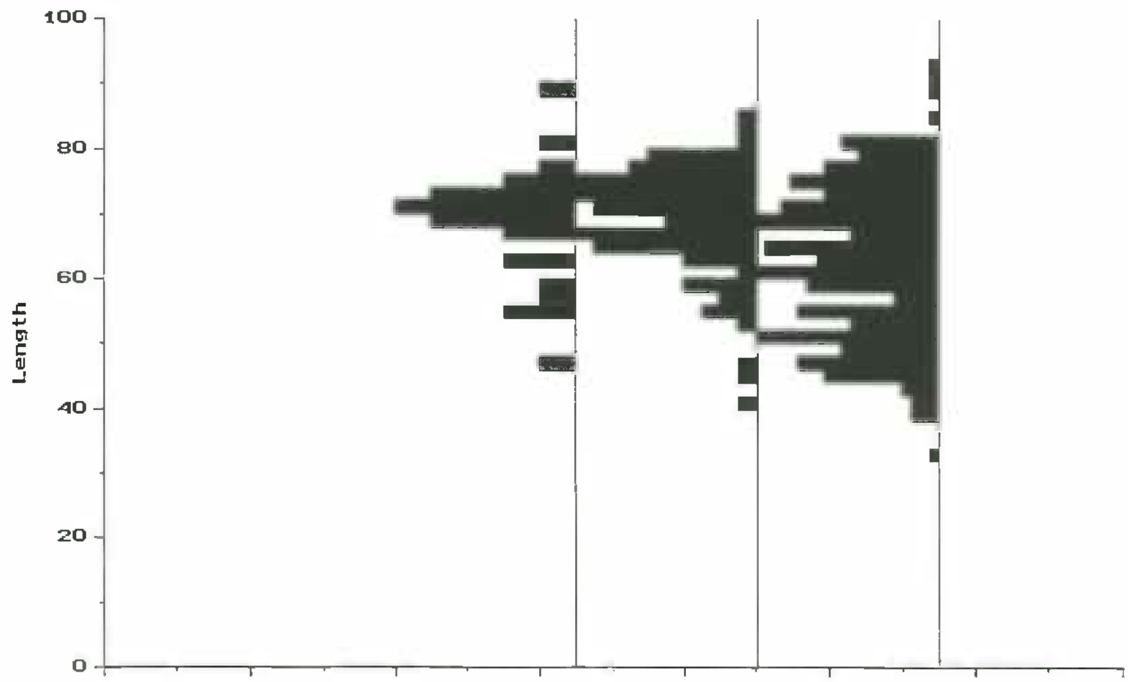


Figure A.7.5 : Mahe Plateau only - *Aprion virescens* length frequency distribution observed for gill nets in 1992, 1993, and 1994 respectively.

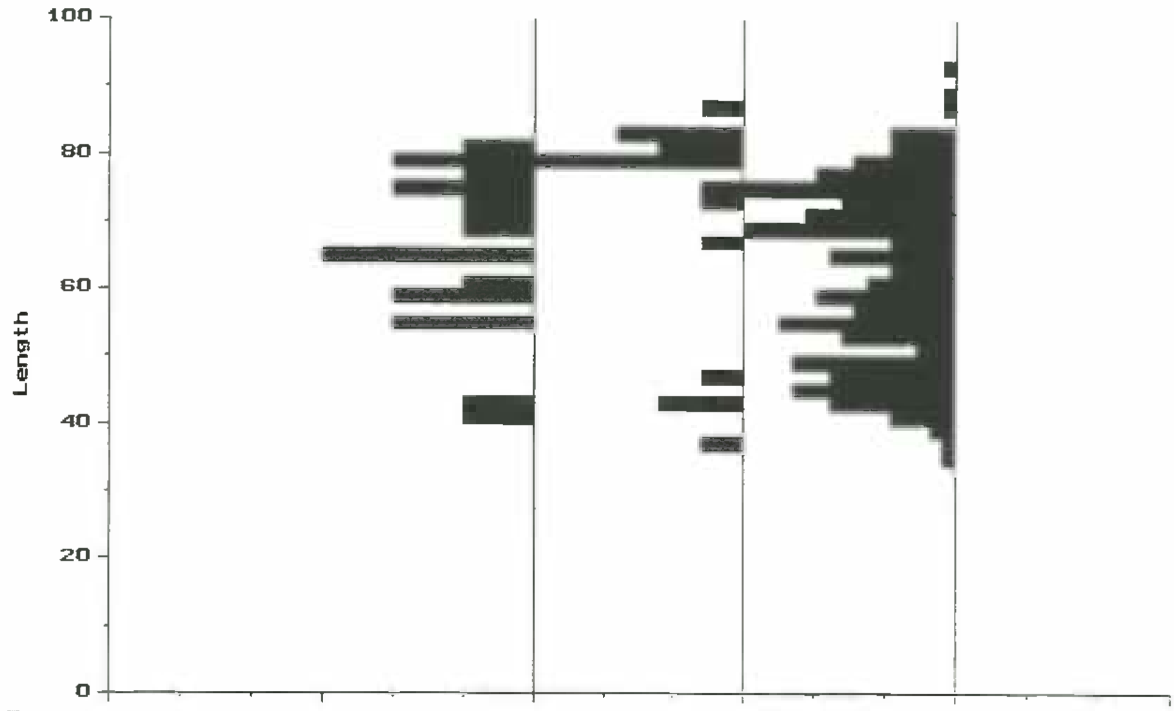


Figure A.7.6 : Mahe Plateau only - *Lutjanus sebae* length frequency distribution observed for all gear types in 1990, 1991, 1992, 1993, and 1994 respectively.

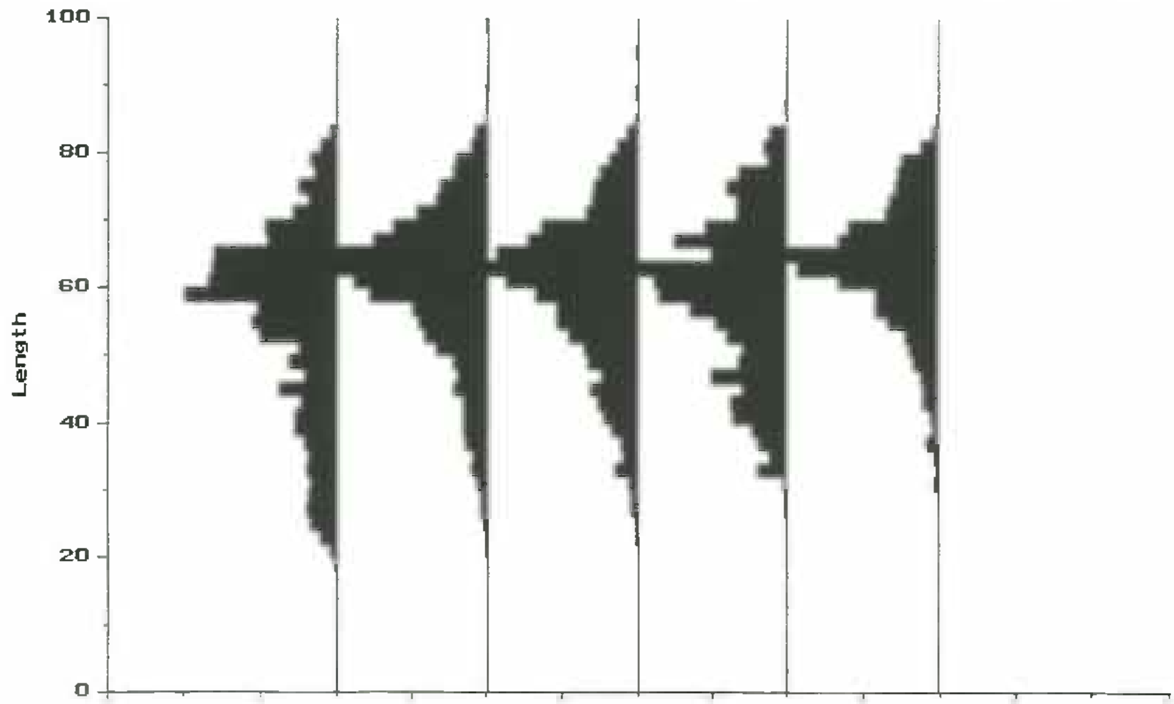


Figure A.7.7 : Mahe Plateau only - Mahe Plateau only - *Lutjanus sebae* length frequency distribution observed for hand lines in 1990, 1991, 1992, 1993, and 1994 respectively.

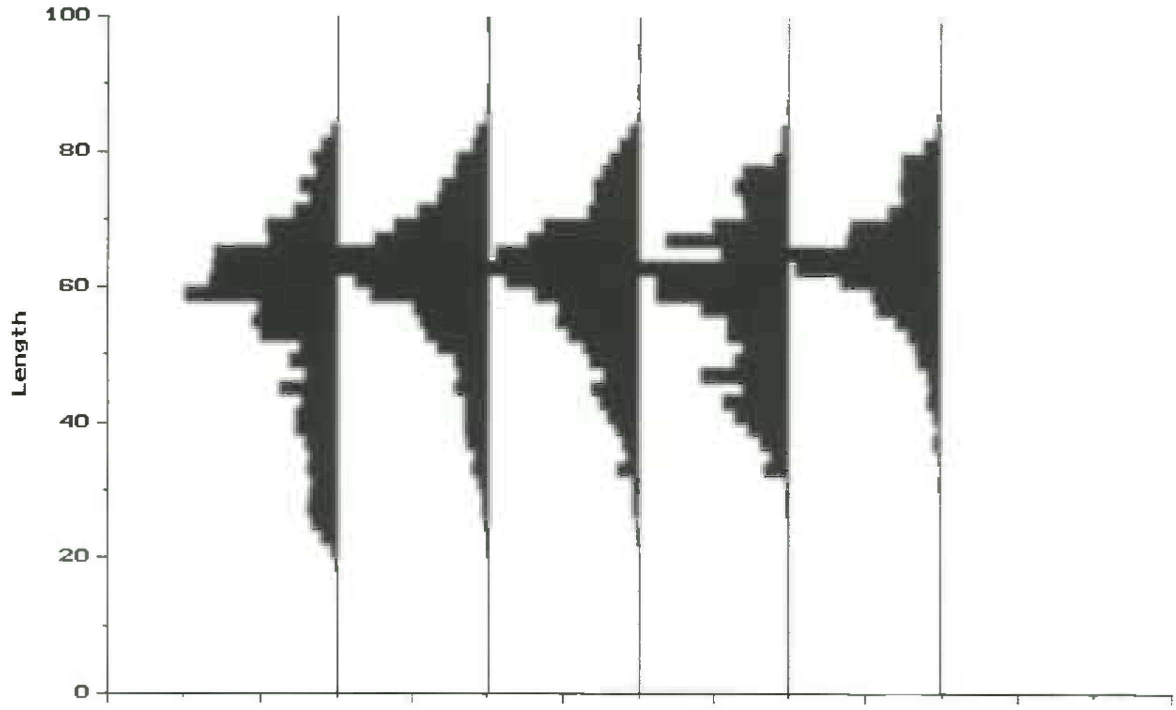


Figure A.7.8 : Mahe Plateau only - *Lutjanus sebae* length frequency distribution observed for all electric reels in 1993 and 1994 respectively.

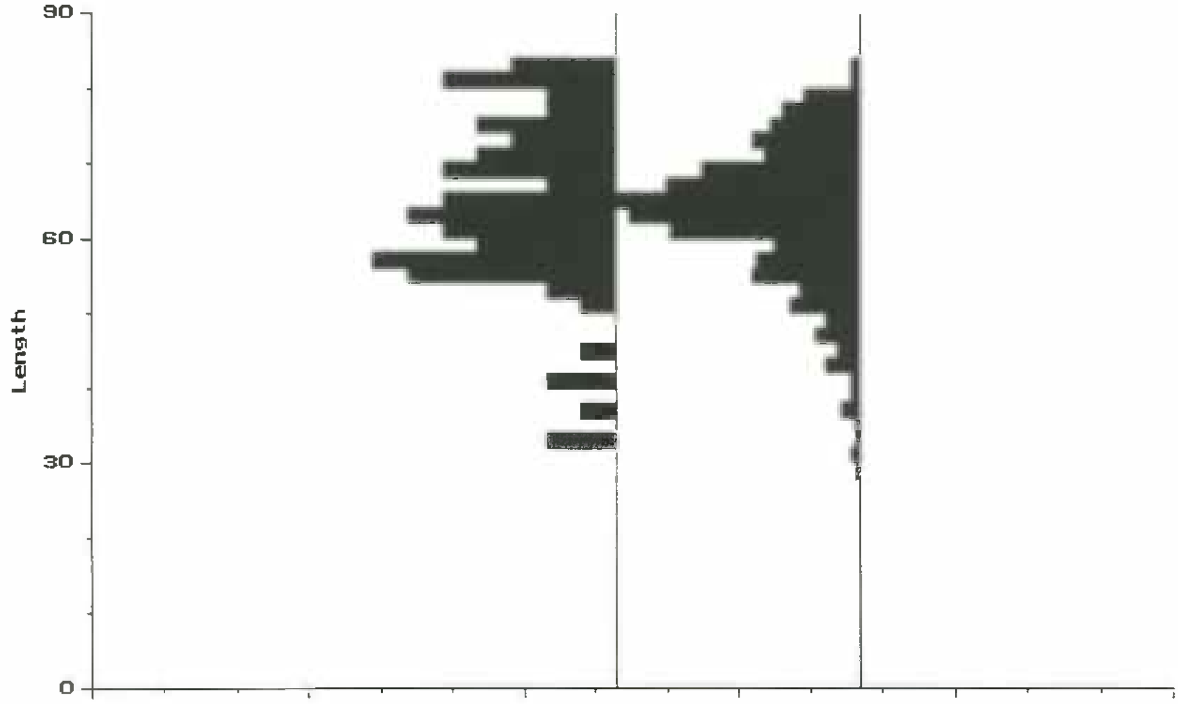


Figure A.7.9 : Mahe Plateau only - *Lutjanus sebae* length frequency distribution observed for gill nets in 1994.

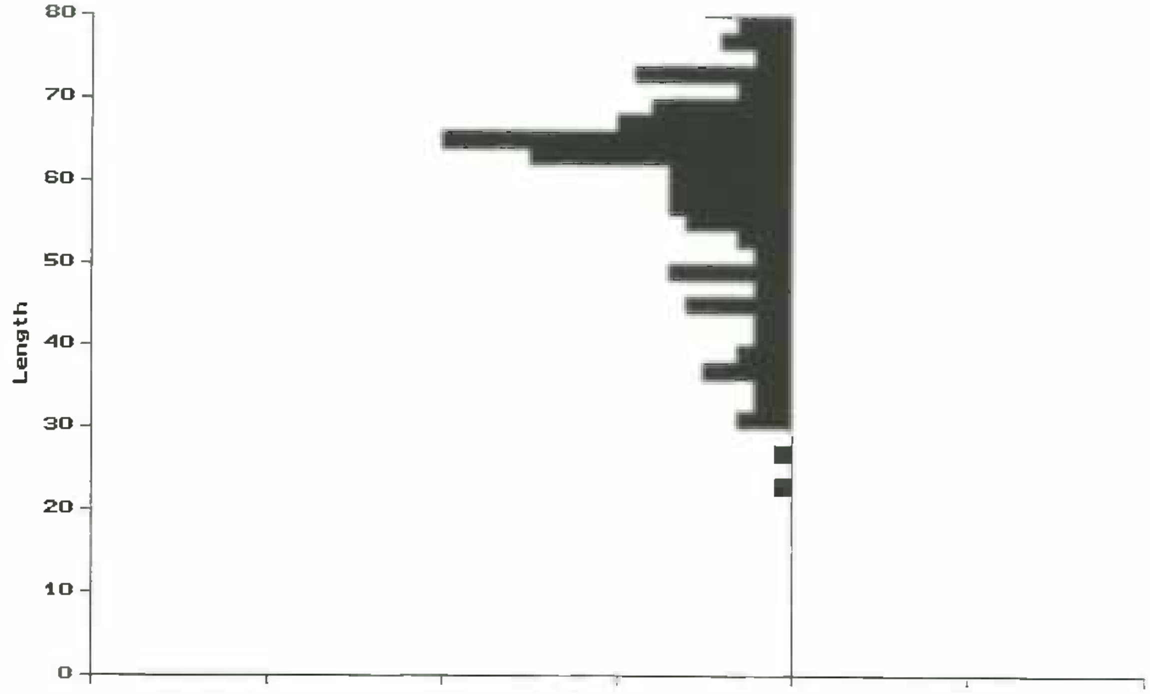


Figure A.7.10 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for all gear types in 1991, 1992, 1993, and 1994 respectively.

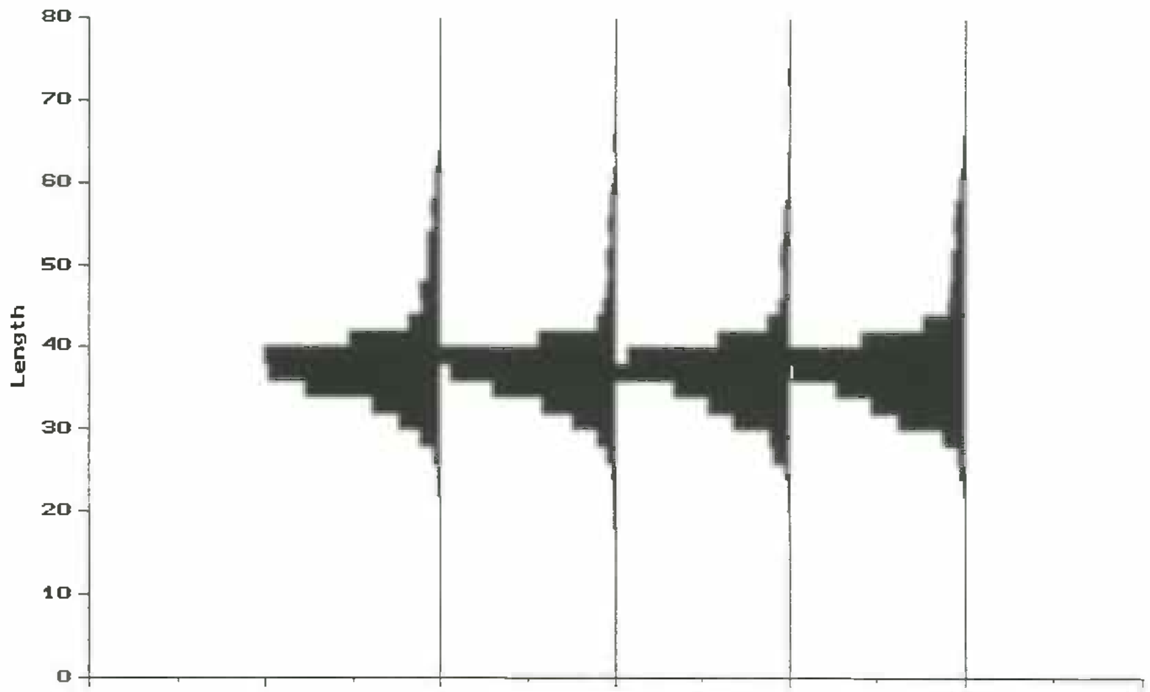


Figure A.7.11 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for unspecified gear types in 1991, 1992, and 1993 respectively.

Figure A.7.12 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for hand lines in 1991, 1992, 1993, and 1994 respectively.

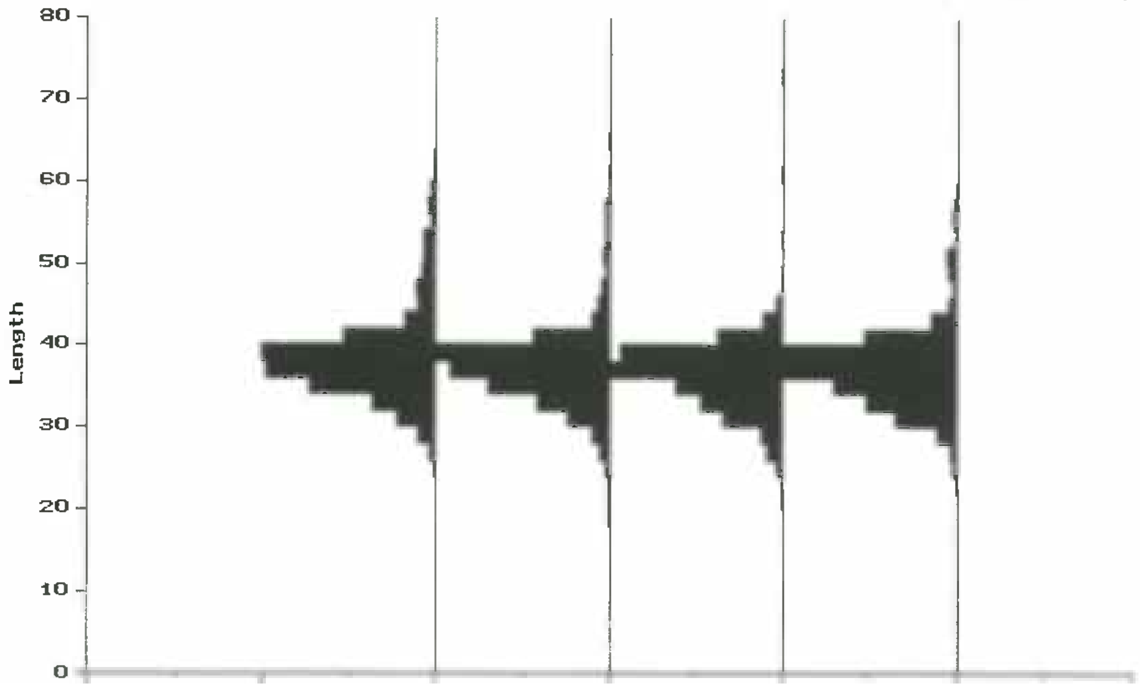


Figure A.7.13 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for electric reels in 1991, 1992, 1993, and 1994 respectively.

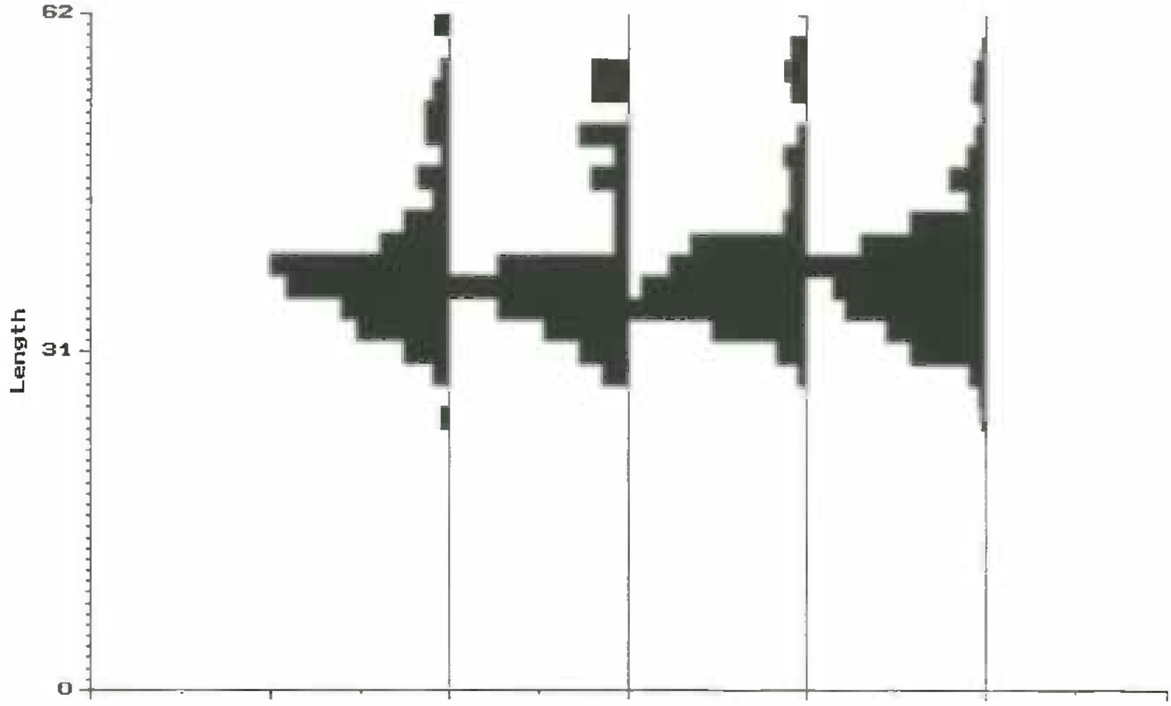


Figure A.7.14 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for gill nets in 1991, 1992, 1993, and 1994 respectively.

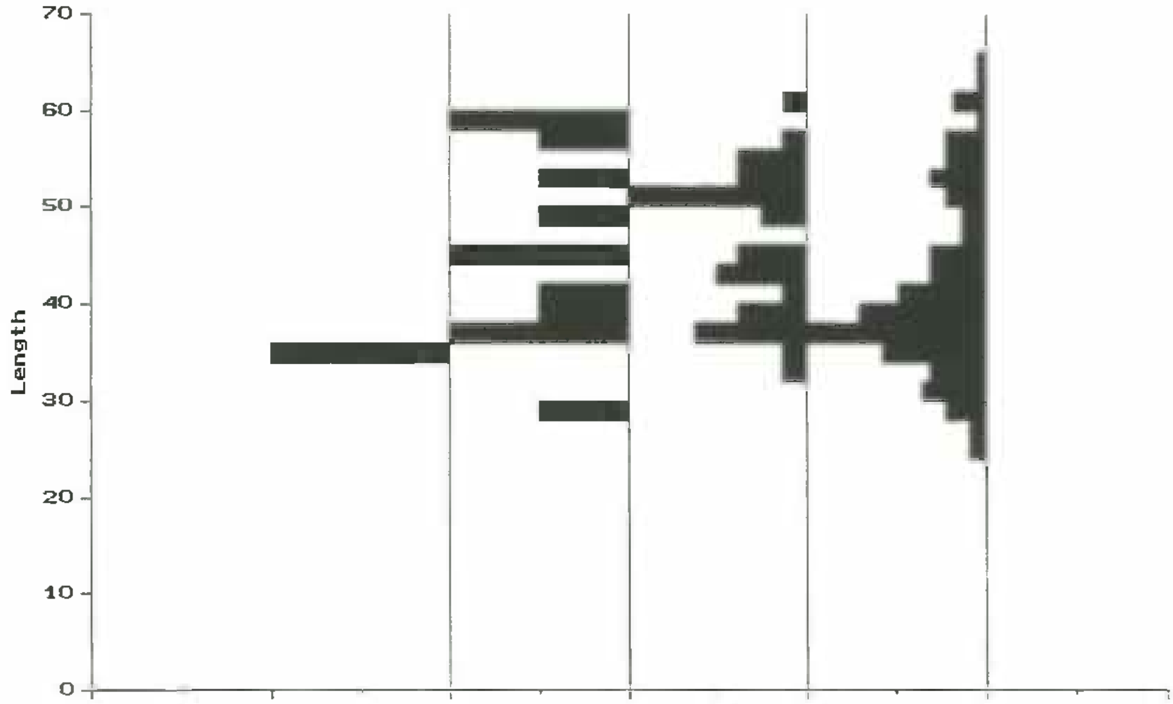


Figure A.7.15 : Mahe Plateau only - *Epinephelus chlorostigma* length frequency distribution observed for traps in 1993, and 1994 respectively.

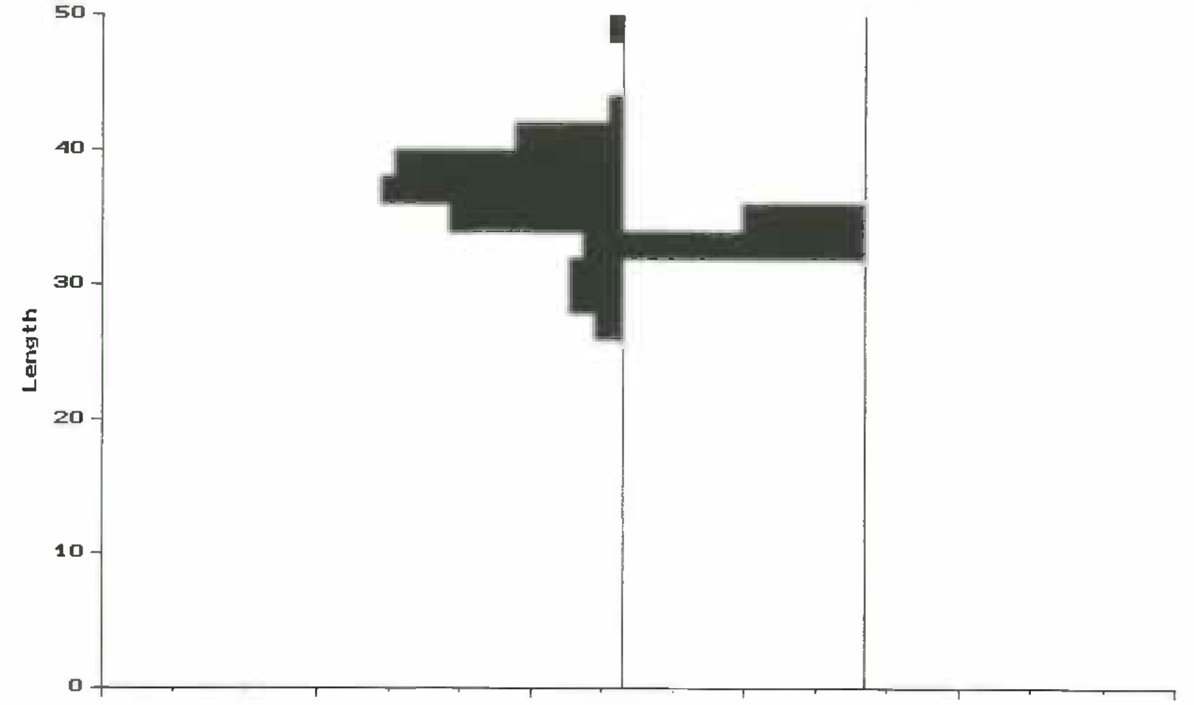


Figure A.7.16 : Mahe Plateau only - *Pristipomoides filamentosus* length frequency distribution observed for all gear types in 1990, 1991, 1992, 1993, and 1994 respectively.

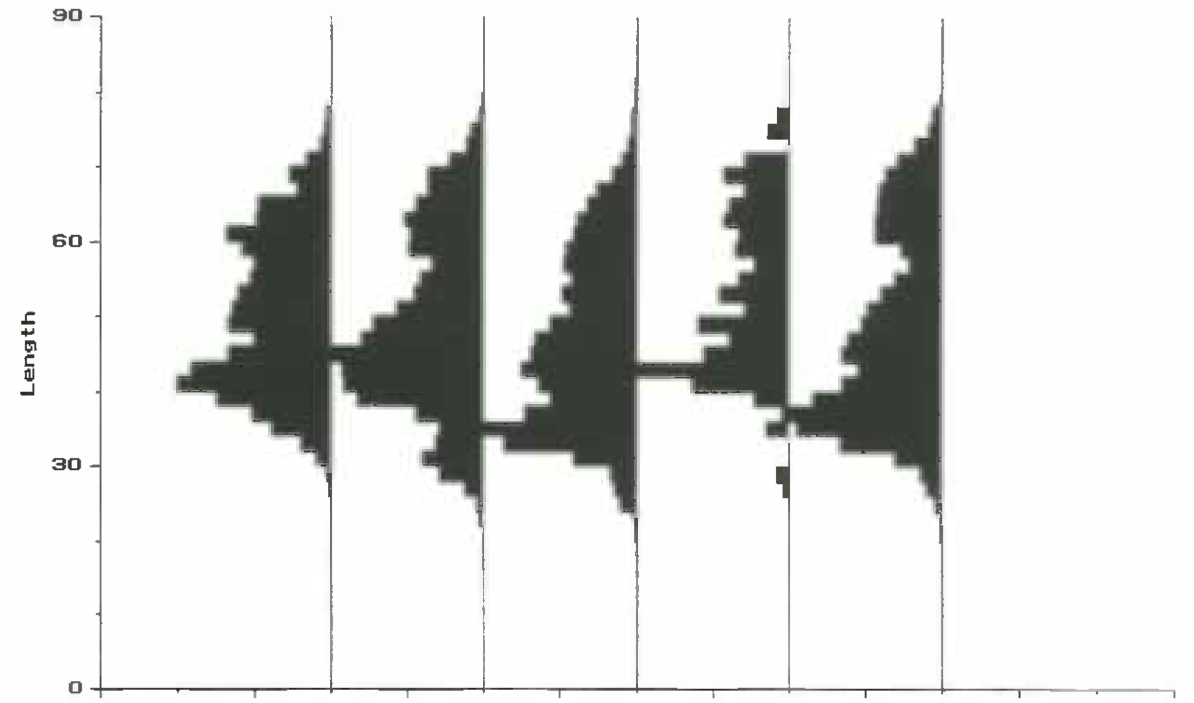


Figure A.7.17 : Mahe Plateau only - *Pristipomoides filamentosus* length frequency distribution observed for all handlines in 1990, 1991, 1992, 1993, and 1994 respectively.

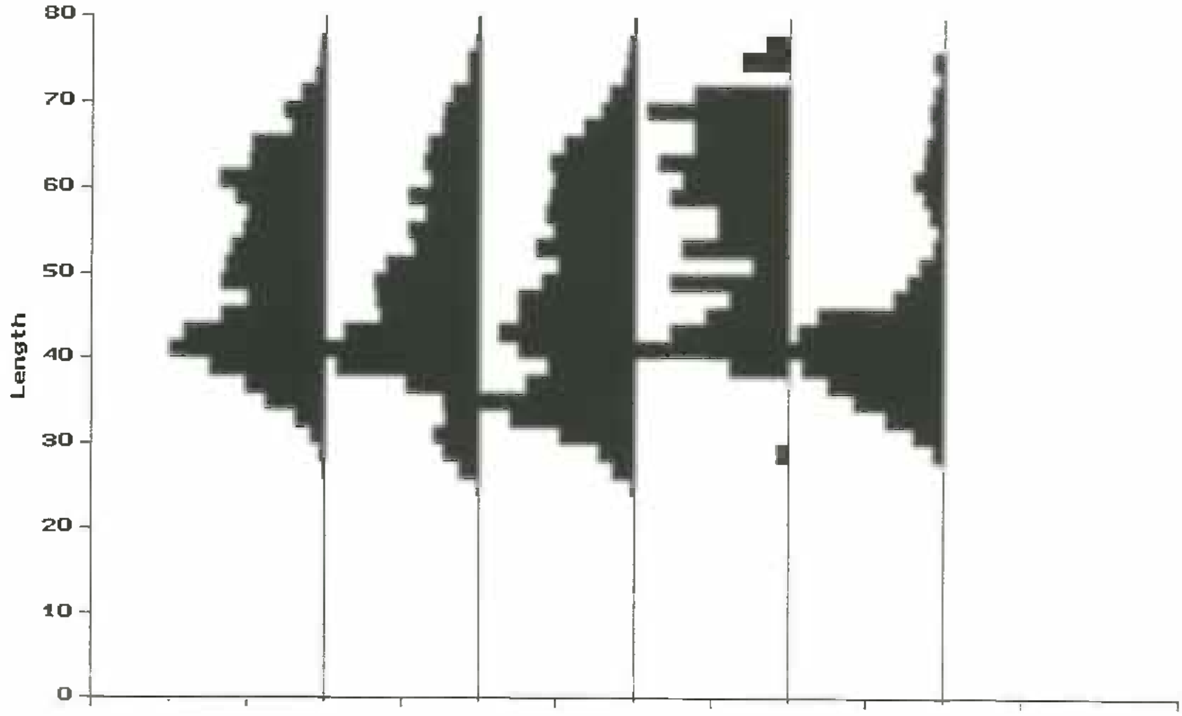


Figure A.7.18 : Mahe Plateau only - *Pristipomoides filamentosus* length frequency distribution observed for electric reels in 1992, 1993, and 1994 respectively.

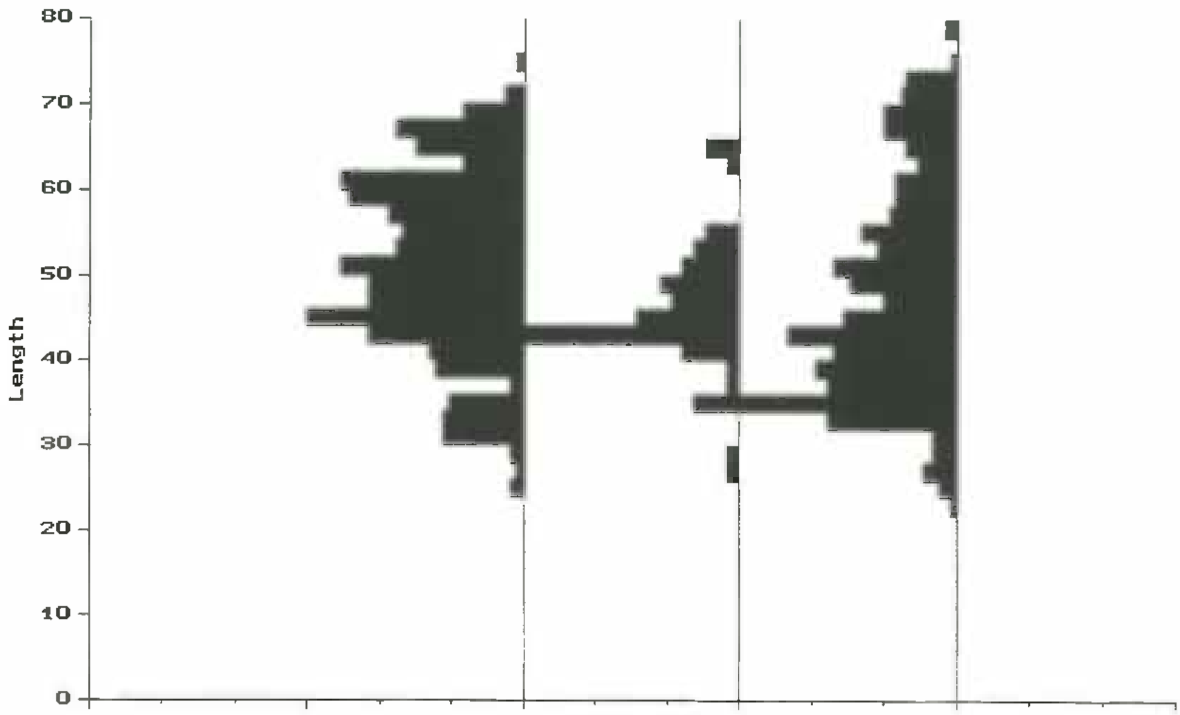


Figure A.7.19 : Mahe Plateau only - *Pristipomoides filamentosus* length frequency distribution observed for drop lines in 1991, 1992, and 1994 respectively.

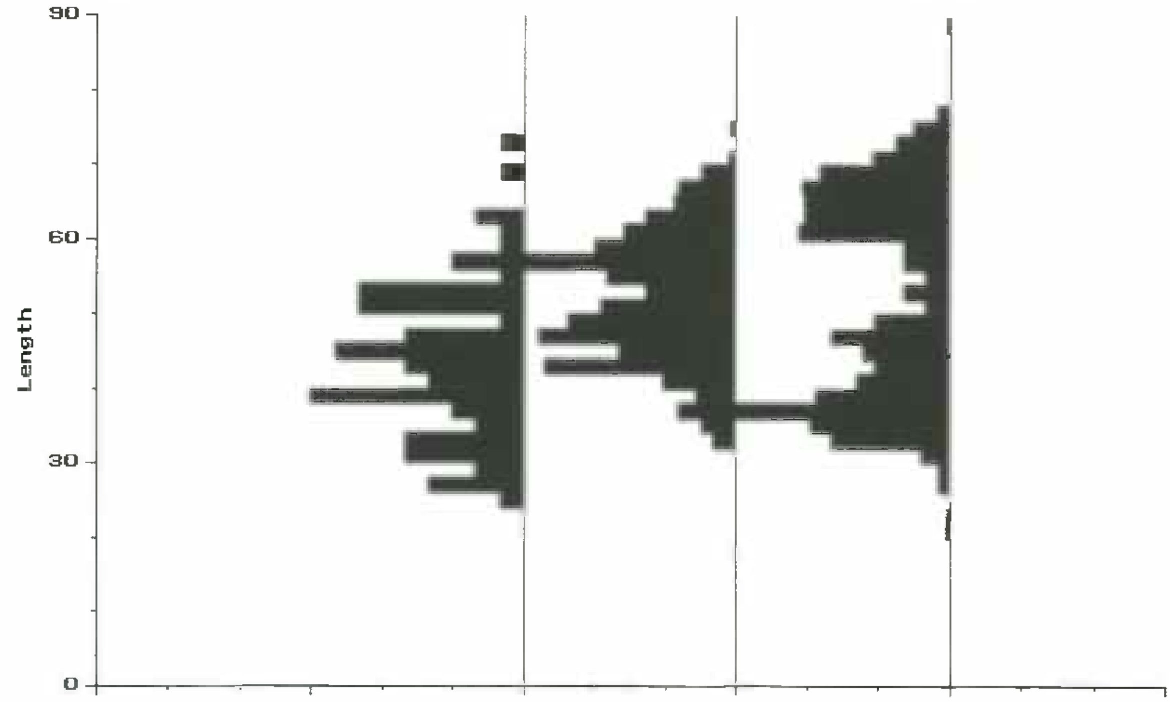
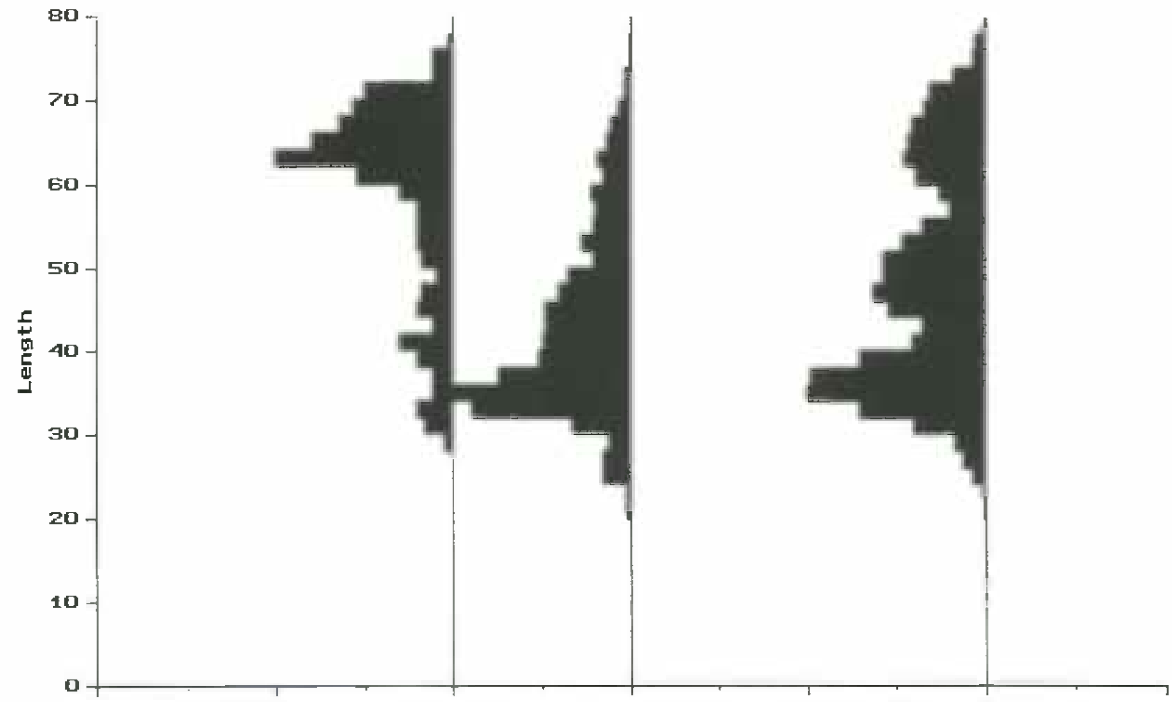


Figure A.7.20 : Mahe Plateau only - *Pristipomoides filamentosus* length frequency distribution observed for gill nets 1991, 1992, and 1994 respectively.



ANNEX 8 : Reproductive Biology.

Fish measured during biometric studies were employed for assessment of reproductive biology. Although sex and maturity stage was recorded from incompletely gutted fish during length frequency measurements, these data were not employed except in the case of *L. sebae* for which no biometric data was available. Maturity was assessed on a scale of 1-5 for females, described in Mees (1992b). Fish at stages 3+, 4 and 5 were mature. A gonadosomatic index (GSI, gonad weight in grammes / total fish weight in kg) was determined for both sexes.

Summary analyses indicating size (fork length, cm) at maturity stage each year are given in Tables A.8.1-A.8.4 for *P. filamentosus, A. virescens, L. nebulosus* and *L. sebae* respectively, aggregated over gear and location. Gear type, although in theory capable of affecting sex ratio (eg. traps may catch more dominant males / ovigerous females?) was not considered likely to affect the results in relation to reproductive development. Similarly, location within Seychelles would have minimal effect on the timing of reproductive events. Annex 7 indicates the small amount of biometric data by gear and location for each species.

To examine the incidence of reproductive events over time and in relation to fork length, data were additionally aggregated annually. This increased the sample size, and 'averaged' slight annual variations. Since the samples derived from lightly fished locations, fishing pressure over time was unlikely to significantly affect parameters such as size at sexual maturity or the timing of life cycle events. Results are indicated in Figures A.8.1 - A.8.15. Despite aggregating annual data, the number of fish sampled at any one fork length was small (Tables A.8.5-A.8.7) and in the case of *A. virescens* a moving average was employed to smooth out erratic jumps in the data.

TABLE A.8.1. : *P. filamentosus* females maturity stage analyses, data aggregated for all locations and gear types : biometric study data. Descriptive statistics by maturity stage per annum (stages 1 to 3- are immature/unripe, 3+ the gonads are ripe, 4 ripe and running, 5 spawned, see Mees, 1992b)

NUMBER

YEAR	1	2	3	-3	3+	4	5	TOT
89	0	0	0	0	4	15	0	19
90	0	219	2	47	137	165	0	570
91	2	182	0	24	41	20	1	270
	2	401	2	71	182	200	1	859

MIN LENGTH

YEAR	1	2	3	-3	3+	4	5	TOT
89	0.00	0.00	0.00	0.00	46.30	40.30	0.00	40.30
90	0.00	30.10	45.40	37.30	36.60	38.10	0.00	30.10
91	30.80	22.50	0.00	48.20	46.40	44.10	62.00	22.50
	30.80	22.50	45.40	37.30	36.60	38.10	62.00	22.50

MEAN LENGTH

YEAR	1	2	3	-3	3+	4	5	TOT
89	0.00	0.00	0.00	0.00	47.58	47.55	0.00	47.55
90	0.00	44.81	46.00	55.70	55.11	58.20	0.00	52.06
91	31.00	43.10	0.00	59.93	60.87	61.73	62.00	48.65
	31.00	44.03	46.00	57.13	56.24	57.75	62.00	50.89

MAX LENGTH

YEAR	1	2	3	-3	3+	4	5	TOT
89	0.00	0.00	0.00	0.00	48.90	51.50	0.00	51.50
90	0.00	64.60	46.60	68.10	72.60	73.10	0.00	73.10
91	31.20	69.60	0.00	69.50	68.60	68.00	62.00	69.60
	31.20	69.60	46.60	69.50	72.60	73.10	62.00	73.10

Figure A.8.1 Female *P. filamentosus* maturity stage at fork length, all biometric study data 1989 -1991.

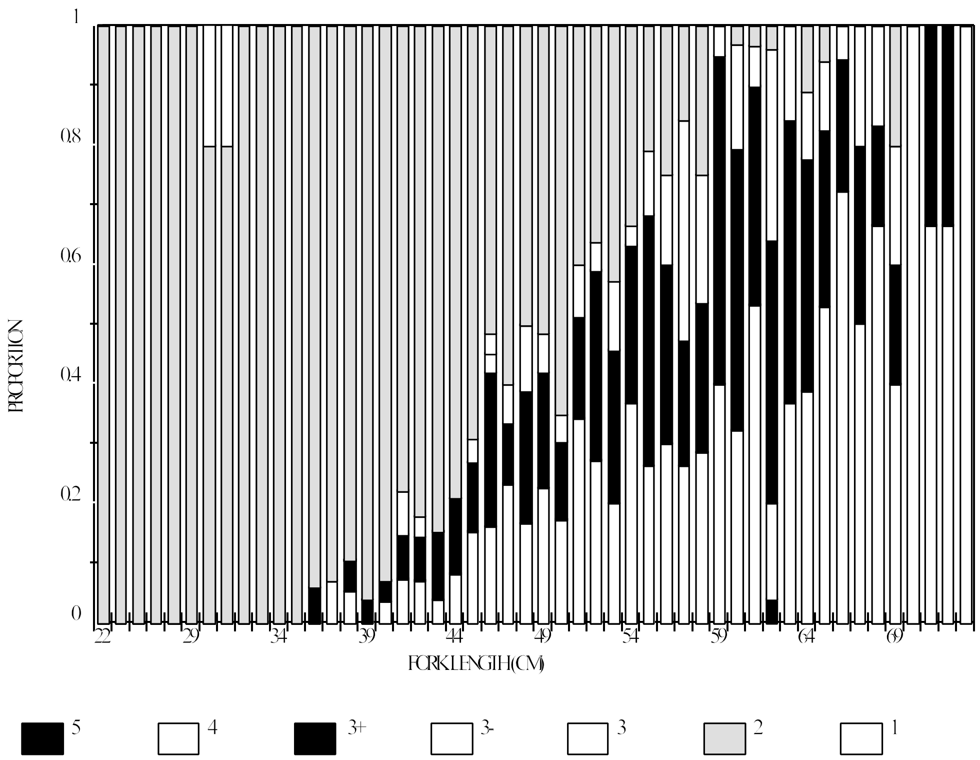


Figure A.8.2. *P. filamentosus* mean GSI at fork length, all data.

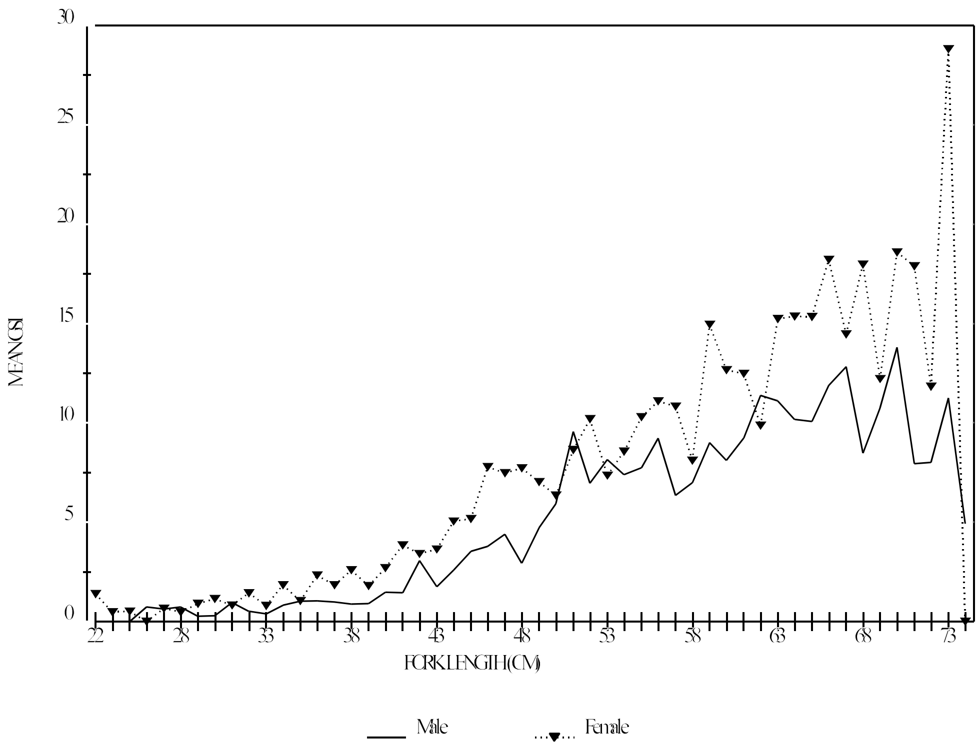
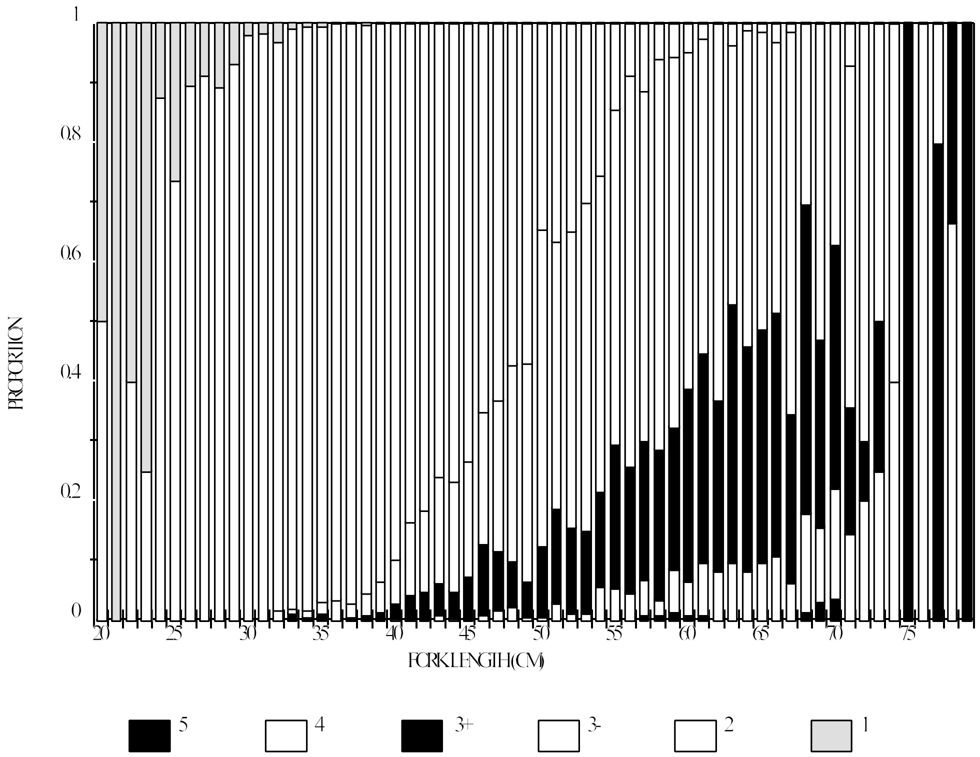


Figure A.8.3. Female *P. filamentosus* maturity stage at fork length, all length frequency study data 1989 -1991.



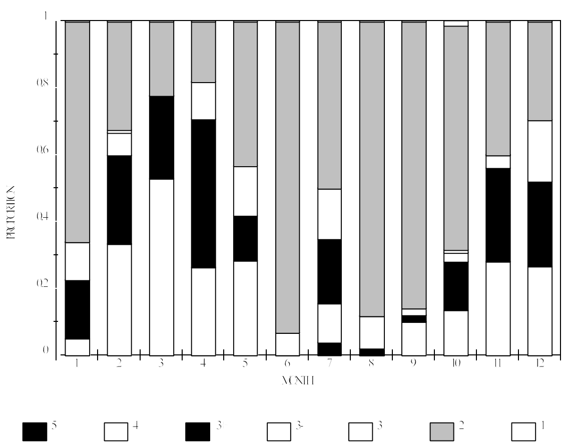


Figure A.8.4 *P. filamentosus*, proportion at maturity stage each month

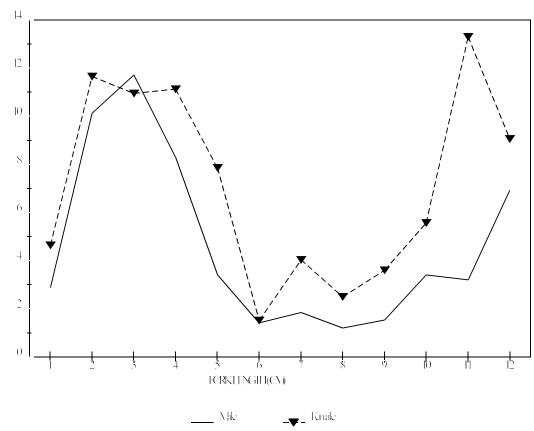


Figure A.8.5 *P. filamentosus*, mean GSI each month

TABLE A.8.2 Female *A. virescens* maturity stage analyses, data aggregated for all locations and gear types : biometric study data. Descriptive statistics by maturity stage per annum

NUMBER

YEAR	2	3-	3+	4	5	TOT
91	64	60	35	25	17	201
92	63	25	71	4	1	164
93	28	5	0	1	0	34
TOTAL	155	90	106	30	18	399

MIN LENGTH

YEAR	2	3-	3+	4	5	TOT
91	35.50	52.00	51.00	64.00	63.30	35.50
92	37.30	50.20	38.00	42.40	72.10	37.30
93	27.00	57.90	0.00	54.90	0.00	27.00
TOTAL	27.00	50.20	38.00	42.40	63.30	27.00

MEAN LENGTH

YEAR	2	3-	3+	4	5	TOT
91	51.12	69.99	70.17	73.98	71.42	64.63
92	53.08	69.08	64.22	60.43	72.10	60.64
93	33.55	74.20	0.00	54.90	0.00	40.16
TOTAL	48.74	69.97	66.18	71.53	71.46	60.90

MAX LENGTH

YEAR	2	3-	3+	4	5	TOT
91	67.30	83.80	86.10	86.90	82.40	86.90
92	65.40	85.20	86.10	79.70	72.10	86.10
93	49.00	87.80	0.00	54.90	0.00	87.80
TOTAL	67.30	87.80	86.10	86.90	82.40	87.80

Fig. A.8.6. Female *A. virescens* proportion at maturity stage at fork length, all biometric study data 1991-1993 (Moving average proportion).

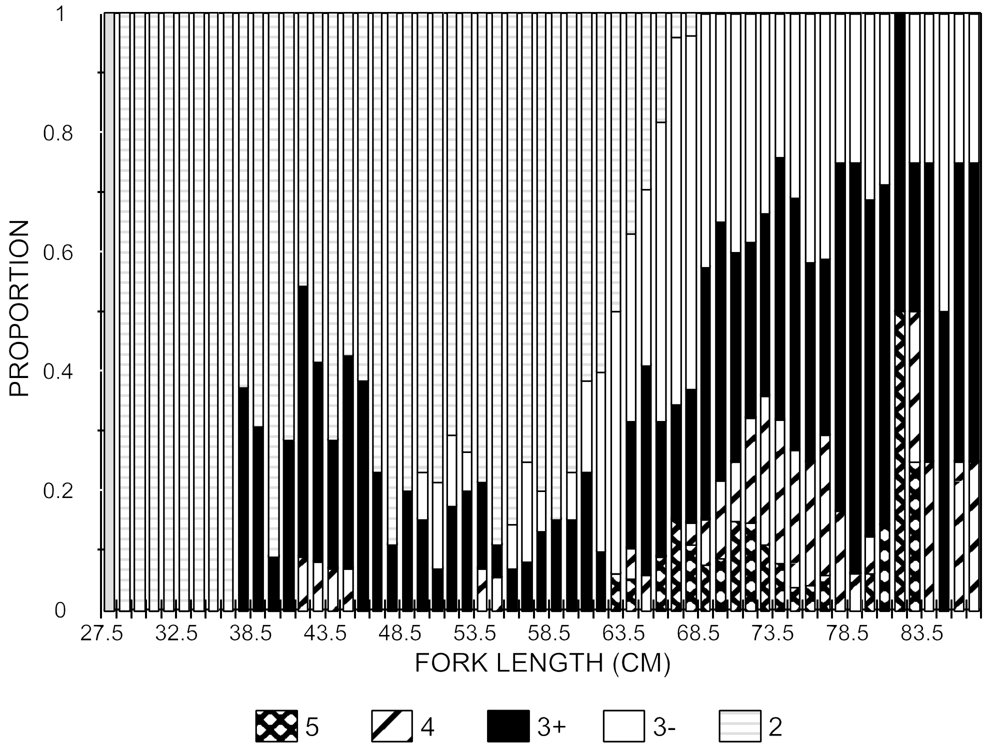


Fig. A.8.7. *A. virescens* mean GSI at fork length, all biometric study data 1989 -1991.

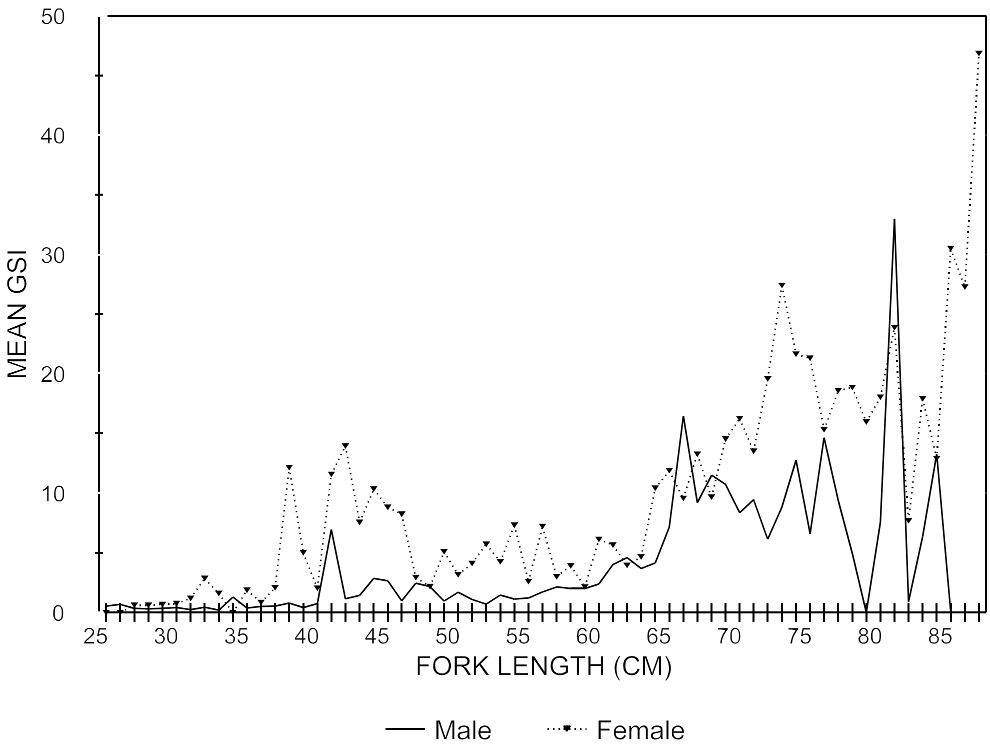
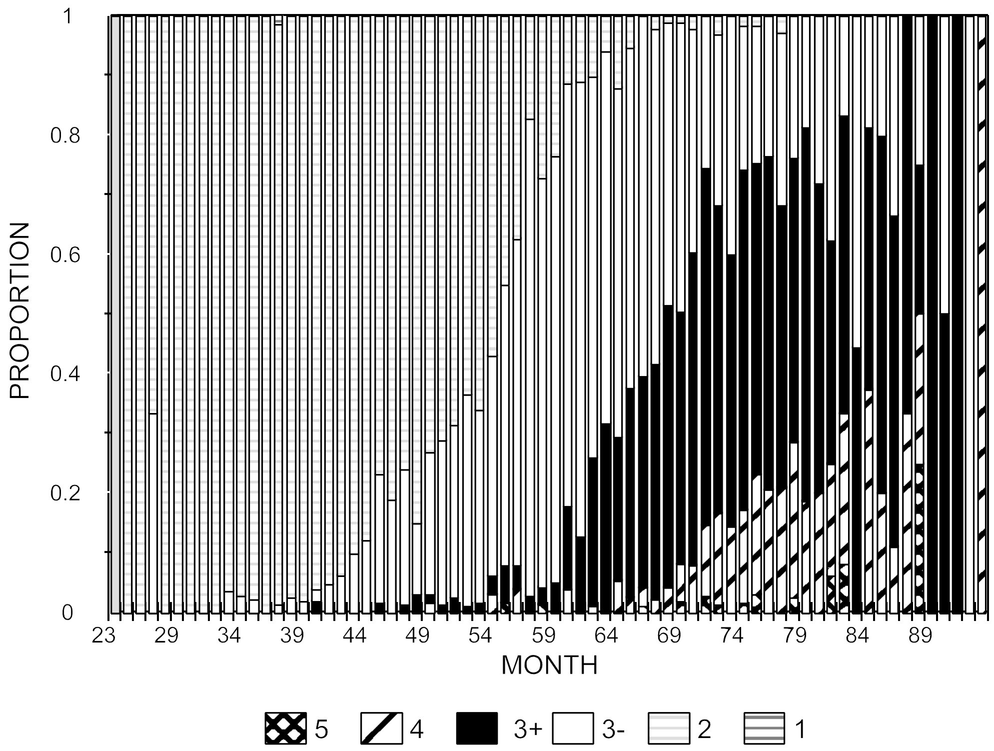


Fig. A.8.8.Female *A. virescens* maturity stage at fork length, all length frequency study data 1989 -1991.



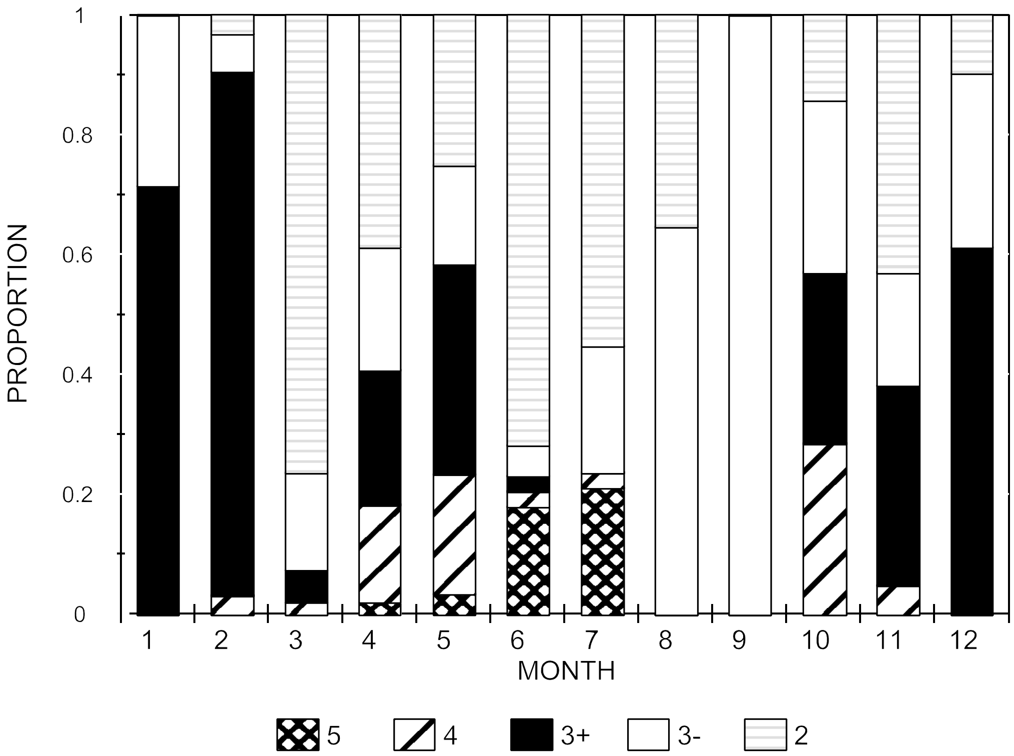


Fig. A.8.9. *A. virescens* proportion at maturity stage each month.

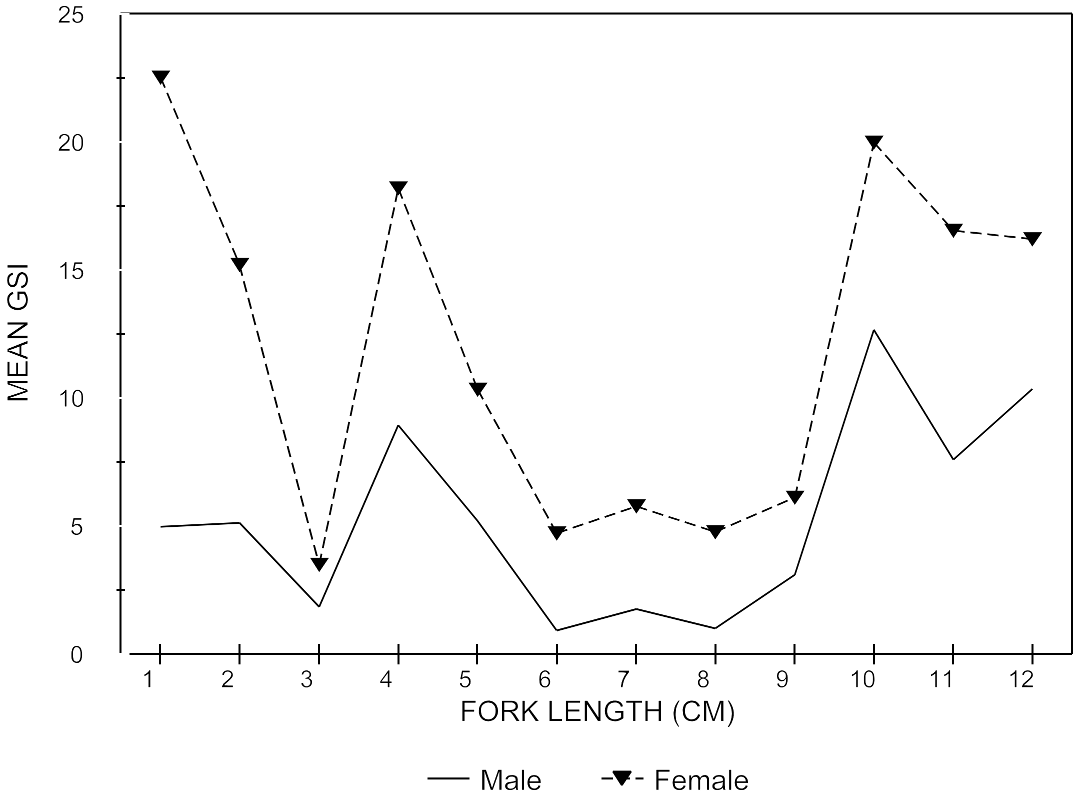


Fig. A.8.10 *A. virescens*, mean GSI each month

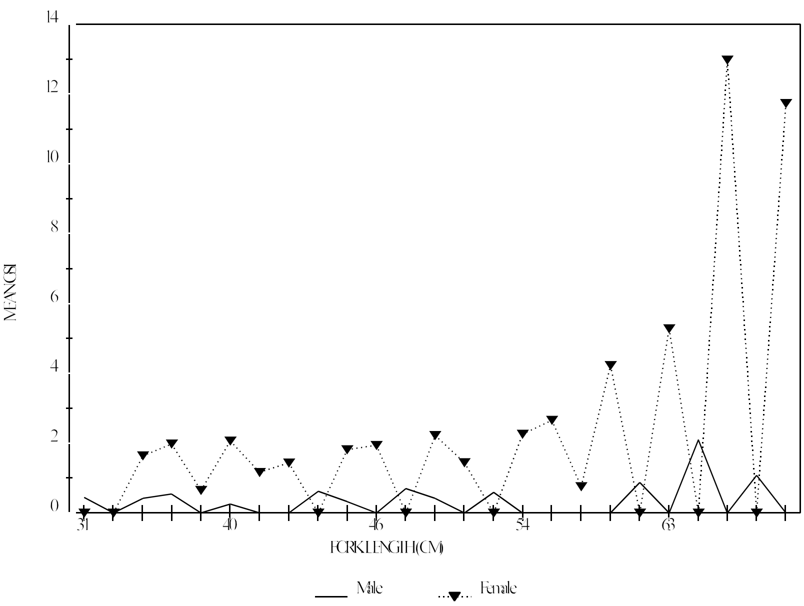


Fig. A.8.11 : *L. nebulosus* mean GSI at fork length, all biometric study data (April 1992 only).

TABLE A.8.3. : Female *L. nebulosus* maturity stage analyses, data aggregated for all locations and gear types : biometric study data. Descriptive statistics by maturity stage per annum

DETAILS	YEAR	2	3-	3+	TOT
NUMBER	92	25	1	2	28
MIN FL	92	37.50	63.50	69.30	37.50
MEAN FL	92	47.15	63.50	71.50	49.48
MAX FL	92	61.60	63.50	73.70	73.70

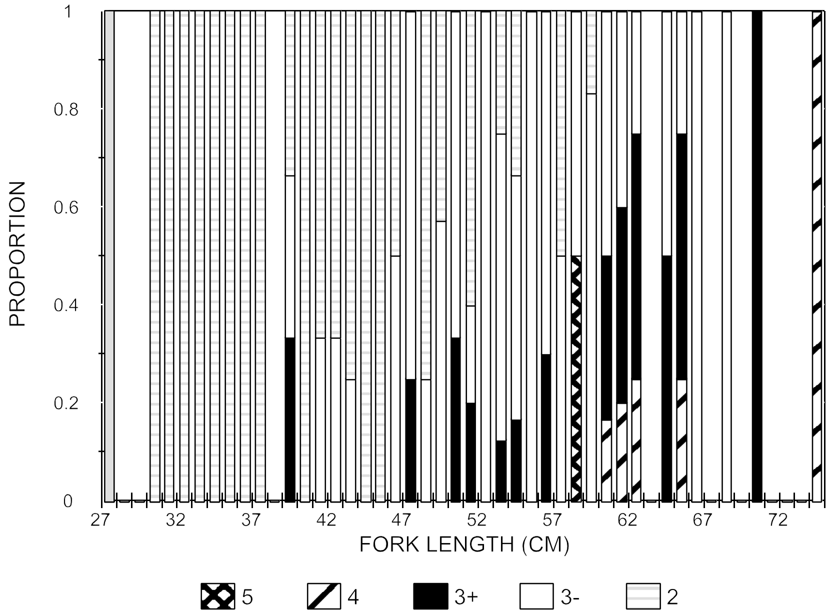


Fig A.8.12 *L. nebulosus* proportion at maturity stage at fork length, all length frequency study data

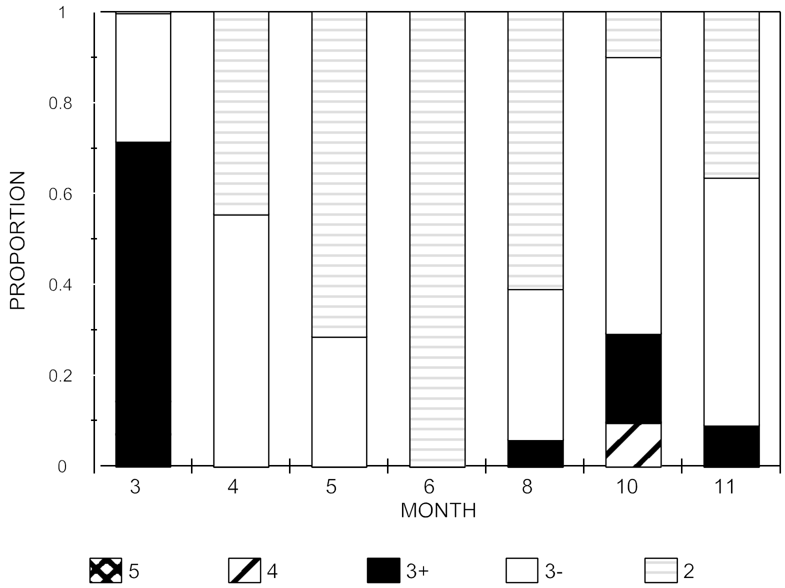


Fig A.8.13. *L. nebulosus*, proportion at maturity stage each month, all length frequency data

TABLE A.8.4 : *L. sebae* maturity stage analyses, data aggregated for all locations and gear types : length frequency data. Descriptive statistics by maturity stage per annum

NUMBER								
YEAR	1	2	3	3-	3+	4	5	TOT
89	0	66	52	70	68	31	3	290
90	0	780	37	519	269	35	0	1640
91	2	977	1	1117	516	110	1	2724
92	2	658	1	857	406	55	0	1979
93	1	146	0	578	142	15	0	882
TOTAL	5	2627	91	3141	1401	246	4	7515
MIN LENGTH								
YEAR	1	2	3	3-	3+	4	5	TOT
89	0.00	23.70	37.80	46.00	51.40	51.20	63.80	23.70
90	0.00	19.50	37.00	33.10	34.60	51.20	0.00	19.50
91	27.20	15.40	61.60	31.00	47.80	48.50	66.40	15.40
92	25.30	21.50	59.50	33.20	33.50	51.30	0.00	21.50
93	26.20	23.70	0.00	32.20	51.00	58.90	0.00	23.70
TOTAL	25.30	15.40	37.00	31.00	33.50	48.50	63.80	15.40
MEAN LENGTH								
YEAR	1	2	3	3-	3+	4	5	TOT
89	0.00	40.97	58.45	57.65	61.61	63.02	66.43	55.59
90	0.00	38.31	57.51	58.45	63.57	63.31	0.00	49.79
91	40.10	38.89	61.60	59.07	63.46	64.18	66.40	52.86
92	26.40	38.41	59.50	57.88	61.66	64.16	0.00	52.32
93	26.20	40.81	0.00	58.56	62.64	63.41	0.00	56.33
TOTAL	31.84	38.76	58.11	58.52	62.78	63.86	66.43	52.56
MAX LENGTH								
YEAR	1	2	3	3-	3+	4	5	TOT
89	0.00	59.80	77.00	66.30	70.00	69.80	68.20	77.00
90	0.00	61.90	69.30	74.40	78.20	74.00	0.00	78.20
91	53.00	75.20	61.60	78.20	78.50	77.50	66.40	78.50
92	27.50	68.50	59.50	80.20	77.00	81.60	0.00	81.60
93	26.20	75.00	0.00	73.20	72.80	66.50	0.00	75.00
TOTAL	53.00	75.20	77.00	80.20	78.50	81.60	68.20	81.60

Figure A.8.14. Female *L. sebae*, proportion at maturity stage at fork length, all length frequency study data.

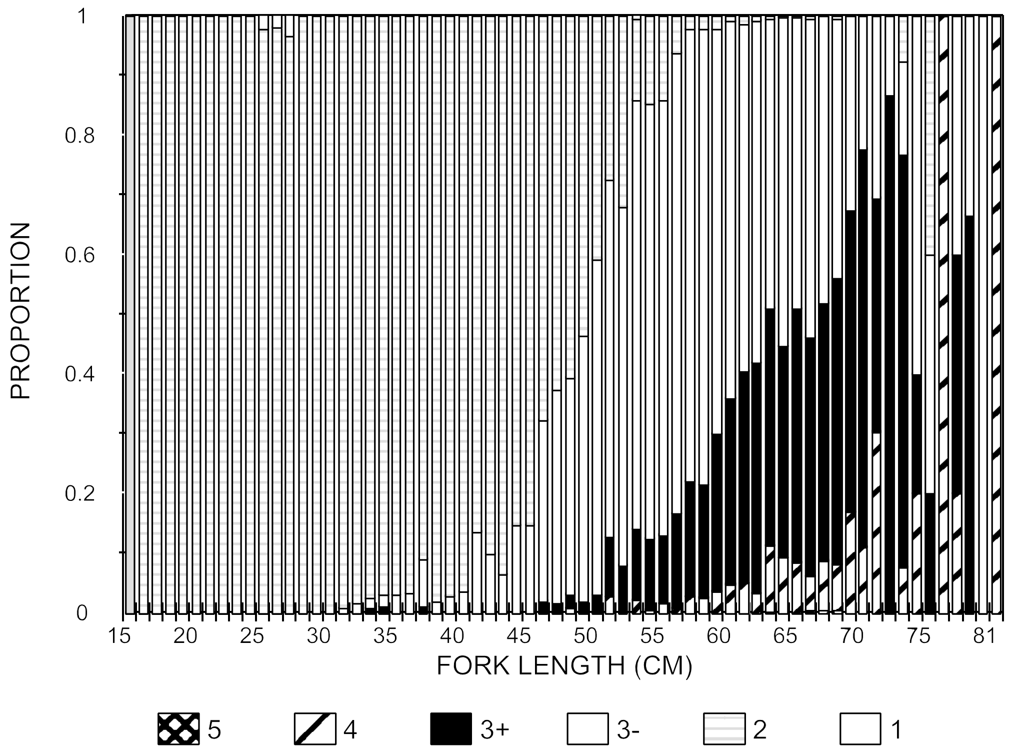


Figure A.8.15. Female *L. sebae*, proportion at maturity stage each month, all length frequency study data.

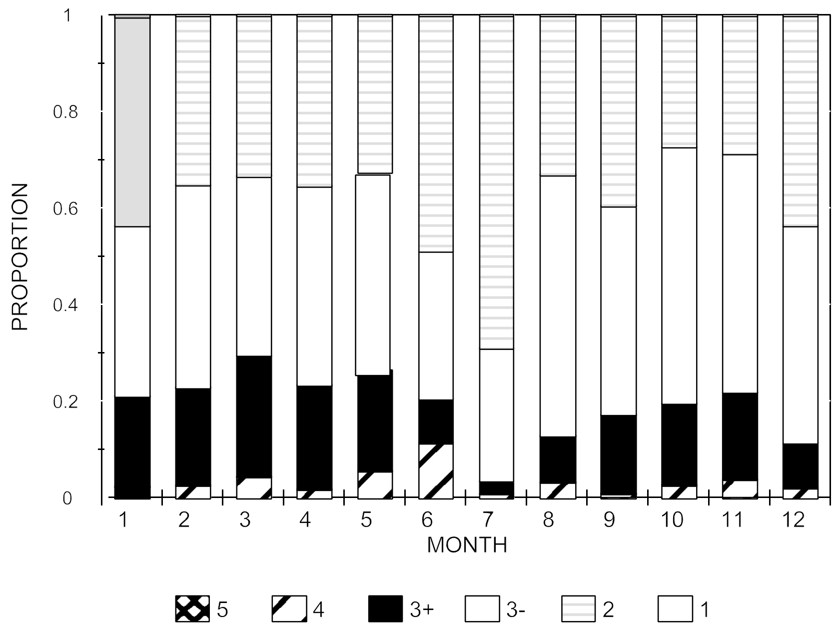


Table A.8.5 The number of female fish sampled at length during biometric studies : *P. filamentosus*

FL	N	FL	N	FL	N	FL	N	FL	N
22	1	34	6	44	24	54	30	64	18
24	1	35	4	45	26	55	19	65	17
25	3	36	17	46	31	56	20	66	18
27	2	37	14	47	30	57	19	67	10
28	1	38	19	48	36	58	28	68	12
29	5	39	26	49	31	59	20	69	5
30	5	40	28	50	23	60	34	70	3
31	5	41	27	51	35	61	30	71	3
32	6	42	28	52	22	62	25	72	3
33	8	43	26	53	35	63	19	73	1

Table A.8.6 The number of female fish sampled at length during biometric studies : *A. virescens*

FL	N	FL	N	FL	N	FL	N	FL	N	FL	N
27	1	38	4	48	3	58	7	68	13	78	6
28	3	39	9	49	7	59	6	69	13	79	10
29	4	40	2	50	6	60	7	70	10	80	6
30	2	41	5	51	8	61	6	71	10	81	1
31	5	42	6	52	9	62	4	72	24	82	1
32	4	43	6	53	6	63	12	73	12	83	3
33	2	44	8	54	8	64	7	74	13	84	1
35	2	45	6	55	10	65	10	75	13	85	1
36	1	46	7	56	4	66	12	76	11	86	3
37	4	47	6	57	8	67	14	77	6	87	1

Table A.8.7 The number of female fish sampled at length during biometric studies : *L. nebulosus*

FL	N	FL	N
37	2	51	2
38	3	54	1
39	1	55	3
40	1	59	1
41	1	61	2
42	3	63	1
45	1	69	1
46	2	73	1
48	2		

Annex 9 : Gear Selectivity : Probability of capture

To investigate the probability of capture at length for each species by fishing gear, length frequency data (see Table 12; Annex 7 for sample size) were aggregated by location. Annual length frequency distributions for *P. filamentosus*, *A. virescens*, *L. sebae*, and *E. chlorostigma* from sectors 2-10 of the Mahe Plateau aggregated by gear type are illustrated (Annex 7, Figs A.7.1-A.7.20) Similar series of data were also generated for data aggregated over all locations for this analysis (not shown). Additionally a small amount of data was collected for *L. nebulosus* (Figs A.9.1-A.9.3), *L. variegatus* (Fig. A.9.4) and *A. rutilans* (Fig. A.9.5) by gear type. For specified gear types for each species, inter-annual length frequency distributions are similar except for:

- *P. filamentosus* and handlines (Fig A.7.17). 1993 data suggests a larger size of fish were caught that year, but sample size was small (230) compared to previous years (>3,000 fish). The mode in 1992 for fish caught on the Mahe Plateau was smaller than other years but this was not the case for data aggregated over all locations

- *P. filamentosus* and gill nets (Fig A.7.20) : 1991 and 1992 data (for each of which sample size was large) indicate different distributions. The major mode in 1991 was around 62 cm compared to 34 cm in 1992, suggesting different mesh sizes were employed each year. In 1994 the distribution was similar to 1992. Unfortunately this information was not recorded with length frequency data, and suggests that this refinement should be added to data collection procedures.

- *L. sebae* and gill nets (not shown) : 1992 data indicate a smaller size of fish were caught than in 1993. However, sample size was small in both cases and sampled fish were caught outside the Mahe Plateau.

- *A. virescens* and both handlines and gill nets (Figs. A.7.3 and A.7.28) indicated a smaller mode in 1994 than previous years suggesting a recruitment of smaller fish that year

For *E. chlorostigma* (Figs A.7.10-A.7.15) within gear types inter-annual variation in the size of fish caught was not observed but different gear caught different sizes of fish. Lines and traps selected for small fish, and above 42 cm (total length) and 40 cm respectively few larger fish were caught. By contrast, gill nets display a more evenly spread length frequency distribution although the major mode was around 34-36 cm.

In order to determine the length at first capture, gear specific selection parameters were derived from length frequency data using probability of capture at length information derived through catch curve analysis (Gayanillo *et al*., 1994). A moving average was used :

$$P_{L,i(new)} = (P_{L,i-1} + P_{L,i(old)} + P_{L,i+1}) / 3$$

where P_L is the probability of capture for length L, a smoothed series of probabilities is produced from which Lc_{25} (probability of 25 % of all fish at that length being caught), Lc_{50} and Lc_{75} are estimated through linear interpolation. Lc, the first fully exploited length class was taken as the cut off point of the catch curve analysis (see Table 15). As inputs, catch curve analysis requires estimates of growth parameters, and these were taken from the literature : *P. filamentosus* (Mees, 1993), *A. virescens* (Mees, 1992b), *L. sebae* (Lablache and Carrara, 1988), *E. chlorostigma* (Mees, 1992b), *L. nebulosus* (Carpenter and Allen, 1989, for Fiji, chosen because the $L\infty$ parameter estimate was closest to Lmax observed for this species in Seychelles), *L. variegatus* (Loubens, 1980, for New Caledonia) and *A. rutilans* (Ralston and Williams,1988, for N. Marianas). For the last two species no other estimates of growth parameters were available and so whilst the value of K given in the literature was used, a value of $L\infty$ close to Lmax was selected since this affects the estimate of the selectivity parameters (below).

Owing to the uncertainty inherent in estimation of growth parameters through length frequency analysis from long lived slow growing species such as these (5.2.4; Annex 10), the sensitivity of Lc_{50} to changes in these parameters was tested (Figs. A.9.6-A.9.7). Changes in K had little effect on Lc_{50}. For values of $L\infty$ below Lmax, Lc_{50} tended to be underestimated, but Lc_{50} was insensitive to changes in $L\infty$ when this parameter was around, or greater than Lmax. This suggests that providing the value of $L\infty$ used is close to Lmax, we may be confident in the value of Lc_{50} derived, providing that the sample size was sufficiently large.

L. nebulosus : Length frequency distributions by gear type for 1992.

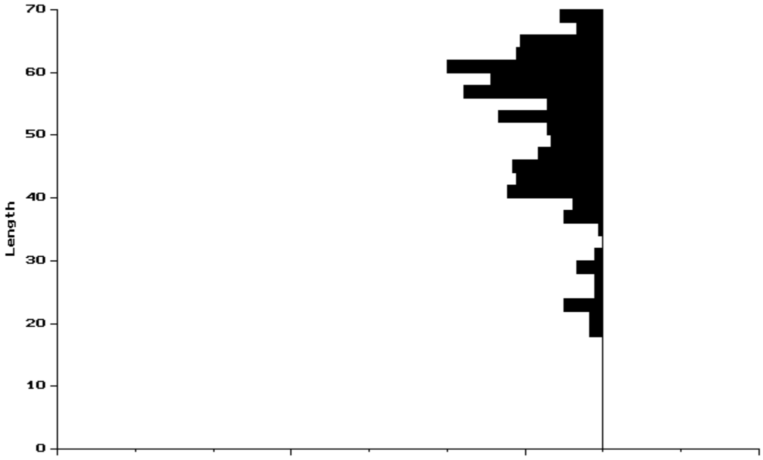


Figure A.9.1 : Un- specified gear type.

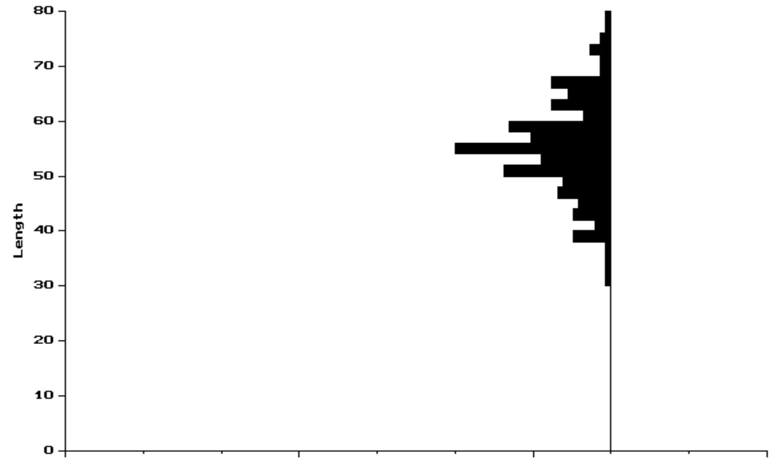


Figure A.9.2. : Hand lines.

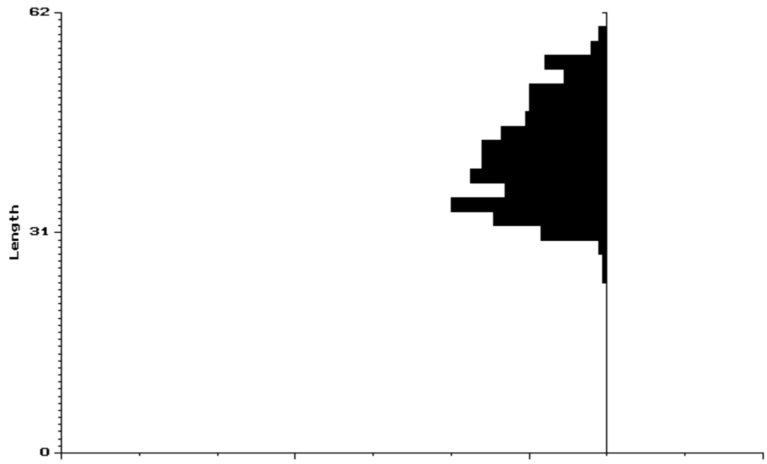


Figure A.9.3. : Gill nets.

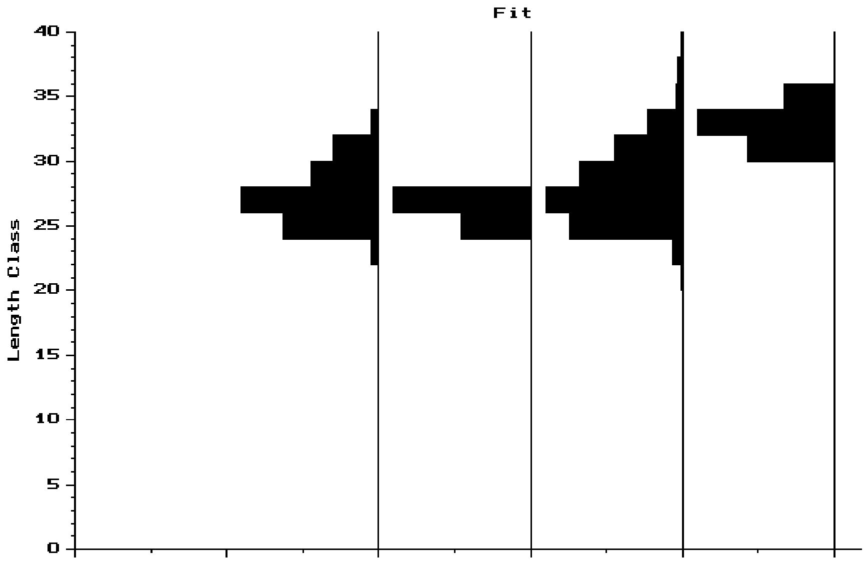


Figure A.9.4: *L.variegatus* length frequency distribut-ions by gear type in 1994. Unspecified gear; gill nets; hand lines; electric reels respectively.

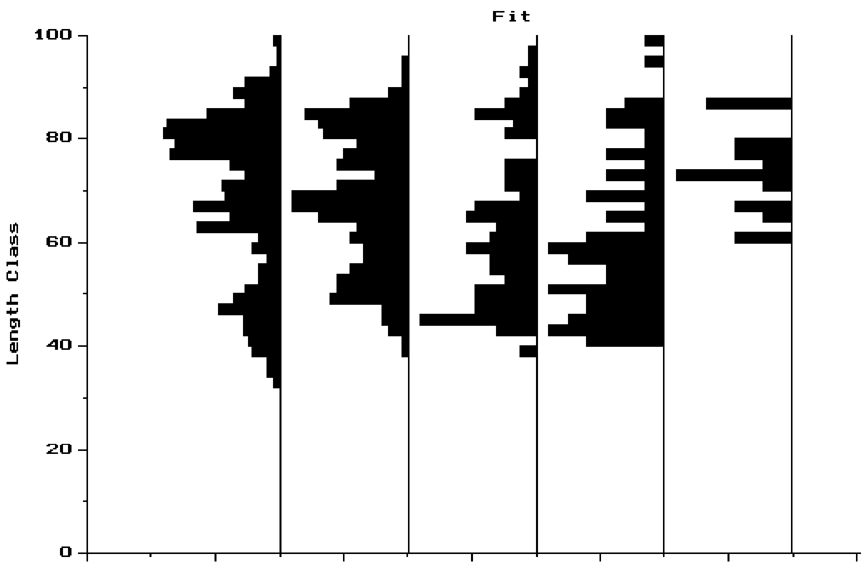


Figure A.9.5 : *A. rutilans* length frequency dist-ributions by gear type in 1994. Unspecified gear; drop lines; gill nets; hand lines; electric reels respectively.

Figures A.9.6 and A.9.7 : Sensitivity of the estimate of Lc_{50} to changes in growth parameter estimates used during catch curve analysis.

Fig A.9.6

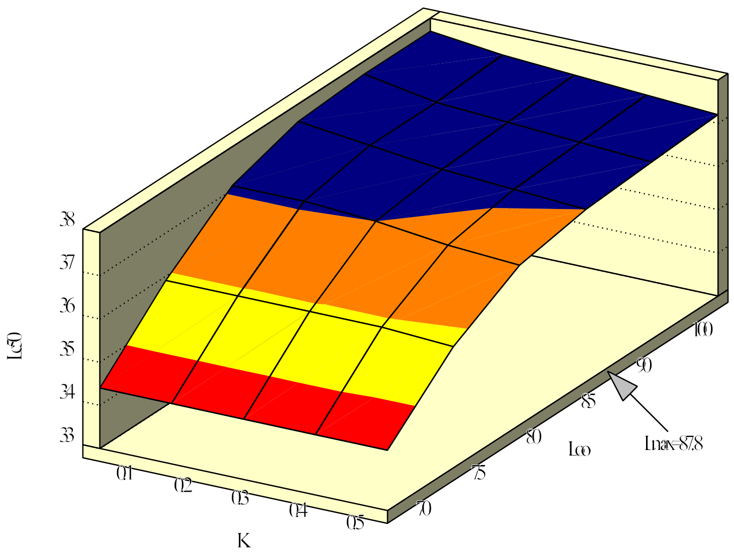
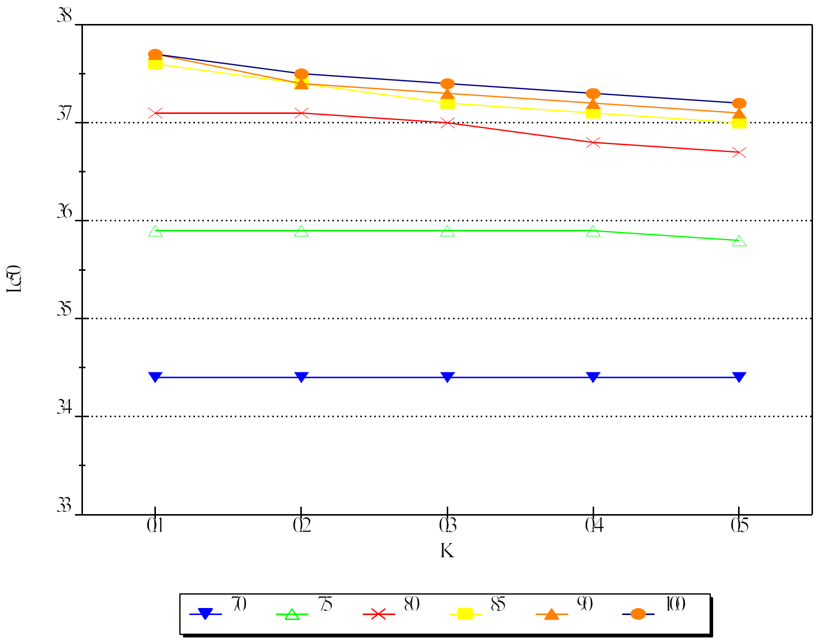


Fig A.9.7



Annex 10: Growth parameter estimates.

The von Bertalanffy growth parameters, L_∞ (the asymptotic maximum length), K (the growth rate) and t_0 (the theoretical time at which length is zero) were estimated from length frequency data for each of the key species using LFDA4 (MRAG,1995). This analytical tool allows non seasonal growth curves to be fitted to length frequency data using three methods : Sheppards Length Curve Analysis (Shepherd, 1987), a projection matrix method (Basson *et al*, 1988) and a version of the ELEFAN method (Pauly, 1987). Seasonal growth may be fitted for the latter two methods using either one of two methods :Hoenig and Choudry Hanumara (1982) to describe C (the relative amplitude of seasonal oscillations) and t_s (the phase of these oscillations, t_s+1/2 is referred to as the 'winter point'), or Pauly *et al* (1992) to describe additionally NGT (no growth period).

Typically these methods are most suited to short lived fast growing species. Shepherd *et al* (1987) described four types of length frequency distribution and their suitability for assessment using length based methods. In order to estimate growth it is necessary to have one or more modes which increase in length steadily with time. For long lived slow growing species such as snappers, groupers and emperors, length classes of the older fish frequently overlap, making modal separation difficult. Sampling biases and inadequacies may also affect the length frequency distribution observed. Nevertheless, in the absence of other means of assessing growth (eg. hard parts) length frequency data analysis may be applied to these species providing that analytical models are applied sensibly, and that the limitations of the outputs are understood.

Choice of data set

Hilborn and Walters (1992) stress the need for representative sampling in the analysis of length frequency data and warn that often this is not achieved when commercial catches are sampled. Problems include gear selectivity, size related changes in fish distribution, and inadequate sub-sampling of catches. By contrast Gulland and Rosenberg (1992) suggest that only by sampling different locations and times will statistically adequate data be collected fully representing the population in question. In this report, dis-aggregated data is employed to estimate growth parameters and it is only aggregated where justified. Full details of the procedure followed in the choice of data set are indicated for the example of *P. filamentosus*. These details are not shown for the other species. The following description of the procedure applies generally to each species.

From Annex 7 it is clear that most data exists for handlines for each species, whilst Annex 9 indicates that in general length at capture and length distribution is similar for all line fishing methods. Gillnets and traps tend to differ. Thus it is valid to aggregate all line fishing data in order to increase sample size. Next spatial and temporal variation was investigated by plotting monthly length frequency data by sector for handlines only and all line methods. Data for certain months and sectors were frequently scarce or lacking indicating a need to aggregate spatial data to obtain an adequate sample size. Whilst annually aggregated data suggested spatial differences in length frequency distribution within any year, these differences were not consistent over several years. The monthly plots failed to indicate consistent spatial differences. This indicated that it was valid to aggregate spatial data. For each species the following sub sets of data were analysed for estimation of growth parameters :

- All line fishing methods for sectors 2-10 (Mahe Plateau)
- All line fishing methods for individual fishing sectors where the sample size was sufficiently large
- Handlines only for sectors 2-10 (Mahe Plateau)
- Handlines only for individual fishing sectors where the sample size was sufficiently large

In each case the full data set (several years) was employed, except where large gaps in the data indicated that it would be more appropriate to examine a sub set. Monthly plots were studied for evidence of modal separation and progression of those modes with time indicating growth. The distributions were classified according to Shepherd *et al* (1987).

Length frequency data was available for *A. virescens, P. filamentosus, L. sebae,* and *E. chlorostigma*. That for *L. variegatus, L. nebulosus* and *A. rutilans* was inadequate for estimation of growth. Sample size by month and location per annum for fish sampled from the Mahe Plateau is indicated in Table A.10.1.

LFDA4 (MRAG, 1995) was employed to estimate growth parameters. The following general procedures were applied to each species, but full details are only shown for *P. filamentosus*. The LFDA user manual should be referred to for full details. In summary, the PC based computer package aids the user in the search for the best fitting growth curve to a time series of length frequency distributions. It is necessary to have some idea of the range of K and L∞ values about which to search. Low values of K are expected for the species studied, whilst L∞ should be set around Lmax. Alternatively, as a first step, the Powell-Wetherall method (Wetherall *et al*., 1987) may be applied to obtain an initial estimate of L∞. Having defined the parameters about which to search, a contour plot of the score function (ie, the goodness of fit of model to data) is generated. This should ideally be a banana shape indicating the range of K and L∞ values over which a reasonable fit may be achieved. Sometimes, however, more than one area of maxima may be indicated and it is necessary to investigate both/all of these. LFDA4 provides a maximisation routine based on the Amoeba simplex method in order to search for the highest score function (best fit) within a range of K and L∞ values defined after examination of the contour plot.

Initially, the non seasonal von Bertalanffy growth parameters are established by applying the above methodology to one of the three growth models provided (SLCA, PROJMAT, ELEFAN). Subsequently, if there is reason to believe that seasonal growth may occur, and the length frequency distributions warrant it, seasonal growth may be investigated. Alternatively, LFDA4 provides an auto-find option. At present, the package does not indicate confidence intervals about the point estimates of the growth parameters. The estimates provided are the best fit of model to data. However, common sense is required in their interpretation. Inappropriate values may in fact provide the highest score, and in judging goodness of fit a combination of : details of the score function, the plotted fit of the growth curve to the data, and experience are required.

Table A.10.1 Number of fish sampled from the Mahe Plateau (sectors 2-10) taken by handlines only

APRION VIRESCENS

MONTH	91	92	93	94	TOTAL
1	0	600	68	0	668
2	0	152	32	0	184
3	0	272	204	68	544
4	0	380	18	205	603
5	35	246	46	282	609
6	0	102	0	39	141
7	0	0	0	126	126
8	205	0	0	0	205
9	187	0	0	0	187
10	445	14	377	49	885
11	273	155	223	91	742
12	186	103	109	242	640
TOTAL	1331	2024	1077	1102	5534

PRISTIPOMOIDES FILAMENTOSUS

MONTH	90	91	92	93	94	TOTAL
1	0	0	605	0	0	605
2	49	0	269	0	0	318
3	342	0	199	0	120	661
4	409	0	269	0	450	1128
5	374	0	99	0	10	483
6	218	0	453	0	0	671
7	239	79	0	0	24	342
8	58	219	0	0	0	277
9	301	5	101	0	189	596
10	228	786	11	0	0	1025
11	120	447	0	147	0	714
12	121	60	65	0	0	246
TOTAL	2459	1596	2071	147	793	7066

LUTJANUS SEBAE

MONTH	90	91	92	93	94	TOTAL
1	0	173	358	33	32	596
2	0	202	675	39	18	934
3	0	386	971	192	99	1648
4	0	530	537	32	392	1491
5	0	484	242	146	98	970
6	0	242	6	0	0	248
7	198	0	0	0	0	198
8	122	238	0	0	0	360
9	116	510	0	0	0	626
10	385	628	51	0	268	1332
11	37	610	46	0	14	707
12	0	368	1	0	121	490
TOTAL	858	4371	2887	442	1042	9600

EPINEPHELUS CHLOROSTIGMA

	MONTH	91	92	93	94	TOTAL
	1	0	268	47	71	386
	2	0	414	65	83	562
3	0	619	159	123	901	
4	0	644	0	340	984	
	5	0	249	116	60	425
	6	0	129	0	0	129
	7	36	0	0	0	36
	8	276	0	0	0	276
	9	313	0	0	0	313
10	409	43	341	71	864	
	11	321	15	306	13	655
	12	354	75	0	58	487
TOTAL		1709	2456	1034	819	6 0 1 8

Table A.10.1 Continued.

LETHRINUS VARIEGATUS

MONTH	94	TOTAL
10	31	31
11	36	36
12	111	111
TOTAL	178	178

LETHRINUS NEBULOSUS

MONTH	92	TOTAL
4	38	38
5	20	20
6	4	4
11	6	6
12	3	3
TOTAL	71	71

APHARAEUS RUTILANS

MONTH	94	TOTAL
10	25	25
12	36	36
TOTAL	61	61

Pristipomoides filamentosus

Following the procedure outlined above, data for handline caught fish only were examined to determine spatial variation in length frequency distributions by comparison of annually aggregated data. Certain years suggested spatial differences (eg. 1990, Fig A.10.1), but these were inconsistent over several years (not shown). Monthly aggregated data was examined in order to test whether spatial differences were related to sampling time. This was done for handline caught fish only (Fig. A.10.2.a-j) and for those caught by all hook and line fishing methods (Fig A.10.3.a-j). No consistent spatial differences were observed with time for those sectors of the Mahe Plateau (Sectors 2-10). Figures A.10.2 and A.10.3 indicate the 'patchiness' of data spatially and temporally, and that in certain months sample sizes were small. Thus, whilst dis-aggregated data may be the ideal (ie. handlines only by sector), in practice to increase sample size, and based on these observations it was considered valid to aggregate data for all line fishing methods, and for the Mahe Plateau.

Length frequency distributions for *P. filamentosus* were of type C (Shepherd *et al* (1987), having several modes. However, progressive length increases in these modes were not always evident suggesting estimation of growth may be difficult. As a generalisation, for all sub-sets of data analysed with the aid of LFDA4, SLCA tended to select unreasonably high K and L_∞ values, and PROJMAT selected for high L_∞ and low K. Only ELEFAN selected for L_∞ values around Lmax, and this model was chosen for further analysis of each data set (Table A.10.2).

Table A.10.2. Growth parameter estimates derived by maximisation using the computer aided package, LFDA4, for *P. filamentosus* caught by all line fishing methods.

Data set	K	L_∞	t_0	C	t_s	Score	Method
All MP, 1990-1994	0.41	70.71	-0.5			0.24	ELEFAN
All MP, 1990-Jun 92	0.486	66.22	-0.4			0.27	ELEFAN
Sect 9, 1990-94 (1)	0.454	75.6	-0.7			0.28	ELEFAN
Sect 9, 1990-94 (2)	0.235	74.7	-0.5			0.22	ELEFAN
Sect 6, 1990-1994	0.231	75	-0.4			0.29	ELEFAN
Sect 6, Apr 90- Jun 92	**0.244**	**75.8**	**-0.3**			**0.53**	**ELEFAN**
Sect 6, Apr 90- Jun 92	0.244	75.8	-0.3	0.29	-0.210	0.54	HOENIG/ELEFAN
Sect 6, Apr 90- Jun 92 Auto find	**0.24**	**76.24**	**-0.3**	**0.42**	**-0.258**	**0.56**	**HOENIG/ELEFAN**

Initially, aggregated data for all of the Mahe Plateau and all line fishing methods over the 5 year period, 1990-1994 were investigated. The contour plot of the score function suggested L_∞ values around that derived from the Powell-Wetherall plot (73.5 cm for 1990-94 at the Mahe Plateau to 82.3 cm at the Banks) and relatively high values of K (> 0.4, Fig A.10.4). By eye, the fit from the maximisation routine (Fig. A.10.5) was poor. After June 1992, data was patchy, with several months of missing information. The shorter data set from 1990 to June 1992 was examined, but only marginal improvement in the fit occurred (Fig. A.10.6; Table A.10.2).

Length frequency plots (Fig A.10.3) indicated that adequate data may exist to analyse sectors 9 and 6 separately. The contour plot of the score function for dis-aggregated data for sector 9 for all line fishing gears over the period 1990-1994 indicated two principle areas of maxima, suggesting alternative combinations of K / L_∞ pairs fit the data (Fig A.10.7). In fact, this score function plot suggests more than two areas and indicates that the data are not well suited to this analysis. Investigation of the two principle areas produced maxima with similar values of L_∞ but different K (Figs. A.10.8; A.10.9; Table A.10.2). The full time series of data for sector 6 also indicated two areas of maxima. However, the contour plot for the shorter data set from April 1990 to June 1992 (eliminating the period with no information / smaller sample sizes) suggested a good fit of model to data and produced only a single banana shaped area of maxima (Fig. A.10.10). Whilst by eye the fit of the K/L_∞ pair providing the highest score function was good for the full time series of data (Fig A.10.11), that for the shorter data set was better (Fig. A.10.12), and the score function was significantly improved (Table A.10.2).

Seasonal changes in the environment are indicated for the Mahe Plateau (See 2.2). A seasonal growth curve was thus fitted to data for sector 6 (April 1990-June 1992) starting with the best parameter estimates for the non seasonal growth curve. Only a marginal improvement in score function (Table A.10.2) and fit (Fig A.10.13) were achieved. The Auto-find routine gave similar results , with a slightly higher score function (Table A.10.2; Fig A.10.14).

Similar analyses were performed for these spatial and temporal data sets using length frequency information for handline caught fish only. No improvement in the score function was achieved in any case and the results are not shown. These analyses suggest that aggregation of data for like-gear improves the analysis by providing a greater sample size. However, spatial aggregation, tends to obscure any trends in the data. Fish from different locations may grow at different rates owing to environmental or fishing pressures, or the data sampled may be biased through sampling at different depths or parts of the population. Where possible spatial dis-aggregation is therefore recommended, but the cost, for data sampled from the commercial fleet, is patchy information with small sample sizes and months without data. Indeed, whilst data for sector 6 provided a good fit, that for sector 9 was inadequate, highlighting the difficulty of using these methods with long lived slow growing species, and the need for care in interpreting the results.

The best estimates of both the non seasonal, and seasonal von Bertalanffy growth curve parameters produced, by eye, a good fit to the aggregated data for all sectors of the Mahe Plateau (Fig. A.10.15; A.10.16), indeed, better than that produced from the maximisation routine for this data (although the score function for these parameters and this data set was low <0.15). The combination of the goodness of fit by eye, the score function, and experience suggest that of the estimates derived, those highlighted in Table A.10.2 best describe the non seasonal and seasonal growth parameters for *P. filamentosus.*

Aprion virescens

Length frequency distributions for A. virescens were type C (Shepherd *et al*, 1987), and displayed several modes. The following data were examined : Sectors 6 and 9, and 2-10 (Mahe Plateau) for handlines only and for all line fishing methods. The maximum fork length observed was 96.3 cm and the Powell-Wetherall plot indicated a value of L_∞=101.4 cm for annually aggregated data over the Mahe Plateau. The contour plots of the score functions indicated that the data were inadequate for accurate determination of growth parameters and in no case was a clear single area of maxima found. The best fitting parameter estimates for each sub set of data examined indicate a range of values (Table A.10.3). Subjectively based on the fit by eye there was little to choose between the values derived for sector 9 with handlines only (Fig A.10.17), and those for all the Mahe Plateau with handlines (Fig A.10.18). The former gave a smaller K value. The autofind routine applied to the latter data set derived a similar K value, but the fit by eye was not as convincing as that for the non seasonal growth curve (Fig A.10.19).

Table A.10.3. Growth parameter estimates derived by maximisation using the computer aided package, LFDA4, for *A. virescens,* for data sets where a reasonable fit was suggested by examination of contour plots and by eye.

Data set	K	L∞	t_0	C	t_s	Score	Method
Sect 6, all lines, 90-Oct 93	0.390	96.53	-0.67			0.34	ELEFAN
Sect 9, all lines, 90-Aug 93	0.217	98.69	-0.90			0.07	ELEFAN
Sect 9, handlines, 90-Sept 93	0.217	108.5	-0.70			31.45	SLCA
All MP, handlines, 90-Sept 93	0.321	94.68	-0.19			37.93	SLCA
All MP, Hlines, 90-9/93, autofind	0.321	101.5	-0.65	0.19	0.226	0.226	HOENIG/ELEFAN

Lutjanus sebae

Length frequency distributions for *L. sebae* were type C (Shepherd *et al*, 1987). The maximum length observed was 98.3 cm, and the Powell-Wetherall plot indicated an L∞ of 90.7 cm for annually aggregated data over the Mahe Plateau. Data for all of the Mahe Plateau and sectors 2, 6 and 9 were analysed. A range of values were suggested (Table A.10.4). A contour plot of the score function of data for sector 9 and handlines only was good and whilst it indicated 2 areas of maxima, one was for particularly high values of both K and L∞ and was discounted. The other was a banana shaped range of values in the expected limits. Maximisation produced values which gave a good fit by eye to the data (Fig. A.10.20). This data set was further studied for assessment of seasonal growth parameters by maximisation and with the auto find function which produced similar parameter estimates and fit by eye (Fig A.10.21), but a slightly higher score function.

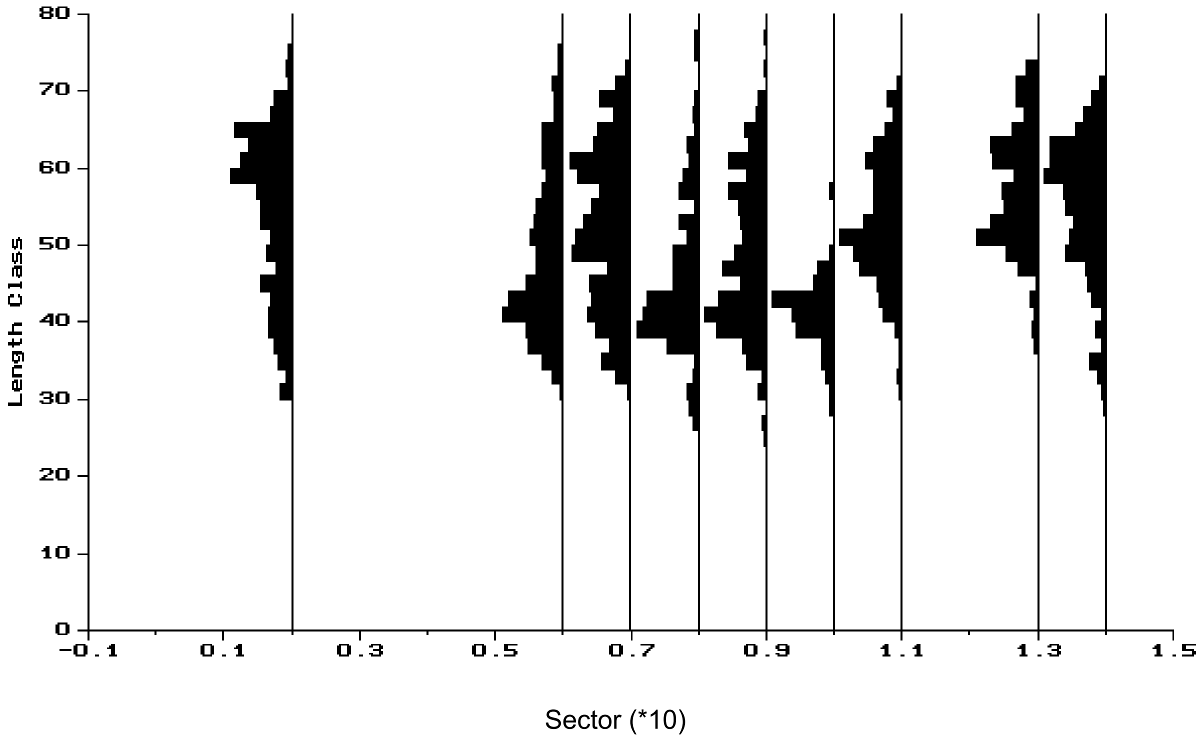
Table A.10.4. Growth parameter estimates derived by maximisation using the computer aided package, LFDA4, for *L. sebae,* for data sets where a reasonable fit was suggested by examination of contour plots and by eye.

Data set	K	L∞	t_0	C	t_s	Score	Method
Sect 2, all lines, 90-Oct 93	0.296	89.71	-0.42			0.256	ELEFAN
MP, handlines, 90-Jun 94	0.177	92.41	-0.57			26.3	SLCA
Sect 6, handlines, 90-Apr 94	0.171	112.7	-0.61			0.244	ELEFAN
Sect 9, handlines, 90-Jul 92	0.180	99.10	-0.63			0.280	ELEFAN
Sect 9, Hlines, 90-Jul 92	0.180	99.10	-0.57	0.47	-0.22	0.318	HOENIG/ELEFAN
Sect 9, Hlines, 90-Jul 92, autofind	0.193	97.41	-0.35	0.64	-0.24	0.345	HOENIG/ELEFAN

Epinephelus chlorostigma

Length frequency distributions for *E. chlorostigma* were uni-modal and did not indicate any change in length with time (Type A, Shepherd *et al*, 1987; eg. Fig A.10.22). Dis-aggregation of the data did not improve the resolution of the information. Such data are inadequate for assessment of growth parameters using length based methods, and the analysis was not taken any further.

Figure A.10.1. : Length frequency distribution by fishing sector observed for *Pristipomoides filamentosus* caught by handlines during 1990.



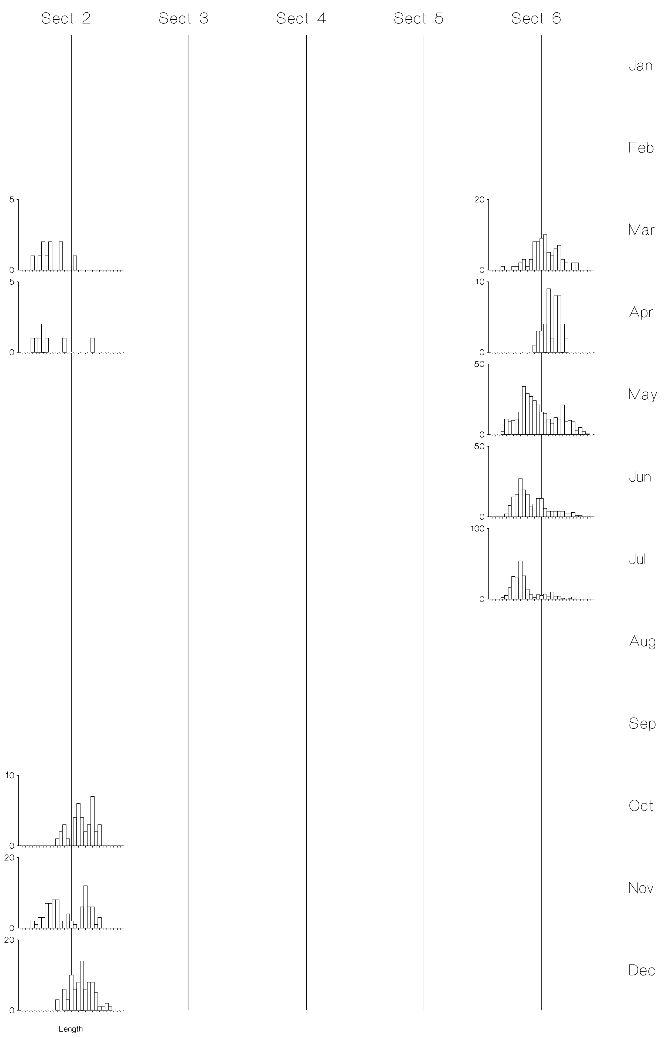


Figure A.10.2a. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1990 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

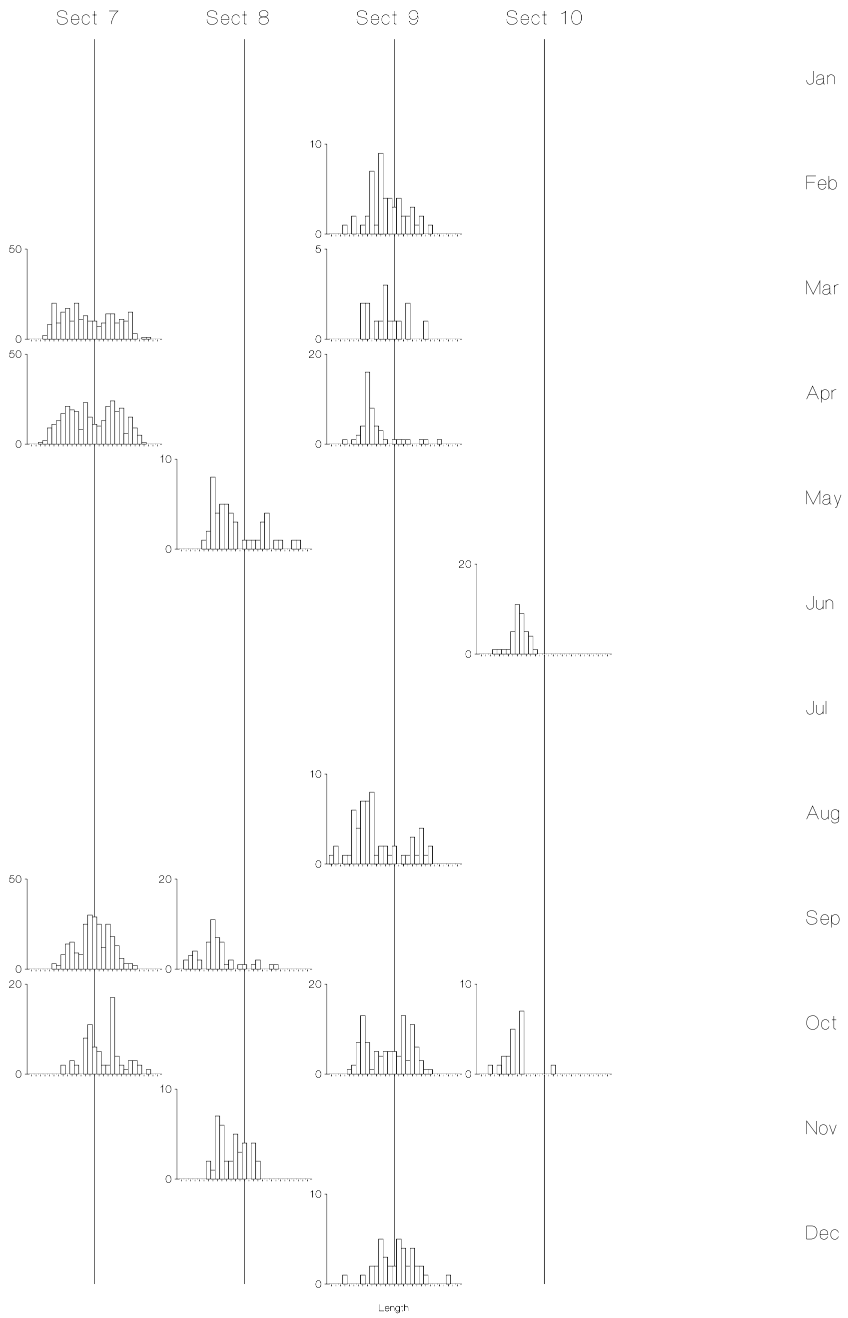


Fig. A.10.2b. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-10) in 1990 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

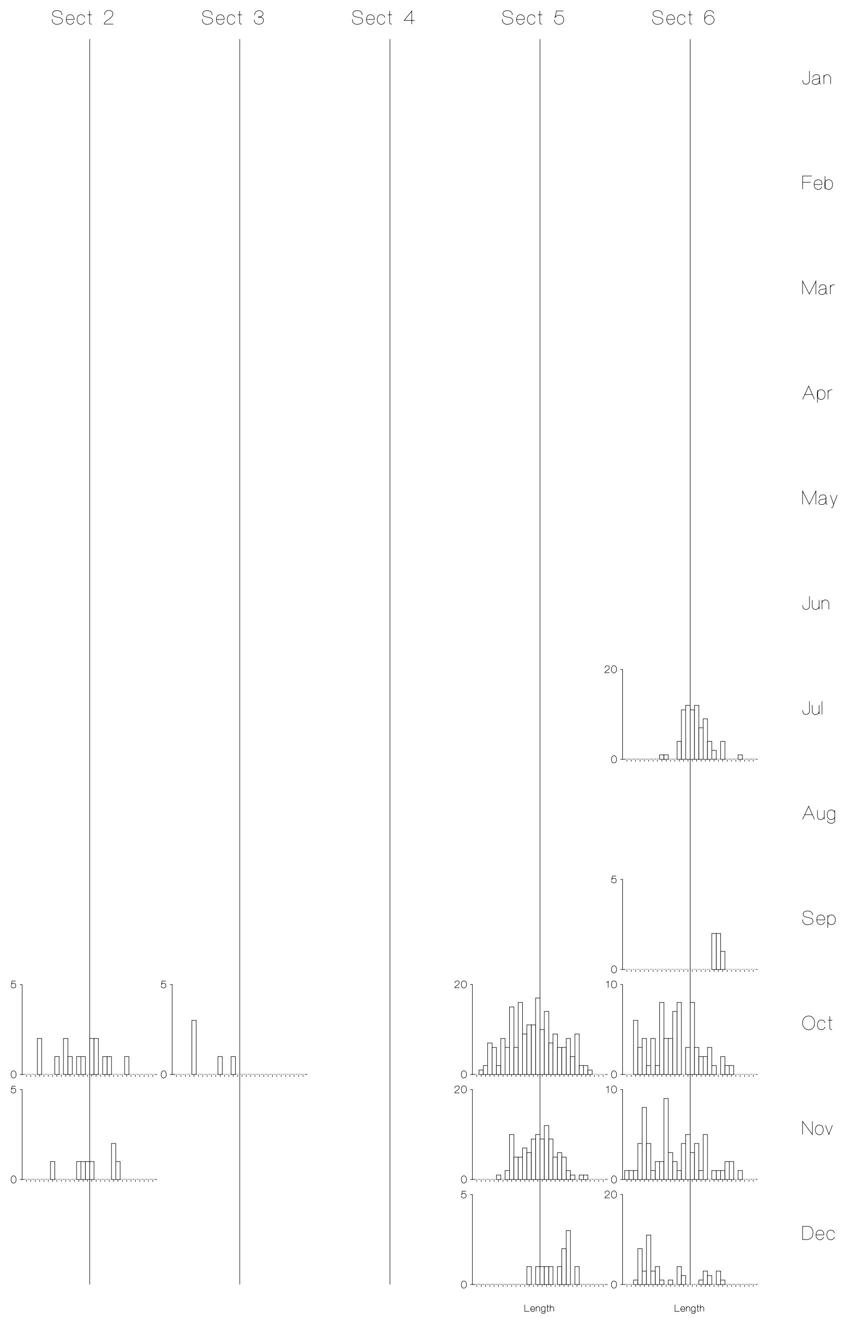


Figure A.10.2c. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1991 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

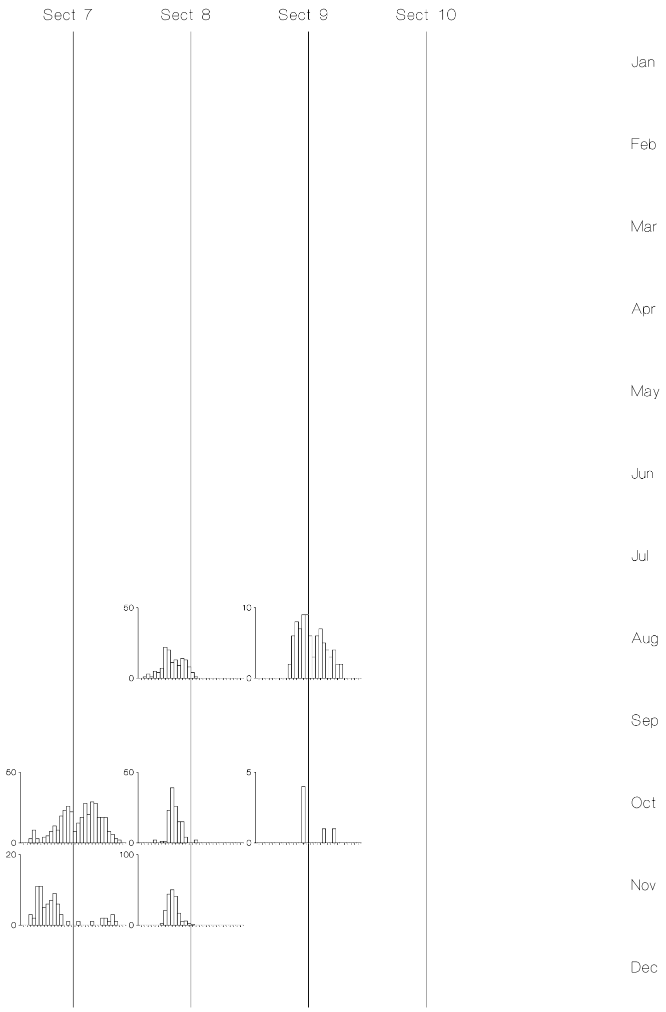


Figure A.10.2d. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-10) in 1991 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

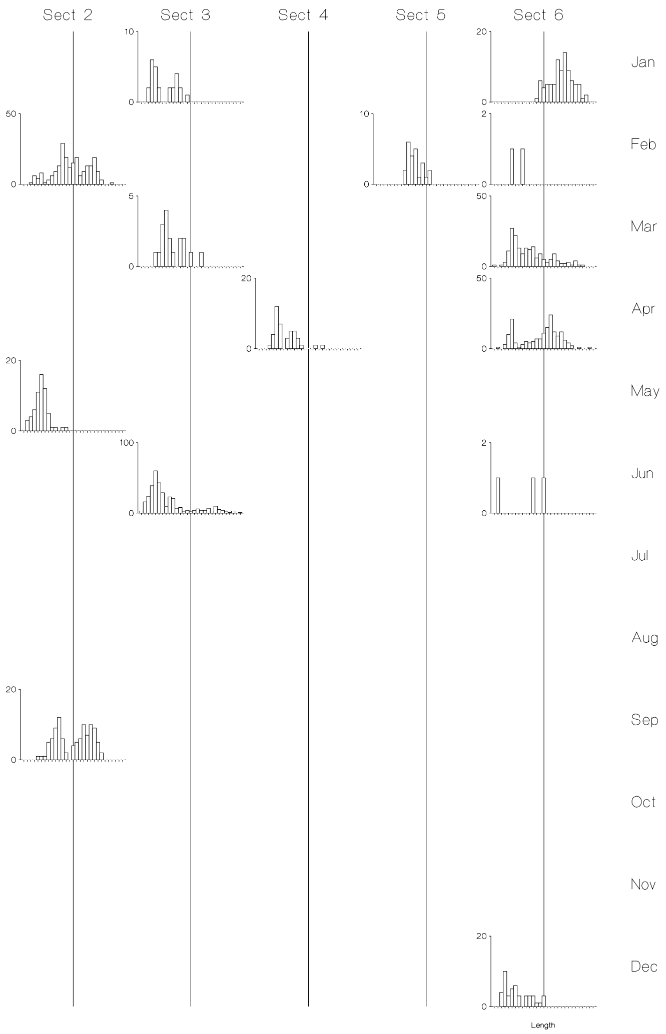


Figure A.10.2e. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1992 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

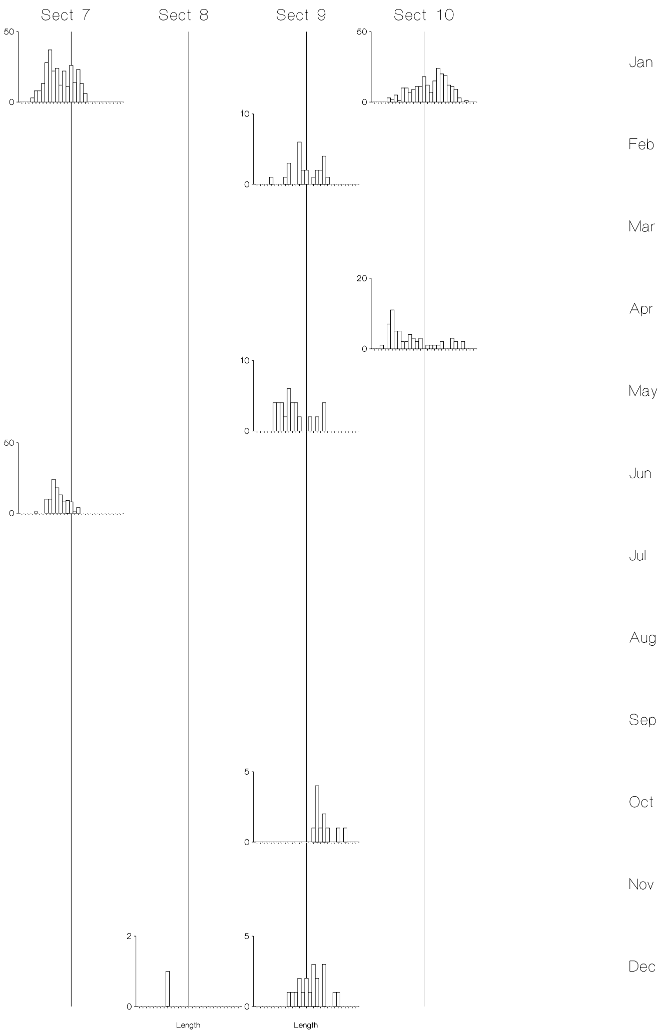


Figure A.10.2f. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-10) in 1992 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

Figure A.10.2g. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1993 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

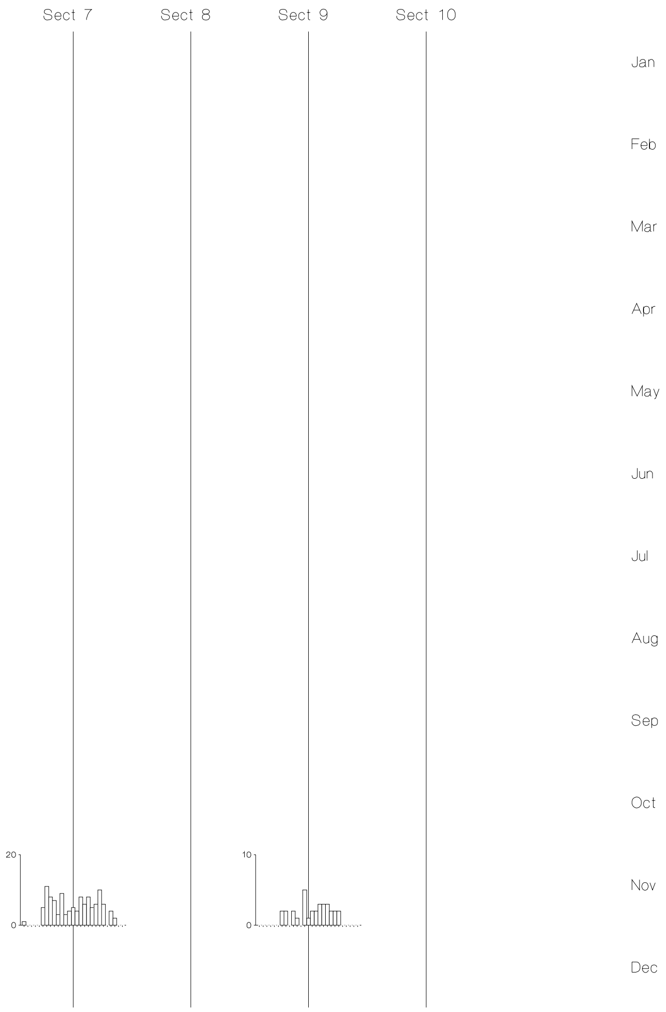


Figure A.10.2h. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-10) in 1993 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

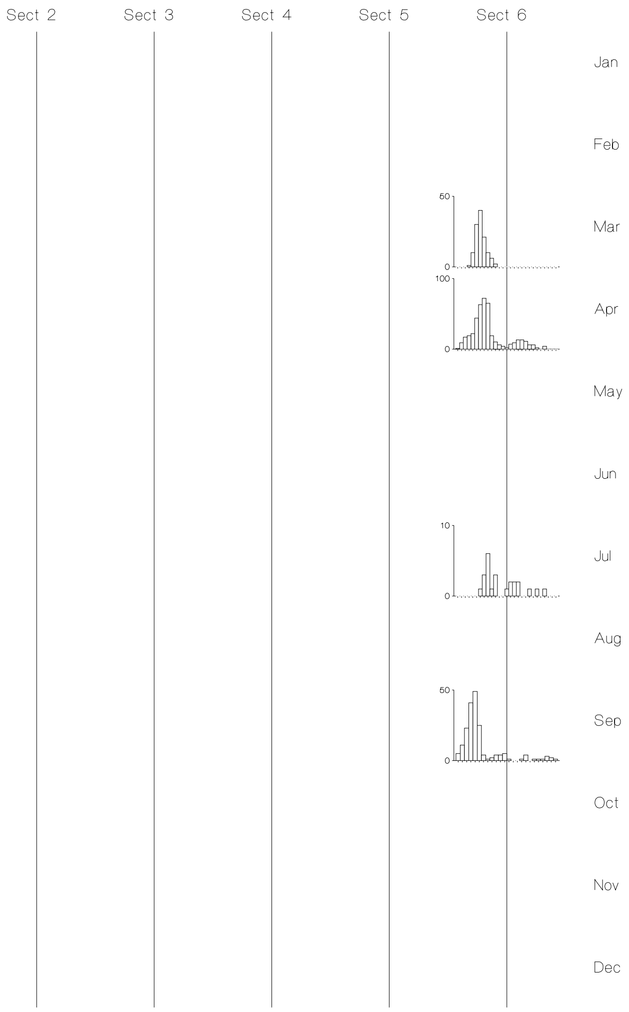


Figure A.10.2i. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1994 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

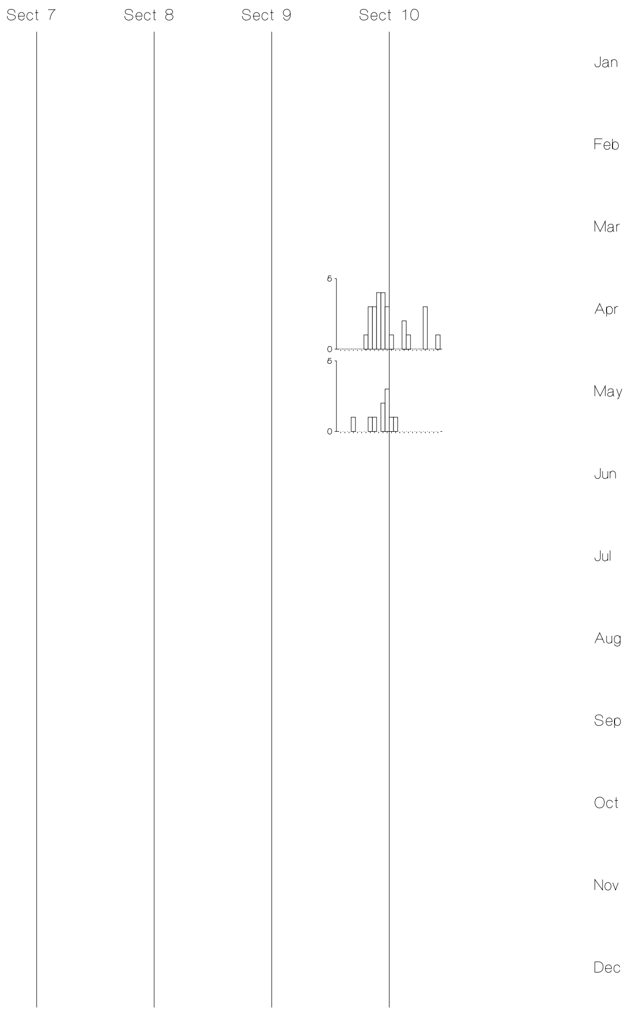


Figure A.10.2j. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-10) in 1994 for fish caught by handlines only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

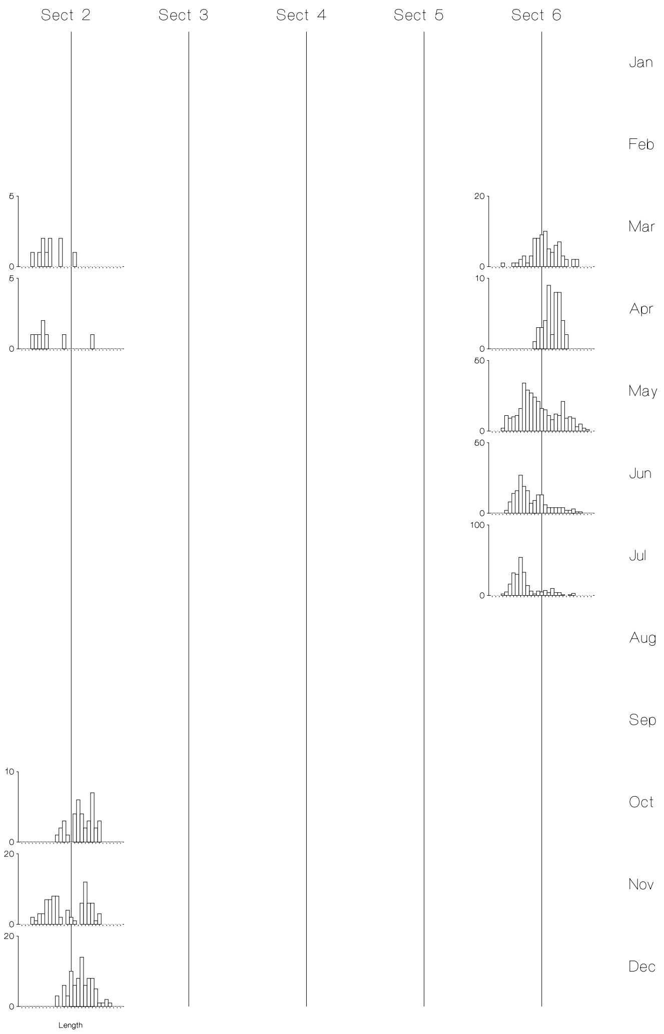


Figure A.10.3a. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1990 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

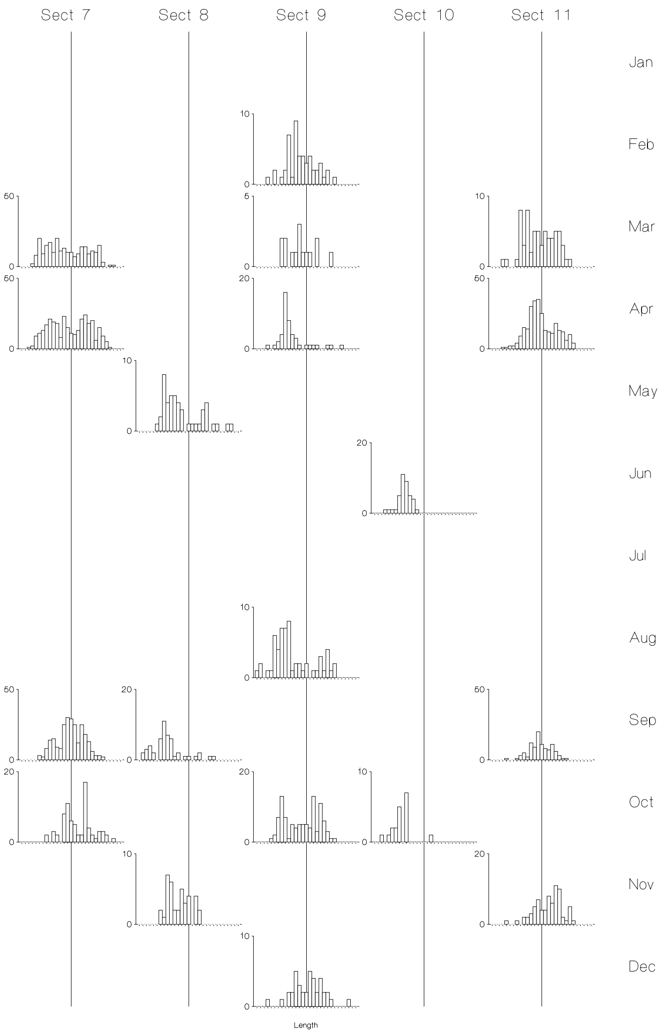


Figure A.10.3b. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-11) in 1990 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

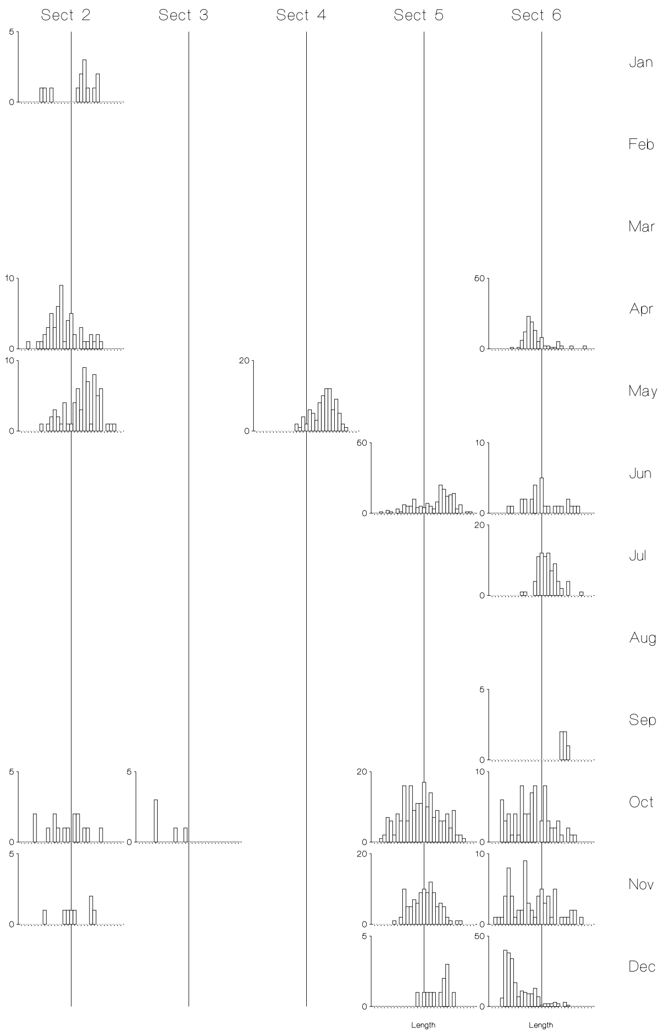


Figure A.10.3c. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1991 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

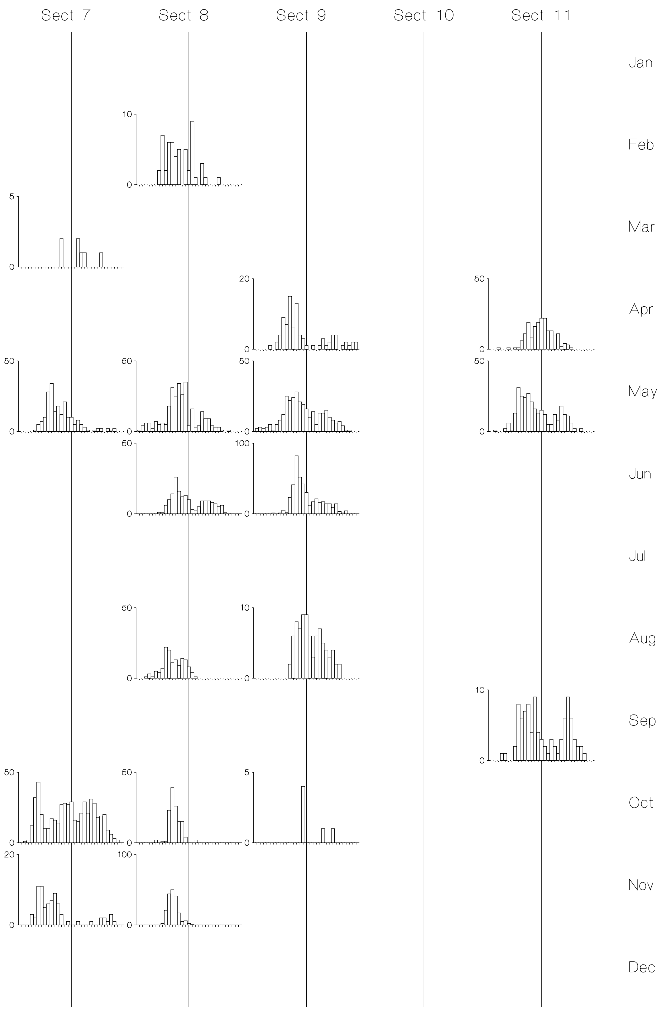


Figure A.10.3d. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-11) in 1991 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

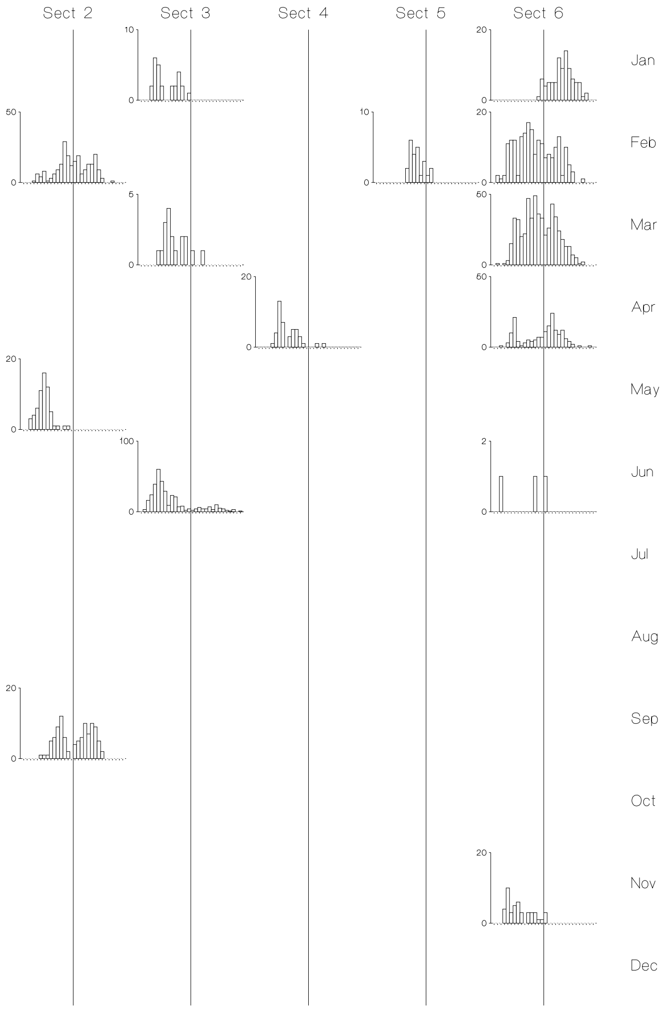


Figure A.10.3e. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1992 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

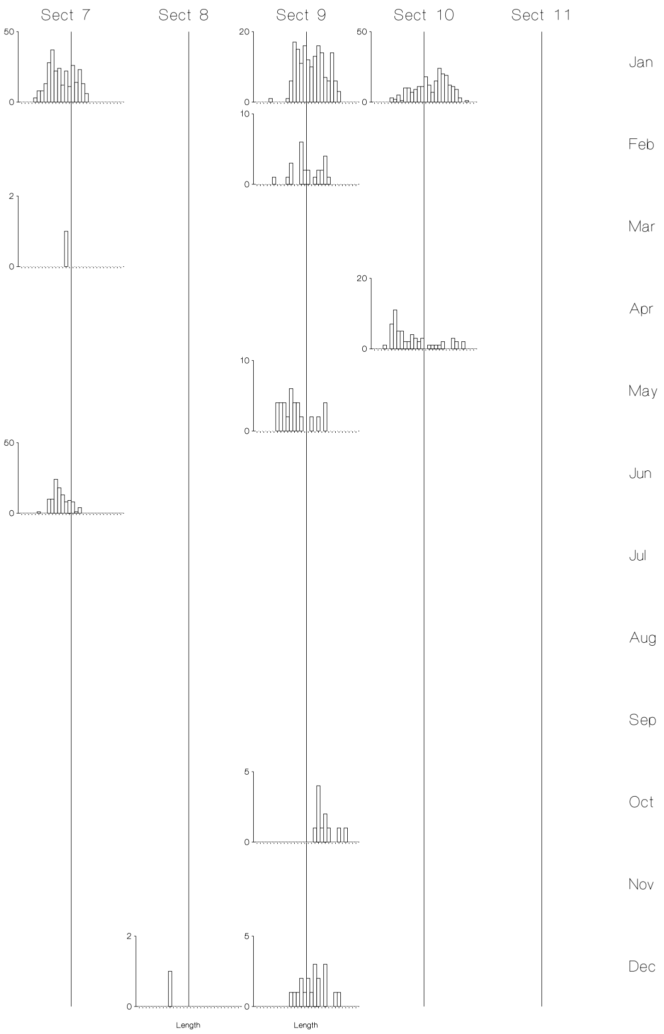


Figure A.10.3f. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-11) in 1992 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

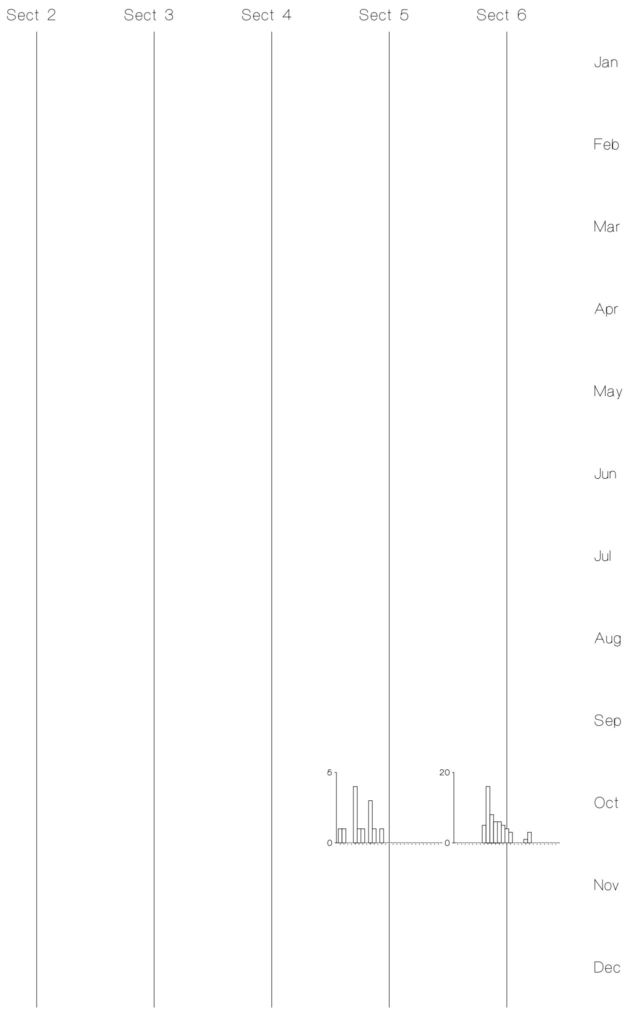


Figure A.10.3h. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-11) in 1993 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 80 cm with centre line at 40 cm.

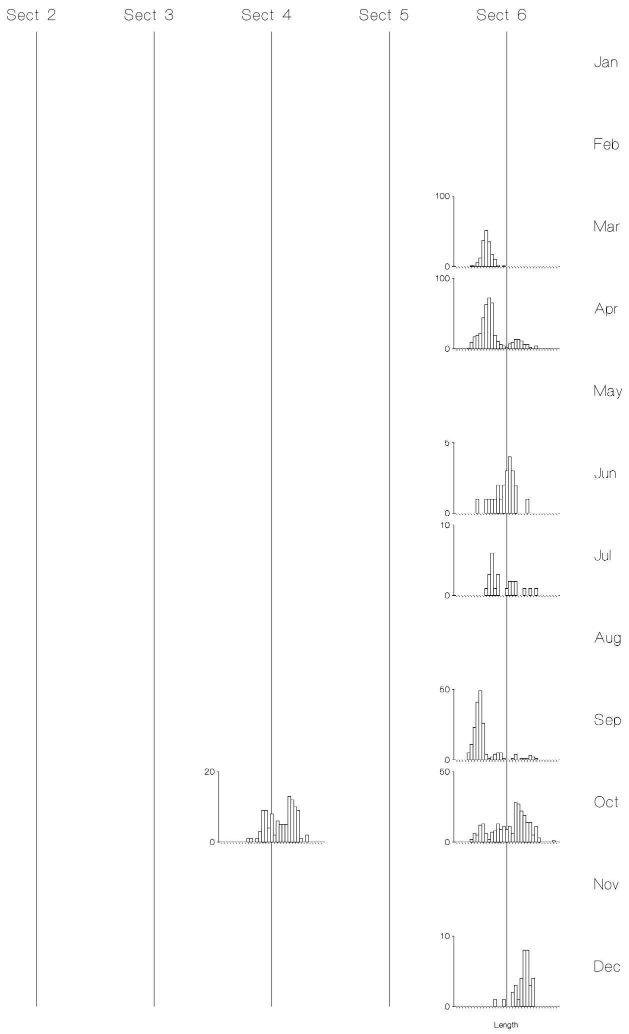


Figure A.10.3i. : *P. filamentosus* monthly length frequency distributions by fishing sector (2-6) in 1994 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 88 cm with centre line at 44 cm.

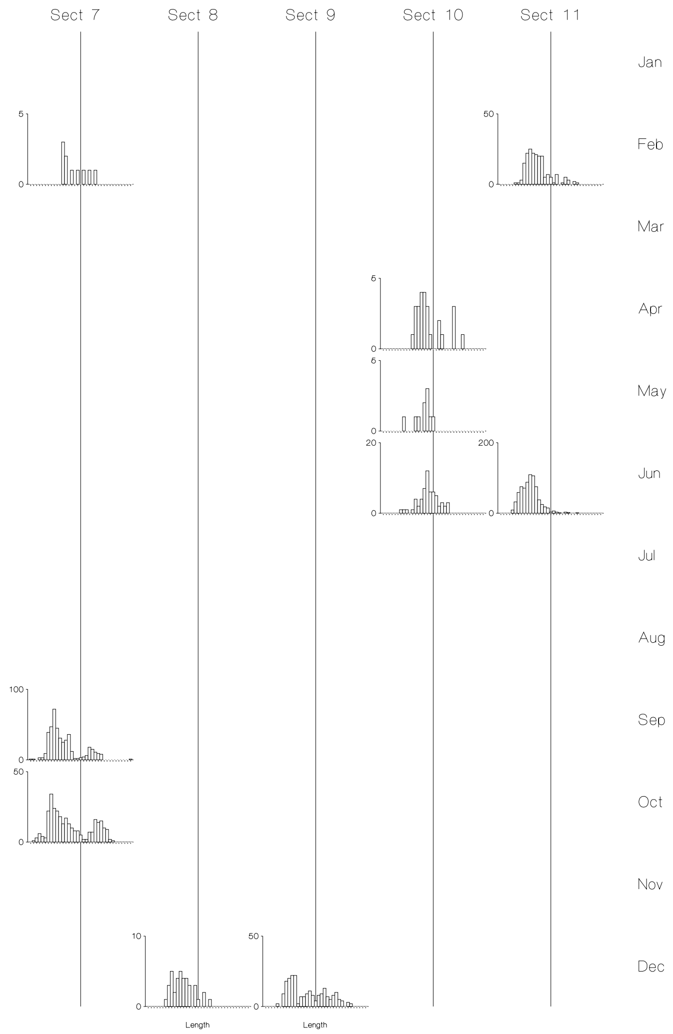


Figure A.10.3j. : *P. filamentosus* monthly length frequency distributions by fishing sector (7-11) in 1994 for fish caught by all line fishing methods only. Length Scale : 2 cm length classes from 0 to 88 cm with centre line at 44 cm.

Figure A.10.4. Contour plot showing the score function of K against L∞ for *P. filamentosus* from sectors 2-10 of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

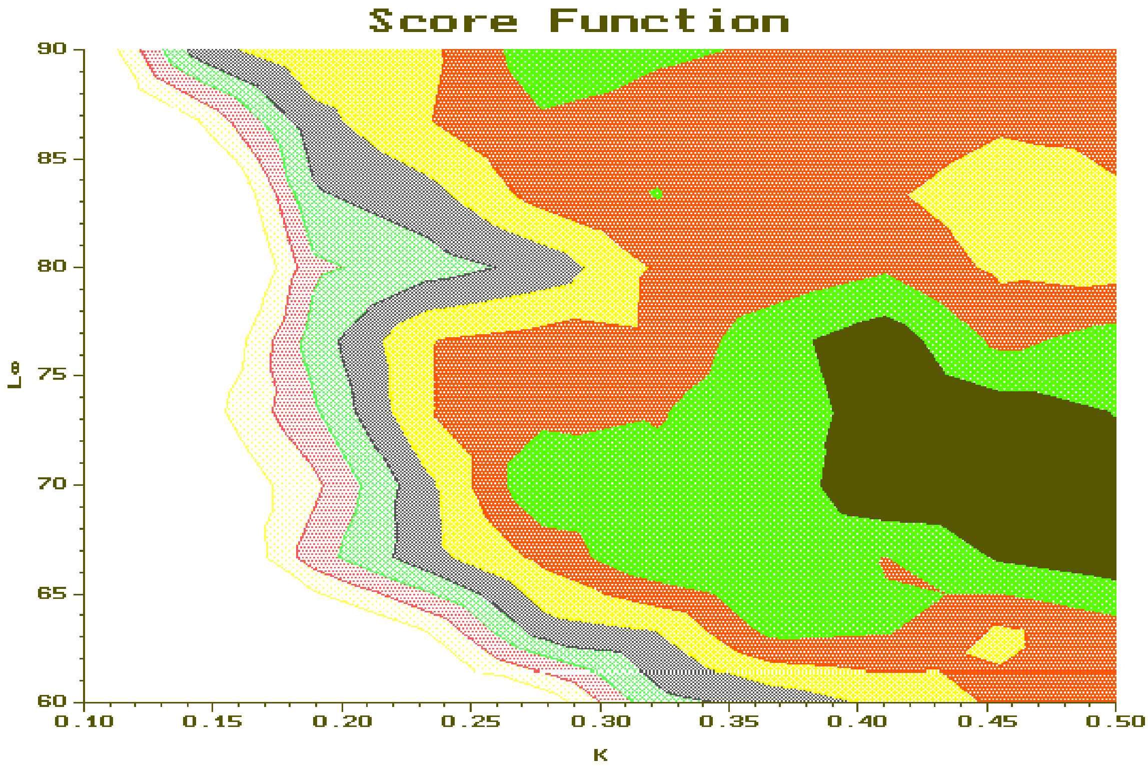


Figure A.10.5. Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.410, L∞=70.71, t_0=-0.5) for *P. filamentosus* from sectors 2-10 of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

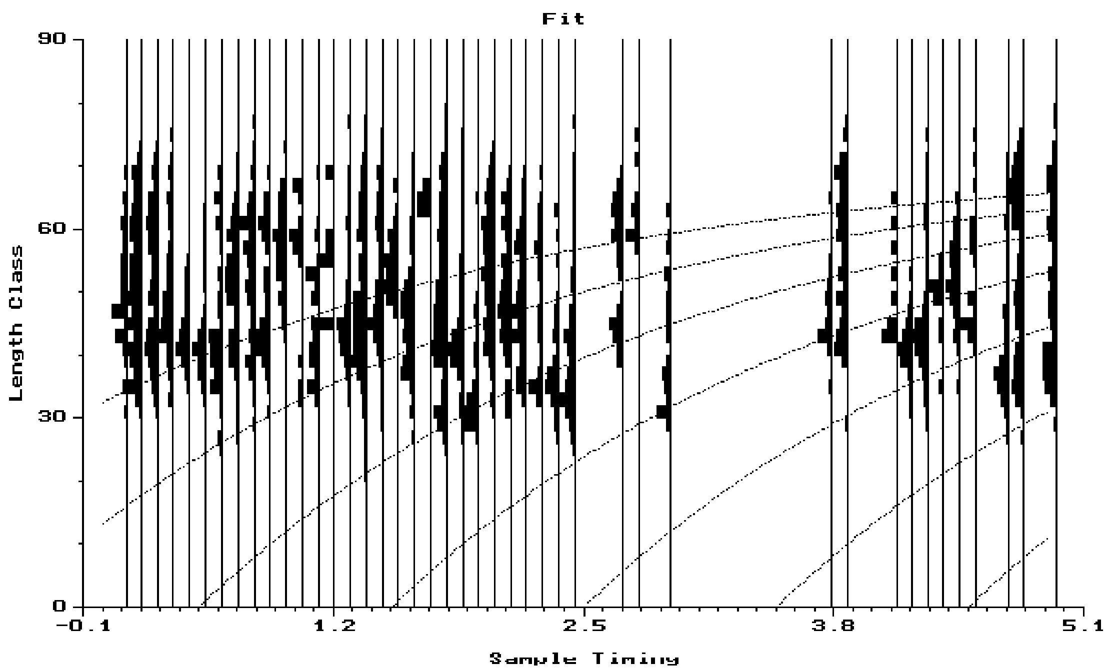


Figure A.10.6. Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.486, L∞=66.22, t_0=
filamentosus from sectors 2-10 of the Mahe Plateau, all hook and line fishing methods, 1990-June 1992.

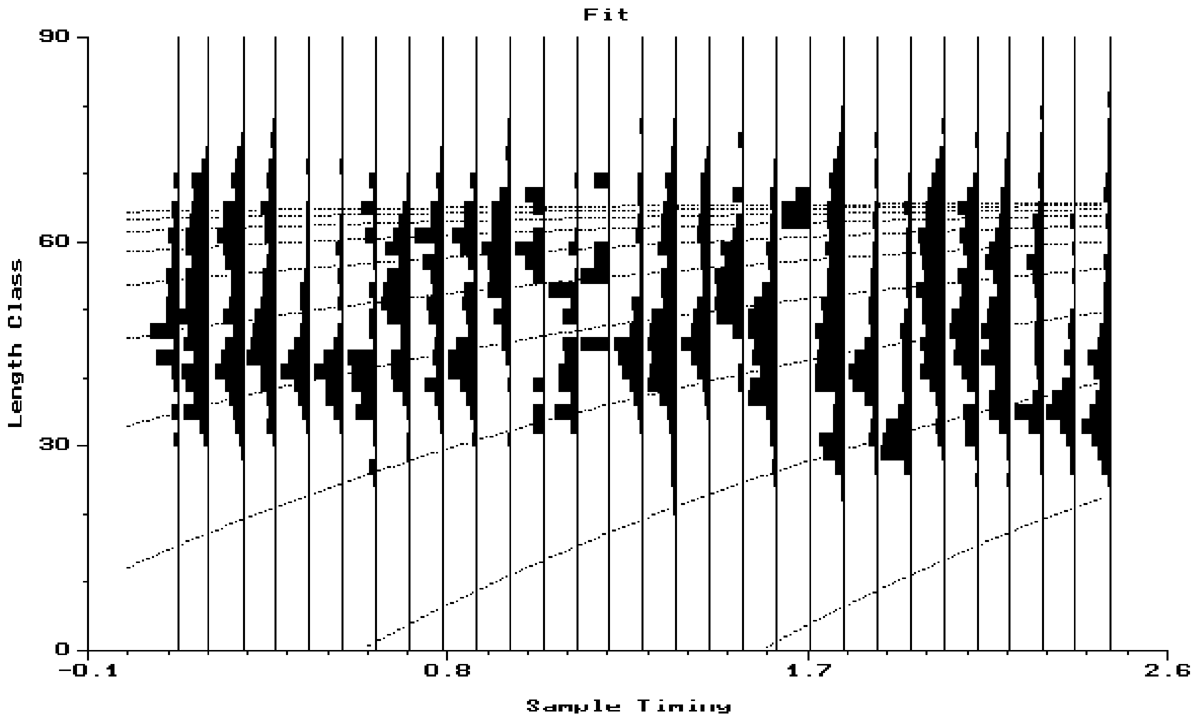


Figure A.10.7. Contour plot showing the score function of K against L∞ for *P. filamentosus* from sector 9 only of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

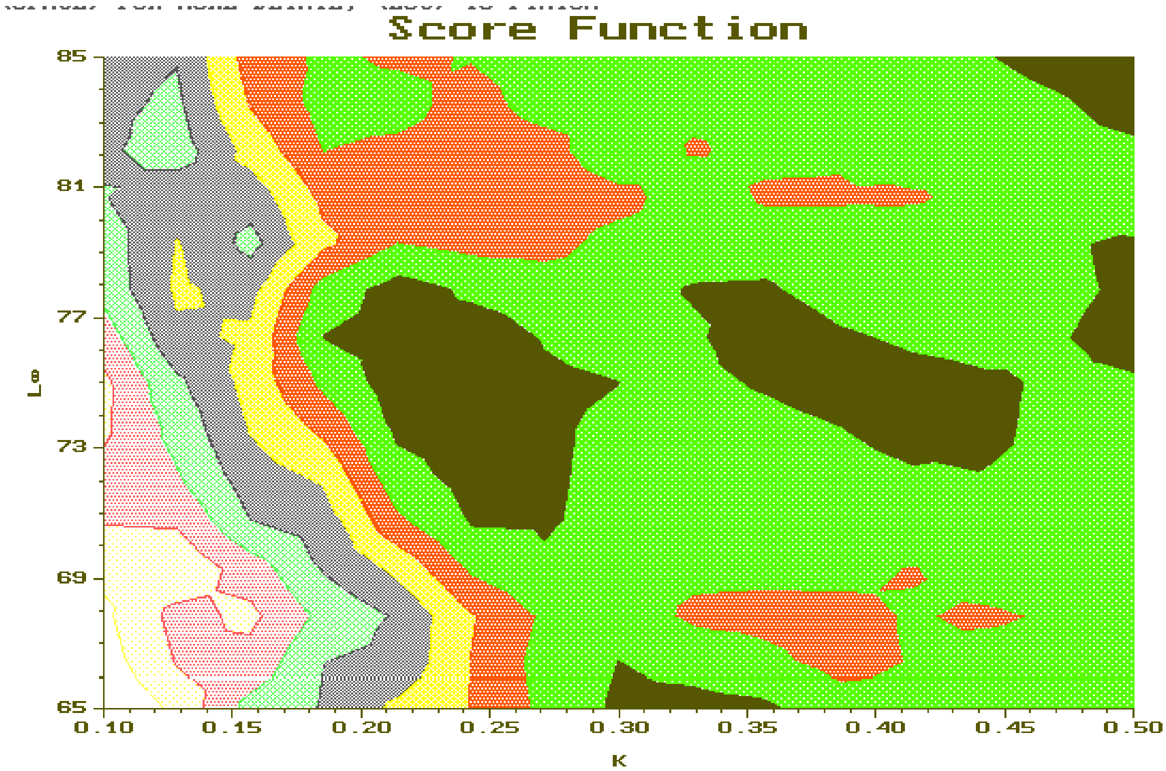


Figure A.10.8. Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.454, L∞=75.60, t_0=-0.74) for *P. filamentosus* from sector 9 only of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

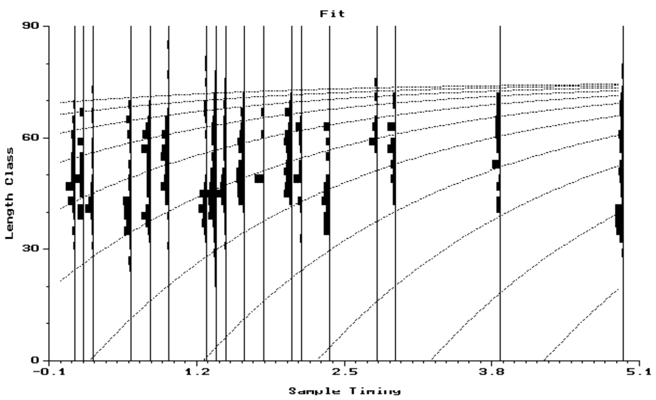


Figure A.10.9. Plot of alternative fitting von Bertalanffy growth curve found by maximisation (K=0.235, L∞=74.70, t_0=-0.5) about second 'high point' for *P. filamentosus* from sector 9 only of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

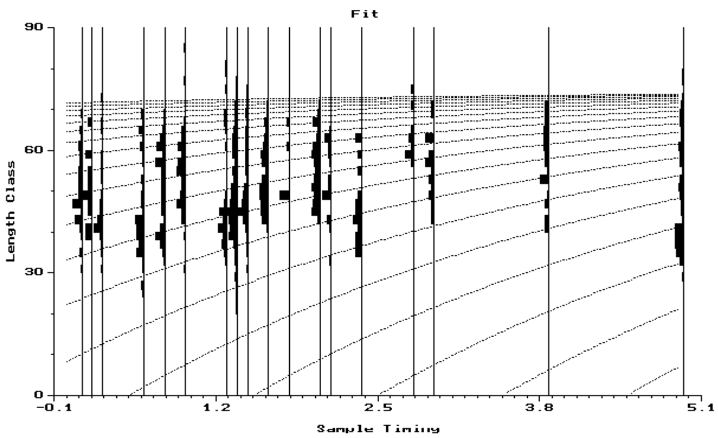


Figure A.10.10. Contour plot showing the score function of K against L∞ for *P. filamentosus* from sector

6 only of the Mahe Plateau, all hook and line fishing methods, April 1990-June 1992.

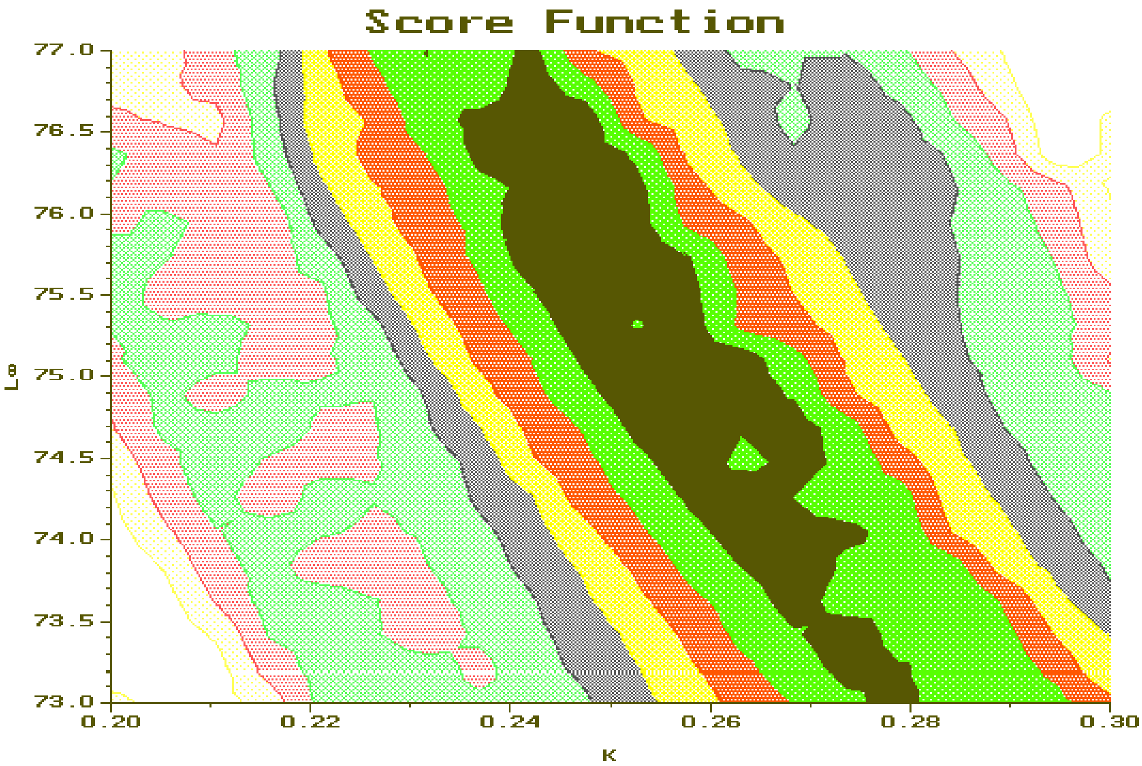


Figure A.10.11. Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.231, L∞=75.00, t_0=-0.35) for *P. filamentosus* from sector 6 only of the Mahe Plateau, all hook and line fishing methods, 1990-1994.

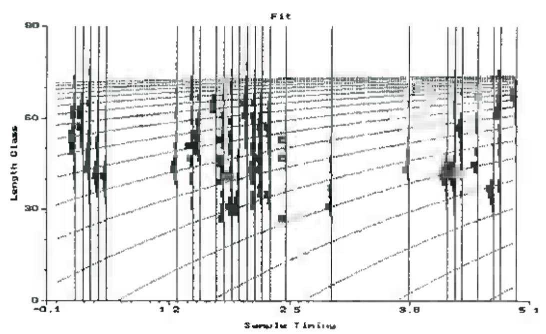


Figure A.10.12. Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.244, L∞=75.80, t_0=-0.26) for *P. filamentosus* from sector 6 only of the Mahe Plateau, all hook and line fishing methods, April 1990-June 1992.

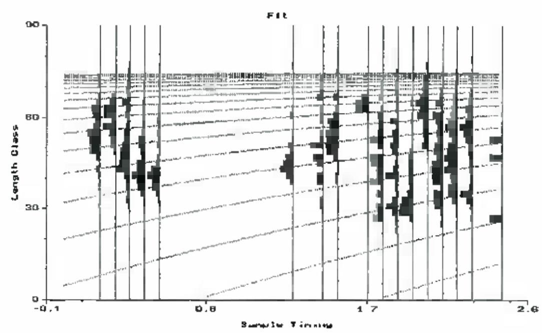


Figure A.10.13. Plot of the best fitting seasonal (Hoenig) von Bertalanffy growth curve found by maximisation (K=0.244, L∞=75.80, t_0=-0.26, C=0.29, t_s=-0.21) for *P. filamentosus* from sector 6 only of the Mahe Plateau, all hook and line fishing methods, April 1990-June 1992.

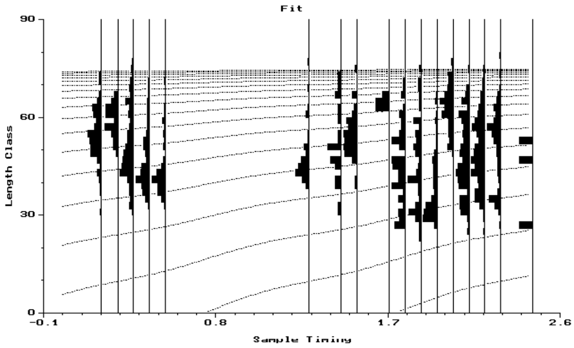


Figure A.10.14. Plot of the best fitting seasonal (Hoenig) von Bertalanffy growth curve found by 'Auto-find' (K=0.240, L∞=76.24, t_0=-0.28, C=0.42, t_s=-0.258) for *P. filamentosus* from sector 6 only of the Mahe Plateau, all hook and line fishing methods, April 1990-June 1992.

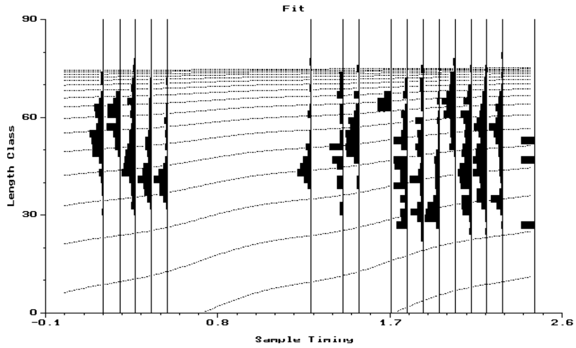


Figure A.10.15. Plot of the best fitting non seasonal von Bertalanffy growth curve (K=0.244, L∞=75.80, t_0=-0.26) overlaid on data for *P. filamentosus* from sectors 2-10 of the Mahe Plateau, all hook and line fishing methods, 1990-June 1992.

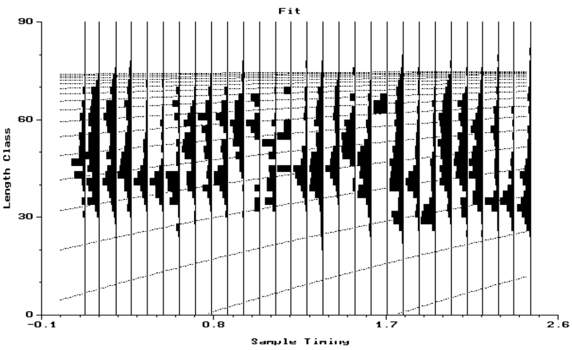


Figure A.10.16. Plot of the best fitting seasonal (Hoenig) von Bertalanffy growth curve (Auto find, K=0.240, L∞=76.24, t_0=-0.28, C=0.42, t_s= -0.258) overlaid on data for *P. filamentosus* from sectors 2-10 of the Mahe Plateau, all hook and line fishing methods, 1990-June 1992.

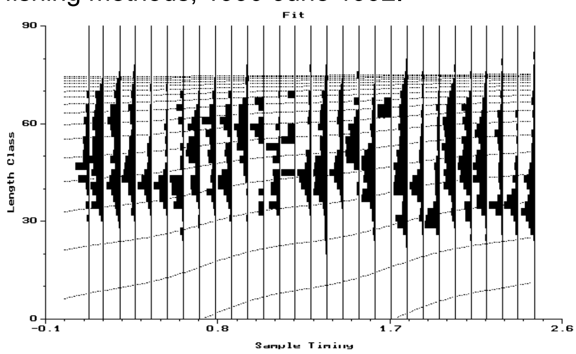


Figure A.10.17 : Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.217, L_∞=108.5, t_0=-0.70) for *A. virescens* from sector 9 only of the Mahe Plateau caught by handlines only.

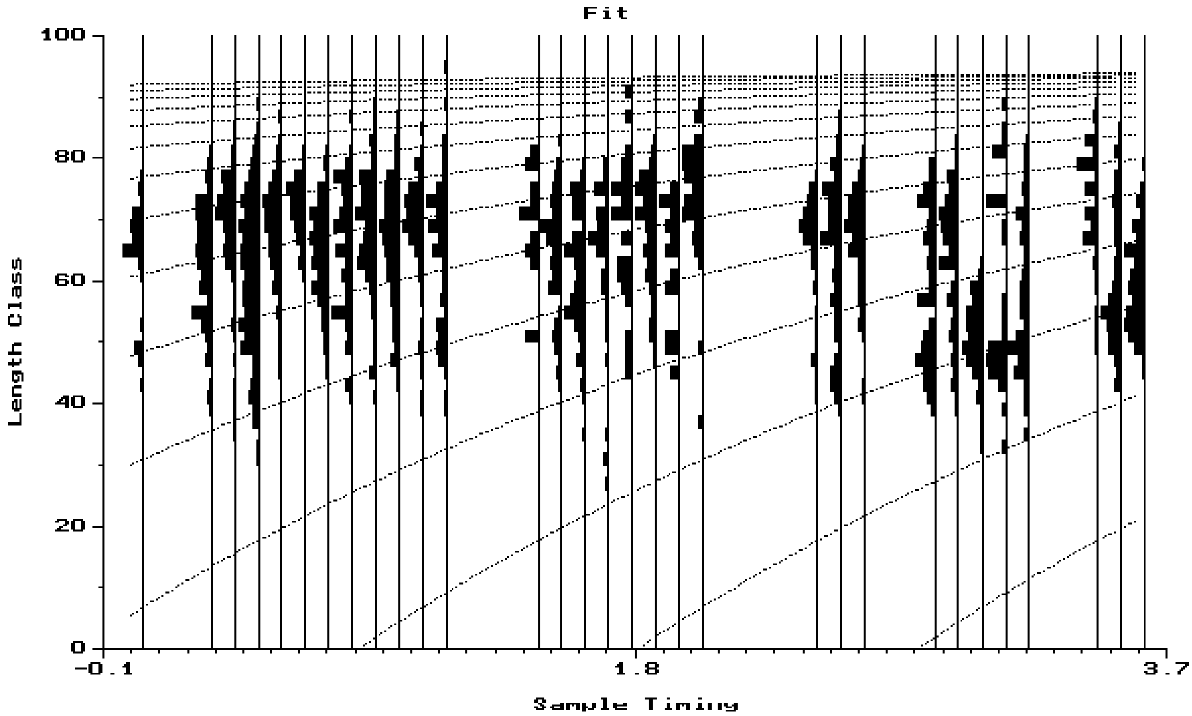


Figure A.10.18 : Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.321, L_∞=94.68, t_0=-0.19) for *A. virescens* from sectors 2-10 of the Mahe Plateau caught by handlines only.

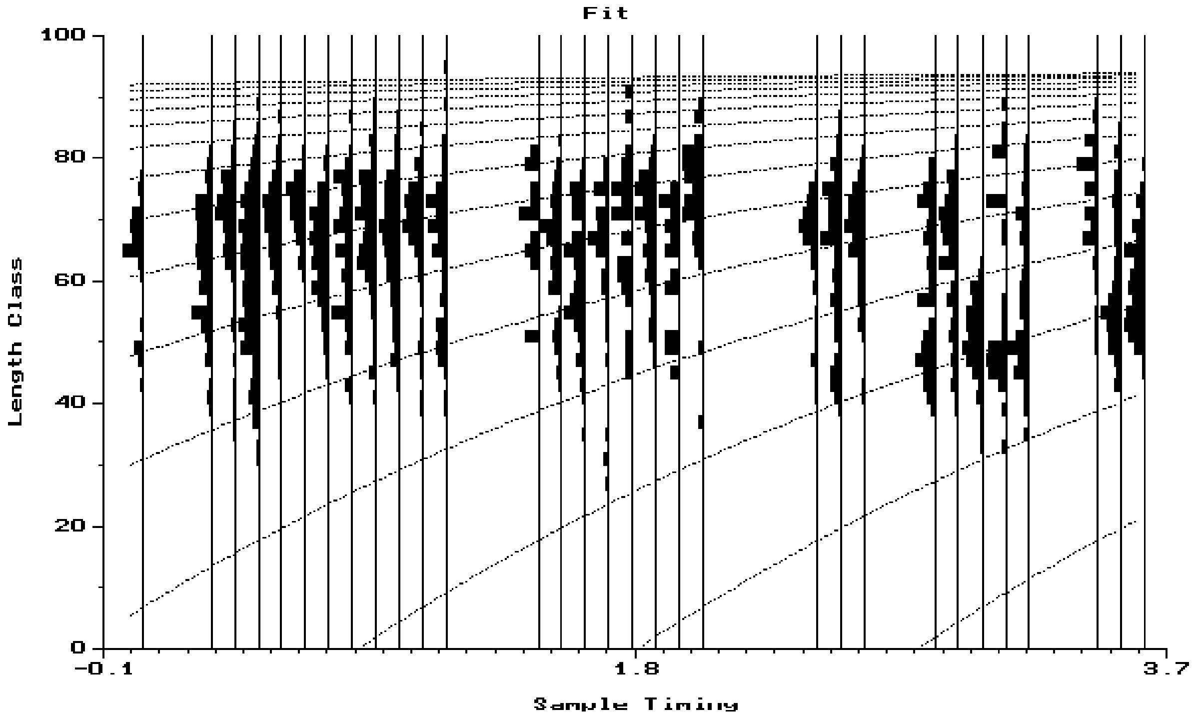


Figure A.10.19 : Plot of the best fitting seasonal (Hoenig) von Bertalanffy growth curve (autofind K=0.321, L∞=101.49, t_0=-0.65, t_s=0.226, C=0.193) for *A. virescens* from sectors 2-10 of the Mahe Plateau caught by handlines only.

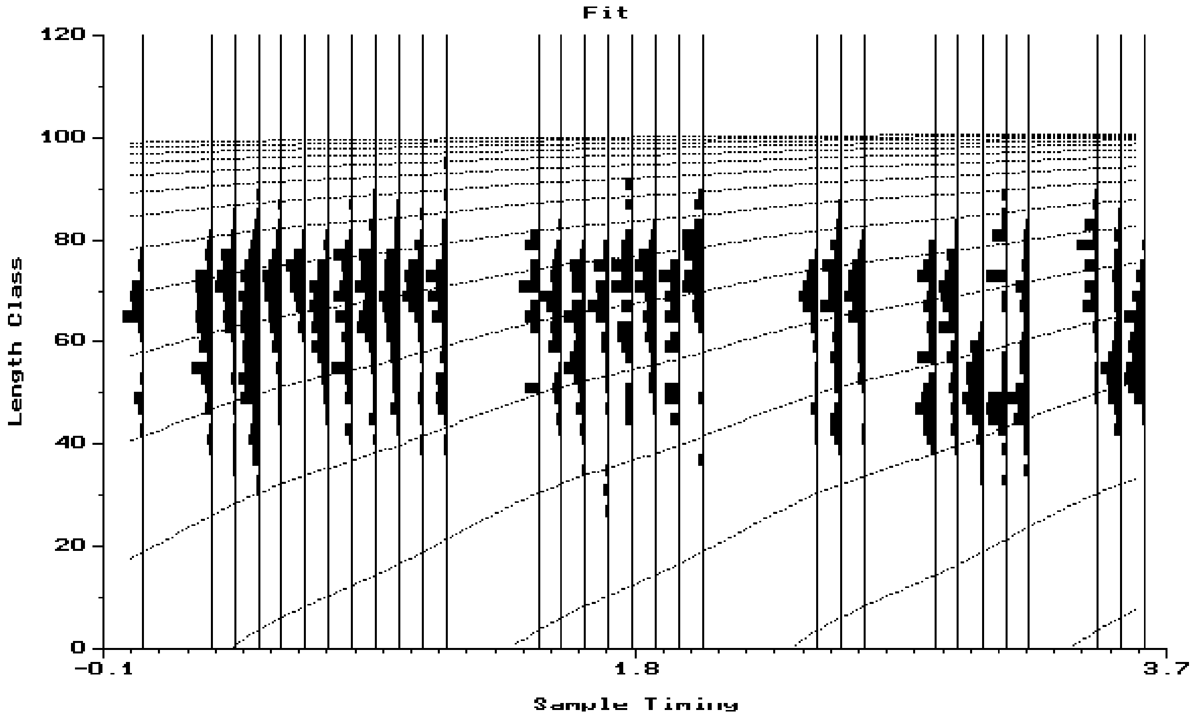


Figure A.10.20 : Plot of the best fitting von Bertalanffy growth curve found by maximisation (K=0.180, L∞=99.1, t_0=-0.63) for *L. sebae* from sector 9 only of the Mahe Plateau caught by handlines only.

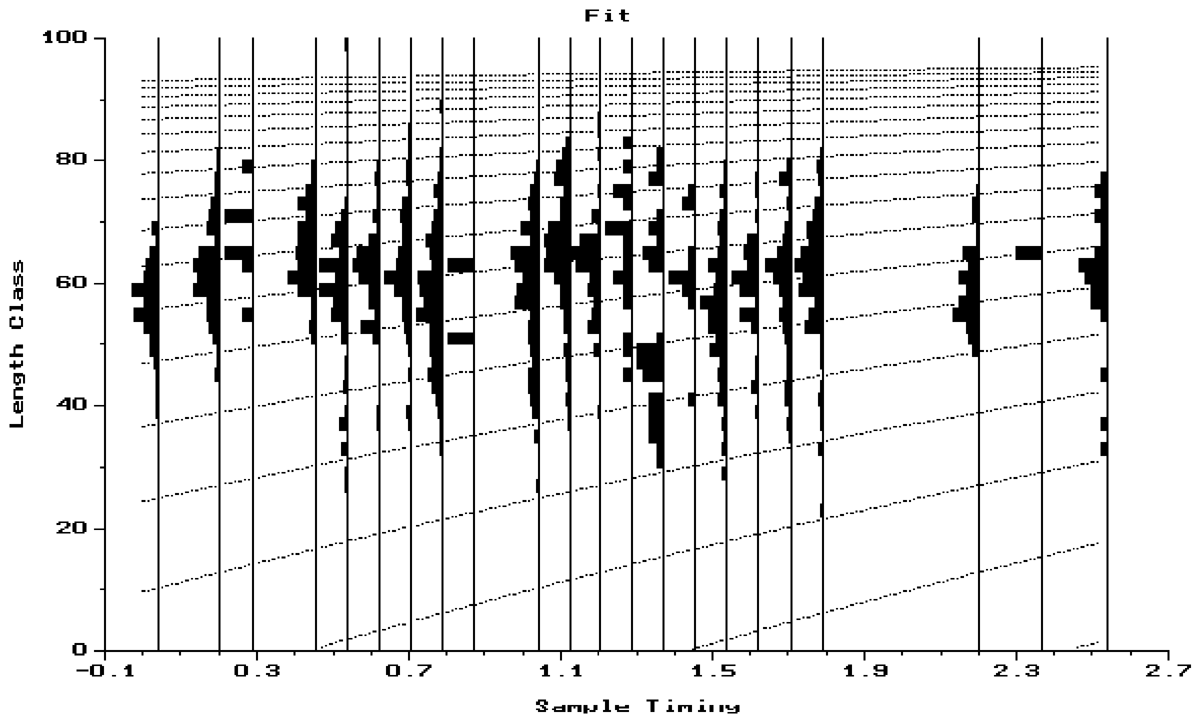


Figure A.10.21 :Plot of the best fitting seasonal (Hoenig) von Bertalanffy growth curve found by maximisation (K=0.180, L∞=99.1, t_0=-0.57, t_s=-0.22, C=0.47) for *L. sebae* from sector 9 only of the Mahe Plateau caught by handlines only.

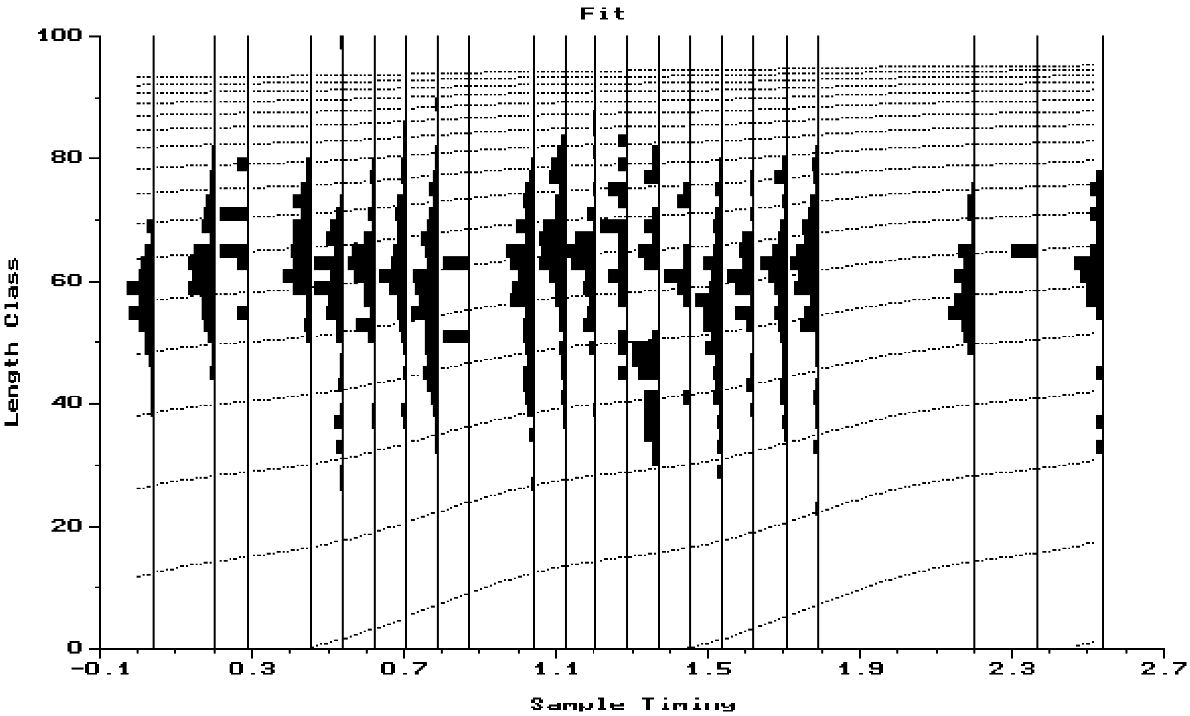
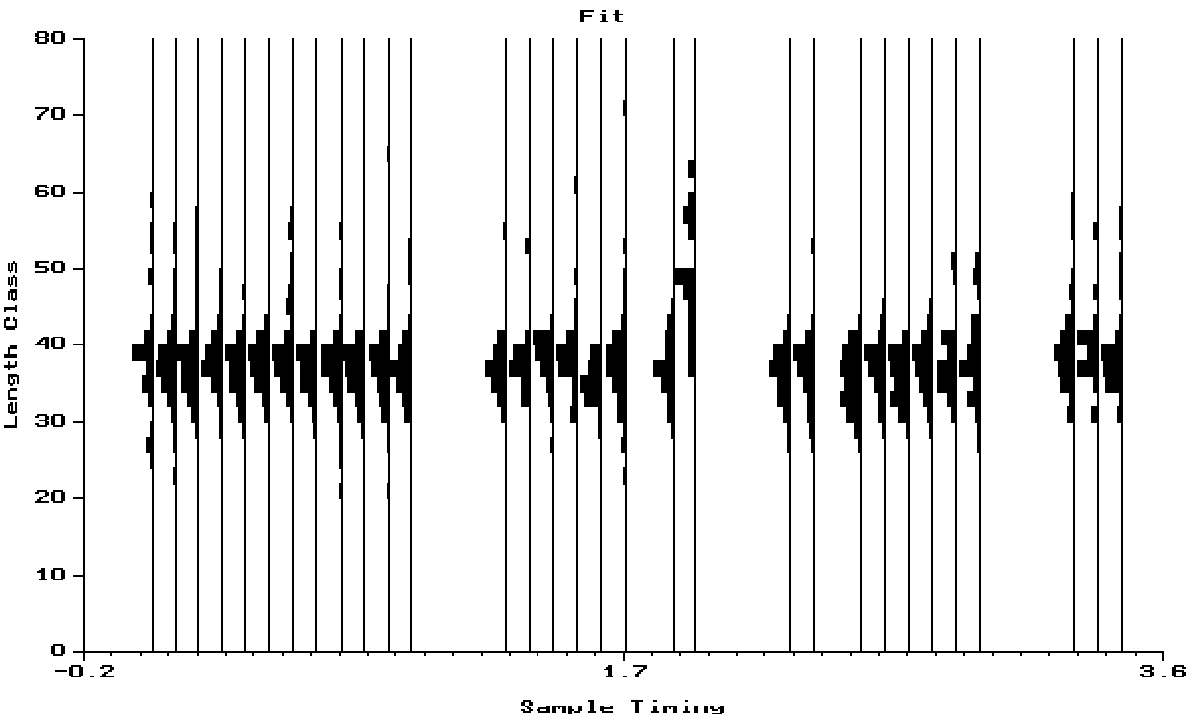


Figure A.10.22. Monthly length frequency distributions for E. chlorostigma caught by all line fishing methods form all sectors of the Mahe Plateau during the period 1990-July 1993



Annex 11 : Mortality Estimates for Key Study Species

Section 5.2.4 discusses the estimation of mortality parameters by means of length converted catch curves, and the sensitivity of model outputs to variation in the estimates of growth parameters. For each of the species studied growth parameters were selected where L_∞ was close to Lmax. The Powell-Wetherall method is also presented as an alternative independent of the requirement for growth parameter inputs. Monthly aggregated length frequency data per annum by fishing sector were assessed with the aid of LFDA4 (MRAG, 1995). Sample size information is presented in Annex 7. Details of the catch by species by sector per annum indicated in Annex 1 were used to calculate the catch per unit area in order to better compare relative catch and effort between locations and years. The catch of *P. filamentosus* was related to the area of intermediate-depth substrate, whilst the total area of shallow banks was employed for the other species (Table 3 of main text).

Mortality estimates were derived for *P. filamentosus* by sector within the Mahe Plateau (Table A.11.1; Figs A.11.1-3). Additionally, the Beverton Holt Z estimator was applied for this species. However, for such dis-aggregated data the sample size was frequently small (Annex 7) and the catch curve and Powell-Wetherall plot were poor, or could not be fitted at all. Subsequently, for this and all other species, aggregated data for all of the Mahe Plateau (Sectors 1-10), and all locations was used. Data for the banks south of the Mahe Plateau (Sector 11), the Amirantes Plateau (Sector 13), and Providence / Farquahar (Sector 14) were also examined where sufficient data existed: *Aprion virescens* (Table A.11.2; Figs A.11.4-6); *Lutjanus sebae* (Table A.11.3; Figs A.11.7-9); *Epinephelus chlorostigma* (Table A.11.4; Figs A.11.10-12).

Mean annual fishing effort was greatest on the Mahe Plateau, about half to one third of this value at each of the Banks, Amirantes and Providence/Farquhar and lowest at Alphonse and Cosmoledo, although particularly high effort was recorded at certain locations in certain years (See 5.1.2 Spatial Analyses and Table A.11.5).

P. filamentosus

High catches of *P. filamentosus* were achieved on the Mahe Plateau in 1990, the Banks in 1991, and the Amirantes in 1992, and the maximum catch per unit area was similar for each location. The total mortality, estimated from catch curve (Zcc) followed the order MP>Banks>Amirantes which might be predicted from the effort history, but estimates from the Powell-Wetherall method (Zpw) were similar at each location for these years. Annually aggregated data (All) used to compare Z by location did not follow the expected trend for either Zcc or Zpw.

Comparing annual data within locations, the catch removed may be used as a guide to expected fishing and total mortality if the natural mortality and the number of fish are assumed to be constant each year (C=FN, Z=F+M). The annual pattern of Zcc for the Mahe Plateau follows that of the catches (although the magnitude of changes is not the same) but Zpw does not. At the other locations mortality and catch estimates do not agree. For example, at the banks, the catch was high in 1991 but mortality was low, and high in 1992. In the Amirantes the catch was high in 1992 but mortality was lower that year than previously, and high (Zcc) in 1994. The question is whether this is an indication that the mortality estimates are inadequate, or whether, in the case of the banks, high catches in 1991 reduced the biomass (N) and so despite lower catches fishing mortality was greater the next year. Sample sizes were small for these locations and so inaccuracies in the estimates are possible.

Aprion virescens

Annual variation in total mortality generally agreed with the changes in catches of *A. virescens* from the Mahe Plateau, and Zcc and Zpw followed the same pattern but the latter method produced a lower estimate. In the Amirantes this was also true except in 1992 when catches were high but mortality estimates (Zcc, Zpw) were low. Comparing locations, mortality was greatest on Mahe Plateau > Amirantes > Providence / Farquhar. If these estimates are reliable, that for Providence in 1991 may be considered equivalent to M, natural mortality (PW, 0.29 - CC, 0.79) since prior fishing had been negligible, since 1977, if it occurred at all. However, as was the case with *P. filamentosus*, due to the small sample sizes and irregularities in the observed mortality patterns for locations other than the Mahe Plateau, these estimates may be inaccurate.

Lutjanus sebae

Sufficient length frequency data was available for only the Mahe and Amirantes Plateaux. Mortality of *L. sebae* was greater on the Mahe Plateau. Zcc better reflected changes in annual catches on the Mahe Plateau than did Zpw. This was also true for the Amirantes. Whilst catches on the Amirantes Plateau were less than those on the Mahe Plateau, abundance is also considered to be less. Notably, mortality estimates were not that dissimilar between the two locations for the catch curve analysis.

Epinephelus chlorostigma

Length frequency distributions for this species were classified as type C (Shepherd *et al*, 1987; see Annex 10) and are not strictly suited to growth or mortality estimation using length based methods. The catch curve and Powell-Wetherall methods each suggested an opposite spatial rank order and neither method agreed well with the observed pattern of catches. These data were not suitable for estimation of mortality.

Table A.11.1. Total mortality estimates for *Pristipomoides filamentosus* by location and year derived from catch curve analysis (Zcc) and the method of Beverton and Holt (Zbh) applied to length frequency data where L_∞=81.7 cm K=0.288 and Lc=41 cm; the ratio Z/K derived by the Powell-Wetherall method (and Zpw by division); and the estimated catch per unit area.

Year	Est.	2	3	4	5	6	7	8	9	10	11	13	14	MP	All
1990	Zcc	1.14				0.73	0.84	0.76	0.76	1.84	0.85	0.61	0.68	1	0.9
	Zbh	0.42				0.71	0.52	0.96	0.72	3.02	0.59	0.39	0.42	1.06	0.82
	Z/K	0.86				2.12	1.98	2.84	2.06	2.31	1.83	0.9	1.34	1.84	1.72
	Zpw	0.25				0.61	0.57	0.82	0.59	0.67	0.53	0.26	0.39	0.53	0.5
	kg/km^2											6.1		590.9	451.6
1991	Zcc	0.63	1.05	1	0.68	0.72	0.56	1	0.73		0.78	1.1	0.94	0.81	0.8
	Zbh	0.48	1.71	0.27	0.46	0.78	0.41	1.22	0.69		0.65	0.82	0.8	0.75	0.74
	Z/K	1.3	2.11	0.97	1.75	2.96	1.16	1.87	3.15		1.96	1.72	2.46	2.03	2.21
	Zpw	0.37	0.61	0.28	0.5	0.85	0.33	0.54	0.91		0.56	0.5	0.71	0.58	0.64
	kg/km^2										686.4	115.1	29	395.6	332.8
1992	Zcc	0.76	0.71	1.15	1.36	0.83	0.86	0.84	0.6	0.95	1.86	0.62		0.91	0.95
	Zbh	0.55	0.69	1.77	1.51	0.69	0.87	0.71	0.52	0.41	1.05	0.68		0.86	0.83
	Z/K	1.04	1.43	3.51	1.8	2.14	2.85	1.95	1.21	0.99	4.98	1.91		1.92	1.95
	Zpw	0.3	0.41	1.01	0.52	0.62	0.82	0.56	0.35	0.29	1.43	0.55		0.55	0.56
	kg/km^2										196.4	608.4	238	296.5	319.5
1993	Zcc					1.27	0.31		0.51		0.22			0.71	0.23
	Zbh					1.27	0.42		0.39		0.36			1.1	1.29
	Z/K					3.3	0.98		0.78		0.72			57.5	1.08
	Zpw					0.95	0.28		0.22		0.21			16.56	0.31
	kg/km^2										84.3	12.4		174.1	125.7
1994	Zcc			0.41	0.61	0.66	0.54	0.88	0.44	0.73	1.16	1.84		0.61	0.81
	Zbh			0.26	0.4	0.56	0.48	0.77	0.46	0.7	1.79	2.16		0.52	0.82
	Z/K			0.93	1.49	1.35	1.25	2.44	1.36	2.9	2.14	1		1.78	3.25
	Zpw			0.27	0.43	0.39	0.36	0.7	0.39	0.84	0.62	0.28		0.51	0.94
	kg/km^2											118.8		132.1	128.9
All	Zcc										0.88	1.04	0.81	0.7	0.79
All	Z/K										2.33	1.23	1.9	1.74	2.58
All	Zpw										0.67	0.35	0.55	0.5	0.74

Figure A.11.1. Catch per unit area by year and location : *P. filamentosus*

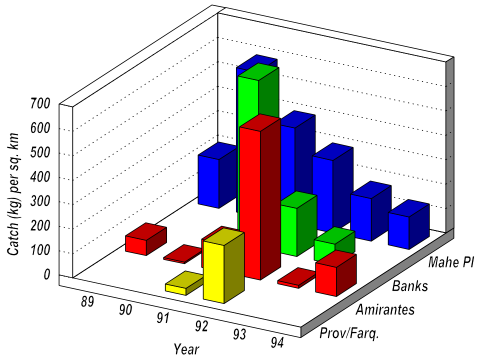


Figure A.11.2: Total mortality from catch curve by year and location : *P. filamentosus*

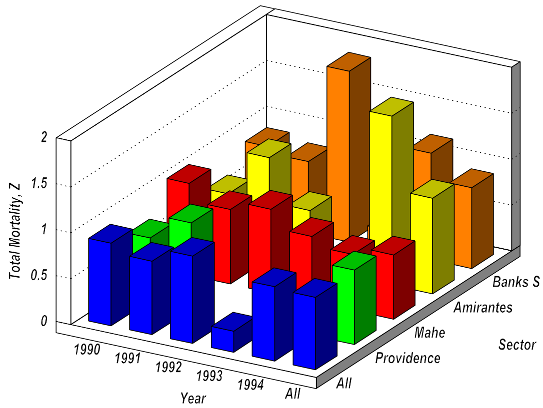


Figure A.11.3: Total mortality from Powell-Wetherall method by year and location : *P. filamentosus*

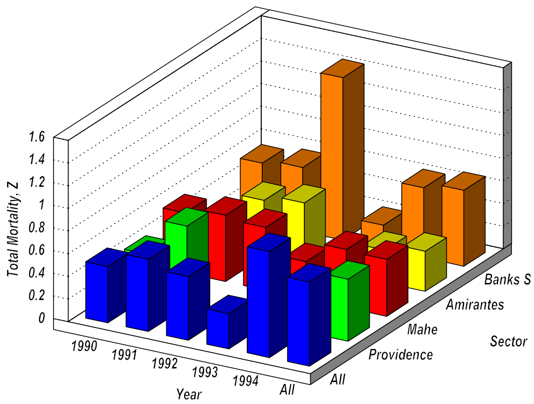


Figure A.11.4: Catch per unit area by year and location : *A. virescens*

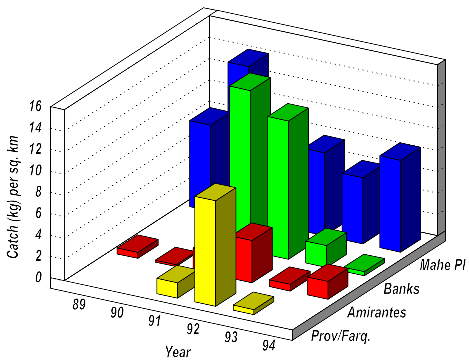


Table A.11.2. Total mortality estimates for *Aprion virescens* by location and year derived from catch curve analysis (Zcc) applied to length frequency data where L∞=104.0 cm, K=0.260 (All2, L∞=101.5, K=0.321); the ratio Z/K derived by the Powell-Wetherall method (and Zpw by division); and the estimated catch per unit area.

Year	Mortality Estimate	Banks S of MP	Amirantes Plateau	Providence /Farquhar	Mahe Plateau	All data	All (2)
1991	Zcc		1.75	0.79	1.86	1.69	1.79
1992			0.53		1.43	1.68	1.86
1993			0.51		1.56	1.69	1.83
1994			0.78		1.42	1.32	1.42
All			1.01	0.79	1.57	1.59	1.72
1991	Z/K		3.66	1.11	4.94	6.53	
1992			1.39		5.95	6.85	
1993			1.25		6.05	7.97	
1994			2.13		4.89	5.87	
All			2.29	1.11	5.46	6.8	
1991	Zpw		0.95	0.29	1.28	1.7	
1992			0.36		1.55	1.78	
1993			0.33		1.57	2.07	
1994			0.55		1.27	1.53	
All			0.6	0.29	1.42	1.77	
1989	Kg/km2		0.57		8.05	7.39	
1990			0.18		14.29	13.04	
1991		15.01	2.07	1.43	9.65	8.96	
1992		12.93	3.96	9.87	7.75	7.71	
1993		2.05	0.64	0.47	6.19	5.39	
1994		0.36	1.67		8.58	7.76	

Figure A.11.5: Zcc by year and location : *A. virescens*

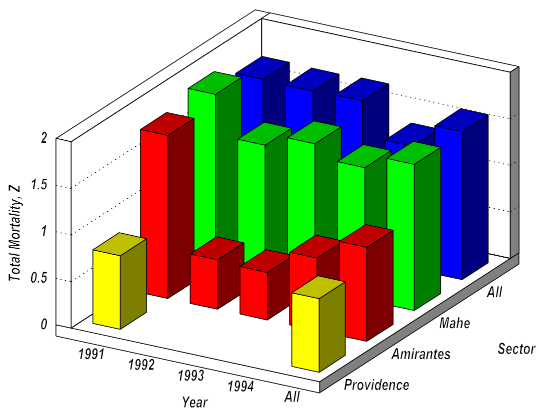


Figure A.11.6 : Zpw by year and location : *A. virescens*

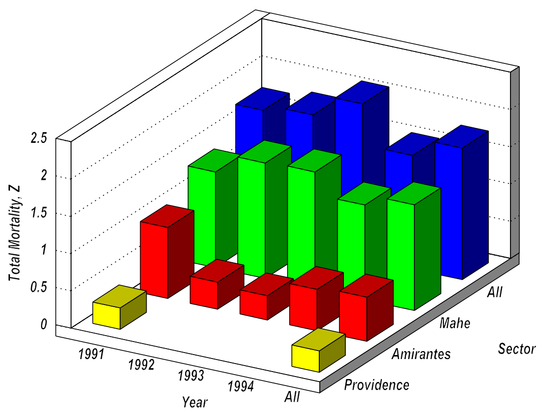


Figure A.11.7 : Catch per unit area by year and location : *L. sebae.*

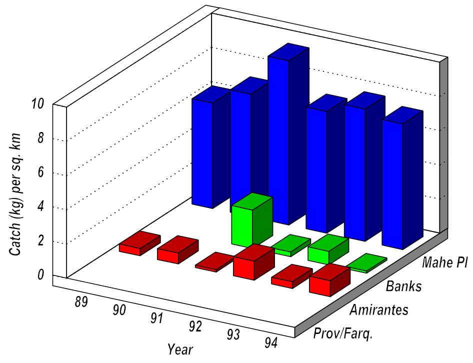


Figure A.11.8 : Zcc by year and location : *L. sebae*.

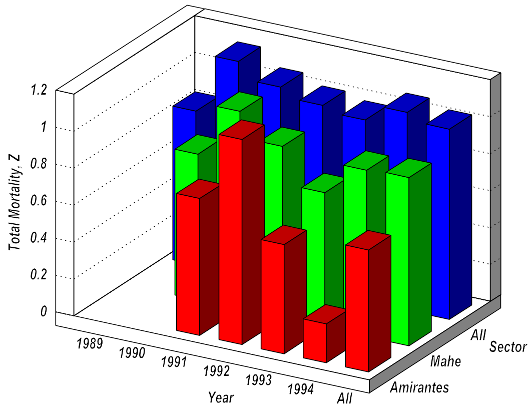


Figure A.11.9. Zpw by year and location : *L sebae*.

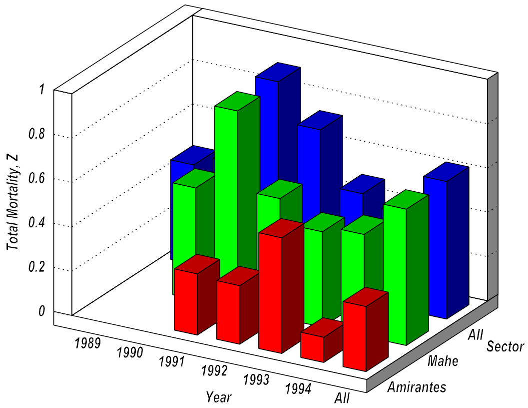


Table A.11.3. Total mortality estimates for *Lutjanus sebae* by location and year derived from catch curve analysis (Zcc) applied to length frequency data where L∞=97.41 cm, K=0.193 (All2, L∞=96.0, K=0.23); the ratio Z/K derived by the Powell-Wetherall method (and Zpw by division); and the estimated catch per unit area.

Year	Mortality Estimate	Banks S of MP	Amirantes Plateau	Providence /Farquhar	Mahe Plateau	All data	All (2)
1989	Zcc					0.83	1.06
1990					0.79	1.15	1.45
1991			0.74		1.07	1.06	1.29
1992			1.11		0.93	1.01	1.36
1993			0.59		0.73	0.98	1.31
1994			0.21		0.9	1.07	1.36
All			0.66		0.91	1.03	1.32
1989	Z/K					2.32	
1990					2.61	2.57	
1991			1.43		4.62	4.69	
1992			1.37		2.79	3.78	
1993			2.7		2.23	2.5	
1994			0.59		2.38	2.25	
All			1.52		3.18	3.22	
1989	Zpw					0.45	
1990					0.5	0.5	
1991			0.28		0.89	0.91	
1992			0.26		0.54	0.73	
1993			0.52		0.43	0.48	
1994			0.11		0.46	0.43	
All			0.29		0.61	0.62	
1989	Kg/km2		0.42		6.16	5.66	
1990			0.63		7.17	6.59	
1991		2.25	0.14		9.6	8.51	
1992		0.27	1.11		7.11	6.34	
1993		0.79	0.4		7.73	6.84	
1994		0.12	0.93		7.35	6.52	

Table A.11.4. Total mortality estimates for *Epinephelus chlorostigma* by location and year derived from catch curve analysis (Zcc) applied to length frequency data where L∞=64.5 cm, K=0.175; the ratio Z/K derived by the Powell-Wetherall method (and Zpw by division); and the estimated catch per unit area.

Year	Mortality Estimate	Banks S of MP	Amirantes Plateau	Providence /Farquhar	Mahe Plateau	All data
1990	Zcc					0.52
1991			0.34		0.46	0.44
1992			1.14		0.59	0.51
1993			0.52		0.58	0.63
1994			0.72		0.49	0.57
All			0.68		0.53	0.54
1990	Z/K					2.85
1991			1.13		2.94	5.11
1992			1.4		2.66	3.94
1993			1.57		5.06	3.79
1994			3.62		2.46	5.66
All			1.93		3.28	4.27
1990	Zpw					0.5
1991			0.2		0.51	0.89
1992			0.24		0.47	0.69
1993			0.27		0.89	0.66
1994			0.63		0.43	0.99
All			0.34		0.57	0.75
1989	Kg/km2		0.17		2.73	2.51
1990			0.14		2.8	2.57
1991		6.65	0.39	1.21	2.93	2.81
1992		1.71	2.8	8.2	2.6	2.77
1993		1.01	0.09	0.4	2.68	2.33
1994		0.08	0.62		1.04	0.97

Figure A.11.10 : Catch per unit area by year and location : *E. chlorostigma*

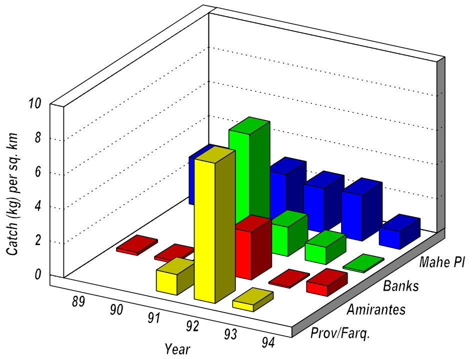


Figure A.11.11 : Zcc by year and location : *E. chlorostigma*.

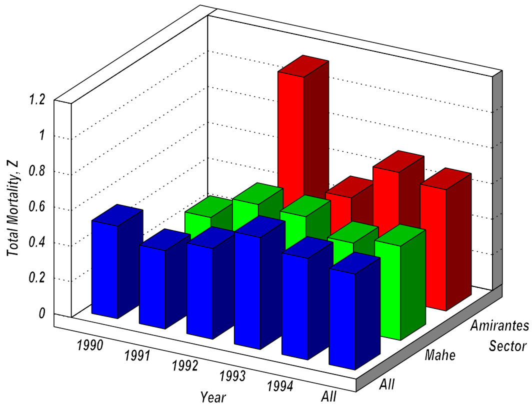


Figure A.11.12 : Zpw by year and location : *E. chlorostigma*.

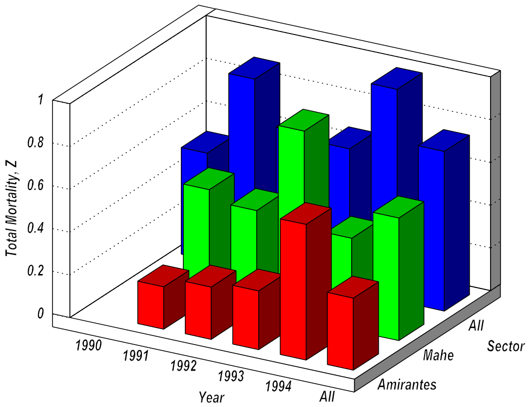


Table A.11.5 : To indicate the mean annual fishing effort by major location (Bank or plateau)

Location	Period	Mean annual catch rate per sq. km				Effort
		Demersal species All depths	Shallow demersal species	Intermediate depths	Total Catch	MEAN MD /KM^2/YR
Alphonse/Cosmoledo	1977-1993	3.1	3.4	0.0	3.33	0.0271
Providence/Farquhar	1977-1993	17.7	17.4	22.5	18.91	0.1214
Amirantes Plateau	1985-1993	12.3	10.0	93.3	14.48	0.1558
Mahe Plateau	1985-1993	34.4	32.7	222.8	40.27	0.3682
Banks / Platte	1985-1993	13.7	9.3	85.9	16.31	0.1506