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Preliminary Investigations on the Population Dynamics of *Otolithes ruber* (Sciaenidae) on Sofala Bank, Mozambique

by

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ABSTRACT

Catch length-frequency data of *Otolithes ruber* (Schneider, 1801) obtained from the "Projecto de Pesca Experimental da RDA" on Sofala Bank, Mozambique, in 1987 were used to estimate growth parameters, mortalities and exploitation rates. The yield- and biomass-per-recruit analyses based thereon suggest that the stock is overfished.

RESUMO

Foram estimados os parâmetros de crescimento, os coeficientes de mortalidade e as taxas de exploração do espécie *Otolithes ruber* (Schneider 1801), através das distribuições de comprimentos das capturas do "Projecto de Pesca Experimental da RDA", no Banco de Sofala, Moçambique, em 1987. A análise das curvas de captura e de rendimento e biomassa por recruta leva a sugerir que o stock desta especie se encontra intensamente explorado.

INTRODUCTION

Data on the fish stocks of Sofala Bank were obtained in the past through surveys aimed at the shrimp stocks. In 1985, studies of the landings of one segment of the industrial fishery were initiated. It is only in 1987 that the Instituto de Investigacão Pesqueira initiated studies aimed specifically at the coastal fish resources of Sofala Bank.

The croaker *Otolithes ruber* (Sciaenidae) represents one of the most important resources in the coastal part of Sofala Bank. It is caught by all fisheries in this area: the industrial, semi-industrial and the traditional fisheries. The present contribution is an attempt to assess the status of this resource.

MATERIALS AND METHODS

The basic data used for this preliminary study of the population dynamics of *O. ruber* are given in Table 1.

The data were sampled from the landings of the "Projecto de Pesca Experimental da RDA" in Beira in 1987, and originated from four 26.5-m sidetrawlers operating as part of the industrial bottom trawl fishery in the coastal area of the Sofala Bank (Fig. 1) at water depths from 7 to 20 m.

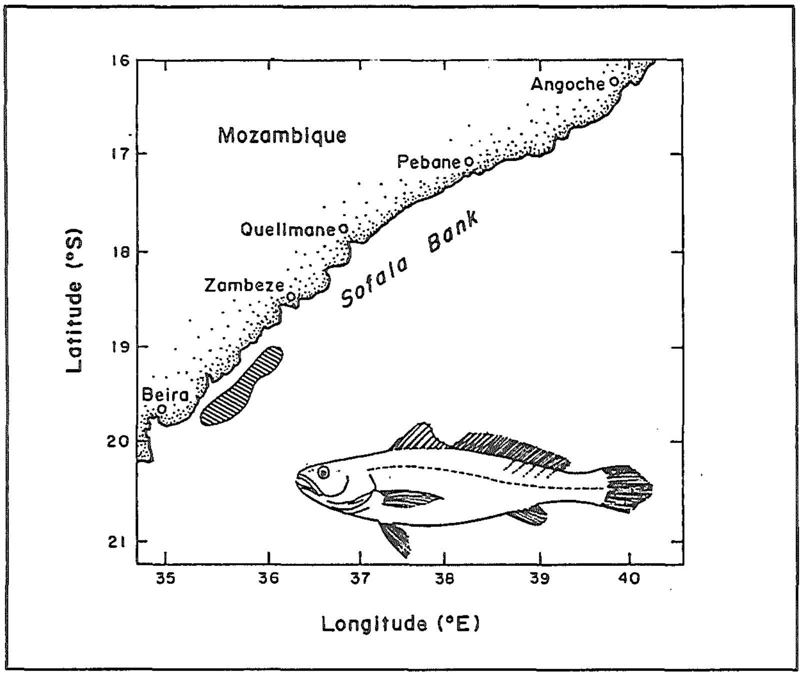

Fig. 1. Fishing area of the "Projecto de Pesca Experimental da RDA", on Sofala Bank, with schematic representation of Otolithes ruber.

The fish caught by that fishery are graded into three classes and *O. ruber* is not abundant in the first of these. The second class, generally medium-sized fish, represents 6% of the total catch; of this, *O. ruber* represented 71% in weight. The

Table 1. *Otolithes ruber* - length distribution in the landings of the second and third class fish, Projecto de Pesca Experimental da RDA, Sofala Bank, 1987.

Month TL-class*	Jan 2nd/3rd	Feb 2nd/3rd	Mar 2nd/3rd	Apr 2nd/3rd	May 2nd/3rd	Jun 2nd/3rd	Jul 2nd/3rd	Aug 2nd/3rd	Sep 2nd/3rd	Oct 2nd/3rd	Nov 2nd/3rd	Dec 2nd/3rd
2.5					4 / 0	0 / 3						
3.5			0 / 7		0 / 3	0 / 5	0 / 4	0 / 1				0 / 2
4.5		0 / 2	0 / 10	0 / 1	3 / 16	0 / 9	0 / 7	0 / 13				0 / 3
5.5		0 / 2	0 / 21	0 / 13	1 / 11	2 / 8	0 / 17	0 / 20	0 / 4	0 / 7	0 / 2	0 / 9
6.5	0 / 5	0 / 8	1 / 20	0 / 31	2 / 49	1 / 13	1 / 27	0 / 38	0 / 12	1 / 19	0 / 30	0 / 5
7.5	0 / 2	0 / 3	0 / 23	1 / 30	3 / 55	0 / 24	0 / 24	0 / 51	0 / 27	2 / 37	1 / 75	1 / 17
8.5	0 / 5	0 / 3	1 / 23	0 / 27	8 / 47	0 / 39	0 / 28	1 / 26	1 / 27	1 / 31	5 / 109	1 / 52
9.5	0 / 14	0 / 5	0 / 14	0 / 39	6 / 44	0 / 45	1 / 23	0 / 12	1 / 19	0 / 26	1 / 65	0 / 80
10.5	0 / 25	0 / 6	2 / 14	0 / 31	2 / 33	0 / 25	0 / 21	0 / 4	0 / 15	0 / 27	3 / 45	3 / 72
11.5	3 / 41	0 / 7	0 / 20	0 / 26	0 / 14	0 / 9	0 / 13	0 / 5	0 / 7	0 / 25	1 / 45	0 / 76
12.5	0 / 22	1 / 6	0 / 13	0 / 20	0 / 9	0 / 12	0 / 11	0 / 17	0 / 6	0 / 16	0 / 41	2 / 67
13.5	2 / 7	1 / 17	0 / 12	0 / 29	0 / 14	1 / 10	0 / 20	0 / 20	0 / 9	0 / 12	1 / 26	0 / 44
14.5	2 / 13	1 / 6	0 / 9	0 / 19	0 / 19	1 / 14	0 / 15	0 / 28	0 / 14	0 / 3	1 / 29	1 / 44
15.5	1 / 5	3 / 10	3 / 17	0 / 14	0 / 10	0 / 10	0 / 14	0 / 30	0 / 26	0 / 8	0 / 31	0 / 56
16.5	1 / 2	2 / 11	5 / 19	1 / 22	1 / 4	1 / 12	0 / 25	2 / 32	0 / 28	2 / 10	0 / 30	0 / 31
17.5	1 / 7	6 / 8	2 / 18	5 / 19	2 / 10	1 / 8	2 / 36	13 / 36	7 / 44	10 / 11	1 / 25	0 / 29
18.5	2 / 10	20 / 10	10 / 12	14 / 23	5 / 17	4 / 13	2 / 23	23 / 37	20 / 29	33 / 14	10 / 39	6 / 48
19.5	1 / 5	30 / 5	33 / 17	17 / 24	6 / 15	16 / 4	17 / 33	41 / 32	50 / 30	34 / 6	28 / 38	13 / 51
20.5	14 / 7	40 / 7	56 / 24	32 / 17	26 / 18	27 / 15	27 / 41	74 / 30	65 / 9	38 / 14	36 / 35	25 / 22
21.5	30 / 5	42 / 1	70 / 25	55 / 16	53 / 13	30 / 12	44 / 27	90 / 16	66 / 7	39 / 5	38 / 20	48 / 35
22.5	38 / 2	39 / 1	78 / 12	66 / 6	73 / 6	56 / 11	56 / 11	08 / 5	81 / 2	24 / 4	47 / 12	65 / 22
23.5	54 / 1	29 / 1	78 / 11	63 / 1	73 / 8	69 / 7	68 / 10	89 / 9	54 / 1	23 / 3	33 / 2	55 / 12
24.5	55 / 4	14 / 0	49 / 4	47 / 0	60 / 1	52 / 7	64 / 4	76 / 6	67 / 0	21 / 3	30 / 3	38 / 5
25.5	50 / 0	18 / 0	38 / 4	53 / 1	42 / 0	62 / 2	79 / 3	71 / 2	52 / 0	17 / 0	27 / 0	38 / 5
26.5	44 / 0	14 / 0	29 / 0	33 / 0	33 / 1	34 / 0	32 / 0	36 / 1	26 / 0	4 / 1	15 / 1	26 / 4
27.5	35 / 0	6 / 0	29 / 0	29 / 1	20 / 0	39 / 0	46 / 2	27 / 0	22 / 0	3 / 0	16 / 1	17 / 0
28.5	37 / 0	7 / 0	21 / 0	27 / 2	27 / 0	29 / 0	44 / 0	22 / 0	15 / 0	2 / 0	5 / 1	19 / 2
29.5	20 / 0	4 / 0	11 / 0	17 / 0	15 / 0	14 / 0	27 / 0	31 / 0	9 / 0	1 / 0	5 / 0	11 / 0
30.5	7 / 0	4 / 0	7 / 0	11 / 0	12 / 0	14 / 0	19 / 0	15 / 1	17 / 0		7 / 0	12 / 1
31.5	4 / 0	1 / 0	8 / 0	7 / 0	4 / 0	8 / 0	18 / 0	6 / 0	6 / 0		5 / 0	2 / 0
32.5	1 / 0		6 / 0	2 / 0	2 / 0	3 / 0	7 / 0	7 / 0	6 / 0	1 / 0	1 / 0	8 / 0
33.5	8 / 0		2 / 0	5 / 0	2 / 0	1 / 0	5 / 0	9 / 0	1 / 0		2 / 0	3 / 0
34.5		2 / 0		4 / 0	1 / 0	1 / 0	6 / 0		1 / 0		2 / 0	3 / 0
35.5	3 / 0		1 / 0	3 / 0		1 / 0	7 / 0	2 / 0	3 / 0		3 / 0	3 / 0
36.5					1 / 0	1 / 0	5 / 0	2 / 0			1 / 0	1 / 0
37.5	1 / 0						2 / 0	1 / 0				
38.5	/ 0				1 / 0		1 / 0	1 / 0	1 / 0			
39.5	1 / 0											
40.5	2 / 0								1 / 0			
41.5												
42.5					1 / 0							0 / 1
total n	417 / 182	284 / 119	540 / 349	492 / 412	489 / 417	466 / 317	582 / 439	750 / 472	572 / 316	256 / 282	325 / 705	401 / 795
n samples	3 / 3	3 / 3	4 / 6	4 / 6	4 / 7	3 / 6	3 / 6	4 / 8	4 / 5	1 / 3	3 / 6	3 / 7
W(kg) of samples	75.780 / 5.580	27.590 / 3.715	79.673 / 13.770	78.410 / 21.435	77.269 / 10.915	77.917 / 10.517	96.435 / 20.280	111.945 / 18.750	100.759 / 12.995	28.610 / 7.985	46.718 / 20.710	63.673 / 31.605
catch (kg)	4440 / 6499	1124 / 4211	2525 / 5967	2804 / 3397	6134 / 4763	6351 / 3277	1551 / 7619	6983 / 7389	9470 /13850	4990 /10117	2772 /11802	7366 /10706

third class, which consists of small-sized fish and the juveniles of larger fishes, contributes 87% of the landings; *O. ruber* represented 7% of the landings. Only the landings of second and third class fish were sampled and compiled per month.

Total lengths (TL) were measured to 1 cm below and the total weight of each sample was noted. To obtain the total length distribution of *O. ruber* in the catch, the sample frequencies were raised to total catch.

The calculations were all performed using the Compleat ELEFAN software (Pauly, this vol.).

As a first step, estimates of TL_∞ and Z/K were obtained using the modified Wetherall plot (Wetherall, 1986; Pauly, 1986). Then, response surface analyses were performed, using ELEFAN I, to obtain an initial estimate of K. The initial estimates of TL_∞ and K were then refined using the search routine of ELEFAN I. This analysis suggested that the data should be regrouped into classes of 2 cm.

Subsequently, a standard length-converted catch curve was constructed to estimate probabilities of capture, which were smoothed using a moving average. The original length distributions were then corrected for incomplete selection/recruitment and new growth parameter estimates were obtained; these were used to construct a second catch curve, using the method of Pauly (1990), and to estimate M, for T = 25°C, using the empirical equation of Pauly (1980).

The yield- and biomass-per-recruit analyses were performed assuming knife-edge selection (Beverton & Holt, 1966), then using a realistic selection ogive (Pauly, this vol.). A length-structured VPA, i.e., the VPA version of Jones' length cohort analysis (Jones, 1984) was performed to complement the catch curve and Y/R analyses.

RESULTS AND DISCUSSION

The Wetherall plot provided estimates of $TL_\infty = 45.9$ cm and $Z/K = 6.7$ (Fig. 2). The initial estimate of K (left panel) used to estimate the probabilities of capture was 0.32 $year^{-1}$; Fig. 3 shows the catch curve of the derived probabilities, used to correct the original length distribution for the effects of selection and/or incomplete recruitment. The subsequent analyses, using ELEFAN I, of the corrected data confirmed the first estimates of TL_∞ and K, and generated associated values of C = 0.45 and

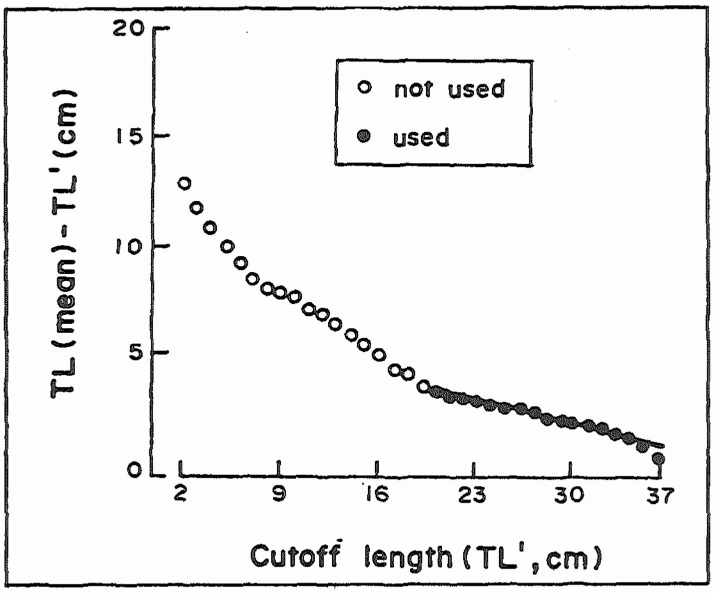

Fig. 2. Modified Wetherall plot for Otolithes ruber, *"Projecto de Pesca Experimental da RDA", Sofala Bank; the regression equation is $Y = 5.95 - 0.129X$, with $r = 0.989$. This leads to TL_∞ = 45.9 cm and Z/K = 6.7.*

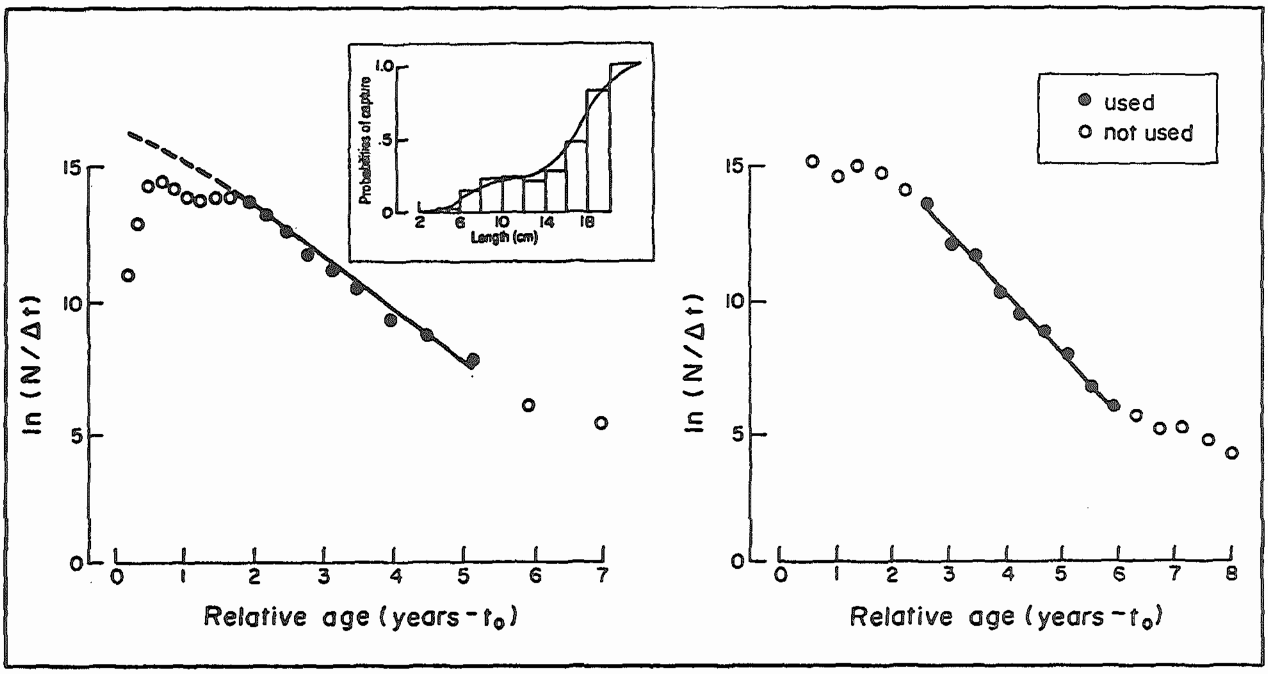

Fig. 3. Catch curves for Otolithes ruber *at Sofala Bank, Mozambique.*

WP = 0.65 (Fig. 4). This figures suggests that one strong cohort dominated the fishery in 1987, and leaves only a faint possibility of a second, weaker cohort.

Table 2 compares the growth parameters obtained here with those of other authors. As might be seen, the value of TL_∞ obtained here compares well with Gislason's (1985) value, although not with his values of K which appears to be too low.

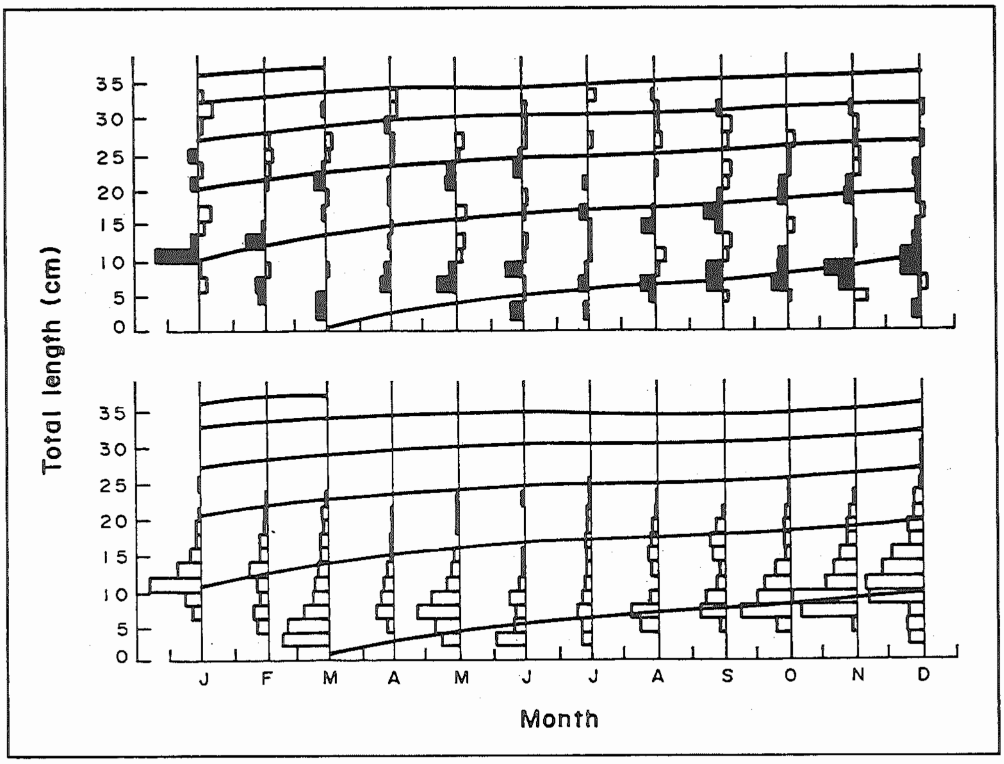

Fig. 4. Length distribution of Otolithes ruber *with estimated growth curves, "Projecto de Pesca Experimental da RDA", Sofala Bank, 1987. Above: Restructured length distribution. Below: Original length distribution; the parameters are TL_∞ = 45.9 cm; K =), 32 $year^{-1}$, C = 0.45 and WP = 0.650.65.*

Table 2. Comparison of growth parameter estimates in *Otolithes ruber*.

Area	Source	TL_∞ (cm)	K ($year^{-1}$)	ϕ'^{a}
San Miguel Bay, Philippines	Navaluna (1982)	29.5	0.4555	2.60
		33.5	0.43	2.73
		35.6	0.43	2.74
Sofala Bank, Mozambique	Gislason (1985)	42.9	0.144	2.42
Sofala Bank, Mozambique	this study	45.9	0.32	2.84

[a] $\phi' = \log_{10}K + 2\log L_\infty$ (Pauly & Munro, 1984).

Navaluna's (1982) growth parameter estimates are also different from those estimated here, which can be attributed to the extremely strong fishing pressure in San Miguel Bay, Philippines, which led to the absence of fish above 28.5 cm from the bay (Pauly, 1982).

The values of TL_∞ and K obtained here, although preliminary, thus appear credible, both because of the representativeness of the data analyzed here, and because seasonal growth oscillations were explicitly considered, something never done before with *O. ruber*.

The catch curve analysis based on the method of Pauly (1990), i.e., accounting for seasonal growth oscillation (Fig. 3, right panel) led to an estimated value of Z = 1.95 $year^{-1}$. This is higher than the estimate of Z that can be obtained by multiplying the Wetherall estimate of Z/K with the estimate of K, i.e., 6.5 x 0.32 = 1.34 $year^{-1}$. Natural mortality (M) was 0.7 $year^{-1}$. This leads to a fishing mortality of F = 1.25 $year^{-1}$ and an exploitation rate of E = 0.64 for the fully exploited part of the stock.

A trial run with length-structured VPA (not shown) suggested that fishing mortality is relatively constant in the older fish. This validates the results of the catch curve analysis, which assumes constant mortality for the larger sizes.

Fig. 5 presents the results of the yield- and biomass-per-recruit analyses. As might be seen, the results obtained based on the knife-edge assumption differ greatly from those using the estimated probabilities of capture, with the latter being more conservative than the former. Thus, the value of E giving maximum yield-per-recruit (E_{max}) is 0.64 in the knife-edge case, and only 0.44 in the other case. The corresponding values of $E_{0.1}$ are 0.55 and 0.43, respectively, while the values of E corresponding to half the unexploited stock ($E_{0.5}$) are 0.32 and 0.28, respectively.

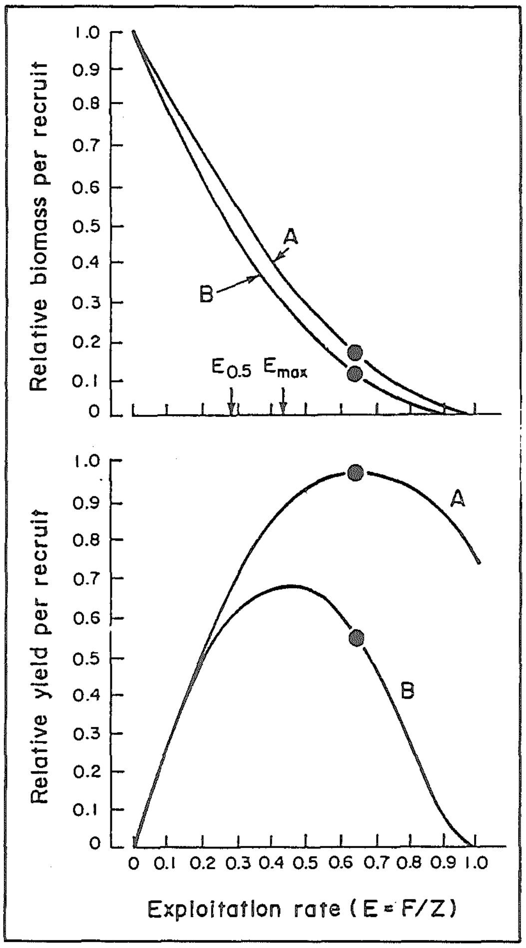

Fig. 5. Yield- and biomass per recruit of Otolithes ruber, *Sofala Bank, 1987 (full dots refer to present 1988 conditions). A: Assuming knife-edge selection. B: Using estimated probabilities of capture.*

The actual value of $E = 0.64$ is well above $E_{0.5}$ and even above E_{max} and hence suggests that the stock of *O. ruber* of Sofala Bank is overfished. Note that this conclusion stands even if one relies on the lower estimate of $Z = 1.34$ year^{-1} presented above.

The available length-frequency data cover a wide length range which includes both juveniles and adults. Thus problems of size selectivity are minimized, although some juveniles may have been missed, as well as some large adults, because they were consumed by the crews. The absence of strong size selection may be the reason why correcting the data for selection effect did not change the growth parameter estimates.

It may also be noted that the two length-converted catch curves used here led to the same estimate of Z (=1.95 year^{-1}), in spite of the fact that only one of them accounted explicitly for seasonal growth. This is attributed to the fact that the samples analyzed here included numerous annual cohorts, a feature which tends to reduce the impact of growth oscillations on standard catch curve estimates of Z (Pauly, 1990).

Further investigations will have to be performed to verify the results presented here, notably to assess the quality of the growth and mortality estimates, and to test whether our assessment of the state of the demersal fishery of Sofala Bank, presently based on *O. ruber* only, can be confirmed for other species.

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