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ASSESSMENTS OF THE STOCKS OF NOTOTHENIA ROSSII MARMORATA AND CHAMPSOCEPHALUS GUNNARI IN THE SOUTH GEORGIA AREA

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Abstract

The stocks of Notothenia rossii marmorata and Champsocephalus gunnari in the South Georgia area are assessed using USSR age sample data and recent biomass estimates from surveys by the FRG. These data indicate that the stock of N. rossii in 1985 was about 2.5% of its pre-exploitation biomass, while the stock of Champsocephalus gunnari has fluctuated greatly with no obvious trend.

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EVALUATIONS DES STOCKS DE NOTOTHENIA ROSSII MARMORATA ET CHAMPSOCEPHALUS GUNNARI DANS LA ZONE DE LA GEORGIE DU SUD

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Résumé

Les stocks de Notothenia rossii et de Champsocephalus gunnari dans la zone de la Géorgie du Sud sont évalués en utilisant les données d'échantillons d'âge soviétiques et les estimations récentes de la biomasse réalisées à partir d'études de la République Fédérale d'Allemagne. Ces données indiquent que le stock de N. rossii était en 1985 d'environ 2,5% de la biomasse présente avant l'exploitation, alors que le stock de Champsocephalus gunnari a subi d'importantes fluctuations sans tendance évidente.

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EVALUACIONES DE LAS RESERVAS DE NOTOTHENIA ROSSII MARMORATA Y CHAMPSOCEPHALUS GUNNARI EN EL AREA DE GEORGIA DEL SUR

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Resumen

Las reservas de *Notothenia rossii marmorata* y *Champsocephalus gunnari* en el área de Georgia del Sur se evalúan usando los datos de la URSS sobre la edad de las muestras y cálculos recientes de las prospecciones hechas por la RFA. Estos datos indican que las reservas de *N. rossii* en 1975 constituían aproximadamente 2.5% de su biomasa antes de la explotación, mientras que la reserva de *Champsocephalus gunnari* ha fluctuado mucho con ninguna tendencia obvia.

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ОЦЕНКИ ЗАПАСОВ NOTOTHENIA ROSSII MARMORATA И CHAMPSOCEPHALUS GUNNARI В РАЙОНЕ ЮЖНОЙ ГЕОРГИИ

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Резюме

Сделаны оценки запасов *Notothenia rossii marmorata* и *Champsocephalus gunnari* в районе Южной Георгии с использованием данных СССР по пробам по возрасту и недавних подсчетов биомассы по результатам съемок, выполненных ФРГ. Данные указывают, что запас *N. rossii* составлял в 1985 г. около 2,5% биомассы, имевшейся до начала промысла, в то время как величина запаса *Champsocephalus gunnari* сильно колеблется, не показывая какой-либо ярко выраженной тенденции.

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ASSESSMENTS OF THE STOCKS OF NOTOTHENIA ROSSII MARMORATA AND CHAMPSOCEPHALUS GUNNARI IN THE SOUTH GEORGIA AREA

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1. NOTOTHENIA ROSSII

1.1 Introduction

The stock of N. rossii in the South Georgia area was assessed at the 1985 CCAMLR Fish Stock Working Group Meeting using a Virtual Population Analysis (CCAMLR, 1985), using age readings from samples collected from USSR exploratory fishing 1969-84, and assuming a fishing mortality rate of 0.6 in 1985. Since it proved impossible to recreate the analyses performed at the 1985 Working Group meeting, this paper presents some refinements on the previous year's analyses.

Although most attention is usually paid to the catch at age data input into a VPA, it is important to recognise that the age data themselves provide little or no information on the status of a stock. Figure 1 shows some hypothetical stock trajectories derived from VPAs using the same set of age data, but with different input values of the terminal fishing mortality and natural mortality rates.

The key features of the input data which affect the assessment of the stock are the estimate of terminal stock size (equivalent to the terminal fishing mortality rate, when the catches are known) and the net recruitment rate to the stock in each year implied by the age data. The catch at age data themselves do not provide any information on the nautral mortality rate, unless additional assumptions are made, such as that the age structure of the stock was in approximate equilibrium prior to the start of fishing.

1.2 Age-specific Natural Mortality and Catchability Rates

Figure 2 shows the age distribution from USSR samples in 1970, prior to the start of major commercial fishing on the stock. Assuming the age readings to be correct, these imply a strongly age-specific mortality rate. Under these circumstances, use of a single value for the natural mortality rate in all age classes would lead to underestimation of the strength of year classes recruited before the start of the fishery compared to later year classes. However, in selecting an age-specific natural mortality schedule, account must be taken of the relative age-specific catchability of the fishery (the product of age-specific selectivity of the fishing gear and the age-specific availability of fish on the grounds).

Since it is not possible to separate the age-specific availability function from the survivorship schedule, a range of alternatives must be considered. At one extreme, the survival rate can be taken to be 100% up to age 8, the modal age class. If recruitment is assumed to be complete by this age, this implies the survival and catchability schedules in Table 1A. Alternatively, if a constant coefficient of natural mortality of 0.2 per year up to age 8 is assumed, this implies the schedules given in Table 1B.

The survival rate of the recruited population in each year is given by :

$$S_t = \Sigma_a s_a p_{at}$$

where :

s_a = survivorship of age class a

p_{at} = proportion by number of recruited population in year t consisting of age class a

s_a is input from Table 1A or 1B, while p_{at} is taken directly from the age sample data. The annual survival rate estimates are given in Table 2.

1.3 Biomass Estimates

Kock (1985a) gives an estimate of the biomass of *N. rossii* within the 500m depth contour around South Georgia in January/February 1985 of 12,781 tonnes with a log (?) s.d. of 99.9%, based on experimental trawls. This value, and also one s.d. below and above this value and a log scale were used in the analyses that follow. Since the length distribution in these trawls is similar to that of the USSR samples in the later years, it is reasonable to assume a common age-specific catchability function for both data sets.

1.4 Annual Recruitment Rates

If the recruitment to the fishery were a knife-edged process, the estimate of the annual per capita recruitment rate to the population would be simply the proportion of the recruited stock consisting of the recruiting year class. When recruitment occurs over a range of ages, the following formula is required :

$$r_{II}(t) = \Sigma_a \rho_{at} P_{at}$$

where :

$r_{II}(t)$ = proportion by number of the recruited stock in year t made up of new recruits

ρ_{at} = proportion by number of age class a in year t consisting of new recruits

ρ_{at} is given by the assumed age-specific catchability functions given in Table 1. The annual recruitment rate estimates are given in Table 2.

1.5 Population Dynamics

The recruited stock in numbers follows the equations :

$$N_{t+1} = (N_t - C_t)\ S_t / \ (1 - r_{II}(t))$$

where C_t is the catch in numbers.

To convert the stock and catch by number to the stock and catch by weight, the mean weight of fish caught is used where this is recorded. Where this is not recorded, a weight-at-age curve is applied to the catches by age. To estimate the spawning stock biomass, an age-specific maturity function is also required. Weight-at-age and maturity-at-age curves were taken from Kock (1985b). Annual catches by weight are given in CCAMLR (1985, p. 210ff).

Figures 3a and 3b show estimated recruited biomass by year for each of the three terminal biomass estimates and for each of the two survivorship/catchability schedules. Figures 4a and 4b show the corresponding results for the spawning stock biomass.

1.6 Discussion

In this case, the historical catches have been so large compared with the current biomass that large relative changes in the estimate of terminal biomass have little effect on the estimated initial biomass.

The data indicate a strong dependence of gross recruitment on stock size, since a 20-fold reduction in the stock in the early 1970's led to only a 3-fold increase in per capita recruitment. Since the initial reduction of the stock in the period 1970-71 was rather abrupt, these data provide no information about the shape of the stock recruitment relationship and hence of the yield curve. However, the r_{II} recruitment rates and survival rates during a period of reasonable stability of the stock in the latter part of the 1970's, give some indication of the sustainable exploitation rate at very low stock sizes. In an equilibirum situation, the sustainable exploitation rate, U, is given by :

$$U = 1 - (1 - r_{II})/S$$

This is approximately 0.35 for both survivorship/recruitment schedules using 1978 values. If one assumes that the yield curve is a simple (symmetrical) logistic, then this would imply a maximum sustainable yield of 45,000 tonnes per annum at a recruited stock size of 255,000 tonnes. The estimated current replacement is 1,680 and 12,000 tonnes per annum for the lower and higher biomass estimates used here, although the range of uncertainty is considerably wider than this. The corresponding expected recovery times to 50% of initial biomass are approximately 20 and 10 years respectively. Only continued monitoring of the stock biomass and recruitment rates while the stock is permitted to recover up to and beyond this level would provide more information on the maximum potential of the stock.

It is instructive to consider the sensitivity of the above assessments to the accuracy of the age readings. Alternative trajectories were calculated using the central estimate of terminal biomass, with all the age readings (a) doubled and (b) halved. The corresponding estimates of initial biomass were (a) 499,000 and (b) 519,000 tonnes. However, estimates of current replacement yield are halved when the age readings are doubled, and vice versa. Predicted recovery times will be similarly affected.

2. CHAMPSOCEPHALUS GUNNARI

Similar analyses to the above were performed for the stock of *Champsocephalus gunnari* in the South Georgia area. USSR age samples, maturity-at-age and weight-at-age curves (from Kochkin, 1985) supplied to CCAMLR were used, with biomass estimates from Kock (1985a). Two alternative survivorship/recruitment schedules are given in Table 3. The corresponding estimates of annual survival rate and r_{II} recruitment rates are given in Table 4, trajectories of recruited stock biomass are shown in Figures 5a-b.

In this case, the length distributions of the USSR catch at age samples are very dissimilar from FRG samples on which the biomass estimates are based (CCAMLR, 1985, p. 133), the latter including a considerable proportion of smaller fish not found in the USSR samples. This means that the biomass estimates will overestimate the catchable biomass available to the fishery. On the other hand, the Working Group noted that the research trawls may underestimate density of this species due to incomplete entrapment of all length classes (CCAMLR, 1985, p. 81).

The turnover of C. gunnari is much faster than that of N. rossii with up to 90% of the stock consisting of new recruits. There have been three periods of very high fishing mortality : 1971, 1977-78 and 1981-84. The stock apparently recovered after each of the first two periods. The age at recruitment is 3-4 years, hence up to two consecutive years of heavy fishing can occur and still be followed by one year class from a lightly fished stock. If the recent period of heavy fishing mortality continues, recovery might be slower since there will be no "unfished" year classes in the pipeline.

Management of this stock from catch quotas based on recruited biomass estimates may not be very effective. Since the stock in most years consists mainly of new recruits, and recruitment appears to fluctuate considerably, there would be a high probability that any catch quota would exceed the actual stock size in any given year, unless the quota were set very conservatively. Regulation of the maximum level of fishing mortality, for example by restricting the proportion of the area fished, may be worth considering. Alternatively, management could be based partly on larval surveys conducted annually to gain advance notice of imminent recruitment, although a baseline of up to 10 years data would first have to be established.

Because of the great fluctuations in year class strength, positive evidence of the effect of fishing on recruitment would only be obtained if a prolonged period of heavy fishing led to a period of consistently poor year classes. It is a perennial problem in fisheries management that the limits to the productivity of a stock can only be detected by exceeding them. Even if there were no dependence of recruitment on stock size in the range encountered, yield per recruit considerations (CCAMLR, 1985, p. 88) indicate that there is little to be gained by increasing the fishing mortality rate above 0.4. Using the central estimate of terminal biomass, the fishing mortality rate in 1984 was 2.4.

The available data series is too short to determine a typical level of stock size. However, the rapid recovery to higher catches in the mid and late 1970's suggests that the level in 1971 may by chance have been unusually low for an unexploited stock, and should not be used as a baseline.

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Table 1. Alternative survival and catchability schedules for *Notothenia rossii*

	A		B	
age (years)	cumulative survival	relative catchability	cumulative survival	relative catchability
0	1.00	0.00	1.00	0.00
1	1.00	0.00	0.82	0.00
2	1.00	0.00	0.67	0.00
3	1.00	0.08	0.55	0.03
4	1.00	0.34	0.45	0.15
5	1.00	0.67	0.37	0.36
6	1.00	0.93	0.30	0.62
7	1.00	0.91	0.25	0.73
8	1.00	1.00	0.20	1.00
9	0.91	1.00	0.18	1.00
10	0.74	1.00	0.15	1.00
11	0.42	1.00	0.08	1.00
12	0.34	1.00	0.07	1.00
13	0.08	1.00	0.02	1.00

Table 2. Estimates of annual survival and r_{II} recruitment rates for *N. rossii* in the South Georgia area.

Year	Survivorship/catchability schedule			
	A		B	
	Survival	r_{II}	Survival	r_{II}
1970	0.84	0.16	0.76	0.24
1971	0.82	0.19	0.73	0.26
1972	0.84	0.20	0.75	0.28
1973	0.89	0.32	0.77	0.39
1975	0.95	0.40	0.80	0.48
1977	0.97	0.35	0.81	0.45
1978	0.96	0.38	0.81	0.47
1982	0.99	0.50	0.82	0.58
1983	0.99	0.41	0.82	0.51
1985	0.99	0.49	0.82	0.57

Table 3. Alternative survival and catchability schedules for <u>Champsocephalus gunnari</u>.

age (years)	A: cumulative survival	A: relative catchability	B: cumulative survival	B: relative catchability
0	1.00	0.00	1.00	0.00
1	1.00	0.00	0.74	0.00
2	1.00	0.002	0.55	0.001
3	1.00	0.35	0.41	0.26
4	1.00	1.00	0.30	1.00
5	0.41	1.00	0.12	1.00
6	0.038	1.00	0.011	1.00
7	0.003	1.00	0.001	1.00
8	0.001	1.00	0.0003	1.00

Table 4. Estimates of annual survival and r_{II} recruitment rates for <u>C. gunnari</u> in the South Georgia area.

Year	Survivorship/catchability schedule A: Survival	A: r_{II}	B: Survival	B: r_{II}
1971	0.087	0.087	0.65	0.88
1973	0.45	0.55	0.39	0.60
1974	0.92	0.41	0.69	0.41
1975	0.82	0.77	0.62	0.78
1976	0.55	0.56	0.44	0.58
1977	0.57	0.63	0.46	0.67
1978	0.93	0.60	0.70	0.60
1979	0.87	0.91	0.66	0.93
1980	0.88	0.90	0.66	0.91
1981	0.92	0.91	0.69	0.92
1983	0.77	0.81	0.60	0.83
1984	0.68	0.62	0.52	0.64

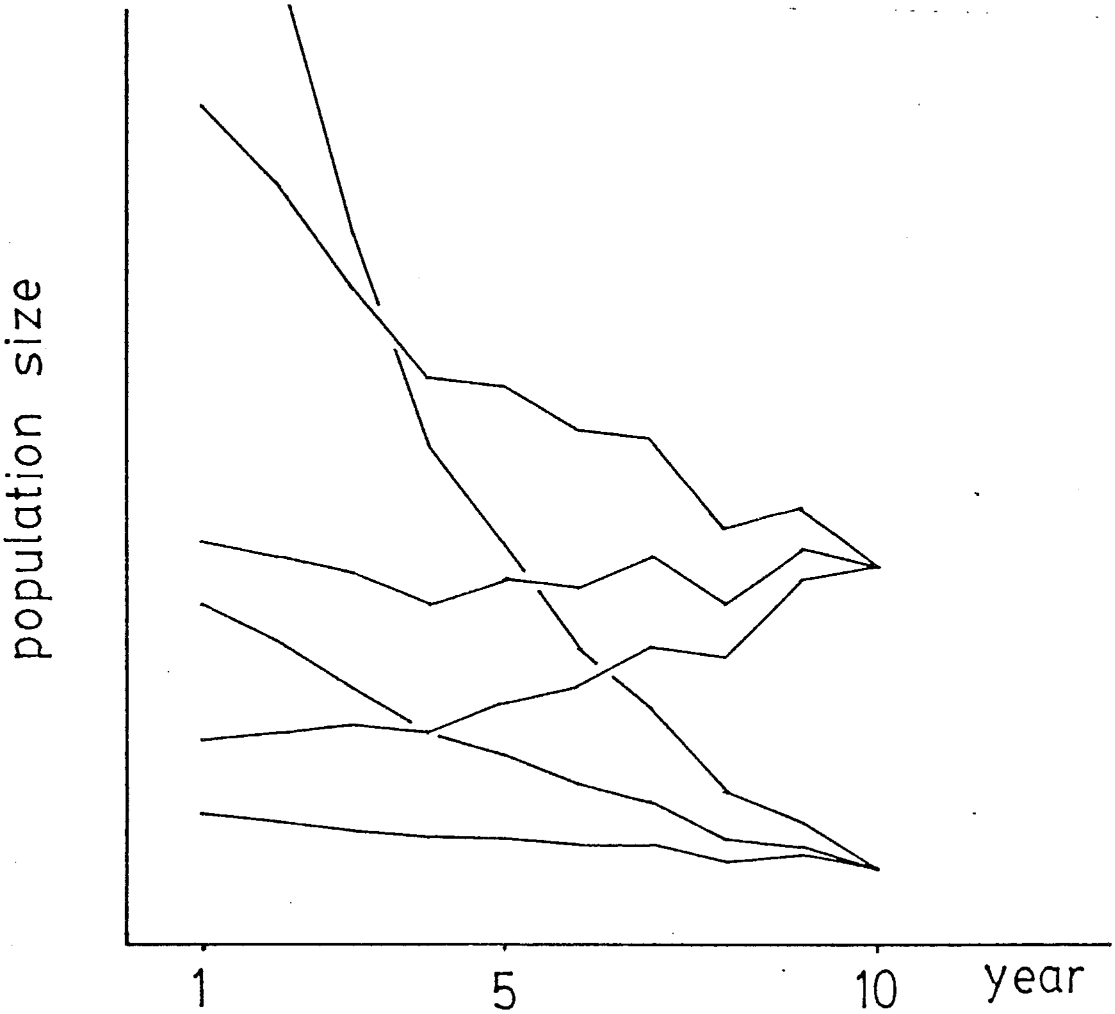


Figure 1 Examples of some stock trajectories derived from the same set of hypothetical age data

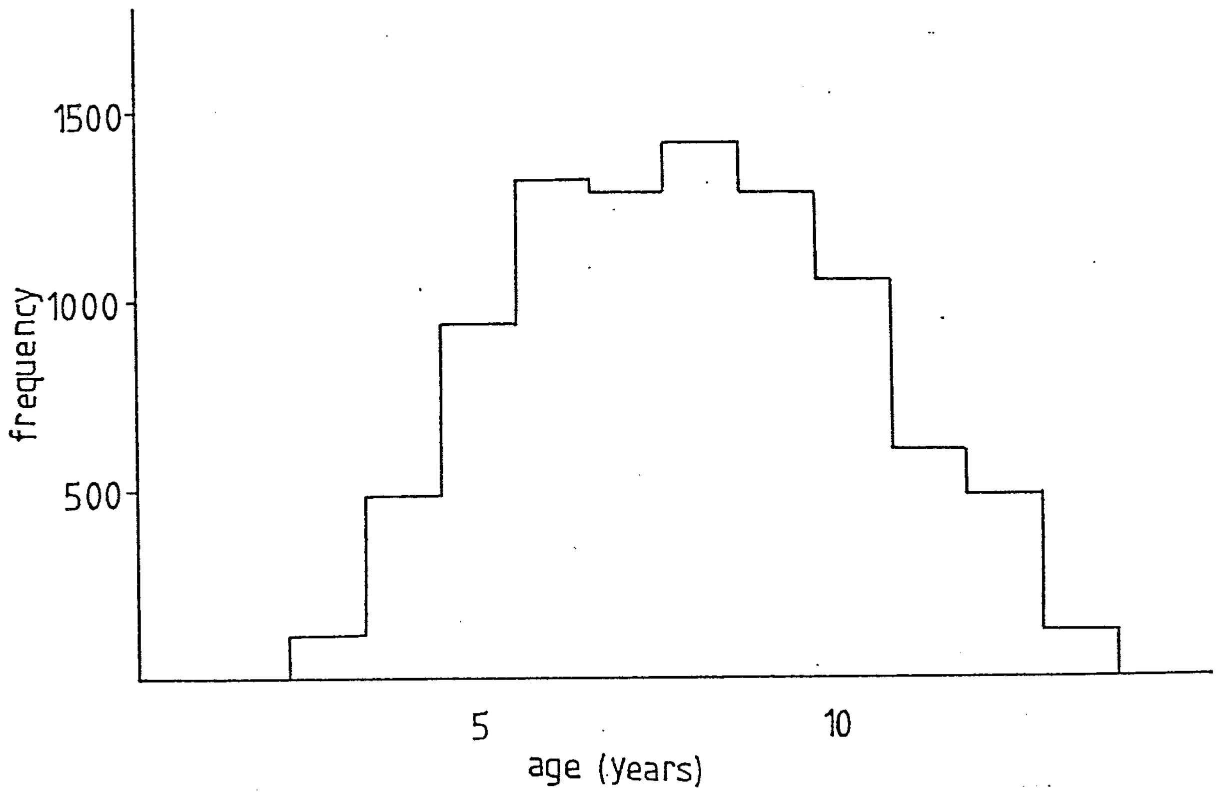


Figure 2 Age distribution of USSR samples of Notothenia rossii taken in Area 48.3 in 1970

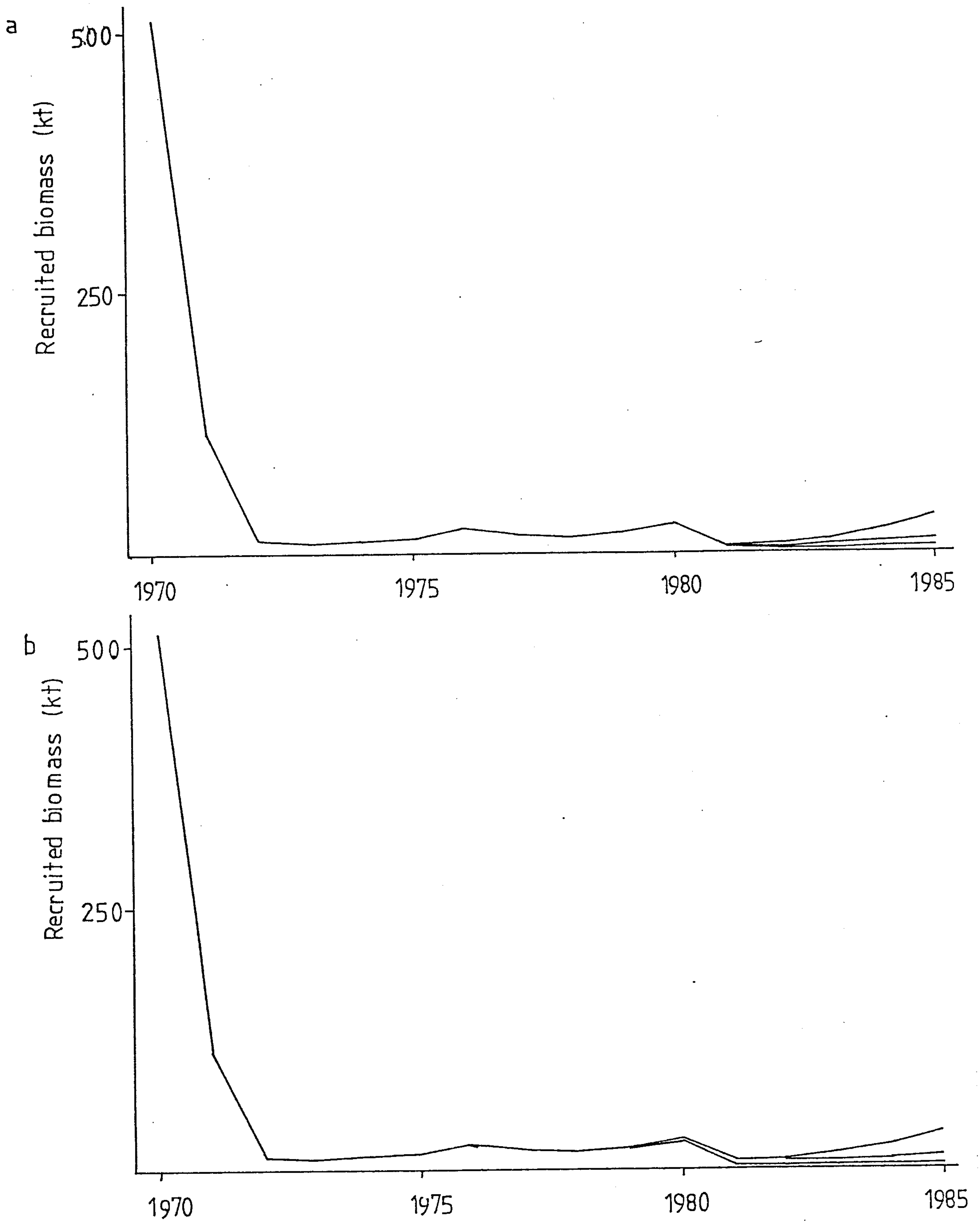


Figure 3 Annual estimates of recruited biomass of Nototheni rossii in the South Georgia area for three values of the 1985 biomass, using survivorship/recruitment schedule from a. Table 1A. b. Table 1B

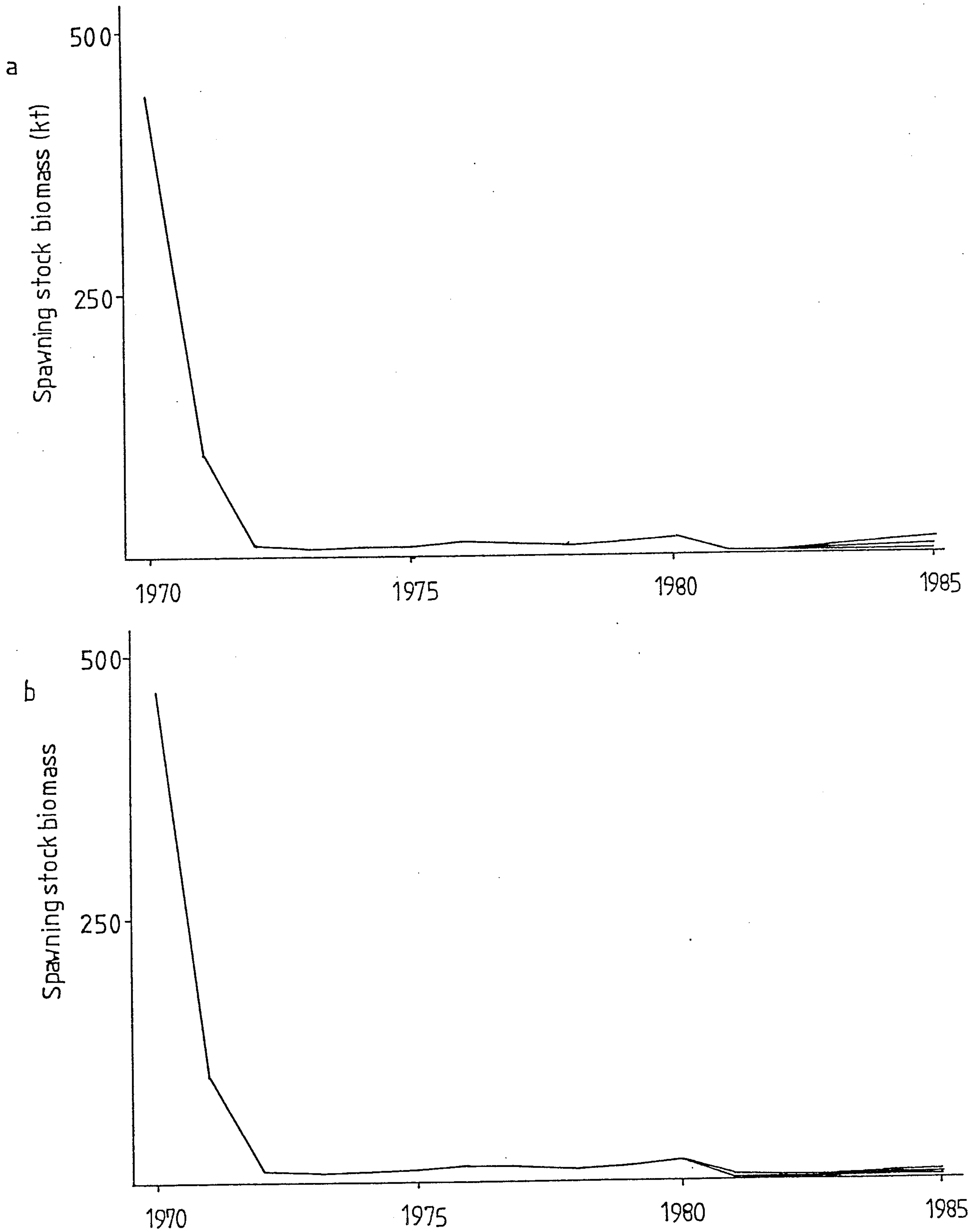
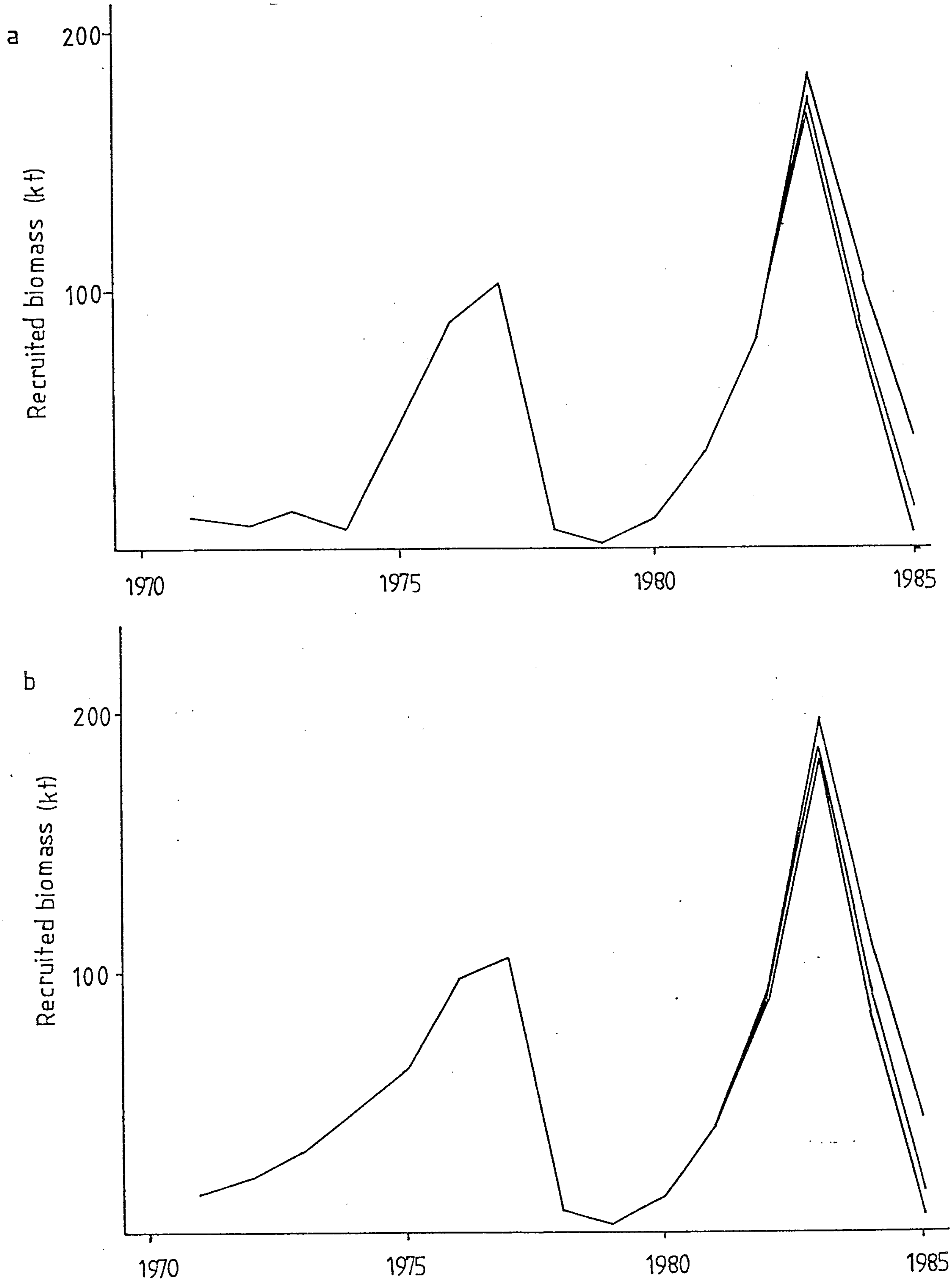


Figure 4 Annual estimates of spawning stock biomass of <u>Notothenia rossii</u> in the South Georgia area for three values of the 1985 biomass, using survivorship/recruitment schedule from a. Table 1A. b. Table 1B.



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