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AN ASSESSMENT OF THE STOCK OF SCAD AND MACKEREL AT SOFALA BANK AND BOA PAZ, MOZAMBIQUE

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SUMMARY

1. INTRODUCTION

The fishery for scad and mackerel along the coast of Mozambique began as a licensed fishery in 1977.

In 1980, MOSOPESCA, a joint venture between Mozambique and the Soviet Union was formed and the licensed fishery ceased. MOSOPESCA started fishing with four vessels, but since 1984 the number of vessels has gradually been increased and at the end of 1985 a total of seven vessels were in operations.

The fishery takes place at Sofala Bank and Boa Paz, Fig. 1.

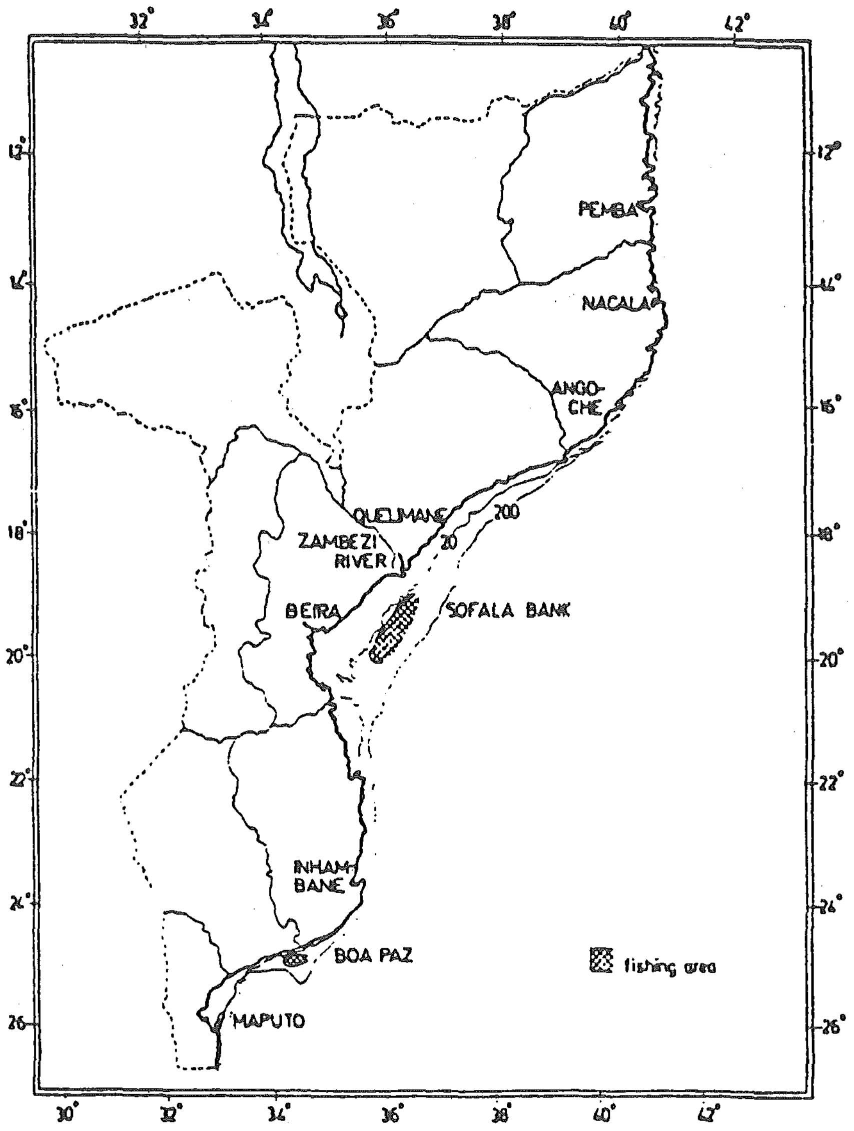

Fig. 1 Fishing areas at Sofala Bank and Boa Paz.

In 1985 the total catch amounted to 7200 tonnes of which app. 60% consisted of scad and mackerel. Except for mackerel which can be found in the bycatch of the fishery for shallow water shrimps no other fishery exploits these resources.

A preliminary assessment was made by Borges et al. (1984). Their main conclusion was that the fishery could be expanded gradually in the future.

This report contains an updated assessment based mainly on information collected from July 1984 to May 1986.

2. THE FISHERY

2.1. Fleet

The fleet of MOSOPESCA consists of seven vessels of the SRTM type (GRT 2910 total length 60 m). Five of the vessels have engines of app. 1000 hp, the remaining two, "Baical" and "Bilibiza", which started fishing in December 1984 and November 1985, respectively, have engines of app. 1200 hp.

2.2. Landings

The annual and monthly landings as reported by the company and as estimated from the logbooks of the licensed vessels are given in table 1 and tables 1.1 and 1.2. (Annex 1).

The total annual catch reached a peak of 17000 tonnes in 1978 and decreased thereafter to a level of between 5000 and 7000 tonnes. Sofala Bank is generally the most important fishing area, except for October when most of the vessels are fishing at Boa Paz.

Table 1 Annual landings (tonnes) of the trawl fishery for scad and mackerel at Sofala Bank and Boa Paz

Year	Sofala Bank	Boa Paz	Total
1977	850	1950	2801
1978	13478	3431	16909
1979	8897	29	8926
1980	3907	1342	5249
1981	4973	1893	6866
1982	2673	3226	5899
1983	5907	1259	7166
1984	3546	2143	5599
1985	4295	3039	7334

2.3. Total effort and catch per unit of effort

The total annual number of fishing hours was estimated from the logbooks and divided into the catch in order to give the average per fishing hour, Table 2.

Table 2 Total catch (tonnes), total number of hours fishing (SRTM trawling) and catch per hour fishing at Sofala Bank and Boa Paz

	Sofala Bank			Boa Paz		
Year	Total catch (tonnes)	Fishing hours	Tonnes hours	Total catch (tonnes)	Fishing hours	Tonnes hours
1977	850	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	5907	6501	.91	1259	2033	.62
1984	3546	4184	.85	2143	2881	.74
1985	4295	7128	.60	3039	5301	.57

On Sofala Bank the catch per hour has remained more or less constant from 1980 onwards, while a decrease from a very high value in 1980 to a level below that of Sofala Bank can be observed at Boa Paz.

As the two new SRTM vessels are different from the old ones in terms of horsepowers it was necessary to correct the number of fishing hours for differences in fishing power. This was done by making linear regressions (forced through zero) of the monthly catch per fishing hour of different vessels. By use of these regressions, Table 1.3 (Annex 1), the monthly fishing hours of each vessel was converted into "Baical" hours and summed to give a total yearly figure of standardized effort.

2.4. Species compositon of the catch

The catch is sorted into commercial categories onboard the vessels and landed frozen in Maputo harbour in cartoon boxes of 30 Kg. each containing three separate blocks of fish. Each landing consists of app. 200 tonnes of fish.

The catches are sampled in Maputo harbour by assitents from IIP.

The total catch is first split into fishing areas and categories by combining the area information of the logbooks with information on the daily catch of different categories recorded by the fish technologist, the person responsible for packing and freezing the fish at sea. A total of 20 boxes are then selected at random, distributed on the different category/area combinations in proportion to the relative landing of that category/area. From each box one block of fish is thawed up and analysed for species composition. If possible the lengths of 20 individuals of each of the most important species of scad: Decapterus russelli, D. macrosoma, S. crumenophthalmus and T. trachurus, and indian mackerel: Rastrellinger kanagurta are measured to the nearest 0,5 cm below.

The percentage species composition of the catch at Sofala Bank and Boa Paz are shown in Table 3.

The most important species in both areas is indian scad, Decapterus russelli. At Sofala Bank, layang scad Decapterus macrosoma and indian mackerel, Rastrelliger kanagurta, are also of importance. At Boa Paz they are replaced by horse mackerel, Trachurus trachurus and by Scomber japonicus.

Table 3 - Average percentage species composition of the catch at Sofala Bank and Boa Paz in 1985

	Sofala Bank	Boa Paz
Decapterus russelli	37.8	45.2
Decapterus macrosoma	10.0	0.7
Rastrelliger kanagurta	10.0	2.7
Caranx malabaricus	2.7	2.2
Sphyraena spp	3.7	4.2
Scomber japonicus	+	5.7
Trachurus trachurus	-	6.3
Other pelagics	4.6	17.4
PELAGICS	68.8	84.4
Upeneus spp	11.9	2.6
Nemipterus delagoae	2.7	0.5
Saurida undosquamis	10.9	5.0
Other demersals	5.1	6.4
DEMERSALS	30.6	14.5

Among the demersal species particularly goatfishes, *Upeneus* spp, and lizardfish, *Saurida undosquamis*, are common.

The variations in the species composition during the year are illustrated by Figs. 2 and 3.

At Sofala Bank the percentage of *D. russelli* reached high values from August to November 1985. The percentage of other small pelagic species remained more or less constant, while the demersals were most abundant from April to July.

At Boa Paz the percentage of *D. russelli* was high from January to March 1985 and again in the end of the year from November to December. The percentage of other small pelagic species, mainly *T. trachurus* and *S. japonicus*, was high from July to December 1984 and from July to October 1985. The demersal species remained more or less constant during the period.

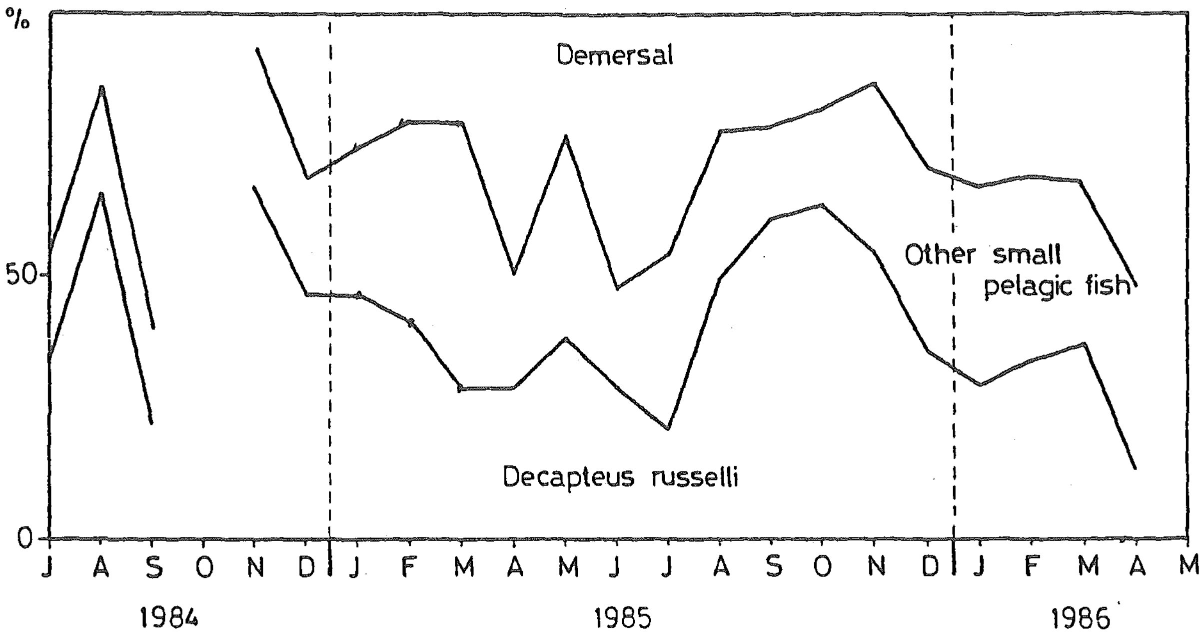

Fig. 2 Sofal Bank. Species composition of catch.

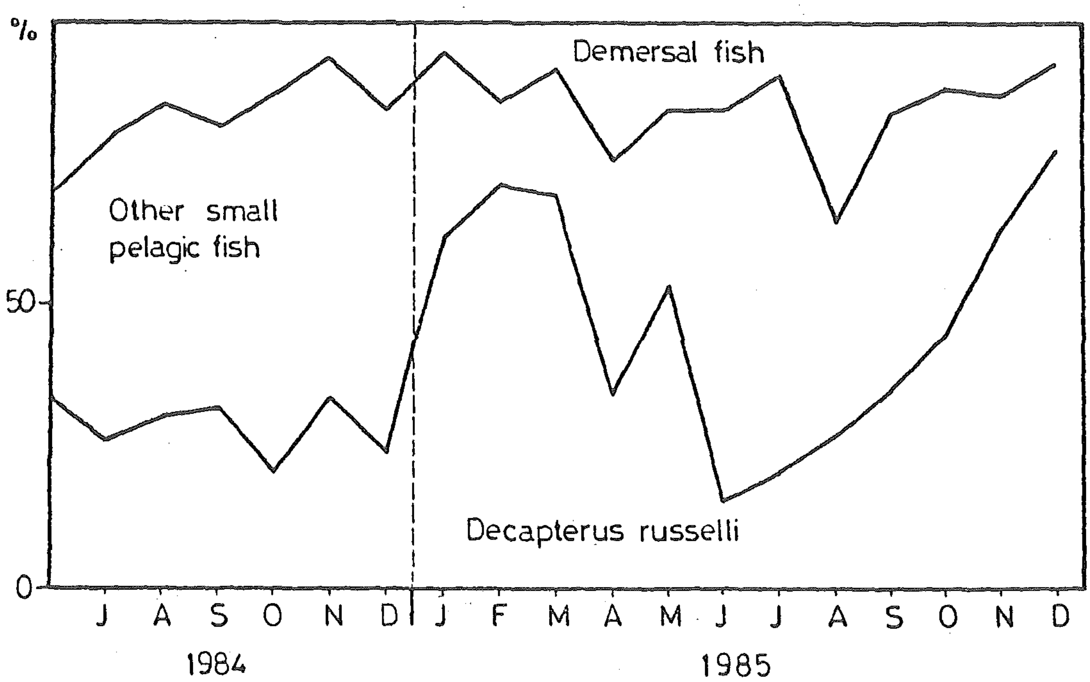

Fig. 3 Boa Paz. Species composition of catch.

The catch per unit of effort of the most important species was estimated by applying the percentage species composition to the catch per standardized fishing hours, Tables 1.4 to 1.8 (Annex 1).

3. SURVEYS

In May/June 1984 and December 1984/January 1985 the Soviet research vessel "Nauka" made two stratified random bottom trawl surveys for scad and mackerel (Gislason & Sousa, in press).

The area between 16° 00' S and 26° 30' S was divided into 13 strata in the depth range from 20 to 200 m. The fishing areas at Sofala Bank and Boa Paz were chosen as separate strata in order to allow comparison between the catch rate of "Nauka" and the commercial vessels. Each strata was subdivided into a number of substrata from which fishing positions were selected at random.

During the survey in May/June 1984 the strata from the north of Sofala Bank down to Maputo were covered. In the December 1984/January 1985 survey only the part of Sofala Bank south of the mouth of the Zambezi river was covered.

The biomass of scad and mackerel was estimated by the "swept area" method assuming the catchability coefficient to be one, Table 4. This will most likely result in underestimates of biomass.

Table 4 Average biomass estimated during the bottom trawl surveys of "Nauka" in May-June 1984 and December-January 1985.

Area	Depth Range (m)	Period	Size of the Area (nm^2)	*D. russellii* Biomass (x 10^3 tonnes)	*D. macrosoma* Biomass (x 10^3 tonnes)	*R. kanagurta* Biomass (x 10^3 tonnes)
Sofala Bank North of Zambezi river	20 - 200	May-June (1984)	3150	9.0	4.1	7.8
Sofala Bank South of Zambezi river	20 - 200	May-June (1984)	5675	11.0	2.3	7.8
		Dez-Jan (1985/86)		12.9	2.2	3.4
Boa Paz	20 - 200	May-June (1984)	2225	4.0	+	1.3

4. SOFALA BANK

4.1. Indian scad, Decapterus russelli

4.1.1 Catch per hour in numbers at length.

The catch per hour in numbers at length is shown in Table 1.9 (Annex 1)

Recruitment is taking place in the first half of the year. From October 1985 to march 1986 large fish ($\geq$ 19 cm) entered the fishery.

4.1.2. Total mortalily

The total yearly mortality was estimated from the total yearly catch in numbers at lenght in 1985 by the "catch curve" method as described by Sparre (1985). The growth parameters used for estimating the time spent in each size class were taken from Sousa (in press) (L_{∞} = 27.9 cm., K = 0.56 year $^{-1}$). Total mortality, Z, was estimated to 4.9 from the slope of the curve.

Because of the extended period of recruitment to the fishery and the migrations of large fish away from the fishing area no attempt was made to estimate the total mortality directly from the drop in the total monthly catch in numbers per hour.

4.1.3. Fishing mortality

The fishing mortality was estimated by the "swept area" method and corrected for the tendency of the commercial trawlers to fish in areas of high concentrations by comparing their average catch rate with the catch rate obtained during the stratified random survey of "Nauka" from December 1984 to January 1985 (Gislason & Sousa, in prep.), Table 1.10 (Annex 1).

As the maximum catch in numbers per hour of the commercial vessels was found in the length from 15 to 16.5 cm it was assumed that fish within this length range was fully recruited to the fishery and had not yet started to migrate - away from the fishing area.

Assuming the catchability coefficient to be 1.0 and dividing the numbers per nm² in this size range estimated from the catch per hour of the commercial vessels with the numbers per nm² estimated by "Nauka" it was found that the commercial vessels were 8.78 times more efficient than "Nauka".

The yearly fishing mortality was then estimated by calculating the total area swept by the commercial vessels in 1985, multiplying with 8.78 and dividing by the size of the total area covered on Sofala Bank during the survey of "Nauka" (5675 nm²). The resulting fishing mortality of fish in the length range from 15 to 16.5 cm was 0.35 $year^{-1}$.

4.1.4. Stock size and biomass

The stock size was estimated by Virtual Population Analysis (VPA, see appendix 1) from the catch in numbers at length in 1985 assuming the stock to be in equilibrium (Sparre, 1985), Tables 1.11 and 1.12 (Annex 1).

Two values of natural mortality, M were used. One, M = 1.2 $year^{-1}$ was derived by the formula of Pauly (1980,b) assuming an average sea temperature of 25°C. The other was estimated by the "catch curve" method from the catch in numbers at length at Boa Paz, see ch. 5.1.2.

The calculation were initiated by using the value of fishing mortality estimated for the length group from 15 to 15.6 cm to calculate the total number of fish which had passed through the lower and upper limit to the length group during the year (N_{L1}). After calculating these numbers the VPA equations were used to go forwards and backwards in length and time. Finally the average number of fish present in each length during the year (N_{yearly}) was estimated by dividing the catch in numbers with the estimated yearly fishing mortality.

As assumed the fishing mortality reached maximum values for the length group from 15 to 16.5 cm and decreased rapidly for both smaller and large fish.

The average biomass was calculated by multiplying N_{yearly} with the weight of one individual estimated by inserting the average length into the length weight relationship given by Borges et al (1984). The results were 19200 tonnes and 14500 tonnes for the two values of M. During the two surveys of "Nauka" the biomass in the same area was estimated to 11300 and 12900 tonnes, respectively.

4.1.5. Yield per recruit and biomass per recruit

The yield and biomass per recruit was calculated with the exploitation pattern estimated by the VPA and with individual weights estimated from the length weight relationship. The length and first recruitment was set to 10.5 cm.

The results are given in Table 5 for two values of M. All yield, catch per unit of effort and biomass values are expressed relative to the present situation.

As shown by the Table a doubling of the effort will lead to a increase in yield per recruit of between 85 and 86% depending on the value of M assumed This corresponds to a reduction in the catch per unit of effort of between 7 and 8% and to a drop in the biomass of app. 7%.

Table 5 *Decapterus russelli*. Sofala Bank, Yield per recruit (Y/R), catch per unit of effort per recruit (cpue) and biomass per recruit (B/R) relative to the present level of fishing mortality. (F_{max} = 0.35 year^{-1}) for two values of natural mortality. (M = 1.2 year^{-1}, M = 2.3 year^{-1})

F_{max}	M = 1.2			M = 2.3		
	Y/R	cpue	B/R	Y/R	cpue	B/R
0.20	0,59	1.04	1.05	0.59	1.04	1.03
0.35	1.00	1.00	1.00	1.00	1.00	1.00
0.40	1.13	0.99	0.98	1.13	0.99	0.99
0.50	1.38	0.97	0.95	1.38	0.97	0.97
0.70	1.85	0.92	0.90	1.86	0.93	0.93
1.75	3.68	0.74	0.66	3.76	0.75	0.79

4.2. Layang scad, Decapterus macrosoma

4.2.1. Catch per hour in numbers at length

The catch per hour in numbers at lenght is given in Table 1.13.

Recruitment seems to take place along most of the year. Large fish ($\geq$ 20 cm) were found from January to July 1985 and from December 1985 onwards. In the period from August to November they seem to have migrated out of the fishing area.

4.2.2 Total mortality

Because of the extended recruitment period and the migrations in and out of the fishing area no attempt was made to estimate the total mortality from the catch per hour in numbers at length.

4.2.3. Fishing mortality

The fishing mortality was estimated by the "swept area" method in the same way as for D. russelli, Table 1.14 (Annex 1).

The highest catch per hour in numbers at length occurred in the length range from 17 to 18.5 cm. Comparing the number of fish per square nautical mile estimated from the average catch in numbers of the commercial vessels with the results of "Nauka", the commercial vessels were found to be 12.17 times more efficient than "Nauka". The fishing mortality was hence estimated to 0.49 $year^{-1}$.

4.2.4. Stock size and biomass

As for D. russelli the average stock size and biomass was estimated by VPA, using the total catch in 1985 and the above estimated fishing mortality of the maximum exploited length group to start the calculations, Table 1.15 (Annex 1).

The natural mortality, M was derived from Pauly (1980,b) using and average sea temperature of 25^{o}C and growth parameters ($L\infty$ = 27.4 cm K = 0.43 $Year^{-1}$) and length weight relationship from Borges et al (1984).

The total biomass in the size range from 11 to 24.5 cm was estimated to 2600 tonnes, which is quite comparable to the total biomass figures of 2300 and 2600 tonnes obtained during the surveys of "Nauka" in the southern part of Sofala Bank.

4.2.5. Yield per recruit and biomass per recruit

The yield per recruit, Table 6, was calculated in the same way as for D. russelli

A doubling of the fishing effort will result in a 68% increase in the yield per recruit and a 16% decrease in the catch per fishing hour.

Table 6 D. macrosoma. Sofala Bank. Yield per recruit (Y/R), catch per unit of effort per recruit (cpue) and biomass per recruit (B/R) relative to the present level of fishing mortality (F_{max} = 0.49 $year^{-1}$). M = 1.0 $year^{-1}$. Length at first recruitment, 11 cm.

F_{max}	Y/R	cpue	B/R
0.28	0.62	1.08	1.08
0.49	1.00	1.00	1.00
0.56	1.11	1.97	0.98
0.70	1.32	0.93	0.93
0.98	1.68	0.84	0.85
2.45	2.07	0.53	0.61

4.3. Indian mackerel, Rastrelliger kanagurta

Besides being caught in the fishery for scad and mackerel Indian mackerel is caught as by-catch in the fishery for shallow water shrimp in Sofala Bank. In 1982 this bycatch amounted to 200 tonnes (Gislason & Sousa, 1985). This negligeable figure, which can be assumed to be similar in 1985, was not considered in the present assessment.

4.3.1. Catch per hour in numbers at length

Table 1.16 (Annex 1) shows the catch per hour in numbers at length.

Recruitmemt takes place in the first half of the year. The large fish ($\geq$ 19 cm) is most abundant from December to April and from July to September.

Fish above 23 cm are only rarely caught.

4.3.2. Total mortality

The total mortality was estimated to 1.0 year^{-1} by the "matched samples" method (Sousa, in press) from the catch per hour in numbers at length of the one year old fish in March and April 1985, Fig 4. The growth parameters were taken from Sousa & Gislason (1985).

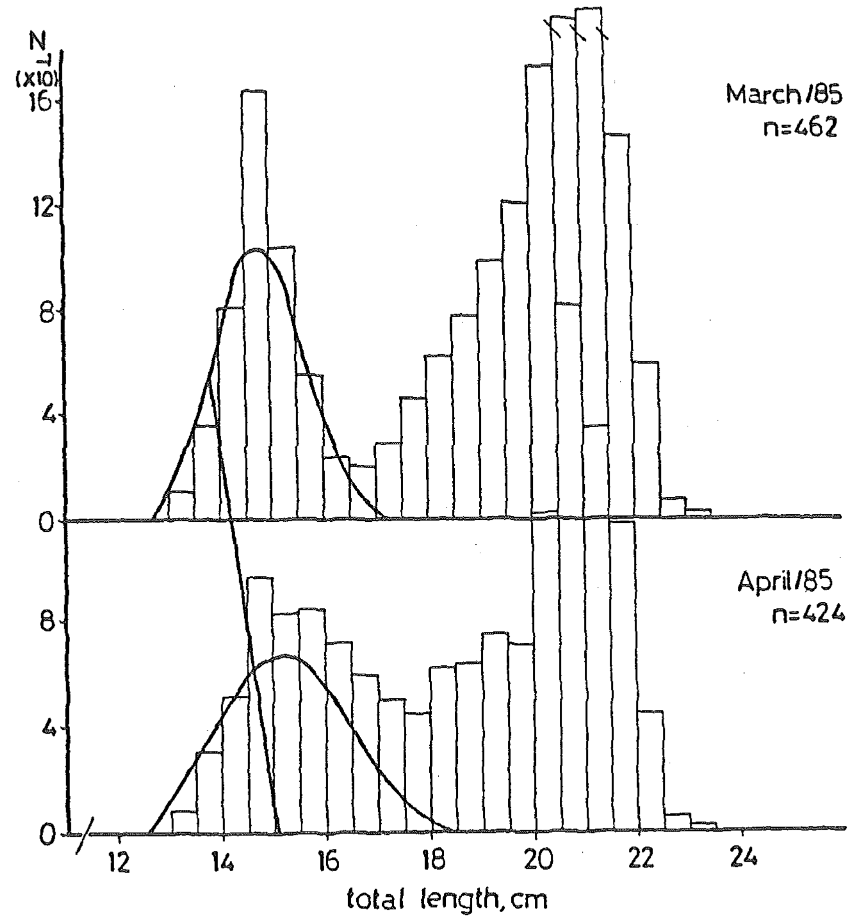

Fig. 4 Rastrelliger kanagurta. "Matched samples" method. Catch in numbers per hour at length and fitted normal distributions.

4.3.3. Fishing mortality

The fishing mortality was estimated to 0.30 year^{-1} by the "swept area" method. The highest catch in numbers occured in the length range from 19.5 to 21 cm. The commercial vessels were found to be 7.43 times more efficient than "Nauka", Table 1.17 (Annex 1).

4.3.4. Stock size and biomass

The VPA was run with two values of M, Tables 1.18 and 1.19 (Annex 1). One value (M =1.4) was derived by the formula of Pauly (1984). For the other (M = 1.0) the value of total mortality estimated by the "matched samples" method was used.

By use of the length weight relationship from Borges et al (1984) the total biomass of R. kanagurta was estimated to 4200 and 4100 tonnes, respectively. During the surveys of "Nauka" the total biomass in the area south of the Zambezi river was estimated to 7800 tonnes and 3400 tonnes.

4.3.5. Yield per recruit and biomass per recruit

The yield per recruit, Table 7, show that a doubling of the fishing effort will increase the yield per recruit by 81% for both values of M and reduce the catch per unit of effort with app. 10%.

Table 7 R. kanagurta. Sofala Bank. Yield per recruit (Y/R),catch per unit of effort (cpue) and biomass per recruit (B/R) relative to the present level of fishing mortality (F_{max} = 0.30 $year^{-1}$) for two values of natural mortality (M = 1.0 $year^{-1}$, M = 1.4 $year^{-1}$)

F_{max}	M = 1.0			M = 1.4		
	Y/R	cpue	B/R	Y/R	cpue	B/R
0.17	0.60	1.05	1.05	0.60	1.04	1.04
0.30	1.00	1.00	1.00	1.00	1.00	1.00
0.34	1.13	0.99	0.98	1.13	0.99	0.98
0.43	1.37	0.96	0.95	1.37	0.96	0.96
0.60	1.81	0.90	0.90	1.81	0.91	0.92
1.50	3.40	0.68	0.68	3.47	0.69	0.75

5. BOA PAZ

5.1. Indian scad, Decapterus russelli

5.1.1. Catch per hour in numbers at length

The catch per hour in numbers at length is given in Table 1.20 (Annex 1). As at Sofala Bank the main recruitment takes place in the first half of the year. Large fish (≫21 cm) were abundant in the catch from February to June and again from November to December. The fish are in general much larger than at Sofala Bank.

5.1.2. Total mortality

The total mortality was estimated by the "catch curve" method (Sparre,1985), Table 1.21.(Annex 1) and Fig. 5. Only data from March and April, the time when most of the large individuals are present were considered. For fish in the lenght range from 20 to 24.5 cm the total mortality was estimated to 2.3 $year^{-1}$.

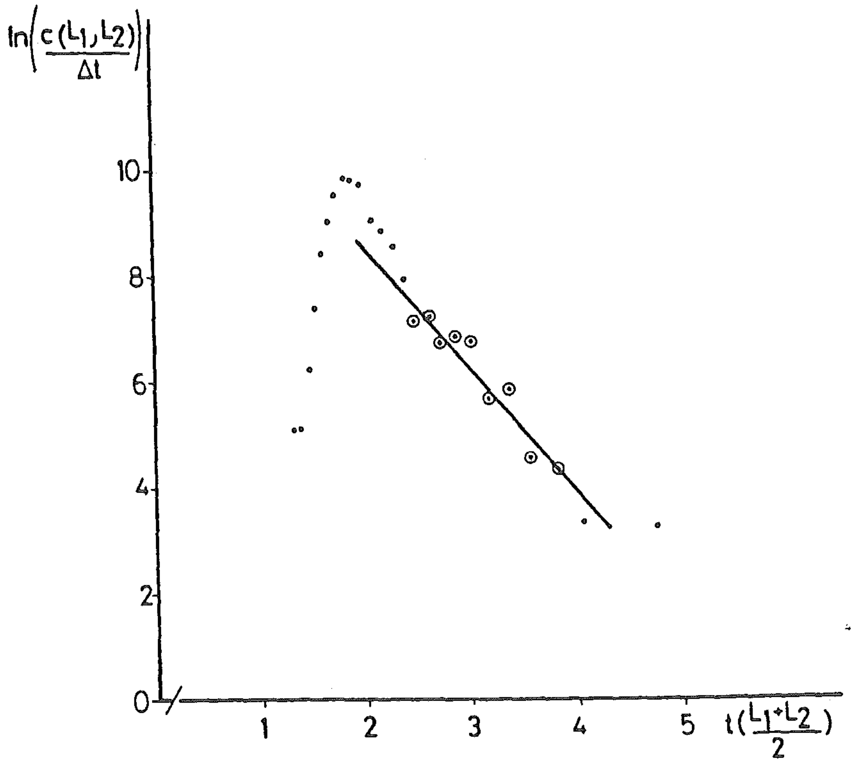

Fig. 5 D. russelli Boa Paz. "Catch curve" method. Data from March and April 1985.

5.1.3. Fishing mortality

The fishing mortality was estimated to 0.41 $year^{-1}$ for the length range from 16.5 to 18 cm by the "swept area" method, Table 1.22 (Annex 1). The commercial vessels were on average 11.64 times more efficient than "Nauka" during its 1984 May/June servey.

5.1.4. Stock size and biomass

The VPA was run with the same two values of M and the same growth parameters as used for D. russelli at Sofala Bank, Table 1.23 and 1.24 (Annex 1).

The average biomass in the length range from 10.5 to 27 cm was estimated to be 12000 and 9600 tonnes, respectively. During the survey of "Nauka" in May/June 1984 the biomass at Boa Paz was estimated to 4000 tonnes. The discrepancy between the biomass figures from the VPA and from the survey may be explained by our high value of catchability coefficient, thus, if we have used 0.5 (as suggested by D. Pauly) the survey estimate would be 8000 tonnes, rather close to the VPA estimate.

5.1.5. Yield per recruit and biomass per recruit

The yield per recruit and biomass per recruit, Table 8, were estimated with the same exploitation patterns as used in the VPA's.

A doubling of the present effort will result in a 75% increase in yield per recruit corresponding to a 12% decrease in catch per fishing hour for both values of M.

Table 8 Decapterus russelli. Boa Paz. Yield per recruit (Y/R), catch per unit of effort per recruit (cpue) and biomass per recruit (B/R) relative to the present level of fishing mortality (F_{max} = 0.41 $year^{-1}$) for two values of natural mortality (M = 1.2 $year^{-1}$, M = 2.3 $year^{-1}$). Length at recruitment, 10.5 cm.

F_{max}	M = 1.2.			M = 2.3		
	Y/R	cpue	B/R	Y/R	cpue	B/R
0.23	0.61	1.06	1.07	1.61	1.06	1.04
0.41	1.00	1.00	1.00	1.00	1.00	1.00
0.47	1.12	0.98	0.98	1.12	0.98	0.99
0.59	1.35	0.94	0.94	1.35	0.94	0.97
0.82	1.75	0.88	0.86	1.75	0.88	0.93
2.05	3.07	0.61	0.60	3.09	0.62	0.81

6. DISCUSSION

The migrations of fish in andout of the fishing areas constitute the main problem for making an assessment of the stocks of scad and mackerel at Sofala Bank and Boa Paz.

These migrations, which were assumed by Borges et al (1984), seem now to have been confirmed by the variations in the catch per fishing hour over the year. For D. russelli and T. trachurus the fishing area at Sofala Bank and at Boa Paz seem to be part of the spawning area (Borges et al, 1984) and the migrations of large fish to be spawning migrations. For R. kanagurta and D. macrosoma the picture is more unclear.

Nothing is at present known about the extent of these migrations. In the present assessment, it has been assumed that the stocks at Sofala Bank and Boa Paz are separated so that no fish migrate from Sofala Bank to Boa Paz or the opposite. This assumption remains to be proved.

The migrations make it very difficult to obtain reliable estimates of total and natural mortality. Only in one case was it possible to use the "matched samples" method of Sousa (in press) to connect normally distributed components of the size spectrum by growth curves and estimate total mortality from the drop in the numbers caught per fishing hour. Fortunately, however, the yield per recruit and biomass per recruit do notdepend very much on the value of natural mortality assumed.

Because of these and other uncertainties it was decided to use estimates of fishing mortality and stock size which most likely would lead to an oaverstimation of the effect of the present fishery. When using the "swept area" method to estimate the fishing mortality at Sofala Bank it was implicitly assumed that the whole population was found south of the mouth of the ambezi river. In addition the catchability coefficient was assumed to be one. Both of theses assumptions probably leads to overestimates of the fishing mortality and hence to underestimates of stock size.

Even so the effect of the present fishery is negligeable compared with the natural mortality and average stock size. A doubling of the fishing mortality corresponding to a doubling of the number of fishing hours will thus, depending on the species only lead to a 7 to 16% reduction in the average catch per fishing hour. It can thus be concluded that the fishery for scad and mackerel may by expanded gradually in the future without endangering the stock, the same conclusion as reached by Borges et al (1984).

The catch predictions presented in this report in the form of yield and biomass per recruit calculations have all been long term predictions of average conditions. They can not be transformed into predictions of actual yield and biomass without some knowledge of the future recruitment.

From time to other the fishing sector has expressed a wish to have short term predictions of the catch of the following year.

For short lived species like scad and mackerel a short term prediction will also depend heavily on estimates of recruitment. However, prediction just one year ahead it may be possible to obtain an estimate of the number of recruits of e.g. D. russelli supposed to enter the fishery in the first half of the following year from a special yearly recruitment survey. Such a survey will give a relative index of recruitment which afterwards has to be related to the total number of recruits (estimated for instance by VPA) before it can be used in the predictions.

Short term predictions of catch depend, however, also on predicting the fishing mortality. As the fleet at present only consists of 7 vessels of which the majority are old and need frequent repairs, the total number of fishing hours show big changes from year to year. Before the fleet has grown to a size where the total number of fishing hours does not depend so much on the breakdown of single vessels it will be almost impossible to make reliable catch predictions.

In 1985 the fishing company, MOSOPESCA, complained about low catch rates in the first half of the year. Unfortunately, no data on species composition is available from the first half of 1984, but comparing the average catch per standardized fishing hour in January to April 1985 with that of the same period in 1986 a significant (95% level) difference was found. The average of 1986 was 106 Kg above that of 1985. Dividing the catch into pelagics and demersals the catch rate of the pelagics showed a small and insignificant decrease, while the demersals increased significantly by 110 Kg per hour.

The difference between 1985 and 1986 is thus due to the demersals and not to pelagics, which again may indicate that more effort should be put into studying the demersal species caught in the fishery for scad and mackerel.

7. MAIN CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

7.1.1. The fishery for scad and mackerel can be increased gradually in the future.

7.1.2. The variations in the number of fishing hours from year to year and the lack of suitable recruitment indices make it impossible to make reliable short term predictions at present.

7.1.3. The low average catch rate obtained in the first four months of 1985 compared to the same period in 1986 was due to a significantly lower catch rate of demersal species.

7.2. Recommendations

7.2.1. The stratified random trawl surveys for scad and mackerel should be continued in order to give yearly estimates of fishing mortality.

7.2.2. Sampling of the catch should be continued at the present level.

7.2.3. The possibility for differentiating the stocks of scad and mackerel by means of meristic characters should be investigated.

7.2.4. The identification of *T. trachurus* should be verified.

7.2.5. Whenever possible indices of recruitment to the stocks of scad and mackerel should be examined.

7.2.6. The growth, mortality and stock size of the most important demersal species should be investigated.

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A N N E X 1

Tables

Table 1.1 - Monthly catch (tonnes) of the trawl fishery for scad and mackerel at Sofala Bank

Month \ Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
JAN		1056	1155	44	747	507	995	864	765	825
FEB		717	1121	410	396	216	699	842	264	738
MAR		230	1196	282	41	232	613	291	182	766
APR		1210	927	89	242	135	684	152	427	604
MAY		1914	857	226	539	-	392	275	176	819
JUN		2313	875	607	464	50	423	98	259	
JUL		516	1331	617	515	598	615	154	432	
AUG		459	742	428	753	288	451	334	593	
SEP	121	1687	347	487	585	274	39	40	406	
OCT	-	1241	-	365	249	-	-	-	22	
NOV	-	1195	-	215	22	-	260	91	92	
DEC	730	949	346	137	420	373	738	405	677	
TOTAL	851	13478	8897	3907	4973	2673	5907	3546	4295	

Table 1.2 - Monthly catch (tonnes) of the trawl fishery for scad and mackerel at Boa Paz

Month \ Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
JAN		2	-	-	9	129	75	7	111	36
FEB		-	-	-	214	230	109	-	304	73
MAR		-	-	69	629	219	61	40	199	-
APR		2	-	139	58	156	44	-	262	84
MAY		-	-	126	5	142	140	74	223	83
JUN		-	1	-	-	405	8	321	117	
JUL		1940	27	-	33	287	-	255	87	
AUG		1422	-	205	84	273	11	51	123	
SEP	39	5	-	-	118	107	346	119	326	
OCT	937	33	-	40	195	699	385	661	758	
NOV	917	11	-	409	463	310	81	398	468	
DEC	57	16	1	354	85	269	-	217	61	
TOTAL	1950	3431	29	1342	1893	3226	1259	2143	3039	

Table 1.3 - Relative fishing power of individual SRTM vessels, July 1984-May 1986

Sofala Bank

Vessel 1 = 0.7663 × A	n = 11
Vessel 2 = 0.8178 × A	n = 10
Vessel 3 = 0.5526 × A	n = 1
Vessel 4 = 0.8702 × A	n = 10
Vessel 5 = 0.8312 × A	n = 10
Vessel 6 = 1.0056 × A	n = 6

Boa Paz

Vessel 1 = 1.1092 × B	n = 8
Vessel 2 = 0.7453 × B	n = 8
Vessel 3 = 0.6533 × B	n = 2
Vessel 4 = 0.7786 × B	n = 6
Vessel 5 = 1.3205 × B	n = 10
Vessel 6 = 1.3910 × B	n = 2

A and B - Standard vessels

Table 1.4 - Catch per unit of effort (kg/stand. fishing hour) of species caught in the trawl fishery for scad and mackerel at Sofala Bank, July-December, 1984

Month	D.russellii	D.macrosoma	S.crumenophth.	R.kanagurta	C.malabaricus	D.acuta	Sardinella sp.	A.indica	Sphyraena sp.	Other pelagic	P E L A G I C	U.vittatus	U.bensasi	N.delagoae	P.natalensis	S.undosquamis	Other demersals	D E M E R S A L	IA	TOTAL Cpue
Jul	249	18	6	48	25		28	+	14	9	397	31	51	30	1	150	69	332	15	744
Aug	786	11	40	129	27		16		22	4	1033	12	21	17		84	35	168	5	1206
Sep	181	7	32	36	42			6	19	3	325	8	103	46		241	94	491		816
Oct																				
Nov	510	102		32	21				39	5	711		24	5		6	12	47	+	758
Dec	517	52		98	71	2		2	21		763	205	9	7		93	33	347		1110

Table 1.5 - Catch per unit of effort (kg/stand. fishing hour) of species caught in the trawl fishery for scad and mackerel at Sofala Bank, 1985

Month	D.russellii	D.macrosoma	S.crumenophth.	R.kanagurta	C.malabaricus	D.acuta	Sardinella sp.	A.indica	Sphyraena sp.	Other pelagic	P E L A G I C	U.vittatus	U.bensasi	N.delagoae	P.natalensis	S.undosquamis	Other demersal	D E M E R S A L	I	TOTAL Cpue
Jan	251	85	3	38	18	1		2	13	13	528	28	39	18	2	62	38	187	1	613
Feb	323	174	6	100	11	1			14	1	629		37	37	4	33	48	160		791
Mar	196	82	11	131	12	1	1	1	34	1	467	12	32	10	2	42	22	121	1	591
Apr	248	94	35	103	8	+	1	+	25	7	521	10	85	14	3	199	40	349	6	882
May	229	143	12	41	24	2	3	1	4	6	464	40	14	10	1	57	22	216	4	618
Jun	169	86	4	25	11	+		1	3	11	310	174	42	9	+	29	11	265	+	583
Jul	139	64	10	57	27	1	4	3	35	20	361	102	26	31	+	108	39	307		673
Aug	305	28	8	73	23	10	3	1	19	29	499	51	14	24	+	73	29	192	1	697
Sep	484	17	9	90	30	4	2	1	3	7	646	30	9	18	+	84	35	176	5	825
Oct	358	12	7	67	22	3	2	1	2	6	478	22	7	13	+	62	26	130	3	611
Nov	219	13	11	11	7	4	76	8	66	5	419	24	1	+	1	27	32	88	1	508
Dec	272	46	14	102	18	+	+	1	64	31	547	75	20	14	2	72	39	222	+	769

Table 1.6 - Catch per unit of effort (kg/stand. fishing hour) of species caught in the trawl fishery for scad and mackerel at Sofala Bank, January-April, 1986

Month	D.russellii	D. macrosoma	S.crumenophth.	R.kanagurta	C.malabaricus	D.acuta	Sardinella sp.	A.indica	Sphyraena sp.	Other pelagic	P E L A G I C	U.vittatus	U.bensasi	N.delagoae	P.natalensis	S.undosquamis	Other demersal	D E M E R S A L	I	TOTAL Cpue
Jan	201	68	12	135	17		+	7	17		465	17	28	34	2	46		224	3	693
Feb	294	110	11	142	1		4	3	18		602	58	25	45	21	57		267	2	869
Mar	338	135	18	81	8	+	3	11	26		622	72	32	41	2	82	16	293	2	829
Apr	120	116	8	101	14	4	8	16	38		435	198	20	143		56		473	3	911

Table 1.7 - Catch per unit of effort (kg/stand. fishing hour) of species caught in the trawl fishery for scad and mackerel at Boa Paz, July-December, 1984

Month	D.russellii	D.macrosoma	S.crumenophth.	T.trachurus	S.japonicus	R.kanagurta	C.malabaricus	D.acuta	Sardinella sp.	A.indica	Sphyraena sp.	Other pelagics	P E L A G I C	U.vittatus	U.bensasi	N.delagoae	P.natalensis	P.olivaceae	S.undosquamis	Other demersals	D E M E R S A L	IA	TOTAL Cpue
Jul	182	2	2	195	17	15	22	1	62	19	18	23	557	23		1	16	67	8	26	141	3	701
Aug	153	+	2	153	9	9	20		43	17	10	21	437				14	32	6	18	70		507
Sep	278		1	249	109	2	17		17	24	9	14	719		1	2	33	93	20	5	155		874
Oct	233		9	381	122	6	18	2	118	38	65	5	991	4	+		89	32	9	6	141		1132
Nov	216	9	16	155	42	12	6		108	3	29		595	7	4	1	4	7	8	8	39		634
Dec	125	3	15	58	16	4	15		69	7	131	1	443	3	1	2	1	14	31	24	75		518

Table 1.8 - Catch per unit of effort (kg/stand. fishing hour) of species caught in the trawl fishery for scad and mackerel at Boa Paz, 1985

Month	D.russellii	D.macrosoma	S.crumenophth.	C.malabaricus	T.trachurus	S.japonicus	R.kanagurta	D.acuta	Sardinella spp.	Sphyraena spp.	Other pelagic	P E L A G I C	N.delagoae	S.undosquamis	P.natalensis	U.vittatus	U.bensasi	P.olivaceae	Other demersal	D E M E R S A L	I	TOTAL Cpue
Jan	841	19	40			122	40	37	175	4	21	1295		8	7	36	7			57	16	1367
Feb	826	2	44	21	13	27	8	36	25	32	2	1033	2	46	7	46	5		30	135	2	1170
Mar	329	6	33	13	22	3	3	3	26	31	2	470	2	30	8	1	6		31	76	9	556
Apr	241	8	12	16	66	9	24	2	95	42	10	526	2	42	15	13	5	8	84	167	6	699
May	40	12	7	8	35	4	49	5	63	21	5	459	3	41	7	5	8	5	33	103	25	586
Jun	84		5	29	3		62	6	69	188	21	467	1	37	5	26		3	13	86	57	610
Jul	176	5	10	31	337	46	24	7	29	1	32	695	8	38	17	11	2		50	130	4	828
Aug	128	5	2	44	60	38	16	16	9	28	24	345	27	102	6	19	8	6	55	211	8	564
Sep	394	7	12	12	69	215	32	84	55	6	55	939	3	45	44	14	9	11	33	159	8	1105
Oct	389	2	26	15	72	68	13	50	50	24	22	732	2	36	12	17	2	6	20	94	2	828
Nov	429	7	40	15	9	15	13	15	31	30	8	610	3	26	4	15	2	17	19	86	1	697
Dec	186	2	5	14		2		14	1	14	6	246	1	10	1	2	1		7	22	1	269

Table 1.9 - D. russelli. Sofala Bank. Catch in numbers at length per standard fishing hour

Cm	1984	1985												1986			
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
10			42	10		11	2						13	45			8
			60	16										12			2
11			60	16										100			3
			123	29	31	25	7							101			6
12			402	124	124	92	90	44	8				146	714	9	37	11
			348	139	370	56	16	52	12	26	8		146	901	54	87	92
13			679	391	1523	67	457	108	32	157	56		366	1003	191	681	323
		47	1099	687	1882	254	124	133	38	120	28		420	662	404	2177	466
14		144	1333	733	1205	324	824	564	305	787	333	114	476	639	625	1515	808
	238	740	1396	844	924	827	241	580	523	630	194		363	416	528	1804	391
15	2375	1053	1390	925	622	1106	1324	1220	1553	2618	944	142	966	532	678	703	572
	3208	1545	1465	922	1027	743	194	586	1426	1841	583		778	687	1297	1256	193
16	2849	1234	805	515	331	669	1020	389	1470	2785	1139	369	1049	409	797	590	198
	1307	961	835	508	200	521	164	172	871	1583	750	341	859	289	721	367	109
17	1430	290	333	238	231	461	297	183	510	1124	889	744	531	137	376	137	74
	718	291	249	85	12	194	36	80	300	539	667	716	274	64	541	134	35
18	238	59	33	52	52	187	74	63	157	285	417	483	207	67	289	40	39
		46	96	16	8	109			66	73	111	114	163	71	208	40	8
19			18	10		70	20	20	72	51	278	369	85	13	105	14	6
		6				21			47	4	139	199	53	39	67	11	2
20									8	8	167	227	22		34	8	
											56	85	6	6	29	2	
21											28	28	17		14	1	
															14	1	
22																	
23																	
													6				
24																	
25																	
26																	
27																	
Nº./hour	12363	6416	10766	6260	8542	5737	4890	4194	7398	12621	6787	3931	6946	6907	6981	9605	3346
Kg/hour	518	251	323	196	248	229	168	139	305	483	311	219	271	201	294	310	120
Hours	365	1246	333	307	484	284	444	640	847	492	36	176	879	1191	849	924	663

Table 1.10 - D. russelli. Sofala Bank. Estimation of fishing mortality

cm	Commercial vessels (CV)					Nauka (N)			Nº./nm² (CV) / Nº./nm2 (N)
	Dec/84	Jan/85	Average	Nº./nm²		Dec/84-Jan/85	Nº./nm2		
7									
.5						4	88		
8						-	-		
.5						-	-		
9						-	-		
.5						1	22		
10						4	88		
.5						12	265		
11						22	485		
.5						20	441		
12						20	441		
.5						13	287		
13						10	220		
.5		47	24	654		34	750		0.87
14		144	72	1961		55	1213		1.62
.5	238	740	489	13318		248	5468		2.44
15	2375	1053	1714	46681		330	7276		6.42
.5	3208	1545	2377	64738	167033	450	9921	19027	6.53
16	2849	1234	2042	65614		208	4586		12.13
.5	1307	961	1134	30885		205	4520		6.83
17	1430	290	860	23422		157	3461		6.77
.5	718	291	505	13754		130	2866		4.80
18	238	59	149	4058		91	2006		2.02
.5		46	23	626		92	2028		0.31
19		-	-	-		35	772		-
.5		6	3	82		20	441		0.19
20						4	88		
.5						2	44		
21						-	-		
.5						-	+		

Total fishing hours = 6168

Total area = 5675 nm²

Table 1.11 - D. russelli. Sofala Bank. Virtual population analysis.
$L\infty = 27.9$ cm, $K = 0.56$ year^{-1} $M = 1.2$ year^{-1},
$F_{15-16.5} = 0.35$ year^{-1}

cm	△t years	Catch in numbers (× 10^{-3})		F	N(L$_1$) (× 10^{-6})	$\bar{N}$ 1985
10		32			627	
		25				
11	0.1610	25	125	0.0014		92
		75			516	
12		461				
	0.1769	544	2807	0.0342		82
13		1802			415	
		2220				
14	0.1964	3487	9592	0.1337		72
		3885				
15		7554			319	
	0.2207	6684	20897	0.3500		60
16		6659				
		4419			227	
17	0.2519	2652	8556	0.1772		48
		1485				
18		795			160	
	0.2934	384	1456	0.0369		39
19		277				
		135			112	
20	0.3513	76	221	0.0069		32
		10				
21		21			73	
	0.4377		21	0.0008		25
22					43	
23	0.5811		5	0.0003		18
		5				
24					21	

Average biomass (10.5 - 24 cm) ~ 19200 tonnes

Table 1.12 - D. russelli. Sofala Bank. Virtual population analysis.
L_∞ = 27.9 cm, K = .56 $year^{-1}$, M = 2.30 $year^{-1}$,
$F_{15-16.5}$ = 0.35 $year^{-1}$.

cm	Δ t years	Catch in numbers (× 10^{-3})		F	$N(L_1)$ (× 10^{-6})	$\bar{N}$ yearly
10		32				
		25			1252	
11	0.1610	25	125	0.0007		168
		75				
12		461			865	
	0.1769	544	2807	0.0224		125
13		1802				
		2222			573	
14	0.1964	3487	9592	0.1069		90
		3885				
15		7554			357	
	0.2207	6684	20897	0.3500		60
16		6659				
		4419			199	
17	0.2519	2652	8556	0.2308		37
		1485				
18		792			105	
	0.2934	384	1456	0.0654		22
19		277				
		135			53	
20	0.3513	76	221	0.0175		12
		10				
21		21			23	
	0.4377		21	0.0033		6
22		-				
					8	
23	0.5811		5	0.0018		3
		5				
24					2	

Average Biomass (10.5 - 24 cm) ~ 14500 tonnes

Table 1.13 - D. macrossoma. Sofala Bank. Catch in numbers at length per standard fishing hour

cm	1984	1985												1986			
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
10																	
11																	
12													1				
13									4				6	1	4	2	
		1	3		2								6	2	6	6	5
14		2	21	10	2	18	20	3	4	4	2		15	15	6	26	2
		2	84	29	6				6				22	12	11	38	2
15		5	195	78	52	53	54	6	1	8	3		33	97	20	23	5
		16	300	107	85	106	38	13	7		26		39	124	29	37	18
16	115	36	387	121	159	134	245	38	26	18	15	34	64	254	108	133	54
	288	126	456	182	225	183	90	67	20	22	58	11	48	317	224	255	136
17	230	173	405	221	298	257	394	148	57	55	80	67	98	278	359	237	161
	258	468	664	306	390	363	131	233	96	49	53	111	116	202	449	424	383
18	258	404	459	280	393	419	306	283	125	85	29	33	135	126	438	319	409
	27	322	586	283	219	479	158	170	61	41	3	22	146	84	300	440	481
19	27	88	345	163	120	394	149	136	26	8	2		106	49	134	167	306
		33	135	68	52	218	63	52	12	4			55	27	134	184	149
20		4	30	7	12	151	43	70	2				25	8	58	82	66
		2	18	3	8	74	20	11					2	3	32	31	30
21						18	7	2							6	9	
						7	2										
22								2									
23																	
24																	
25																	
26																	
27																	
Nº./hour	1203	1682	4088	1858	2023	2874	1720	1234	427	294	271	278	917	1599	2318	2413	2207
Kg/hour	52	84	174	81	94	143	86	64	28	17	14	13	46	68	110	124	116
Hours	365	1246	333	307	484	284	444	640	847	492	36	176	879	1191	849	924	663

Table 1.14 - D. macrosoma. Sofala Bank. Estimation of fishing mortality

cm	Commercial vessels (CV)				Nauka (N)		Nº./nm² (CV) / Nº.nm² (N)
	Dec/84	Jan/85	Average	Nº./nm²	Dec/84-Jan/85	Nº./nm²	
12							
.5					+	+	
13					2	44	
.5		1	1	27	4	88	0.31
14		2	1	27	7	154	0.18
.5		2	1	27	21	463	0.06
15		5	3	82	15	331	0.25
.5		16	8	216	12	265	0.83
16	115	36	76	2070	11	243	8.52
.5	288	126	207	5638	24	529	10.66
17	230	173	202	5502	26	573	9.60
.5	258	468	363	9886 } 24403	36	794 } 2006	12.45
18	258	404	331	9015	29	639	14.11
.5	27	322	175	4766	26	573	8.32
19	27	88	58	1580	9	198	7.98
.5		33	17	463	5	110	4.21
20		4	2	54	1	22	2.46
.5		2	1	27	+	1	27.00

Total fishing hours = 6168

Total area = 5675 nm²

Table 1.15 - D. macrosoma. Sofala Bank. Virtual population analysis.
$L_\infty = 27.4$ cm., $k = 0.43$ year^{-1}, $M = 1.0$ year^{-1},
$F_{17-18.5} = 0.49^{-1}$

cm	t years	Catch in numbers ($\times 10^{-3}$)		F	$\bar{M}$ ($\times 10^{-6}$)	N (L_1) ($\times 10^{-6}$)	$\bar{N}$ 1985
12							
						72	
13	.2468	1, 8, 8	17	.0011	64		16
14						56	
	.2761	47, 66, 196	309	.0228	49		13
15							
						43	
16	.3133	285, 544, 651	1480	.1318	36		11
17						30	
	.3622	1038, 1512, 1544	4094	.49	23		8
18							
						17	
19	.4292	1230, 695, 307	2232	.3974	13		6
20						10	
	.5268	153, 52, 9	214	.0554	7		4
21							
						5	
22	.6824	3, 1, -	4	.0015	4		3
23						3	
Average biomass (11 cm - 24.5 cm) ~ 2.6 tonnes × 10^{-3}							

Table 1.16 - R. kanagurta. Sofala Bank. Catch in numbers at length per standard fishing hour

Cm	1984	1985												1986			
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
10																	
11																	
12													1	1	1	1	
			6												2	1	
13			6	10	8									1	4	1	
			36	36	31									5	5	5	2
14			75	81	52	7	7						8	11	4	3	
			144	163	97	11	5						8	4	4	9	5
15			81	104	83	18	34						32	14	12	16	5
		1	45	55	85	35	18						15	19	18	29	5
16		2	18	23	72	28	41	2		4			15	65	12	30	17
		25	39	20	60	35	5	8	1	4	1		2	78	24	45	27
17		29	33	29	50	39	32	19	8	4	1		22	71	38	23	24
		33	45	46	45	56	5	13	5	8	1		24	59	49	39	63
18	22	12	24	62	62	85	106	27	19	22	2		25	107	74	43	42
	-	38	90	78	64	74	16	39	14	18	5		7	107	105	115	137
19	22	59	129	98	76	53	38	77	63	122	4	23	27	134	188	120	87
	132	68	165	121	72	42	5	64	74	85	67	34	9	142	263	184	128
20	460	51	123	173	122	35	52	120	246	358	79	34	125	112	183	98	94
	284	39	138	293	202	11	14	100	171	175	139	11	196	232	366	80	110
21	88	30	114	205	155	18	18	95	169	199	59	28	328	206	187	58	128
	44	30	99	147	118	18	7	63	44	55	92	6	152	228	171	36	112
22	22	21	45	59	45	11	5	27	26	14	22	6	99	66	55	15	72
		8	24	7	6	7		11	1	4	13		24	22	25	4	59
23		1		3	2			5			1		17	4	4	3	18
													2		2		5
24																	
															1		
25																	
															1		
26																	
27																	
Nº./hour	1047	447	1479	1813	1507	583	405	670	841	1072	486	142	1138	1688	1798	961	1140
Kg/hour	98	38	100	131	103	41	25	57	73	90	46	12	105	135	142	81	121
Hours	365	1246	333	307	484	284	444	640	847	492	36	176	879	1191	849	924	663

Table 1.17 - R. kanagurta. Sofala Bank. Estimation of fishing mortality

cm	Commercial vessels (CV)					Nauka (N)			Nº./nm² (CV) / Nº./nm² (N)
	Dec/84	Jan/85	Average	Nº./nm²		Dec/84-Jan/85	Nº./nm²		
12						2	44		
.5						5	110		
13						2	44		
.5						2	44		
14						4	88		
.5						-	-		
15						2	44		
.5		1	1	27		+	+		
16		2	1	27		2	44		0.61
.5		25	13	354		3	66		5.36
17		29	15	409		7	154		2.66
.5		33	17	463		9	198		2.34
18	22	12	17	463		16	353		1.31
.5	-	38	19	517		30	661		0.78
19	22	59	41	1117		30	661		1.69
.5	132	68	100	2724		31	683		3.99
20	460	51	255	6945	14081	26	573	1895	12.12
.5	284	39	162	4412		29	639		6.90
21	86	30	59	1607		55	1213		1.32
.5	44	30	37	1008		35	772		1.31
22	22	21	22	599		22	485		1.24
.5		8	4	109		5	110		0.99
23		1	1	27					

Total fishing hours = 6168

Total area = 5675 nm²

Table 1.18 - R. kanagurta. Sofala Bank. Virtual population analysis.
$L\infty = 27.8$ cm, $K = 0.75$ year^{-1}, $M = 1.0$ year^{-1},
$F_{19.5-21\ cm} = 0.30$ year^{-1}

cm	Δt years	Catch in numbers ($\times 10^{-3}$)		F	N (L_1) ($\times 10^{-6}$)	$\bar{N}$ yearly
12		1			72	
	0.1330	2	12	0.001330		9
13		9				
		38			63	
14	0.1478	87	282	0.032447		9
		157				
15		147			54	
	0.1662	105	344	0.041400		8
16		92				
		101			46	
17	0.1899	145	393	0.049845		8
		147				
18		209			38	
	0.2215	212	828	0.112412		7
19		407				
		388			29	
20	0.2658	829	1977	0.30		6
		760				
21		824			21	
	0.3323	419	1463	0.259577		6
22		220				
		56			14	
23	0.4436	21	79	0.016197		5
		2				
24					9	
Average biomass (10 - 24 cm) ~ 4200 tonnes						

Table 1.19 - R. kanagurta. Sofala Bank. Virtual population analysis.
$L\infty = 27.8$ cm, $K = 0.75$ year^{-1}, $M = 1.4$ year^{-1},
$F_{19.5-21\ cm} = 0.30$ year^{-1}

cm	Δt years	Catch in numbers ($\times 10^{-3}$)		F	N (L_1) ($\times 10^{-6}$)	$\bar{N}$ yearly
12		1			107	
	0.13300	2	12	0.000927		13
13		9				
		38			89	
14	0.14775	87	282	0.023913		12
		157				
15		147			72	
	0.1662	105	344	0.032436		11
16		92				
		101			57	
17	0.1899	145	393	0.041857		9
		147				
18		209			43	
	0.2215	212	828	0.102236		8
19		407				
		388			31	
20	0.2658	829	1977	0.30		7
		760				
21		824			20	
	0.3323	419	1463	0.293524		5
22		220				
		56			11	
23	0.4436	21	79	0.021489		4
		2				
24					6	
25						
Average biomass (10 - 24 cm) ~ 4100 tonnes						

Table 1.20 - D. russelli. Boa Paz. Catch in numbers at length per standard fishing hour

cm	1984	1985												TOTAL
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
10														
11														
12														
13	136				11	89			9					109
	346		27		11	89		67	9					203
14	482		85		35	226		48	23	3		7		427
	346	395	277	62	51	441		114	88	-		-		1428
15	73	790	554	174	147	648	84	190	212	724	106	33		3662
	136	3580	2000	454	160	509	26	314	350	728	92	16		8229
16	136	3185	2973	574	447	940	157	457	553	1364	633	343	44	11670
	621	2383	3085	896	733	667	173	362	350	1146	955	419	71	11240
17	621	790	1865	896	623	517	304	286	244	833	1313	1276	378	9325
	1040	1593	1912	824	696	530	183	429	217	813	1011	1095	360	9660
18	419	1198	1000	409	366	220	157	381	212	745	926	1125	493	7232
	764	1198	835	387	342	283	84	143	78	503	499	593	191	5136
19	346	1593	431	275	259	152	89	162	41	221	446	641	373	4683
	694	395	515	179	139	37	63	114	37	163	250	323	156	2371
20	272	-	196	95	43	13	110	95	23	133	198	353	280	1539
	346	395	196	101	72	13	10	48	-	20	46	82	27	1010
21	136		108	59	51	144	110	19	9	-	54	122	84	760
	346		192	101	37	13	-	67		-	24	51	44	546
22	73		108	92	45	8	5	19		10	24	83	102	496
	209		77	25	24	8		-		-	1	16	18	169
23	73		58	39	27	8		67		44	12	18	9	282
	73		27	20	-	-		19			4	10	4	84
24				6	13	5						12	22	58
				-	8	5						-	-	13
25				-	-							-	-	-
				6	5							-	-	11
26												3	4	7
												-	-	-
27												3	4	7
Nº./hour	7688	17495	16521	5674	4342	5565	1555	3401	2455	7450	6594	6624	2664	
Kg/hour	301	81	260	357	374	381	191	105	217	294	913	671	225	80340
Hours	125	841	826	329	241	40	84	176	128	394	389	429	186	

Table 1.21 - *D. russelli*. Boa Paz. Worksheet for estimating Z from a catch curve. Length composition from commercial vessels, March-April 1985

Length L (cm)	Sum of Catch per hour C	Age (L_1) t (years)	Δt	$t\left(\frac{L_1+L_2}{2}\right)$	$\ln\left(\frac{C}{\Delta t}\right)$	Z ($years^{-1}$)
13	11	1.300	.061	1.331	5.195	
13.5	11	1.361	.063	1.393	5.163	
14	35	1.424	.066	1.457	6.273	
14.5	113	1.490	.067	1.524	7.430	
15	321	1.557	.071	1.593	8.417	
15.5	614	1.628	.074	1.665	9.024	
16	1021	1.702	.076	1.740	9.506	
16.5	1629	1.778	.080	1.818	9.921	
17	1519	1.858	.084	1.900	9.803	
17.5	1517	1.942	.088	1.986	9.755	
18	775	2.030	.093	2.077	9.028	
18.5	729	2.123	.097	2.172	8.925	
19	534	2.220	.104	2.272	8.544	
19.5	318	2.324	.109	2.379	7.978	
20	138	2.433	.117	2.492	7.073	2.8
20.5	173	2.550	.125	2.613	7.233	
21	110	2.675	.134	2.742	6.710	
21.5	138	2.809	.145	2.882	6.858	
22	137	2.954	.159	3.034	6.759	2.3
22.5	49	3.113	.173	3.200	5.646	
23	66	3.286	.192	3.382	5.840	
23.5	20	3.478	.216	3.586	4.528	
24	19	3.694	.245	3.817	4.351	
24.5	8	3.939	.284	4.081	3.338	
25	-	4.223	.338	4.392	-	
25.5	11	4.561	.417	4.770	3.273	
26		4.978				

Table 1.22 - D. russelli. Boa Paz. Estimation of fishing mortality

cm	Com. vessels (CV)			Nauka (N)			No./nm² (CV) / No./nm² (N)
	Jun/84	No./nm²		May-June/84	No./nm²		
13	12	327					
.5	12	327					
14	52	1416					
.5	267	7272					
15	365	9941		3	66		150.6
.5	748	20372		6	132		154.3
16	267	7272		28	617		11.8
.5	690	18792	63649	56	1235	5468	16.2
17	1032	28107		91	2006		14.0
.5	615	16750		101	2227		7.5
18	487	13264		65	1433		9.3
.5	487	13264		32	706		18.8
19	377	10268		34	750		13.7
.5	371	10104		16	353		28.6
20	273	7435		18	397		18.7
.5	145	3949		8	176		22.4
21	209	5692		12	265		21.5
.5	162	4412		7	154		28.6
22	145	3949		11	243		16.3
.5	29	790		7	154		5.1
23	116	3159		5	110		28.7
.5	41	1117		-	-		-
24	-	-		-	-		-
.5	-	-		1	22		-
25	-	-					
.5	12	327					

Total fishing hours = 2164

Total area = 2225

Table 1.23 – D. russelli. Boa Paz. Virtual population analysis
L_∞ = 27.9 cm, K = 0.56 $year^{-1}$, M = 1.2 $year^{-1}$,
$F_{16.5\ -\ 18\ cm}$ = 0.41 $year^{-1}$

cm	Δt years	Catch in numbers		F	N (L_1) (x 10^{-6})	$\bar{N}$ yearly
13		40			219	
		54				
14	0.1964	137	535	0.0140		38
		344			172	
15		986				
	0.2207	1649	5813	0.1770		33
16		3178			127	
		3496				
17	0.2519	3825	10807	0.41		26
		3486			85	
18		2770				
	0.2934	1771	6064	0.3012		20
19		1523			55	
		856				
20	0.3513	662	1785	0.1162		15
		267			34	
21		298				
	0.4377	178	664	0.0573		12
22		188			20	
		57				
23	0.5811	87	172	0.0208		8
		28			10	
24		22				
	0.8670	5	27	0.0051		5
25		–			3	
		4				
26	1.7515	3	7	0.0028		2
		–			+	
27		3				
Average biomass (10.5 – 27 cm) ~ 12000 tonnes						

Table 1.24 - *D. russelli*. Boa Paz. Virtual population analysis.
L_∞ = 27.9 cm, K = 0.56 $year^{-1}$, M = 2.3 $year^{-1}$,
$F_{16.5-18\ cm}$ = 0.41 $year^{-1}$.

cm	t years	Catch in numbers ($\times 10^{-3}$)		F	N (L_1) ($\times 10^{-6}$)	$\bar{N}$ yearly
13		40			389	
		54				
14	0.1964	137	535	0.0087		61
		344			247	
15		986				
	0.2207	1649	5813	0.1377		42
16		3178			144	
		3496				
17	0.2519	3825	10807	0.41		26
		3486			73	
18		2770				
	0.2934	1771	6064	0.4108		15
19		1523			33	
		856				
20	0.3513	662	1785	0.2330		8
		267			14	
21		298				
	0.4377	178	664	0.1839		4
22		188			5	
		57				
23	0.5811	87	172	0.1209	1	1
		28				
24		22				
	0.8670	5	27	0.0656	+	+
25		-				
		4				
26	1.7515	3	7	0.1196	+	+
		-				
27		3				

Average biomass (10.5 - 27 cm) ~ 9600 tonnes

ANNEX 2

A. Y/R AND B/R.

The programme estimates Y/R and B/R by summing up the Y/R and B/R of 9 consecutive length groups, ie. by solving:

$$Y/R = \sum_{i=1}^{9} F_i * W_i * N_i * (1-\exp(-Z_i \Delta t_i))/Z_i$$

and

$$B/R = \sum_{i=1}^{9} W_i * N_i * (1-\exp(-Z_i \Delta t_i))/Z_i$$

where

$$W_i = a*(L_i + \Delta L/2)^b$$

$$Z_i = M + F_i$$

$$F_i = E_i * FMAX$$

$$\Delta t_i = (1/K) * \ln((L_\infty - L_i)/(L_\infty - (L_i + \Delta L)))$$

$$N_i = N_{i-1} * \exp(-Z_i \Delta t_i)$$

The following input must be available and in placed in the correct registers:

Parameter	Description	Register
M	Natural mortality	0
L_1	Length at recruitment	1
ΔL	Width of length intervals	2
L_∞	Par. in vBert. growth eq	3
K	- " - " - " - " -	4

a	Factor in L-W relationship	5
b	Exponent in L-W relationship	6
E_1 to E_9	Relative exploitation pattern	S_1 to S_9
FMAX	Fishing mort. of Max exploited length group	X

In addition the number of recruits must be entered into the program starting at line 3.
If Y/R and B/R figures are wanted a 1.0 should be inserted.
If total yield and biomas figures are wanted the actual number of recruits must be inserted here.

The program is run by presing d->A.

The output consists of FMAX, Y/R and B/R.

B. VPA.

The VPA programme consists of 3 subprogrammes: One for initializing the calculations (LBLB B), another for going backwards in size (and time) (LBLB D) and one for going forwards in size (and time) (LBLB C). The two latter programmes are iterative, ie. the user has to run them several times until the resulting fishing mortality has stabilized.

Programme B is used when the fishing mortality and catch of a length interval are known. It determines the numbers passing through the lower and upper limit of the interval by:

$$N(L_1) = (C_1/F_1) * Z_1/(1-\exp(-Z_1 \Delta t_1))$$

and

$$N(L_2) = N(L_1) * \exp(-Z_1 / \Delta t_1)$$

where C is catch, F fishing mortility, Z total mortality and Δt the time required to grow through the length interval.

Programme C uses $N(L_2)$ to go forwards in time by:

$$F(L_2) = C_2 * Z_2/(N(L_2)*(1-\exp(Z_2 \Delta t_2))$$

and

$$N(L_3) = N(L_2) * \exp(-Z_2 \Delta t_2)$$

it displays L_2, $F(L_2)$, $N(L_2)$, $N(L_3)$, N_{year} (the average number present in the time period (eg. year) from which the catch data are taken) and C/F.

Programme D uses $N(L_1)$ to go backwards in time by:

$$F(L_0) = C_0 * Z_0/(N(L_1)*(\exp(Z_0 \Delta t_0)-1))$$

and

$$N(L_0) = N(L_1) * \exp(Z_0 \Delta t_0)$$

It displays L_1, $F(L_0)$, $N(L_0)$, $N(L_1)$, N_{year} and C/F.

In all 3 programmes Z_i and Δt_i are calculated by:

$$Z_i = M + F_i$$

$$\Delta t_i = (1/K)* \ln((L - L_i)/(L - (L_i + \Delta L)))$$

The input for the programmes is the following:

Parameter	Description	Register
N	Number at the lower (prog. C) or upper (prog. D) limit of length interval	0
F	Initial Fishing mortality	1
M	Natural mortality	2
C	Catch in numbers at length	3
L	vBer. growth param.	5
L	Lower (prog. C) or upper (prog.D) limit of length interval.	6
ΔL	Width of length interval	7
K	vBer. growth param.	8

In additon to the above output Δt is kept in reg. 9.,