A Preliminary assessment of the scad and mackerel stocks at Sofala Bank, Mozambique

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I N D E X

PREFACE

A research project on small pelagic fish in Sofala Bank and Boa Paz areas has been conducted by the "Instituto de Investigação Pesqueira" since 1979.

In 1983 IIP requested a consultancy for this project from "Instituto Nacional de Investigação das Pescas", Lisboa, Portugal. In addition a DANIDA expert joined the consultancy.

This report presents an analysis of the fishery for small pelagic species at Sofala Bank and Boa Paz with the purpose of making a preliminary assessment of the scad and mackerel stocks.

The guidelines for future activities in the project are also presented.

ABSTRACT

Scads (Decapterus russellii, D. macrosoma, Selar crumenophthalmus), Indian mackerel (Rastrelliger kanagurta) and horse mackerel (Trachurus trachurus) are the main pelagic species caught in a bottom trawl fishery at Sofala Bank and at Boa Paz.

Information on catch and effort is presented together with available data on distribution, spawning, size at first maturity, growth, mortality and biomass of the species. As the present catch and fishing mortality are low compared to the estimates of biomass and total mortality it is concluded that the fishery may be expanded further in the future.

RESUMO

O carapau, Decapterus russellii, D. macrosoma, Selar crumenophthalmus, Trachurus trachurus e a cavala, Rastrelliger kanagurta são as principais espécies pelágicas da pescaria de arrasto de fundo no Banco de Sofala e Boa Paz.

Apresentam-se os dados de captura e esforço de pesca, bem como informação sobre distribuição, desova, tamanho da primeira maturação, crescimento, mortalidade e biomassa das espécies. Como as capturas e a mortalidade por pesca são baixas comparadas com as estimativas da biomassa e mortalidade total, concluiu-se que esta pescaria poderá ser desenvolvida no futuro.

0 - INTRODUCTION

Since 1979 the "Instituto de Investigação Pesqueira" has been conducting a programme on small pelagic species, mainly on scads (Decapterus russellii, D. macrosoma and Selar crumenophthalmus)and mackerels (Rastrelliger kanagurta and Trachurus trachurus).

These species are caught in a bottom trawl fishery which started in September 1977. The fishery takes place at Sofala Bank and at Boa Paz (Fig. 1). In 1982 the total catch was 5900 tonnes of which 2700 tonnes

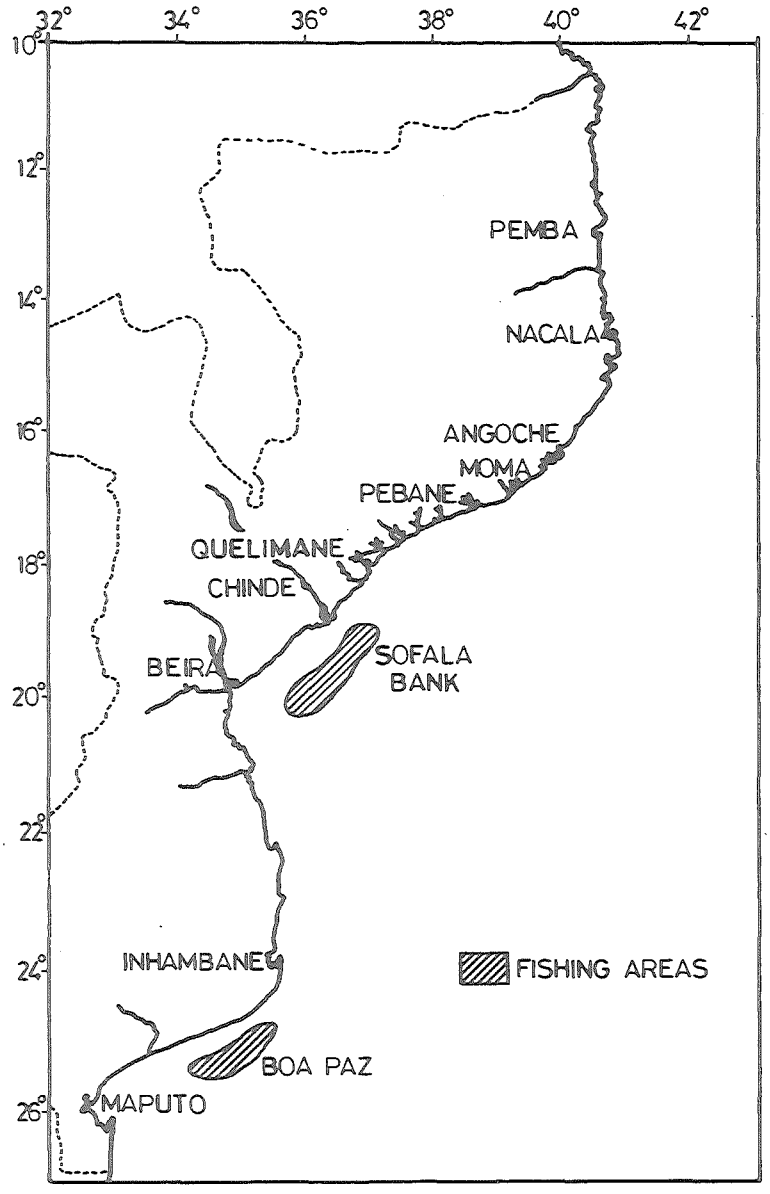

Fig. 1 - Fishing areas for scad and mackerel

came from Sofala Bank and 3200 tonnes from Boa Paz. Between 60 and 70% of this catch consists of scads and mackerels. The rest is mainly demersal species among which goatfishes, threadfin breams and lizardfishes are the most abundant.

Statistical data on commercial catches and effort are available from 1977 until now and biological data has been collected since 1979. Data on fishing effort from 1977 to 1979 were reported by Budnitchenko (1979 and 1980).

R. kanagurta is also caught in small quantities in the shrimp fishery taking place north of Zambezi river at Sofala Bank (C. Silva, pers. comm.), but apart from this no other fishery exploits the stocks.

Age, growth and reproduction of Decapterus russellii have been thoroughly investigated by GJØSAETER and SOUSA (1983) using samples from the commercial catches and research cruises at Sofala Bank.

From August 1977 to June 1978 the norwegian research vessel "Dr. Fridtjof Nansen" conducted an acoustic survey along the coast of Mozambique. The results from this investigation, reported by SAETRE and SILVA (1979), gave an estimated biomass of small pelagic species, excluding anchovy, of about 300 000 tonnes. At Sofala Bank the biomass was estimated to 123-140 000 tones.

During the periods October-November 1980 and September 1982 "R/V Dr. Fridtjof Nansen" carried out further acoustic surveys. In 1980 the estimated total biomass of small pelagic fish at Sofala Bank, excluding anchovy, was estimated to 100-140 000 tonnes of which 13-32 000 tonnes consisted of Decapterus spp.. In 1982 the estimated pelagic biomass was 130 000 tonnes, excluding anchovy.

Finally an acoustic survey was made in May-June 1983 from which the results are however not yet available.

From April to June 1981 two vessels carried out exploratory fishing and some samples of scads and mackerels were collected.

Bottom trawl surveys were carried out by the soviet commercial vessel "PANTIKAPEY" during June and July 1981. The results have been reported by SOUSA (1983).

From October to December 1982 these investigations were continued by another soviet commercial vessel "S. Rybak". The results are presented by Timochin et al. (in press).

1 - DESCRIPTION OF THE FISHERY

1.1 - Fleet

The commercial bottom trawlers operating at Sofala Bank and Boa Paz can be classified into two main types: RTM vessels (GRT ~2910; HP ~1300 and total length ~80 m) and SRTM vessels (GRT ~1920; ~1000 and total length ~60 m).

A licensed fishery started in September 1977 with two RTM vessels. In 1978 a total of 8 RTM and 4 SRTM vessels were registered. In 1979 the fleet decreased to 5 RTM and 4 SRTM vessels and from 1980 onwards only 4 SRTM vessels now belonging to the joint venture MOSOPESCA have been fishing.

1.2 - Total catch

Since 1980 the catch has been landed in Maputo but earlier the catches were landed at several ports along the coast.

Data on monthly catches have been collected from September 1977 to July 1983. Two sources of information, logsheets and records from the enterprise are available. Logsheets have since 1977 been sent every month to IIP (Appendix 0). After the joint venture "MOSOPESCA" was formed in 1980 daily radio contacts have been established between MOSOPESCA and the skippers in order for MOSOPESCA to get the position of the vessel and the total catch of the previous day. These records are collected monthly by IIP.

From 1977 to 1980 total catches were estimated from logsheets. From 1981

onwards some boats abstained from filling in the logsheets, and for this reason total catches of 1981, 1982 and 1983 were estimated from the records of MOSOPESCA.

The total annual catch at Sofala Bank and Boa Paz from 1978 to 1982 is presented in Table 1. The catch reached a maximum of 17000 tonnes in 1978 decreased to 9000 tonnes in 1979 and have been at a level between 5000

TABLE 1 - Annual catch (tonnes) at Sofala Bank and Boa-Paz

Year	Sofala Bank	Boa-Paz	Total
1977	851	1950	2801
1978	13478	3431	16909
1979	8897	29	8926
1980	3907	1342	5249
1981	4973	1893	6866
1982	2673	3226	5899
1983*	4911	794	5705

* To September (incl.)

and 7000 tonnes in the last three years. From 1978 to 1981 the catches at Sofala Bank represented 70 to 99 percent of the total catches. In 1982 this picture changed and only 45 percent of the catch was taken at Sofala Bank. Again in 1983 high catches were observed at Sofala Bank. Monthly catches for both areas are shown in Tables 2 and 3.

TABLE 2 - Total monthly catch (tonnes) at Sofala Bank from September 1977 to September 1983

Year / Month	1977	1978	1979	1980	1981	1982	1983
JAN		1056	1155	44	747	507	995
FEB		717	1121	410	396	216	699
MAR		230	1196	282	41	232	613
APR		1201	927	89	242	135	684
MAY		1914	857	226	539	-	392
JUN		2313	875	607	464	50	423
JUL		516	1331	617	515	598	615
AUG		459	742	428	753	288	451
SEP	121	1687	347	487	585	274	39
OCT	-	1241	-	365	249	-	
NOV	-	1195	-	215	22	-	
DEC	730	949	346	137	420	373	
Total	851	13478	8897	3907	4973	2673	4911*

* Incomplete

TABLE 3 - Total monthly catch (tonnes) at Boa-Paz from September 1977 to September 1983

Year / Month	1977	1978	1979	1980	1981	1982	1983
JAN		2	-	-	9	129	75
FEB		-	-	-	214	230	109
MAR		-	-	69	629	219	61
APR		2	-	139	58	156	44
MAY		-	-	126	5	142	140
JUN		-	1	-	-	405	8
JUL		1940	27	-	33	287	-
AUG		1422	-	205	84	273	11
SEP	39	5	-	-	118	107	346
OCT	937	33	-	40	195	699	
NOV	917	11	-	409	463	310	
DEC	57	16	1	354	85	269	
Total	1950	3431	29	1342	1893	3226	794*

* Incomplete

1.3 - Total effort and catch per unit of effort

The total effort and the catch per unit of effort at Sofala Bank and Boa Paz are given in Tables 4 and 5. The trawlers only fish between 6 a.m. and 8 p.m.. Approximately 5 hauls are made per fishing day, each haul lasting app. $2\frac{1}{2}$ hours.

TABLE 4 - Fishing effort and catch per unit of effort (cpue) of RTM and SRTM vessels at Sofala Bank from September 1977 to September 1983 (incl.). Data in brackets estimated from available log sheets

Year	No. of fishing days		Av. no. of hauls per day		Av. duration of haul (hours)		Total no. of fishing hours		Total catch (tonnes)		cpue (tonnes/hour)	
	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM
1977	65		4.8		2.4		749		851		1.14	
1978	739	237	4.7	4.7	2.6	2.6	9031	2896	12385	1093	1.37	.38
1979	562	63	5.2	3.9	3.1	2.0	9059	491	8550	347	.94	.71
1980		534		4.6		1.9		4667		3907		.84
1981		589		(5.1)		(2.1)		6308		4973		.79
1982		276		(5.2)		(2.3)		3301		2673		.81
1983*		408		(5.2)		(2.5)		5304		4911		.93

* To Sept. (incl.)

TABLE 5 - Fishing effort and catch per unit of effort (cpue) of RTM and SRTM vessels at Boa-Paz from September 1977 to September 1983 (incl.). Data in brackets estimated from available log sheets

Year	No. of fishing days		Av. no. of hauls per day		Av. duration of haul (hours)		Total no. of fishing hours		Total catch (tonnes)		cpue (tonnes/hour)	
	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM	RTM	SRTM
1977	106		4.8		2.4		1221		1950		1.60	
1978	250	59	4.5	1.3	2.8	2.8	3150	215	3290	141	1.04	.66
1979	4	2	3.8	2.0	3.4	1.7	52	7	28	1	.54	.14
1980		158		4.4		1.9		1321		1342		1.02
1981		233		(5.3)		(2.0)		2470		1893		.77
1982		374		(5.0)		(2.6)		4862		3226		.66
1983*		85		(6.0)		(2.7)		1377		794		.58

* To Sept. (incl.)

The proportion of the total effort spent in each of the two areas differs from year to year. One of the reasons for this variability seems to be that the trawlers on their way to Sofala Bank stop at Boa Paz to make a few hauls. If the catch rate is high they continue to fish. If not they proceed to Sofala Bank. On the way back to Maputo they usually stop at Boa Paz for 2 to 3 days.

The monthly cpue from 1980 to 1983 is given in Tables 6 and 7. No obvious trend in the cpue values during the year is apparent.

TABLE 6 - Monthly cpue (tonnes/hour) at Sofala Bank

Year / Month	1980	1981	1982	1983
JAN	.64	.79	.87	.94
FEB	.99	.90	.47	.77
MAR	.70	.77	.61	.93
APR	.74	.75	.94	.89
MAY	.83	.85	-	1.04
JUN	.97	.70	.70	.93
JUL	.74	.66	1.06	1.48
AUG	1.05	.90	.80	.75
SEP	.83	.94	.79	.59
OCT	.76	.75	-	
NOV	.90	1.04	-	
DEC	.66	.63	.94	
Average	.84	.79	.81	.93*

* Incomplete

TABLE 7 - Monthly cpue (tonnes/hour) at Boa-Paz

Year / Month	1980	1981	1982	1983
JAN	-	.28	.62	.51
FEB	-	.78	.68	.42
MAR	1.72	.84	.50	.54
APR	.68	.60	.71	.54
MAY	.61	.47	.40	.62
JUN	-	-	.60	.25
JUL	-	.38	.71	-
AUG	1.13	.72	.58	.34
SEP	-	1.11	.55	.71
OCT	1.26	.62	1.25	
NOV	1.52	.86	.61	
DEC	.85	.62	.54	
Average	1.02	.77	.66	.58*

* Incomplete

The estimation of an overall index of effort and cpue for the total fishery from 1977 to 1979 presents some problems as the cpue of RTM and SRTM vessels show opposite trends. However, the RTM trend was thought to be the most representative and an overall measure of fishing effort was hence calculated by comparing the average cpue of RTM vessels with that of SRTM vessels. By use of data from 1978 and 1979 from both areas it was estimated that one hour of RTM trawling corresponds to 2.45 hours of SRTM trawling. The total effort expressed in SRTM hours was thus calculated by multiplying the fishing hours of RTM vessels by 2.45 and adding the number of SRTM hours, Table 8.

TABLE 8 - Total catch (tonnes), total effort (hours of SRTM trawling) and cpue (tonnes per hour SRTM trawling) at Sofala Bank and Boa Paz

	Sofala Bank			Boa-Paz		
Year	Total catch (tonnes)	Effort (hours)	cpue (tonnes/hour)	Total catch (tonnes)	Effort (hours)	cpue (tonnes/hour)
1977	851	1835	.46	1950	2991	.65
1978	13478	25022	.54	3431	7933	.43
1979	8897	22686	.39	29	134	.22
1980	3907	4667	.84	1342	1321	1.02
1981	4973	6308	.79	1893	2470	.77
1982	2673	3301	.81	3226	4862	.66
1983*	4911	5304	.93	794	1377	.58

* To September (incl.)

At Sofala Bank the total effort decreased from a high level in 1978-79 to a level of about 5000 SRTM hours per year from 1980 onwards as a result of the removal of the RTM trawlers. Catch per unit of effort increased at the same time from 0.4 to 0.8 tonnes per hour, a level which has since been maintained.

At Boa Paz the same trend is visible although there seems to have been a decline in the catch per unit of effort from 1980 onwards.

1.4 - Catch composition

Onboard the vessels the catch is sorted into commercial groups each of which includes from one to several species.
From 1977 to 1980 scad and mackerel were included in the commercial groups STAVRIDA, MIXFISH and MAKREL. However, the sorting practise differed from

vessel to vessel and during the year.
In 1980, when the joint venture MOSOPESCA took over, this system was changed. From then on the catch was sorted into 3 groups according to the size and quality of the fish: second (high), second (low) and third (see Appendix 1). After sorting the fish is frozen in blocks of 10-12 kg each.

The catch was sampled by IIP as follows:

From January to August 1979 samples were taken from the landings of STAVRIDA and MIXFISH in order to examine the biology of the species.

Further biological samples were collected onboard the vessels from March 1979. Only from April 1981 onwards attempts were made to estimate the species composition of the catch.

From each haul a random sample of 30 kg of scad and mackerel was taken from the catch before it was sorted into commercial groups. From 1982 onwards demersal fish were also analysed.

In April 1983 the sampling scheme was revised once more. From then on two blocks of fish were sampled daily onboard the vessel from each of the three commercial groups. Appendix 2 summarizes the 1983 sampling scheme and gives data on the number of individuals measured, the number of gonads examined and the number of otoliths read.
The estimated quarterly species composition of the catch from 1981 to 1983 is shown in Table 9.

TABLE 9 - Quarterly proportion of scad and mackerel in the total catch from 1981 to 1983

Area	Species	1981				1982				1983				Average			Average
		1	2	3	4	1	2	3	4	1	2	3	4	1981	1982	1983	1981-83
Sofala Bank	D. russellii		0.21	0.35	0.36	0.42	0.44	0.34	0.32	0.28	0.30			0.32	0.38	0.29	0.34
	D. macrosoma		0.02	0.06	0.19	0.11	0.15	0.08	0.05	-	0.08			0.08	0.10	0.08	0.09
	S. crumenoph-thalmus		0.05	0.06	0.05	0.03	0.04	0.08	0.02	0.03	0.02			0.06	0.04	0.02	0.04
	R. kanagurta		0.08	0.09	0.09	0.19	0.05	0.20	0.10	0.19	0.26			0.09	0.16	0.21	0.14
Boa-Paz	D. russellii		0.31	0.34	0.35	0.21	0.62	0.31	0.28	0.35				0.33	0.39	0.35	0.35
	D. macrosoma		0.08	+	+	-	-	-	0.03	-				0.04	0.03	-	0.04
	T. trachurus		-	-	0.11	0.42	0.14	-	0.15	0.05				0.11	0.20	0.05	0.17
	S. crumenoph-thalmus		0.12	0.09	0.15	0.01	0.01	0.18	0.05	0.13				0.12	0.06	0.13	0.09
	R. kanagurta		0.08	0.09	0.05	0.01	0.02	-	0.02	0.09				0.08	0.02	0.09	0.05

D. russellii is the most important species and constitutes 34% and 35% of the total catch at Sofala Bank and Boa Paz, respectively. The second most important species at Sofala Bank is R. kanagurta. At Boa Paz T. trachurus comes second. The remaining two species make up less than 15% of the catch in both areas.

As the variation between quarters and years is relatively small the average percentages of the period from 1981 to 1983 was used to estimate the total yearly catch of the five species, Table 10. As no samples were considered in 1980 the estimates from this year must be looked upon as tentative only.

TABLE 10 - Estimated annual catch (in tonnes) by species at Sofala Bank and Boa-Paz

Year	1980	1981	1982	1983*
Total catch	5249	6866	5899	5705
D. russellii	1798	2354	2038	1948
D. macrosoma	405	475	370	474
S. crumenophthalmus	277	260	397	196
T. trachurus	228	115	548	135
R. kanagurta	614	791	535	727

* To September (incl.)

2 - BIOLOGY

2.1 - Decapterus russellii (Ruppell, 1828)

The russell's scad, Decapterus russellii, family Carangidae, is one of the most important species in the trawl fisheries of Mozambique, making up as much as 35 percent of the total catch of the fishery. In earlier works D. russellii has been identified as D. maruadsi (Saetre and Silva, 1979 and Brinca et al 1981).

2.1.1 - Distribution areas and vertical migrations

Birkett (1979) reported the presence of Decapterus spp. along the East African Coast, off Kenya, Zanzibar Channel (Tanzania), Sofala Bank and Boa Paz (Mozambique), Seychelles and Saya de Malha Bank (Mauritius). During this survey high concentrations of economic interest were found in the areas covered. Saetre and Silva (1979) also referred to the

presence of D. russellii from Boa Paz to Angoche although small concentrations were found up to Cabo Delgado.

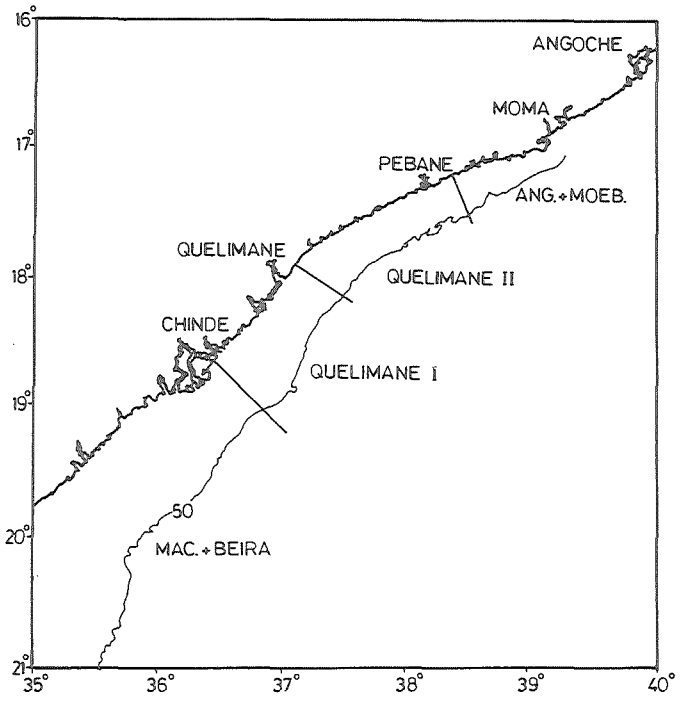

Fig. 2 - Sofala Bank. Subareas used during the surveys of "PANTIKAPEY" and "S. RYBAK" in 1981 and 1982.

Table 11 shows the results of the bottom trawl surveys conducted by "PANTIKAPEY" and "S. RYBAK" in 1981 and 1982. The area and subareas covered are presented in Figure 2. Higher catch rates were obtained in

TABLE 11 - Catch rates (kg/hour) of D. russellii from the surveys of "PANTIKAPEY" and "S. RYBAK" at Sofala Bank. The number of hours of trawling is shown in brackets.

Vessel	Period	Depth (m)	SUBAREAS				Total Area
			Beira + Machese	Quelimane I	Quelimane II	Moebase + Angoche	
Pantikapey	June/81	<45	16.05(9.00)	48.84(11.00)	2.35(9.00)	0.24(4.00)	18.33(33.00)
		45-100	.00(2.00)	1.60(2.00)	16.66(2.08	-	7.19(6.08)
	Jul/Aug/81	<45	20.16(14.25)	-	.00(39.00*)	-	5.39(53.25)
		45-100	13.22(10.42)	-	-	-	13.22(10.42)
S. Rybak	Oct/82	<45	7.85(27.50)	0.62(29.00)	1.22(17.25)	.00(15.00)	2.87(88.75)
		45-100	16.77(2.83)	129.64(7.00)	308.03(3.67)	5.18(1.42)	140.27(14.92)
	Nov/82	<45	62.64(11.67)	0.30(9.50)	0.06(9.00)	.00(10.00)	18.28(40.17)
		45-100	150.79(7.00)	45.06(2.00)	.00(1.00)	21.30(3.00)	93.04(13.00)
	Dec/82	<45	134.04(7.00)	2.38(11.00)	.00(7.00)	0.14(9.00)	28.40(34.00)
		45-100	609.12(2.00)	15.54(2.00)	-	67.76(6.33)	162.46(10.33)

* Quelimane II and Moebase+Angoche combined.

the wet season (October, November, December) than during the dry season (June, July, August). The distribution by subareas varies during the year. In July/August/81 fish were caught only in the subarea Beira + + Machese and in November and December/82 they were not found in Quelimane II. Comparing catch rates by depth intervals high values appeared at depths from 45 to 100 meters during the wet season while no special preference was observed during the dry season.

Information on vertical migrations of D. russellii are given by Saetre and Silva (1979) and Sousa (1983). During the day schools are found very close to the bottom. During the night fish disperse in the water column. The average catch per hour of D. russellii is between 12 and 33 times higher during day time than during the night.

Fish caught by pelagic trawl are generally much smaller than those caught by bottom trawl (Brinca et al, in press). At Sofala Bank the juvenile fish is mainly caught in the southern part of the Bank.

2.1.2 - Reproduction

SAETRE and SILVA (1979) found peaks of spawning in April and September.

GJØSAETER and SOUSA (1983) reported from studies of the gonadosomatic index and the maturity stages of female gonads sampled onboard the commercial vessels that two main spawning peaks are found at Sofala Bank, one at the end of the wet season (February-March) and another one at the end of the dry season (August-September).

This study has been carried on during 1982 and 1983 and the monthly variations of maturity stages of both sexes at Sofala Bank are shown in Table 12. The relative percentage of the different maturity stages observed during scientific cruises at Sofala Bank in the same period are shown in Table 13. Only samples collected from bottom hauls are included.

TABLE 12 - Maturity stages (percent) of D. russellii collected on board commercial vessels at Sofala Bank, 1979-1983

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1979														
Jan														
Feb														
Mar	23.9	27.9	40.0	3.4	4.7		527	23.1	34.6	27.1	0.2	15.0		480
Apr	6.0	35.0	53.0	6.0			100	18.8	56.2	22.9		2.1		96
May														
Jun		0.4	9.6	7.2	76.3	6.4	249	0.4	0.8	1.2		87.0	10.6	246
Jul		1.9	0.7	6.1	75.8	15.5	264			0.3		96.4	3.3	304
Aug			8.5	2.4	85.4	3.7	82			5.7		94.3		53
Sep														
Oct														
Nov														
Dec		3.3	37.2	16.4	41.6	1.5	519		1.5	18.7	13.1	65.7	1.0	610
1980														
Jan														
Feb		0.6	1.6	1.0	90.6	6.2	309	0.3				89.7	10.0	349
Mar		1.7			82.3	16.0	232		0.4			73.6	26.0	246
Apr	3.3	1.3		0.7	68.4	26.3	152	5.2				24.7	70.1	97
May														
Jun	8.3	24.3	54.9		10.4	2.1	144	2.0	44.4	31.3		11.1	11.1	99
Jul	17.8	24.1	14.5	2.1	28.6	12.9	241	8.7	18.0	12.6	2.4	38.4	19.9	206
Aug	4.1	4.1	3.2	4.9	78.9	4.9	123	0.8	0.8	0.8		84.8	12.8	125
Sep	4.6		2.3	9.1	79.6	4.6	132				1.7	94.0	4.3	116
Oct	3.6		6.2	1.0	57.4	31.8	195	1.8	0.6			69.9	27.7	166
Nov	1.0		8.9	2.0	58.4	29.7	101					49.4	50.6	77
Dec	0.7	0.7	15.1	2.1	39.7	41.8	146	2.7		2.7		37.0	57.5	73
1981														
Jan	3.2	1.6	18.1	7.1	38.6	31.5	127	2.2	2.2	1.3	1.7	54.6	38.1	231
Feb	12.8	1.3	4.5		31.4	50.0	156	28.0	19.0			20.0	33.0	100
Mar														
Apr	77.8				18.5	3.7	27	71.4				4.8	23.8	21
May	61.0	8.9	0.3		5.9	24.0	338	34.9	22.3	1.3		9.2	32.3	229
Jun														
Jul														
Aug	0.5		1.4	6.2	89.6	2.4	211	0.5	3.3	2.8	6.1	86.5	0.9	215
Sep					100.0		87		2.2		9.5	87.6	0.7	137
Oct														
Nov														
Dec		1.3		0.5	95.5	2.4	398	0.4	1.0	0.6	0.8	95.2	2.1	526
1982														
Jan		4.1			43.5	52.4	147		5.8		0.6	57.0	36.6	172
Feb		7.8			37.3	54.8	217		8.5			72.0	19.5	200
Mar		16.7	0.4	0.4	12.1	70.4	240		10.8		0.4	65.3	23.5	251
Apr														
May														
Jun		23.3	7.0		25.6	44.2	43		18.0	19.7	4.9	44.3	13.1	61
Jul		6.4	3.8	14.3	55.6	20.0	315		3.1	14.6	19.5	56.4	6.5	323
Aug		6.4		33.8	47.0	12.8	219		0.9		11.3	73.6	14.2	212
Sep														
Oct														
Nov														
Dec		1.8			80.5	17.7	113		2.0			86.7	11.2	98
1983														
Jan	0.3	11.6	0.3	0.3	63.3	24.2	335		3.7	1.3	0.7	80.9	13.4	299
Feb														
Mar														
Apr		26.5			38.2	35.3	34	2.4	4.9			41.5	51.2	41
May		7.0	4.6	2.3	51.2	34.9	43		7.4	7.4	3.7	55.6	25.9	27
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
Dec														

TABLE 13 - Maturity stages (percent) of D. russellii from research surveys in 1981, 1982 and 1983 at Sofala Bank

	FEMALES							MALES						
	I	II	III	IV	V	VI	n.	I	II	III	IV	V	VI	n
1981														
S. Kadanchik (21/04-17/05)	52.8	8.1	1.8	0.7	16.2	20.4	284	43.4	27.9	0.9	0.9	4.9	22.1	226
Pegago IV (22/05-12/06)	46.6	37.5	1.4		3.4	11.4	88	50.0	33.7			1.1	15.2	92
Pantikapey (7/06-23/06	54.5	17.4	3.3		8.3	16.5	121	49.3	32.0	4.0		1.3	13.3	75
Pantikapey (21/07- 5/08)	1.3	18.8	12.9	6.7	53.1	7.1	224	0.7	15.2	13.0	2.2	58.7	10.1	138
1982														
Fr. Nansen* (29/08-30/09)	0.8	1.7	8.3	29.3	59.1	0.8	242		12.9	11.7	1.8	73.7		171
S. Rybak (25/09-27/10)		1.6	35.0	53.7	8.9	0.8	123		1.5	60.6	37.1	0.8		132
S. Ribak (9/11-18/12)		2.5	3.4	27.6	50.5	16.1	323		1.7	2.1	21.8	67.6	6.8	293
1983														
Fr. Nansen (29/05- 8/06)		25.0	33.3		41.7		12		13.3	53.3	26.7	6.7		15

* Only samples from bottom hauls included.

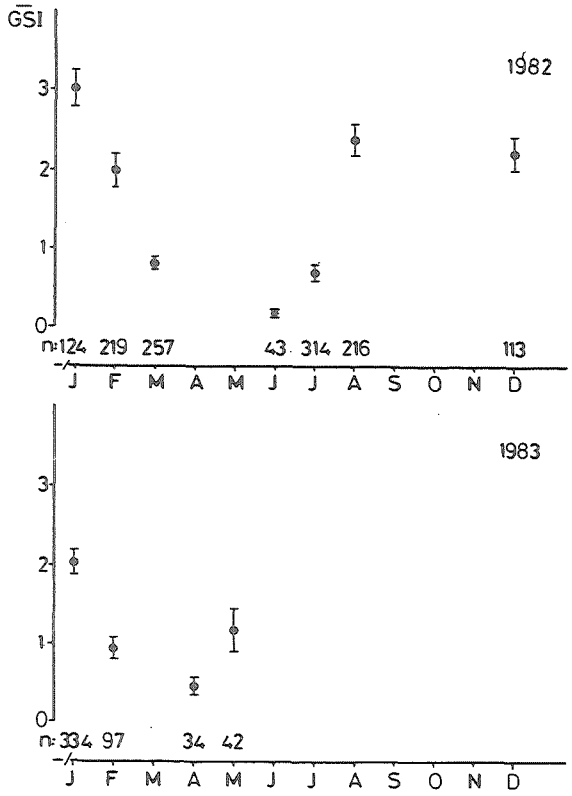

Fig. 3 - D. russellii. Average monthly value of gonadosomatic index at Sofala Bank (vertical bars indicate 95% confidence limits). Samples from commercial vessels.

Both sets of data show that high percentages of gonads in stage V (spawning) appear in both females and males at the same time. High spawning activity was also here observed twice during the year. The first peak falls in August-September. In 1980 the second peak could be observed in February while in 1981, 1982 it appeared two months earlier.

The monthly estimates of maturity stages and gonadosomatic index at Boa Paz are shown in Table 14 and Fig. 4 for the period 1980 to 1983.

TABLE 14 - Maturity stages (percent) of D. russellii collected on board commercial vessels at Boa-Paz, 1980-1983

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1980														
Jan														
Feb														
Mar														
Apr		2.6	2.6		44.9	50.0	78	1.7				33.9	64.5	121
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov			11.7	11.7	66.7	10.0	60	1.9			25.0	69.2	3.9	52
Dec	1.5	2.9	8.8	29.4	50.0	7.4	68				13.4	70.2	16.4	67
1981														
Jan														
Feb	5.7				78.9	15.5	123	6.9	2.6			71.6	19.0	116
Mar	9.5		17.6	8.1	28.4	36.5	74	12.2	18.9	2.7		46.0	20.3	74
Apr	58.3	8.3	8.3		16.7	8.3	12	17.6	35.3	5.9		41.2		17
May	38.3	11.4	5.0	0.7	22.0	22.7	141	21.1	17.7	3.4		18.4	39.5	147
Jun														
Jul														
Aug				13.9	78.2	8.0	151		3.7		1.8	92.6	1.8	217
Sep				13.3	86.7		45		1.0		4.0	93.0	2.0	100
Oct														
Nov				0.9	94.9	4.3	233	0.4			0.4	96.4	2.9	274
Dec														
1982														
Jan		12.2		2.4	36.6	48.8	41		9.3			38.9	51.9	54
Feb		9.1	0.9	0.4	36.6	52.9	221		11.8	0.6	2.2	59.6	25.8	178
Mar					40.2	59.8	107		4.2			87.4	8.4	119
Apr														
May	1.1	37.5	31.3	23.9	6.3		176	1.3	40.0	36.0	17.3	4.7	0.7	150
Jun		18.1	30.1	23.0	25.7	3.1	226	0.9	10.7	43.7	24.6	17.2	2.8	215
Jul														
Aug				3.7	81.5	14.8	27				18.2	72.7	9.1	11
Sep														
Oct			0.2	23.7	76.1		397			0.3	2.4	95.6	1.6	367
Nov														
Dec					66.7	33.3	3		4.6			86.4	9.1	22
1983														
Jan					100.0		27					90.0	10.0	30
Feb														
Mar														
Apr				5.0	95.0		40				4.4	73.9	21.7	46
May		8.3		25.0	66.7		12			3.6	3.6	92.9		28
Jun														

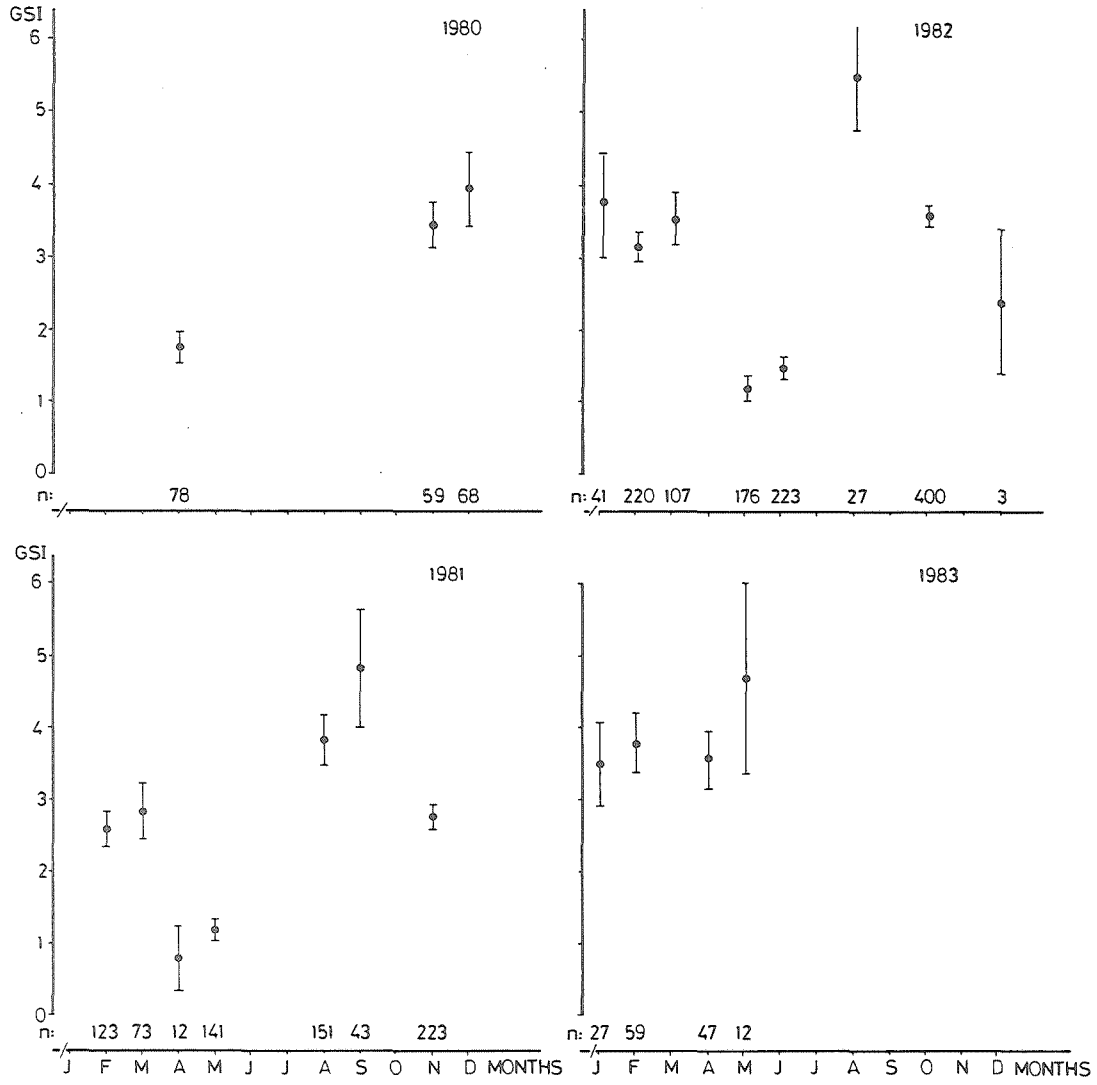

Fig. 4 - D. russellii. Average monthly value of gonadosomatic index at Boa Paz (vertical bars indicate 95% confidence limits). Samples from commercial vessels.

Available data from research cruises is presented in Table 15. Two main spawning peaks can be seen, one in November-December and another one in August-September.

TABLE 15 - Maturity stages (percent) of D. russellii from research surveys in 1981 and 1982 at Boa-Paz

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1981														
Primorets (27/03-11/05)		47.8	20.1	26.4	5.7		159		14.8	33.3	42.2	9.6		135
Pantikapey (30/06-15/07)	4.6	9.7	23.9	6.8	42.1	13.1	176	4.2	17.7	7.9	1.5	37.7	30.9	265
1982														
S. Ribak (16-19/09)		4.0	56.0	40.0			25		29.3	53.7	17.1			41

The size at first maturity was studied by BRINCA et al. (in press). Females reach their first maturity at a size of 13-14 cm while males reach their first maturity between 12 and 13 cm.

2.1.3 - Length-weight relationship

The lenght-weight relationship was studied by GJØSAETER and SOUSA (1983). About 3 400 individuals collected from commercial catches between February and December 1980 were analysed.

The resultant relationship for fish in the size range from 11.5 to 20.5 cm was:

$$W = 0.00681\ L^{3.121} \qquad (r^2 = 0.86)$$

where W is the weight in grams and L the total length in centimeters.

2.1.4 - Growth

A total of 55 otoliths from fish ranging from 13.4 to 18.6 cm was used by GJØSAETER and SOUSA (1983) to determine the age from daily growth rings.

Based on these data the following growth equation was obtained:

$$L_t = 24.8\ (1-e^{-0.56\ (t+0.10)})$$

Fish ranging from 4.2 to 13.0 cm in total length were analysed by the same method by BRINCA et al (in press), who arrived at the following equation:

$$L_t = 22.0\ (1-e^{-0.64\ (t-0.14)})$$

Figure 5 presents the two growth curves. The readings of the two sets of otoliths cannot be combined as a difference of 3-4 months can be observed. At least two reasons may be given for this discrepancy. The fish were sampled in different seasons and by different gears. Secondly an improvement of the technique used to prepare the otoliths of the smaller fish has probably increased the number of visible rings.

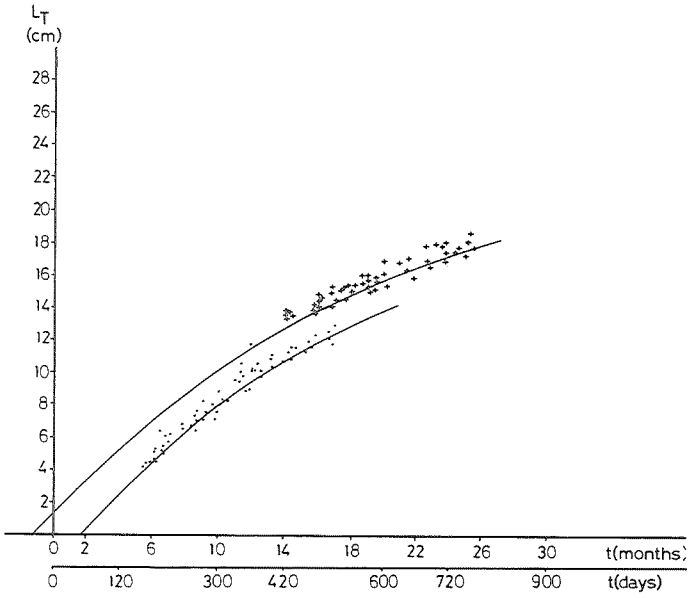

Fig. 5 - D. russellii. Growth curves based on two sets of otolith readings.

GJØSAETER and SOUSA (1983) used also the ELEFAN I program (PAULY and DAVID, 1981) to fit von Bertalanffy growth curves to length distributions from 1979 to 1981. Values of L_∞ from 24.4 to 26.0 and of K from 0.42

to 0.46 were obtained for individual years.

2.1.5 - Length composition and catch in numbers at length

Figures 6 and 7 show the monthly length composition of the samples from Sofala Bank and Boa Paz. In general much larger fish are caught at Boa Paz than at Sofala. As an example Figure 8 shows the average annual length compositions of 1981 from the two areas. The average length is 16.3 cm at Sofala Bank while at Boa Paz it is 18.0 cm.

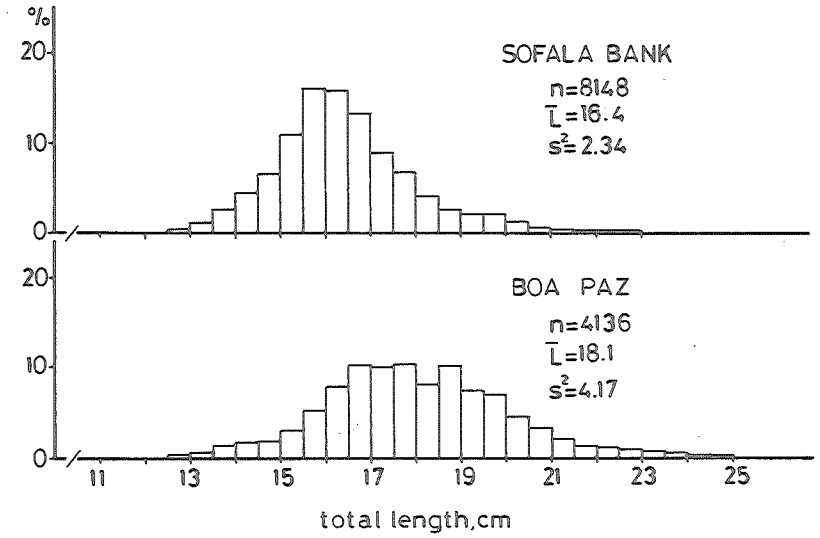

Fig. 8 - D. russellii. Average percentage length composition of samples from Sofala Bank and Boa Paz in 1981

Fish start to be caught at about 11.0 cm at Sofala Bank while the smallest ones are 13.0 cm at Boa Paz. The exactime they appear in the catches seem to vary from year to year. From the growth curve obtained for this species juveniles of 11.0 cm are app. 11 months old, they reach the size at first maturity with 12-14 months and leave the fishery at the end of their third year of life.

The catch in numbers at length was estimated for 1980 and 1981 at Sofala Bank by use of the monthly percentage length composition. The average weight was calculated by taking the average of the weight of the lower and upper limit of each length group. The parameters of the length weight relationship given by GJØSAETER and SOUSA (1983) were used. Afterwards the total numbers in the catch were calculated by

dividing the estimated weight of the sample into the total monthly catch and multiplying by the numbers in the sample. At last the monthly catches in numbers were added in order to estimate the annual numbers.

2.1.6 - Total mortality

The total mortality at Sofala Bank was calculated from the average catch in numbers at length of 1980 and 1981 assuming L_∞ = 25 cm and K= 0.5. The Jones & Zalinge method gives an estimate of Z of 3.16 in the size range from 16 to 21.5 cm, Table 16 and Figure 9. The individual Z values

TABLE 16 - Decapterus russellii. Estimates of Z from length composition of av. catch 1980-81 in Sofala Bank

Length group (cm)	Average catch in numbers ($x10^3$) 1980 - 1981	Average Z [1]	Z at length [2]
16.0 - 16.5	5550		
16.5 - 17.0	5024		1.35
17.0 - 17.5	3706		2.94
17.5 - 18.0	2381		3.82
18.0 - 18.5	1221		5.19
18.5 - 19.0	645	3.16	4.66
19.0 - 19.5	369		3.86
19.5 - 20.0	318		1.32
20.0 - 20.5	174		3.53
20.5 - 21.0	96		3.19
21.0 - 21.5	43	—	3.73
21.5 - 22.0	31		1.65
22.0 - 22.5	27		.91
22.5 - 23.0	27		.50

1) Calculated by the method of Jones & Zalinge (1981)
2) Calculated as described in appendix 3.

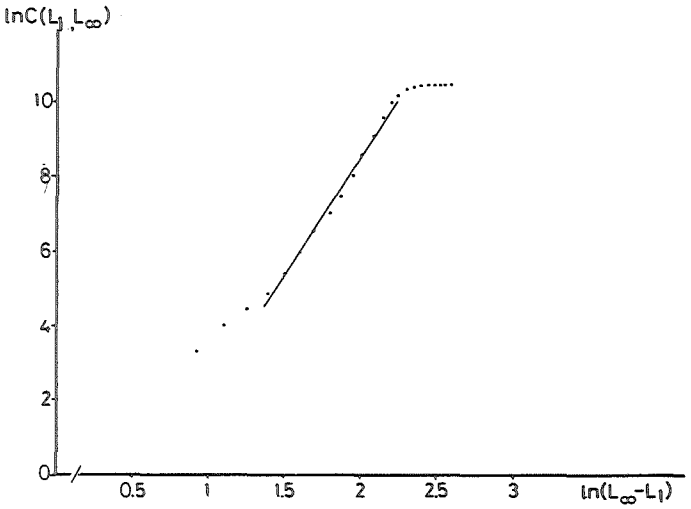

Fig. 9 - D. russellii. Estimation of Z by the method of Jones and Zalinge (1981). Data from Sofala Bank, 1980-1981 (combined). L_∞ = 25 cm, K= 0.5 $year^{-1}$.

for the same size range show no systematic trend and varies from 1.32 to 5.19 with an average of 3.36.

For Boa Paz the average percentage length composition of the samples from 1981 were used to estimate Z. This was done because of the large variations in the catch from month to month.

Assuming the growth at Boa Paz to be the same as at Sofala, Z was estimated by the J & Z method for the length range from 18.0 to 21 cm (Table 17 and Figure 10). This gave a Z value of 1.77 for Boa Paz.

TABLE 17 - Decapterus russellii. Estimates of Z from the average percentage length composition of samples in 1981 at Boa-Paz

Length group (cm)	Average Percentage (x 102)	Average Z [1]	Z at length [2]
< 16	1391		
16 - 16.5	785		
16.5 - 17	1022		
17 - 17.5	999		
17.5 - 18	1033		
18 - 18.5	809		
18.5 - 19	1013		2.39
19 - 19.5	739		.86
19.5 - 20	692	1.77	2.49
20 - 20.5	465		2.06
20.5 - 21	329		2.58
21 - 21.5	196		2.02
21.5 - 22	127		.85
22 - 22.5	113		1.30
22.5 - 23	82		.60
23 - 23.5	78		1.13
23.5 - 24	51		
24 - 24.5	33		
24.5 - 25	26		
25 - 25.5	7		
25.5 - 26	6		
26 - 26.5	6		

1) Calculated by the method of Jones & Zalinge (1981)
2) Calculated as described in appendix 3.

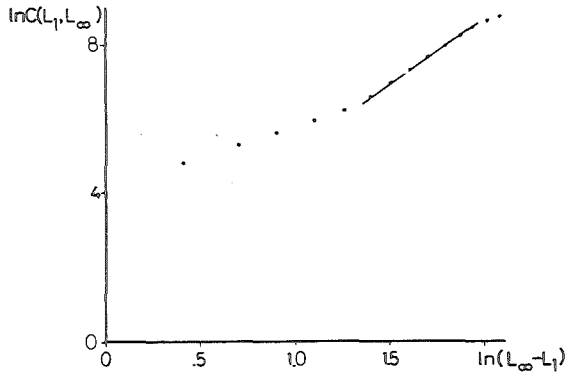

Fig. 10 - D. russellii. Estimation of Z by the method of Jones and Zalinge (1981). Data from Boa Paz, 1980. L_∞ = 25 cm, K= 0.5 $year^{-1}$.

2.2 - Rastrelliger kanagurta (Cuvier, 1816)

The Indian mackerel, Rastrelliger kanagurta, is the most common scombrid in the catch.

Information on the biology of this species in other areas can be found among others in Jones and Rosa (1965), Menon and Radhakrishnan (1974) and Losse (1974).

2.2.1 - Distribution areas and vertical migrations

Birkett (1979) reports that Indian mackerel is present along the coasts of Kenya, Tanzania and Mozambique. SAETRE and SILVA (1979) and BRINCA et al. (1981) found R. kanagurta from Boa Paz to Angoche.

Table 18 shows the results of the surveys made by "PANTIKAPEY" and "S. RYBAK". The areas and subareas covered are shown in Figure 2.

TABLE 18 - Catch rates (kg/h) of R. kanagurta from the surveys of "PANTIKAPEY" and "S. RYBAK" at Sofala Bank. The numbers of hours of trawling are shown in brackets.

Vessel	Period	Depth (m)	SUBAREAS				Total Area
			Beira + Machese	Quelimane I	Quelimane II	Moebase + Angoche	
Pantikapey	June/81	<45	2.13 (9.00)	6.11 (11.00)	1.36 (9.00)	6.61 (4.00)	3.79 (33.00)
		45-100	.00 (2.00)	7.91 (2.00)	3.50 (2.08)	-	3.80 (6.08)
	Jul/Aug/81	<45	60.44 (14.25)	-	1.40 (39.00)*	-	17.20 (53.25)
		45-100	1.85 (10.42)	-	-	-	1.85 (10.42)
S. Rybak	Oct/82	<45	7.14 (27.50)	0.16 (29.00)	0.18 (17.25)	2.39 (15.00)	2.70 (88.75)
		45-100	4.73 (2.83)	8.29 (7.00)	6.94 (3.67)	6.04 (1.42)	7.07 (14.92)
	Nov/82	<45	2.67 (11.67)	0.36 (9.50)	.00 (9.00)	0.16 (10.00)	0.90 (40.17)
		45-100	48.27 (7.00)	2.15 (2.00)	.00 (1.00)	11.50 (3.00)	28.98 (13.00)
	Dec/82	<45	4.36 (7.00)	0.95 (11.00)	1.07 (7.00)	2.39 (9.00)	2.06 (34.00)
		45-100	14.04 (2.00)	125.57 (2.00)	-	4.98 (6.33)	30.08 (10.33)

* Quelimane II and Moebase + Angoche combined.

R. kanagurta was present in all the subareas. The catch rate varied with season and depth. High values were found in the rainy season (November-December) at depths between 45 and 100 m in the Beira-Machese subarea.

As for D. russellii the highest catch rates are obtained during daytime. During the "PANTIKAPEY" survey the catch rate obtained by bottom trawl were app. 13 times higher during daytime than during the night and probably R. kanagurta show the same behaviour as D. russellii. The fish stay close to the bottom during daytime and disperse in the water column at night.

The juveniles are mainly caught in the southern part of Sofala Bank and are found closer to the surface than the adults. BRINCA et al. (in press) found that the average length of fish caught by pelagic trawl was 7.7 cm while fish caught by bottom trawl had a mean length of 21.3 cm.

2.2.2 - Reproduction

The spawning season and the size at first maturity was studied by SOUSA and GISLASON (in prep.). Samples were taken from the commercial catches and from surveys at Sofala Bank and Boa Paz from 1979 to 1983. Monthly percentages of maturity stages of males and females and the gonadosomatic index of females were estimated. The results show that R. kanagurta has a long spawning season which lasts from July to April and that only one spawning peak is present. At Sofala Bank the peak is found in the period from November to February, at Boa Paz it occurs one or two months later. The time the peak appears varies however from year to year.

The size at which 50% of the females are in spawning was found to be between 20 and 21 cm.

2.2.3 - Length-weight relationship

The length-weight relationship was determined from individual measurements of 2464 fish sampled throughout 1980 at Sofala Bank (SOUSA and GISLASON, in prep.). The relationship could be described by:

$$W = 0.0041\ L^{3.304}$$

where W is the weight in grams and L the total length in centimeters.

2.2.4 - Growth

SOUSA and GISLASON (in prep.) studied the growth of R. kanagurta. The age of the fish were estimated by counting the daily growth rings in otoliths. A total of 62 fish of the size range from 4.5 to 21.0 cm were aged. The von Bertalanffy growth equation was fitted to the data and estimates of the parameters obtained. It was thus found that the growth could be described by:

$$L_t = 27.8\ (1-e^{-0.75\ (t\ -\ 0.13)})$$

where t is time in years and L_t the length in cm, at time t (Fig. 11).

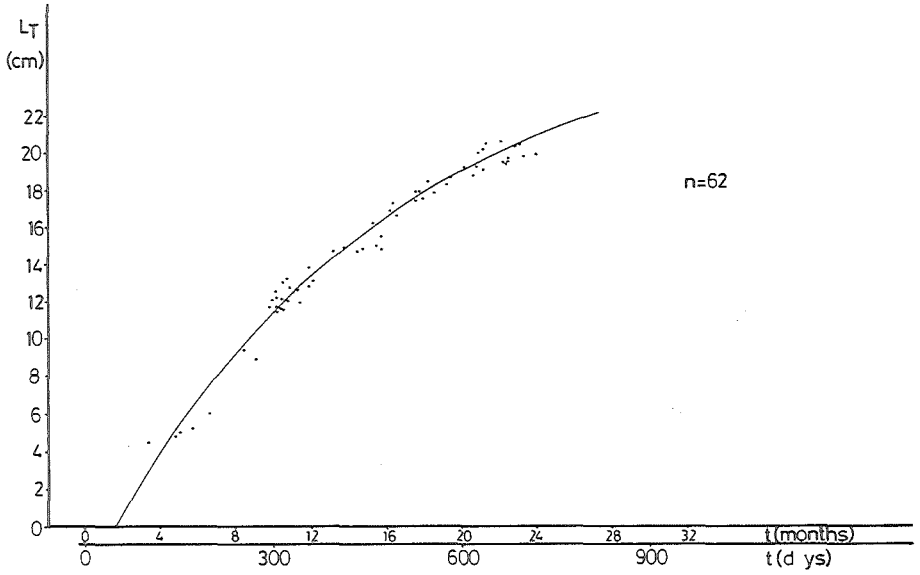

Fig. 11 - R. kanagurta. Growth curve based on otolith readings. From SOUSA and GISLASON (in prep.).

The ELEFAN II (PAULY et al., 1981) was also used to fit growth curves to length samples from the commercial catch in 1979, 1980 and 1981. The growth equation used was:

$$L_t = L_\infty\ (1-e^{-(Kt\ +\ C\frac{K}{2II}\ \sin\ (2II\ (t\ -\ WP\ +\ 0.5)}$$

and contains besides the usual parameters, K and L_∞, two more parameters which have been introduced in order to take seasonal variation of growth into account. The additional parameters C and WP are used to describe the

magnitude of the seasonal influence and the time at which the growth rate is at a minimum, respectively. The estimated parameters are given in Table 19.

TABLE 19 - R. kanagurta. Growth parameter as estimated by ELEFAN II

Growth parameter	1979	1980	1981
L_∞ (cm)	29.5	28.5	30.5
K (year^{-1})	0.85	.83	0.90
C (year)	(0.4)*	(0.4)*	0.4
WP (year)	0.7	0.7	0.6

* Value fixed before iteration (i.e., not estimated from the data)

As can be seen the values of L_∞ are a bit larger than the one estimated from age readings and the K values smaller.

2.2.5 - Length composition and catch in numbers

Figures 12 and 13 show the monthly composition of the samples from Sofala Bank and Boa Paz. As for D. russellii there is a tendency towards larger fish to appear at Boa Paz than at Sofala Bank, Fig. 14, although the difference in average length is smaller. The average length in 1981 is 20.5 cm at Sofala Bank and 21.3 cm at Boa Paz.

Recruitment to the fishery seems to occur during the first half of the year although the exact time is variable from year to year. The fishstart to be caught at a length of 12.0 cm at Sofala Bank and at a length of 15 cm at Boa Paz. Using the growth curve estimated by otolith readings fish measuring 12.0 cm are app. 11 months old. When they reach the size at first maturity they are 2 years old and at an age of 3 years only a very few are left to be caught in the fishery.

The average catch in numbers at length was estimated in the same way as for D. russellii (ch. 3.1.5) for Sofala Bank 1980 and 1981 by use of the length weight relationship given above.

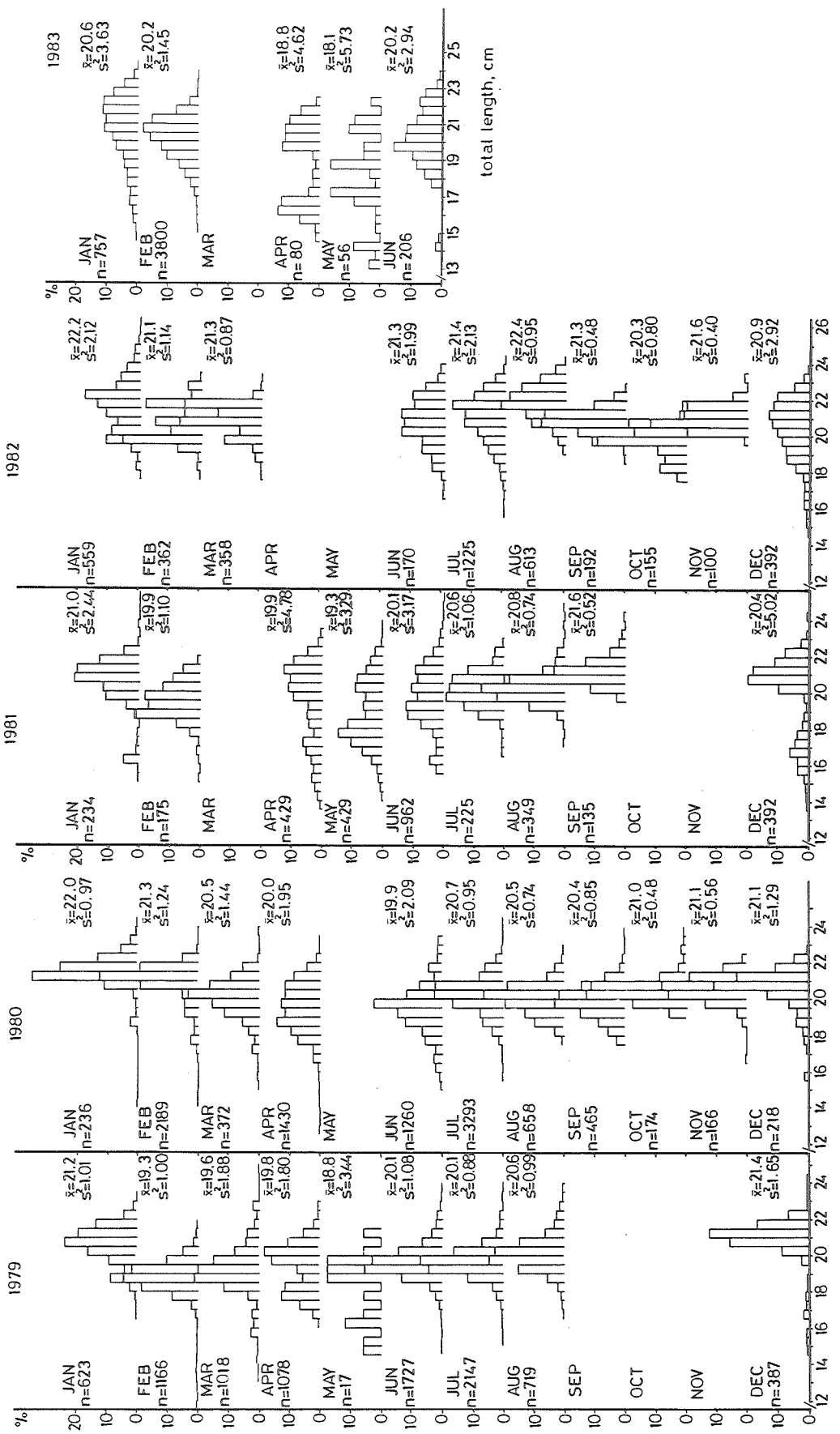

Fig. 12 - R. kanagurta. Percentage length composition of commercial catch at Sofala Bank.

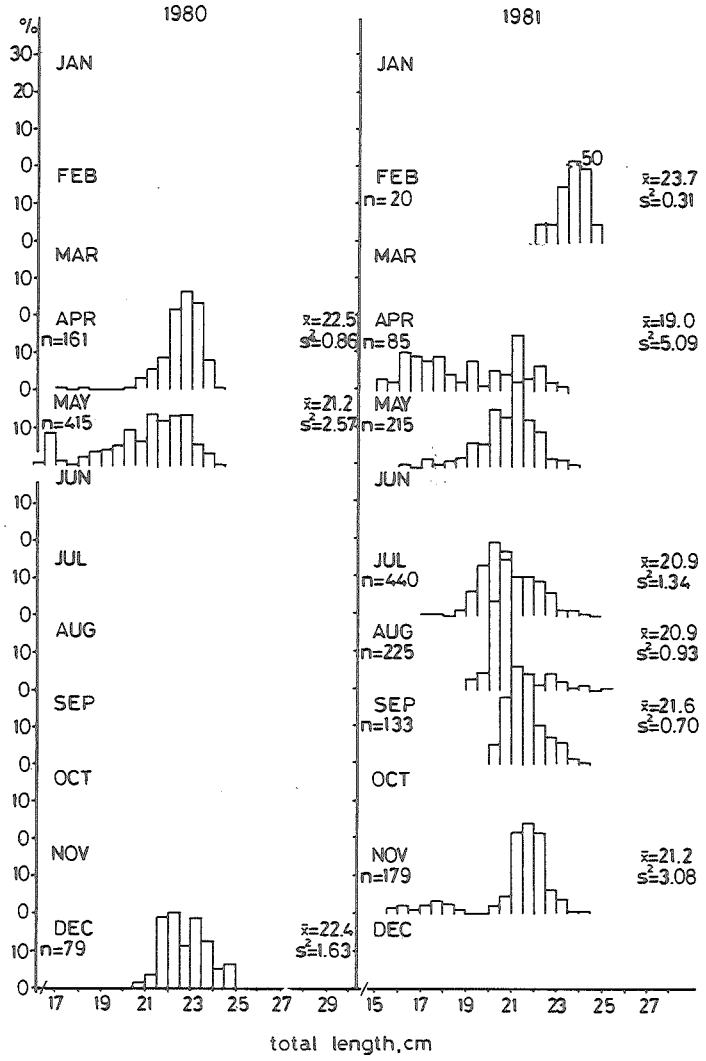

Fig. 13 - R. kanagurta. Percentage length composition of commercial catch at Boa Paz.

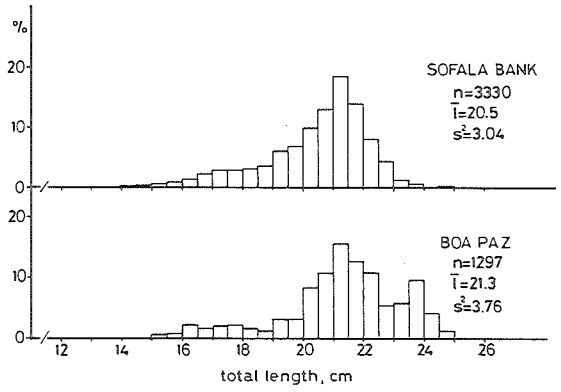

Fig. 14 - R. kanagurta. Average percentage length composition of commercial catch at Sofala Bank and Boa Paz in 1981.

2.2.6 - Total mortality

Table 20 shows the estimates of the total yearly mortality of R. kanagurta at Sofala Bank calculated by use of the growth parameters obtained from the age readings.

TABLE 20 - Rastrelliger kanagurta. Estimates of Z from length composition of average catch 1980-81 at Sofala Bank

Length group (cm)	Average catch in numbers ($x10^{-3}$) 1980-1981	1) Average Z	2) Z at length
< 18	379		
18 -18.5	224		
18.5-19	291		
19 -19.5	501		
19.5-20	646		
20 -20.5	990		
20.5-21	1146		
21 -21.5	1216		
21.5-22	775		5.04
22 -22.5	461	7.07	5.30
22.5-23	187		8.00
23 -23.5	59		9.17
23.5-24	22		9.31
24 -24.5	10		
24.5-25	5		
25 -25.5	1		
25.5-26			
26 -26.5			
26.5-27			
27. -27.5			
27.5-30.5	4		

1) Calculated by the method of Jones & Zalinge (1981)

2) Calculated as described in appendix 3.

Both the Jones and Zalinge method, Fig. 15, and the individual estimations of Z at length give very high mortality estimates. The Jones and Zalinge methods gives Z= 7.07 and the average of the individual values over the same range gives Z= 7.36.

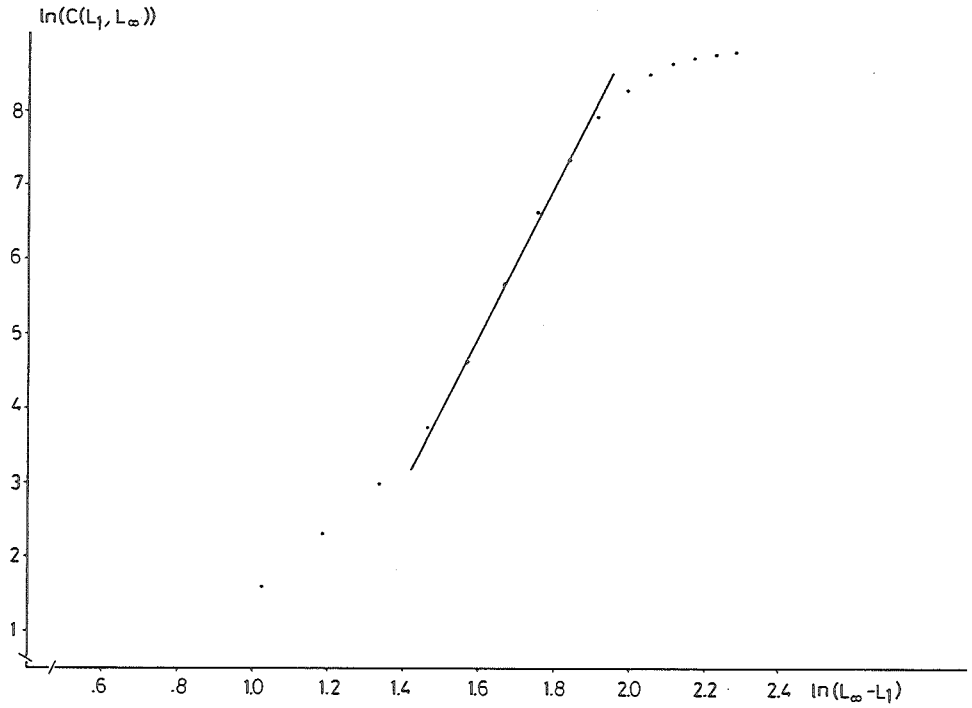

Fig. 15 - R. kanagurta. Estimation of Z by the method of Jones and Zalinge (1981). Data from Sofala Bank, 1980-81. L_∞ = 27.8 cm, K= 0.75 year^{-1}.

Z was also estimated by the ELEFAN II (PAULY et al., 1981). For 1979, 1980 and 1981 the estimates were 9.98, 8.86 and 9.29 even higher than the values obtained above. Such high values, corresponding to more than 50% of the stock dying per month, are unlikely. The explanation may either be that the large fish migrate out of the fishing area or that their catchability is much lower than the smaller ones.

The mortality was also estimated from the average percentage length composition at Boa Paz, Table 21. The points, Figure 16, seem to fall on a straight line in the size range from 21 to 24 cms. However, the individual values of Z are highly variable. Further sampling and migration studies seem to be needed before reliable estimates of Z can be obtained for R. kanagurta.

TABLE 21 - Rastrelliger kanagurta. Estimates of Z from average percentage length composition of samples in 1981 at Boa-Paz

Length group (cm)	Average Percentage ($x10^2$)	Average Z [1]	Z at length [2]
< 18	820		
18 -18.5	140		
18.5-19	108		
19 -19.5	290		
19.5-20	302		
20 -20.5	828		
20.5-21	1066		
21 -21.5	1543		2.68
21.5-22	1259		2.11
22 -22.5	1078	2.43	6.43
22.5-23	531		.31
23 -23.5	565		2.61
23.5-24	953		
24 -24.5	395		
24.5-25	113		
25 -25.5	4		
25.5-26			
26 -26.5			
26.5-27	5		
27 -27.5			
27.5-30.5			

1) Calculated by the method of Jones & Zalinge (1981)
2) Calculated as described in appendix 3.

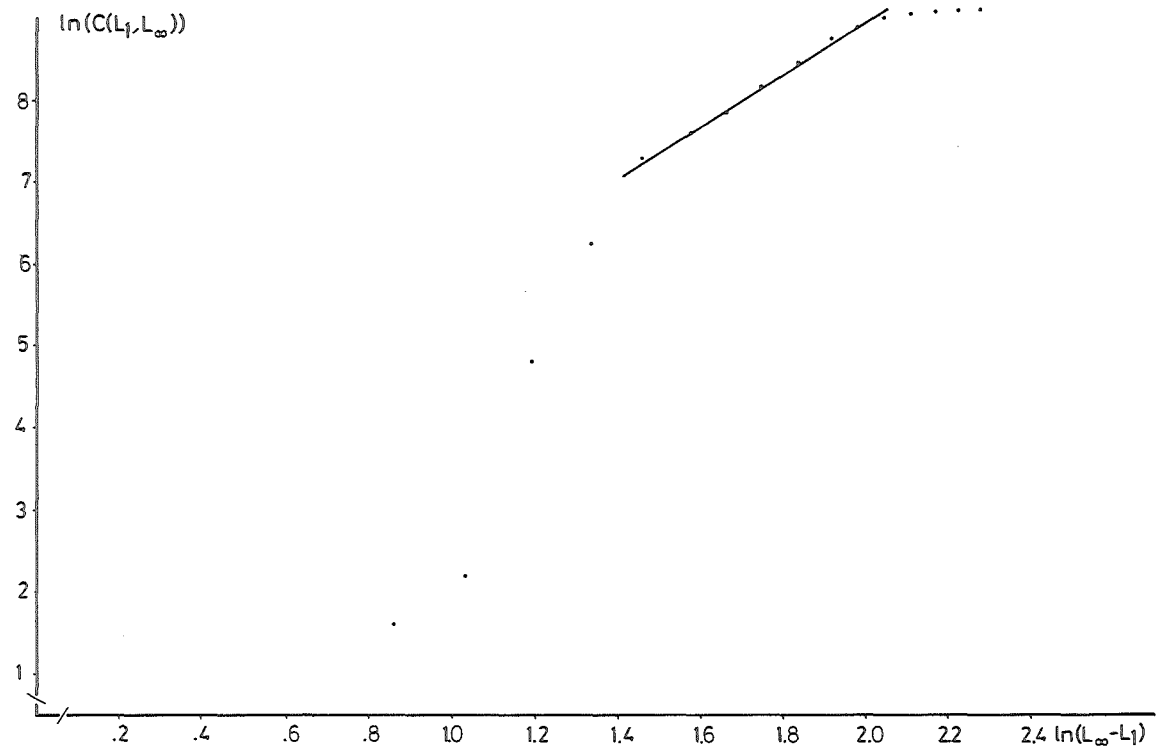

Fig. 16 - R. kanagurta. Estimation of Z by the method of Jones and Zalinge (1981). Data from Boa-Paz 1981. L_∞ = 27.8 cm, K= 0.75 $year^{-1}$.

2.3 - Decapterus macrosoma Bleeker, 1851

2.3.1 - Distribution areas and vertical migrations

Saetre and Silva (1979) report the presence of this species from Boa Paz to Angoche where it is caught together with Decapterus russellii, although in lower quantities.

The catch rates (kg/h) from the surveys of "PANTIKAPEY" and "S. RYBAK" are shown in Table 22. The distribution pattern is the same as for

TABLE 22 - Catch rates (kg/h) of D. macrosoma from surveys of "PANTIKAPEY" and "S. RYBAK" at Sofala Bank. The number of hours trawling is shown in brackets.

Vessel	Period	Depth (m)	SUBAREAS				Total
			Beira + Machese	Quelimane I	Quelimane II	Moebase + Angoche	
Pantikapey	June/81	<45	5.34(9.00)	1.12(11.00)	1.80(9.00)	0.24(4.00)	2.35(33.00)
		45-100	.00(2.00)	0.17(2.00)	13.65(2.08)	-	4.72(6.08)
	Jul/Aug/81	<45	+ (14.25)	-	.00(39.00)*	-	+ (53.25)
		45-100	0.26(10.42)	-	-	-	0.26(10.42)
S. Rybak	Oct/82	<45	0.03(27.50)	0.01(29.00)	.00(17.25)	.00(15.00)	0.01(88.75)
		45-100	.00(2.83)	11.47(7.00)	70.20(3.67)	.00(1.42)	22.65(14.92)
	Nov/82	<45	0.23(11.67)	0.02(9.50)	.00(9.00)	.00(10.00)	0.07(40.17)
		45-100	1.17(7.00)	1.08(2.00)	.00(1.00)	.00(3.00)	0.80(13.00)
	Dec/82	<45	15.09(7.00)	.00(11.00)	.00(7.00)	.00(9.00)	3.11(34.00)
		45-100	4.23(2.00)	69.00(2.00)	-	0.01(6.33)	14.19(10.33)

* Quelimane II and Moebase + Angoche combined.

D. russellii. Although the data are scanty the highest catch rates are observed during the wet season at depths from 45 to 100 meters.

Like D. russellii this species has daily vertical migrations concentrating near the bottom during day time and dispersing in the water column at night.

2.3.2 - Reproduction

SOUSA and GISLASON (in prep.)studied the spawning of D. macrosoma at Sofala Bank from the monthly variations in maturity stages of males and females and the gonadosomatic index (GSI) of females. Data collected onboard the commercial vessels and during surveys were used.

Both methods indicate two spawning peaks, one in August-September and another one in February. The last one is probably of less importance as a lower percentage of females in spawning and a lower value of GSI suggest. The same was observed for D. russellii.

2.3.3 - Length-weight relationship

SOUSA and GISLASON (in prep.) studied the length weight relationship by use of data collected at Sofala Bank from February to December 1980. A total of 1955 fish were sampled and the following equation obtained:

$$W = 0.0038\ L^{3.258} \qquad (r^2 = 0.89)$$

where W is total weight in grams and L total length in centimeters.

2.3.4 - Growth

A total of 52 otoliths of fish between 14 and 20.5 cm were used to determine the age from daily growth rings (SOUSA and GISLASON, in prep.). The following equation was obtained:

$$L_t = 27.4\ (1-e^{-0.432\ (t\ +\ 0.54)})$$

where L_t is the total length in centimeters at time t (Figure 17).

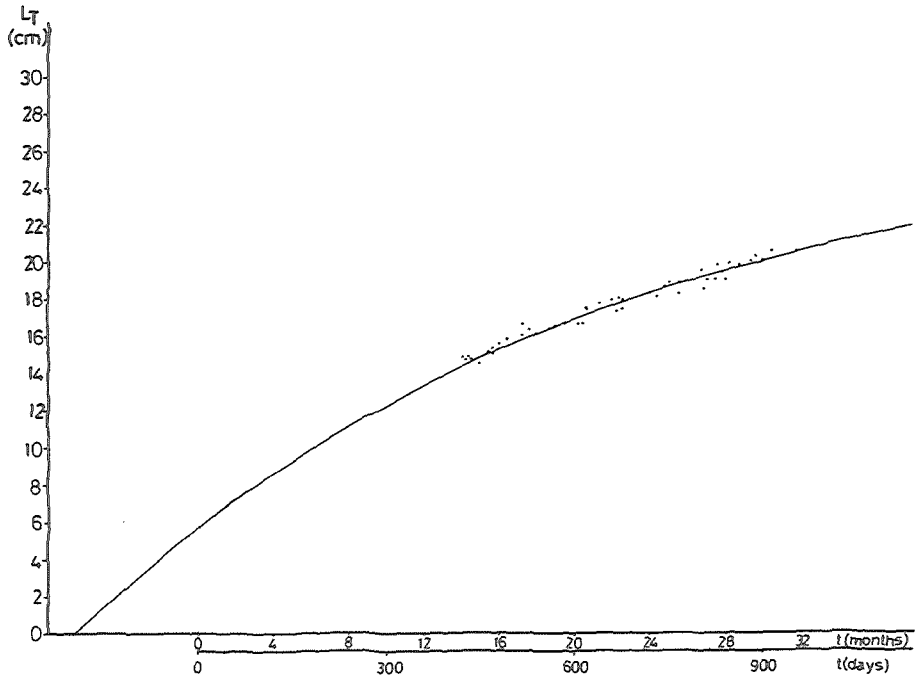

Fig. 17 - D. macrosoma. Growth curve based on otolith readings. From SOUSA and GISLASON (in prep.)

Samples of D. macrosoma have been collected since 1979 from commercial fish trawlers and from surveys at Sofala Bank. Fig. 18 presents the monthly length distributions and the corresponding mean lengths and variances. At Boa Paz only a few individuals were sampled.

2.3.6 - Total mortality

As for D. russellii and R. kanagurta the total mortality was estimated by the method of Jones and Zalinge and by the method described in Appendix 3. The average percentage length composition from 1980 and 1981 of fish collected at Sofala Bank was used. Only fish in the size range from 20 to 23 cm were considered (Table 23 and Figure 19). High values of total mortality were obtained by both methods. The reasons for such high estimates could be migration of big fish away from the fishing area or a high ability of the big ones to escape from the net.

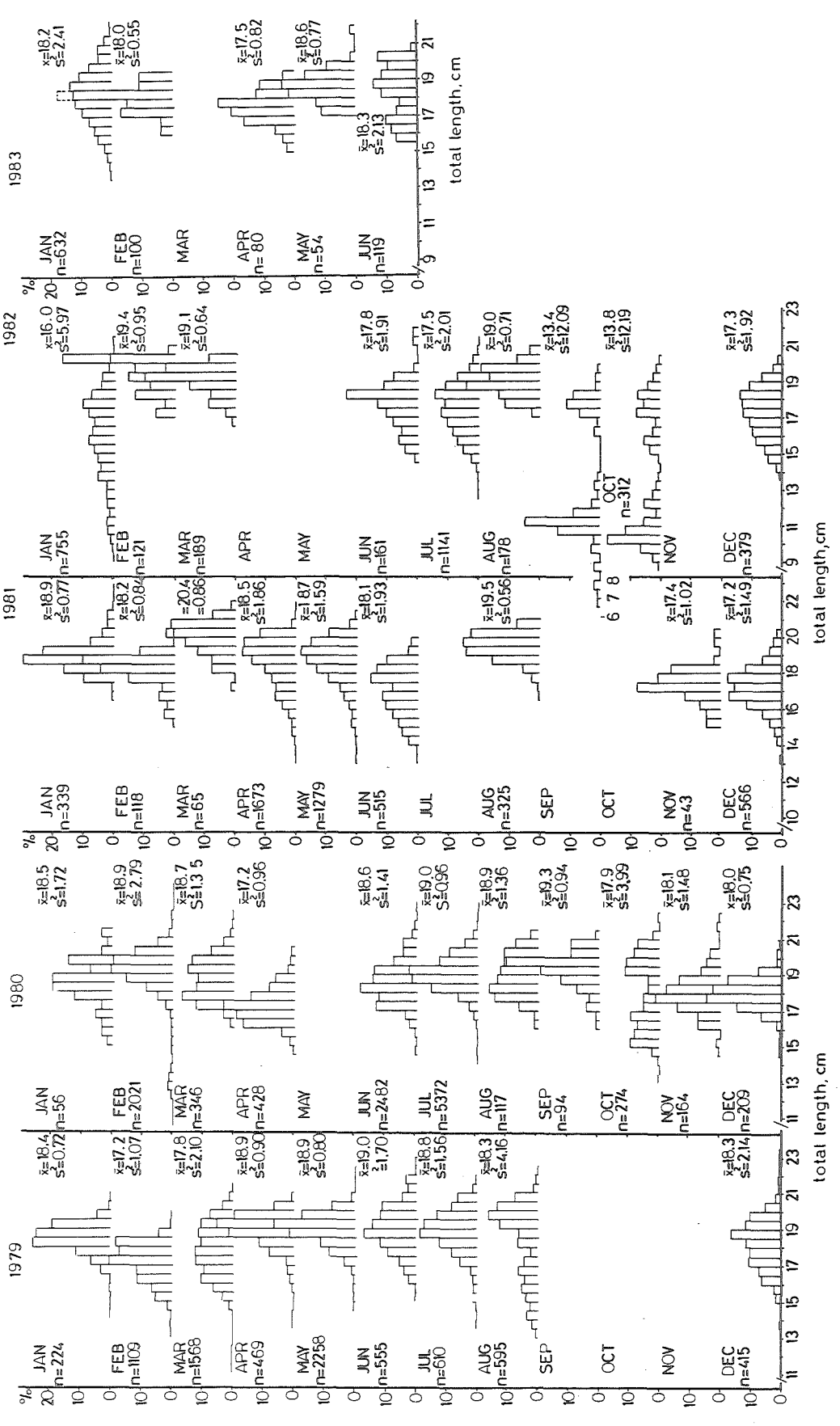

Fig. 18 - D. macrosoma. Percentage length composition of commercial catch at Sofala Bank

TABLE 23 - Decapterus macrosoma. Estimates of Z from the average percentage length composition of samples in 1980 and 1981 at Sofala Bank

Length group (cm)	Average Percentage ($x10^2$)	Average Z [1]	Z at length [2]
<14	37		
14 -14.5	19		
14.5-15	49		
15 -15.5	104		
15.5-16	166		
16 -16.5	342		
16.5-17	495		
17 -17.5	729		
17.5-18	935		
18 -18.5	1252		
18.5-19	1603		
19 -19.5	1703		
19.5-20	1287		2.35
20 -20.5	777		3.67
20.5-21	352		5.17
21 -21.5	109	6.86	6.96
21.5-22	29		7.24
22 -22.5	8		6.49
22.5-23	2		6.36
23 -23.5	-		
23.5-24	+		

1) Calculated by the method of Jones & Zalinge (1981)

2) Calculated as described in appendix 3.

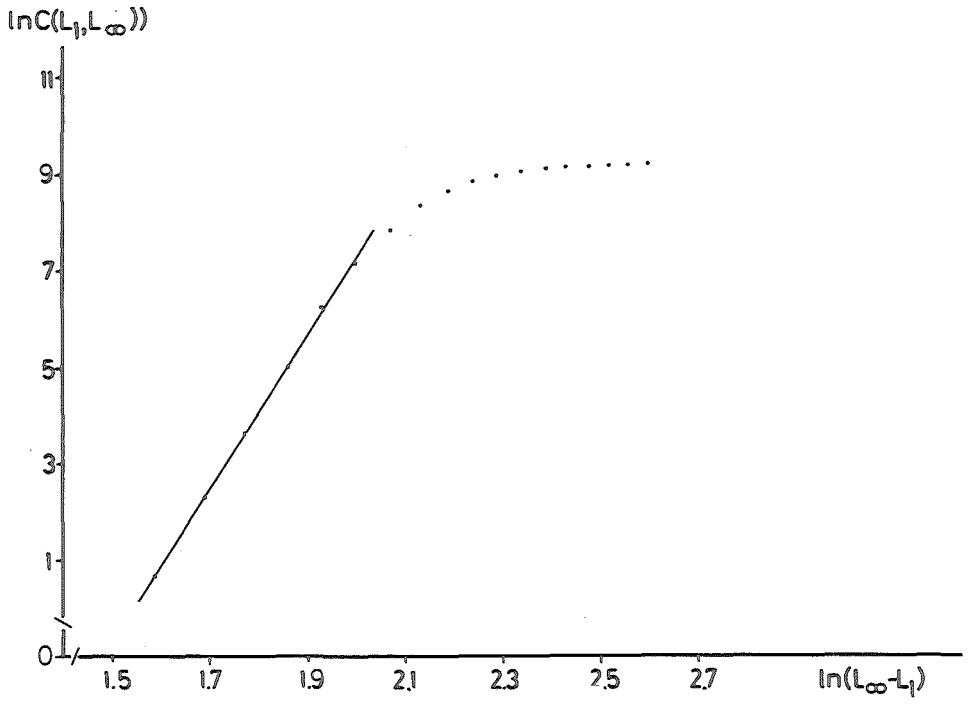

Fig. 19 - D. macrosoma. Estimation of Z by the method of Jones and Zalinge (1981). Data from Sofala Bank. L_∞ = 27.4 cm, K= 0.43 $year^{-1}$.

2.4 - Selar crumenophthalmus (Bloch, 1793)

2.4.1 - Distribution areas and vertical migrations

The species was caught during the surveys of "PANTIKAPEY" at Sofala Bank (SOUSA, 1983). The best catch rate was obtained in the area between Pebane and Chinde, at a depth of 80 meters but the species was caught in the whole area from Beira to Moma.

At Boa Paz it was present in the catches at depths around 50 meters.

In the first survey the highest catch rates were obtained during daytime. The opposite was found during the second.

2.4.2 - Reproduction

Gonads of fish collected onboard the commercial vessels and during surveys from 1980 to January 1982 were analysed and the average monthly gonadosomatic index estimated (Figure 20 and Tables 24 and 25).

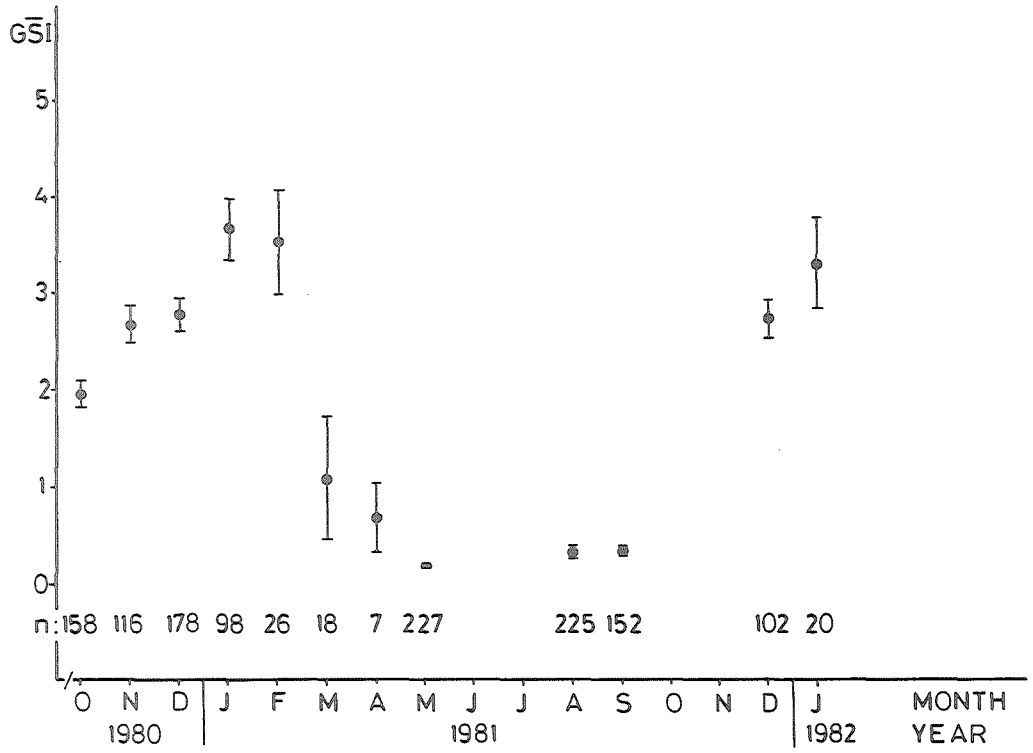

Fig. 20 - S. crumenophthalmus. Average monthly value of gonadosomatic index at Sofala Bank (vertical bars indicate 95% confidence limits). Samples from commercial vessels and surveys combined.

The main spawning season seems to be between October and February.

TABLE 24 - Maturity stages (percent) of S. crumenophthalmus collected on board the commercial vessels at Sofala Bank, 1980-1982

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1980														
October	6.2		1.2	1.9	64.4	26.2	160	2.2				65.2	32.6	92
November	0.9	1.7	2.6	7.8	73.3	13.8	116					62.6	37.4	91
December	1.7	1.1	2.8	4.5	74.7	15.2	178				2.2	74.5	23.4	137
1981														
January	2.0		1.0	15.3	68.4	13.3	98				3.8	81.2	15.0	133
February					76.9	19.2	26					80.0	20.0	40
March	57.1	4.8		4.8	28.6	4.8	21		27.3			36.4	36.4	11
April	28.6	28.6			14.3	28.6	7		44.4	22.2		11.1	22.2	9
May	92.7	1.3				6.0	232	89.1				3.6	7.3	55
June														
July														
August	98.0	2.0					101	100.0						89
September	49.0	27.0		1.0	23.0		196	63.4	10.7			26.0		131
October														
November														
December				13.7	84.3	2.0	102		4.3		2.1	93.6		47
1982														
January					60.0	40.0	20			5.6		88.9	5.6	18

TABLE 25 - Maturity stages (percent) of S. crumenophthalmus collected during the surveys at Sofala Bank, 1981-82

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1981														
S. Kadanchik (21/04-17/05)	90.3	4.8			0.8	4.0	124	52.1	2.1				45.8	48
Pegago IV (22/05-12/06)	68.9	15.6			1.1	14.4	90	54.8	9.7				35.5	62
Pantikapey (7/06-23/06)	94.0	4.5				1.5	67	88.6	5.7				5.7	70
Pantikapey (21/07- 5/08)	61.4	36.4				2.3	44	75.0	20.0				5.0	20
1982														
S. Rybak (25/09-27/10)		14.5	38.2	43.6	3.6		55			42.6	53.7	3.7		54
S. Rybak (9/11-18/12)				87.5	12.5		40				48.3	51.7		60

2.4.3 - Length-weight relationship

A total of 1261 individuals collected onboard the commercial vessels during 1981 were analysed. The following equation was obtained

$$W = 0.00224\ L^{3.506} \qquad r^2 = 0.96$$

where W is the weight in grams and L total length in centimeters.

2.4.4 - Growth

No information available.

2.4.5 - Length composition and catch in numbers at length

Monthly length frequency distributions from October 1980 to July 1983 from Sofala Bank are presented in Fig. 21. Fish in the size range from 14.5 to 29.0 cm are caught. Recruitment seems to take place during the first half of the year.

The number of fish collected at Boa Paz was too small to be considered further.

2.4.6 - Total mortality

No information available.

2.5 - Trachurus trachurus L., 1756

2.5.1 - Distribution areas

This species was recorded only at Boa Paz. Birkett (1979) refers to T. delagoa but probably the species was the same.

The subspecies is still unknown, but it may be the same one as caught off South Africa.

T. trachurus is more abundant during summer than during the winter. SAETRE

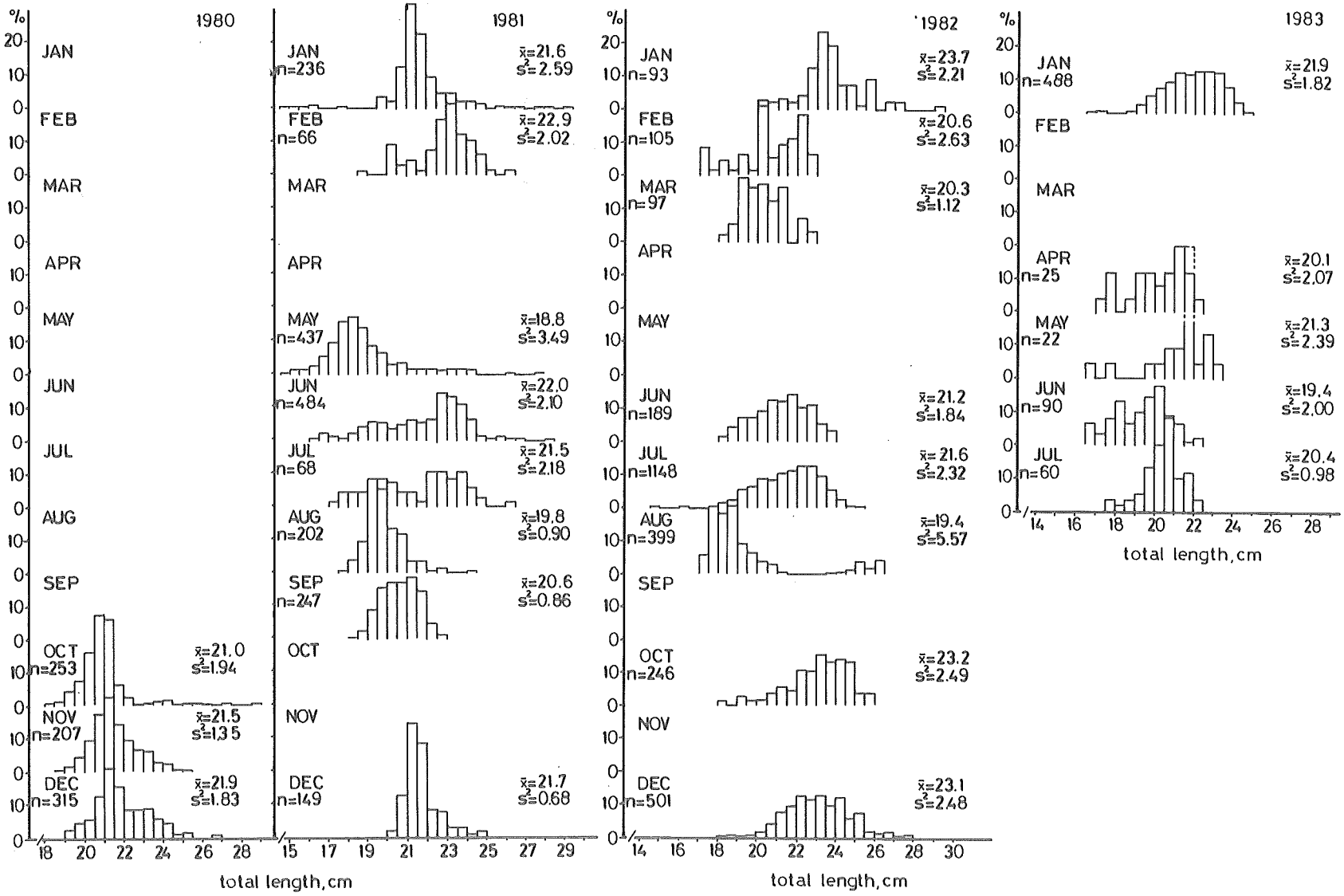

Fig. 21 - S. crumenophthalmus. Percentage length composition of commercial catch at Sofala Bank

and SILVA (1979) report the presence of horse mackerel at depths between 30 and 150 m, with the greatest concentrations at about 50 m, the depth at which the commercial vessels operate.

2.5.2 - Reproduction

The time of spawning was studied by observation of the maturity stages of the gonads and by estimating the mean monthly gonadosomatic index. Data were collected onboard the commercial vessels and during surveys from April 1981 to May 1983 (Figure 22 and Tables 26 and 27).

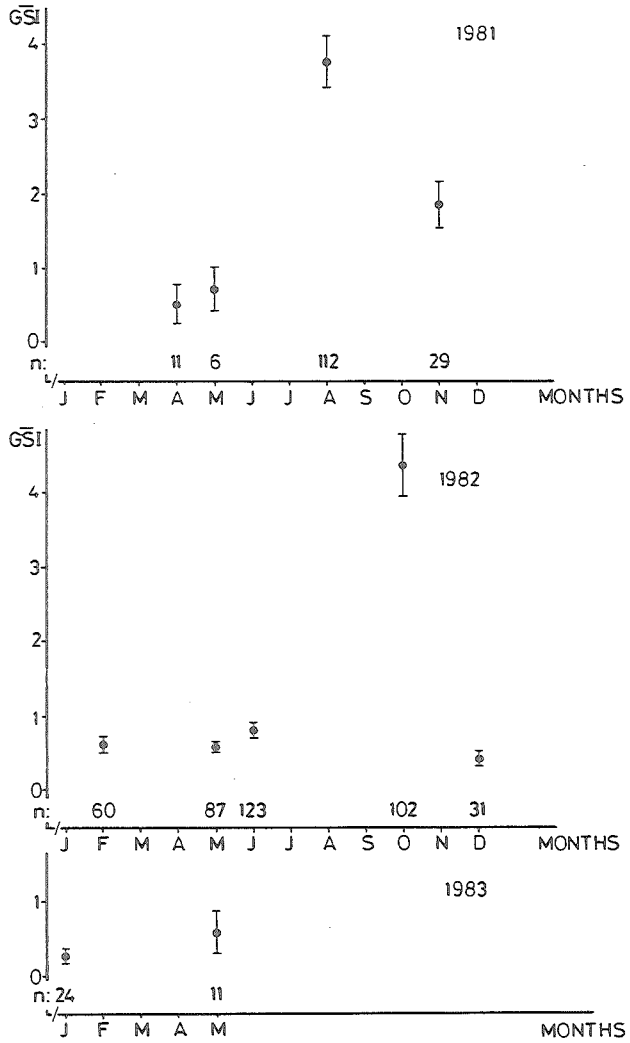

Fig. 22 - Trachurus trachurus. Average monthly value of gonadosomatic index (vertical bars indicate 95% confidence limits). Samples from commercial vessels and surveys combined.

TABLE 26 - Maturity stages (percent) of T. trachurus collected on board the commercial vessels at Boa Paz, 1981-1983

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1981														
January														
February														
March														
April	63.6	36.4					11	93.3	6.7					15
May	16.7	50.0				33.3	6	60.0					40.0	5
June														
July														
August		0.9		8.0	90.2	0.9	112	1.0	2.0	1.0	13.9	81.2	1.0	101
September														
October														
November		3.5			93.1	3.5	29					83.5	16.5	91
December														
1982														
January												25.0	75.0	4
February		30.2			4.8	65.1	63		35.7	7.1		14.3	42.9	14
March														
April														
May	1.2	86.2	12.6				87	10.0	84.3	5.7				70
June	3.1	55.4	22.8	12.4	2.6	3.6	193	4.3	35.7	45.4	9.7	3.8	1.1	185
July														
August														
September														
October				39.1	60.0	0.9	110				5.4	93.9	0.8	130
November														
December		25.8				74.2	31		82.4			5.9	11.8	17
1983														
January		37.5				62.5	24		83.3				16.7	6
February														
March														
April														
May		81.8	9.1		9.1		11		100.0					10
Jun														

These data suggest that the main spawning season is between August to November. The same conclusion was reached by SAETRE and SILVA (1979).

TABLE 27 - Maturity stages (percent) of T. trachurus collected during the surveys at Boa-Paz, 1981-1982

	FEMALES							MALES						
	I	II	III	IV	V	VI	n	I	II	III	IV	V	VI	n
1981														
Primorets (27/03-11/05)		93.8	6.2				32		95.2	4.8				42
Pantikapey (30/06-15/07)	14.0	22.1	31.4	19.8	12.8		86	12.0	16.0	2.0	8.0	58.0	4.0	50
1982														
S. Rybak (16-19/9)				100.0			14				100.0			14

2.5.3 - Length-weight relationship

A total of 908 individuals collected onboard the commercial vessels in 1982 were analysed. The following equation was obtained

$$W = 0.0167\ L^{2.825} \qquad (r^2 = 0.96)$$

where W is the weight in grams and L total length in centimeters.

2.5.4 - Growth

No information available.

2.5.5 - Length composition and catch in numbers at length

Figure 23 shows the monthly length frequency distributions of horse mackerel of the period 1981 to June 1983. The size range is 11 to 27 cm total length and the mean length varies from 16.4 cm in May 1982 to 20.4 cm in January 1983.

The time the juveniles enter the fishery seems to vary from year to year.

2.5.6 - Total mortality

As no growth parameters and reliable catch per effort were available total mortality was not estimated.

3. BIOMASS ESTIMATES

3.1 - Trawl surveys

The biomass of scad and mackerel in the area between 16°20'S and 20°50'S was estimated by the "swept area" method from the data collected in July-August 1981 by "PANTIKAPEY" and in October, November and December 1982 by "S. RYBAK".

The total area was divided into two subareas, one south and one north of the Zambezi river. The area south of Zambezi covers the fishing grounds at Sofala Bank, Figure 2. The size of the two subareas was taken from BRINCA et al. (1981, Tab.6).

Only hauls made during daytime were included as scad and mackerel disperse in the watercolumn at night. The trawl was the same as the one used by the commercial trawlers and had a horizontal opening of 15 m. The towing speed was 4 knots. In lack of better estimates the efficency coefficient of the trawl was assumed to be 1.0. This is probably an overestimate (see discussion in SAETRE and SILVA (1979)) and the estimates must thus be considered as conservative.

The estimated stock sizes of scads and mackerel are given in Table 28 together with the corresponding catch rates.

The biomass figures are very variable. The total biomass of scad and mackerel increases from 9 to 80 thousand tonnes from October to December 1982. The length compositions observed onboard indicated that this increase may partly be explained by recruitment.

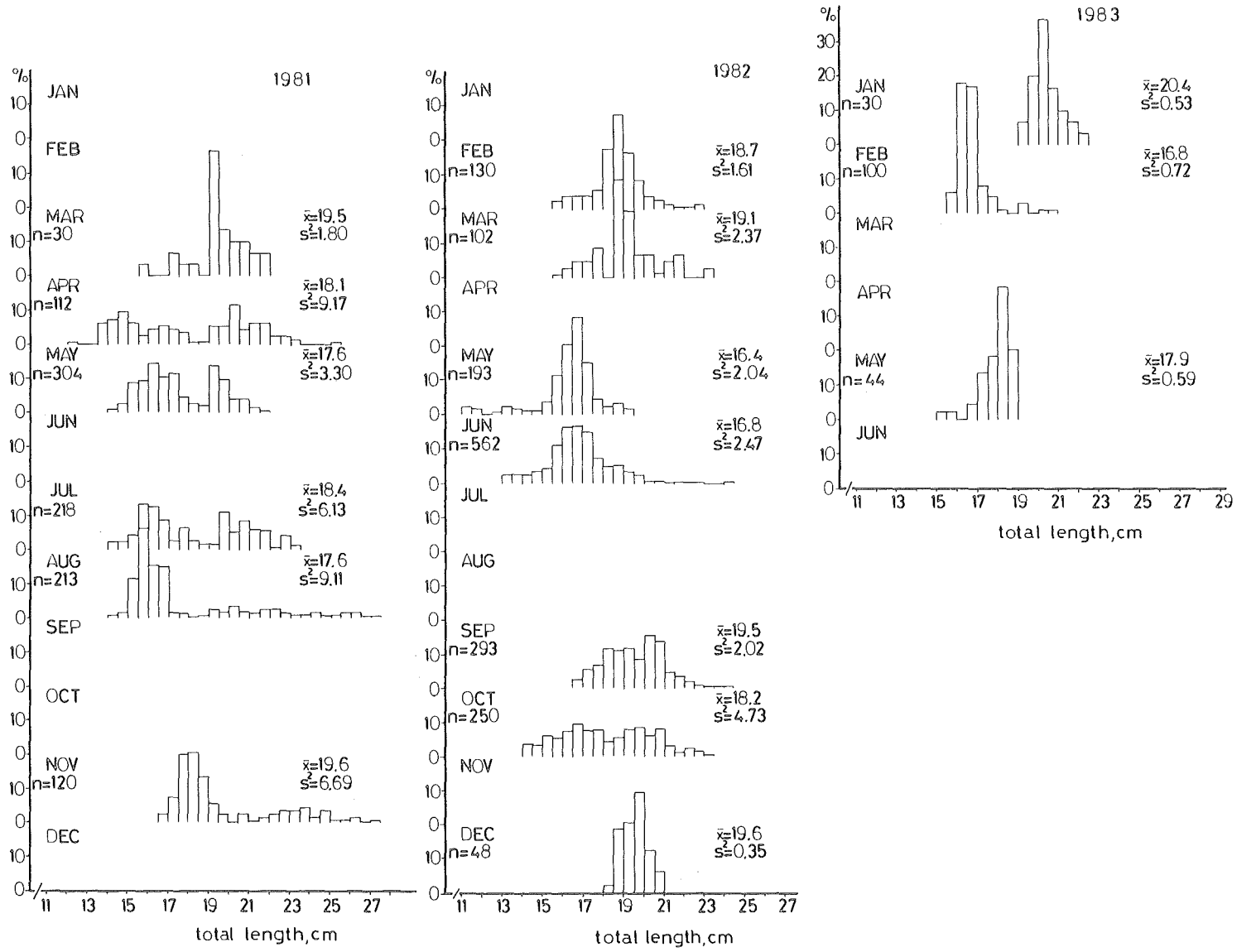

Fig. 23 - Trachurus trachurus. Percentage length composition of commercial catch at Boa Paz

TABLE 28 - Biomass estimates and catch rates from trawl surveys (tonnes x 10^3). Area South of Zambezi = 7472 nm^2, Area North of Zambezi = 4432 nm^2

Period	Area	No. of hours trawling	D. russellii		D. macrosoma		S.crumenophthalmus		R. kanagurta		Scads and mackerel	
			kg/h	Biomass	kg/h	Biomass	kg/h	Biomass	kg/h	Biomass	kg/h	Biomass
July-August 1981	South of Zambezi	24.6	17.3	4.3	.1	+	.5	.1	96.9	23.9	114.7	28.3
	North of Zambezi	40.3	-	-	-	-	.5	.1	1.4	.2	1.9	.3
	Total	64.9	17.3	4.3	+	+	.5	.2	61.3	24.1	72.7	28.6
October 1982	South of Zambezi	30.3	8.7	2.0	+	+	.1	+	6.9	1.6	15.7	3.6
	North of Zambezi	73.3	28.4	3.9	4.6	.6	7.7	1.1	1.9	.3	42.6	5.8
	Total	103.7	16.0	5.9	1.7	.6	2.9	1.1	5.0	1.8	25.7	9.4
November 1982	South of Zambezi	18.7	95.7	22.0	.6	.1	.1	-	19.8	4.5	116.1	26.7
	North of Zambezi	34.5	4.6	.6	.1	+	8.1	1.1	1.3	.2	14.0	10.7
	Total	53.2	61.8	22.6	.4	.1	3.0	1.1	12.9	4.7	78.1	28.6
December 1982	South of Zambezi	9.0	239.6	55.0	12.7	2.9	.4	.1	6.5	1.5	259.2	59.5
	North of Zambezi	35.3	13.8	1.9	3.9	.5	123.6	16.8	9.1	1.2	150.4	20.5
	Total	44.3	155.6	56.9	9.4	3.4	46.2	16.9	7.5	2.7	218.7	80.0

In July-August 1981 the biomass was estimated to be 29 thousand tonnes. Except for October 1982 the highest catch rates were found in the area south of Zambezi which covers the fishing area.

3.2 - Acoustic surveys

The biomass of small pelagic fish at Sofala Bank was estimated by R/V "Dr. Fridtjof Nansen" during surveys in 1977-78, 1980 and 1982. Table 29 shows the results.

The total stock of small pelagic species was found to be between 100000 and 140000 tonnes excluding anchovy. In 1977-78 and 1980 the estimates of the total stock size of Decapterus spp. varied between 13000 and 41000 tonnes. In 1982 the estimate of Decapterus spp. and R. kanagurta was 94000 tonnes which suggest that there may have been an increase in the stocks of scad and mackerel from 1980 to 1982.

TABLE 29 - Biomass of small pelagic species (excl. anchovy) estimated by acoustic methods (thousand tonnes).

Authors	Period	Pelagics (excl. anchovy)	Decapterus spp + R. kanagurta	Decapterus spp
Saetre and Silva (1979)	Aug.77/Sep.78	123-140	*	25 - 41
Brinca et al. (1981)	Oct./Nov.80	100-140	*	13 - 32
Brinca et al. (in press)	September 82	130	94	

* No information

4. FISHING MORTALITY

The fishing mortality was estimated in two ways: by dividing the catch by the estimated biomass and by the "swept area" method (Gulland, 1971).

The present annual catch of scad and mackerel at Sofala Bank is in the

order of 1600 to 3000 tonnes. The biomass estimates varies between 9000 and 94000 tonnes and the fishing mortality should thus be in the range from 0.02 to 0.3.

The second method uses the "swept area" of the trawlers to estimate the proportion of the total area which is fished annually and hence, by assuming both the fish and the trawlers to be randomly distributed, the proportion of the stock caught. However, as fish trawlers tend to concentrate their effort in areas of high fish abundance this assumption is seldomly fullfilled.

One way of solving this problem is to compare the catch rate of the trawlers with that of random surveys using the same gear. In July-August the area south of Zambezi was surveyed by "PANTIKAPEY", and an average catch rate of 114.7 kg per hour obtained. In the same months the trawlers operating in the fishing area at Sofala Bank had an average catch rate of scads and mackerel of app. 440 kg per hour, which is app. 3.8 times higher than "PANTIKAPEY". If the trawlers had been fishing in a random way they should thus have swept an area 3.8 times larger than the area actually swept in order to obtain the same catch.

The trawler fished 6308 hours at Sofala Bank in 1981. This corresponds to an area of 204 nm^2. Multiplying by 3.8 this corresponds to 775 nm^2 swept. As the size of the total area is 7172 nm^2 the fishing mortality can thus be estimated to app. 0.1.

This estimate covers only the stock in the area south of Zambezi. It seems however reasonable to assume that the fish in the area north of Zambezi belong to the same stock. During the survey of "PANTIKAPEY" 99 percent of the stock was found in southern area. The fishing mortality of the total stock in 1981 can thus be estimated to 0.1 x 0.99 ~0.1.

The fishing mortality in 1982 was estimated in the same way. In this year the trawlers had on average a catch rate 4.6 times higher than the one obtained during the surveys. However, the total number of fishing hour spent on Sofala Bank was only 3301 and the fishing mortality calculated thus only 0.045.

The biomasses estimated by dividing the total catch of scads and mackerel by the estimated fishing mortalities were 30000 and 36000 tonnes for 1981 and 1982, respectively. These estimates are well within the range of biomass estimates available.

5. CATCH PREDICTION

5.1 - Surplus production models

Due to the problems associated with estimating the total effort expressed in SRTM units for the period from 1977 to 1979 it was decided not to try to fit any surplus production model to the data.

5.2 - Yield and biomass per recruit

Table 30 shows the result of yield per recruit calculations for Decapterus russellii for two values of M. Assuming the present fishing mortality, F. to be equal to 0.1 it is possible to calculate the Y/R and B/R relative to the present situation for both values of M, Figure 24. As an example the figure show that with an increase in F from 0.1 to 0.5 the yield per recruit will increase between 3.8 and 4.3 times and the biomass per recruit decrease to between 77 and 88 percent of its present value.

TABLE 30 - Decapterus russellii. Yield per recruit (Y/R) and biomass per recruit (B/R) in grammes and relative to the present situation (F=0.1) for two values of natural mortality (M=3.3, M=1.7).
W_∞=157.1g, K=0.5, t_o=0.1, t_r=1.12 (~10 cm)
t_c =1.93 (~15 cm).

	M= 3.3				M= 1.7			
Fishing Mortality	Y/R (g)	Y/R Relative to present level	B/R (g)	B/R Relative to present level	Y/R (g)	Y/R Relative to present level	B/R (g)	B/R Relative to present level
0	-	-	0.93	1.04	-	-	7.94	1.08
0.1	0.09	1.0	0.89	1.00	0.74	1.0	7.36	1.00
0.2	0.17	1.9	0.86	.97	1.37	1.9	6.85	0.93
0.3	0.25	2.8	0.83	.93	1.92	2.6	6.40	0.87
0.4	0.32	3.6	0.81	.91	2.40	3.2	6.00	0.82
0.5	0.39	4.3	0.78	.88	2.83	3.8	5.65	0.77
1.0	0.67	7.5	0.67	.75	4.35	5.9	4.35	0.59
1.5	0.89	9.9	0.59	.63	5.27	7.1	3.51	0.48

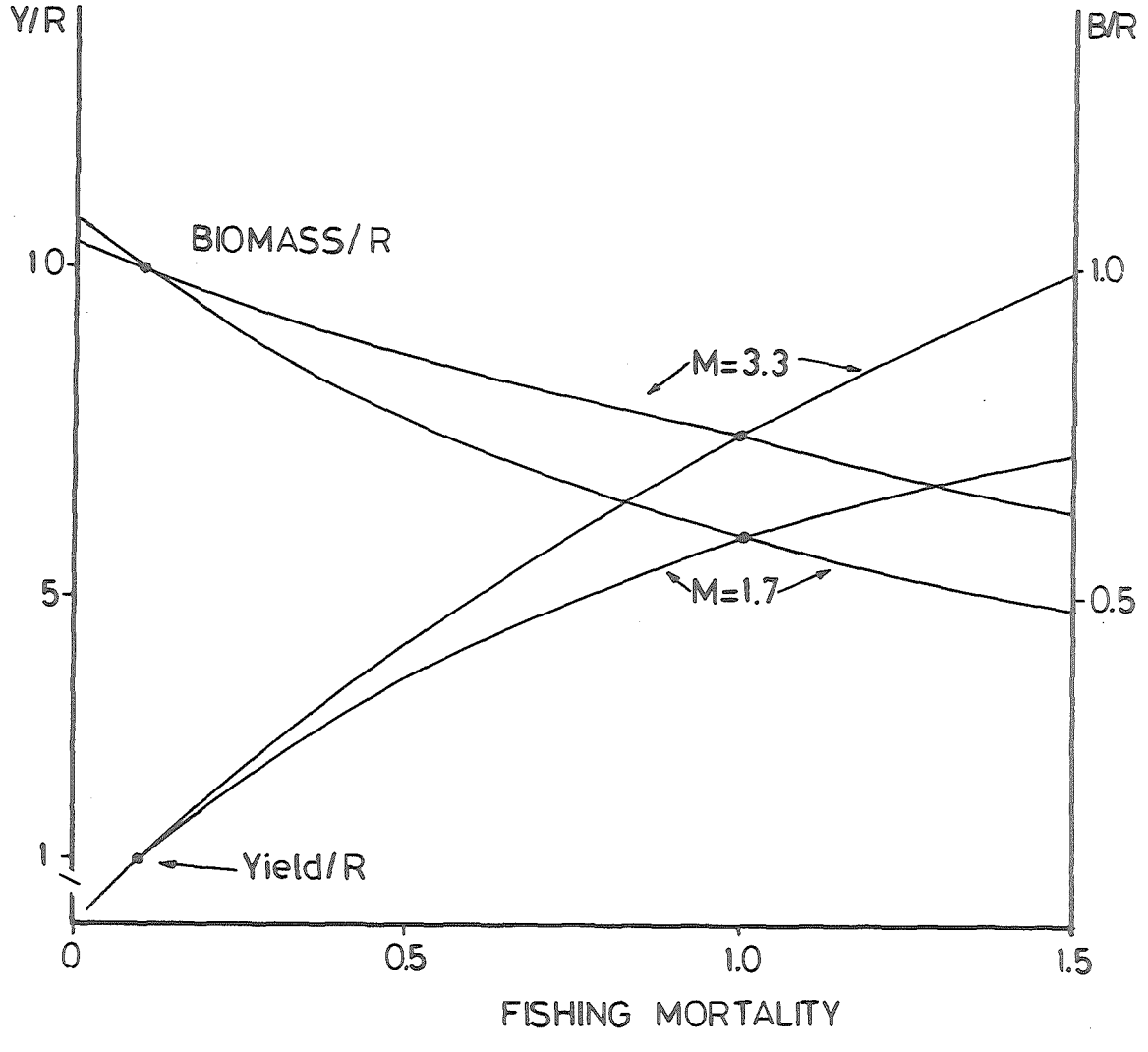

Fig. 24 - Yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of fishing mortality. Arbitrary units. Y/R and B/R at present level of fishing mortality (=0.1) set equal to 1.0.

As only 35% of the total catch consist of D. russellii the yield per recruit curve cannot be used to predict the future of the total fishery.

However, the other small pelagic at Sofala Bank seem to follow more or less the same growth curve and probably have natural mortalities in the same range as D. russellii. It thus seems justifiable to assume that the predictions made will be more or less representative for the total catch of scads and mackerel at Sofala Bank.

6. DISCUSSION

The main conclusions from the assessment is that the present fishing mortality is low and that the fishery may be expanded in the future. However, on the long term the actual catch will depend very much on recruitment.
Furthermore the predicted yield per recruit is based on the yield per recruit curve of only one species, D. russellii, a fact which introduces an extra uncertainty into the assessment. Probably the demersal fish which constitutes about 40 percent of the catch will recruit to the fishery at a smaller length and have a smaller natural mortality than the scads and mackerels. This will lead to a lower increase in yield per recruit for these species and to a steeper decrease of the total catch rates than predicted in this report.
The problems associated with the database for the assessment falls into three categories. Problems associated with the collection of data from the fishery, lacks in the knowledge of the biology of the species and problems in interpreting the indices of biomass from acoustic and bottom trawl surveys.

With respect to the fishery the main problem is the uncertainty of the estimates of the monthly species composition of the catch. If proper data on the species composition and its variation during the year had been available it would have been possible to check the estimates of total mortality by looking at the drop in catch per unit of effort in periods of no recruitment.

The biology has been fairly well covered. Detailed studies of growth, length weight relationship and spawning season are available. However, the migrations of adult fish are still largely unknown and the whole problem of a possible separation of the stocks at Sofala Bank and Boa Paz is untouched.
In this context it would be of great importance to know why the large R. kanagurta does not show up in the catch at Sofala Bank. Do they migrate to other areas or are they still at Sofala Bank but unavailable to the fishery.
Better estimates of total mortality are also badly needed. The crucial assumption behind the estimates given in this report is that the stock has a stable age structure, i.e. that recruitment and total mortality is constant for the years considered. Furthermore, the methods require the average yearly length composition as input. If the cpue had reflected abundance it might have been used. Here it has been necessary to use either the total catch in numbers estimated from the available length samples and a constant species composition or the average percentage length composition. Both are probably biased.

The biomass estimates from the acoustic surveys and the estimates from the bottom trawl surveys show great fluctuations. The last acoustic estimates gives a biomass of app. 94 thousand tonnes for September 1982, while the biomass estimated by the swept area method from October, November and December the same year are 4, 27 and 60 thousand tonnes, respectively. Such a high variability stresses the importance of having confidence limits attached to the figures in order to investigate the sources of variation further.

The estimation of fishing mortality is subject to the same problems as the estimation of total biomass by the "swept area" method. In both calculations we assumed that all fish in the path of the trawl were caught. This assumption is probably overestimating the efficiency of the trawl and the fishing mortality is thus likely to be overestimated too.

However, this will not affect the main conclusion, that fishing mortality is low compared to the total mortality.

As pointed out earlier the estimates of future yield in the fishery depend very much on recruitment. However, the biomass per recruit curve indicates that if the present effort is doubled the biomass per recruit of the small pelagic species will only be reduced by between 3 and 7 percent, a reduction which is likely to have only a negligible influence on the subsequent recruitment. If the fishery is going to expand further in the future a high priority must be given to the study of the stock and recruitment relationship. With the present exploitation pattern growth overfishing is unlikely to occur and recruitment overfishing is the real danger. Any increase in effort should thus from the biological point of view take place gradually in order to make sure that a drop in recruitment is discovered in time.

Recommendations for future activities

0. The collection of catch and effort data by gear and area should be reviewed. Attention should be given to the collection of information from the experimental fishery and from the shrimp trawlers operating at Sofala Bank.

1. The sampling scheme should be reviewed in order to provide monthly estimates of the species composition of the catch and the size distribution of the main species both for Sofala Bank and Boa Paz.

2. Whenever possible studies on juveniles should be carried out in order to investigate indices of recruitment.

3. The possibility of improving the biomass estimates from acoustic and bottom trawl surveys should be examined.

4. Attention should be given to the problems associated with migration of large fish away from the fishing areas and to the possible separation of the total stock into separate managements units.

5. Regular assessments should be made, the next one preferably in the beginning of 1985.

For 1984 the following activities are proposed:

- A consultancy on sampling schemes and evaluation of biomass estimates from bottom trawl surveys.

- To start collecting information from experimental fisheries and shrimp trawlers operating at Sofala Bank.

- To stablish a closer contact with the fishing sector.

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OFFICIAL COMMERCIAL GROUPS OF FISH (1980) IN USE IN MOZAMBIQUE

1st Category Fish

- Tunas, goatfishes, groupers, spanish mackerels
- Flatfishes (> 250 g)
- Croakers, breams, red snappers, grunters, scavengers, kingfishes (> 500 g)

2nd A Category Fish

- Scads, mackerel, barracudas, smelts, mullets
- Flatfishes (< 250 g)
- Croakers, breams, snappers, grunters, scavengers, kingfishes (< 500 g)

2nd B Category Fish

- Halfbeaks, small scads, gurnards, sardines

3nd Category Fish

- Soapys, tigerfishes, cornetfishes, lizardfishes, catfishes
- Sharks, rays
- Congers

APPENDIX 2 - Number of fish measured, number of gonads analysed and number of otoliths read from 1979 to July 1983

Area	Species	No. of fish measured					No. of gonads analysed					No. of otoliths read				
		1979	1980	1981	1982	1983	1979	1980	1981	1982	1983	1979	1980	1981	1982	1983
Sofala Bank	D. russellii	21003	44322	6622	8165	5011	3530	3329	4051	3895	806	3	54	-	62	-
	D. macrosoma	7803	11560	4880	3438	413	1513	1942	2451	304	-	4	48	-	-	-
	S. crumenoph-thalmus	-	775	1941	2768	685	-	774	1823	247	-	-	-	-	-	-
	R. kanagurta	8882	10465	3330	4126	5008	1941	2628	2632	2049	1133	23	-	4	33	2
Boa-Paz	D. russellii	-	9084	4336	2417	2516	-	446	2459	2380	126	-	-	-	-	-
	D. macrosoma	-	860	1173	-	-	-	-	-	-	-	-	-	-	-	-
	T. trachurus	-	-	997	1584	174	-	-	580	932	-	-	-	-	-	-
	S. crumenoph-thalmus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R. kanagurta	-	655	1297	-	-	-	258	1072	13	-	-	-	-	-	-

SAMPLING SCHEME IN USE IN 1983

1. Every month, one vessel is sampled

2. In each fishing day only the 1st haul is sampled in order to know the exact position of the samples taken.

3. From each commercial group two blocks of 10 kg each are taken randomly

4. The species composition is determined for each block separately

5. From each block 10 fish of each of the following species are measured

   - D. russellii
   - D. macrosoma
   - R. kanagurta
   - S. crumenophthalmus
   - T. trachurus

6. Species are measured to the 0.5 cm below in total length. Total length is measured from the tip of the snout to the tip of upper limb of the caudal fin

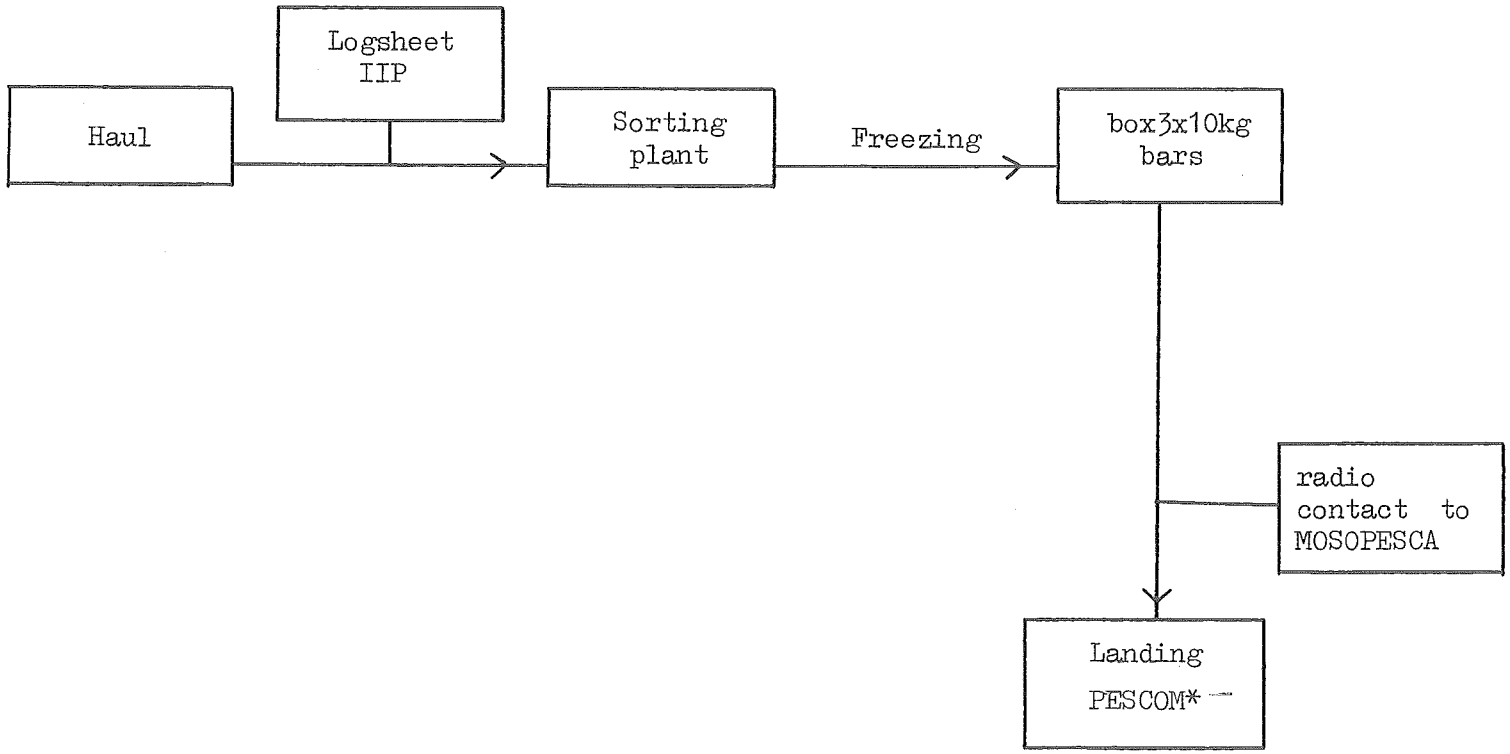
7. From D. russellii and R. kanagurta 2 fish are collected from each length group for biological analysis in the laboratory.

8. A maturity scale of 6 stages was used for both males and females. Immatures were included in stages I and II, maturing fish in stages III and IV. Fish in spawning and post-spawning were at stages V and VI respectively.

9. A gonadosomatic index was estimated for each specimen by:

$$GSI = \frac{\text{gonad weight}}{\text{total weight}} \times 100$$

Production scheme of MOSOPESCA from 1980 anwards and sources of information used to estimate total catch and effort



* State enterprise which distributes the fish.

Estimation of total mortality

The total mortality, Z, was estimated by two methods: The method of Jones and Zalinge (1981) and a new method described below. Both methods estimate Z from the catch in numbers at length of a single cohort. The J and Z method gives an average value of Z for all fully recruited length groups, the other method Z for adjacent length groups.

Unfortunately it was not possible to split the monthly catches of scad and mackerel into individual cohorts. Instead the average yearly catch in numbers at length was used. This can only be done if we assume that the stock is in an equilibrium situation, where recruitment and mortality are constant with time. As such a situation probably never occurs in nature, random fluctuations in mortality and recruitment must be accounted for by averaging several years. In this case only two years, 1980 and 1981, could be used. In the other years the numbers of samples were too low.

Another problem is that both methods assume constant Z and effort over the year. The estimates of Z will thus be biased if the effort is concentrated in certain periods. This bias could probably have been avoided if we instead of the total yearly catch in numbers had been able to use the average yearly cpue of each length group.

The method described here was developed in order to be able to study the variation of Z with length in more detail than it can be done with the J and Z method.

Assume fishing mortality, F, and total mortality, Z, to be constant for fish belonging to the length group from L_1 to L_3. If the catch in numbers of two adjacent length groups, $C(L_1, L_2)$ and $C(L_2, L_3)$ and the parameters L_∞ and K of the von Bertalanffy growth equation are known it is possible to calculate Z for the length group from L_1 to L_3.

The total catch in numbers from the length group from L_1 to L_2 can be expressed as:

$$(1) \qquad C(L_1, L_2) = \frac{F}{Z} N_{t_1} \left(1 - e^{-Z (t_2 - t_1)}\right)$$

where t_1 is the age of a fish of length L_1 and t_2 the age of a fish of length L_2. However, by use of the von Bertalanffy growth equation:

$$t_1 = t_o + \frac{1}{K} \ln L_\infty - \frac{1}{K} \ln (L_\infty - L_1)$$

$$t_2 = t_o + \frac{1}{K} \ln L_\infty - \frac{1}{K} \ln (L_\infty - L_2)$$

and

$$t_2 - t_1 = -\frac{1}{K} \ln (L_\infty - L_2) + \frac{1}{K} \ln (L_\infty - L_1)$$

$$= \frac{1}{K} \ln \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)$$

Inserting in eq. (1):

$$(2) \qquad C(L_1, L_2) = \frac{F}{Z} N_{t_1} \left(1 - e^{-\frac{Z}{K} \ln \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)}\right)$$

$$= \frac{F}{Z} N_{t_1} \left(1 - \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{-\frac{Z}{K}}\right)$$

The cacth in numbers from L_2 to L_3 can be expressed in the same way:

$$C(L_2, L_3) = \frac{F}{Z} N_{t_2} \left(1 - \left(\frac{L_\infty - L_2}{L_\infty - L_3}\right)^{-\frac{Z}{K}}\right)$$

we have

$$(3) \qquad C(L_2, L_3) = \frac{F}{Z} N_{t_1} \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{-\frac{Z}{K}} \left(1 - \left(\frac{L_\infty - L_2}{L_\infty - L_3}\right)^{-\frac{Z}{K}}\right)$$

Dividing eq. (2) by eq. (3) we get

$$\frac{C(L_1, L_2)}{C(L_2, L_3)} = \frac{1 - \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{-\frac{Z}{K}}}{\left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{-\frac{Z}{K}} \left(1 - \left(\frac{L_\infty - L_2}{L_\infty - L_3}\right)^{-\frac{Z}{K}}\right)}$$

$$= \frac{\left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{Z\frac{Z}{K}} - 1}{1 - \left(\frac{L_\infty - L_3}{L_\infty - L_2}\right)^{\frac{Z}{K}}}$$

which finally can be transformed to:

$$(4) \quad C(L_1, L_3) = C(L_1, L_2) \left(\frac{L_\infty - L_3}{L_\infty - L_2}\right)^{\frac{Z}{K}} + C(L_2, L_3) \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{\frac{Z}{K}}$$

Equation (4) has two solutions of which the non-trivial ($Z \neq 0.0$) provides an estimate of Z for fish belonging to the length interval from L_1 to L_3. The solution can be found by the solve routine of a Hewlett Packard HP-15C pocket calculator.

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