REPRODUCTION, AGE AND GROWTH OF THE RUSSELL'S SCAD, *DECAPTERUS RUSSELLII* (RÜPPELL, 1828) (CARANGIDAE) FROM SOFALA BANK, MOZAMBIQUE

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ABSTRACT

Age, growth and reproduction of D. russellii (Rüppell, 1828) were studied. Most of the material used were caught by the commercial fishing fleet, operating in the Sofala Bank area. A total of 68 000 fish were examined during the period 1979-1981. Usually there seems to be two main spawning periods a year, one in February-March and another one in August-September. The sex ratio is about 1 : 1. Ageing was carried out using primary growth rings in the otoliths and using analysis of size-frequency distributions. The parameters of the von Bertalanffy's growth equation were about L_∞= 25 cm, W_∞= 160 g and K= 0,5. Males and females seem to grow at the same rate.

RESUMO

Foi estudada a idade, crescimento e reproducão de D. russellii (Rüppell, 1828). A maior parte da informacão analisada foi collida a bordo dos barcos comerciais, que operam na área do Banco de Lofala. Durante o periodo de 1979-1981 foram examinados 68 000 peixes. Parecem existir dois, periodos de desova importantes por ano, um em Fevereiro-Marcos e outro em Agosto-Septembro. O "sex-ratio" é de cerca de 1:1. Foi determinada a idade a pantir da contafem dos aneis de crescimento dário nos otolitos e da análise de distribuicóes de frequencia de comprimentos. Os parametros da egnacéo de von Bertalanffy obtidos foram L_∞= 25 cm, W_∞= 160 g e K= 0,5. Os machos e os fémeas parecem crescer na mesma proporcão.

INTRODUCTION

The russell's scad, Decapterus russellii (Rüppell, 1828) is one of the most important species in the trawl fisheries of Mozambique, making up as much as 25 percent of the total catch in the demersal trawl fisheries (excluding shrimp trawl bycatches).

Due to taxonomical confusion, little is known about the distribution of this species, but there are reliable records from India (Nekrasov, 1969), from the Phillipines (Thiews et al. 1970, Ronquillo, 1974) and from Mozambique. The specimens identified as D. maruadsi in earlier works from Mozambique also belong to D. russellii (e.g. Sætre and Paula e Silva, 1979; Brinca et al. 1981).

Little information is available on the biology of D. russellii. Sætre and Paula e Silva (1979) summarize the observations from Mozambique, and Thiews et al. (1970) and Ronquillo (1974) those from the Phillipines. Some observations from the western coast of India are given by Dmitrenko and Fursa (1969) and Anon (1976a, b).

The present paper is based on material collected from the commercial fisheries in the Sofala Bank area (Fig. 1) and from a few surveys in the same area.

The main objectives are to present information on age, growth, reproduction and other biological characteristics important for a rational management of this species.

MATERIALS AND METHODS

Collection of data

During the period 1979 to 1981 samples were usually taken monthly from the commercial fishing vessels. In September 1977, two licenced stern trawlers started the fishery of pelagic and demersal fish in Mozambican waters. They were

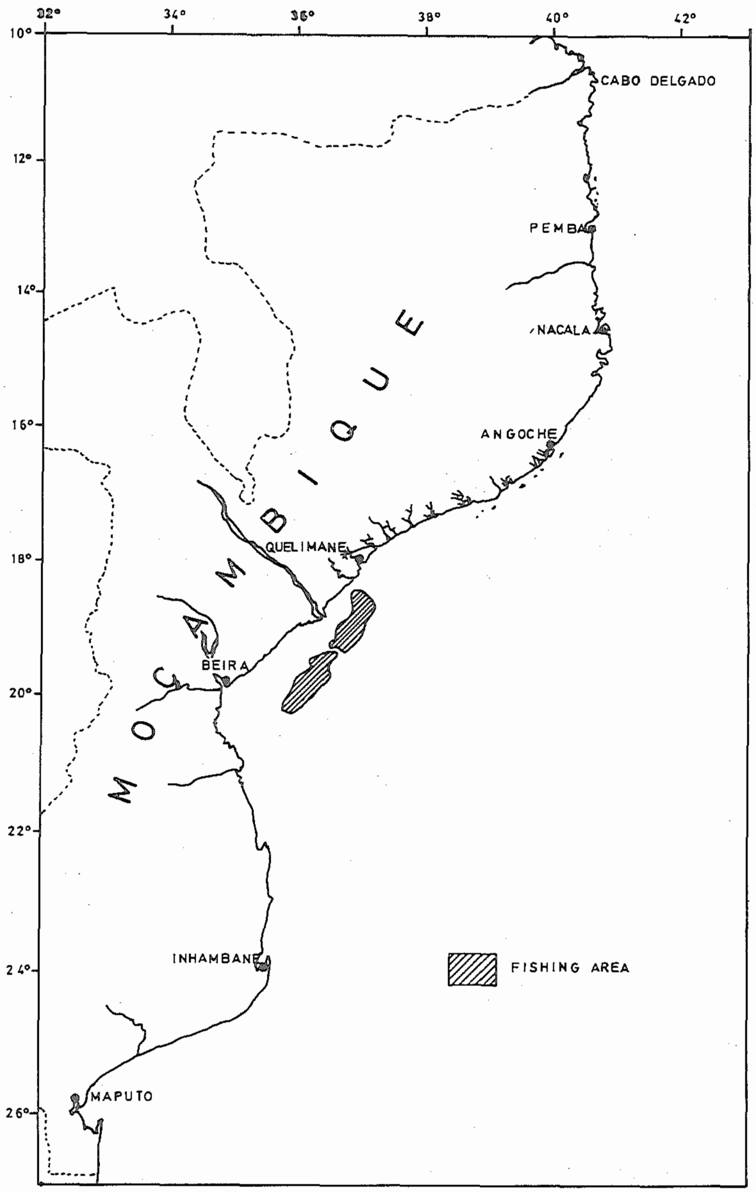

Fig. 1. Fishing area for D. russellii off Mozambique.

mainly confined to the Sofala Bank and Boa-Paz areas (Fig. 1), on the continental shelf but more than 12 miles from the coast. The number of fishing boats increased in 1978 and during the following year a programme of sample collection was settled. At that time the samples were taken from a RTM type vessel with 2907 GRT and 1340 HP. In 1980, after a fishing enterprise had been formed, the samples were taken from a SRTM type vessel with 1919 GRT and 1000 HP. The fishing area was then extended to the continental shelf inside the 12 miles. Both of these two types of vessels were fishing with bottom trawls, with 21 m and 13-15 m of horizontal and vertical opening, respectively. The mesh size in the cod end was 20 mm. During the period 1979-1981 a total of 374 samples were taken and 68.000 fish were examined.

During April-May of 1981 a set of samples was taken from a RTM type vessel used for experimental fishing. A bottom trawl with 21 m horizontal opening was used. During May-June 1981 an exploratory fishery survey for cephalopods was carried out by a trawler and samples of D. russellii were taken. During June-August 1981 two cruises were made on a SRTM type vessel. From these cruises a total of 90 samples were collected, and 3400 fish were examined.

The total length of the fish was measured from the tip of the snout to the projection of the upper lobe of caudal fin on the horizontal line passing the midpoint of the two lobes. The length distribution in the samples was recorded. From each sample 100 specimens were taken randomly and the following biological parameters were recorded: total length in millimeters, total weight in grams, gonad weight in grams, gutted weight in grams, sex and maturity stage. A maturation scale of 6 stages was used for both males and females (Appendix 1). The size of gonads in the abdominal cavity, the size distribution of eggs and blood vessels in the ovaries were taken into account. The gonads were classified as juveniles (stage I and II), maturing (stage III), mature (stage IV), spawning (stage V) and post spawning (stage VI). For the whole period the biological parameters were recorded for a total of 9800 fish. A large number of otoliths were extracted.

Otolith extraction and preparation

Only the largest of the three otoliths on each side, the sagittae, were used for ageing. These otoliths were removed by lateral dissection, dried and stored in paper envelopes, after being washed in water.

The otoliths were ground into thin sagittal sections in two different ways: with a dentist drill equipped with polishing discs and with a sharpening stone. They were first ground from the distal sagittal plane, alternating grinding with observation under a microscope and stopping just before the nucleus was reached. They were then fastened to a glass slide with a drop of transparent cement with the ground surface against the slide. The proximal side was now exposed and it was ground until the nucleus was reached. When a sharpening stone was used, the otoliths were first dipped in water and ground from both sides before they were fastened to the glass slides. After grinding the otoliths were cleaned with a drop of 1% HCl, for 5-10 seconds. The acid removes most of the particles on the ground surface and the rings became clearer. They were then rinsed in water and mounted in DPF mounting.

Otolith readings

The otoliths were read under a microscope at a magnification of 640 x. All readings were done from the nucleus to the rounded edge opposite to the rostra, as the rings were more distinct in this section. A hand counter was used to ease the readings. For most otoliths, two countings were made for each and only those with a difference between readings less than 10% were considered. As the fish grow the number of rings in otoliths increase, but they become thinner and are more densely packed. For this reason, it was found that the otolith readings of fish larger than 18.5 cm total length were very difficult and probably underestimate the true age. They were therefore not included in the final results.

Fitting of length-age equations

To fit a growth curve to the length-frequency distributions, the ELEFAN I program was used (Pauly and David, 1981). This program "traces" a von Bertalanffy growth curve through a series of length-frequency samples sequentially arranged in time so that it passes through as many peaks as possible. The program, originally written in BASIC, was run on a Univac 1100 computer. The three years from which data were available were treated separately.

The growth curve based on otolith readings was fitted using graphical methods (Beverton & Holt, 1957).

The statistical methods used are described by Zar (1974).

RESULTS AND DISCUSSIONS

Length-weight relationship

The length-weight relationship was studied based on about 3400 individuals from commercial catches taken between February and December 1980, and about 1200 specimens taken during the scientific cruises for the period April-August 1981.

Statistical analysis (mainly analysis of covariance and t-tests) were performed on logarithmically transformed data fitted to a predictive linear regression

$$\lg W = a + b \lg l$$

where W is weight in grams and l is length in centimeters.

Following the recommendations of Ricker (1973) the relationships were, however, transformed to and presented as functional regressions

$$\lg W = u + v \lg l$$

Confidence limits for v were calculated as by Ricker (1975). In June, July, November and December 1980 males and females were treated separately (Table 1). T-tests were used to test the hypothesis that the regressions for the two sexes had different slopes. For three months the differences were not significant, while for one month (July) the males had a significantly steeper sloper than the females. In spite of this

Table 1. Predictive regressions (lg W = a + b lg l) for weight on length for D. russellii from four cruises in 1981. t shows the significance in the difference between b for males and females.

Month	Males		Females		t
	b	a	b	a	
Nov.	2.66	-1.62	2.91	-1.91	1.55 ns
Dec.	2.59	-1.53	2.86	-1.86	1.33 ns
July	2.72	-1.69	2.99	-2.01	2.22 xx
June	2.67	-1.62	2.50	-1.41	-1.62 ns

difference, males and females were combined for all the other analysis.

Results of the regression analysis for commercial catches are given in Table 2, showing the functional regression parameters.

Table 2. Weight-length relationship for D. russellii from commercial catches 1980. Parameters v and u from the function regression lg W = u + v lg l and the corresponding correlation coefficient r.

Month	N	v	u	r	Size Range (cm)
January					
February	658	3.114	-2.148	0.916	14.0 - 19.0
March	478	3.477	-2.601	0.926	14.0 - 19.0
April	249	3.073	-2.117	0.947	13.5 - 19.5
May					
June	243	2.929	-1.930	0.880	14.0 - 19.0
July	447	3.109	-2.152	0.914	11.5 - 20.0
August	248	2.995	-2.016	0.954	13.5 - 19.0
September	248	2.912	-1.904	0.935	13.0 - 19.5
October	362	3.028	-2.068	0.909	13.5 - 18.5
November	175	3.126	-2.177	0.895	14.0 - 18.0
December	288	2.991	2.019	0.906	13.5 - 20.5
TOTAL	3396	3.121	-2.167	0.927	11.5 - 20.5
TOTAL (excluding March)	2918	3.089	-2.129	0.927	11.5 - 20.5

The regression coefficient, v, varies between 2.912 and 3.477. Its seasonal variation is shown in Fig. 2. An analysis of covariance (Zar, 1974) showed that the lines had different slopes ($F= 5.38$, $p \ll 0.01$). Inspection of the coefficients suggests that this could be due to the very high value in March. This month was therefore excluded, and a new analysis was performed. In this case the slopes were not significantly different ($F= 1.82$, $p > 0.05$), but the elevations were different ($F= 29.02$, $p \ll 0.01$).

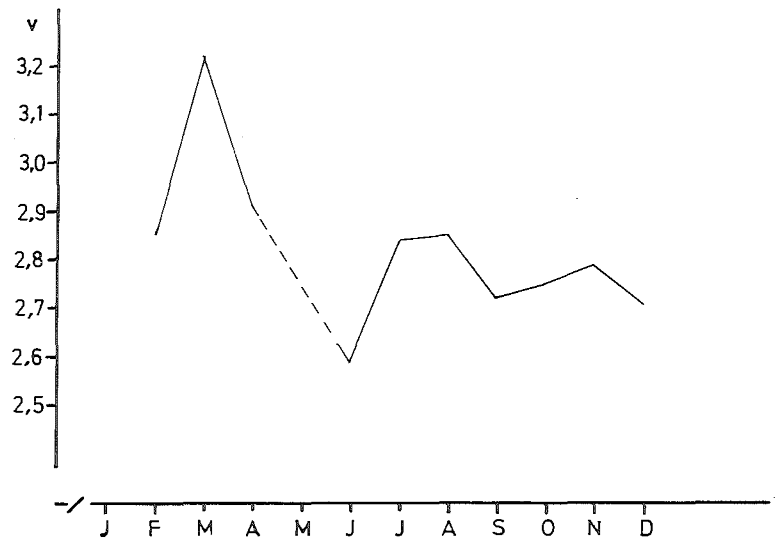

Fig. 2. Seasonal variation in the regression coefficient v from the function regression line lg W = u + v lg l between weight and length of D. russellii.

For practical purposes one common regression line based on all the material is probably best. This regression based on fish in the size range 11.5 to 20.5 cm is:

$$\lg W = 3.121 \lg l - 2.167 \quad \text{or} \quad W = 0.00681\, l^{3.121}$$

with $r= 0.927$ and the 95% confidence limits of the regression coefficient are 3.076 and 3.166. These values are close to those given by Ronquillo (1974) for D. russellii from Phillipines waters.

During April-August 1981 four surveys were conducted. The results of the length-weight analysis on the material from these surveys are given in Table 3.

Table 3. Weight-length relationship for *D. russellii* from four cruises conducted in 1981. Parameters v and u from the function regression lg W = u + v lg l and the corresponding correlation coefficient r.

Vessel	Time of cruise	N	v	u	r	Size range (cm)
S. Kadanchik	21/4 - 17/5-81	512	3.124	-2.170	0.964	12.0 - 19.5
Pegago IV	22/5 - 12/6-81	181	2.955	-1.962	0.945	14.0 - 19.5
Pantikapey I	7/6 - 23/6-81	199	2.822	-1.817	0.960	13.5 - 19.0
Pantikapey II	21/7 - 5/8-81	340	3.186	-2.248	0.940	13.0 - 19.0

For a period for which data were available both from the commercial fisheries and from a survey, the difference between these sources of information was studied. The predictive regressions were

$$\lg W = 2.837 \lg l - 1.837 \quad N = 617$$

and

$$\lg W = 3.012 \lg l - 2.035 \quad N = 512$$

for commercial catches and scientific surveys, respectively. A t-test was performed to test the significance of the difference and the result was $t = 2.85$ ($p < 0.01$). Data from commercial catches and from scientific cruises were therefore not combined.

Time of spawning

To estimate the time of spawning the maturity stages and the gonadosomatic index (GSI, gonad weight/total weight x 100) were studied.

There was a good correlation between these two parameters, specially for the females (Fig. 3). The highest index is found in stage IV. The values for stage V are much lower, indicating

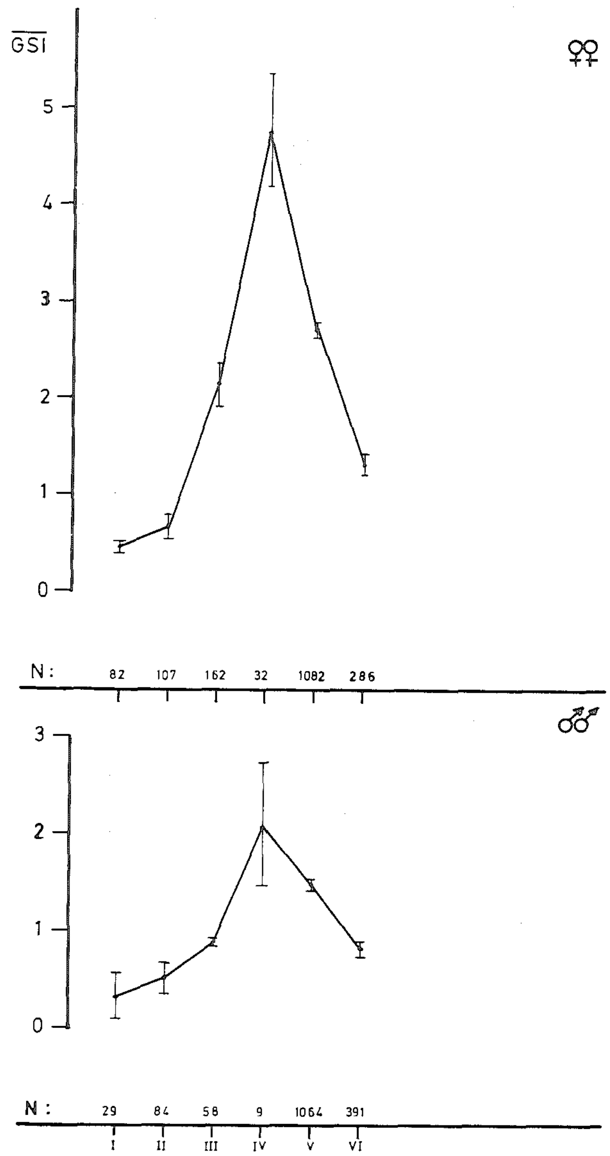

Fig. 3. Mean gonadosomatic index and its confidence limits (vertical bars) for the different stages of maturity of D. russellii.

that at least parts of those fishes classified to this stage are partly spent. The highest values of GSI should therefore be expected just before a peak in the spawning activity.

The monthly variations in maturity stages of the females are given in Table 4. In 1979 data are sparce, but they indicate a high spawning activity in June-August. Data are lacking in September-November, but the high GSI in August may suggest that the peak was not yet reached in that month (Fig. 4).

Table 4. Monthly variation (in %) of maturity stages of female *D. russellii* from commercial catches.

	I	II	III	IV	V	VI	N
1979							
Jan							
Feb							
Mar	23.9	27.9	40.0	3.4	4.7		527
Apr	6.0	35.0	53.0	6.0			100
May							
June		0.40	9.64	7.23	76.31	6.43	249
July		1.89	0.76	6.06	75.76	15.53	264
Aug			8.54	2.44	85.37	3.66	82
Sep							
Oct							
Nov							
Dec		3.28	37.19	16.38	41.62	1.54	519
1980							
Jan							
Feb		0.65	1.62	0.97	90.61	6.15	309
Mar		1.72			82.33	15.95	232
Apr	3.29	1.32		0.66	68.42	26.32	152
May							
June	8.33	24.31	54.86		10.42	2.08	144
July	17.84	24.07	14.52	2.07	28.63	12.87	241
Aug	4.07	4.07	3.25	4.88	78.86	4.88	123
Sep	4.55		2.27	9.09	79.55	4.55	132
Oct	3.59		6.15	1.03	57.44	31.79	195
Nov	0.99		8.91	1.98	58.42	29.70	101
Dec	0.68	0.68	15.07	2.05	39.73	41.78	146
1981							
Jan	3.15	1.57	18.11	7.09	38.58	31.50	127
Feb	12.82	1.28	4.49		31.41	50.00	156
Mar							
Apr	77.78				18.52	3.70	27
May	60.95	8.88	0.30		5.92	23.96	338
June							
July							
Aug	0.47		1.42	6.16	89.57	2.37	211
Sep					100.00		87
Oct							
Nov							
Dec		1.26		0.50	95.48	2.37	398

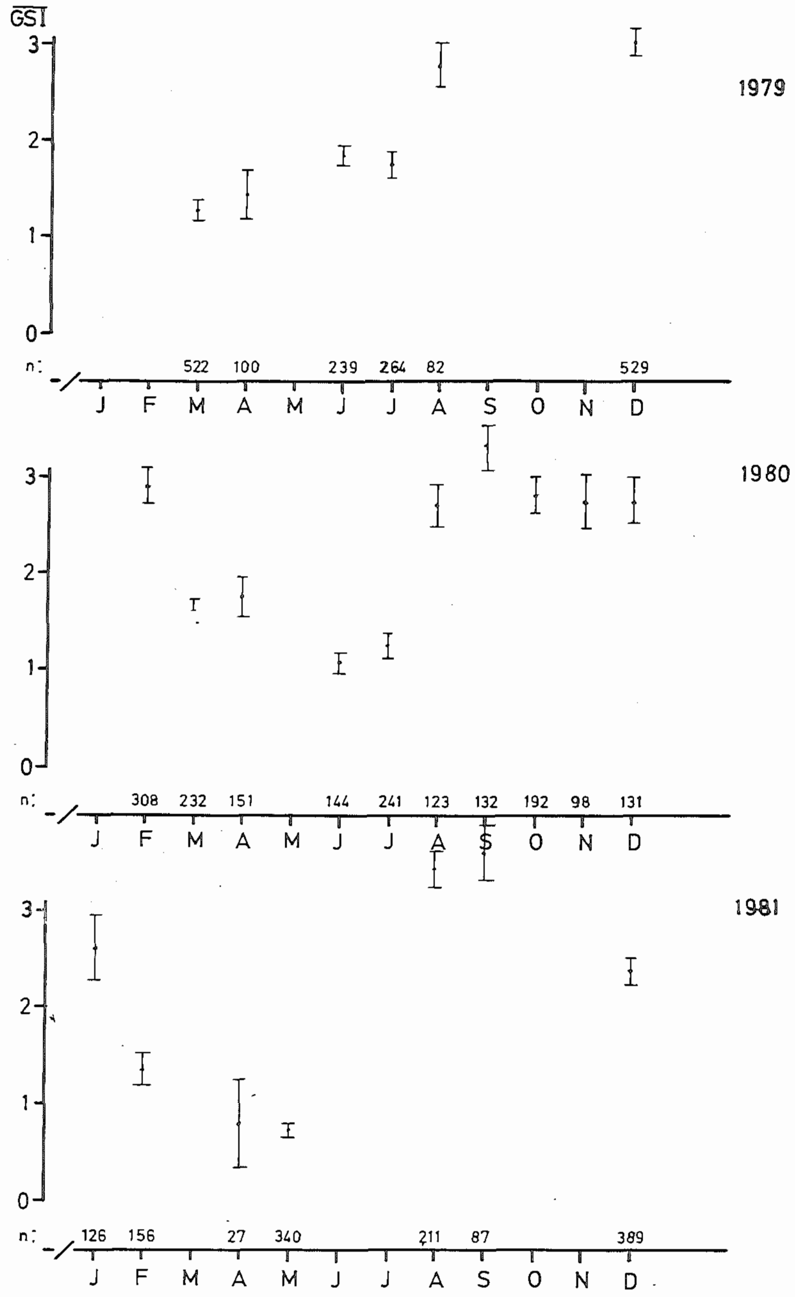

Fig. 4. Variation in gonadosomatic index (mean ± confidence limits) of female D. russellii.

In 1980 the distribution of maturity stages indicates one spawning period in February-April (possibly starting in January when no data is available) and another one in August-November. The first one is confirmed by the high values of GSI in February and also in December 1979, and the other one is also coinciding with high values of GSI (Fig. 4).

In 1981 few spawning fish were observed during the first part of the year, but a very high percentage of fish in stage VI taken in February indicates that some spawning had taken place. A high value of GSI in January may support this assumption.

From the second half of 1981 maturity stages were recorded in August-September and December only. All these months show a high percentage of fish in stage V. In August and September the GSI was also high. Four scientific cruises conducted during April-August showed very low values for GSI except for the last cruise where a high value was observed (Table 5). The last cruise also gave a high percentage of fish in stage V (Table 6).

Table 5. Gonadosomatic index (mean ± standard deviation) for D. russelli caught during four cruises in 1981.

		♀♀		♂♂	
Vessel	Time	GSI	n	GSI	n
S. Kadanchik	21/4 - 17/5-81	0.98 ± 0.111	283	0.38 ± 0.040	223
Pegago	22/5 - 12/6-81	0.52 ± 0.066	88	0.27 ± 0.033	93
Pentikapey I	7/6 - 23/6-81	0.73 ± 0.093	120	0.30 ± 0.035	75
Pantikapey II	21/7 - 5/8-81	1.81 ± 0.152	202	1.01 ± 0.121	127

These data suggest that generally there are two main spawning periods, one at the end of the wet season (February-March) and another one at the end of the dry season (August-September). The exact time and the relative importance of these spawning seasons seem, however, to vary among the years.

This confirm Sætre and Paula e Silva's (1979) conclusion that peaks of spawning are found in April and September. These peaks coincide with the shifts in the monsoon regime which influence the water circulation of the area from the Sofala Bank and northwards (Sætre and Jorde de Silva, 1982).

Table 6. Distribution of maturity stages of *D. russellii* caught during four cruises in 1981.

		♀♀							♂♂						
Vessel	Time of cruise	I	II	III	IV	V	VI	N	I	II	III	IV	V	VI	N
S. Kadanchik	21/4-17/5-81	52.8	8.1	1.8	0.7	16.2	20.4	284	43.3	27.9	0.9	0.9	4.9	22.1	226
Pegago IV	22/5-12/6-81	46.6	37.5	1.4		3.4	11.4	88	50.0	33.7			1.1	15.2	92
Pantikapey I	7/6-23/6-81	54.5	17.4	3.3		8.3	16.5	121	49.3	32.0	4.0		1.3	13.3	75
Pantikapey II	21/7- 5/8-81	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

Geographical distribution of spawning

The geographical distribution of spawning fish was studied during a cruise with R/V "Pantikapey" in July-August 1981.

The area between 17° and 21° was covered. Decapterus russellii was observed only in the area south of the Zambezi river (18° 55'S) (Fig. 5). Spawning fish were observed all over this area at depths between 11 and 95 m. The hypothesis that this species migrates to deeper waters to spawn (Sætre and Paula e Silva, 1979) is therefore not supported by this information.

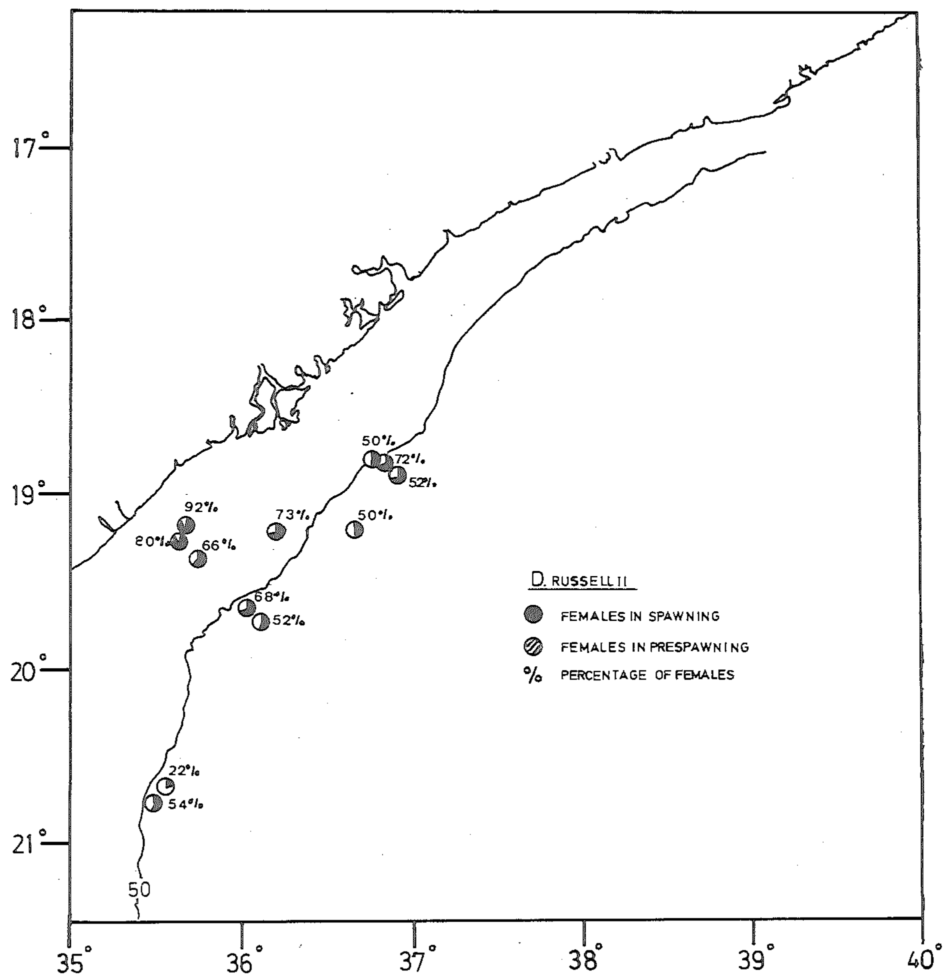

Fig. 5. Sex composition and developmental stages of the female D. russellii caught during a survey in July-August 1981.

Sex ratio

The sex ratio was studied in samples from 22 months in 1979, 1980 and 1981 with a total of 9748 fish (Fig. 6). X^2-test showed that there were significantly (0.05 level) more males than females in December 1979, and in January, September and December 1981. There were significantly more females than males in April 1979, in April and June 1980, and in May and August 1981.

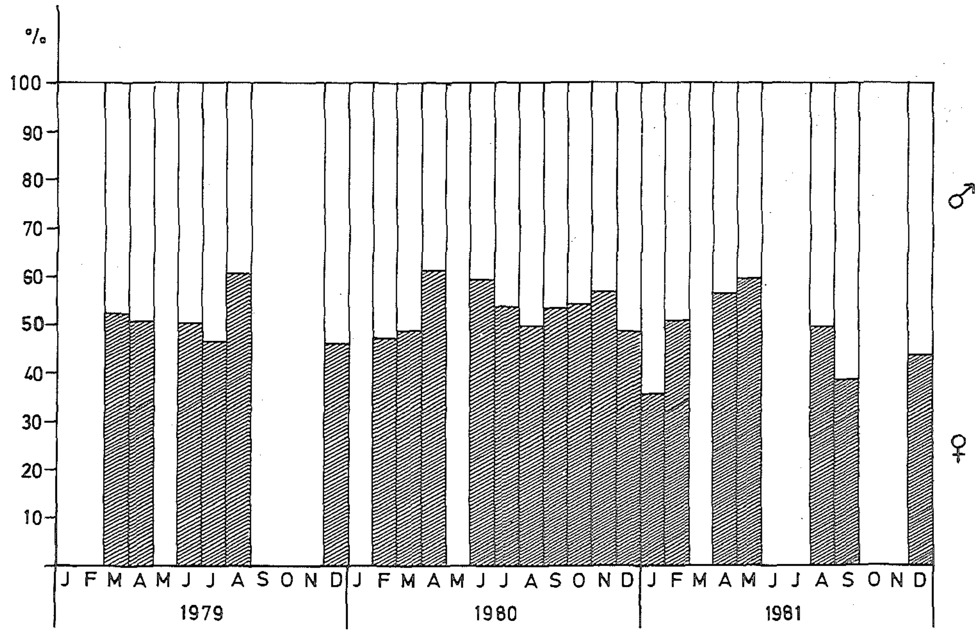

Fig. 6. Sex composition of D. russellii from the commercial samples.

There seems to be no seasonal trend in the sex composition, and for all samples combined males and females are equally abundant.

The samples from the four scientific cruises taken during April-August 1981 were analysed separately. The second cruise showed a sex ratio not different from one, while the others gave significantly more females than males (1:1.29, 1:1.59 and 1:1.61).

Otoliths and ageing

The otoliths are thin and about 4-6 mm long in a medium sized fish. They have a prominent rostrum and a smaller antirostrum while the opposite edge is rounded.

Fig. 7. Primary rings in an otolith of D. russellii.

The primary growth rings are deposited concentrically around the nucleus (Fig. 7). In the central part of the sagitta they were found in very regular groupings of 2-3 rings. After this pattern has been laid down (40-80 first rings, light and dark bands were visible, each of which was composed of a number of primary rings varying from 7, 10 or 14 ones. The number of rings along this section was easily estimated by counting the bands and multiplying by the number of primary rings in them.

In a fish of medium size these periodical bands are usually visible until about 2/3 of the size of the otolith. The last third comprises very thin primary rings not disposed in bands. No spawning rings were seen.

A few otoliths were read independently by two persons. The results were as follows:

	No. of rings		
Reader	Mean	SD	Range
1	506	55	409 - 650
2	525	74	421 - 563

The mean deviation between the readers was 20 rings (SD = 61). Using a t-test for paired observations it was found that the results were not significantly different (t= 0.97).

Length and growth

The length composition of D. russelli in the samples from the commercial fisheries is shown in Fig 8.

The total length range was 11.5 - 22.5 cm. For all months taken together the females had a mean length 16.14 cm (SD= 1.19) and the males 16.29 cm (SD= 1.63). The difference is very small although statistically significant (t= 5.52), and males and females are pooled in the following analysis.

The ELEFAN I program (Pauly and David, 1981) was used to trace von Bertalanffy growth curves through the length-frequency data. Each year was treated separately and the resulting equations were

1979 $l_t = 24.8\ (1 - e^{-0.43\ (t - t_o)})$

1980 $l_t = 24.4\ (1 - e^{-0.42\ (t - t_o)})$

1981 $l_t = 26.0\ (1 - e^{-0.46\ (t - t_o)})$

The curves are shown in Fig. 8. The value of t_o will depend on how the date of birth is fixed.

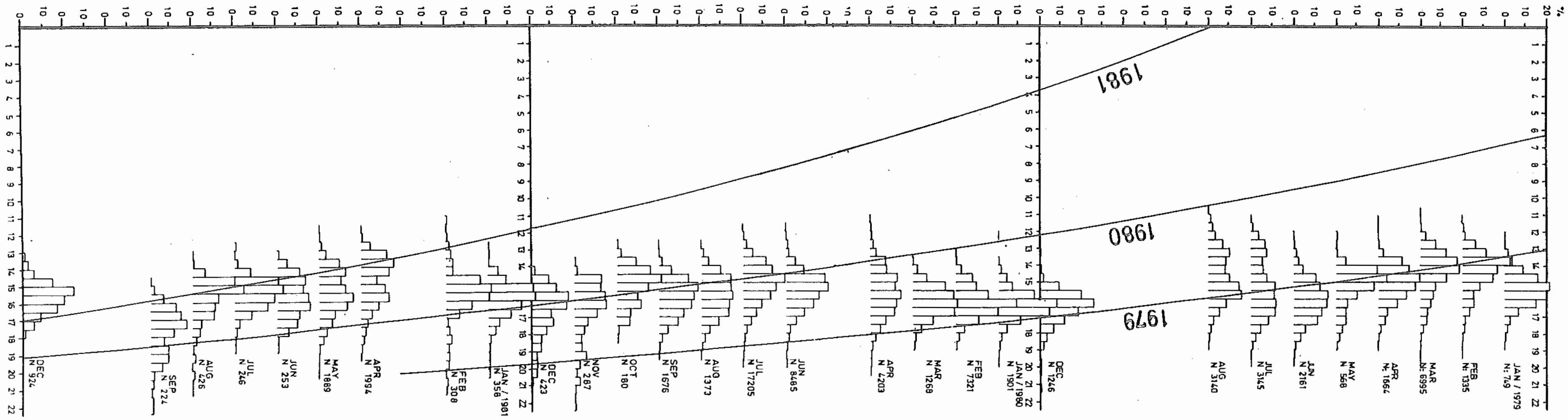

Fig. 8. Length distribution and growth curves fitted by the elefan program for D. russellii.

The results must be treated with caution for several reasons. Apparently this species usually has more than one spawning period per year, resulting in more modes in the length frequency distribution. This makes it more difficult to select those modes belonging to one cohort. The fishery mostly took place in the spawning area and young fish were very sparce in the samples. This also increases the difficulties of fitting a growth curve.

Otoliths of 55 specimens in the length range 13.4 - 18.6 cm were studied to count primary growth rings (Fig. 7). If these rings are formed daily as in many other tropical fishes (e.g. Pannella, 1974; Brothers, Mathews and Lasker, 1976; Brothers, 1981) the age-length relationship shown in Fig. 9 is derived. Based on these data the following growth equation was fitted:

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

This is in good accordance with the growth curves fitted to the length-frequency data.

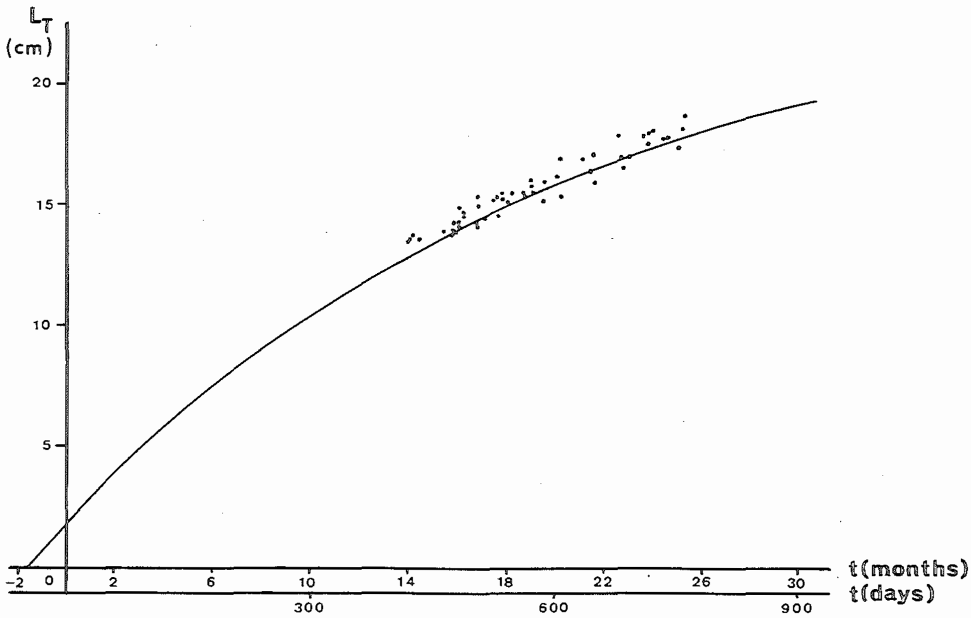

Fig. 9. Growth curve for D. russellii based on otolith readings.

Discussion

The present study is based on samples from the commercial fishery and from a few cruises conducted in the fishing areas. D. russellii is usually not caught in these areas until they reach a size of 13-14 cm, and the juvenile part of the stock is therefore not sampled.

Dmitrenko and Fursa (1969) showed that D. russellii caught at a depth of 150-160 m were larger than those caught at about 100 m (mean length 19.8 and 17.2 cm respectively). Information from the cruises of R/V "Dr. Fridtjof Nansen" and R/V "Pantikapey" off Mozambique also suggests some correlation between depth and size (M.I. Sousa, unpubl.). It is, however, not possible to analyse the present material from commercisl trawlers for depth-size correlation.

The estimated growth rate is in reasonable agreement with those given by Tiews et al. (1970). There is also good agreement between growth rates as estimated from the length-frequency distributions and from counting primary growth rings in the otoliths. Therefore, although the two methods used for estimating growth are not quite satisfactory in the case of D. russellii, the similarity of the results gives some confidence to them.

Data for direct estimation of natural mortality is not available. An approximate value can, however, be derived using the regression line given by Pauly (1982).

$$\lg M = - 0.0066 - 0279 \lg L_\infty + 0.6543 \lg K + 0.4634 \lg T$$

Using the values $K = 0.5$, $L_\infty = 25$ and $T = 27^o$ the natural mortality, M, was 1.2.

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APPENDIX I

Maturity stages of *Decapterus russellii*.

Size of gonad in the abdominal cavity	General aspect of gonad	Stage
Less than 1/3 of the size of the cavity	Gonads of very small size; Pink ovaries, translucent; The eggs are not visible. Pinkish testis.	I Immature
From 1/3 to ½ of the size of the cavity	Ovaries increase in size and weight and are reddish. The eggs are not visible. Testes present already a triangular section.	II Immature
From ½ to 2/3 of the size of the cavity	Orange to pink ovaries with visible blood vessels; eggs are visible. Testis increase in size and weight and are whitish. The triangular section is evident.	III Maturing
Filling 2/3 or more of the body cavity	Gonads reach their maximum size. The eggs and sperm can come out under a light pressure on the ovaries and testes.	IV Mature
Contracted to about ½ of the size of the cavity; feeble walls	The sexual products are being eliminated; Ovaries with feeble walls; Testis are plain, pinkish with some residual sperm.	V Spawning
Contracted to less than ½ of the length of the cavity	Eggs and sperms are eliminated. Some disintegrated eggs may be left in the ovaries.	VI Post-spawning