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Population Dynamics of Emperor Red Snapper *(Lutjanus sebae)*, with Notes on the Demersal Fishery on the Mahé Plateau, Seychelles

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Abstract

Growth parameters of emperor red snapper (*Lutjanus sebae*, Fam. Lutjanidae) were estimated from length-frequency data collected during trawl surveys carried out on the Mahé Plateau, Seychelles, from 1977 to 1981. The von Bertalanffy growth parameters were estimated as K = 0.23/year and L_∞ = 96 cm. The relationship between gutted weight (kg) and total length (cm) can be expressed as $W = 0.0000525\ L^{2.77}$ or $W = 0.0000198\ L^3$.

From data on gonad maturity stages, one major spawning season from February to April and a second period of sexual activity around September to October were suggested.

Mortality rates were estimated from length composition data of the commercial handline fishery (September 1983 to August 1984) using two methods: length-converted catch curve and Jones' length cohort analysis. The two methods gave similar results of Z = 0.73, F = 0.25/year and Z = 0.78, F = 0.3/year. respectively, for the exploited part of the population, with M = 0.48 as estimated by Pauly's empirical formula.

Length cohort analysis gave a density of 1.2 t/nm^2 (0.35 t/km^2) for *Lutjanus sebae* on the offshore banks of the Mahé Plateau. An estimate of 4.4 t/nm^2 (1.29 t/km^2) was obtained for the overall fishery.

Thompson and Bell yield analysis was applied based on results obtained from the length cohort analysis. Long-term predictions of yield and biomass were attempted for varying changes in fishing mortality.

Munro's version of the surplus production model was applied to catch and effort data from the schooner handline fishery.

Introduction

Handlining is by far the most important method of fishing in the Seychelles waters accounting for 60% of all landings. In 1974 this fishery was extended to the offshore banks and periphery of the Mahé and Amirantes Plateau, with the introduction of larger boats locally known as schooners.

Emperor red snapper (*Lutjanus sebae*), locally called "bourgeois", represents 8% of the total landings by the artisanal fishery in Seychelles and 28% of the schooner landings.

In view of its economic importance both for domestic consumption and for exports, a study was started in 1983 by the Research Section of the Fishing Development Company (FIDECO) in collaboration with the UNDP/FAO South-West Indian Ocean Project. The main objective of the project was to assess the state of exploitation of this species on the offshore banks of the Mahé Plateau. This work is now being continued through the assistance of the Institut Français de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM) (see Marchal et al. 1979, 1981).

In this paper, we present the data available on the biology of the principal species caught by this fishery, *Lutjanus sebae*. Growth and mortality estimates for this species are also given for the offshore banks of the Mahé Plateau, Seychelles, along with a preliminary estimate of biomass and potential yield.

Due to the lack of long series of historical data on this offshore demersal fishery, an attempt has been made to evaluate the stock accessible to handline fishery by using a comparative approach (Munro and Thompson 1973; Gulland 1979). This study is based on two years' data collected from the fishery during the period 1982 to 1984. A rough assessment of the fishable biomass for this fishery is also attempted using cohort analysis.

Description of the Fishery

Total landings by the artisanal fishery in Seychelles is around 4,000 t annually and has remained stable for the past few years. The fishery can be divided into two broad categories: the inshore and offshore fisheries.

Inshore fishing is carried out by small open boats ranging from 5 to 8 m mostly equipped with outboard engines, and open whalers (7-9 m) powered with inboard engines.

The most common inshore gear used are handlines (60%), traps (35%), gill nets and beach seines. Two-thirds of the production is landed by inshore boats, with bourgeois representing only 5% of their catches.

The offshore fishery contributing the remaining one-third of the landings is practised by larger decked boats ranging from 9 to 12 m and known locally as schooners. These boats of wooden construction are equipped with inboard engines (27 to 37 horsepower mostly) and usually carry a Marconi sail rig. The facilities on board include a cabin for 4-6 crew and an insulated hold with a capacity of 1-2 t of ice and fish.

The fishing method practised is handlining. The fishing gear consists of a cotton main line and a monofilament leader with several branch lines with 2/0 to 4/0 size barbed hooks. The main line is weighed at the bottom with about 700 g of iron. The number of hooks varies according to the target species; for larger species, such as snappers and big groupers, 4-8 hooks are used.

Fishing activity is mostly concentrated on banks situated near the periphery of the Mahé and Amirantes Plateau. The navigation equipment on board the schooners is limited to a compass. Fishing grounds are generally out of sight of land. Fig. 1 shows a map of the fishing grounds divided into statistical sectors.

General Features of the Biology of Lutjanus sebae

Lutjanus sebae, the emperor red snapper or bourgeois, belongs to the family Lutjanidae. This species is widely distributed along the coasts of the Indian Ocean (Druzhinin 1970). In the Seychelles, unlike other coastal countries in the region, it is better represented in the catches than the blood snapper (*Lutjanus sanguineus*), a similar species.

According to Allen and Senta (1984), the juveniles inhabit shallow mangrove and seagrass areas while the adults may be found down to a depth of 100 m.

No study has been conducted in Seychelles on the distribution of juveniles but small individuals are occasionally trapped around the reef areas. Adults are caught in depths ranging from 20 to 50 m only, on substrates characterized by large scattered coral heads.

However, no precise information is available on depth distribution of smaller age groups and the migration of this species. A common belief of the local fishermen is that the bourgeois tends to congregate on shallow coral heads during the spawning season (around March to April) and is then more vulnerable to the gear.

Though the bourgeois seems to prefer rough substrates, significant numbers are also caught in trawl catches on more even grounds.

Analyses of the stomach contents of the bourgeois (Marchal et al. 1981) show that it has a carnivorous diet consisting of fish and crustaceans in similar proportions. Cephalopods were also present.

Results of trawl surveys indicate that the sexes can be differentiated at lengths greater than 20 cm; eggs are usually first observed in females of 50 to 60 cm and milt in males of 60 cm (Tarbit 1980). However, fully mature gonads have occasionally been observed in much smaller fish (de Moussac, pers. comm.). *L. sebae* is reported to reach a length of over 100 cm (Allen and Senta 1984).

Materials and Methods

Data on catch, fishing grounds, duration of trip and number of fishermen were recorded for each trip during the period September 1982 to August 1984 on FIDECO schooners. Since all the fish are gutted on board, all catches are expressed as kg or tonnes of gutted fish.

Fishing Areas

The Mahé Plateau has been divided into 10 sectors (Fig. 1). The boundary of each sector was chosen so as to enclose one major bank or related groups of banks. Sector I is not included in this study as the stock there is almost exclusively exploited by open boats (Lablache and Carrara 1984).

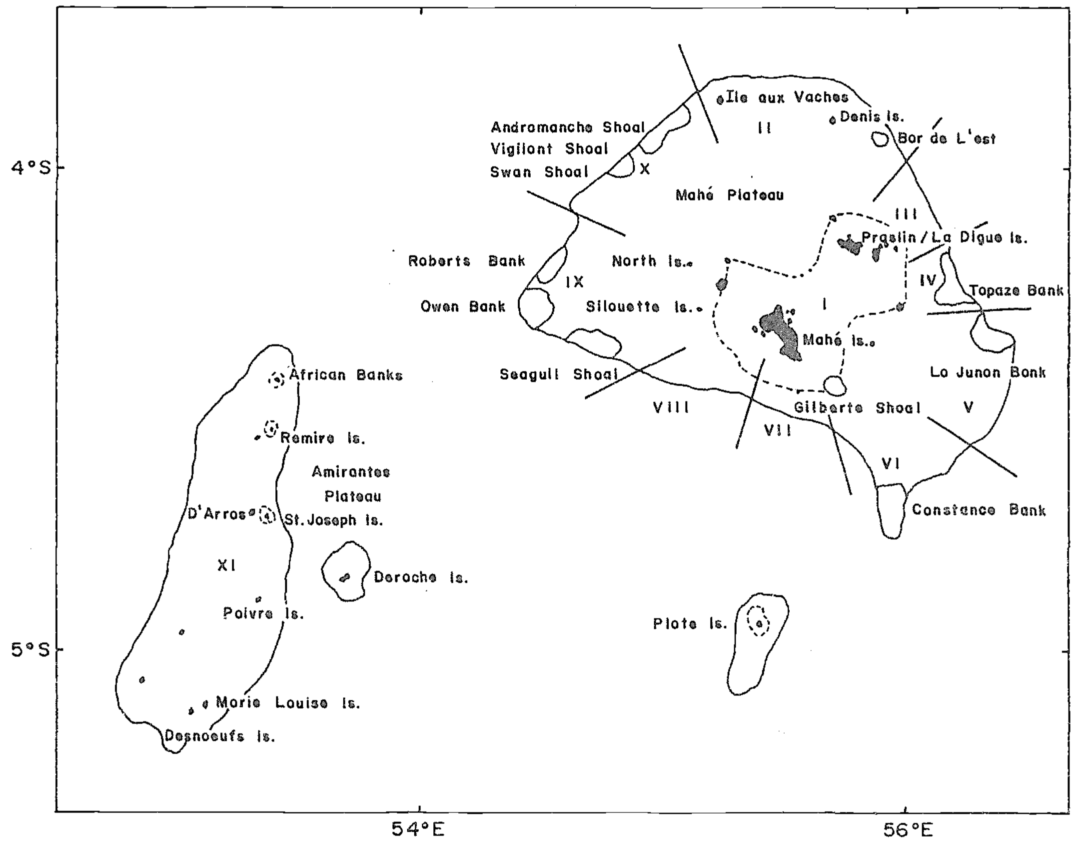


Fig. 1. Fishing sectors. I: Inner Islands area; II: Bird, Denis, North edge; III: NE edge; IV: Topaze Bank; V: La Junon Bank; VI: SE edge, Constance Bank; VII: South edge; VIII: SW edge; IX: Owen, Robert's, Seagull Banks; X: NW edge; XI: Amirantes Plateau.

The surface of the fishing banks and associated plateau edges have been estimated using the Admiralty Charts of the Seychelles group and interviewing skippers. Altogether a total of 1,920 nm^2 have been estimated to be exploited by the offshore fishery; the fishing areas are located mostly near the edges of the Mahé Plateau.

Previous estimates for the Mahé Plateau, presented here for comparison, are:

"Fishable area 3,000 nm^2" (Wheeler and Ommaney 1953)
"Edge zone 3,800 nm^2" (Steinberg et al. 1982)
"Suitable for line fishing - 35 to 65 m 1,600 nm^2" (Gulland 1979)
"Shelf and Bank areas - 20 to 50 m - 1,950 nm^2" (Birkett 1979)

Considering that the first two estimates have been calculated as a "peripheric ribbon" containing the fishing areas, our estimate of the actually fished area seems reasonable (see also Azov-Black Sea Research Institute of Marine Fisheries and Oceanography 1979; Marchal et al. 1979, 1981; Löwenberg et al. 1984).

Catch and Effort

Catch and effort data collection started in September 1981 on the parastatal fishing company (FIDECO) schooners (Nageon n.d.; Lablache and Carrara 1984). Since 1982, estimates have also been made for the privately operated schooners:

- September 1982 to August 1983 for the schooners operated by FIDECO which runs 47% of the fleet; estimates for the remainder of the fleet are based on two months' worth of data, collected during October and November 1982 (Lablache and Carrara 1984).
- September 1983 to August 1984 for the FIDECO schooners; with partial coverage by month, for the remainder of the fleet.

The mean catch rate in the different fishing sectors for FIDECO schooners was calculated from all trips carried out during the study period. Comparing the average catch rate for October-November 1982 for the rest of the fleet with the mean catch rate for FIDECO schooners during the same months, the latter was observed to be 34% lower. A similar difference of 32% was also observed for data collected in the second year of the study period.

Applying this percentage to the FIDECO figures in each sector, we estimated the corresponding catch rates for the rest of the fleet. The overall catch rate in each sector was taken as the weighted mean (by number of boats) of the two fleets. The results are shown in Table 1.

The effort exerted by the rest of the fleet during the study period was calculated as shown in Table 2, and the distribution by fishing sector was assumed to be similar to that of FIDECO schooners (Table 1).

Gonad Analysis

Since the fish are gutted at sea, only few specimens of *L. sebae* could be examined for gonad activity. The data obtained by the authors were combined with data from trawls surveys, data collected by ORSTOM staff (1984 to 1985) and other data from the files of the now renamed Fisheries Division (1976 to 1977) and are shown in Table 3 (see also Fig. 2).

Weight-Length Measurements

The gutted weights of 70 specimens of *L. sebae* for a wide range of lengths were taken during the study period (see Fig. 3).

Tarbit (1980) gives a graph of weight against fork length for males and females; they suggest no difference in length-weight relationship with sex.

Table 1. Catch and effort data by fishing zone, September 1982 to August 1984 (C/M/D: catch (kg)/man/day).

Zone	Catch FIDECO	Catch others	Catch overall	C/M/D FIDECO	C/M/D[1] overall	% of Bourgeois	Effort FIDECO	Effort[3] others	Total effort
1982-1983									
II	11,791	19,957	31,748	30.90	36.46	30.97	440	482	922
III	51,419	92,844	144,263	42.31	49.93	27.59	1,495	1,637	3,132
IV	37,006	64,097	101,103	46.07	54.36	29.57	948	1,038	1,986
V	43,400	75,386	118,786	52.63	62.10	37.82	976	1,069	2,045
VI	83,298	130,713	214,011	51.04	60.23	33.77	1,745	1,911	3,556
VII + VIII	20,609	33,513	54,122	41.14	48.55	18.20	555	608	1,163
IX	65,637	105,892	171,529	48.19	56.78	30.83	1,501	1,644	3,145
X	13,842	20,688	34,530	39.37	46.46	29.47	358	392	750
Mahé Plateau	327,002	543,090	870,092	46.10	54.40	29.78	8,018	8,781	16,800
Amirantes Plateau	45,500	72,094	117,594	34.18	40.33	1.42	1,437	1,577	3,011
Total	372,502	615,184	987,686				9,455	10,358	19,811
1983-1984									
II	6,304	9,268	15,572	24.55	28.18[2]	27.25	257	286	543
III	17,909	30,098	48,007	23.47	26.94	24.97	873	972	1,845
IV	5,621	8,931	14,552	27.02	31.01	29.32	225	250	475
V	9,808	16,141	25,949	42.26	48.50	31.57	260	289	549
VI	28,813	43,841	72,654	36.44	41.82	35.97	819	911	1,730
VII + VIII	4,975	8,061	13,036	20.10	23.07	33.40	273	304	577
IX	93,355	158,856	252,211	51.13	58.68	19.19	2,115	2,354	4,469
X	9,015	13,499	22,514	32.13	36.88	27.08	286	318	604
Mahé Plateau	175,800	288,695	464,495	38.80	44.53	28.59	5,108	5,685	10,793
Amirantes Plateau	93,899	168,711	262,610	46.05	52.85	4.81	2,494	2,775	5,269
Total	269,699	457,406	727,105				7,602	8,460	16,062

[1]((C/M/D FIDECO * 16 boats) + (1.34 * C/M/D FIDECO * 18 boats))/34.
[2]((C/M/D FIDECO * 14 boats) + (1.32 * C/M/D FIDECO * 12 boats))/26.
where boats = mean no. of boats in operation/month.
[3]Effort distribution assumed to be similar to FIDECO boats (applied to the estimated total from Table 2).

Table 2. Estimation of effort by non-FIDECO schooners of the schooner fleet (see text).

Year	Men/ boat	Days fishing per trip	Trip/ month	Mean no. of boats fishing	Annual effort man days
1982-1983	4.8	3.7	2.7	18	10,358
1983-1984	5.0	4.7	2.5	12	8,460

Table 3. Gonad activity for *Lutjanus sebae* on the Mahé Plateau, Seychelles.

		Male						Female					
Maturity stage	II	IA	A	AR	R	S	N	IA	A	AR	R	S	N
Jan	8	6	12		1		19	11	8		8		27
%		31.6	63.2	0	5.3	0		40.7	29.6	0			
Mar	252	20	140	53	5	13	231	20	149	131	28	23	351
%		8.7	60.6	22.9	2.2	5.6		5.7	42.5	37.3	8	6.5	
Apr		6	10		8	1	25	16	8		14	3	41
%		24	40	0	32	4		39	19.5		34.1	7.3	
May	8	1	2		2		5	7	2		1	9	19
%		20	40	0	40			36.8	10.5	0	5.3	47.4	
July	7	7	2				9	3	7				10
%		77.8	22.2					30	70				
Sep	36	45	11		9	7	72	50	29	5	32	15	131
%		62.5	15.3		12.5	9.7		38.2	22.1	3.8	24.4	11.5	
Oct	36	19	13		1	2	35	25	18	9	9	2	63
%		54.3	37.1		2.9	5.7		39.7	28.6	14.3	14.3	3.2	
Nov	6	34	29				62	45	27				72
%		54.8	46.8					62.5	37.5				
Dec	5	7	17		4		28	10	12		4		26
%		25	60.7		14.3			38.5	46.1		15.4		

II = Immature, IA = Inactive, A = Active, AR = Active Ripe
R = Ripe, S = Spent, N = Number of fish examined

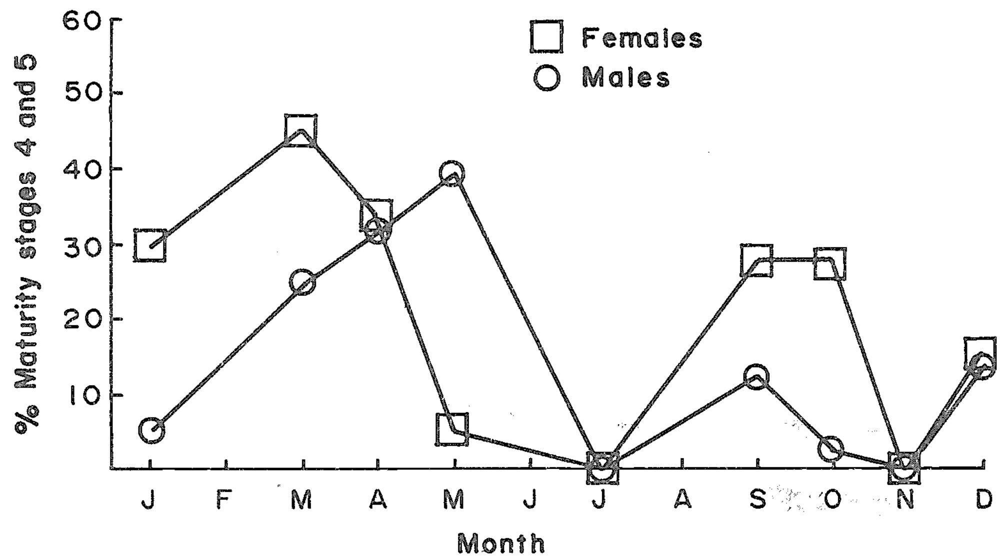


Fig. 2. Percentage maturity stages, AR and R, against month. *(Lutjanus sebae)*

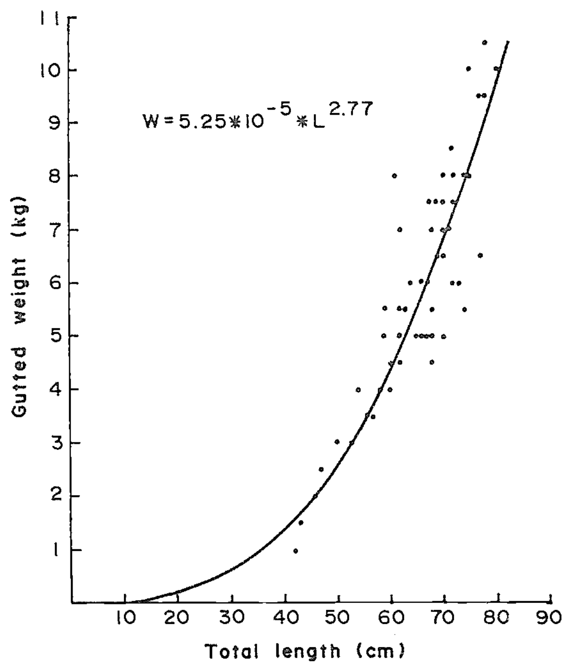


Fig. 3. Plot of gutted weight (kg) against total length (cm) for *Lutjanus sebae*.

Growth

The length-frequency samples taken from the fishery do not include the smaller age groups due to the selectivity of the gear and are therefore not suitable for estimation of growth parameters. These growth parameters have been estimated from data collected by trawl surveys carried out on the Mahé Plateau by *R/V Professor Mesyatsev,* October 1977 (Birkett 1979); *Nauka*, February to April 1979 (Azov-Black Sea Research Institute of Marine Fisheries and Oceanography 1979); and in the frame of a bilateral project with the Federal Republic of Germany, March to November 1981 (Steinberg et al. 1982). The samples used in the analysis are given in Table 4 and Fig. 4 for males and females combined. Length measurements were taken as total lengths to the cm below.

The modes in each sample were identified by separating the available length-frequency samples into their component distributions using the Bhattacharya (1967) method. By plotting the difference between consecutive logarithmic values of the number caught against length, a normal distribution is transformed into a straight line. In this manner, by visually inspecting the obtained plot, the first group can be separated and the number of fish belonging to this first group is calculated and subsequently subtracted from the sample. The process is repeated until the whole sample has been divided up into its component distributions (see also Asila and Ogari, this vol.).

The means of each group identified were plotted against time as shown in Fig.4. The most probable progression of these means was then visually identified.

The von Bertalanffy growth parameters were obtained by the Gulland and Holt (1959) method as described in Sparre (1985). This requires a plot of the difference in length between consecutive means over difference in time ($\Delta L/\Delta t$) against the mean length between the two corresponding mean lengths. By undertaking a regression analysis of the available data pairs (Fig. 5) the growth parameters L_∞ and K were estimated. These values were then used as initial values of L_∞ and K for the ELEFAN I (Electronic LEngth-Frequency ANalysis) as described by Pauly and David (1981) and implemented by Saeger and Gayanilo (1986).

Growth parameters obtained were then compared to results available on the same and/or related species.

Since growth is not linear, growth comparisons in two fish populations using L_∞ and K separately may be misleading (Pauly 1979; Kimura 1980; Merona 1983; Moreau et al. 1986).

Table 4. Percent length-frequency samples of *Lutjanus sebae* from trawl surveys in Seychelles waters.

Class midlength (cm)	MESYATSEV 14-28 Oct 1977	NAUKA 12 Feb-12 Mar 1979	German survey Mar-May 1981	Sep-Nov 1981
7.5	0	0	0.60	0
10.5	0	0	1.61	0
13.5	0	0	4.43	0
16.5	0	0.12	1.01	0.10
19.5	0	0.14	0.40	1.40
22.5	0	0.18	0.40	1.60
25.5	0	0.22	0.00	0.80
28.5	0	0.24	0.60	0.80
31.5	0	0.30	2.11	0.10
34.5	0	0.32	1.41	0.70
37.5	0	0.36	0.40	1.10
40.5	0.4	0.80	0.81	1.50
43.5	0.4	1.02	0.81	1.10
46.5	0.8	0.78	1.61	1.20
49.5	2.9	1.18	3.63	1.60
52.5	2.0	1.99	2.32	2.71
55.5	5.7	2.39	2.32	4.21
58.5	4.1	2.59	5.84	6.42
61.5	11.5	4.34	5.94	13.24
64.5	20.5	6.61	11.38	17.45
67.5	15.6	11.14	12.19	13.74
70.5	7.4	14.48	15.61	9.53
73.5	6.1	16.14	7.96	8.63
76.5	8.2	7.65	3.02	6.02
79.5	11.1	6.75	4.53	3.31
82.5	3.3	4.94	3.83	2.01
85.5	0	5.62	3.02	0.60
88.5	0	5.96	2.01	0.10
91.5	0	2.05	0.20	0
94.5	0	1.43	0	0
97.5	0	0.18	0	0
100.5	0	0.06	0	0
No. sampled	224	1,009	471	729

Pauly and Munro (1984) proposed that growth performance can be expressed by an index ϕ' defined by:

$$\phi' = \log K + 2 \log L_\infty$$

where K is expressed on an annual basis and L_∞ in cm.

When originally deriving this formula, Pauly (1979) started from the von Bertalanffy growth equation

$$W = W_\infty (1 - \exp(-K(t - t_o)))^3$$

The highest growth rate according to this equation is:

$$dw/dt_{max} = 4/9\ KW_\infty \qquad (1)$$

Pauly (1979) and Munro and Pauly (1983) used this maximum growth rate as an index of growth performance. However, based on both biological and empirical considerations (Pauly 1979 and see Moreau et al. 1986), W_∞ was replaced by an arbitrary surface of the fish $AW^{2/3}$ (where A is a constant).

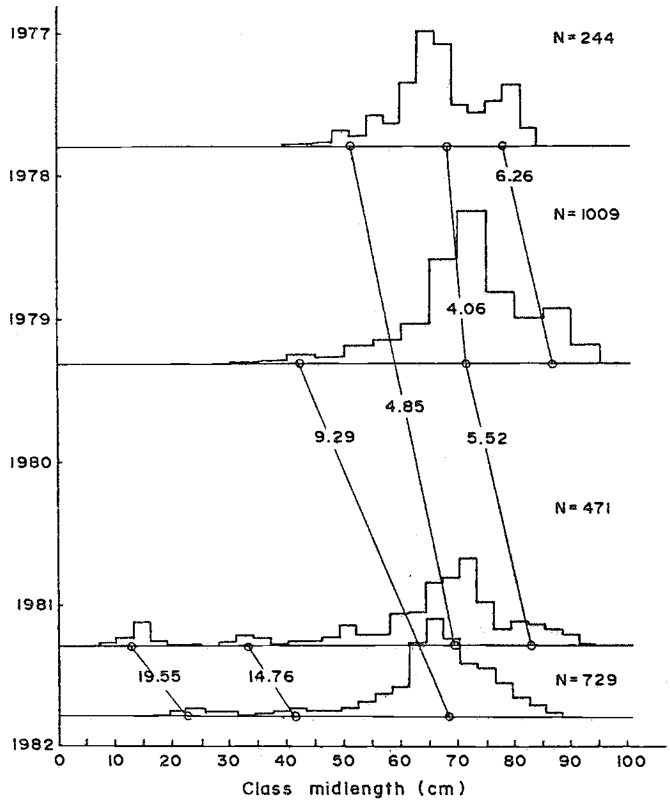


Fig. 4. Plot of modal midlengths against time and progression of the modes *(Lutjanus sebae)*. N = sample size. Growth rates in centimeters per year are listed above each progression.

This leads to

$$4/9\ KAW^{2/3}$$

as index of growth performance.

Converting W_∞ into length by $W_\infty = qL_\infty{}^3$ gives the expression

$$4/9\ Aq^{2/3}KL_\infty{}^2 \qquad (2)$$

For the purpose of statistical analysis the logarithm of expression (2) is preferred, and thus defining the index ϕ_o of growth performance

$$\phi_o = \psi + \log K + 2 \log L_\infty$$

$$\text{where } \psi = \log 4/9\ Aq^{2/3}$$

The term can be shown to remain approximately constant within small taxonomic groupings; it depends on the condition factor q and the weight/surface conversion factor A (Moreau et al. 1986).

Thus within species, and between closely related taxa, the index of growth performance

$$\phi' = \phi_o - \psi = \log K + 2 \log L_\infty$$

can be assumed to remain fairly constant.

Mortality

Length-frequency samplings of *L. sebae* landed by the schooners were taken on a quarterly basis for the different fishing sectors. The total length of the fish was measured to the nearest cm below. Table 5 presents the cumulated length composition samples, raised to the total catch in each sector for *L. sebae*. Data for Sector X have been omitted due to insufficient data.

The total mortality coefficient, Z, was calculated from catch-at-length data by combining all sectors for which data were available for the period 1983 to 1984 (Table 5). Two methods were used, the length-converted catch curve (Pauly 1983) and Jones' length cohort analysis (Jones 1984).

Table 5. Total catch by sector of *Lutjanus sebae* Sep 1983-Aug 1984 (in numbers) excluding sector X.

Length group (T.L., cm)	Sector[a] II	III	IV	V	VI	VII + VIII	IX	Total
24.5-29.4	0	41	0	0	0	0	0	41
29.5-34.4	9	41	0	12	40	10	83	195
34.5-39.4	57	20	11	48	189	14	208	546
39.5-44.4	57	102	22	95	388	20	706	1,391
44.5-49.4	76	286	11	95	388	54	665	1,575
49.5-54.4	104	449	60	131	518	81	1,329	2,673
54.5-52.4	161	469	99	357	588	78	1,703	3,455
59.5-64.4	180	469	198	417	827	118	2,451	4,660
64.5-69.4	161	428	258	393	1,235	183	1,703	4,362
69.5-74.4	114	510	93	226	866	146	1,205	3,160
74.5-79.4	85	286	60	119	388	64	1,122	2,125
79.5-84.4	28	184	44	24	269	47	291	887
84.5-89.4	19	82	5	0	129	34	83	352
Total number	1,051	3,367	863	1,917	5,826	850	11,549	25,442
Sample size (number)	111	165	157	161	585	251	278	1,708
Total catch (gutted weight, kg)	4,243	11,987	4,267	8,192	26,134	4,354	48,399	107,576

[a]See Fig. 1.

In the absence of any other information on the fishery, the natural mortality coefficient M was estimated using the approach proposed by Pauly (1980). The formula given below correlates natural mortality coefficient, M with the von Bertalanffy growth constants and the annual mean water temperature, T (in ^oC)

$$\ln M = - 0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$$

where $\ln = \log_e$ replaces $\log_{10}$ used in the original version of this equation.

Biomass and Yield

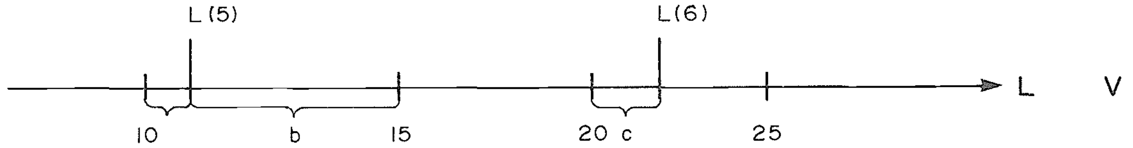
An estimate of stock size was obtained from the length cohort analysis as modified below.

Short-term prediction

The method proposed by Thompson and Bell (1934) was modified to accept length-frequency data as input:

(a) Stock numbers, N calculated by length cohort analysis are transformed into age-frequency data with help of the growth curve:

Age group (a, a + 1) corresponds to the length interval (L(a), L(a + 1)), where L is the input to the von Bertalanffy equation:



The figure above shows a hypothetical example. In this case the entire length group of 15-20 cm, the fraction b/5 of length group 10-15 cm, and the fraction c/5 of length group 20-25 cm, will be transferred to age group 5.

Fishing mortalities by length group are transferred to age groups in a similar way, taking into account the time period used to grow through a length class.

(b) Stock numbers, N, for the next year are calculated by:

$$N(y + 1, a + 1) = N(y,a) \exp^{-Z(y,a)}$$

where y is the index of year and a an index of age; N(y,a) are the numbers estimated from cohort analysis, and Z is the sum of F and M which are the mortalities from cohort analysis.

The following Table shows a hypothetical example:

Results from Jones' length cohort analysis

Length group (cm)	Stock number by length group	Fishing mortality by length group
5-10	N (5-10)	F (5-10)
10-15	N (10-15)	F (10-15)
15-20	N (15-20)	F (15-20)
20-25	N (20-25)	F (20-25)
.	.	.
.	.	.
.	.	.

Conversion of length groups into age groups by the von Bertalanffy growth equation →

Modified Thompson & Bell analysis

Age group[a]	1984 Stock number at beginning of 1984	1984 Fishing mortality during 1984 (Fishing pattern)	1985 Stock numbers at beginning of 1985
1[a]	N (84, 1)	F (84, 1)	N (85, 1) = N (84,1)
2	N (84, 2)	F (84, 2)	N (85, 2) = N (84, 1) exp (−Z(84, 1))
3	N (84, 3)	F (84, 3)	N (85, 3) = N (84, 2) exp (−Z(84, 2))
4	N (84, 4)	F (84, 4)	N (84, 4) = N (84, 3) exp (−Z(84, 3))
.	.	.	.
.	.	.	.
.	.	.	.

[a]As absolute ages were not available the ages given here are relative ones, i.e., the age corresponding to the lower limit of first length group is (arbitrarily) assigned the value 1 year.

(c) The mean stock number $\overline{N}$ during the year y + 1 is then calculated:

$$\overline{N}(y + 1,a) = N(y + 1,a) \; [1 - e^{-Z(y + 1,a)}] \,/\, Z(y + 1,a)$$

e.g., $\overline{N}(85,a) = N(85,a) \, [1 - e^{-Z(85,a)}] \,/\, Z(85,a)$

(d) The number caught in year y + 1 is calculated by:

$$C(y + 1,a) = F(y + 1,a) \, \overline{N}(Y + 1,a)$$

e.g., $C(85,a) = F(85,a) \, \overline{N}(85,a)$

(e) Yield in year y + 1 is calculated by:

$$\sum_a C(y + 1,a) \, W(a)$$

where $W(a) = q\,L(a + 0.5)^b$

(f) Biomass in y + 1 is calculated by

$$\sum_a \overline{N}(y + 1,a)W(a)$$

The procedure described above predicts the status quo catch and stock in 1985, i.e., the catch and stock in case of unchanged fishing pattern, e.g., from 1984 to 1985:

F(85,1) = F(84,1)
F(85,2) = F(84,2)
F(85,3) = F(84,3)
.
.
.

To simulate a change in the overall level of effort in 1985 compared to 1984 a constant factor, X_L, is applied to the 1984 fishing pattern:

F(85,1) = X_L F(84,1)
F(85,2) = X_L F(84,2)
F(85,3) = X_L F(84,3)
.
.
.

Thompson and Bell long-term yield prediction

This model is essentially the same as the short term prediction model. The difference is that the stock is assumed to be in a steady state (all parameters are assumed to have remained constant during a long period, e.g., constant recruitment). The recruitment estimate used is N(84,1).

Results

Spawning Season

The monthly gonad activity for *L. sebae* is given in Table 3 and Fig. 2. A plot of percentage maturity stage (AR to R) against month, as represented in Fig. 2, shows two peaks: a marked one around February to April and a smaller peak around September to October.

Weight at Length

A plot of gutted weight in kg (W') against total length in cm (L) for males and females combined is given in Fig. 3. The regression of the log-transformed weights against log-transformed lengths gives the following relationship:

$$W' = 0.0000525\, L^{2.769}$$

Assuming that the growth can be expressed by $W' = qL^3$, the following relationship between W' (kg) and L(cm) was obtained

$$W' = 0.0000198\, L^3$$

Growth

The modes identified using the Bhattacharya method and linking of the modes are shown in Fig. 4. Using the Gulland and Holt method (Fig. 5), the growth constants L_∞ and K were obtained as 96 cm and 0.23/year, respectively. These estimates shall be used for all further computations.

The ELEFAN I program gave the best fit for L_∞ = 100 cm and K = 0.25/year. The restructured samples used in the ELEFAN I analysis, with superimposed growth curve are shown in Fig. 6.

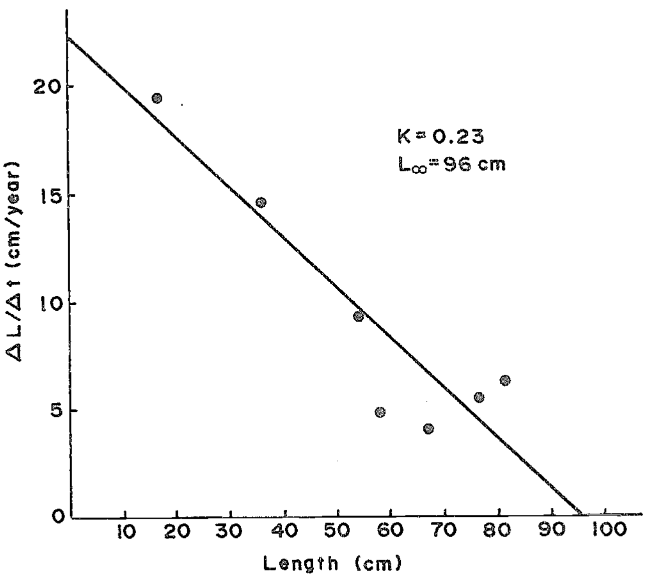


Fig. 5. Gulland and Holt. *(Lutjanus sebae).*

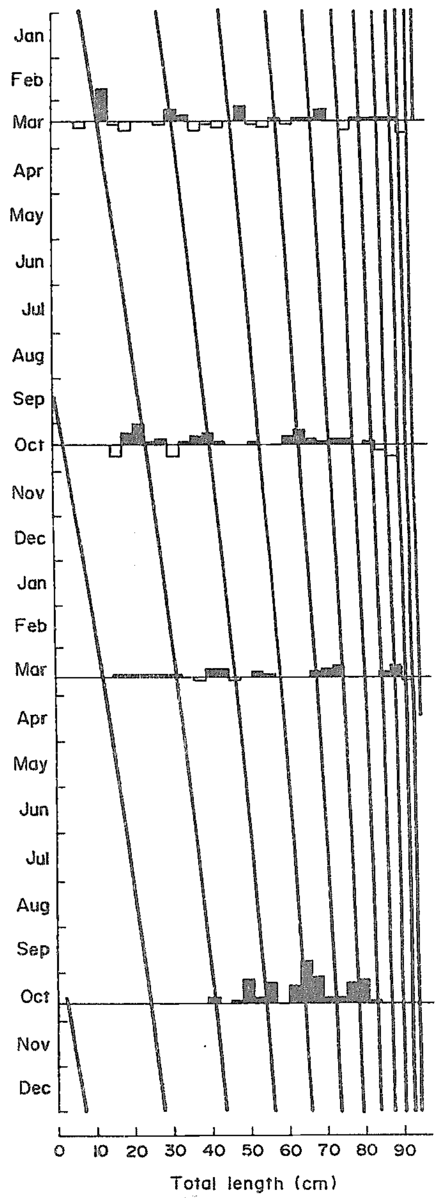


Fig. 6. Restructured length-frequency samples for *Lutjanus sebae* (Mahé Plateau, Seychelles) using ELEFAN I and superimposed growth curve.

Mortality

Using an L_∞ of 96 cm and K of 0.23/year, the length-converted catch curve gave a Z value of 0.73 (Fig. 7).

Tarbit (1980) compiled hydrological information on the Mahé Plateau, from which the mean temperature for depths ranging from 40-60 m is given as 24°C. This value introduced, along

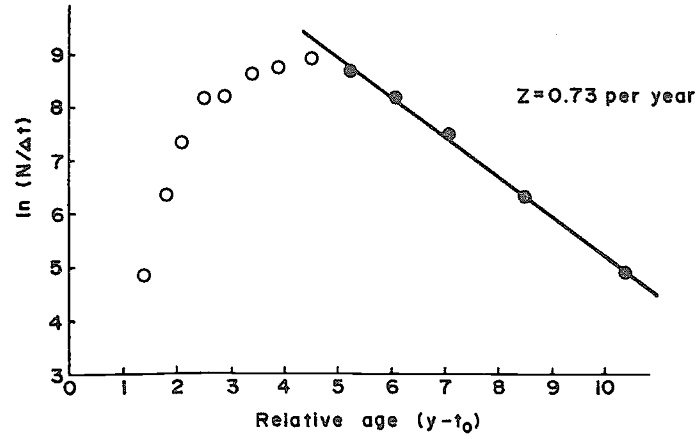


Fig. 7. Length converted catch curve for *Lutjanus sebae* (Mahé Plateau, offshore banks) for L_∞ = 96 cm, K = 0.23 per year.

with the growth parameters $L_\infty = 96$ cm and K = 0.23 into Pauly's formula leads to an estimate of M = 0.48/year.

The fishing mortality coefficient can therefore be estimated as F = 0.25.

Using length-converted cohort analysis (Table 6) with M = 0.48 a similar result was obtained. The mean F (weighted by stock numbers) for the fully exploited part of the stock (L > 64.5 cm) was 0.28.

Thus, the estimated M, F and Z appear to be consistent.

The terminal exploitation rate, F/Z, of 0.4 in Table 6 was chosen as the value giving a constant F/Z in the last length groups.

Fitting a logistic curve to the left hand side of the catch curve gave an estimate of $L_c = 41$ cm (L_c = the length at which 50% of the fish are available to the fishery and are caught if encountering the gear, i.e., the 50% length in the resultant curve).

Table 6. Jones' length cohort analysis for *Lutjanus sebae* (Mahé Plateau, offshore banks) for K = 0.23 per year, L_∞ = 96 cm and M = 0.48 per year.

Interval L (i) L (i+1) (cm)	C	X_L[a]	N	F/Z	F	Z	W (kg)	N*W
4.5- 9.5	0	1.0604	352,700	0.000	0.000	0.480	0.009	3,000
9.5-14.5	0	1.0641	313,700	0.000	0.000	0.480	0.038	12,000
14.5-19.5	0	1.0683	277,000	0.000	0.000	0.480	0.103	29,000
19.5-24.5	0	1.0731	242,700	0.000	0.000	0.480	0.218	53,000
24.5-29.5	41	1.0786	210,800	0.001	0.001	0.481	0.399	84,000
29.5-34.5	195	1.0850	181,200	0.007	0.003	0.483	0.66	120,000
34.5-39.5	546	1.0925	153,700	0.022	0.011	0.491	1.01	156,000
39.5-44.5	1,391	1.1015	128,300	0.058	0.030	0.510	1.48	190,000
44.5-49.5	1,575	1.1125	104,500	0.073	0.038	0.518	2.07	217,000
49.5-54.5	2,673	1.1260	83,000	0.134	0.074	0.554	2.80	233,000
54.5-59.5	3,455	1.1434	63,100	0.194	0.115	0.595	3.68	233,000
59.5-64.5	4,660	1.1662	45,200	0.292	0.198	0.678	4.74	215,000
64.5-69.5	4,362	1.1976	29,300	0.349	0.257	0.737	5.98	175,000
69.5-74.5	3,160	1.2438	16,800	0.373	0.286	0.766	7.42	124,000
74.5-79.5	2,125	1.3181	8,300	0.414	0.339	0.819	9.07	75,000
79.5-84.5	887	1.4575	3,200	0.387	0.305	0.785	10.95	35,000
84.5-89.5	352		900	0.400	0.320	0.800	13.07	11,000
Total number			2,214,400		Gutted biomass (kg) (Sectors I-IX)		=	1,965,000
					Whole biomass (kg) (All sectors)		=	2,358,000[b]

$*X = ((L_\infty - L(Z))/(L_\infty - L(i+1)))^{M/2K}$

[a] $X_L = ((L_\infty - L_i)/(L_\infty - L_{i+1}))^{M/2K}$.

[b] Biomass has been raised by 5% to account for sector X and by 15% to account for gutting effect.

Stock Size Estimates

Using length cohort analysis the biomass of *L. sebae* on the offshore banks of the Mahé Plateau was estimated as 2,360 t; corresponding to a density of 1.2 t/nm^2 (0.36 t/km^2) for a fishable area of 1,900 nm^2 (Table 6).

In the absence of similar information on other principal species exploited by the schooner fishery, a rough biomass assessment was made for the overall fishery based on the assumption that *L. sebae* (representing 28% of the catch) is representative of all fish in this fishery. An overall biomass of 8,400 t and a density of 4.4 t/nm^2 (1.29 t/km^2) were estimated.

Thompson and Bell Yield Analysis

The stock number and fishing mortality by length groups obtained from the cohort analysis were converted to relative age groups, using the von Bertalanffy equation as described in the section on short-term prediction and the results are given in Table 7.

Table 7. Data input for the Thompson and Bell yield per recruit model (by age group) for *Lutjanus sebae* (Mahé Plateau) with K = 0.23 per year, L_∞ = 96 cm, M = 0.48 per year and W = 0.0000198 L^3 (kg, cm).

Age group	Stock no.	Fishing mortality	Weight (kg)
1	1,126,500	0.000	.002
2	565,400	0.004	.251
3	282,400	0.033	1.107
4	136,800	0.097	2.491
5	59,100	0.219	4.178
6	26,400	0.274	5.962
7	10,500	0.322	7.696
8	4,300	0.320	9.292
9	2,000	0.305	10.706
10	900	0.320	11.927
Sum	2,214,400	–	–

Figs. 8 and 9 show the variation of the short-term yield and equilibrium yield, respectively, together with biomasses for different changes in fishing mortality.

To test the reliability of the Thompson and Bell analysis, the 1984 data were applied to predict the 1985 catch. The model predicts a catch of 115 t for a 40% reduction in effort for 1985. This seems consistent with the situation observed in 1985, where the overall fleet, reduced from 34 to 21 schooners landed approximately 120 t (round weight) of *L. sebae*.

The long-term equilibrium model (Fig. 9) seems to indicate that if the 1984 level of effort is maintained, the long term annual yield of *L. sebae* would be around 380 t.

Analysis of CPUE and Effort per Area Using the Surplus Production Model

From the estimated catch and effort figures obtained for the overall fishery (Table 1), the effort per nm^2 and the catch per nm^2 for the different fishing sectors were calculated as shown in Table 8.

These figures, applied to the surplus production model (Munro and Thompson 1973; Gulland 1979) are shown in Fig. 10.

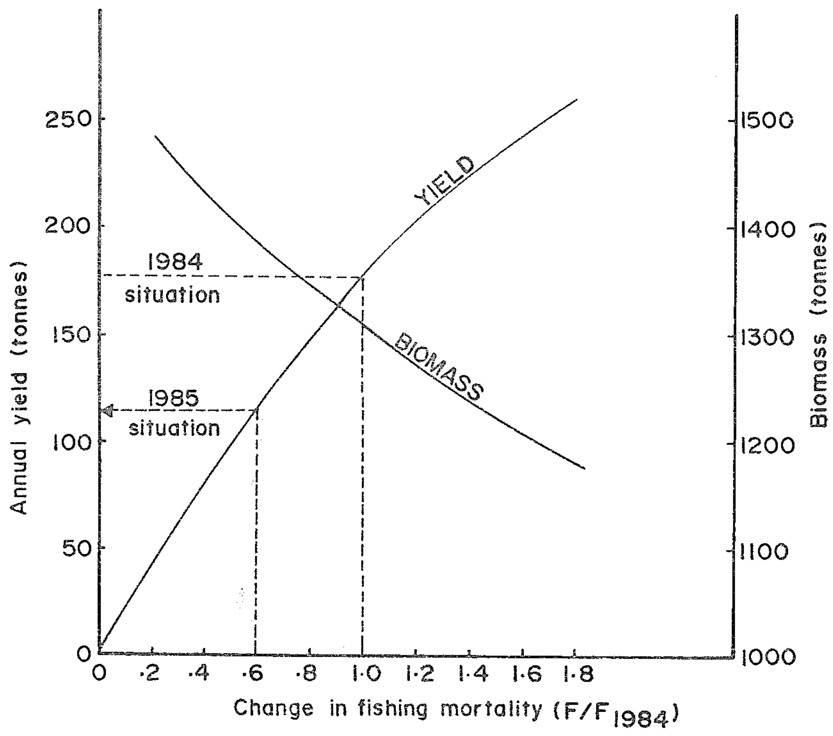


Fig. 8. Thompson and Bell short term model for *Lutjanus sebae* (Mahé Plateau, offshore banks) for L_∞ = 96 cm, K = 0.23 per year, M = 0.48 per year and W = 0.0000198 L^3 kg.

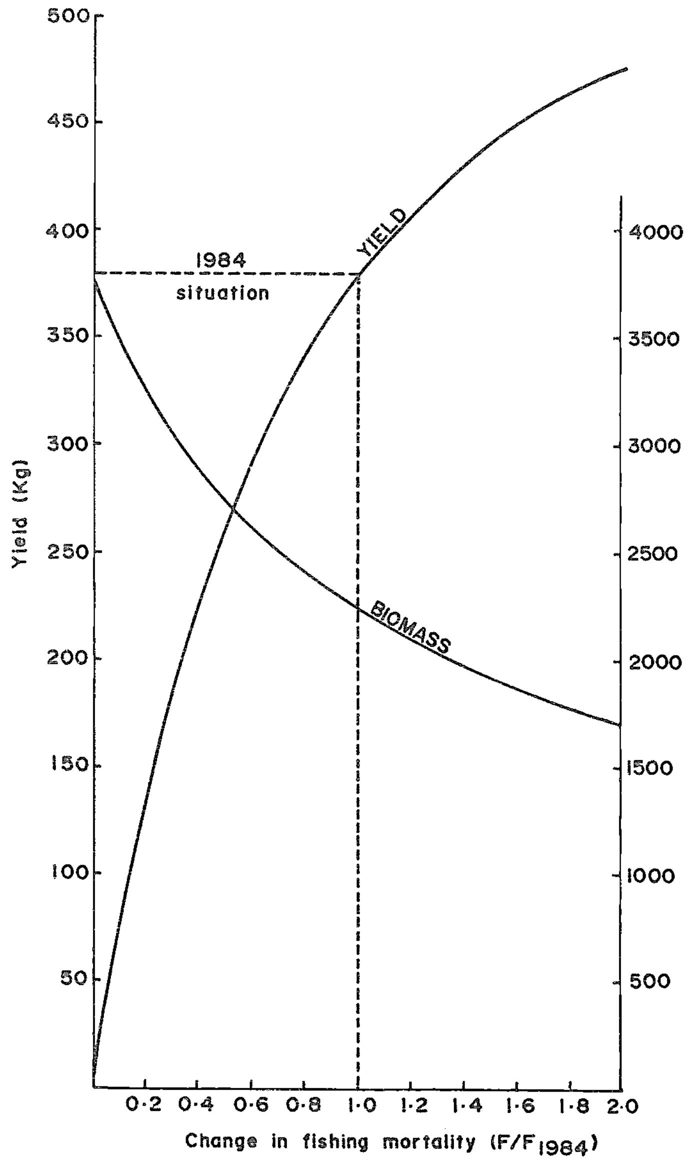


Fig. 9. Thompson and Bell long term equilibrium model for *Lutjanus sebae* (Mahé Plateau, offshore banks) parameters as in Fig. 8.

Table 8. Summary of catch rate and effort/nm^2 by fishing sectors (Mahé Plateau, Seychelles) September 1982 to August 1984. (C/M/D = catch per man per day, M*D/nm^2 = man days per square nautical mile.

Fishing zone	Area (nm^2)	Sep 1982-Aug 1983 C/M/D (kg)	Sep 1982-Aug 1983 M*D/nm^2	Sep 1983-Aug 1984 C/M/D (kg)	Sep 1983-Aug 1984 M*D/nm^2
II	80	36.	11.5	28.6	6.8
III	160	49.9	19.6	26.9	11.5
IV	224	54.4	8.9	31.0	2.1
V	225	62.1	9.1	48.5	2.4
VI	496	60.2	7.4	41.8	3.5
VII + VIII	256	48.5	4.5	23.1	2.2
IX	400	56.8	7.9	58.7	11.2
X	80	46.5	9.4	36.9	7.5

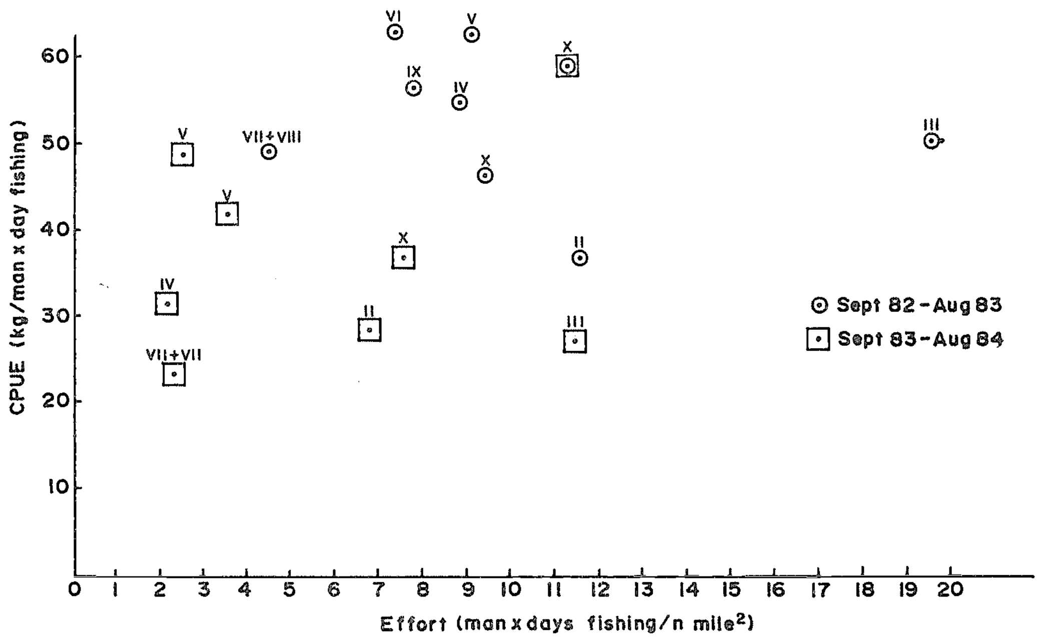


Fig. 10. Plot of CPUE (kg) man*days fishing against effort (man*days fishing/nm^2) by fishing sectors.

Discussion

Lutjanus sebae

The two spawning seasons identified correspond to the intermonsoon periods. Tarbit (1980) proposes that the main spawning season may extend from December/January to April, on the basis of data collected from April to November.

The values of L_∞ and K obtained in this study compares relatively well to other estimates obtained for *L. sebae* and similar Lutjanidae (Table 9). The ϕ' values obtained are consistent with other estimates.

Table 9. Comparison of growth estimates for *Lutjanus sebae* and some related species.

Species	K ($year^{-1}$)	L_∞ (T.L., cm)	ϕ'[a]	Area	Method	Sources
L. malabaricus (m)	0.19	102	3.30	Great Barrier Reef, Australia	Otoliths (ageing)	McPherson et al. (1985)
L. malabaricus (f)	0.25	86	3.27		Otoliths (ageing)	
L. malabaricus	0.31	60	3.05	Vanuatu, S. Pacific	ELEFAN I	Brouard & Grandperrin (1984)
L. malabaricus	0.168	83	3.06	Australian Water (Arafura Sea)	Scales & vertebrae	Edwards (1985)
L. purpureus	0.096	96.7	2.95	Off Recife, Brazil	Non-linear regression	Pauly (1978, based on Fonteles-Filho 1970)
L. sanguineus	0.236	89	3.27	Djiboutian Waters Red Sea, Gulf of Aden	Scales & vertebrae	Reference not available (UNDP/FAO, Red Sea and Gulf of Aden project)
L. sebae (m)	0.14	114	3.26	Great Barrier Reef Australia	Otoliths	McPherson et al. (1985)
L. sebae (f)	0.21	90	3.23			
L. sebae	0.23	96	3.33	Mahé Plateau, Seychelles	Bhattacharya/Gulland Holt Figs. 4 & 5. Values used for further analysis	Present investigation
L. sebae	0.25	100	3.40	Mahé Plateau, Seychelles	ELEFAN I (Fig. 6)	Present investigation

[a] $\phi' = \log_{10} K + 2 \log_{10} L_\infty$.

A difference in growth between males and females of *L. sebae* was observed in Australian waters. McPherson et al. (1985) noted that males were significantly larger than females at lengths greater than 50 cm, whereas younger fish did not show a significantly different growth. Tarbit (1980) states that adult males of *L. sebae* are substantially larger than females. In the absence of length-frequency data by sex, growth parameters estimated in this study indicates the average growth for the males and females of *L. sebae.*

The total mortality coefficient, Z, obtained using the length-converted catch curve is similar to that obtained from the length cohort analysis.

Estimates of M obtained for similar species, e.g., *L. malabaricus* in Vanuatu (Brouard and Grandperrin 1984) and *L. sanguineus* in Djiboutian Waters, Red Sea and Gulf of Aden correspond to 0.545 and 0.51, respectively, compared to 0.48 obtained in this study. However, these estimates have all been derived using Pauly's empirical formula. The value of M = 0.48 obtained corresponds however to M = 2 x K (= 0.46) as found by Ralston (1987) for groupers and snappers.

Similar values of Z obtained from the catch curve and length cohort analysis would seem to indicate that the estimated M value is reasonable.

The density of *L. sebae* estimated for the offshore banks of the Mahé Plateau is comparable to those given by various authors, for trawlable grounds, except for the estimates given by Künzel et al. (1983) which are lower (Table 10).

Biomass estimates given in this report apply only to the offshore banks of the Mahé Plateau since data for the central zone of the plateau were not included. Therefore it has been assumed that no fishing mortality is applied on the smaller length groups in both the cohort analysis and the Thompson and Bell model. Furthermore, the biomass estimate obtained for the offshore banks analysis of the Mahé Plateau is not the actual fishable biomass accessible to the schooner fishery due to the selectivity of the handlines. A reduction of about 30% should be applied to the results in order to remove fish smaller than L_c (= 41 cm) (compare Table 6).

Table 10. Comparison of some density estimates of *Lutjanus sebae* in Seychelles waters.

Estimated density tons/nm^2	t/km^2	Area and sources
0.6[a]	0.18	Mahé Plateau edge zone Künzel et al. (1983)
0.3[a]	0.09	Central zone Künzel et al. (1983)
1.4[a]	0.41	Trawlable area Mahé Plateau Tarbit (1980)
1.0[a]	0.29	Trawlable area Mahé Plateau Marchal et al. (1981)
1.2[b]	0.35	Hard bottom Mahé Plateau (offshore banks, this study)

[a]Observed % of total density estimated using the swept-area method on trawlable grounds.

[b]Length cohort analysis for estimation of population size.

The Overall Fishery

The total biomass for the Mahé Plateau was estimated to be 42,000 t by Birkett (1979), 75,000 t by Marchal et al. (1981), 80,000 t by Tarbit (1980) and 51,000 t by Künzel et al. (1983). It should be noted that these biomass estimates comprise also species not normally exploited by the handline fishery such as Scaridae, Nasidae, Gatherinidae, some shark species and small nonmarketable fish species. These results are also for the whole of the Mahé Plateau, including the central area of the plateau, the plateau edge at depths greater than 60 m and sandy bottom areas.

The density estimates of demersal fish accesible to handlining (see Table 11 for definition) on the offshore banks of the Mahé Plateau are comparable to estimates obtained previously through the use of the swept area method on trawlable grounds. Künzel et al. (1983) obtained a lower value whereas estimates given by Tarbit (1980) and Marchal et al. (1981) were higher (Table 11). The last two papers were expected to give overestimates since it was not possible to extract all the unwanted species from the overall density estimates given.

The potential yield of the offshore banks of the Mahé Plateau for the species actually exploited by the schooner handline fishery is to date not known. Künzel et al. (1983) estimate the MSY for large growing species, for the edge zone of the Mahé Plateau (3,800 nm^2) to be 2,600 t which corresponds to an MSY of 0.68 t/nm^2 (0.2 t/km^2). This figure also includes the above mentioned species not normally caught by schooners (see Löwenberg et al. 1984 and Künzel et al. 1983). By excluding these species, the estimated MSY for offshore demersal fishery will be 0.55 t/nm^2 (0.16 t/km^2).

The nonconformity of our data to the surplus production model used could indicate that this model is inappropriate and/or the data are inadequate. The lack of fit between model and data could be explained by the following:

Table 11. Comparison of some density estimates of demersal fish[a] in Seychelles waters.

Estimated density tons/nm^2			
All species[a]	Species not caught by handline excluded	Reference area and survey period	Remarks
0.8 2.7	0.5 2.1	Mahé Plateau Central zone 8740 nm^2 edge zone 3800 nm^2 1981	actual density were estimated using the swept area method from trawlable grounds and extrapolated to the whole area (incl. hard bottom) Source: Künzel et al. (1983)[a]
5.3[f]	5.0[f]	trawlable area of Mahé Plateau 4176 nm^2 1976-1979	density estimates using swept area method on trawlable grounds (no extrapolation to non-trawlable grounds Source: Tarbit (1980)[b]
4.8[f]	4.5[f]	trawlable area of Mahé Plateau 7000 nm^2 1980	density estimates using swept area method on trawlable grounds Source: Marchal et al. (1981)
4.4[d]	4.4[d]	hard bottom off Mahé Plateau (offshore banks) 1900 nm^2 1984-1985	length-cohort analysis for estimation of population size, length to weight conversion. Whole stock assumed to be represented by *L. sebae* Source: this study

[a]Big fish species. See Table 5 in Künzel et al. 1983 for definition.
[b]Some species groups as in Künzel et al. 1983 (extrapolated from Table in Tarbit 1980).
[c]Some species groups as in Künzel et al. 1983 (extrapolated from Table 3.3 in Marchal et al. (1981).
[d]Density estimates = D/0.28 assuming that *L. sebae* (= 28% of the catch) is representative for all fish.
[e]For comparison with density estimates based on handline data only.
[f]This figure is an overestimate because density estimates are given only for some selected species and the overall fishery. Therefore some unwanted fish species could not be subtracted for lack of data.

- ***Diversity of the species in the catch.*** Catch rates are influenced by the species sought by the fishermen due to pricing strategy. Fishermen have the choice of the type and the number of hooks to be used and the type of substrate and depth.

- ***Man-days fishing may not correctly reflect the fishing mortality exerted on the stock.*** The number of hooks used per line may change and the number of hours fishing per day changes. Time spent searching for fish and other factors affecting the number of hours fishing per day cannot properly be assessed.

- ***There is a sharp drop in catch rates during the bad weather season (May to August).*** This is probably due to the fast drift of the boat and related difficulty in keeping the line close to the bottom, limitation in the choice of fishing grounds and time spent waiting for improvement of weather which cannot be properly accounted for (Lablache and Carrara 1984). Catch rates cannot therefore be compared on a yearly basis if we are to account for the above drop in catch rates and the fact that some areas are visited more during either the good or bad weather season.

- ***Information on the fishing grounds may have been misreported.*** Though the skippers of the company had no real reason for giving false reports, the boats may move to adjacent fishing sectors. Furthermore the distance of the fishing grounds and the lack of navigational aids may render it difficult to obtain correct information on the fishing grounds.

Some of these factors such as the variation in catch per man x days fishing with changes in crew size, duration of fishing trip, weather conditions and fishing location have already been demonstrated by Lablache and Carrara (1984). Some of the bias in the data, mentioned above, could be corrected through the application of a multivariate statistical analysis, by which the different factors other than fishing intensity, influencing the catches per trip could be quantified. This approach applied on a single species and groups of species basis could improve the overall results (Ralston and Polovina 1982). The present study sets the stage for future research, which should entail a more detailed analysis on the existing data, aimed at identifying these variables which are significantly affecting catch rates.

Conclusion

This is the first time that such a study has been attempted on demersal stocks of the Mahé Plateau, and it has been based on limited data. Therefore results obtained here are only preliminary and should be reassessed by further research. Furthermore, consideration must be given to the fact that the schooner fishery is based on a multispecies resource. Before any management measure can be recommended, a similar study must be carried out on other important species exploited by the fishery.

The Thompson and Bell model has so far found little application to tropical fish stocks. The findings of our analysis seem to indicate that such a model could be usefully applied. It should, however, be further tested against observed data. Actually length cohort analysis should preferably be applied to data summed over several years (Jones 1984) which was not the case in the present study. Further, the Thompson and Bell model assumes constant recruitment. The estimate of this recruitment should preferably be the average value observed over several years. In the present study the recruitment was based on a value estimated for one year only. The very high value predicted as the long-term yield when applying the 1984 level of effort might be due to an outstanding high year class recruiting to the fishery in 1984.

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