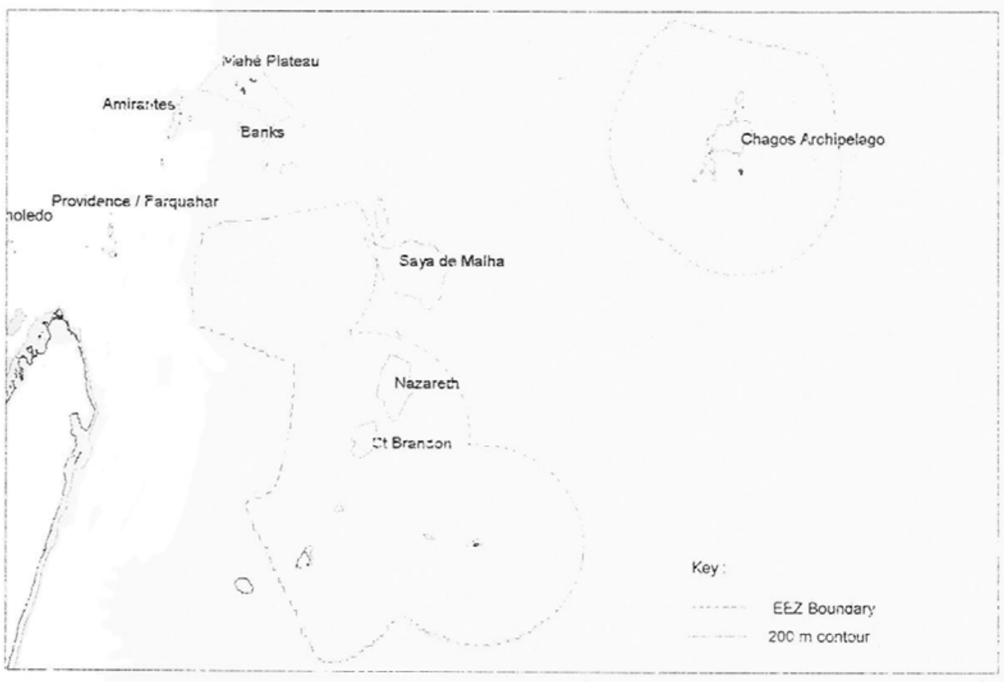
THE MAURITIAN BANKS FISHERY

A REVIEW, AND SPATIAL ANALYSIS



TECHNICAL REPORT

ALBION FISHERIES RESEARCH CENTRE, MAURITIUS /
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FOR

MANAGEMENT OF MULTI-SPECIES TROPICAL FISHERIES - OVERSEAS DEVELOPMENT ADMINISTRATION, FISH MANAGEMENT SCIENCE PROGRAMME PROJECT R5484

MRAG LTD

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CONTENTS

Introduction

The Mauritian banks fishery, its history, and its fleet have been reviewed and described (Wijkstrom and Kroepelein, 1979; Samboo, 1983; Samboo, 1987; Samboo, 1989). Economic and market considerations have been examined (Mondon, 1989; Morel, 1989) and management plans proposed (Sanders, 1989). The present report summarises the available information in the context of the Management of Multi-species Tropical Fisheries project. Some reworking of the data is performed (Part 1). Three years of catch and effort data were available to the project at the time of writing, and analysis of this is also presented in the wider context of Indian Ocean banks fisheries (Part 2).

PART 1. A REVIEW OF AVAILABLE INFORMATION RELATING TO THE MAURITIAN BANKS FISHERY.

Geography / hydrology / climate

The Mauritian banks fishery occurs on the shallow water banks (50m) of the Mascarene Ridge and in the waters of the Chagos Archipelago. The banks are characterised by a central region with sand or shell bottoms, 50-60m deep, surrounded by a shallower coralline rim sloping to around 150m, and a steep outer slope.

The region is subject to the northwest monsoon (from mid November to mid March) and south east Trade Winds (from the end of May to October). In the south the latter may cause cyclones limiting fishing activity. The fishing season is dictated by weather conditions and typically extends from mid September to early June on the Mauritian Banks (St Brandon, all year; Nazareth, October to April; Saya de Malha, September to June). Some of the vessels move to the Chagos Archipelago during the period June to August, although in recent years they have been going as early as April.

Available oceanic data relating to the Indian Ocean is indicated in Part Two. However, locally the presence of the banks and islands may affect productivity and oceanic parameters, and there is a need for more detailed information specific to the banks. The whole of the area is characterised by poor hydrographic conditions, and primary productivity is low (0.15mg C m^{-2} d^{-1}, in Ardill, 1979). Thus except in areas of upwelling, large fish populations are not to be expected.

Fig. 1 : The western Indian Ocean indicating the banks of the Mascarene Ridge and the Chagos Archipelago.

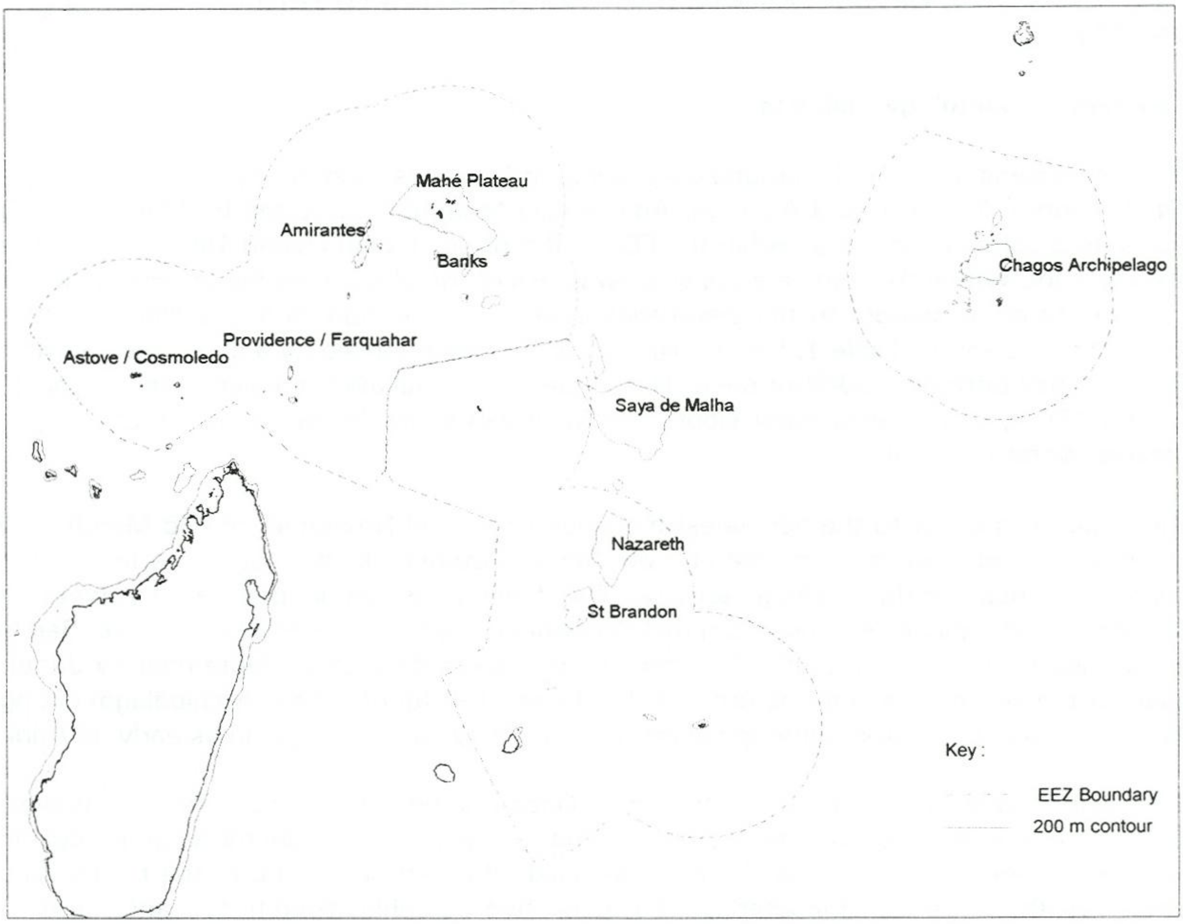


Table 1. The areas (km^2) of the fishing banks of Seychelles and Mauritius along the Mascarene Ridge, and additionally the banks of Cosmoledo/Astove, Providence/Farquahar and the Chagos Archipelago. For banks exploited by Mauritian vessels details of fishing grounds are also shown. Areas (0-75m and 75-150m) were computed from Admiralty Charts by MRAG. Distance (km) from fishing grounds is from Samboo and Mauree (1988).The Code relates to the Indian Ocean analysis (Part Two).

BANK	FISHING GROUNDS	Area-75	A75-150	Distance	Code
Banks west of the Mascarene ridge					
Cosmoledo/Astove		398	32		1
Providence / Farquahar		1621	132		2
Amirantes		3999	136		3
		41338	374		4
Banks on the Mascarene ridge					
Mahe Plateau					
Banks South of Mahe Plateau		2199	135		5
Saya De Malha	Saya North	4965	93	1050	6
	Saya South	37151	257		
	TOTAL	42116	350		
Nazareth	Nazareth	22814	187	650	7
St. Brandon	Albatross	4606	51	370	8
	St. Brandon	4606	50		
	TOTAL	9212	101		
Banks east of the Mascarene ridge					
Grand Chagos Bank	Central Chagos Bank	262	0	2100	9
	East Chagos Bank	445	57		
	North Chagos Bank (inc Nelson Is)	1343	25		
	North-East Chagos Bank	1181	40		
	South Chagos Bank	895	15		
	SE Chagos Bank	1181	23		
	West Chagos Bank	662	30		
	Total	5969	190		
Emergent Islands/reef	Blenheim Reef	42	7		
	Egmont Islands	48	6		
	Peros Bahnos	442	25		
	Salomon Islands	17	7		
	Total	549	45		
Other banks	Cauvin Bank	56	7		
	Centurion Bank	29	6		
	Colvocoresses reef	14	6		
	Gangees Bank	16	4		
	Pit Bank	1296	49		
	Speakers Bank	562	27		
	Victory Bank	21	5		
	Wight Bank	2	0		
	Total	1996	104		
	TOTAL CHAGOS	8514	339		

Historical development of the Mauritian Bank fishery

Sporadic exploitation of the banks fisheries has occurred from vessels engaged in inter island trade since the 18th Century. Fish was salted, and came mainly from the copra islands of Chagos, Agalega and St. Brandon. Trawling on the Nazareth bank was unsuccessfully attempted in 1931, and it was following the survey of Wheeler and Ommaney (1953) that systematic exploitation began (Ardill, 1979). It was not until 1960 and 1962 that frozen banks fish were produced for the Mauritian market, but the venture was commercially unsuccessful due to market resistance (Ardill, 1986). Today this is the standard means of preservation.

Exploitation occurs from refrigerated mother-vessels, 20-60m in length, carrying up to 20 6-8m pirogues or dories. Commonly the mother-vessels are converted second hand tuna long-line vessels. Each dory carries 3 men who fish using hand-lines rigged with 8-10 baited hooks. Other methods have been tried but found not to be commercially suitable (Ardill, 1986). Apart from the Saya de Malha bank, fishing has occurred from Mauritian or chartered vessels only (during the late 1970's in addition to Mauritian vessels, the fleet included two chartered Korean vessels). On Saya de Malha vessels from Reunion and occasionally Seychelles have also exploited the resources (and Russian trawling ventures have occurred in the past, but for other species).

The annual catch from the banks only became substantial in the late 1960's. The number of vessels fell from 8 in 1977 to 3 in 1980, which included the two charter vessels. Catches fell from 3835 to 1686 tons. In 1982 steps were taken to revitalise the banks fishery (IMAS, 1990; see also, Wijkstrom and Kroepelein, 1979) including decontrolling the price of fish, reducing harbour dues, removing duty on fishing gears, equipment and spare parts, waiving import duty on vessels acquired by Mauritian companies, and providing adequate port facilities. Reinvestment in vessels occurred and the fleet has grown to 17 in 1995, although not all vessels have actively fished each year (Table 2). Presently, the fishery employs around 1000 fishermen, of which only about 500 are regularly active and spend about 150 days fishing per annum. Around 150 fishermen are engaged from the Republic of Madagascar.

Table 2. The number of mother-vessels in the Mauritian banks fishery.

Year	No. Vessels	Source
1977	8	Ardill, 1986
1980	3	Ardill, 1986
1984	9	Samboo and Mauree, 1988
1985	13	Samboo and Mauree, 1988
1986	15	Samboo and Mauree, 1988
1992	16	Samboo, 1993
1994	16	Samboo, 1995
1995	17	AFRC data.

Wijkstrom and Kroepelein (1979) indicated that the optimum size for a mother-vessel was 40m LOA. Changing economic conditions may mean that these parameters no longer apply. The present fishing vessels and their size are indicated in Table 3.

The banks fishery contributes in excess of 60% of the marine catch of Mauritius (excluding tuna). Fish production, however, does not satisfy internal demand. Exports of fish are controlled and it is necessary to import the deficit to requirements (Morel, 1989).

Table 3. Mauritian banks fishing vessels active in 1995, indicating their size : Length overall (LOA). The number does not refer to the vessel code used in subsequent effort standardisation analyses (Part 2, Table 13).

No.	Company/Vessel	Size LOA (m)
	Sea Falcon Fishing Co.	
1	Star Hope	40.0
2	Jabeda	44.0
3	Faki	49.0
4	Faki 2	
5	Faki 3	
	Talbot Fishing Co.	
6	Reef	42.0
7	Talbot 3	46.0
8	Talbot 4	48.0
	IKS Fishing Co.	
9	Hoi Siong 1	50.2
10	Hoi Siong 2	54.3
	Noor Star Fishing Co.	
11	Noor Star 1	42.5
12	Noor Star 2	50.8
	Compagnie de Peche Hautiere	
13	Phoenix 1	44.0
	SODIPECHE	
14	Gentilly	50.7
	Hensinchang Fishing Co.	
15	Hensinchang	43.0
	Pasifoo Fishing Co.	
16	Pasifoo	
	Sea Lord Fishing Co.	
17	Shandrani	48.8

Species composition

The species composition of the catch of the Mauritian banks fishing vessels is a result of the combination of fishing method (handlines), depth fished, and fishing location. The rough coral and rubble grounds of the Mascarene Ridge support populations of lutjanids, lethrinids and serranids taken by handlines, and scarids, trigger fish, goat fish and unicorn fish not usually accessible to the line fishery. Species of these families, and additionally nemipterids and round scads are also reported from the shallow sandy areas of the banks accessible to trawlers. A number of trawl surveys of demersal fish resources have been performed in Seychelles and Mauritius and document a large number of demersal species (Birkett, 1979; Kunzell, et al, 1983; see also, FAO/IOP, 1979; Tarbit, 1980). However, commercial trawling is not permitted in Seychelles and does not occur in Mauritius although plans to evaluate the financial feasibility of this pelagic trawls for small pelagics were performed (Guidicelli, 1984). As indicated, the variety of fish available to a handline fishery is limited. Furthermore, fish population densities are less on the sandy trawlable areas than rough grounds, and so the handline fishery is only feasible over parts of the total bank area which have suitable habitat.

Species composition also varies with latitude. Birkett (1979) reports that lutjanids were the predominant type of demersal fishes taken in trawls on the Seychelles bank, but were of little importance except locally on the Saya de Malha bank, and virtually absent further south. However, populations of lutjanids and serranids do occur on the deep outer slopes of all banks in the Mascarene region. Despite good catch rates, these tend to be avoided in the south by Mauritian vessels due to the potential for ciguatera poisoning (SWIOP, 1982), and the Mauritian banks fishery operates predominantly in shallow water (<50m). The species composition of catches from the Chagos Archipelago is similar to that from the Seychelles.

Thus, the more northerly Seychelles Banks and the Chagos Archipelago are predominantly multi-species in nature with snappers being the most commonly caught demersal fish. Further south on the Mauritian banks emperors are the most common, and the single species, *L. mahsena* is reported to constitute around 80-90% of the catch from shallow water (Ardill, 1986; Bertrand et al, 1986). Table 4 indicates the species composition of catches by bank. Typically statistics divide the catch into white fish (usually lethrinids , mostly *L. mahsena*) and red fish (snappers and groupers). In the Chagos, the red fish *Lutjanus bohar* can apparently be caught in large numbers (up to 50% of the catch) but is avoided due to the potential for ciguatera (Samboo, 1989). Since 1994 the British and Mauritian Authorities have operated a joint observer programme for fishing on the Chagos banks. Detailed species composition information not available from logbook returns is collected by the observers (MRAG, 1994a; MRAG 1995a). In 1995 36 demersal species from the families Lethrinidae, Lutjanidae and Serranidae were identified and lutjanids formed 44% of the catch, lethrinids 28%, serranids 16% and other fish 12% (Table 5). Deeper water species were targeted that year, hence the relatively high proportion of *Pristipomoides* spp.. Normally shallow water species are the target, and species composition varies by location within Chagos. *L mahsena* is important from the Grand Chagos bank, but in 1994 its proportion in the catch did not exceed 25% (Maximum 24.5% at Eastern Chagos Bank, MRAG, 1995a).

For the purposes of the multi-species tropical fisheries project, the Mauritian banks handline fishery can thus be regarded as mono-specific, whilst the Chagos Archipelago has a multi-species fishery similar to that of Seychelles.

Table 4 : Species composition observed at different fishing banks for the Mauritian mothership-dory ventures (From Samboo, 1989)

Species	Nazareth & SDM	St Brandon Summer	St Brandon Winter	Chagos
L. mahsena	88	82	86	50
oth. lethrinids	2	2	2	2
Serranidae	4	1	2	26
Carangidae	2	4	0	4
Aprion virescens	1			6
Siganidae		3	2	
Scaridae		4		
Mugilidae			1	
'Licorne'			1	
Lutjanus bohar	n			(50)
Pristipomoides spp.	n			10
Tuna	n			2
others		3	6	

Table 5 : Principle species composition recorded during the Inshore Fishery Observer Programme at Chagos from vessel Talbot IV in 1995 (from MRAG, 1995a).

Species	% of Catch	Total by family
Lethrinidae		28.21%
L. mahsena	12.03%	
L. rubrioperculatus	10.21%	
Other lethrinids	5.97%	
Lutjanidae		44.27%
A. virescens	4.88%	
P. filamentosus	28.19%	
P. multidens	7.52%	
Other lutjanids	3.68%	
Serranidae		15.85%
E. morrhua	4.06%	
Variola loutii	3.34%	
E. chlorostigma	1.76%	
Other serranids	6.69%	
Pelagics/others	11.74%	11.74%

Data Collection

Catch and some effort statistics are available since 1937 for St. Brandon and for the Nazareth and Saya de Malha banks together from 1967 (Ardill, 1979). Statistics on the banks fishery were routinely collected since 1977. Improved data collection procedures were introduced in 1988 and a computerised system was introduced in 1989 (MAU_BANK, Carrara and Ardill, 1989). However, this was not used and only paper records have been maintained. At the time of writing, catch and effort data for the period 1992-1994 was available for analysis in computerised format.

Data collected is vessel characteristics, trip information and catch and effort. These data are recorded in MAU_BANK. Additionally length frequency data is collected for *Lethrinus mahsena* and recently for *L. variegatus*. This is collected in port. Biological data relates to unsexed fish since they are gutted at sea. Other than recent joint British/Mauritian observer programmes in the Chagos Archipelago, no at sea biological data collection occurs.

Carrara and Ardill (1988) recommended that additionally vessel landings should be recorded to cross-check against logbook data since in the past there was some mis-reporting. The AFRC database (1991 to 1994 available to date) compiled from logbook returns does not always agree with the published data. The latter has been corrected for misreporting or non-furnished logbooks (Venkatasami, pers. comm.).

Catch and effort data

Catch and effort statistics reported in the literature are inconsistent. Available information is given in Table 6. Effort statistics are only available for certain years, and catch statistics quoted in different reports vary, sometimes considerably. The data were compiled from (a), 1969-1976 : FAO/IOP (1979); (b), 1984-1986 : Samboo and Mauree (1988, Catch refers to whole weight); (c.)1977-1988, Samboo (1989); (d) 1989-1991, Samboo, unpublished data; (e) 1992, Samboo (1993); (f) 1993-1994, from MAU_BANK database; (g) 1969-1976, Ardill (1979); (h) *L. mahsena* (and some *L. variegatus*), gutted weights, showing catch and effort values for Mauritius and Reunion combined, Samboo and Biasis in Samboo and Mauree (1988); (i.) 1977-1986, Ardill (1986); (j) 1991-1994, from BIOT Inshore logbooks, in MRAG (1994a;1995a). Table 7 represents a synthesis of all the available information. However, the variation in reported catch and effort values by different authors indicates the pressing need to computerise all available paper records of data and to verify estimates of catch and effort.

Catch data for the Mauritian banks should be complete. However, for Saya de Malha bank, vessels from Reunion and Seychelles are known to have fished in certain areas. In 1996 a Sri Lankan vessel is known to have fished on Saya de Malha (British Indian Ocean Territory (BIOT) Fishery Patrol Vessel Report, unpublished). The total catch from this bank is thus under-estimated in Table 7. In addition to the Mauritian catch, about 800 tonnes was landed in Reunion from the Saya de Malha bank up to 1987, and in 1989 about 300 tonnes (in Sanders, 1989; Samboo, 1989).

Table 6 : Catch and effort statistics reported in the literature for the Mauritian Banks handline fishery (see text for references)

Bank	Details	Source	1969	1970	1971	1972	1973	1974	1975	1976
Nazareth (mainly) and	Catch (t)	g	652	756	639	679	714	699	2094	2460
Saya de Malha (some)	Effort (md)	g	8059	9764	6787	5739	7552	8057	27648	38742
Nazareth	Catch (t)	a	700	850	1341	1447	1147	1920	1710	1200
	Effort (md)	a	8653	10978	14423	12231	12132	22130	22577	18898

Bank	Details	Source	1977	1978	1979	1980	1981	1982	1983	1984	1985
Nazareth	Catch (t)	b								1236	1201
	Catch (t)	c	1482	1198	1407	955	874	1282	920	1104	1072
	Catch (t)	c						1196			
	Catch (t)	d,e,f									
	Effort (md)	c				9206	8521	8980	6320	10822	10740
	Effort (md)	e,f									

Bank	Details	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994
Nazareth	Catch (t)	b	1344								
	Catch (t)	c	1200	1475	1429						
	Catch (t)	c			1448						
	Catch (t)	d,e,f				84	555	793	980	1245	1575
	Effort (md)	c	10868	17347	13404						
	Effort (md)	e,f							12648	20150	22947

Table 6: Continued

Bank	Details	Source	1977	1978	1979	1980	1981	1982	1983	1984	1985
Saya de Malha	Catch Lm	h	1700	1490	1170	920	2060	2500	1570	2635	2222
L. mahsena	Effort (dory-d)	h	5513	5207	4095	2253	5133	6694	4712	7297	18307
	stdz Effort	h	4787	4158	3209	2004	3920	5247	3432	4814	4950
Saya de Malha	Catch (t)	b								933	2472
Total catch	Catch (t)	c	1587	1529	372	277	378	1701	1245	833	2207
	Catch (t)	c						1587			
	Catch (t)	d,e,f									
	Effort (md)	c				3865	3288	15302	12897	9463	22092
	Effort (md)	e,f									

Bank	Details	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994
Saya de Malha	Catch L m	h	3390								
L. mahsena	Effort (dory-d)	h	12477								
	stdz Effort	h	7908								
Saya de Malha	Catch (t)	b	3099								
Total catch	Catch (t)	c	2767	3363	2651						
	Catch (t)	c									
	Catch (t)	d,e,f				2177	873	1782	2825	3069	3158
	Effort (md)	c	27885	36383	27995						
	Effort (md)	e,f							41715	44255	46198

Table 6: Continued

Bank	Details	Source	1977	1978	1979	1980	1981	1982	1983	1984	1985
St Brandon	Catch (t)	b								580	852
	Catch (t)	c	95	97	77	172	140	43	112	283	386
	Catch (t)	c				173	22	17	92	32	144
	Catch (t)	d,e,f									
	Effort (md)	c				1646	329	210	1740	1214	2148
	Effort (md)	e,f									

Bank	Details	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994
St Brandon	Catch (t)	b	1034								
	Catch (t)	c	533	374	720						
	Catch (t)	c	167	149	264						
	Catch (t)	d,e,f				407	499	369	446	827	406
	Effort (md)	c	2163	1599	4163						
	Effort (md)	e,f							4398	15041	6846

Bank	Details	Source	1977	1978	1979	1980	1981	1982	1983	1984	1985
Chagos	Catch (t)	b								160	183
	Catch (t)	c	32				81	135		143	163
	Catch (t)	c						121			
	Catch (t)	l	38				98	162		172	202
	Catch (t)	j									
	Catch (t)	d									
	Effort (md)	c					1368	3086		3456	3156
	Effort (md)	d*,j									

Table 6: Continued.

Bank	Details	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994
Chagos	Catch (t)	b	142								
	Catch (t)	c	127	237	314						
	Catch (t)	c									
	Catch (t)	l									
	Catch (t)	j						299	305	200	305
	Catch (t)	d				133	256				
	Effort (md)	c	2604	4907	5454						
	Effort (md)	d*,j				6090	2790	5602	7893	3910	6603

Bank	Details	Source	1977	1978	1979	1980	1981	1982	1983	1984	1985
Albatross	Catch (t)	c			0.4	0.9			3	0.4	2
	Catch (t)	d,e,f									
Agalega	Catch (t)	c							4		

Bank	Details	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994
Albatross	Catch (t)	c		2	26						
	Catch (t)	d,e,f				130	111	161	194		

Table 7 : A synthesis of catch and effort statistics for the Mauritian banks handline fishery form a number of sources.

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 Malha**									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 Malha**	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

* Indicates estimate of effort was calculated from Catch information, assuming average catch rates reported in other years
** Saya de Malha statistics exclude catch and effort by Reunion and Seychelles vessels

Table 7. Continued

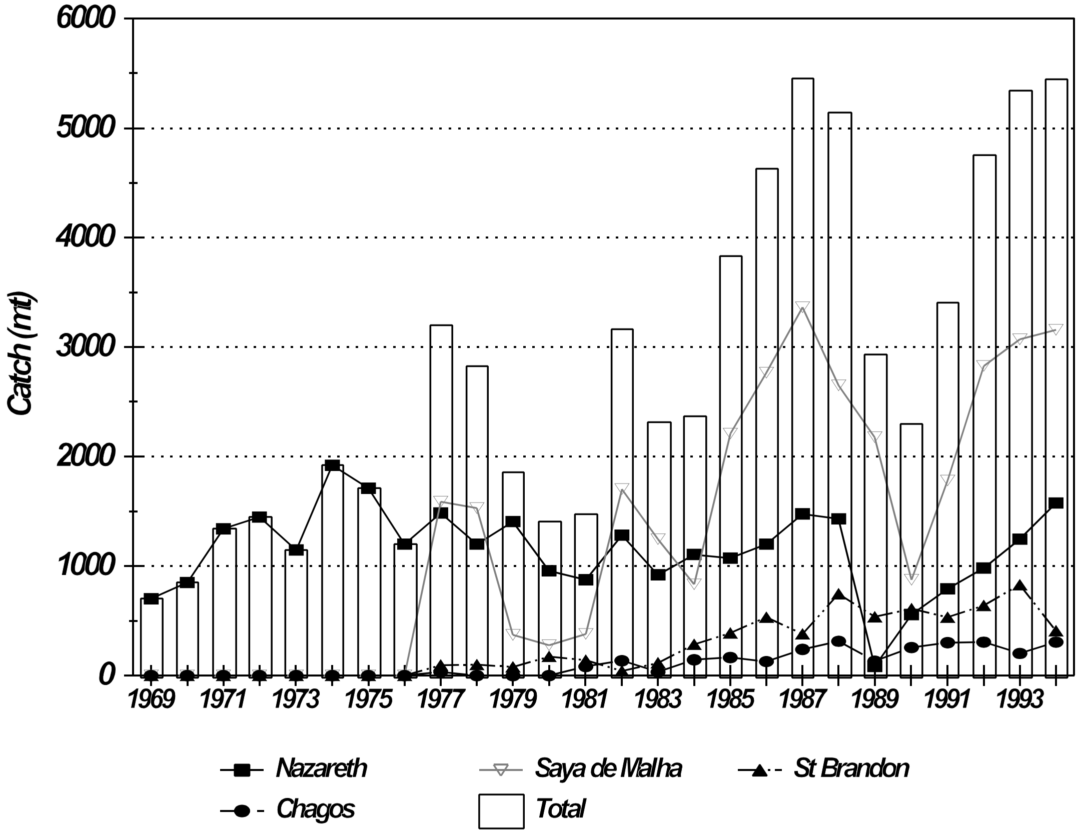
Catch (Tonnes)

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 Malha									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 Malha	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

The total catch peaked in 1987 at around 5,140 tonnes, subsequently falling but rising again to similar levels in 1993 and 1994 (Fig 2). The greatest volume of fish is caught at Saya de Malha (~3,360 tonnes in 1986, 3,158 in 1994) and then Nazareth (1,920 t in 1974; 1,575 t in 1994) banks. Exploitation is least on the Chagos banks (314 t in 1988, 305 t in 1994). The catch per unit area of fishable habitat is similar for the banks exploited by Mauritius on the Mascarene ridge (~ 150 kg km^{-2}) but considerably lower in Chagos (maximum of 42 kg km^{-2} in 1988, see below).

Fig. 2 : Total catch and catch per bank (tonnes-mt)



If catchability remains constant, catch rate is an index of the abundance of the resource. Thus at any one location, a declining catch rate would suggest that the biomass of the resource was also decreasing. Similarly, comparing two locations, different catch rates would suggest different abundance of the resources, assuming other factors such as environmental and habitat characteristics were similar. Catch rate, however, is a function of a number of variables including the fishing power of the vessel, the gear used, annual and seasonal effects, depth effects, and spatial differences in the environment and habitat, both between banks, and at different locations on the same bank. Ideally, catch rates should be standardised to take account of any variations in these variables. Part two of this report examines the relative fishing power of the vessels in the fleet and standardises catch rates in order to compare the different banks. Un-standardised catch rates are indicated in Figs 3 and 4 and Table 8.

Fig. 3 : Catch rates per annum on the Saya de Malha, Nazareth and Chagos banks.

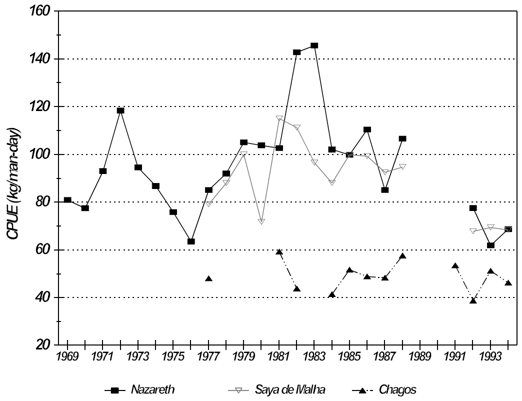


Fig. 4: Annual catch rate at St. Brandon and Albatross (effort may have been under-estimated)

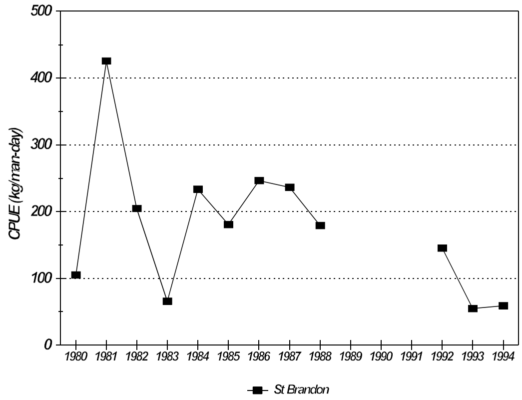


Table 8. Catch rates (kg per man-day) for Mauritian mothership-dory ventures calculated from available catch and effort information from 1969 to 1994.

Bank	max	min	mean	In 1994
Nazareth	146	62	95	69
Saya de Malha	115	68	89	68
St Brandon	426	55	178	59
Chagos	59	39	49	46

Over time, catch rates have fluctuated at all locations. On the Nazareth, Saya de Malha and St Brandon banks, catch per unit effort was greatest in the early 1980's. This was the period of new investment in the fishery. Whilst all boats use the same fishing method (handlines from dories), some vessels nevertheless perform better than others (see Part Two), and so increases in catch rate around that time may relate to the relative fishing power of new vessels entering the fishery, or may be related to other factors such as the skipper of the vessel. Also exploitation was light towards the end of the 1970's when only three boats were operating. Subsequently catch rates have declined at each of these locations suggesting that the biomass of the demersal fish resources has declined. In 1988, the biomass of fish species available to the handline fishery on the Saya de Malha bank was thought to be 40% of the unfished biomass (Bautil and Samboo, 1988).

For the Chagos Archipelago, catch rates have fluctuated over time but have remained basically the same since 1977. Fishing has been intermittent and relatively light, and has not occurred every year at this location. On the scale of the Archipelago there is no evidence of resource depletion from catch rate data. MRAG (1994a, 1995a) have examined the data available for the Chagos banks from 1991-1994 in more detail. At discrete fishing locations within the Archipelago, over the 4 year period, catch rates have similarly fluctuated, but no one location indicates a consistent decrease in catch rate. Although the time series is rather short, this supports the assertion that resource depletion has not occurred. However, catch rates differ between locations within the Archipelago. In order to determine whether these differences relate to differences in abundance resulting from fishing activity, or due to environmental differences requires a more detailed study. Furthermore, since the data are unstandardised, it may be that fishing depth affects catch rates between locations. For example, the catch rate around Peros Banhos (21.5-45.2 kg per man-day) is less than that around Nelson Island on the Great Chagos Bank (40.1-57.4 kg per man-day). However, at Peros Banhos there is effectively no shallow bank area and fishing occurs in deeper water than on the Great Chagos Bank.

Comparing catch rates by location, those for St. Brandon are the highest. However, in the reported statistics there is a separation of data between St Brandon and Albatross. It is not clear that catch and effort are accurately reported and thus the estimates of catch rates may be invalid. Furthermore, effort in the reported statistics may relate to basket traps, and thus will not be directly comparable to handline data from other banks. Thus, discounting St Brandon, catch rate data suggest that demersal resources are more abundant and similar at each of Nazareth and Saya de Malha, and the least at Chagos. Fishing in Chagos principally occurs during the period of the South East Trade Winds when catch rates are known to be depressed elsewhere (eg. Seychelles, Mees, 1992). However, standardised catch rate data reported in Part Two confirms that catch rates in Chagos are lower than the other Mauritian Banks. This suggests that either :

- the banks of the Chagos Archipelago are less productive than other Indian Ocean Banks and have lower abundance of demersal species. Indeed, oceanic data indicates that primary and tertiary production are less in this region. However, localised productivity over the banks would not be apparent from this data and there is a need to investigate this in more detail. It has been noted that species composition varies with latitude and that banks in the south are predominantly mono-specific whilst those nearer the equator are multi-species in nature, and thus productivity may be related to this. However, this would not appear to be the case. Catch rates are high on the multi-species Seychelles banks. Lower productivity is considered a likely explanation in the case of Chagos, and is considered to be the case by other authors (eg. Samboo, 1989).

- or that abundance on the Chagos banks is similar to other Indian Ocean Banks, but catch rates differ due to other factors such as avoidance or discards. Mauritius prohibits certain species (see below) due to the potential that they may contain the ciguatera toxin. The abundance of lethrinids, such as *L. mahsena*, targeted on southern banks is less in the multi-species Chagos. If these species remain the target, and/or non target species are discarded, catch rates will be lower than at other banks. Discards at sea are believed to represent about 5% or less of the catch when deeper water *Pristipomoides* spp. are targeted, and between 15-20% when shallow banks species are targeted (Robert Talbot, Pers. Comm.). This requires further investigation.

- or that illegal fishing activity has depleted the resources. If this is true, such activity must have occurred prior to 1977, and must have occurred at a similar rate each year since that time. Whilst it is known that some illegal fishing has occurred from Sri Lankan vessels, this problem is considered to be a recent one (1995/6) due to more strict enforcement of fishing zones in northerly locations, such as the Maldives, forcing the fishing fleets further south. Illegal fishing is not considered to have been significant in the past. Furthermore, vessels detained by the BIOT Authorities in 1996 were principally fishing with pelagic long lines and drift nets. Sharks and pelagic species were the target, confirmed by the contents of the hold. Demersal species were not found on board in quantity. Illegal fishing is not considered to be an explanation for the lower catch rates.

Table 9 : Available biological and population parameters for *L. mahsena* (*L. enigmaticus*) from the Mauritian banks handline fishery.

Species	*L. mahsena*									*L. enigmaticus*	
Location	Nazareth	SDM	Nazareth	SDM	SDM	SDM	SDM	SDM	SDM	SDM	SDM
Source	Samboo, (1987)	Samboo, (1987)	Bautil and Samboo (1988)	Bertrand et al, 1986	Bertrand et al, 1986	Bertrand et al, 1986	Bertrand et al, 1986	Bertrand et al, 1986	Bertrand et al, 1986	Lebeau and Cuef (1975;1976)	
Sex	Unspecified	Unspecified	both	females	males	both	females	males	both	males	females
Period				Oct-Nov 1983	Oct-Nov 1983	Oct-Nov 1983	Nov 1984	Nov 1984	Nov 1984		
Length-weight	(W=kg,L=cm)	(W=kg,L=cm)		(W=g,L=cm)	(W=g,L=cm)						
a	0.0000806	0.0001539		0.012	0.016						
b	2.74	2.63		3.16	3.077						
Growth											
K			0.1	0.1	0.16	0.1	0.13	0.12	0.1		
Loo			61.7	55.4	50	59.8	50.4	55.6	61		
to			-0.71	1.4	0.2	-1.8	-0.9	-1	-1		
Mortality											
M			0.22 for ages<8.5			0.2 for ages>8.5			0.7	0.2	0.2
Z			0.45								
F			0.23 For 1982-3			0.4 For 1983-4			0.3	0.2-0.3	0.2-0.3
Reproduction											
L 1st Mature										30	25
Length at capture											
Lc50			29.5								
Lc75			31.2								
Maximum age/length											
Tmax										15	11
Lmax										48.9	44.0

Biology / population demographic parameters

Available biological and population parameters for *L. mahsena* are indicated in Table 9. Additionally*, Lethrinus enigmaticus* (Lascar) on the Saya de Malha Bank was studied by Lebeau and Cuef (1975; 1976). Ardill (1986) suggests that *L. mahsena* is the same as *L. enigmaticus* and *L. croccineus*, or that it has been mis-identified as these species.

L. mahsena is a protogynous hermaphrodite. Few females exceed 35cm fork length (age 8 years) and few males are less than 20cm FL (age 3 years). Sex reversal occurs at 5-6 years of age. A single spawning season occurs from October to February (Bautil and Samboo, 1988). Commercially landed fish have been gutted and so sex and reproductive status cannot be determined. Samboo (1987) reported the weight ratio of whole to gutted fish was 1:1.2.

The average weight and length of *L. mahsena* from Saya de Malha bank has apparently declined, and together with the evidence for decreasing catch rates this suggests that the fishery is under some stress and possibly over-exploited. However, no decrease in size has been observed for fish from Nazareth bank. Effort is limited to a shorter fishing period here (Samboo, 1989).

FISHBASE (1995) records growth parameter information for *L. mahsena* from the Yemen only, suggesting that outside Mauritius this is a little studied species. L_∞ was 58.9cm, similar to that estimated in Mauritius, but K was 0.32, around 3 times greater than the estimate for Mauritius.

Productivity and resource assessments

The distribution of fish on the banks of the Mascarene Ridge and Chagos Archipelago is controlled by substrate. Suitable substrate is patchy leading to isolated groups of fish with little lateral exchange or adult migration except where the patches are close together. These types of fishery may be regarded as consisting of meta-populations associated with specific features or habitats, interconnected through larval dispersal. Whilst genetically, fish in different patches may be the same population, practically at the adult stage they are discrete populations. This has implications for resource assessments based on yield per unit area (accurate estimates of the areas of different habitat types will be required), and for population demography. For example, on Saya de Malha the mean length of *L. mahsena* has been reported to have decreased, but since 1985 larger fish have frequently been caught again, suggesting previously unfished patches were being targeted (Samboo, 1989). Another implication is that catch rates can be maintained by moving between patches of habitat (sequential fishing). This limits the usefulness of production models for resource assessment, and also means that the signs that a resource is becoming depleted are difficult to detect. Production models have unsuccessfully been applied to data for Nazareth Bank.

Shallow sandy banks with coral outcrops and sea grass beds in general support fish densities of 1.5-2 tons/km^2. In deeper areas and on those substrates which are of dense coral, the density of fish may vary between 9.9 and 10.9 tons/km^2 (FAO/IOP, 1979). Early resource assessments related to demersal trawl surveys on suitable flat sandy substrates (Table 10, Birkett, 1979; FAO/IOP, 1979). These estimates include all demersal species taken by the trawl, and estimates for line caught fish only will suggest much lower figures.

Table 10 : Estimates of the biomass and yield (t) of all demersal species caught by trawls on Mauritian banks (From FAO/IOP, 1979)

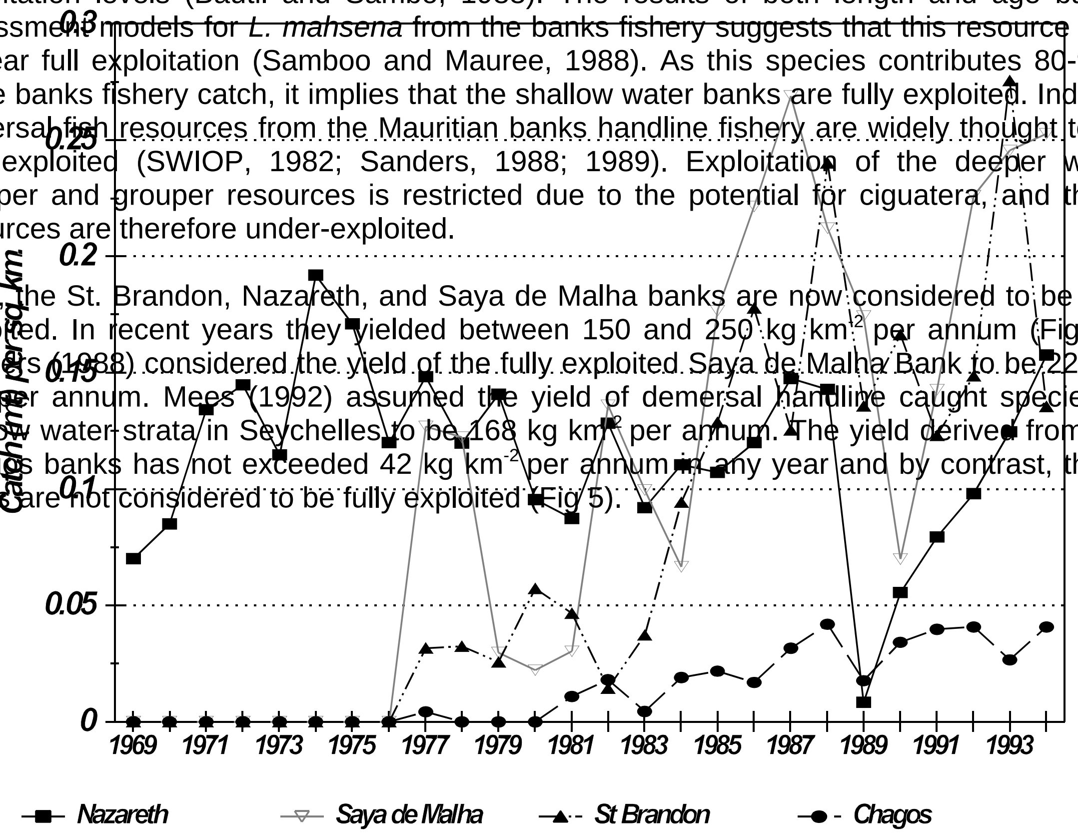
Bank	Area (Km^2)	Density t/km^2	Biomass (t)	Yield (t)
Nazareth <200m	50,274	0.6	30,164	19-25,000
Nazareth >200m	19,404	0.1	1,940	500
Saya de Malha	52,300	1.8	94,140	10-20,000
Others	23,137	No data		11,000

A number of length / age based resource assessments have been performed in relation to the Mauritian banks fisheries, and principally these have related to the Saya de Malha bank, and to shallow water resources, mainly *L. mahsena*. Lebeau and Cuef (1976) determined that an annual yield of ~ 1,400t of *L. enigmaticus* from Saya de Malha equated to the Maximum Sustainable Yield, (MSY) and that MSY could be increased to 2,000 t if age at first capture was increased to 4.9 yrs. Age at first maturity is 3.5 and 4.5 years for females and males respectively. A cooperative stock assessment performed on the Saya de Malha bank by IFREMER (Reunion) and AFRC derived a MSY of 1,800 t (of *L. mahsena* only?, Ardill, 1986) and indicated that the fish resources were fully exploited in the mid 1980's (in Sanders, 1989).

Historical catches of Mauritius and Reunion from Saya de Malha bank have sometimes considerably exceeded these estimates of MSY (Table 7). A reduction in the size of fish caught has been reported. Thompson and Bell yield per recruit analysis suggested that the resource of *L. mahsena* was fully exploited and that (in 1986) the biomass was 40% of pre-exploitation levels (Bautil and Sambo, 1988). The results of both length and age based assessment models for *L. mahsena* from the banks fishery suggests that this resource is at or near full exploitation (Samboo and Mauree, 1988). As this species contributes 80-90% of the banks fishery catch, it implies that the shallow water banks are fully exploited. Indeed, demersal fish resources from the Mauritian banks handline fishery are widely thought to be fully exploited (SWIOP, 1982; Sanders, 1988; 1989). Exploitation of the deeper water snapper and grouper resources is restricted due to the potential for ciguatera, and these resources are therefore under-exploited.

Thus, the St. Brandon, Nazareth, and Saya de Malha banks are now considered to be fully exploited. In recent years they yielded between 150 and 250 kg km^{-2} per annum (Fig. 5). Sanders (1988) considered the yield of the fully exploited Saya de Malha Bank to be 220 kg km^{-2} per annum. Mees (1992) assumed the yield of demersal handline caught species in shallow water strata in Seychelles to be 168 kg km^{-2} per annum. The yield derived from the Chagos banks has not exceeded 42 kg km^{-2} per annum in any year and by contrast, these banks are not considered to be fully exploited (Fig 5).

Fig. 5 : Yield (catch) per unit of fishable area (mt/km^2) on banks fished by Mauritian mother-vessels (St Brandon is that bank only, without Albatross).



Production models have unsuccessfully been applied to catch and effort data from certain banks in order to determine sustainable yield (Bertrand et al, 1986, in Samboo and Mauree, 1988). It would be appropriate to repeat these analyses using standardised catch and effort data and dynamic production models such as those in CEDA (MRAG, 1995b) once computerisation of historical data is completed. Lacking this information, it is appropriate to estimate yield from catch per unit area data, noting that such estimates require improving upon as more data become available. Catch rate data suggested that the abundance of demersal resources on the Chagos Archipelago was between half and two thirds that on the Nazareth and Saya de Malha Banks. Whilst some question remains whether this bank is less productive, or whether lower catch rates may be attributed to other causes, it is prudent to assume the former in determining resource abundance. Current data for the fully exploited banks indicates that it would be appropriate to apply a yield of around 200 kg km^{-2} per annum to the St Brandon, Nazareth and Saya de Malha Banks. MRAG (1994c) derived an estimate of yield for the Chagos based on 168 kg km^{-2} per annum. In the present report the more conservative estimate of 100 kg km^{-2} per annum is used in the light of the uncertainty relating to the productivity of the banks in this Archipelago (Table 11).

Whilst abundance estimates have been derived for demersal resources on the banks of the Indian Ocean, these principally relate to trawl surveys and to all demersal species. Stock density is lower on open trawlable areas than rough and coralline areas accessible to the handline fishery, tending to under-estimate the resource in those areas. Conversely, estimates based on trawl surveys relate to all demersal species, including a number that are not usually accessible to handline fisheries. It is the abundance of shallow water handline caught demersal resources that is relevant to the existing Mauritian banks handline fishery. Table 1 indicated the total area of the banks by depth band. Other authors have attempted to define the fishable area, and to divide this between rough shallow coralline areas and trawlable areas. In determining yield per unit area for the handline fishery it is appropriate to consider only the rough coralline areas, and the fishable area adopted in this report, based on other reported estimates, is indicated (Table 11).

Table 11 : Total and fishable banks areas by depth band given by different authors, the estimated yield of shallow water handline caught demersal species, and the TAC applied by the Mauritian Authorities in 1995.

Source of Estimate (areas in sq.km.)		Chagos	SDM	Nazareth	St Brandon	St Brandon & Albatross
	Area km^2					
MRAG	0-75m (Total)	8514	42116	22814		9212
Samboo and Mauree (1988)	0-35m	6830	15780	8125	2950	
	0-100m		28350	15750		
FAO/IOP (1979)	0-35m (coral)	8575	11000	10633	3087	
	35-100m (trawlable)	5537	24605	17150		
	total	14112	35605	27783	3087	
Wheeler and Ommaney (1953)	Fishable area	6475	11526	8029	2331	
Fishable area adopted this report		7500	12500	10000	3000	6000
This report	Estimated MSY (mt pa)	750	2500	2000	600	1200
AFRC (Samboo, 1989)	Estimated MSY (mt pa)	500	2600	1300	700	
AFRC (Unpublished)	MSY used to set TAC	700	2900	1300	700	
AFRC (pers comm)	TAC (mt) in 1995	630	2734	1264	630	

Samboo (1989) suggested that the sustainable yield of handline caught fish was 3,800t from Saya de Malha and Nazareth banks together, 700 t from St Brandon and 500 t from Chagos (5000 t in total). Sanders (1989) derived MSY estimates of 2,887 t and 1,280t for the Saya de Malha and Nazareth banks respectively using the method of Thompson and Bell. Estimated annual yields for each bank derived in this report and by AFRC are similar, except Nazareth bank. Such estimates depend on the accuracy of the measurement of area of suitable habitat. These estimates also relate to all fishing areas at each bank and therefore accurate spatial monitoring of their exploitation is required to ensure that localised depletion is not occurring unobserved through sequential fishing. It is appropriate to further divide TAC by fishing ground within a bank. This would be more obvious for Chagos where discrete banks and reefs exist than say for Saya de Malha, however, the requirement for monitoring and enforcement may become impractical and too costly. TAC's are not considered an appropriate management instrument for Chagos, and have not been applied by the BIOT Authorities (See below). Furthermore, it should be noted that the estimate of maximum sustainable yield is not necessarily the maximum economic yield. Bertrand et al (in Samboo and Mauree, 1988) considered the MEY of Saya de Malha bank to be 1900 tonnes. Sanders (1989) indicated that MEY for Saya de Malha and Nazareth banks would be attained at about one third of levels in 1988, and that effort at that time was excessive (43,000 man-days in 1988).

Economics of fishery

Detailed analysis of the economics of the banks fishery, including company operations and fish distribution are beyond the scope of the multi-species fisheries project and the reader is referred to SWIOP/ MAFNR (1989) for more information. A few details are highlighted.

Initially there was market resistance to frozen fish in Mauritius, but now it is fully accepted. The demand for frozen fish, however, requires an efficient cold chain, and scrupulous attention to hygiene and quality of the product. At times in the development of the fishery, the infrastructure has not kept pace with the fishery limiting catches and the viability of operations.

The frozen fish product of the banks fishery is subject to price control under regulation G.N. No. 73 of 1989 under the Supplies Control Act. In 1989, frozen red fish (Vielle rouge *(Epinephelus fasciatus, Cephalopholis sonnerati*), Vielle babonne (*Epinephelus* ?), Vielle Grise (*E. merra*), Sacrechien (Pristipomoides spp.), Vacoas (*Aprion virescens*), Guelle pavee *(Rhabdosargus sarba*) and Tirouge (?)) could not be sold for more than MRs 15.00 kg^{-1}. Whole frozen white fish (Capitaine (*Lethrinus nebulosus*), berri (*L. mahsena*), Cordonnier (Siganidae), Carangue (Carangidae), Thon (Tunas), Cateau (Scaridae), Licorne *(Naso unicornis*), Caya (Lethrinidae, *L. reticulatus*), Breton (*Gerres oyena*), and Rouget (*Parupeneus barberinus*)) could not be sold for more than MRs 9.00 kg^{-1}. Price controls have been introduced to guarantee an affordable source of protein for the population of Mauritius. Sturgess (1989) modelled an above average efficient mothership dory fishing operation on the Mauritian banks, and concluded that profit margins were slim, and that only efficiently managed operations would survive.

The size of the mother-vessel appears to be critical to the economic operation. Small vessels (~20m LOA) cannot carry enough fish, whilst larger vessels (~70m LOA) have crew problems. Also they must remain at sea for up to 10 weeks to achieve a full load, and exhaustion of the fishermen leads to reduced catch rates over the period of the fishing trip. 40m LOA was regarded as the optimum size with 40 fishermen and 15 crew (Wijkstrom and Kroepelein, 1979; SWIOP, 1982). A number of vessels are larger than this Table 3).

Legislation / management measures

Management of any fishery requires a combination of biological, social and economic inputs, and a clear idea of the objectives of management are required. In the case of the Mauritian banks handline fishery, as the populations of fish from each bank are discrete, the ideal would be to manage each bank separately. In addition to knowledge of the sustainable biological yield from each bank, economic costs of fishing at each bank, related to their distance from Port Louis are an important factor in determining the economic yield. To manage each bank separately, however, detailed monitoring is required, and enforcement may be a problem at the more distant banks. Sturgess (1989) discusses the management issues related to the distant Saya de Malha Bank.

Existing Mauritian legislation relevant to the banks fishery relates to fish prohibited in Mauritius due to their potential for ciguatera, price control on frozen banks fish, and a total allowable catch (TAC) quota system.

The effect of the restrictions on potentially toxic fish species (Table 12) is to limit fishing activity to shallow waters and thereby target lethrinids, particularly *L. mahsena*. Under-utilised resources remain in the deeper water. Discards (of undesirable fish) on the Mauritian banks are not considered to be a problem since targeting is effective and the fishery is virtually mono-specific. However, in Chagos where the fishery is multi-species in nature, targeting is not so reliable and discards occur. The extent of this problem has not been quantified and requires further research. In fact, in Seychelles, north of the cyclone belt, ciguatera is not a problem and a restricted list is not applied. Similarly in Chagos ciguatera is not believed to be a problem, and recent assays have failed to indicate its presence in potentially toxic species (Claude Talbot, pers. comm.; AFRC, pers. comm.).

Minimum length restrictions exist but relate to the artisanal coastal fishery (Table 13). eg dame berrie length at first maturity is 30 cm. However, this is not the same dame berrie (*L. mahsena*) as caught on the banks - thus some confusion over species occurs in utilising local names in the legislation and length restrictions do not apply to banks fish species. Mortality is usually high, and these fish are not recorded in catch statistics. Hook size regulations have apparently been considered, but are not currently applied. It is believed that hook sizes of 4 and greater will minimise the capture smaller fish. Whilst no documented information on hook sizes has been maintained, it is understood that sizes less than 4 are frequently employed.

Limited entry and quotas are management instruments applied directly to the banks fishery. Price controls act indirectly

Price controls were introduced for a social purpose, but may have acted as a management tool in reducing effort. During the period 1981-1987 when controls were removed, both prices and fishing effort increased. Sturgess (1989) suggested that as long as the objectives of price control remain relevant, it may be sound policy to continue this practice as a management instrument for the fishery, an advantage being that the mechanisms for monitoring and control of price are in place and work. However, he also argues that rather than price control, a tax on the fishery is a more appropriate management mechanism.

Sanders (1989) argues against price control as a management instrument. Increasing the price of fish to allow fishing companies to operate more profitably would disadvantage the consumer and result in increased effort. Effort is already too high and thus it is effort controls that are required. However, rather than limiting effort directly, he argues for Individual Transferable (catch) Quotas (ITQ’s) and proposes a mechanism for implementing them. By reducing catches from the Saya de Malha bank to 2,500 t and the Nazareth bank to 900t per year, the attainment of economic benefits is reasonably rapid. Gradually reducing catches would slow down the attainment of economic benefit compared to immediately implementing lower catch quotas (Sanders, 1989b), but the former would be more acceptable to the fishing companies.

Table 12 : List of prohibited fish in Mauritius : Toxic fish, From fourth schedule of Mauritian fisheries legislation; Minimum fish sizes, From fifth schedule of Mauritian fisheries legislation (GN73/1989 Supplies Control Act).

Scientific name	Local name
Variola louti	Yellow tailed croissant
Plectropomus maculatus	Sinsillac or Vielle Babonne
Epinephelus fuscoguttatus	Vielle Loutre or Otter wrasse
Lutjanus bohar	Vara vara
Lutjanus monostigmus	Giblot
Cephalopholis argus	Vielle Cuisinier, Grabe noir
Anyperodon leucogrammicus	Cheval de bois
Lutjanus gibbus	Chemise
Harengula ovalis	Large tartara or Grosse sardine
Epinephelus areolatus	Vielle Platte or Bambarra
Carpillius maculatus	Crab onze taches
Tridacna spp	Benetier
Echinothrix spp.	Sea Urchin
Eretrochelys imbricata	Caret or Hawksbill turtle
Synanceja verrucosa	Laffe
Diodon hystrix	Boule tangue
Remora remora	Remora, or pilot of the shark
Lactoria cornuta	Coffre
Sphyraena barracuda	Tazar lichien
Lutjanus sebae	Bourgeois

Table 13 : List minimum fish sizes for the lagoon coastal fishery, From fifth schedule of Mauritian fisheries legislation.

Local name	Minimum size (cm)
Barbets	20 cm
Battardets	20 cm
Capitaines	30 cm
Carpes	15 cm
Cordoniers	20 cm
Rougets	20 cm
Dame Berries	30 cm
Guelles Pavees	30 cm
Licornes	30 cm
Mullets (all species)	30 cm
Crabs (Carlet)	15 cm
Oysters and mussels	5 cm
Rock lobsters (carapace)	10 cm

In 1994 a quota system (but not a transferable one) was introduced for the Mauritian banks fisheries by the Ministry of Fisheries and Marine Resources. Estimates of the Maximum Sustainable Yield for each bank were reduced by 10% in order to determine the Total Allowable Catch (TAC) from each bank (Table 11). This was allocated on a per vessel basis related to historical performance. The quotas apply to total fish catch without reference to species. It was also recommended that the number of vessels be limited to the present 17. No new vessels would be licensed and those dropping out of the fishery would not be replaced. The TAC would also be reduced in subsequent years until evidence of recovery, measured as an increase in mean length of fish, was seen. The rationale for the allocation of a quota for Chagos, which is managed by the BIOT Authorities, was that the introduction of quotas on Mauritian banks may result in a shift of effort to Chagos, and to limit this it was appropriate to allocate a quota. The fixed price system for 'white' fish was maintained but the price was under review.

Following implementation, up to January 1995, monitoring indicated that some individual vessels exceeded their TAC but no company had yet reached its TAC. The situation was monitored monthly.

The system introduced in 1994/5 was considered to be inadequate for a number of reasons. Therefore in 1995 the system was improved :

- catch quotas were allocated to companies already in the fishery rather than individual fishing vessels;

- Historical performance of the companies over the past five years was taken into consideration to determine the quota allocated to each company;

- Companies were allowed to trade off their quota in whole, or part of it, if unutilised;

- A single quota is allocated per company for all Mauritian fishing banks, rather than a certain amount per bank

- The Chagos Archipelago was no longer included in the quota system.

Thus the present system is essentially the ITQ system proposed by Sanders (1989). The TAC in 1995/6 was set at 4,750 tonnes.

ITQ’s have a number of advantages and disadvantages. They successfully address the objective of resource conservation and improvement of commercial economic performance (Clark, 1993) and avoid the ‘tragedy of the commons’ which result from the use of simple biological or economic input controls without limiting effort. ITQ’s give fishing companies exclusive right to a guaranteed share of the catch enabling them to behave economically and efficiently to increase profits without having to compete with other companies to remove the fish as quickly as possible before a total quota is achieved. Because the quota may be removed at any time a fishing company may manage its operation more efficiently over time and target fish at the optimum period. Since ITQ’s are transferable, they may provide the incentive for less efficient vessels / companies to leave the fishery. Ultimately the more efficient companies may be expected to acquire the quotas leading to increased profitability from the fishery. This may be retained by the companies or passed on to the public through price controls, commodity taxes or a licensing/management fee. Owners of ITQ’s are less likely to tolerate illegal fishing activities, leading to some self regulation of the fishery.

Collaboration between Government (Managers) and the industry tends to improve.

There are a number of disadvantages, and in particular the high cost of managing the system. Catches need to be monitored and enforced and this may involve both an at-sea presence and a land based auditing procedure for the various logs of catch and the trading movements. Additionally the TAC must be determined each year and allowed to vary according to natural fluctuations in recruitment and abundance of the resource. This is based on complex and detailed scientific analysis of the fishery with its implicit costs. Fishermen tend to resist reductions in quotas even when scientific advice recommends it. ITQ's are considered inappropriate for multi-species fisheries where less desirable species may be discarded such that the quota consists only of high value fish. More complex systems can be applied to multi-species fisheries but have even greater implications for monitoring and control. Similarly high grading may occur if a different price structure applies to different sizes of the same species - the least valuable size will be discarded. ITQ's can lead to false reporting since the logbook returns will always add up to the quota. Where the jurisdiction over the fishery is unclear, reporting of catches can be disguised.

In Mauritius a number of the problems identified with ITQ's may exist, but not all apply to Mauritius. At sea surveillance is limited and the system relies on the honest reporting of fish catches by fishing bank. The incentive to falsify catch data by bank has in fact been reduced with the changed system introduced in 1995. Whilst a land based auditing system is in place, this is only as good as the logbook data provided. Although predominantly a single species fishery, some red fish are accepted at a higher price. The true volume of fish caught may not be accurately determined should any discarding occur, limiting the ability to derive appropriate TAC's. Mean fish size alone is not considered an appropriate indicator of the status of the fishery.

In waters around the Chagos Archipelago, the principle management concern is conservation rather than any maximisation of benefits from the fishery. Effort restrictions are the primary management instrument. Discards are already regarded as a problem in Chagos, and ITQ's are not considered appropriate in this multi-species fishery. A system of restrictive licensing in combination with other management instruments is thus considered most appropriate. Restrictive licences limit effort rather than catch and thus any incentive to discard fish (except in the case of toxic fish lists) or mis-report catches in log books is removed. Hence more reliable data is available for scientific assessment of the fishery. Less enforcement of the fishery is required and so the costs of management are lower than for ITQ's. Presently the number of vessels fishing in the Chagos Archipelago, the duration of fishing ventures, and the volume of catches removed have not posed a serious threat to the resources, and the maximum number of licenses permitted have not been fully utilised. Nevertheless, the possibility of localised depletion is a concern and potential additional management instruments to address such a problem are being considered.

PART TWO SPATIAL ANALYSES OF INDIAN OCEAN BANKS : COMPARISON OF SITES REPRESENTING A GRADIENT OF FISHING PRESSURE.

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. Nevertheless, spatial data Indian Ocean including banks and plateaux fished by vessels from Seychelles and Mauritius were explored.

Indian Ocean Banks Fisheries

The banks fished by Mauritian vessels 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. From 1991 to 1993 a mother-ship-dory venture also operated in Seychelles.

The following Banks/Plateaux were identified (Fig 6) :

1. Cosmoledo / Astove (Fished by vessels from Seychelles)
2. Providence / Farquahar (Fished by vessels from Seychelles)
3. Amirantes Plateau (Fished by vessels from Seychelles)
4. Mahe Plateau (Fished by vessels from Seychelles)
5. Banks South of the Mahe Plateau (Fished by vessels from Seychelles)
6. Saya de Malha Bank (Fished predominantly by vessels from Mauritius)
7. Nazareth Bank (Fished by vessels from Mauritius)
8. St Brandon (including Albatross : Fished by vessels from Mauritius)
9. Chagos Archipelago (Fished by vessels from Mauritius)

Data Sources

- Environmental data :

The distribution of primary production in $gC/m^2/d$ (Fig. 7), 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) in the Indian Ocean was given in Cushing (1971).

The distribution of both fish eggs (Fig 8) and larvae (number per haul; Fig 9) 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 was derived from the World Ocean Atlas 1994 (National Oceanographic Data Centre, Ocean Climate Laboratory, Washington, 1994). It relates to the mean annual data by one degree square at a depth of 50 m (to correspond with common fishing depth). Details examined were : temperature (eg. Fig 10), salinity, dissolved oxygen, oxygen saturation, available oxygen utilisation, phosphates, nitrates and silicates. 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.

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.

Climatic details indicate seasonality in the Indian Ocean which is related to the wet Northwest monsoon and dry S.E. Trade Wind Periods. The wind conditions are the most likely to affect fishing activity (Fig 11), and wind speeds are greatest during the period of the SE Trade winds. Fig 11 (from the Nautical Almanac) is misleading in that the mean wind speeds for Mauritius disguise the fact that cyclones during this period frequently limit fishing activity.

- 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 (MRAG, 1996). 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 three year data set (1992 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.

Figure 12 indicates total catch by bank. Species Composition data was available for all except the Saya de Malha, Nazareth and St. Brandon banks monitored by Mauritius, 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. Species composition was determined only to the family level (Fig 13).

Data Treatment

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. Standardised annual, and mean annual catch rates by location were determined. Catch and effort data used were the totals for 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 full details were not available and catch and effort may be slightly underestimated for this bank.

Data were standardised for relative fishing power of each vessel (boat-gear type), depth fished, and season fished using a generalised linear interactive model (GLIM4, Francis et al 1993 : Table 13; for Seychelles see MRAG, 1996). Effort was standardised relative to one man-day fishing by handline from a dory in the depth range 0-75 m during the period of the SE Trade Winds (model: boat, season and depth). The relative fishing power of the Seychelles mother ship was assumed to be equivalent to that of the average Mauritian vessel. Additionally, standardised (boat and season) annual catch rates were determined by location for data stratified by depth band (shallow, < 75 m; intermediate > 74 m).

Standardised (boat, depth and season) annual catch rate data for guilds of all demersal species, lutjanids, serranids and lethrinids from all 9 locations were correlated with :

- prior fishing history, measured as the mean annual catch and standardised effort per square kilometre of substrate (of all available data, Figs 14 and 15). 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. Total substrate area (less than 75m) was employed, given the lack of previous estimates of fishable habitat for some banks, and the discrepancies between estimates for others. Thus it is assumed in this analysis that the ratio of suitable fishable habitat to total area is similar for all banks. In practise, the catch and effort per square kilometre will be greater than indicated, and the x-axis will be shifted to the right;

- with various environmental parameters (Figs 16, 17).

For correlations utilising data stratified by depth band, catch rate data was determined directly for Seychelles mother-vessel data. For all Mauritian vessels the depth was assumed to be less than 75 m. Seychelles 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 depths >74 m, the remainder represent the shallow depth band. Effort was allocated in proportion to the sampled effort by depth band for the mother-vessel data. Note that owing to the small area of the greater depth band, which forms a narrow ribbon on the drop off at the perimeter of the banks, catch and effort appear high when expressed per unit area.

The relationship between guild catch rate and fishing and environmental parameters was examined singly by regression, and in total by multiple-regression for the depth strata. Analysis by depth band and family-guild was restricted to locations 1-5 (Seychelles) and 9 (Chagos) due to the limited depth and species information available for Mauritius. For analyses relating to the shallow depth band and to lethrinids, all locations (1-9) were included. Regression analyses were initially applied to the guild 'All demersal species' from the shallow (<75m) depth stratum. This indicated the most important parameters, and subsequent analyses by depth band and family guild concentrated on them (fishing parameters, substrate and winter primary productivity).

Correlation of catch rate with fishing and environmental parameters

For shallow water demersal species single regression of catch rate on fishing and environmental parameters indicated that fishing history was the most significant (Table 14a), but that substrate was also important and there was a weak correlation with winter primary productivity. All relationships were poor, and that of catch rate to prior fishing was not linear. 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 of this guild and depth stratum by multiple regression indicated that substrate and fishing effort were the key components determining catch rate (Table 14b). Hence, whilst the analyses showed that catch rate is most significantly affected by prior fishing history, environmental effects could not be discounted. However, the relationship to substrate, in particular, may be an artefact, given the imprecise definition of this variable.

Subsequent analyses including all locations (1-9), indicated that fishing effects were significant for the guild 'all demersal species' both at all depths, and at depths less than 75 m (Table 15). The smaller data set of Seychelles and Chagos only (Table 16), also indicated a significant negative correlation between all demersal species catch rate and increasing fishing pressure both at all depths, and depths less than 75 m, but this was not true for the greater depth band. With respect to the effect of fishing on family-guild 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).

These analyses show only weak correlations of abundance (cpue) relative to fishing pressure and environmental parameters. They indicate that :

- catch rates are inversely proportional to the volume of fish removed, and the fishing effort per unit area per annum;

- as fishing pressure increases, the Serranidae decline in abundance, but no significant changes in the abundance of Lethrinidae or Lutjanidae occur. Whilst environmental influences affect species composition, and it has been noted that the abundance of lutjanids and serranids declines at southerly latitudes, the Mauritian banks were not included in the analysis for this guild;

- catch rates observed for the Chagos Archipelago are less than might be expected given the annual effort and yield removed suggesting a lower abundance of demersal species (see below). However, examination of Figures 14 and 15 indicate that Chagos catch rates are principally lower than expected in the greater depth band, and for the guild 'lutjanids'.

Application of spatial data to production models

Surplus production models examine the relationship between fishing effort and abundance of a resource over time. Munro (1983) assumed that catch rates in a multi-species community would decline exponentially in response to fishing effort and for a single year, the relationship between catch rates at a number of locations and the effort per unit area was applied to spatial data from the Jamaican fishery, plotting the natural logarithm of catch rate against effort per unit area (Thompson and Munro, 1983; 1983a).

For the Indian Ocean, the logarithm of mean aggregated demersal catch rate for mother-vessels fishing in each location between 1991 and 1994, as an index of abundance, was plotted against mean annual fishing effort (mdkm^{-2}yr^{-1}, Table 17, Figs. 18-19. Note that 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). Such a plot is a Munro-Thompson Plot (Thompson and Munro, 1983; 1983a), equivalent to a Fox surplus production model for spatial rather than time-series data (it represents a modification of the method in that rather than examining data for a single year over several locations, mean annual data is employed). It 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. Evidence that the characteristics of Chagos may differ (see below) indicates that it is valid to exclude this data from the analysis.

To increase the amount of data and to allow for annual variation in catch rates, the logarithm of annual catch rate for mother-vessels fishing in each location in each year between 1991 and 1994, as an index of abundance, was plotted against mean annual fishing effort ($mdkm^{-2}yr^{-1}$) up to that year. This was performed for the guild 'all demersal species' at both all-depths and for the shallow depth band (<75 m. logarithmic transformation not shown, but see Fig 14). Data from all locations was utilised (Table 18). For the guild 'serranids' at each depth classification (see Fig 15), and 'all demersal species' at depths greater than 74 m only data from Seychelles and Chagos was used (Table 19). The Fox surplus production model was not applied to data for the guilds 'lutjanids' and 'lethrinids' for which no significant correlation existed between the logarithm of catch rate and effort (Fig 15 and Tables 15-16).

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 $f(MSY) = -1/b$

Maximum sustainable yield was derived for the aggregated data set with and without Chagos included (Table 20, Figs 18-19). 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$mdkm^{-2}yr^{-1}$).

Results of analysis of the annual catch rate data against mean annual effort (Table 20) 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, and the catch per unit area (see Part 1). This could be attributed to :

- the fact that total bank area rather than fishing area was used.

- the fact that mean annual effort was used.

Spatial data was therefore examined for single years, 1992 and 1993 (Table 21) - 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 20). 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 21), 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 20-21).

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 (1992) 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. 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 all banks) 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.

Discussion of demersal species abundance at the Chagos Archipelago

Catch rates in Chagos for all data standardised by depth (and boat and season) were less than expected relative to the level of prior fishing. Depth stratified data indicated this was principally related to depths greater than 75m and to lutjanid catch rates. This observation supports that from unstandardised data (Part 1) and indicates that the explanation is not related to fishing during the period of SE Trade Winds. If all locations had similar ecological and productive characteristics, Chagos would be expected to correlate more closely with the other banks. The fact that it does not for the given historical effort suggests :

- That Chagos does indeed have different ecological and productive characteristics to the other banks, and that production is less. Oceanic primary productivity was indeed lower around the Chagos, but catch rates were poorly correlated with this variable. A more detailed study of the productivity of water over the banks themselves is required to very this;

- That other explanations exist for the lower catch rate, and catch and/or effort have not been accurately reported including : The possibility that there has been unreported illegal fishing effort(effort underestimated); that logbooks have not been accurately completed; that avoidance of potentially poisonous fish (ciguatera) may be responsible for these observations (red fish including lutjanids); that unrecorded discards occur at sea such that catch is not accurately reported (catch underestimated); that inexperience of fishing at greater depth bands (compared to Seychelles fishermen) results in depressed catch rates;

- That the assumption that the ratio of fishing area to total area was the same for all locations was violated. The lower catch rate would suggest that the area of fishable habitat at Chagos relative to total shallow substrate area is less than at other locations. In fact from FAO estimates, and those employed by this author, the opposite is true (fishable area Chagos, 60% (FAO), MRAG (88%); Saya de Malha, 30%, 30%; Nazareth, 38%, 44%; St Brandon, ?%, 65%; Mahe Plateau, 60%,60%). Substrate has not been adequately mapped for any of the banks, and on this basis it is considered most appropriate to use total area of shallow habitat and retain the stated assumption. Habitat mapping would be a useful exercise for the forthcoming Shoals of Capricorn expedition using a combination of remote sensing and ground truthing techniques.

Also relevant to the discussion of Chagos is egg and larval dispersal (Figs 8-9). The precise means of recruitment and settlement of larvae on the banks are not known. Nor is the extent to which egg and larval production at Chagos is retained locally or more widely dispersed. In Seychelles spawning is believed to peak around February to April and in November. Eggs hatch in about 24-45 hours, but it is not clear at what time they settle out of the plankton. Large specimens have been found, and size rather than age is considered to be more important in determining settlement. If the same spawning seasons apply in Chagos, currents from October to April would tend to carry larvae eastwards, whilst from April to October they would pass westwards over the Chagos. Whether this acts to ensure self recruitment of the banks would depend upon the precise time of spawning, and it is a possibility that much production is lost. Being relatively remote, recruitment from other Indian Ocean banks is unlikely.

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

Table 14 :Results of the regression of catch rate data for the guild 'All demersal species' by location at depths less than 69 m against fishing and environmental parameters. 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 14a). 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 14b). 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 by single regression analyses 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.

Table 14a : 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 14b : 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	-67.560		-2.015	0.062					
Demersal cpue < 70 m	Nitrates	208.2	114.3	9.694		1.822	0.089					
Demersal cpue < 70 m	Oxygen	248.0	297.5	2.290	0.002	0.834	0.418					
Demersal cpue < 70 m	Oxygen Saturation	-339.7	161.8	-66.234		-2.100	0.053					
Demersal cpue < 70 m	Phosphates	-92.3	584.2	-0.244	0.005	-0.158	0.877					
Demersal cpue < 70 m	Salinity	-803.0	451.0	-4.335	0.002	-1.780	0.095					
Demersal cpue < 70 m	Silicates	-141.9	74.3	-3.454	0.004	-1.910	0.075					
Demersal cpue < 70 m	CONSTANT	106.1	19.2		.	5.524		0.60	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		0.60	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 15. 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	24.150	-3.44	0.002	0.36	1
	SUBS	77.475	-13.72	6.390	-2.15	0.044	0.18	1
	PPROW	29.566	118.47	45.060	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	22.160	0.29	0.776	0.00	0
	SUBS	56.688	-16.77	3.679	-4.56	0.000	0.50	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	25.500	-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	0.210	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	0.000	0.50	1
	PPROW	24.611	25.37	37.875	0.67	0.510	0.02	0
LNDEMAD	KGDEMAD	4.20	-0.010	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	0.010	0.009	1.15	0.263	0.06	0
	EFFAD	2.97	0.597	0.891	0.67	0.510	0.02	0
LNDEMLT	KGDEMLT	4.30	-0.012	0.004	-3.38	0.003	0.35	1
	EFFLT	4.25	-1.103	0.360	-3.07	0.006	0.31	1
LNLETLT	KGDEMLT	3.06	0.006	0.008	0.79	0.440	0.03	0
	EFFLT	3.01	0.861	0.723	1.19	0.247	0.06	0

Table 16. 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 16 CONTINUED : Log-linear regressions

GUILD CPUE	VARIABLE	CONSTANT	COEFFICIENT	STD ERROR	T	P(2 TAIL)	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 17 : 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	TOTAL BANK AREA	YEARS OF AVAILABLE DATA	CATCH AND EFFORT FOR PERIOD	CUMULATIVE DEM CATCH (KG)	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)
1.Astove / Cosmoledo	431	16	78-93	21591	269	3.13	0.04	80.26	91-93	80.4	4.39
2.Providence / Farquhar	1751	16	78-93	497241	3402	17.75	0.12	146.16	91-93	87.3	4.47
3.Amirantes Plateau	4116	9	85-93	456671	5772	12.33	0.16	79.12	91-93	56.4	4.03
4.Mahe Plateau	4171	9	85-93	12906638	138207	34.38	0.37	93.39	91-93	50.2	3.92
5.Banks S of Mahe Pl.	2326	9	85-93	287546	3152	13.74	0.15	91.23	91-93	54.1	3.99
6.Saya de Mahla	4247	15	77-94	27671951	330926	43.44	0.52	83.62	92-94	46.3	3.83
7.Nazareth	2300	26	69-94	25452917	317832	42.56	0.53	80.08	92-94	50.3	3.92
8.St. Brandon	9313	12	80-94	5625729	41497	50.34	0.37	135.57	92-94	42.7	3.75
9.Chagos Archipelago	8853	18	77-94	1999831	48706	12.55	0.31	41.06	91-94	33.0	3.50

Table 18 : 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	2.70	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	17.70	13.39	0.13	0.07	92	80.9	4.39	92.60	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	0.10	91	53.1	3.97	54.20	3.99
3	85-92	13.36	11.56	0.17	0.04	92	57.0	4.04	48.41	3.88
4	85-91	34.66	32.89	0.38	0.18	91	53.0	3.97	49.94	3.91
4	85-92	34.55	32.74	0.37	0.26	92	31.1	3.44	27.21	3.30
4	85-93	34.46	32.71	0.37	0.33	93	48.8	3.89	54.83	4.00
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	4.00
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	0.50	0.50	92	55.7	4.02	55.7	4.02
7	69-93	41.94	41.94	0.51	0.51	93	49.4	3.90	49.4	3.90
7	69-94	42.56	42.56	0.53	0.53	94	49.0	3.89	49.0	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	35.0	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 19 : 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	31.90	3.46	101.00	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	0.10	1.64	91	7.19	1.97	6.67	1.90	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	12.90	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	1.00	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	7.60	2.03	75.43	4.32
5	85-91	0.13	0.07	1.03	91	10.77	2.38	8.86	2.18	12.80	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	2.10	2.17	0.77	11.70	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	2.40	15.55	2.74	30.26	3.41

Table 20 : 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	-2.20	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	0.80
ANNUAL	ALL XPT 9	ALL	DEMAD	EFFAD	4.33	-1.25	0.349	-3.58	0.002	0.40	1	22.36	0.80
ANNUAL	(1-5 AND 9)	ALL	DEMAD	EFFAD	4.51	-2.53	0.664	-3.81	0.003	0.55	1	13.22	0.40
ANNUAL	(1-5 ONLY)	ALL	DEMAD	EFFAD	4.49	-2.18	0.700	-3.12	0.011	0.49	1	15.03	0.46
ANNUAL	ALL(1-9)	<70	DEMLT	EFFLT	4.25	-1.10	0.360	-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	0.890	-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 21. 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	50.10	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	32.50	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	25.40	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	94.20	0.07	18.41	5.6	4.5
Mahe Plateau	41712	1404972	15598	90.07	52.26	0.37	33.68	4.5	4.0
Banks -Seychelles	2326	22550	266	84.92	47.27	0.11	9.69	4.4	3.9
Saya De Malha	42466	8670	236	36.80	36.80	0.01	0.20	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	0.50	20.55	3.7	3.8
Average 1993						0.56	30.25		

Fig. 6 : Mothership-dory standardised catch rates for Indian Ocean banks fisheries.

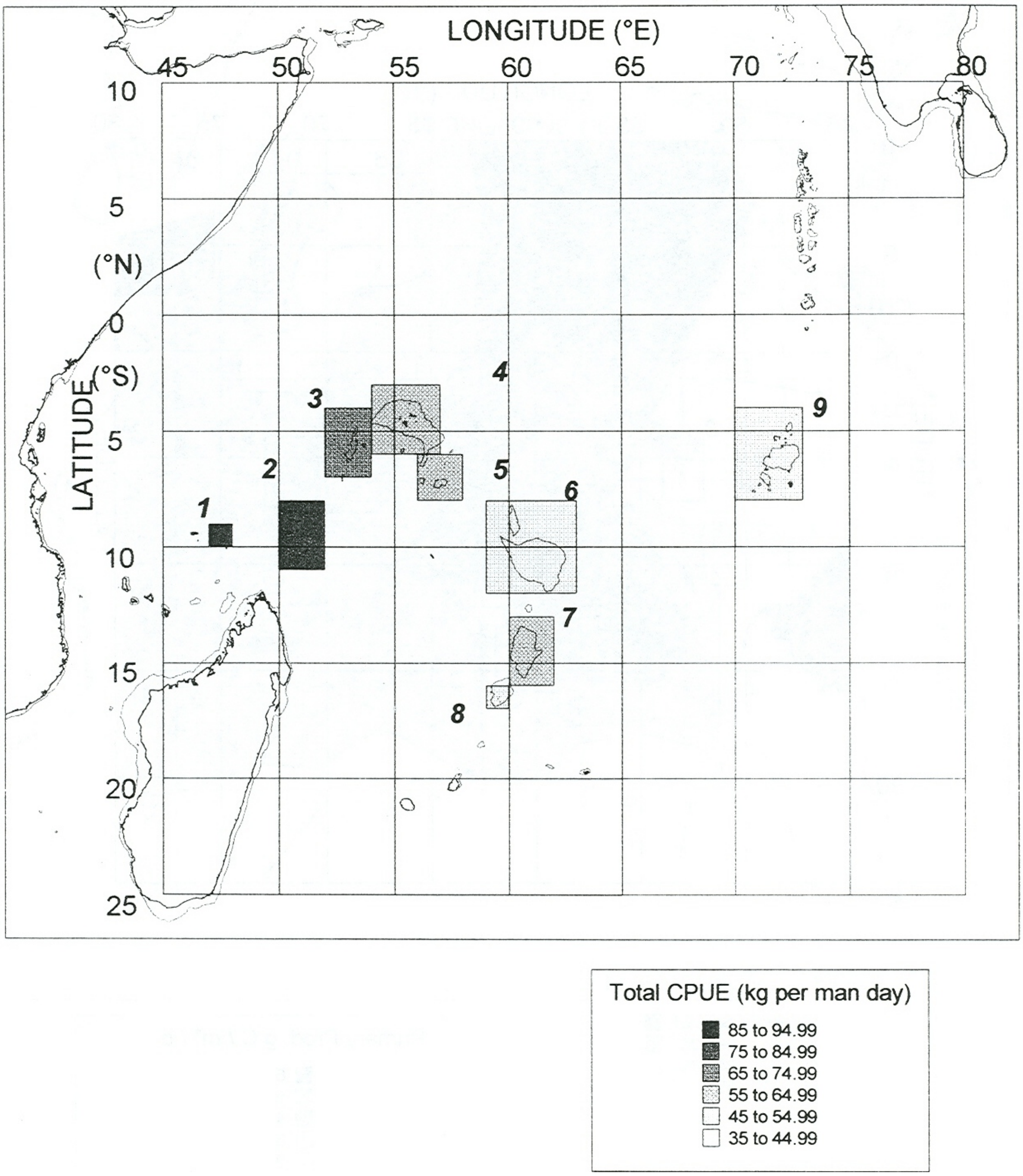


Fig. 7 : The distribution of Primary productivityin the Indian Ocean during the period October - April (after Cushing, 1971)

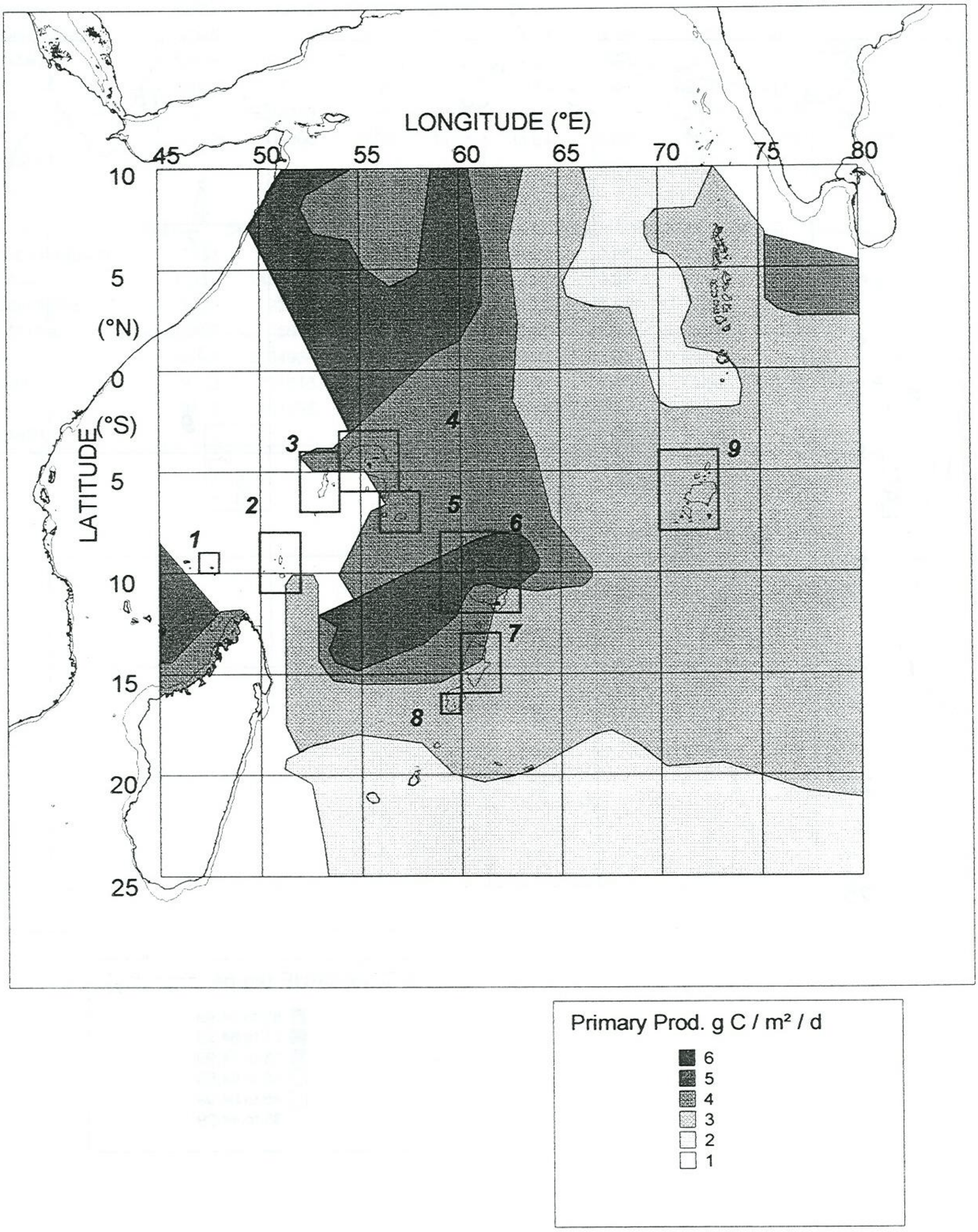


Fig 8. The distribution of fish eggs during the period April 16-October 15 and the predominant direction of the currents during this time of year (after Cushing, 1971)

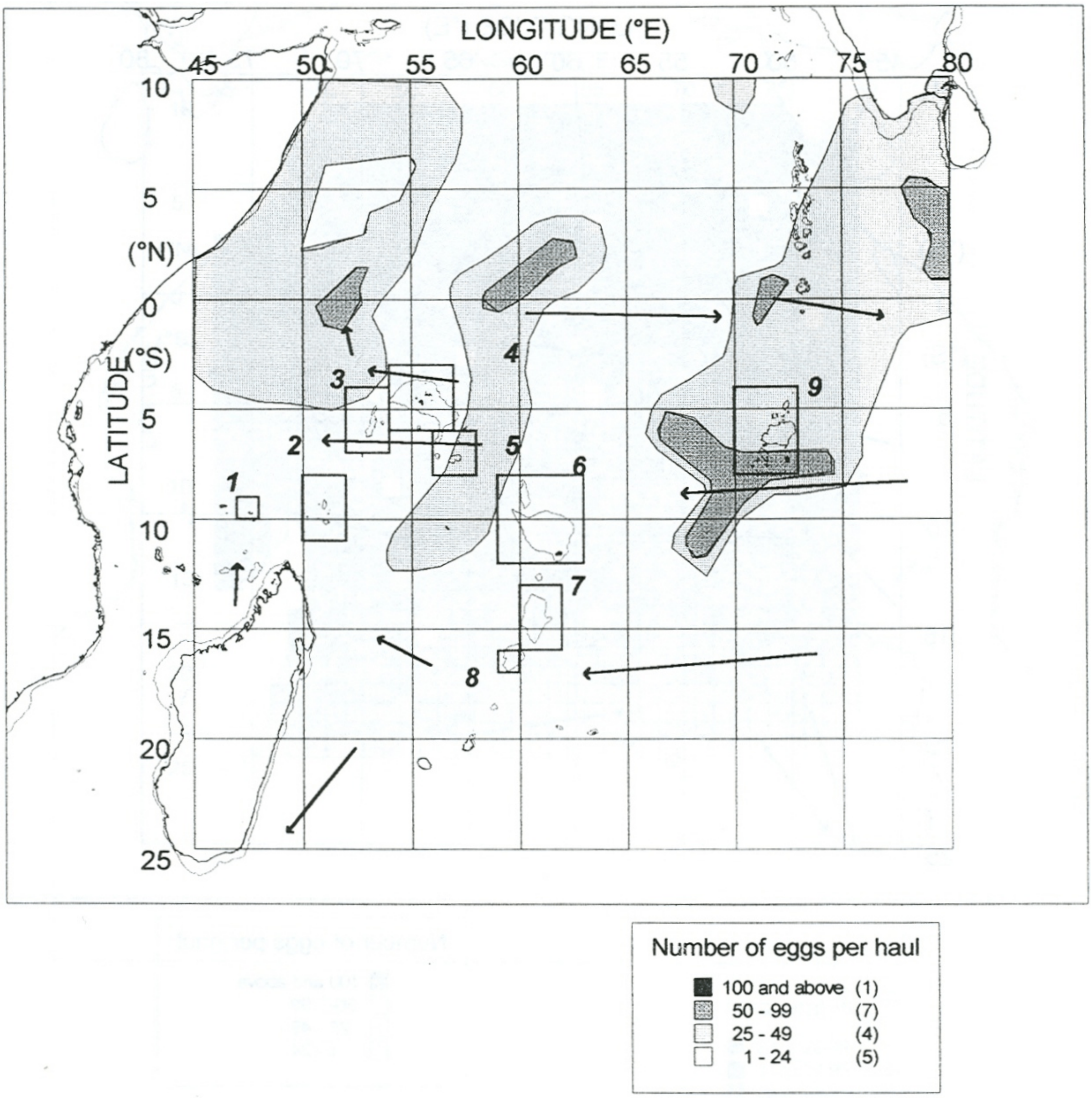


Fig 9. The distribution of fish eggs during the period October 16-April 15 and the predominant direction of the currents during this time of year (after Cushing, 1971)

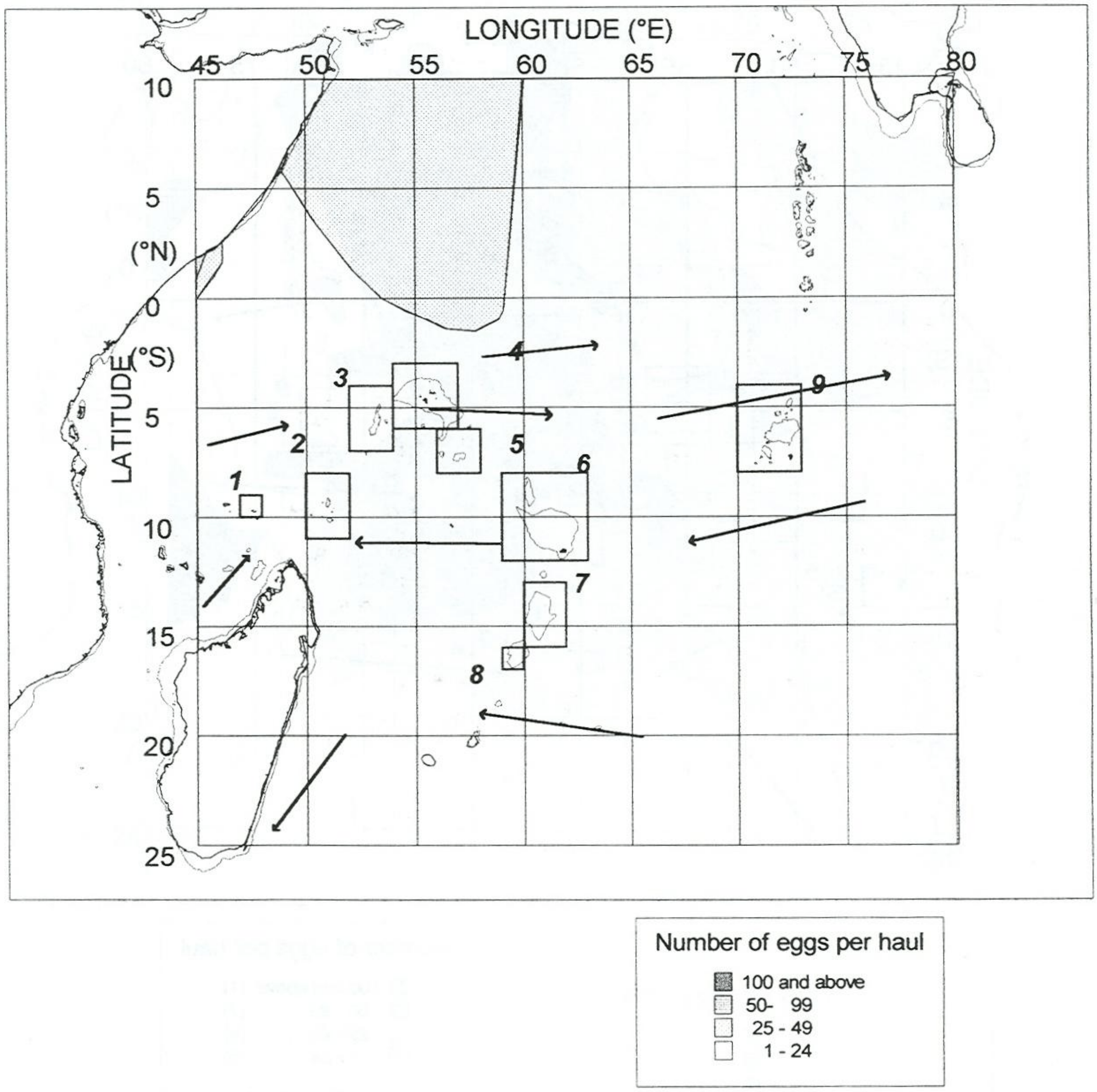


Fig.10. The variation in temperature observed throughout the Indian Ocean at a depth of 50 m (from data extracted from World Ocean Atlas, 1994)

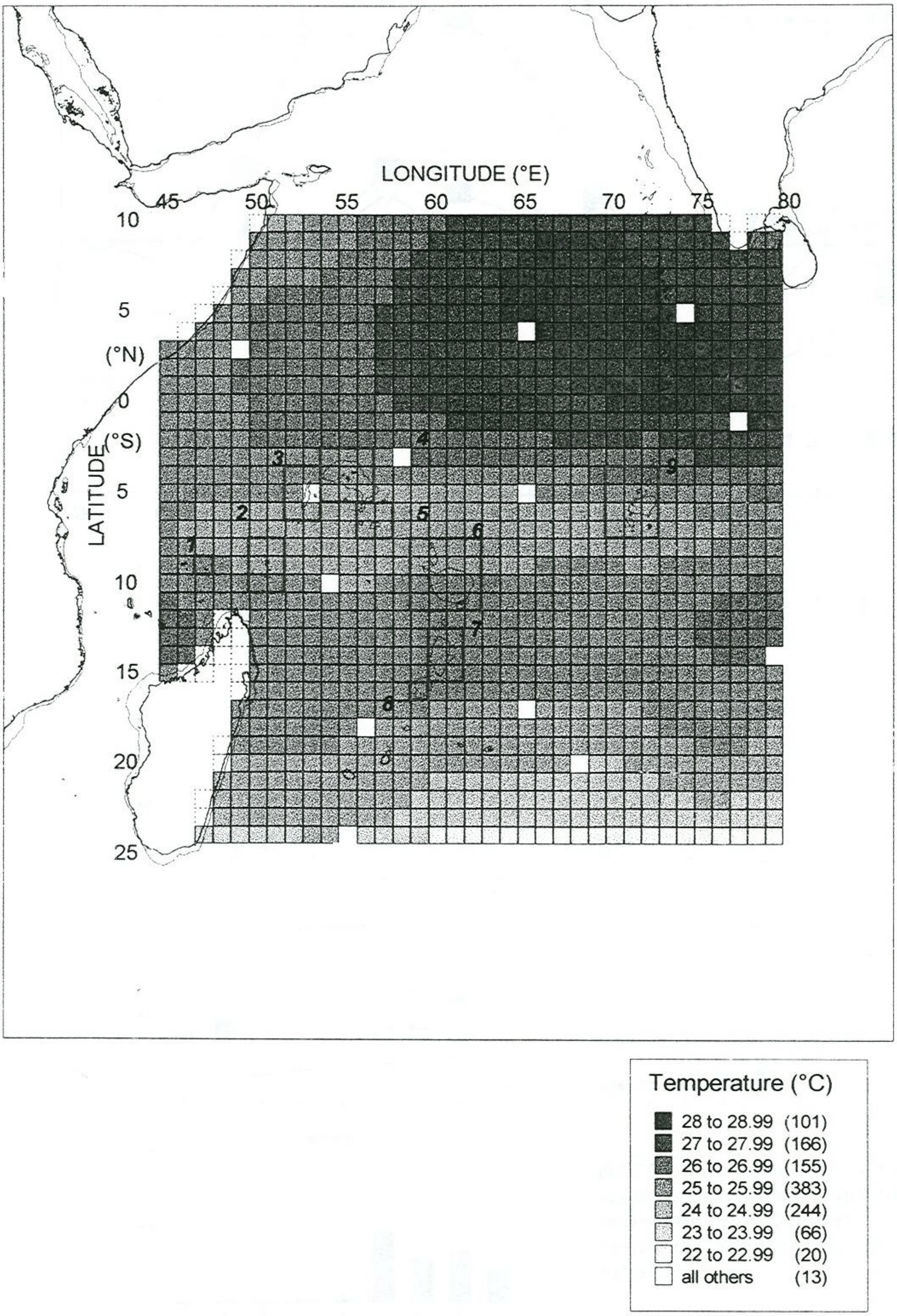
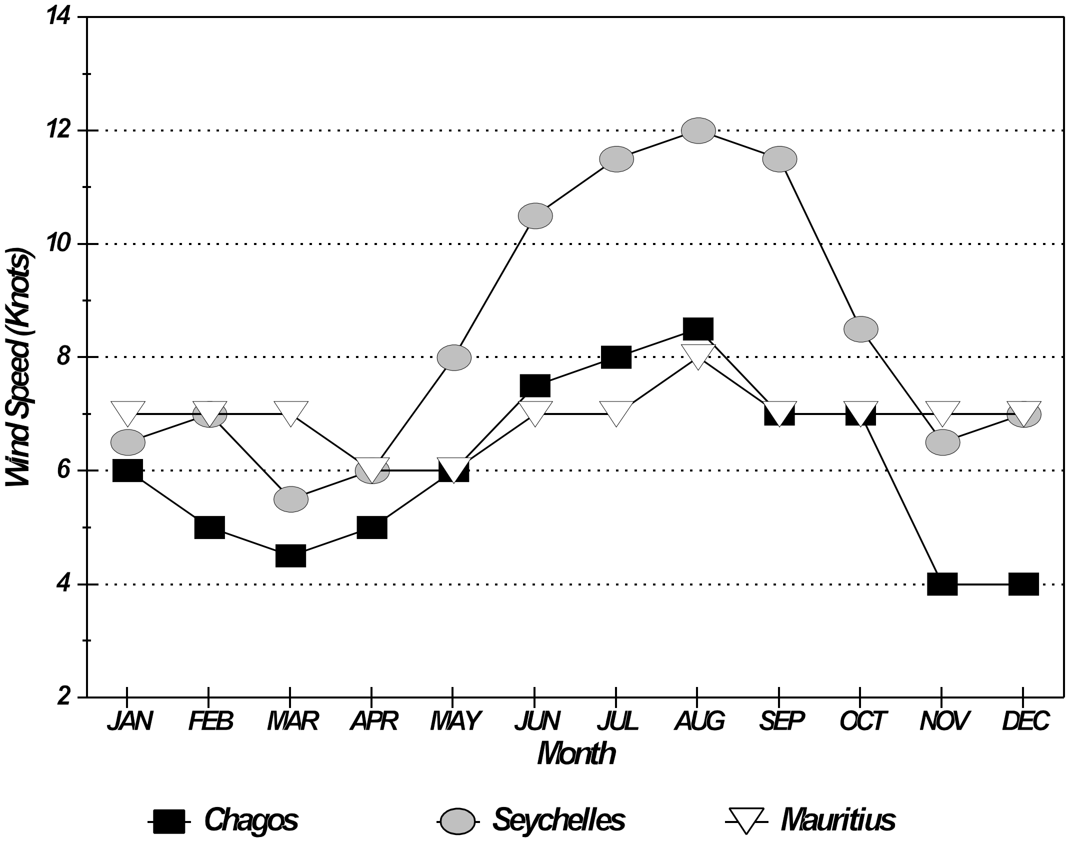


Fig 11. Mean monthly wind speed in the Indian Ocean.



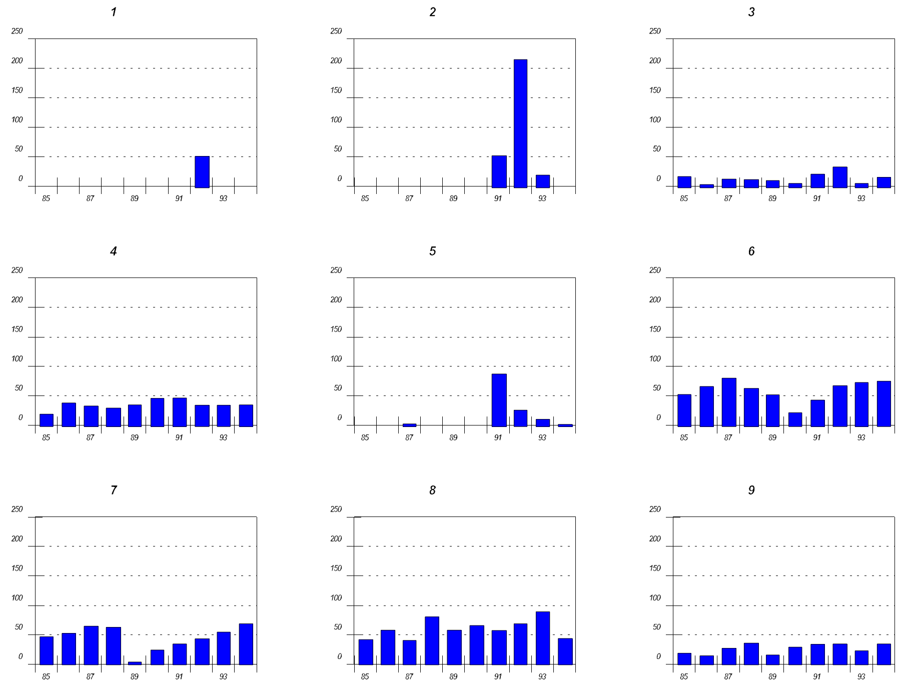


Fig. 12 : Annual catch (kg/km^2) by location.

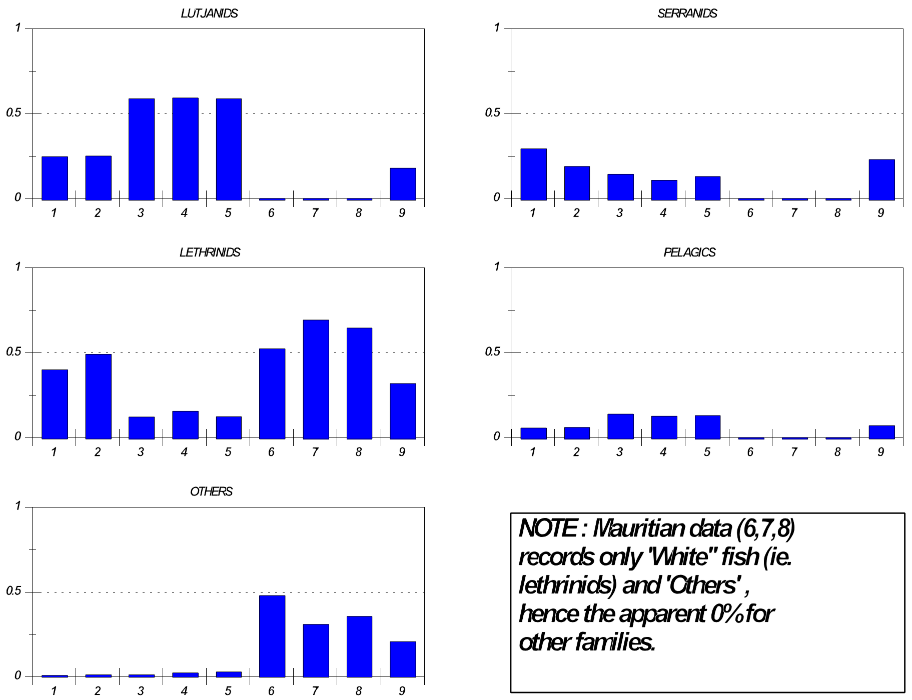


Fig 13 : Gross mean species composition, 1991-94

Fig 14. Standardised demersal catch rates by location (1-9, indicated) related to catch and effort by depth band.

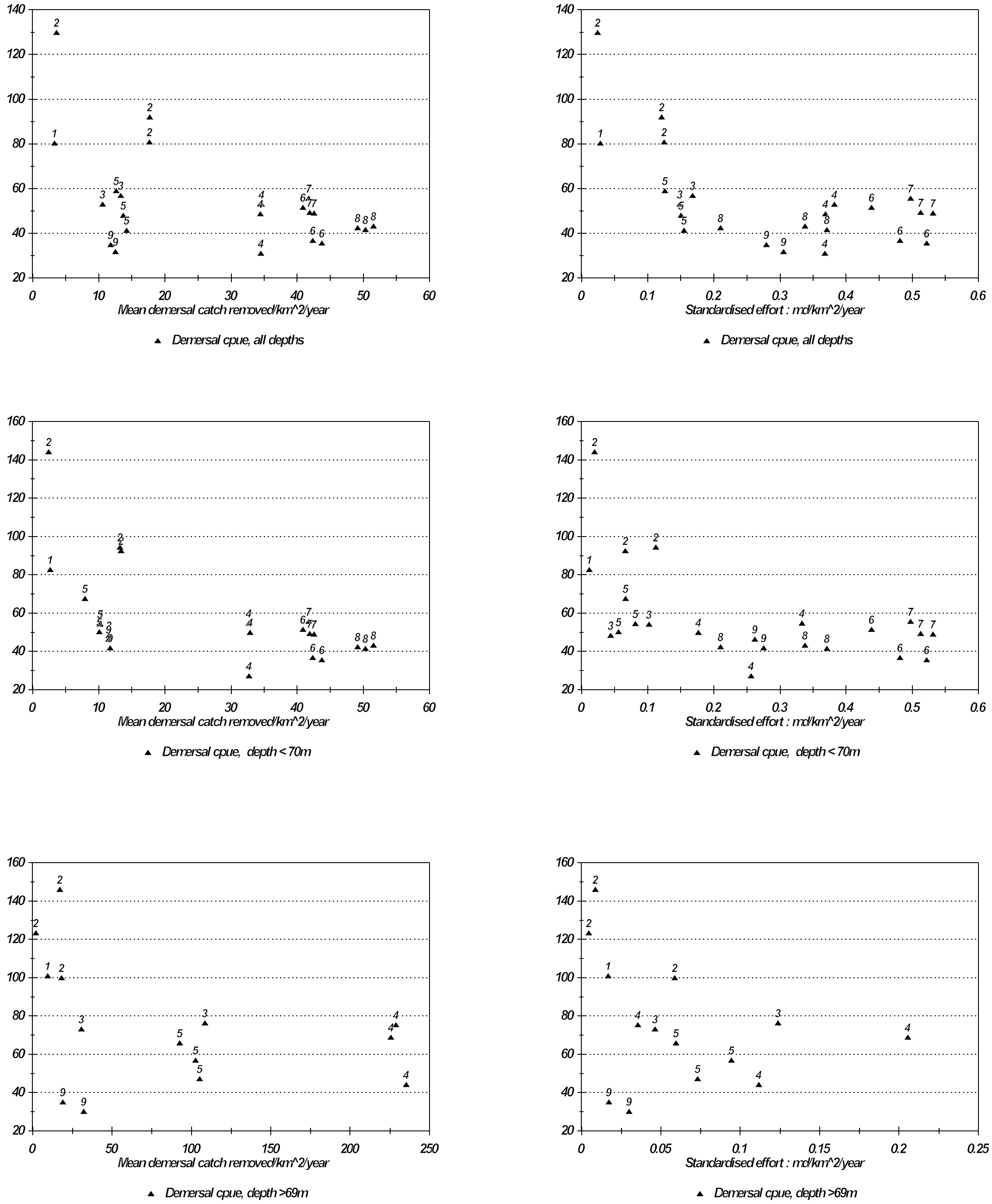
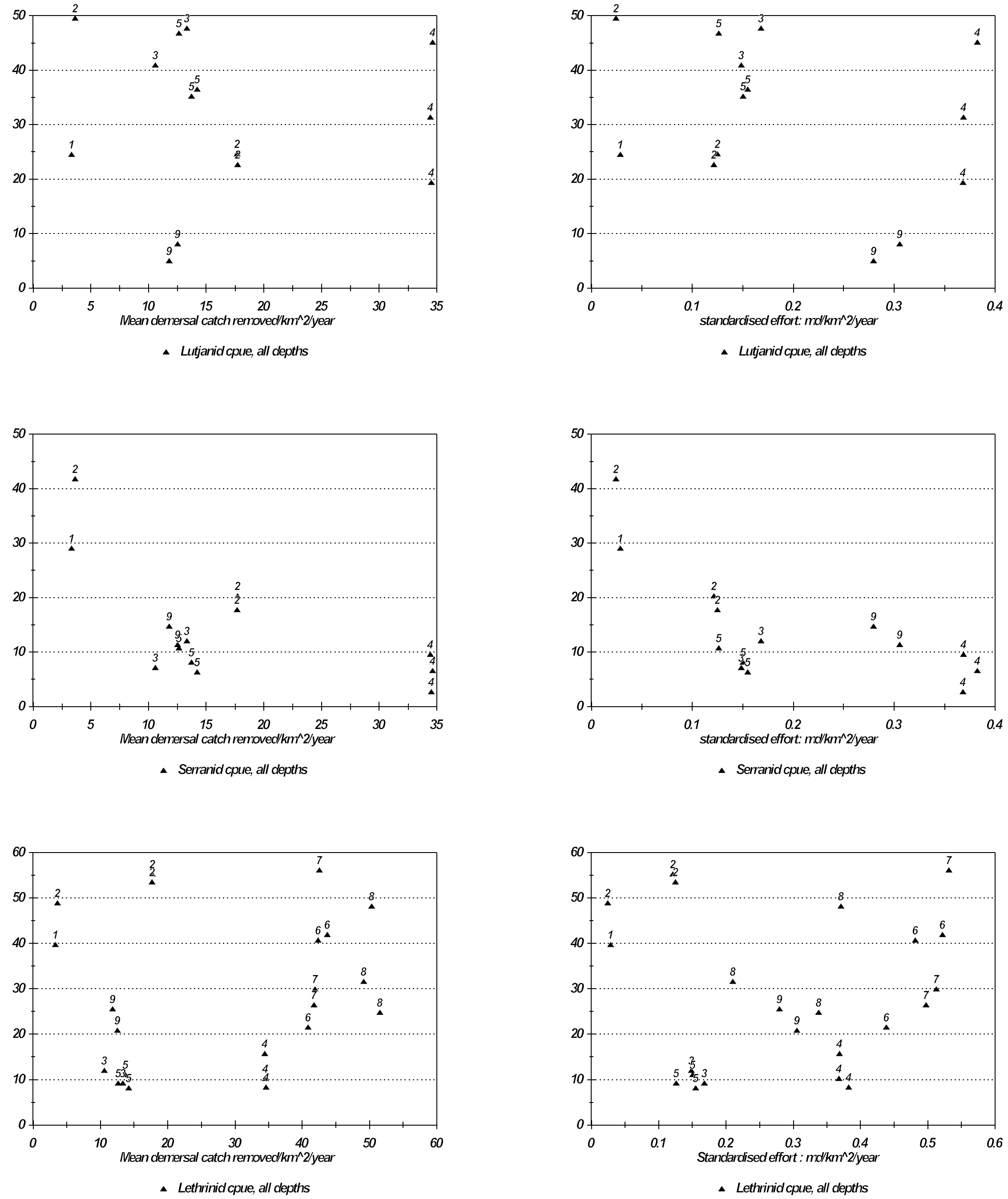


Fig 15. Standardised family guild catch rates (kg/md) by location (1-9, indicated) related to catch and effort for all depths.



Figs. 16 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.

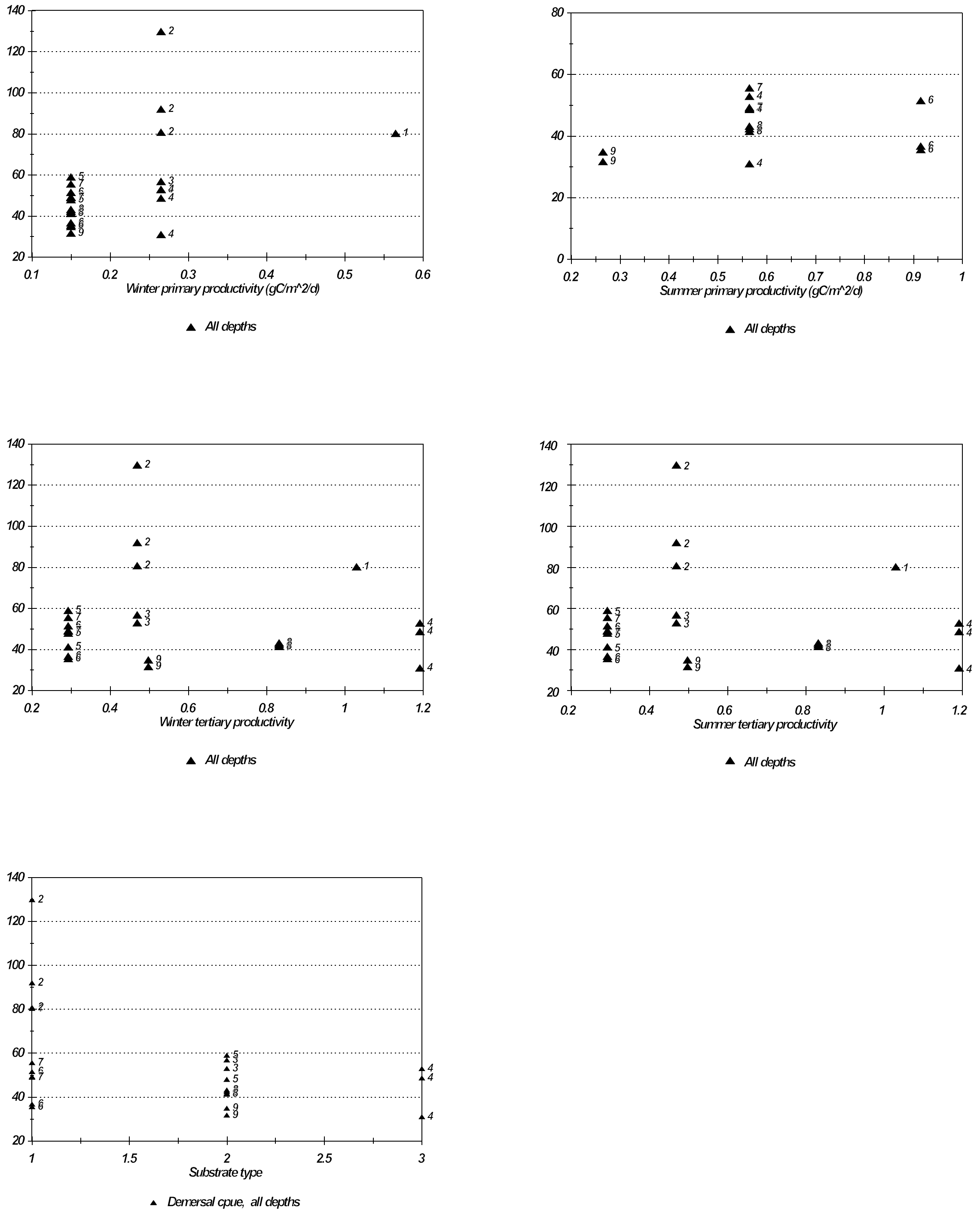
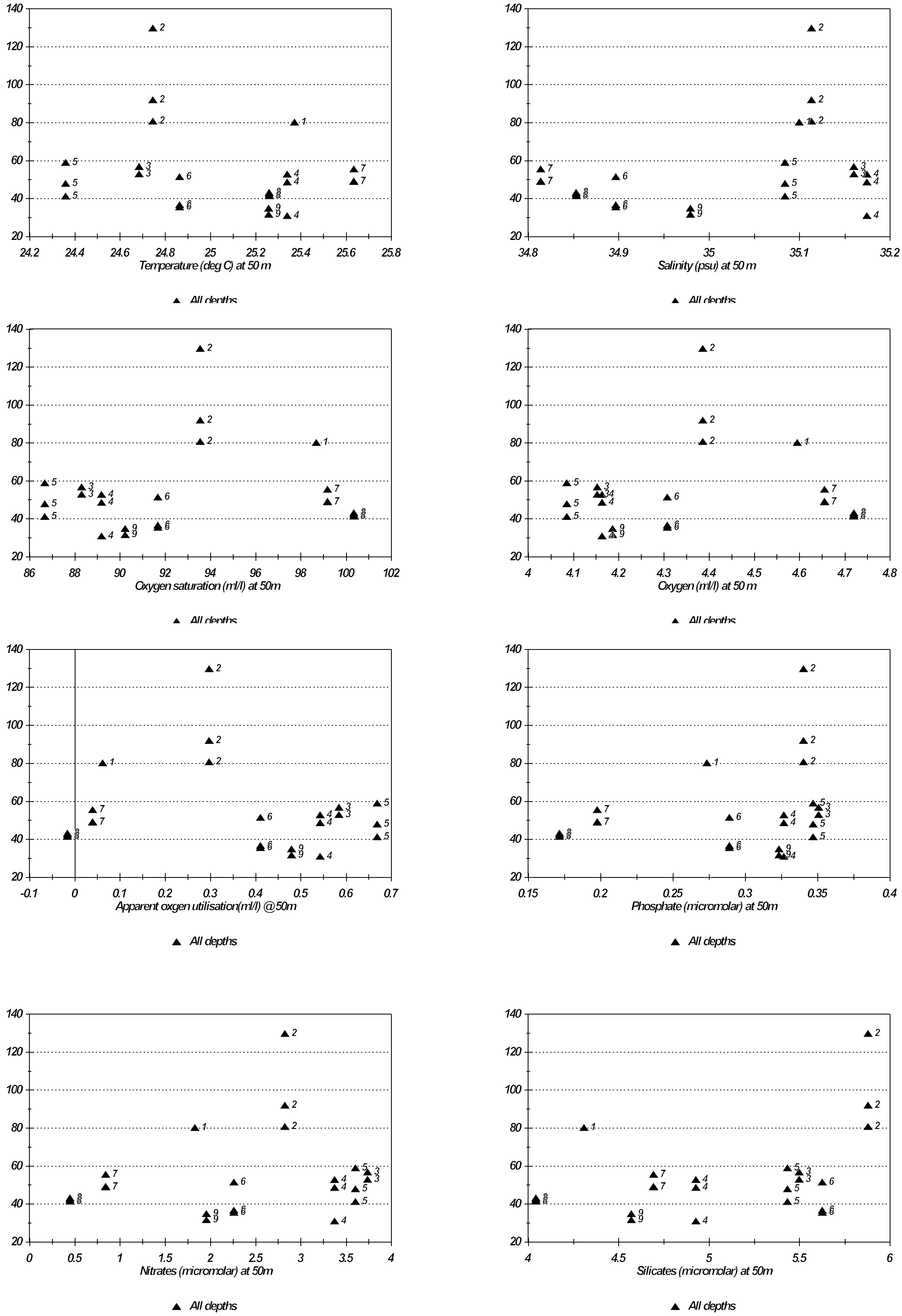


Fig. 17 : Standardised demersal catch rates (kg/md over all depths) by location (1-9 indicated) in relation to oceanic parameters recorded at a depth of 50m.



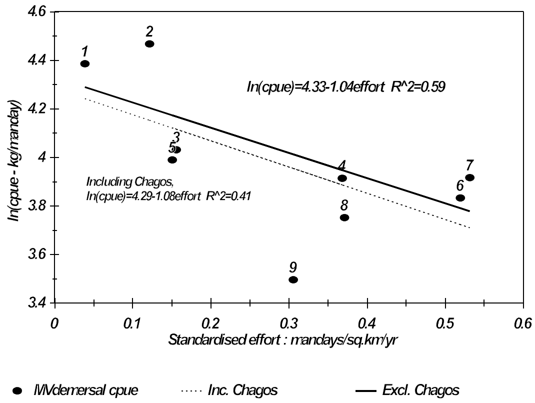


Fig. 18 : Semi-logarithmic plot of demersal catch rate by location against mean annual fishing effort, and regression results with and without Chagos (9).

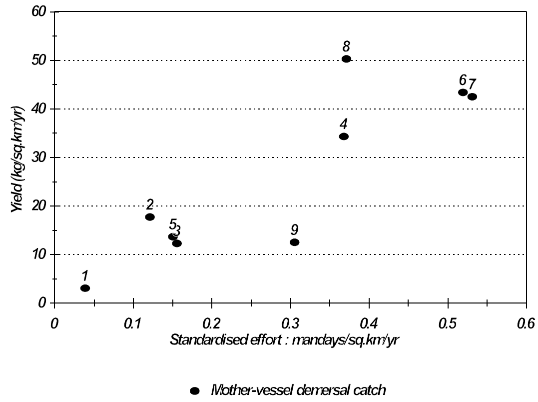


Fig. 19. Plot of mean demersal fish catch by location against mean effort per square kilometre per annum at all depths fished.

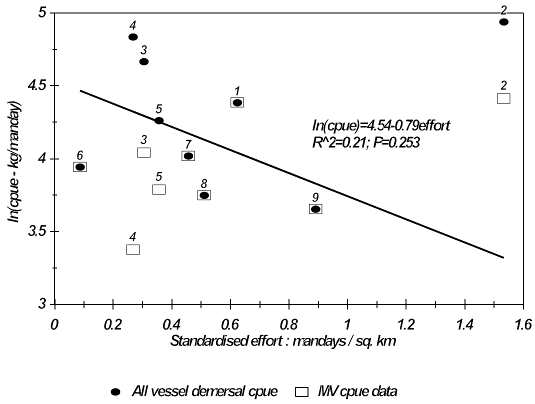


Fig 20. Munro-Thompson plot of Demersal Indian Ocean Banks fisheries in 1992 for observed and mother-vessel catch rates, and regression results for observed catch rate data.

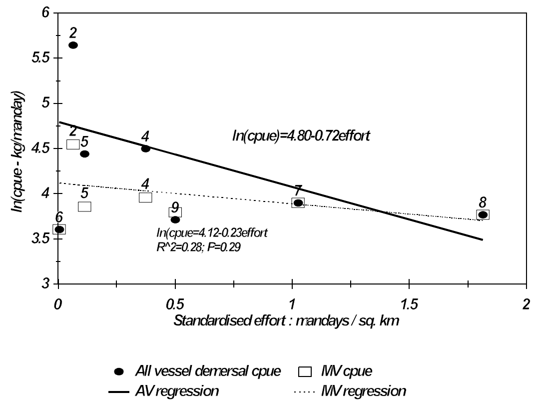


Fig 21. Munro-Thompson plot of demersal Indian Ocean Banks fisheries in 1993 for observed and mother-vessel catch rates, and regression results for these data.

REFERENCES

Ardill, J.D. (1979). Current status of fisheries in Mauritius. *FAO/SWIOP Document OISO RAF/79/065*

Ardilll, J.D. (1986). Current status of fisheries in Mauritius. *FAO/SWIOP Document, OISO RAF/79/065/WP/37/87/E*, 30p.

Bautil, B. and C.R. Samboo (1988). Preliminary stock assessment for the Mahsena emperor (*Lethrinus mahsena*) on the Nazareth Bank of Mauritius. P 260-267 *in* Sanders, M.J., P. Sparre and S.C. Venema (Eds.) (1988). Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. *FAO/UNDP: RAF/79/065/WP/41/88/E*: 277p.

Bertrand, J. (1986). Donnees concernant la reproduction de *Lethrinus mahsena* (Forsskal, 1775) sur les bancs de Saya de Malha (Ocean Indien). *Cybium.* 10(1):15-29

Bertrand, J., *et al.* (1986) Pour une evaluation des resources en capitaine /dame berrie (*Lethrinus mahsena)* des bancs de Saya de Malha. *Rapport du Groupe de Travail. IFREMER/Albion Fisheries Research Centre (Mauritius)*, 23-25 juillet 1985:39p

Bertrand, J. (1988). Selectivity of hooks in the handline fishery of the Saya de Malha Banks (Indian Ocean). *Fisheries Research,* 6:249-255

Birkett, L. (1979) Western Indian Ocean Fishery Resources Survey. Report on the Cruises of R/V "Professor Mesyatsev", December 1975 - June 1976 and July 1977 - December 1977. Rome, FAO/UNDP, Indian Ocean Programme, *IOP/Tech. Rep*. 26, 96p.

Carrara, G. and J.D. Ardill (1989). Report of a mission to Mauritius to introduce statistical systems for the artisanal, sports and banks fisheries. FAO Regional project for the development and management of fisheries in the southwest Indian Ocean.

Clark, I. N. (1993) The New Zealand experience. Paper presented to a conference on 'Managing the Environment' in Shetland, UK. 9p.

Cushing, D.H. (1971). Survey of Resources in the Indian Ocean and Indonesian Area. Indian Ocean Programme, Indian Ocean Fishery Commission. *IOFC/DEV/71/2*. FAO, Rome.

FAO/IOP (1979). Report of the Workshop on the fishery resources of the western Indian Ocean south of the equator. Mahe, Seychelles, 23 October-4 November, 1978. *Dep. Rep. Indian Ocean Programme*, 45:102p

FAO/SWIOP (1983). Mauritius fisheries baseline study. *FAO/SWIOP Document OISO RAF/78/065/WP/8/83*

FISBASE (1995) A biological database on fish. Concepts, design and data sources. Eds. R. Froese and D. Pauly. ICLARM, Manilla, Philippines.

Francis, B., M. Green, and C. Payne (Eds. 1993) GLIM4 : The statistical system for generalised linear interactive modelling. Clarenden Press, Oxford 821 pp.

Guidicelli, M. (1984). Financial feasibility study of trawling operations on Saya de Malha bank. *SWIOP document OSIO/RAF/79/065/WP/16/84.*

IMAS (1990) International Meeting on the Agricultural Sector, Mauritius, 5-7 December, 1990. *IMAS/FARM/7*

Kunzell, T., U. Lowenberg and W. Weber (1983) Demersal Fish Resources of the Mahe Plateau/Seychelles. *Arch. FischWiss*. 34(1):1-22.

Lablache, G. and G. Carrara (1988) Population Dynamics of Emperor Red Snapper (*Lutjanus sebae*) With Notes on the Demersal Fishery of the Mahe Plateau, in : Venema, S.C., J. M. Christiansen and D. Pauly (eds., 1988) Contributions To Tropical Fisheries Biology. Papers Prepared by the Participants at the FAO / DANIDA Follow-up Training Courses on Fish Stock Assessment in the Tropics. Hirtshals, Denmark, 5 - 30 May 1986 and Manila, Philippines, 12 January - 6 February 1987 FAO Fish. Rep., (389): 519p, pp 171-192.

Lebeau, A. and J.C. Cueff (1975). Biologie et peche du capitaine *Lethrinus enigmaticus* (Smith, 1959) du banc de Saya de Malha (Ocean Indien). *Rev. Trav. Inst. Peches Marit.,* 39(4):415-422

Lebeau, A. and J.C. Cueff (1976). Biologie et peche des Letrinides sur les hauts-fonds de Saya de Malha. *Trav et documents. ORSTOM*., 47:333-348

Mees, C.C. (1992) Seychelles Demersal Fishery - An Analysis of Data Relating to Four Key Demersal Species: *Pristipomoides filamentosus; Lutjanus sebae; Aprion virescens; Epinephelus chlorostigma*. *SFA/R&D/019* 143pp.

Mondon, S. (1989). Industry views on the Mauritius banks fishery. P 95-96 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

Morel, M.H. (1989). Mauritius banks fishery study marketing considerations. P 31-43 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

MRAG (1994a). British Indian Ocean Territory Fisheries Conservation and Management Zone - Inshore Fishery and Observer Programme, 1994. A Report to the Commissioner for the British Indian Ocean Territory, MRAG Ltd, November 1994.

MRAG (1994b). A description of the data entry programme for the Mauritian banks fishery catch and effort data prior to 1988 and for length weight data. MRAG Ltd, June 1994

MRAG (1994c). British Indian Ocean Territory Fisheries Conservation and Management Zone - Inshore Fishery - Annual report for 1993 including data for the 1991-1993 fishing seasons and recomendations for 1994. A Report to the Commissioner for the British Indian Ocean Territory, MRAG Ltd, January 1994.

MRAG (1995a). 1995 BIOT Inshore Fisheries Observer Programme, MRAG Ltd, 1995.

MRAG (1995b) Catch Effort Data Analysis, The CEDA User manual, MRAG London, 1995

MRAG (1996). 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. MRAG Ltd 1996.

Munro, J.L. (1983) Caribbean coral reef fishery resources. *ICLARM Stud. Rev. 7, 1-276.*

Samboo, C.R. (1983). Bank fisheries: an appraisal. In Proceedings of a seminar on marine fisheries development. University of Mauritius, 18-19 July, 1983.

Samboo, C.R. (1987). A preliminary review of the artisanal and banks fisheries of Mauritius. *AFRC, RD(F)/SU/87/2*

Samboo, C.R. (1989). A reappraisal of the banks fishery in Mauritius. P 13-30 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

Samboo, C.R. (1993). The Banks Fishery: Albion Fisheries Research Centre Statistical Unit, *Annual Report*, 8p

Samboo, C.R. (1995). The Artisanal and the Banks Fisheries of the Republic of Mauritius. AFRC, Feb 1995

Samboo, C.R. and D. Mauree (1988). Summary of the fisheries and resources information for Mauritius. P 62-79 *in* Sanders, M.J., P. Sparre and S.C. Venema (Eds.) (1988). Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. *FAO/UNDP: RAF/79/065/WP/41/88/E*: 277p.

Sanders, M. J. (1988). Summary of the fisheries and resources information for the southwest Indian Ocean. P 187-230 *in* Sanders, M.J., P. Sparre and S.C. Venema (Eds.) (1988). Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. *FAO/UNDP: RAF/79/065/WP/41/88/E*: 277p.

Sanders, M.J. (1989). An assessment of exploitation levels in the banks handline fishery and a management plan to improve the fishery performance. P 71-85 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

Sanders, M.J. (1989b). An assessment of the short tem effect on the banks handline fishery performance of implimenting an annual catch quota. P 87-94 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

Sanders, M.J., P. Sparre and S.C. Venema (Eds.) (1988). Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. *FAO/UNDP: RAF/79/065/WP/41/88/E*: 277p.

Sturgess, N.H. (1989). Some economic aspects of the Mauritius banks fishery. P 44-70 *in* SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP: RAF/87/008/WP/52/89/E,* 96p

SWIOP (1982). SWIOP Fisheries Bulletin No. 2, December 1982. *RAF/79/065*

SWIOP/MAFNR (1989). Proceedings of the seminar on the management of the banks handline fishery. *FAO/UNDP:RAF/87/008/WP/52/89/E,* 96p

Tarbit, J. (1980) Demersal Trawling in Seychelles Waters. *Fish. Bull. No 4, Fish. Div. Seychelles*, 84pp.

Thompson, R. and J.L. Munro (1983a). The biology, ecology and bionomics of Caribbean reef fishes: Lutjanidae (snappers). p. 94-109. In *J.L. Munro (ed.) Caribbean coral reef fishery resources. ICLARM Stud. Rev* 7.

UNEP/IUCN (1988) *Coral Reefs of the World, Volume 2: Indian Ocean, Red Sea and Gulf*. UNEP regional seas directories and bibliographies. IUCN, Gland, Switzerland and Cambridge.

Wheeler, J.F.G. and Ommanney, F.D. (1953) Report on the Mauritius-Seychelles Fisheries survey, 1948-1949. *Colonial Office, Fishery Publications: Vol* I, No. 3, HMSO London

Wijkstrom, U.N. and T. Kroepelien (1979). Revitalisation of the Mauritian bank fishery, an appraisal. *FAO/IOP/Tech/79/35*,56p

World Ocean Atlas (1994) CD Rom data set documentation. National Oceanographic Data Center, Ocean Climate Laboratory, Washington, DC.

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