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Abstract

This volume contains a selection of the scientific papers presented at meetings of the Scientific Committee and Working Groups of the Scientific Committee in 1989. The text of the papers is reproduced in the original language of submission; abstracts of the papers and captions of tables and figures are translated into the official languages of the Commission (English, French, Russian and Spanish).

Résumé

Le présent tome contient une sélection de communications scientifiques présentées aux réunions du Comité Scientifique et aux Groupes de travail du Comité Scientifique en 1989. Le texte de ces communications est reproduit dans la langue originale dans laquelle celles-ci ont été présentées; les résumés des communications ainsi que les titres des tableaux et des figures ont été traduits dans les langues officielles de la Commission (anglais, français, russe et espagnol).

Резюме

Настоящий том содержит подборку научных работ, представленных на совещаниях Научного комитета и Рабочих групп Научного комитета в 1989 г. Работы представлены на языке оригинала; их резюме, названия таблиц и подписи к рисункам переведены на официальные языки Комиссии (английский, французский, русский и испанский).

Resumen

Este volumen contiene una selección de los documentos científicos presentados en las reuniones del Comité Científico y de los Grupos de Trabajo del Comité Científico en 1989. El texto de estos documentos está reproducido en el idioma original; los resúmenes de éstos y los títulos de los cuadros y figuras están traducidos a los idiomas oficiales de la Comisión (inglés, francés, ruso y español).

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I. ANTARCTIC FISH

WG-FSA-89/15

HYDROLOGICAL CONDITIONS AND CHARACTERISTICS OF ICEFISH (*CHANNICHTHYIDAE*) DISTRIBUTION ON THE SOUTH GEORGIA SHELF IN 1986/87

V.N. Shnar and V.I. Shlibanov

Abstract

Some characteristics of spatial and temporal variability of the distribution of icefish (*Channichthyidae*) on the South Georgia shelf in relation to environmental conditions, have been revealed from summaries and analyses of hydrographic, commercial fisheries and biological data for 1986/87.

Résumé

Certaines particularités de la variabilité spatiale et temporelle de la distribution du poisson des glaces (*Channichthyidae*) sur le plateau de la Géorgie du Sud, par rapport aux conditions du milieu, ont été révélées par les données récapitulatives et les analyses des données hydrographiques, biologiques et en provenance des pêcheries commerciales de 1986/87.

Резюме

На основании сводок данных и анализа данных по гидрографии, биологии и коммерческому промыслу за 1986/87 г. были выявлены некоторые особенности пространственной и временной изменчивости распределения рыб семейства *Channichthyidae* на шельфе Южной Георгии в зависимости от условий окружающей среды.

Resumen

Ciertas características de variabilidad espacial y temporal de la distribución de los peces de hielo (*Channichthyidae*) en la plataforma de Georgia del Sur, en relación a las condiciones ambientales, han sido descubiertos en resumenes y análisis de datos biológicos, hidrográficos y de pescas comerciales para 1986/87.

1. INTRODUCTION

The task of this work has been to try to identify the main characteristics and patterns of spatial and temporal distributions of icefish (*Channichthyidae*) on the South Georgia shelf relative to environmental conditions.

2. MATERIALS AND METHODS USED

Material collected during the course of two integrated surveys conducted on board the vessel BMRT *Gizhiga* in the area of South Georgia is used in this work (Figure 1). The periods chosen for the surveys (16 September to 21 October 1986 and 10 to 31 August 1987) coincided with hydrological winters of the Southern Hemisphere. In South Georgia, this season lasts from 15 July to 10 November (Polishchuk et al., 1987).

Each so called "integrated study station" consisted of a 30 minute census trawl survey by bottom trawl and a hydrological station to determine water temperature and salinity over standard depths.

In total, 75 integrated stations were made. Unfortunately, due to severe ice conditions on the southwest and eastern shelves of the island, a second survey could not be finished.

Mean monthly water temperature data taken from the bench mark area of 10^2 miles (central point at 54°S and 36°W) were used in the analysis of environmental conditions for 1986/1987 in the South Georgia area. Since commercial concentrations of icefish generally occur near the bottom, mean monthly catch-per-unit-effort data have been compared with the anomalies of mean water temperature in the layer from 150 m depth to the bottom. The standard value for mean weighted temperature in this area has been calculated from monthly observations over the period from 1969 to 1988. The boundaries of the Antarctic water modifications were identified by means of plotting TS-diagrams (Timofeev and Panov, 1962).

3. RESULTS AND DISCUSSION

Analysis of environmental conditions and the fishery in 1986 and 1987 showed significant differences between these two years.

In 1986 positive anomalies of the mean weighted water temperature predominated in the layer from 150 m depth to the bottom (Figure 2, a). Three peaks of maximum catches were observed during the year: one pre-spawning peak in March and two post-spawning (feeding) peaks in July/August and December (Figure 2, b). This was consistent with the average long-term pattern of the fishery.

In 1987 the situation was quite different. A negative anomaly of the mean weighted temperature was observed in the layer from 150 m to the bottom from March until the end of the year (Figure 2, c). Throughout the year only two peaks of maximum catches of icefish were noted. These occurred in February and June and coincided either with the period of positive anomalies (January to February) or with the period of decreased value of negative anomaly of the mean weighted temperature (May to June) (Figure 2, d). Maximum catches in 1987 were taken a month earlier than in 1986.

During both periods there was a close relationship between the mean weighted water temperature in the layer from 150 m to the bottom and the dynamics of fisheries. In general, catches of icefish increased under conditions of positive temperature anomalies and decreased when negative temperature anomalies prevailed.

The hydrological regime in the South Georgia area was determined by the interaction of Deep Circumpolar Waters (DCW) and Shelf Waters (SW). This resulted in the formation of a frontal zone in near bottom layers along the shelf periphery. The isotherm line of 1.0 to 1.1°C and isohaline line of 34.20 to 34.25‰ were set as the conventional boundary dividing DCW and SW (1:1 ratio of both waters by volume).

In 1986 commercial concentrations of icefish were observed along the island shelf slope in the water temperature gradient zone (Figure 3). In the exceptionally cold year of 1987, commercial concentrations were also found in the frontal zone but they were very few in number and fishing was carried out only in limited areas to the northeast and west of the island (Figure 4).

Such a distribution of icefish is obviously associated with the weakening intensity of the DCW upwelling over the island shelf slope in exceptionally cold years which results in a decrease in the volume of warm water on the shelf. The variability of the position of the 1° isotherm clearly illustrates this fact (Figures 5 and 6). In September 1986 it was located at a depth of 150 to 190 m, while in August 1987 at 220 to 250 m. It may therefore be assumed that in cold years such as 1987, concentrations of icefish scatter around the periphery of the island shelf or migrate to depths of 300 m or more, and do not form commercial concentrations.

4. CONCLUSIONS

Analysis of the link between mean weighted water temperature in the layer from 150 m depth to the bottom and daily catches by month demonstrated that, in general, catches of icefish increase under conditions of positive temperature anomalies and decrease when negative anomalies prevail.

In 1986/87 commercial concentrations of icefish were noted at a depth of 200 to 300 m and appeared towards the gradient zone formed by the interaction of warm, deep circumpolar waters (DCW) with the colder shelf waters (SW). The most dense concentrations were observed on the warmer side of the gradient zone where the water temperature was above 1.0°C and salinity more than 34.20‰.

In the exceptionally cold year of 1987 the icefish fishing grounds were significantly smaller than in 1986 which is evidently associated with the small volume of DCW waters on the shelf.

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TIMOFEEV, V.T. and V.V. PANOV. 1962. Indirect Methods for Identifying and Analyzing Water Masses. Gidrometeoizdat, Leningrad. p. 348. (In Russian).

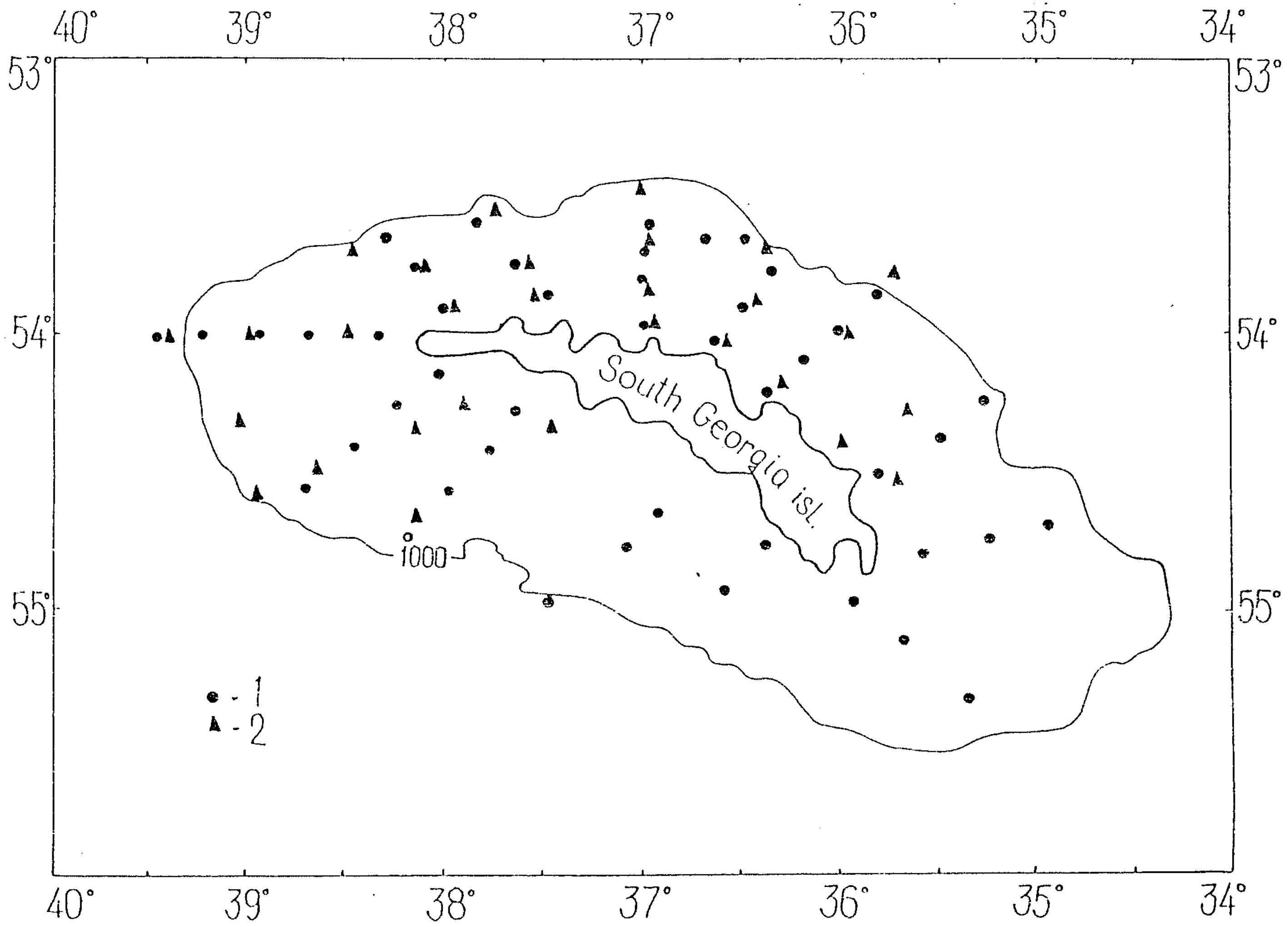


Figure 1: Locations of integrated study stations made from 16 September to 21 October 1986 (1) and from 10 to 31 August 1987 (2) on the South Georgia Island shelf.

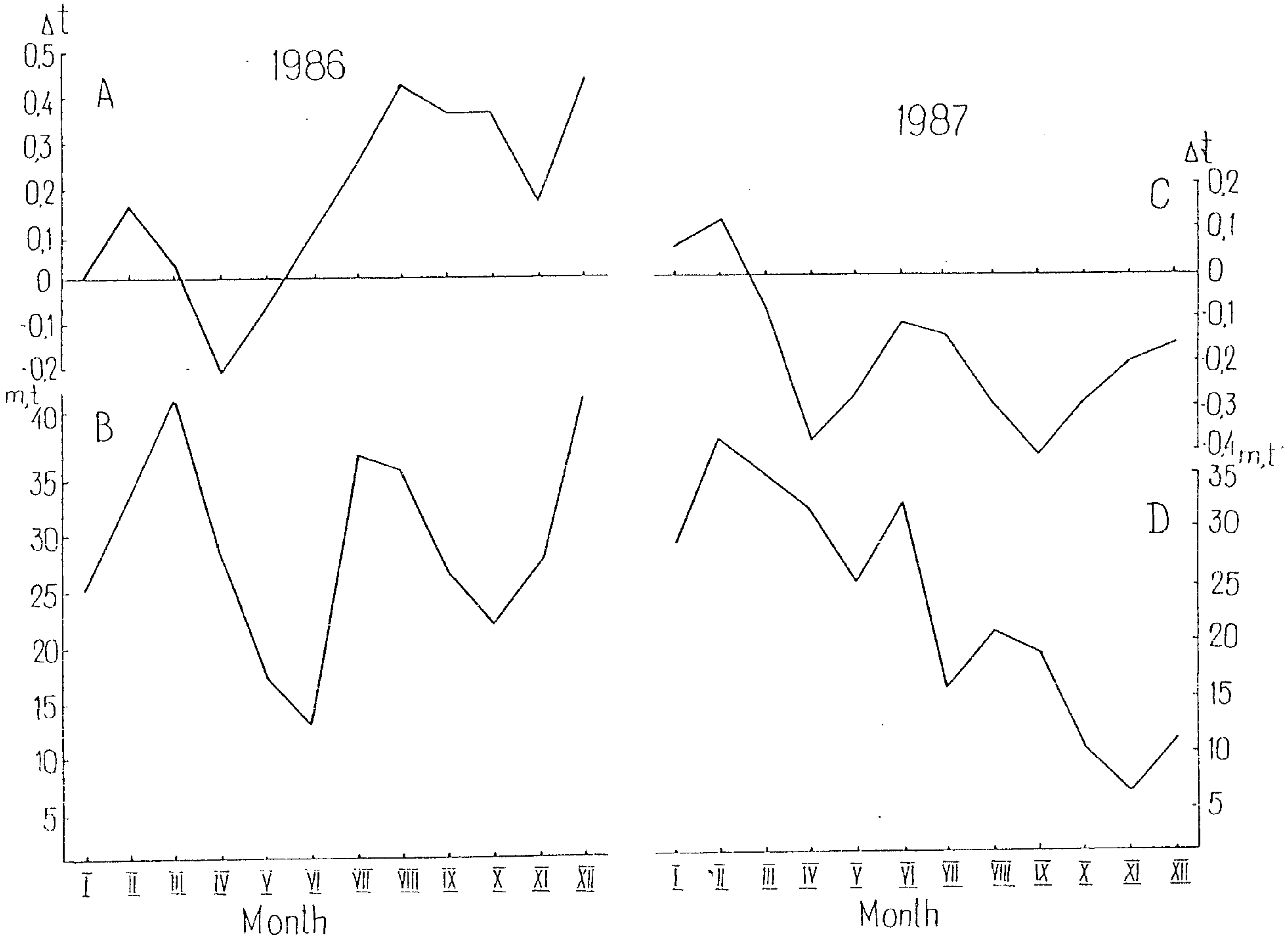


Figure 2: Variation in mean weighted water temperature in the layer from 150 m depth to the bottom (Δt) and daily catches (tonnes) of icefish (*Channichthyidae*) in the South Georgia area in 1986 (a, b) and 1987 (c, d).

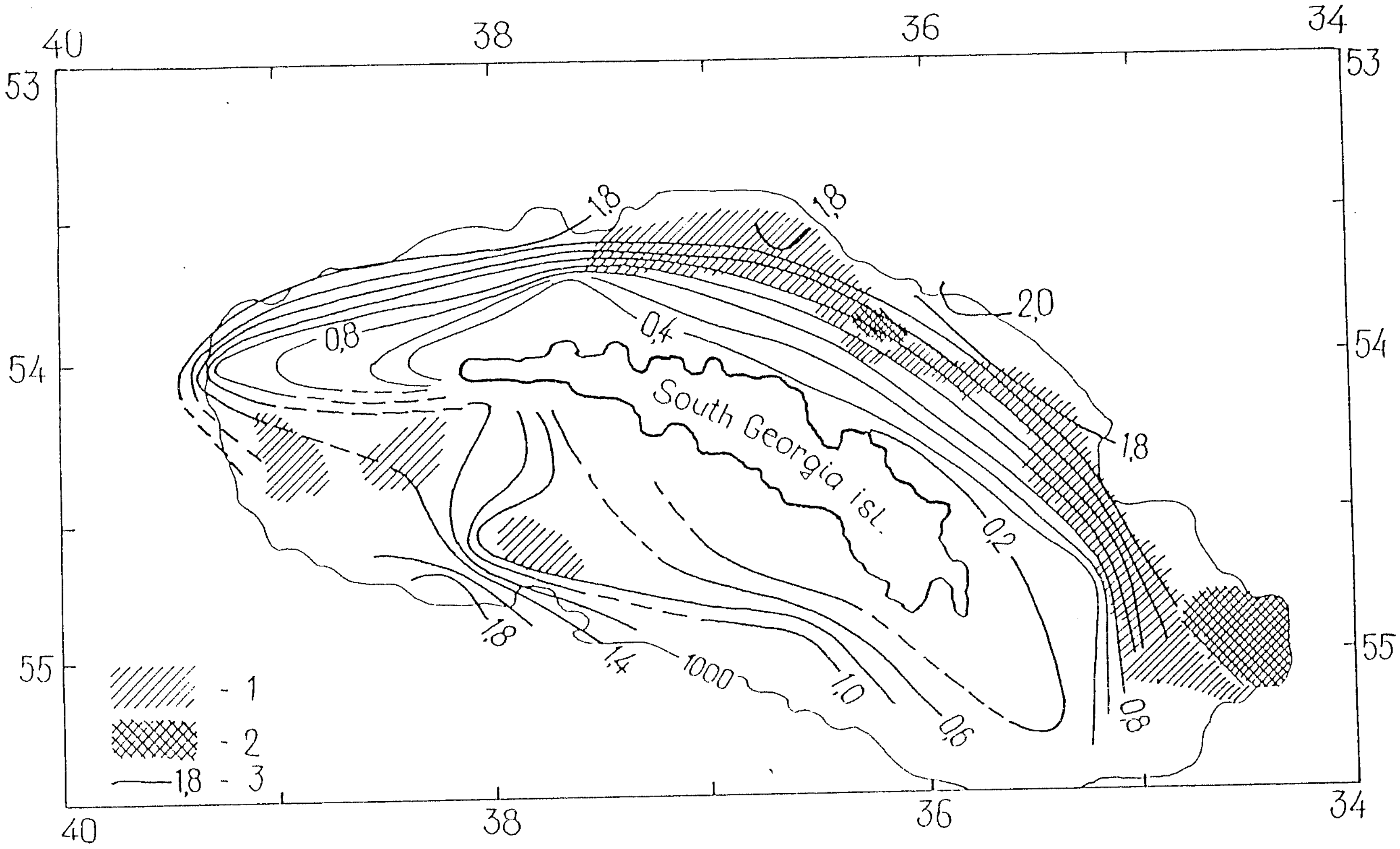


Figure 3: Distribution of near bottom water temperature and catches of icefish (*Channichthyidae*) during the trawl survey from 16 September to 21 October 1986.

1 - catches per hour trawling less than 0.5 tonne
2 - catches per hour trawling more than 1.0 tonne
3 - near bottom temperature

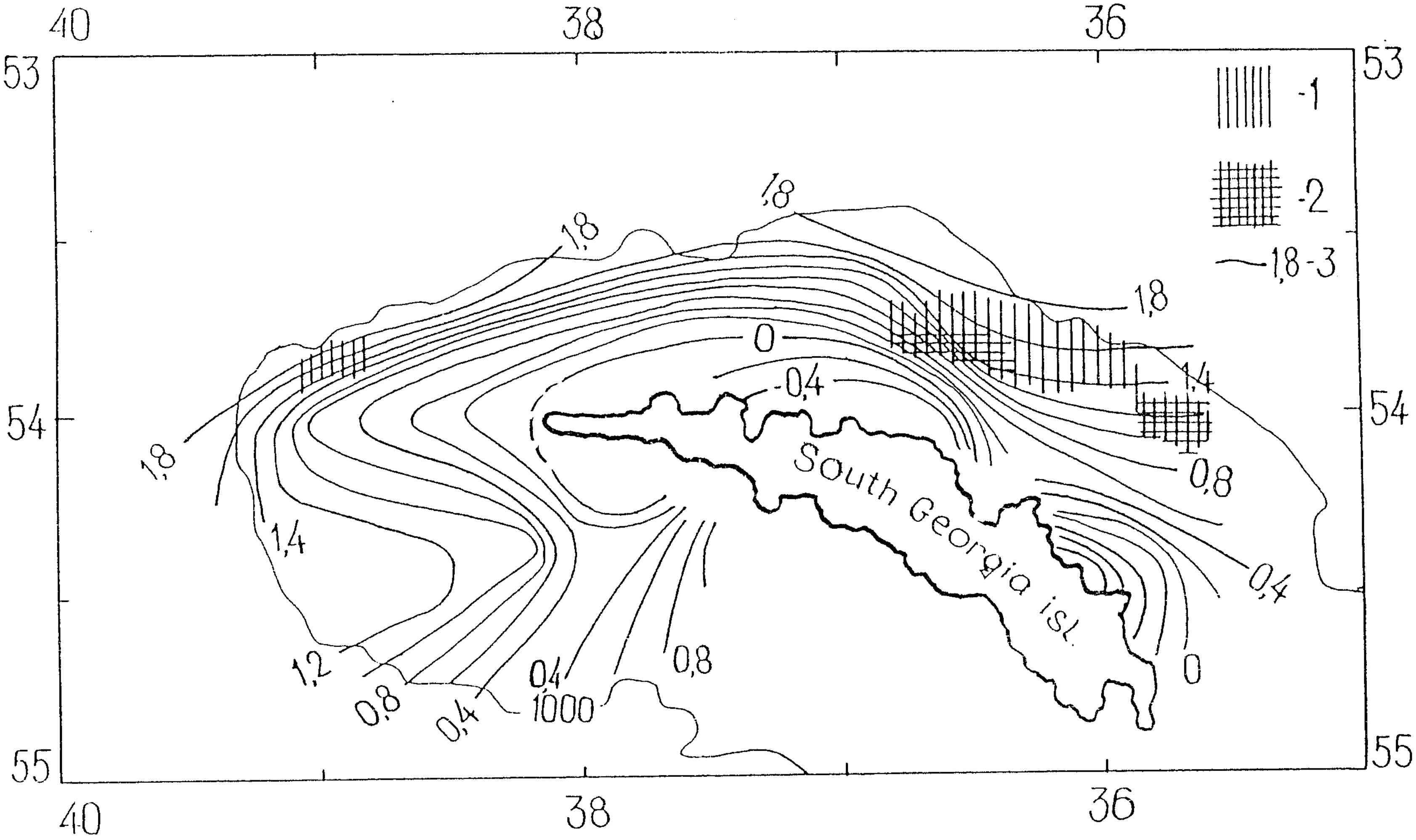


Figure 4: Distribution of near bottom water temperature and catches of icefish (*Channichthyidae*) during the trawl survey from 10 to 31 August 1987.

1 - catches per hour trawling less than 0.5 tonne
2 - catches per hour trawling more than 1.0 tonne
3 - near bottom temperature

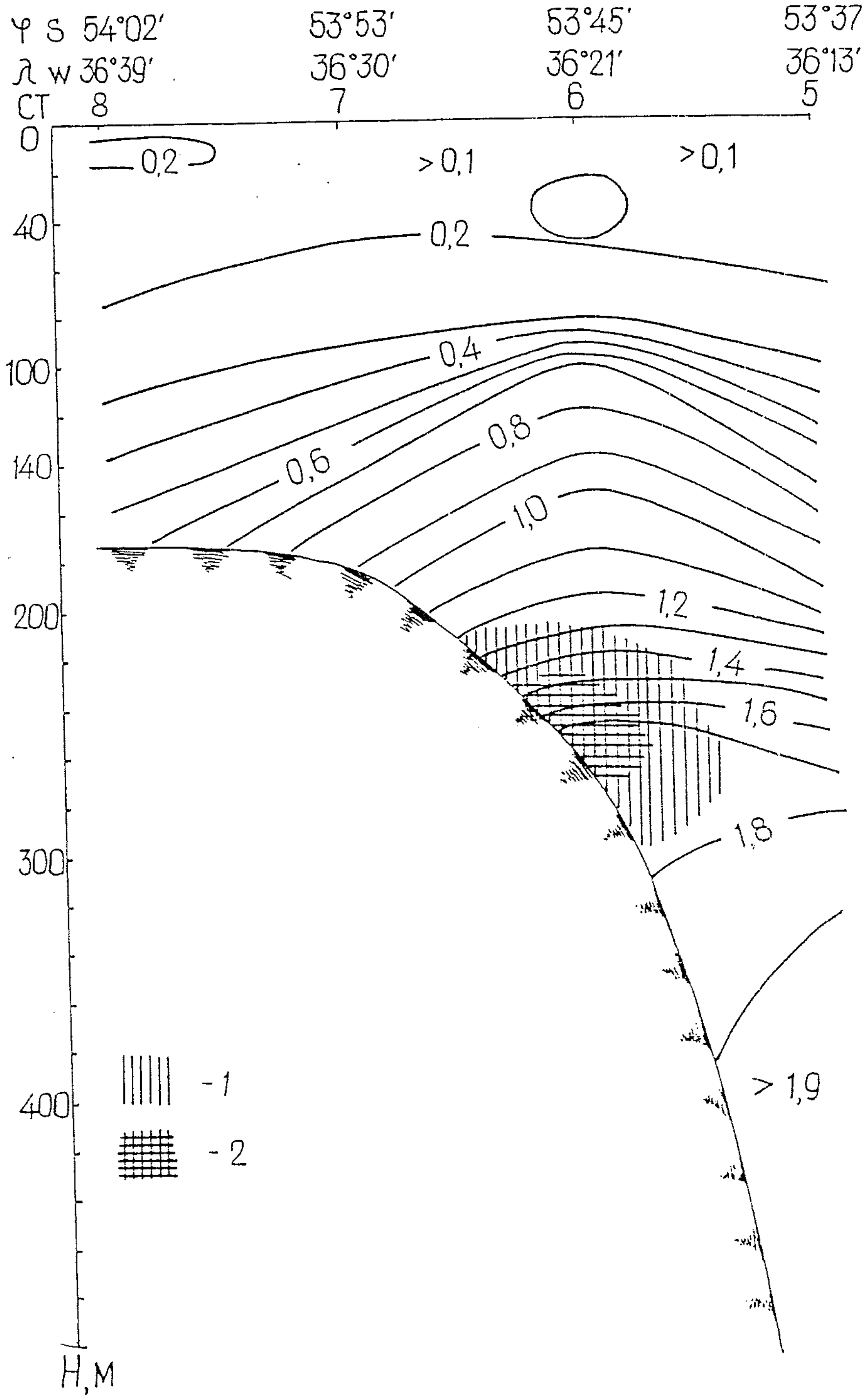
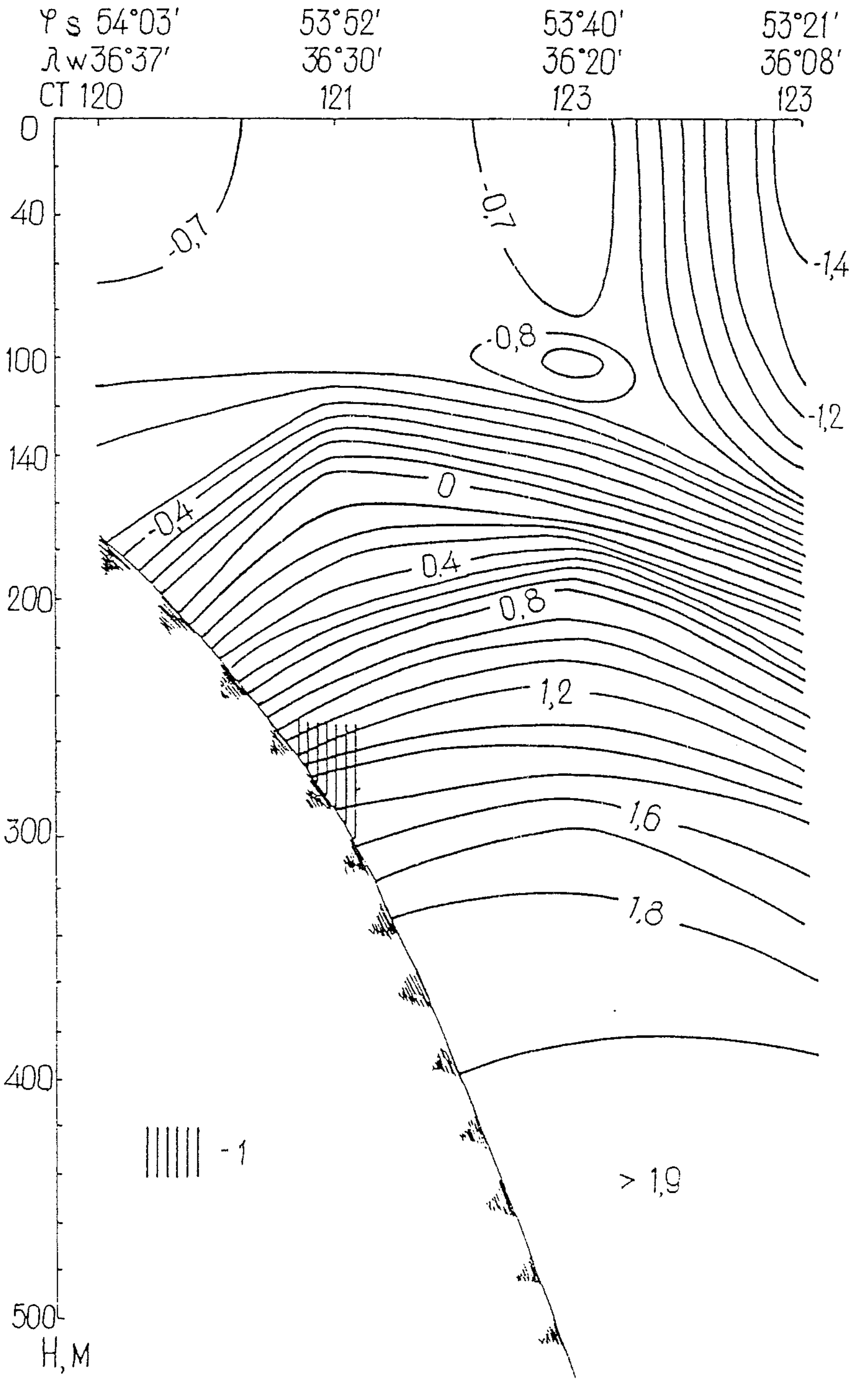


Figure 5: Vertical distribution of water temperature and commercial aggregations of icefish (*Channichthyidae*) in the South Georgia area (17 to 19 September 1986).

1 - catches per hour trawling less than 0.5 tonne
2 - catches per hour trawling more than 1.0 tonne



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1 - catches per hour trawling less than 0.5 tonne

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Figure 3: Distribution de la température des eaux proches du fond et des captures de poissons des glaces (*Channichthyidae*) pendant la campagne d'évaluation par chalutage du 16 septembre au 21 octobre 1986.

1 - captures par heure de chalutage inférieures à 0,5 tonne
2 - captures par heure de chalutage supérieures à 1,0 tonne
3 - température proche du fond

Figure 4: Distribution de la température des eaux proches du fond et des captures de poissons des glaces (*Channichthyidae*) pendant la campagne d'évaluation par chalutage du 10 septembre au 31 août 1987.

1 - captures par heure de chalutage inférieures à 0,5 tonne
2 - captures par heure de chalutage supérieures à 1,0 tonne
3 - température proche du fond

Figure 5: Distribution verticale de la température de l'eau et des concentrations commerciales de poisson des glaces (*Channichthyidae*) dans la zone de la Géorgie du Sud (17 au 19 septembre 1986).

1 - captures par heure de chalutage inférieures à 0,5 tonne
2 - captures par heure de chalutage supérieures à 1,0 tonne

Figure 6: Distribution verticale de la température de l'eau et des concentrations commerciales de poisson des glaces (*Channichthyidae*) dans la zone de la Géorgie du Sud (22 au 23 août 1986).

1 - captures par heure de chalutage inférieures à 0,5 tonne

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1 - уловы за час траления, составляющие менее 0,5 тонны
2 - уловы за час траления, составляющие более 1,0 тонны
3 - температура придонных вод

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1 - уловы за час траления, составляющие менее 0,5 тонны
2 - уловы за час траления, составляющие более 1,0 тонны
3 - температура придонных вод

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1 - уловы за час траления, составляющие менее 0,5 тонны
2 - уловы за час траления, составляющие более 1,0 тонны

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1 - уловы за час траления, составляющие менее 0,5 тонны.

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1 - capturas por hora de arrastre menos de 0.5 tonelada
2 - capturas por hora de arrastre más de 1.0 tonelada
3 - temperatura cerca del fondo

Figura 4: Distribución de temperatura del agua cerca del fondo y capturas de peces de hielo (*Channichthyidae*) durante el arrastre de estudio realizado desde el 10 al 31 de agosto de 1987.

1 - capturas por hora de arrastre menos de 0.5 tonelada
2 - capturas por hora de arrastre más de 1.0 tonelada
3 - temperatura cerca del fondo

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1989/90 STOCK STATUS AND TAC ASSESSMENT FOR *CHAMPSOCEPHALUS GUNNARI* IN SUBAREA 48.3 (SOUTH GEORGIA)

Zh.A. Frolkina and P. Gasyukov

Abstract

The 1989/90 stock status and TAC assessment for *Champsocephalus gunnari* in South Georgia subarea (48.3) has been made using the biostatistic material for 1982/83 to 1987/88 collected by Soviet scientists. VPA tuning has been made by the Laurec-Shepherd method (1985) using standardized fishing effort. For the beginning of the 1989/90 fishing season, the stock was assessed at 130.2 thousand tonnes and the TAC at 23.6 thousand tonnes.

Résumé

L'état du stock et l'évaluation du TAC de *Champsocephalus gunnari* dans la sous-zone de la Géorgie du Sud (48.3) pour 1989/90 ont été effectués en se servant de matériaux biostatistiques recueillis par les scientifiques soviétiques de 1982/83 à 1987/88. La VPA a été ajustée par la méthode Laurec-Shepherd (1985) en utilisant l'effort de pêche standardisé. Pour le début de la saison de pêche 1989/90, le stock a été estimé à 130 200 tonnes et le TAC à 23 600 tonnes.

Резюме

Оценка состояния запаса *Champsocephalus gunnari* в Подрайоне 48.3 (Южная Георгия) в течение сезона 1989/90 г. и оценка величины ТАС для этого запаса были сделаны на основе статистических промысловых и биологических данных по этому запасу за 1982/83 - 1987/88 гг., собранных советскими учеными. Настройка VPA была выполнена по методу Лорека-Шепарда (1985 г.) при стандартизированном промысловом усилии. Оценка величины запаса на начало промыслового сезона 1989/90 г. составила 130,2 тысячи тонн и величины ТАС - 23,6 тысячи тонн.

Resumen

La evaluación de la condición de las poblaciones de 1989/90 y de la capturas totales permisibles (TAC) de *Champsocephalus gunnari* en la subárea de Georgia del Sur (48.3) se ha hecho utilizando material bioestadístico recopilado por los científicos soviéticos desde 1982/83 hasta 1987/88. El ajuste de VPA se ha realizado usando el método Laurec-Shepherd (1985) el cual utiliza esfuerzo de pesca estandarizado. Para el comienzo de la temporada de pesca de 1989/90, las poblaciones fueron evaluadas a 130.2 mil toneladas y el TAC de 23.6 mil toneladas.

1. BACKGROUND DATA

1.1 The Fishery

In 1988/89 fishing for *Champsocephalus gunnari* was conducted over a short period from 1 October to 4 November 1988. Total catch for this time amounted to 21.4 thousand tonnes.

1.2 Age Composition of Catches

Data for the 1982/83 to 1987/88 seasons are taken from the document WG-FSA-89/5 of the Working Group on Fish Stock Assessment.

Age composition of the 1988/89 catch is calculated using an age/length key for the last quarter of 1988 and comprehensive measurements taken in October 1988. Data on age composition of catches are given in Table 1.

1.3 Catch-Per-Unit Fishing Effort and Fishing Effort

A Soviet BMRT (large refrigerator trawler) conducting fishing with bottom trawl was used in assessments as a standard type of fishing vessel. Relevant values of catch-per-unit-effort (CPUE) are taken from the Report of the Seventh Meeting of the Scientific Committee (SC-CAMLR-VII). There were no data for the 1986/87 season. An assumption was made that CPUE in that season was 3.0 tonnes per hour. CPUE for this type of vessel during the 1988/89 season was taken at 2.96 tonnes per hour.

Values for standardizing fishing effort are derived from the division of total catch-per-season by the value of catch-per-effort of a standard vessel.

Total catch, catch-per-unit-effort of standard vessels equipped with bottom trawls and standardized fishing effort by seasons are given in detail in Table 2.

1.4 Mean Fish Mass By Age

Information on average fish mass by age and fishing season from 1982/83 to 1987/88 was also taken from the document WG-FSA-88/5.

Values of mean fish mass in the 1987/88 season were derived from the data collected to establish an age/length key.

Values of mean fish mass by age and fishing season are given in Table 3.

2. PARAMETERS

2.1 Natural Mortality Rate

The same value of natural mortality rate (0.35) was used as agreed at the Seventh Meeting of the Scientific Committee (SC-CAMLR-VII).

2.2 Age of Sexual Maturity

According to our data up to 90% of fish commence spawning for the first time at the age of 3 years; 2 year old spawning fish were observed only in 1984 but their numbers never exceeded 10%. The age of sexual maturity is considered to be 3 years.

3. VPA STOCK ASSESSMENT

The VPAs were tuned by using the Laurec-Shepherd method (Pope and Shepherd, 1985).

Computed values of the fishing mortality rate, abundance and biomass are given in Tables 4 to 6.

Shown below are coefficients of the correlation between fishing mortality rate and fishing effort for each age-group which were derived for and used in this analysis.

Age-Group	Coefficient of Correlation
1	0.52
2	0.75
3	0.92
4	0.60
5	0.72
6	0.66

The tuning of VPA for the first age-group was not successful, therefore its abundance in 1988/89 was estimated using the mean value over six recent years.

The VPA based on these data gives a biomass for *C. gunnari* at the beginning of the 1988/89 season of 103.0 thousand tonnes.

4. YIELD-PER-RECRUIT

The value of yield-per-recruit was calculated using Thompson and Bell's method. Rates of partial recruitment were used in the calculation which assumed that fish from the age of three years and over were fully represented in the catch. The values of rates of partial recruitment for other age-groups were derived by averaging results for the whole period (seven years). The relevant coefficients were as follows:

Age-Group	1	2	3	4	5	6
Rate of partial recruitment	0.07	0.37	1.0	1.0	1.0	1.0

Results of calculations are given in Table 7. The value of F_{MSY} was 0.72; the value of $F_{0.1}$ was 0.42.

5. TAC ASSESSMENT FOR THE 1989/90 SEASON

Calculation of the TAC assumes that:

- the mean mass of fish has remained at the 1988/89 level;

- the rates of partial recruitment for age-groups 1 and 2 were defined for the 1982/83 to 1987/88 seasons by applying rates of fishing mortality derived by the Laurec-Shepherd method; rates for other age-groups are assumed to be 1.0;
- the size of age-group 1 is the mean value taken over a number of years;
- the total fishing mortality rate for 1989/90 will be at a level of $F_{0.}$=0.42; and
- as adopted by the WG-FSA in 1989, the values $F_{0.1}$= 0.313 and F_{max}=0.42 were used.

Results of the TAC evaluation are given in Table 11.

Within these parameters, the stock size of *C. gunnari* at the beginning of the 1989/90 season in Subarea 48.3 is estimated at 130.2 thousand tonnes, while the TAC for this season is 28.6 thousand tonnes.

Values of TAC at $F_{0.1}$=0.313 and F_{max}=0.42 are given in Tables 9 and 10. If these values of F are used, TAC in 1989/90 will be 22.2 and 40.3 thousand tonnes respectively.

Acting upon a suggestion by Dr J. Beddington (UK), the second version of the calculation was carried out using the following set of catch-per-unit data: Country - USSR, Type of vessel - BMRT, Years - 1982/83 to 1988/89, Month - October. The data of this set are given in Table 11.

Results of VPA analyses based on these data are given in Tables 12 to 14 and the calculation of TAC appears in Tables 15 to 17. Assuming the biomass to be 136.6 thousand tonnes at the beginning of 1989/90, the following TAC were obtained:

if $F_{0.1}$ = 0.42 TAC = 30.3
if $F_{0.1}$ = 0.313 TAC = 23.6
if F_{max} = 0.42 TAC = 42.6

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Table 1: Age composition of *C. gunnari* in Subarea 48.3 (millions of specimens).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	25.97	98.63	5.28	21.64	6.92	8.60	10.25
2	162.20	167.08	18.20	39.62	207.12	12.42	128.89
3	428.08	120.92	47.05	34.01	276.94	70.06	14.47
4	68.13	76.11	12.71	1.89	19.31	35.51	9.18
5	24.97	21.54	1.80	0.67	4.21	25.16	11.49
6	8.55	4.31	0.54	0.13	0.70	6.85	2.31

Table 2: Total catch, catch-per-unit-effort of a BRMT type vessel and standardized fishing effort by fishing seasons.

Fishing Seasons	Total Catch	CPUE	Fishing Effort
1982/83	128.2	7.12	18 006
1983/84	80.0	5.42	14 760
1984/85	14.2	4.44	3 187
1985/86	11.1	(3.0)*	3 700
1986/87	71.1	2.73	26 044
1987/88	34.5	1.99	17 387
1988/89	21.4	2.94	7 279

* Adjusted value

Table 3: Average fish mass (in grams) for *C. gunnari* by age-groups (Subarea 48.3).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	29.70	35.80	23.40	29.70	24.90	17.70	23.40
2	87.80	97.20	79.00	87.80	81.90	70.60	79.00
3	175.80	189.00	163.30	175.80	167.40	151.00	163.30
4	291.80	308.00	276.00	291.80	281.20	260.50	276.00
5	430.20	448.90	411.90	430.20	418.00	393.80	411.90
6	585.20	605.50	565.20	585.20	571.80	545.30	565.20

Table 4: Fishing mortality rates of *C. gunnari* in Subarea 48.3 (tuning VPA by Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	0.06161	0.29848	0.00649	0.04278	0.09002	0.00990	0.02003
2	0.58273	0.83807	0.09608	0.07167	0.86721	0.27265	0.23587
3	1.56944	1.67471	0.74571	0.30896	1.24851	1.07525	0.71682
4	1.15659	2.73048	1.07049	0.06656	0.34443	0.61637	0.45455
5	1.59551	2.82028	0.70454	0.15913	0.24392	1.34540	0.49858
6	1.37595	2.77424	0.88668	0.11275	0.29403	0.98007	0.47628

Table 5: Abundance (millions of specimens of *C. gunnari* in Subarea 48.3 (tuning VPA by Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	514.21	449.08	967.72	611.65	95.02	1034.88	612.09
2	428.05	340.71	234.80	677.55	412.97	61.20	722.07
3	613.55	168.43	103.85	150.30	444.44	122.26	32.83
4	114.02	90.00	22.24	34.72	77.76	89.86	29.40
5	35.52	25.27	4.13	5.37	22.89	38.83	34.19
6	13.05	5.08	1.06	1.44	3.23	12.64	7.13
Total	1718.400	1078.570	1333.805	1481.033	1056.319	1359.671	1437.710

Table 6: Biomass (thousands of tonnes) of *C. gunnari* in Subarea 48.3 (tuning VPA by Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	15.272	16.077	22.645	18.166	2.366	18.317	14.323
2	37.583	33.117	18.549	59.489	33.823	4.320	57.043
3	107.861	31.833	16.959	26.423	74.399	18.462	5.362
4	33.271	27.720	6.138	10.131	21.867	23.410	8.114
5	15.283	11.346	1.703	2.311	9.568	15.292	14.083
6	7.635	3.074	0.600	0.843	1.846	6.892	4.028
Total	216.906	123.167	66.593	117.362	143.869	86.693	102.953

Table 7: Yield-per-recruit for *C. gunnari* in Subarea 48.3.

Fishing Mortality Rates	Y/R	Fishing Mortality Rates	Y/R
0.00	0.0	0.60	0.0637
0.02	0.0064	0.62	0.0639
0.10	0.0268	0.64	0.0640
0.20	0.0433	0.66	0.0641
0.30	0.532	0.68	0.0642
0.32	0.0547	0.70	0.0642
0.34	0.0580	0.72	0.0643
0.36	0.0571	0.74	0.0642
0.38	0.0581	0.76	0.0642
0.40	0.0590	0.78	0.0642
0.42	0.0600	0.80	0.0641
0.44	0.0606	0.82	0.0641
0.46	0.0612	0.84	0.0640
0.48	0.0617	0.90	0.0636
0.50	0.0622	1.00	0.0630

Table 8: Calculation of TAC for *C. gunnari* in Subarea 48.3 for the 1989/90 season ($F_{0.1}$=0.42) (tuning VPA by Laurec-Shepherd method).

Age-Group	M	W	FD	N	B	Y
1	0.3500	23.400	0.0726	612.09	14.323	0.363
2	0.3500	79.000	0.3708	422.78	33.400	4.083
3	0.3500	163.300	1.0000	401.92	65.634	19.224
4	0.3500	276.000	1.0000	11.30	3.118	0.913
5	0.3500	411.900	1.0000	13.15	5.416	1.586
6	0.3500	565.200	1.0000	14.63	8.271	2.423
Total				1475.88	130.162	28.593

Table 9: Calculation of TAC for *C. gunnari* in Subarea 48.3 for the 1989/90 season ($F_{0.1}$=0.313) (tuning VPA by Laurec-Shepherd method).

Age-Group	M	W	FD	N	B	Y
1	0.3500	23.400	0.0726	612.09	14.323	0.272
2	0.3500	79.000	0.3708	422.78	33.400	3.099
3	0.3500	163.300	1.0000	401.92	65.634	15.019
4	0.3500	276.000	1.0000	11.30	3.118	0.714
5	0.3500	411.900	1.0000	13.15	5.416	1.239
6	0.3500	565.200	1.0000	14.63	8.271	1.893
Total				1475.88	130.162	22.235

Table 10: Calculation of TAC for *C. gunnari* in Subarea 48.3 for the 1989/90 season ($F_{0.1}$=0.645) (tuning VPA by Laurec-Shepherd method).

Age-Group	M	W	PD	N	B	Y
1	0.3500	23.400	0.0726	612.09	14.323	0.554
2	0.3500	79.000	0.3708	422.78	33.400	6.037
3	0.3500	163.300	1.0000	401.92	65.634	26.816
4	0.3500	276.000	1.0000	11.30	3.118	1.274
5	0.3500	411.900	1.0000	13.15	5.416	2.213
6	0.3500	565.200	1.0000	14.63	8.271	3.379
Total				1475.88	130.162	40.273

Table 11: CPUE (tonnes/hours) in Subarea 48.3 for *C. gunnari*, OTB. Monthly catch ≥75% (<75% in brackets).

Month	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
Jul		2.372	4.442			1.675	
Aug						1.969	
Sep			(0.263)		2.875	(1.944)	
Oct	5.556	8.444	(4.0)*	2.358	2.992	2.018	3.207
Nov		4.820			(0.389)	(1.185)	(1.299)
Dec		(0.402)			3.117	(0.192)	
Jan	4.451	(0.408)			2.080	(0.387)	
Feb	10.740	6.828			2.255	(0.306)	
Mar	9.519	4.667			2.355	(0.594)	
Apr	7.683				2.268		
May	4.699			1.422	2.804		
Jun	1.457	4.955			2.821		

* Interpolated

Table 12: Population numbers (millions of specimens) of *C. gunnari* (Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	775.08	730.78	1547.81	860.82	152.01	1709.92	962.74
2	519.53	450.13	367.81	934.77	505.46	86.88	1030.47
3	676.07	192.60	147.45	209.10	536.50	151.47	43.20
4	128.07	98.22	28.65	53.91	100.86	120.35	39.68
5	39.05	27.33	5.79	7.89	31.25	46.46	46.14
6	14.48	5.51	1.41	2.15	4.27	15.73	9.61
Total	2152.273	1504.570	2098.923	2068.641	1330.349	2130.806	2131.836

Table 13: Fishing mortality for *C. gunnari* (Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	0.04343	0.18656	0.00434	0.03242	0.05944	0.00641	0.01362
2	0.49232	0.61607	0.06476	0.05524	0.70510	0.19866	0.17176
3	1.42909	1.40530	0.50609	0.22909	0.99468	0.83951	0.53843
4	1.04464	2.33147	0.78931	0.04548	0.27515	0.45877	0.34230
5	1.45775	2.46185	0.48992	0.11357	0.18621	1.07603	0.37344
6	1.25145	2.39811	0.64041	0.07964	0.23089	0.76847	0.35819

Table 14: Population biomass for *C. gunnari* (thousands of tonnes), (Laurec-Shepherd method).

Age-Group	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	23.020	26.162	36.219	25.566	3.785	30.266	22.528
2	45.615	43.753	29.057	82.072	41.397	6.134	81.407
3	118.854	36.401	24.078	36.759	89.810	22.872	7.055
4	37.370	30.252	7.909	15.732	28.361	31.351	10.952
5	16.798	12.268	2.384	3.396	13.061	18.295	19.004
6	8.473	3.338	0.799	1.259	2.444	8.578	5.430
Total	250.129	152.173	100.445	164.784	178.858	117.495	146.376

Table 15: Projections for 1989, F_{OPT}=0.313, *C. gunnari* (Laurec-Shepherd method).

Age-Group	M	W	FD	N	B	Y
1	0.5000	23.400	0.0640	962.74	22.528	0.352
2	0.5000	79.000	0.3629	576.03	45.506	3.863
3	0.5000	163.300	1.0000	526.38	85.957	18.415
4	0.5000	276.000	1.0000	15.29	4.221	0.904
5	0.5000	411.900	1.0000	17.09	7.040	1.508
6	0.5000	565.200	1.0000	19.26	10.887	2.332
Total				2116.79	176.140	27.376

Table 16: Projections for 1989, F_{OPT}=0.42, *C. gunnari* (Laurec-Shepherd method).

Age-Group	M	W	FD	N	B	Y
1	0.5000	23.400	0.0640	962.74	22.528	0.471
2	0.5000	79.000	0.3629	576.03	45.506	5.095
3	0.5000	163.300	1.0000	526.38	85.957	23.603
4	0.5000	276.000	1.0000	15.29	4.221	1.159
5	0.5000	411.900	1.0000	17.09	7.040	1.933
6	0.5000	565.200	1.0000	19.26	10.887	2.990
Total				2116.79	176.140	35.250

Table 17: Projections for 1989, F_{OPT}=0.645, *C. gunnari* (Laurec-Shepherd method).

Age-Group	M	W	FD	N	B	Y
1	0.5000	23.400	0.0640	962.74	22.528	0.718
2	0.5000	79.000	0.3629	576.03	45.506	7.547
3	0.5000	163.300	1.0000	526.38	85.957	33.012
4	0.5000	276.000	1.0000	15.29	4.221	1.621
5	0.5000	411.900	1.0000	17.09	7.040	2.704
6	0.5000	565.200	1.0000	19.26	10.887	4.181
Total				2116.79	176.140	49.783

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ON ASSESSMENT OF BERTALANFFY GROWTH EQUATION PARAMETERS AND INSTANTANEOUS NATURAL MORTALITY RATE OF SOUTH GEORGIA MACKEREL ICEFISH

Zh.A. Frolkina and R.S. Dorovskikh

Abstract

An analysis and summary of extensive published and unpublished data on size-weight and size-age composition of South Georgia mackerel icefish (*Champsocephalus gunnari*) for 1965 to 1987 is presented. The results enable the calculation of reliable weight-length equations for males and females by season and the verification of parameters for the Bertalanffy growth equation. Mean value of natural mortality rate was estimated at 0.55.

Résumé

Une analyse et un résumé des données exhaustives, publiées ou non, sur la composition par poids-taille et âge-taille du poisson des glaces (*Champsocephalus gunnari*) de Géorgie du Sud sont présentés pour 1965 à 1987. Les résultats permettent le calcul d'équations poids-longueur fiables, pour les mâles et les femelles, par saison, et la vérification des paramètres de l'équation de croissance de Bertalanffy. La valeur moyenne du taux de mortalité naturelle a été estimée à 0,55.

Резюме

Представлен анализ и сводка обширных опубликованных и неопубликованных данных за 1965-1987 гг. по размерно-весовому и размерно-возрастному составу ледяной рыбы (*Champsocephalus gunnari*) в районе Южной Георгии. Результаты позволяют вывести точные уравнения взаимосвязи вес-длина для самцов и самок по сезонам, а также дают возможность выверить параметры уравнения Берталанффи. Вычисленное среднее значение коэффициента естественной смертности равняется 0,55.

Resumen

Se presenta un análisis y resumen de un gran número de datos publicados e inéditos sobre la composición de talla-peso y talla-edad del draco rayado (*Champsocephalus gunnari*) de Georgia del Sur para 1965 hasta 1987. Los resultados permiten el cálculo de razones fidedignas de peso-talla para machos y hembras por temporadas y la verificación de parámetros para la ecuación de crecimiento de Bertalanffy. El valor medio del índice de mortalidad natural se estimó en 0.55.

1. INTRODUCTION

Several papers have been published on the estimation of parameters of the Bertalanffy growth equation and instantaneous natural mortality rate for mackerel icefish (*Champsocephalus gunnari*) (Kochkin, 1985; Olsen, 1955; Kock, 1981; Linkowsky and Rembiszewsky, 1978 as cited from Kock, 1981).

Although the concept of change of natural mortality by age is generally accepted now, the problem of producing scientifically reliable assessments of pertinent coefficients has not been solved. This problem hampers the practical application of variable natural mortality rates in stock and catch assessments.

In this context, an attempt was made to determine the natural mortality rate M as a mean value, not subject to changes with age, so that this value could be used in future stock assessments.

2. MATERIALS AND METHODS

In order to calculate the parameters of weight-length relationships the 1970 to 1987 data on length and weight of *C. gunnari* were used. The results of approximately 50 000 biological analyses were considered.

The following equations were tested in order to reliably describe growth of *C. gunnari*.

$$W_t = W_\infty \{1 - e^{-K(t-t_o)}\}$$

(Bertalanffy equation)

$$Wt = W_\infty e^{-\frac{c}{a} e^{-at}}$$

(Gompertz curve)

$$W_t = \frac{W_\infty}{1 + \text{æ}^{-Kt}}$$

(logistic curve)

The method of non-linear parameter estimation (Bard, 1979) was used to define non-linear dependence parameters. The error of the observed data approximation was taken to be a criterion for selection of one or another equation and was expressed as mean-square error:

$$S^2 = \min \Sigma \frac{W_t - W_t'}{n - 1}$$

where W_t = observed value of fish weight at age t,
W_t' = weight value calculated from the equation.

Averaged data based on age determinations of 3 500 fish were used in the calculations. The age-groups which had less than three specimens in each group (primarily older age-groups) were rejected.

The methods of Baranov, Rikhter-Efanov, Beverton and Holt and Alverson-Carney were used to determine natural mortality rates, **M** (Babayan, Bulgakov et al., 1984).

The value of **M** was estimated from the age data averaged for 1965 to 1969 (unexploited population). The percentage of mature specimens by age was derived using data from biological analyses made from January to March in 1984 to 1987.

3. RESULTS AND DISCUSSION

Parameters of the weight-length equation were estimated for each season (quarter) by sex and for males and females combined. As is evident from Table 1, certain differences exist between parameters for the females and males, namely, the females have a somewhat larger weight. The change of the parameter **b** in the weight-length equation by season is related to changes in the fish condition, amount of food in the stomach and gonad maturity state. The largest values of the parameter **b** correspond to pre-spawning, spawning and pre-wintering periods. As the **b** value considerably differ from 3.0 (3.204-3.572), the use of equations with the assumed isometric dependence should be avoided.

Our estimates are similar to those of Kock (1981) ($W=0.0017\ L^{3.3627}$), but differ from estimations of Linkowsky and Rembiszewski (1978) ($W=0.0515\ L^{2.554}$), which can be evidently attributed to a small set of data used in the latter estimations (n=75).

As mentioned above, several curves were used to estimate the growth equation parameters. As is evident from Table 2, the results gained from the use of the logistic curve and Gompertz curve appeared to be unacceptable since values of **k** and W_∞ are obviously inflated. The method of Hohendorf for the linear growth yielded good results, however, W_∞ from this method also appear to be much larger than that observed (W_{max}=2 750). Mean long-term data on the length and weight by age were the initial data used in the calculation (Table 3).

In terms of the least approximation error, the best results were obtained for the Bertalanffy growth equation using the method of non-linear estimation with some samples rejected (data for the older age-group were rejected because of their paucity and, hence, unreliability).

The analysis of data presented in Table 4 shows that there is a close agreement between authors of all growth parameters except those estimated by Olsen. The growth coefficient **k** defined by other authors ranges from 0.1202 to 0.1478. The value of **k** calculated by Kochkin fits the same range, and the values estimated by Kock (1981) approach the upper range limit.

The parameter **k** shows at what rate the fish achieves its maximum length. As L_∞ calculated by Kock (1981) is somewhat lower than our value, his value for **k** appears to be higher. Considering that the maximum observed length of the fish in the study area is 69 cm (i.e. very close to our estimation of L_∞=68.8) k=0.1340 is used for further calculations.

No reliable rates of instantaneous mortality have been found as yet. Kock (1981) reported two quite different values: 0.61 estimated by Rikhter-Efanov method and 0.22 estimated by Pauly method. As previously mentioned, the averaged data for 1965 to 1969 were used by the authors for estimating **M**. These data are presented below.

Age	1	2	3	4	5	6	7	8
n	20	258	509	272	227	119	49	15
lnn	2.99	5.55	6.23	5.60	5.42	4.78	3.89	2.70
$lnn_{i+1} - lnn_i$	2.56	0.68	-0.62	-0.19	-0.64	-0.89	-1.19	-

For calculation according to the Baranov method, age-groups 3 to 7 were used:

$$M = \frac{0.62 + 0.19 + 0.64 + 0.89}{4} = 0.58$$

The resultant mean square error of this value will be 0.31.

Two values of M based on Beverton and Holt method are as follows:

$$M_1 = \frac{1}{\bar{t} - t'} = \frac{1}{4.67 - 3.0} = 0.60$$

where $\bar{t}$ = mean age of year classes fully represented in a sample
t' = age, beginning from which year classes begin to be fully represented in a sample,

$$M_2 = \frac{L_\infty - T\ K}{(T - l')} = \frac{(68.90 - 35.31) \cdot 0.134}{35.31 - 26.55} = 0.51$$

where T = mean length of fish fully represented in a sample,
l' = length of fish, beginning from which year classes are fully represented in a sample,
L_∞ = maximum length.

The value of **M** estimated by Rikhter-Efanov method is as follows:

$$M = \frac{1.521}{t_m 0.72} - 0.155 = \frac{1.521}{3.0^{0.72}} - 0.155 = 0.54$$

where t_m = age at massive maturation (as shown by our studies, 90% of the fish attain sexual maturity at the age of 3).

The value of **M** estimated by the Alverson-Carney method was 0.32.

$$M = \frac{3K}{e^{T \cdot K} - 1} = \frac{3 \cdot 0.134}{e^{6 \cdot 0.134} - 1} = 0.32$$

where T = time of biomass culmination estimated by the authors at 6 years.

The variety of **M** values calculated by these different methods is presented in the table below.

Name of Method	Value of M
Rikhter-Efanov (1976)	0.54
Baranov	0.58
Beverton and Holt, by age	0.60
Beverton and Holt, by length	0.51
Alverson-Carney	0.32

Most of the resultant values of **M** are close to and have $\bar{M}=0.55$. One exception is M=0.60 calculated by Beverton and Holt method.

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Table 1: Weight-length ratio parameters for *C. gunnari* by sex and season ($W=aL^b$).

Quarter of the year	Combined Data		Males		Females	
	a	b	a	b	a	b
1	0.0001935	3.372	0.003446	3.204	0.002221	3.338
2	0.001510	3.424	0.001026	3.528	0.000998	3.552
3	0.000947	3.548	0.001004	3.530	0.000908	3.574
4	0.002212	3.299	0.04558	3.299	0.002184	3.302

Table 2: Parameters of different growth equations for *C. gunnari*: linear and weight growth.

Growth Equation (Method of Estimation)	Parameters and their mean square errors (in brackets) for Linear Growth Equation			Parameters and theirmean square eErrors (in brackets) for Weight Growth Equation		
	L_∞ (cm)	t_o	K	W_∞ (g)	t_o	K
Bertalanffy equation (Hohendorf method)	71.20	0.1548	0.1354	5287.5	0.8656	0.0793
Logistic curve (Nonlinear regression analysis)				3509.9 (945.2)	0.2349 (0.050)	28.0539 (7.936)
Gompertz curve (Nonlinear regression analysis)				5107.1 (228.3)	0.1028 (0.036)	0.4709 (0.209)
Bertalanffy equation (Nonlinear regression analysis)	68.8 2.91	0.28 0.19	0.1340 0.0140	3276.1 (708.6)	0.180 (0.874)	0.12 (0.028)

Table 3: Mean long-term length and weight values for *C. gunnari* by age.

Age	1	2	3	4	5	6	7	8	9	12	15
Weight (g)	2.7	24.8	77.6	163.1	227.8	416.4	572.4	739.7	912.9	1427.2	1881.6
Length (cm)	10.8	18.1	24.5	30.0	34.9	39.1	42.8	46.1	49.0	55.5	49.9

Table 4: Parameters of linear growth for *C. gunnari* calculated by different authors.

Parameters	Olsen, 1955 Ford-Walford Method	Kock, 1981 Ford-Walford Method	Kock, 1981 Nonlinear Regression Method	Kochkin, 1985 Hohendorf Method	Our Estimates Nonlinear Regression Method
K	0.3978	0.1570	0.1528	0.1296	0.1340±0.0138
L_∞	42.10	65.10	64.30	71.94	68.9±2.9
t_o	- 1.3557	0.3849	0.2673	- 0.6722	-0.2798±0.19

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METHODS OF AGE DETERMINATION FOR MACKEREL ICEFISH (*CHAMPSOCEPHALUS GUNNARI* LÖNNBERG 1905) FROM THE SOUTH GEORGIA ISLAND SHELF

Zh.A. Frolkina

Abstract

Radii of annual elements of otoliths of mackerel icefish (*Champsocephalus gunnari*) from the South Georgia shelf were determined by analyzing data on length frequency distribution of fish in catches simultaneously with otolith radii of fish taken in the period July to September. The latter was done using specimens from strictly defined age groups. It is suggested that the determined radii of annual elements of otolith could be used to adjust age assessments of fish longer than 30 cm having an enlarged otolith centre. An age/length key for the third quarter of the year was also calculated.

Résumé

Le rayon des éléments annuels des otolithes de poisson des glaces (*Champsocephalus gunnari*) du plateau de la Géorgie du Sud ont été déterminés par analyse simultanée des données de distribution des fréquences de poissons dans les captures et des rayons d'otolithes de poissons échantillonnés de juillet à septembre. Ces derniers ont été mesurés à partir de spécimens provenant de classes d'âge définies avec précision. L'utilisation des rayons déterminés des éléments annuels des otolithes a été suggérée pour ajuster les évaluations de l'âge des poissons d'une longueur supérieure à 30 cm dont l'otolithe est dilaté en son centre. Une clef âges-longueurs a également été calculée pour le troisième trimestre de l'année.

Резюме

Радиусы годовых колец отолитов ледяной рыбы (*Champsocephalus gunnari*) в районе шельфа Южной Георгии были рассчитаны на основе изучения частотного распределения длины особей в уловах, проводимого одновременно с измерением радиусов отолитов рыб, выловленных за период с июля по сентябрь. При измерении радиусов отолитов использовались экземпляры точно определенных возрастных групп. Было предложено использовать рассчитанные радиусы годовых колец отолитов для оценки возраста особей, длина которых превышает 30 см, с увеличенным центром отолита. Также был рассчитан размерно-возрастной ключ для третьего квартала.

Resumen

Los radios formados por los elementos anuales en los otolitos del draco rayado (*Champocephalus gunnari*) de la plataforma de Georgia del Sur fueron determinados analizando los datos de distribución talla-frecuencia de los peces capturados, simultáneamente con radios de otolitos de peces pescados en el período de julio a septiembre. Esto último fue hecho usando especímenes de grupos de edad estrictamente definidos. Se sugiere que los radios de elementos anuales de otolitos puede ser utilizados para ajustar la evaluación de peces de longitud mayor de 30 cm que tengan el centro del otolito agrandado. También se calculó una clave de edad/longitud para el tercer trimestre del año.

1. INTRODUCTION

The mackerel icefish (*Champsocephalus gunnari*), is a member of the *Channichthyidae* family and is widely distributed in the Antarctic and sub-Antarctic waters of the Atlantic Ocean. The study of its various ecological characteristics has received a great deal of attention from Soviet and foreign researchers. (Andriyashev, 1969; Efremenko,1979; Kochkin, 1979; Lisovenko, 1982; Permitin,1972-3; Bellisio, Tomo 1970; Kock, 1975, 1979, 1980; Kompowski, 1980; Olsen 1955; Rudd, 1954; Rembiszewski, Krzeptowski 1978, Sosinski, 1983). To the present, however, agreement upon the correct method of age determination has not been reached. Therefore insufficient investigation has been undertaken regarding growth rate, natural mortality, age at maturation and, consequently, patterns of population dynamics.

At the Workshop on Age Determination of Antarctic Fish held in Moscow in 1986, it was decided that it was necessary to continue development of age determination techniques for *C. gunnari*.

Methods of age determination of fish are quite well detailed by Chugunova (1959). Age assessment, however, is somewhat subjective and much depends on the experience of the scientist. Thus, experienced scientists achieved a 95% agreement rate in a cross-checking of 101 cases of age determination and a rate of 89% for age determination in the case of older specimens while those of little experience managed rates of 78% and 36% respectively (Clark, 1958, cited in Shentyakova, 1971). Hence it is essential to develop more objective ways of interpreting results of scale "reading". A technique for verification and clarification of age assessments has been suggested by Mina (1973).

This technique has been applied in this work for age determination of a range of Antarctic fish. This technique has proven to be beneficial in decreasing the possibility of errors in age determination when used by different scientists.

2. MATERIALS AND METHODS

Research material was collected aboard research vessels *Gizhiga*, *Pioner Latvii*, *Slavgorod*, *Evrika* and others from 1984 to 1986. This material is comprised of otoliths representing all major size groups of fish which were sampled monthly.

Approximately 2.5 thousand pairs of otoliths were examined for age determination. These age reading structures are very small and fragile. First dry otoliths were used, which were further treated with glycerine to make them transparent when required. Using these otoliths a second time is impossible, however, because the process of their discolouration is irreversible. Good results were achieved by the method of preserving otoliths in alcohol vapour and then allowing them to air for 30 minutes. They were then placed in camphor-oil and examined under a microscope (magnification 2 x 8) in direct light (a black block-dish with oblique light).

Since alternation of hyaline and opaque elements is most distinct on the dorsal side of the otolith, its radius was measured on this side. The data thus obtained were used to identify growth rate. Zoological total length of fish is used in all calculations.

3. RESULTS

Researchers applied several approaches in developing methods of age determination. Using a device he had constructed himself, Kochkin (1982, 1985) prepared a sagittal otolith section, dyed it and examined it at 130-500 x magnification. Daily and weekly growth increments were in this way identified. This method is very time consuming and cannot be applied to the processing of large quantities of material.

In respect of the difficulty of examining individual specimens, the West German scientist, Kock, (Kock, 1981) conducted a graphic analysis of fish length distribution frequency (the Petersen method). In Kock's opinion, this method can only be successfully applied to the first age classes (i.e. fish up to 32 cm long). At the same time he examined otolith ring structures. By superimposing age distribution on a length frequency curve, he obtained a more accurate age assessment for specimens of the first four age classes. Even after cleansing, the centre of otoliths of older specimens remains too opaque to clearly identify first annual elements (AE)* .

Our first task was to establish the periods over which AE were formed. To this end 20 pairs of otoliths were analysed every month for the period 1984 to 1988. Data obtained from this analysis showed that the formation of AE occurs from June to September (i.e. austral winter). Moreover, depending on year-to-year fluctuations in environmental conditions, the periods of AE formation and the number of specimens with AE around the edges may vary from year to year. According to our observations, the formation of AE generally ends in June for 10%, in July for 40%, in August for 95% and in September for 100% of specimens. Fish otoliths consist mainly of crystals of inorganic calcium carbonate (aragonite) which is impregnated into the organic matrix (wavy protein, known as otolin). The difference in the proportion of organic and inorganic components leads to the alternation of concentric hyaline and opaque areas of the otolith. Opaque areas appear during periods of rapid growth when larger amount of aragonite forms on the otolith surface, while hyaline areas consisting of less aragonite appear during periods of slow growth. The formation of hyaline areas is generally associated with spending of energy for spawning, worsening feeding conditions and decreased metabolic rates due to a drop in water temperature. All of the above are important factors during the formation of AE for *C. gunnari* and may impact on this process. Fluctuations in the periods of AE formation by year were noted. In order to identify the factor having the most influence upon the changes in growth rate of *C. gunnari* and hence on the formation of AE, data on the monthly change in modal length of fish, obtained from numerous measurements taken in 1985, 1986, 1987 were summarized.

The growth rate curves for two adjacent year-classes differ significantly (Figure 1a). The growth period in 1985 to 1986 can be divided into periods of slackened growth (July to November 1985 and July to September 1986) and accelerated growth (December to June 1985). A gradual increase in length was observed throughout 1987 with a slight decrease only in September to November.

During the study period from 1985 to 1987, maximum density of krill was observed in 1987, when krill remained available to *C. gunnari* even in the autumn. Minimum density of krill on the South Georgia shelf was noted in 1985. An analogous tendency was also observed in the index of stomach fullness of *C. gunnari* over these years (Figure 1b).

A difference in AE formation was noted on otoliths of fish caught in July, October and November 1987. In July 1986, 50% of specimens had a broad hyaline area around the edges, comparable with the width for the previous annual area while only 5% of specimens taken in July 1987 had this hyaline area. One hundred percent of fish taken in November 1986 showed a slight increase in growth, whereas in November 1987 only a narrow hyaline area around the edges was observed and later, in January 1988 only, the growth increments became clearly visible. This may be explained by the fact that the cessation of growth and

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* We consider the term "element as a part of an age reading structure which differs from its other parts by one or another characteristic" (suggested by Mina and Klevezal, 1971) to be more appropriate than the term "ring", since it may be of any shape.

consequently, the formation of AE in 1987 probably occurred two months later than usual. The much narrower hyaline area in 1987 when compared to 1985 and 1986 is apparently associated with the shorter period of decreased intensity of metabolism.

Growth rate of *C. gunnari* is evidently influenced by the density and availability of krill swarms. The periods when krill ceases to be available to fish generally coincide with periods of AE formation which makes it highly likely that these processes are interlinked. A comparison of Figures 1a and 1b demonstrates that a slackening in growth occurred when the index of stomach fullness decreased, and the onset of intense growth was timed to the period of increasing stomach fullness.

Shcherbich (1975) suggested that for age determination of *Notothenia rossii*, the beginning of the reference year should be 1 July and not 1 January as is the practice for fish in the Northern Hemisphere. The concept of the beginning of the year is a formal one. The formation of AE does not occur simultaneously in various specimens of the same population over the year. There are also year-to-year variations in the dates of its formation.

Study of population dynamics, however, especially with a view to ecosystem modelling using multispecies models, demands standard in the choice of the beginning of the reference year. Since the beginning of the year for many Southern Ocean fish is taken to be 1 July, this date is proposed here for *C. gunnari.*

As in Kock (1981), length frequency distribution of *C. gunnari* in catches was used for developing this method. Analyzing data on numerous fish measurements taken from catches in May, July and August 1985 and from trawl census surveys in April/May 1984, facilitates division of fish into distinct size groups related to adjacent age classes. By comparing our material with Kock's data the similarity is evident. We can now determine to which age groups these data refer.

The research of both Soviet and foreign scientists (Efremenko, 1979; Kochkin, 1985; Olsen, 1955; Rembiszewski, 1978; Kock, 1980), in addition to our data from a trawl census survey of the zero age class, clearly demonstrates fish growth in the first year of life (Figure 2). Consequently, towards the end of the first year a length of 9 to 10 cm is reached and the radius of the element formed during this period for a fish of the above length should correspond to the size of the first AE. Therefore, the first group before 1 July (Table 1) refers to the zero age class, the next group refers to the first age class and so on.

According to the length distribution frequency in catches, the fish lengths in July are as follows: first year, 9 to 10 cm; second year, 17 to 18 cm; third year, 24 to 25 cm; fourth year, 29 to 30 cm. Therefore, choosing otoliths of fish taken in July to September and measuring radii from the centre to the edge of otolith gives the most likely position of the first four annual elements (Table 2). This finding will assist in more accurate age determination of cases in doubt.

Taking into consideration the existence of annual fluctuations in the growth rate of *C. gunnari*, radii of otoliths from 1984 to 1988 were measured and the data are presented in Table 2.

A large volume of age data for 1983 to 1985 was used to verify the reliability of our methods. An age/length key was calculated for the third quarter of the calendar year (i.e. beginning of the reference year) with the help of these data. Using material covering these three years enabled the differences in growth rate for various years to be averaged. For this reason the derived age/length key may not be used in the future for stock assessment of *C. gunnari.*

In accordance with our method, these annual quarterly keys were calculated using the large amount of materials. In this way mean lengths by age for the South Georgia population were obtained. By comparing these mean lengths with the modal lengths derived from extensive measurements taken annually in the third quarter, the close agreement between these values is evident. The growth of the strong 1983 year class was also monitored by measuring the modal lengths of a large number of specimens (Figure 3). A comparison of mean lengths obtained when determining age with the modal lengths of this year class demonstrates that they are practically identical. Therefore the proposed method can be used for age determination since those elements taken as annual are precisely that.

Differences in mean lengths described in this work and by other authors (Kochkin, 1985; Kock, 1981; Sosinski, 1983) obviously occur due to the fact that intensive fishing in the area is primarily conducted in the fourth quarter, the period in which extensive age data is primarily collected. The modal length of *C. gunnari* in this period is 26 to 28 cm.

An extensive amount of age determination material is presently being processed by means of the proposed method. The study of age composition of *C. gunnari* from the South Georgia Shelf demonstrated that the predominant fish in this area have a length of 35 to 40 cm and are aged 5 to 7, while individual specimens aged 8 to 9 attain a length of 51 to 53 cm. The largest specimens taken in May 1984 had the following characteristics:

female - length, 66 cm; weight, 2 400 g; age - 16
male - length, 62 cm; weight, 2 000 g; age - 14

4. CONCLUSIONS

(i) Otoliths can be preserved for age determination by means of treating them in the field and storing in alcohol vapour.

(ii) Since formation of annual elements occurs during July/August and fry are hatched in August/September, the formal date of birth for *C. gunnari* can be considered as 1 July.

(iii) Towards the end of the first year of life the majority of fish reaches 9 to 10 cm in length and the radius of the first annual element is 9 to 15 points of an ocular micrometre. Towards the end of the second year these figures are 17 to 19 cm and 17 to 23 points, for the third year, 23 to 25 cm and 23 to 28 points and for the fourth year, 30 cm and 27 to 35 points.

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Table 1: Comparison of Kock's (1981) and our data (1984, 1985) on modal lengths of various linear (age) groups.

Kock		Our Data			
1981		1984		1985	
December	March-April	April	May	July	August
5.6	-	9.5	-	9.4	-
15.4	18.2	18.0	-	17.0	17.0
22.6	25.5	25.0	22.0	24.0	24.0
			23.0	25.0	25.0

Table 2: Radii of fish otoliths having annual rings around the edges and sizes of annual elements of the first four age groups.

Age-groups	1	2	3	4
Size groups (cm)	9-11	17-19	23-25	30
Otolith radii (oc. micr. points)	9-12	18-22	25-27	32-34
Radii of elements taken to be annual (oc. micr. points)	9-15	17-23	23-28	27-35

Table 3: Age/length keys for *C. gunnari* from the South Georgia Shelf (July to September).

Length (cm)	Age in years							
	1	2	3	4	5	6	7	8
7	8							
8	16							
9	54							
10	39							
11	31							
12	26							
13	5							
14		1						
15		8						
16		19						
17		44						
18		50						
19		48						
20		36	4					
21		20	22					
22		11	37					
23		7	41					
24		3	46	2				
25			52	2				
26			36	16				
27			22	27				
28			14	30				
29			7	44				
30			1	59	1			
31				31	3			
32				5	10			
33				2	35			
34					35			
35					31			
36					31	2		
37					21	4		
38					10	7		
39					1	9		
40						2		
41						2		
42						1	1	
43							2	
44							4	
45							1	1
46							1	3
47								2
48								1
n	179	247	282	218	178	27	9	7
$\bar{L}$	9.98	18.73	24.37	29.02	34.80	38.61	43.94	46.48

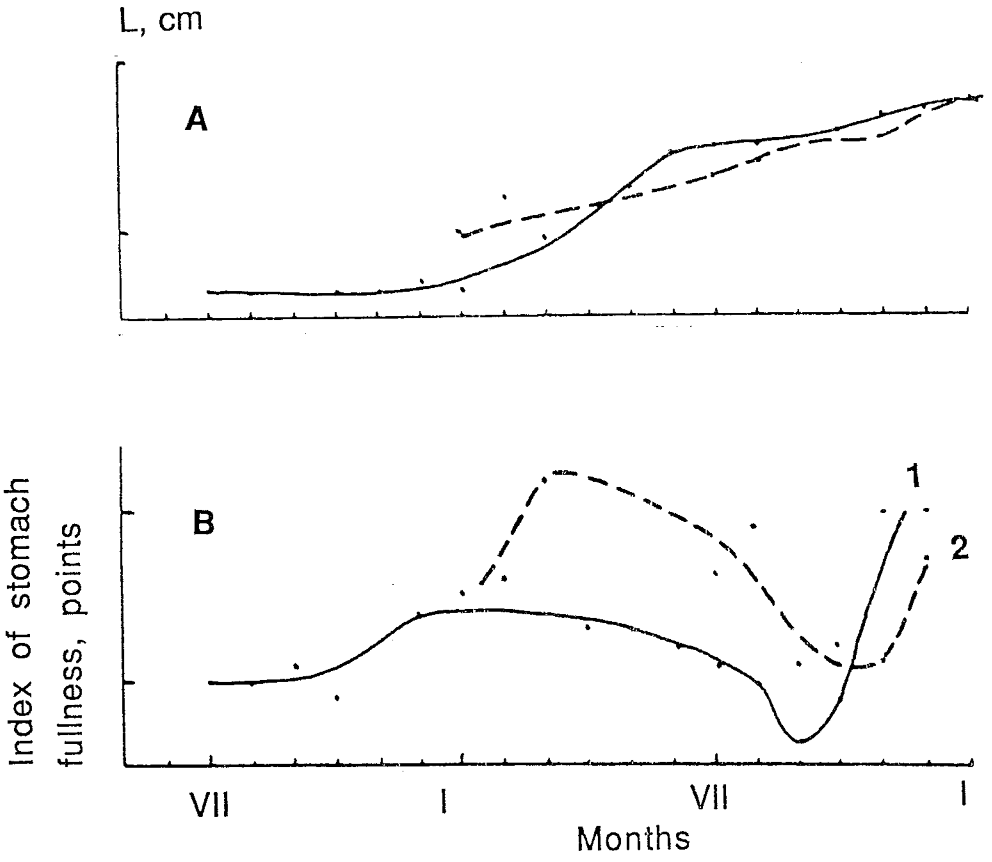


Figure 1: Growth rate of *C. gunnari*. Data obtained from extensive measurements in 1985, 1986 and 1987 (a).

Level of stomach contents for the same period (b).

- - - 1985-1986
- - - 1987

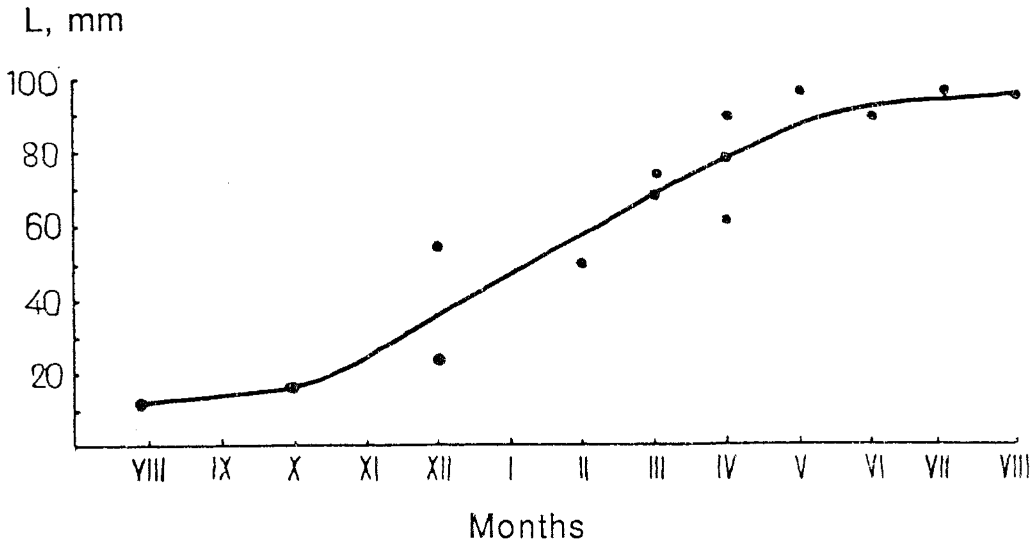
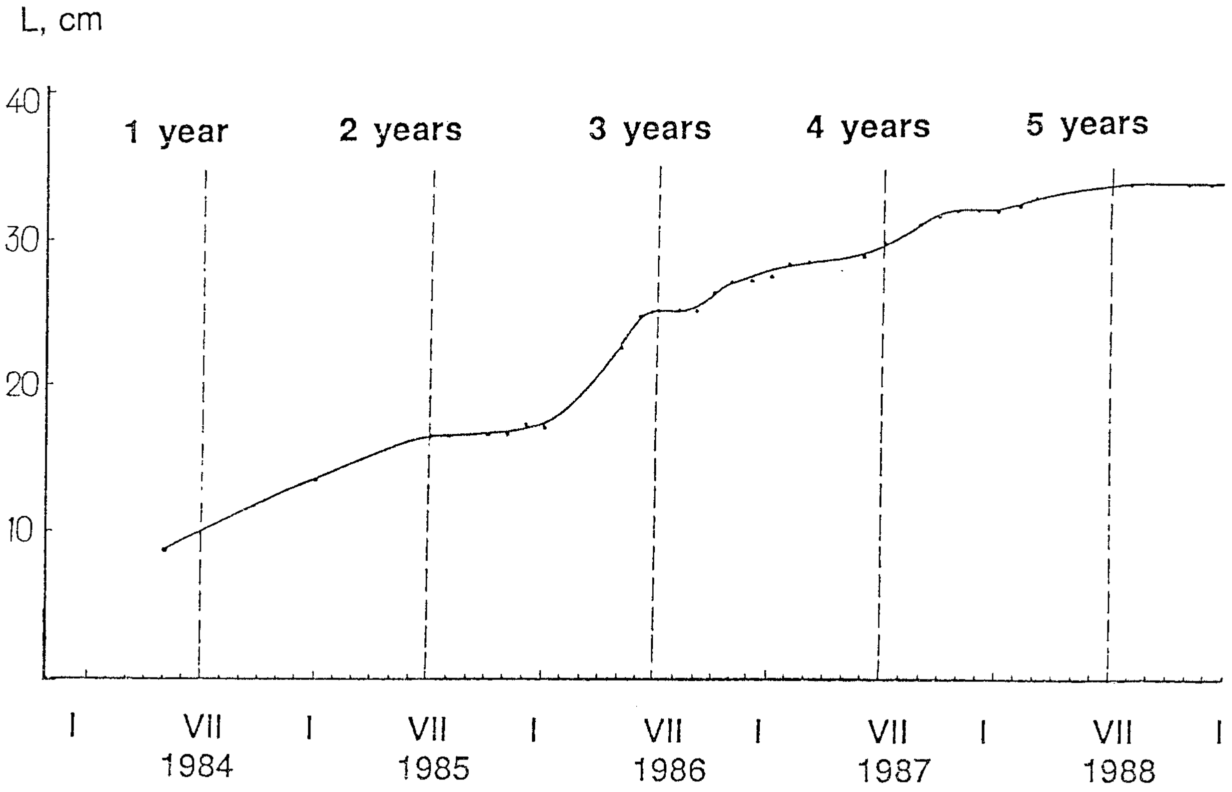


Figure 2: Growth rate of *C. gunnari* during the first year of life. Data from various sources.



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--- 1985-1986
- - - 1987

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--- 1985-1986 г.
- - - 1987 г.

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REPRODUCTION OF THE MACKEREL ICEFISH (*CHAMPSOCEPHALUS GUNNARI*) AND ITS IMPLICATIONS FOR FISHERIES MANAGEMENT IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN

K.-H. Kock

Abstract

Available information on key reproduction parameters of the mackerel icefish (*Champsocephalus gunnari*) has been reviewed and discussed in the light of existing conservation measures. Length at first spawning is approximately 25 cm around South Georgia and Kerguelen Islands, but approximately 35 cm around the South Orkney Islands and in the South Shetland Islands/Antarctic Peninsula region. Around South Georgia spawning takes place from March to May. Spawning around the South Orkney Islands and the South Shetland Islands probably occurs in June/July. Around South Georgia males start their spawning migration earlier than females. Fjords have been reported to be important spawning grounds. Fecundity is highest around South Georgia and Kerguelen but is decreasing towards higher latitudes.

Mesh size regulations presently in force offer very little protection to first spawners around South Georgia and juveniles and first spawners on the other South Atlantic fishing grounds. Spawning activities of *C. gunnari* and those of other exploited species could be best protected by the establishment of a permanent closed fishing season from 1 March to the end of each year's meeting of CCAMLR which is usually held in late October or early November.

Résumé

Les informations disponibles sur les paramètres clés de la reproduction du poisson des glaces (*Champsocephalus gunnari*) ont été examinées et discutées dans le contexte des mesures de conservation actuelles. La longueur au premier frai est d'environ 25 cm autour de la Géorgie du Sud et des îles Kerguelen, mais de 35 cm autour des îles Orcades du Sud et dans la région des îles Shetland du Sud et de la péninsule Antarctique. Autour de la Géorgie du Sud, le frai a lieu de mars à mai. Le frai, autour des îles Orcades du Sud et des îles Shetland du Sud, a probablement lieu aux mois de juin et juillet. Autour de la Géorgie du Sud, les mâles commencent leur migration de frai plus tôt que les femelles. Il a été signalé que les fjords sont des frayères importantes. La fécondité est au plus haut niveau autour de la Géorgie du Sud et des îles Kerguelen, mais diminue vers les latitudes plus élevées.

La réglementation sur la taille du maillage actuellement en vigueur n'offre que très peu de protection aux poissons qui se reproduisent pour la première fois autour de la Géorgie du Sud, et aux juvéniles et poissons frayant pour la première fois sur les autres lieux de pêche de l'Atlantique du Sud. Les activités de reproduction de *Champsocephalus gunnari* et d'autres espèces exploitées pourraient

être protégées au mieux par l'établissement d'une saison permanente de fermeture de pêche effective du 1er mars à la fin de chaque réunion annuelle de la CCAMLR, qui se tient, de coutume, fin octobre ou début novembre .

Резюме

В настоящей работе рассматривается и обсуждается в свете действующих Мер по сохранению имеющаяся информация о ключевых параметрах воспроизводства ледяной рыбы (*Champsocephalus gunnari*). В районах Южной Георгии и островов Кергелен длина при первом нересте приблизительно равняется 25 см, в то время как в районе Южных Оркнейских островов и районе Южных Шетландских островов/Антарктического полуострова она равняется 35 см. В районе Южной Георгии нерест происходит с марта по май. Нерест в районе Южных Оркнейских и Южных Шетландских островов, вероятно, происходит в июне/июле. В районе Южной Георгии нерестовая миграция самцов начинается раньше, чем нерестовая миграция самок. Имеются сведения о том, что фиорды являются важными нерестовыми участками. Плодовитость наиболее высока в районах Южной Георгии и островов Кергелен, но снижается на более высоких широтах.

Действующие в настоящее время меры по ограничению минимального размера ячеи не обеспечивают эффективной охраны впервые нерестующих особей в районе Южной Георгии, а также молоди и впервые нерестующих особей на других промысловых участках южной Атлантики. Самым эффективным методом обеспечения охраны нереста *C. gunnari* и прочих эксплуатируемых видов является введение постоянного закрытого сезона с 1 марта до окончания каждого ежегодного совещания АНТКОМа, которые обычно проводятся в конце октября - начале ноября.

Resumen

La información disponible acerca de los principales parámetros reproductivos del draco rayado (*Champsocephalus gunnari*) se ha examinado y debatido de acuerdo con las medidas de conservación existentes. El largo al primer desove es alrededor de 25 cm cerca de Georgia del Sur y las Islas Kerguelen, pero es alrededor de 35 cm cerca de las Islas Orcadas del Sur y en las Islas Shetland del Sur y la región de la Península Antártica. Cerca de Georgia del Sur el desove ocurre desde marzo a mayo. Alrededor de las Islas Orcadas del Sur y las Islas Shetlands del Sur es posible que ocurra alrededor de junio/julio. Cerca de Georgia del Sur, los machos comienzan su migración de desove antes que las hembras. Se ha observado que los fiordos son terrenos importantes para desove. La fecundidad es mayor alrededor de Georgia del Sur y Kerguelen pero disminuye hacia las latitudes más altas.

Reglamentos gobernando la abertura de la malla que están en vigor en este momento ofrecen muy poca protección a los desovadores alrededor de Georgia del Sur y a los reproductores juveniles y los de primer desove en los otros caladeros de pesca en el Atlántico Sur. Actividades de desove de *Champsocephalus gunnari* y de otras especies explotadas podrían ser protegidas más eficazmente estableciendo una temporada de veda de pesca permanente desde el 1° de marzo hasta el final de la reunión de CCRVMA cada año, la cual es generalmente conducida a fines de octubre o principios de noviembre.

1. INTRODUCTION

Since 1975/76 fishing in the Atlantic sector of the Southern Ocean has been mainly directed to the mackerel icefish (*Champsocephalus gunnari*). Catches were highest at about 240 000 tonnes, 220 000 tonnes and 100 000 tonnes in 1976/77 to 1977/78, 1982/83 to 1983/84 and 1986/87 to 1987/88 respectively. South Georgia has been the most important fishing ground for the species except in the seasons 1977/78 to 1979/80 when most of the catches were taken further south around the South Orkney Islands and in the South Shetland Islands/Antarctic Peninsula region.

Peak catches in the 1970s around South Georgia were based primarily on age classes 4 and 5 whereas catches in the 1980s consisted of age classes 2 and 3 (age class 2 being the recruiting age class). Since 1987/88 biomass estimates from the Virtual Population Analysis (VPA) indicate a downward trend. Assuming a mean level of recruitment and a fishing mortality of $F_{0.1}$ (0.25 to 0.3) spawning stock biomass could fall well below 100 000 tonnes in 1989/90 (CCAMLR, 1988b; Kock and Köster, 1989).

Since 1984 the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) established a number of conservation measures for the fish stocks around South Georgia (CCAMLR, 1988a, c) which were aimed either directly (mesh size regulations, closed season, TAC) at *C. gunnari* or should have some benefit for the species indirectly (closure of waters within 12 miles around the island). The prohibition of directed fishing of *C. gunnari* from 1 April to 30 September 1988 has been established specifically to protect spawning of the species. No such regulations exist for the other South Atlantic fishing grounds.

In its report of the annual meeting in 1988, CCAMLR asks the Scientific Committee to provide further advice on minimum mesh sizes to protect juvenile fish and on closed seasons for *C. gunnari* (CCAMLR, 1988c). In what follows, available information on key reproductive parameters (length at first spawning, spawning migration, spawning grounds, spawning time, fecundity) of *C. gunnari* has been reviewed. These parameters are discussed in the light of existing conservation measures and future implications for management of the species in compliance with Article II (3) of the Convention in the Atlantic sector of the Southern Ocean, in particular around South Georgia.

2. MATERIAL AND METHODS

Analysis was mostly based on published information. In addition some unpublished results of the Antarctic Expedition 1984/85 of the Federal Republic of Germany in South Georgia waters have been taken into account.

Maturity was determined either according to Everson's (1977) five point scale (Kock, unpublished) or Maier's (1908) eight point scale (Sosinski, 1985). Length at first spawning (see Kock, 1989) was estimated by fitting total length versus proportion of fish at maturity stages 3 to 5 (Kock) or 3 to 8 (Sosinksi) to a logistic equation (see Kock, 1989).

Potential or absolute fecundity was estimated by three different methods:

(i) All ova was washed out of the ovary and counted with an automatic egg counting device (e.g. Kock, 1979);

(ii) A weighed subsample of oocytes from an ovary was counted and then extrapolated to the entire ova (e.g. Sosinski, 1985); and

(iii) Sections of 0.9 to 2.9 g were taken from the central part of the right ovary. The proportion of the weight of the section to the weight of the entire ovary was used to extrapolate the number of oocytes in the subsample to that of the whole ovary (e.g. Lisovenko and Zakharov, 1988).

The following expressions are commonly used to describe the relationship between size and fecundity:

$F = a \cdot L^b$ (all authors, see Table 1)
$F = a + b \cdot W$ (Kock, Sosinski, Duhamel, see Table 1)
$F = a \cdot W^b$ (Lisovenko and co-authors, see Table 1).

3. RESULTS

3.1 Length at First Spawning

Length at first spawning L_{m50}, which corresponds to length at first maturity as determined by some authors (Kock, 1989) has been derived from data of Sosinski (1981 and 1985) and Kock (unpublished) (Table 1 and Figures 1 to 3). At South Georgia no significant difference in L_{m50} was apparent between the sexes nor between years (Figures 1 to 3). Length at first spawning of approximately 25 cm was similar in the late 1970s and 1985, in both cases after periods of heavy fishing.

Length at first spawning is much larger around the South Orkney Islands (Table 1). Data for the Elephant Island/South Shetland Islands region could not be fitted to a logistic curve (Sosinksi, 1985, Figure 10; Kock, 1989). However, there is evidence that L_{m50} is similar to that observed in the South Orkney Islands (Kock, 1989).

Spawning maturity curves for the population around South Georgia (Figures 1 to 3) were characterized by an asymmetrical shape, i.e. more juvenile individuals or fish with gonads in resting stage in the prespawning period (maturity stages 1 and 2 of the Everson scale) were present in the upper part of the curve than fish in prespawning condition (maturity stage 3) in its lower part. The difference between the theoretical (straight line) and the observed (dashed line) curve therefore represented the part of the population which was sexually mature but did not spawn in that particular season. An amount of specimens > 35 cm in the sample was too small to be representative. They have therefore been omitted here. Part of these specimens also had gonads in resting stage (i.e. were unlikely to spawn in the current season).

Although *C. gunnari* spawns annually, 15 to 25% of the population (both males and females) obviously do not spawn each year (Figures 1 to 3, shaded area) (see also Lisovenko and Silyanova, 1980; Sosinski, 1985, Figure 10). This is most likely the case also in the South Orkney Islands/South Shetland Islands region (Sosinski, 1985, Figure 10; Kock, 1989). The proportion of non-spawners cannot be assessed at present. In contrast to the populations in the Atlantic sector, *C. gunnari* around Kerguelen Islands obviously attains maturity within a very narrow length range (24 to 26 cm, Sosinski, 1985, Figure 10; Duhamel, 1987) and obviously spawns annually thereafter.

3.2 Spawning Migrations

No direct observation on spawning migrations (e.g. from tagging experiments) is available. The preponderance of fish in prespawning condition in coastal waters of South Georgia from March onwards points at a spawning migration to nearshore waters and fjords. In late March to mid April males outnumbered females in prespawning concentrations in fjords (Table 2) which indicates that males start their spawning migration earlier than females (Kock, 1981; Anon, 1985). Prior to spawning, sex ratio was again approaching 1:1 (Table 2, Fortuna Bay).

No such information exists for the other South Atlantic populations.

An inshore movement for spawning has also been described for the population at Kerguelen (Duhamel, 1987). The Skif Bank population, however, does not carry out extensive spawning migrations but reproduces on the bank (Duhamel, 1987).

3.3 Spawning Grounds

Olsen (1955) was the first to describe the inshore waters of South Georgia as spawning grounds of *C. gunnari*. These observations have been confirmed by Kock (1981) who recorded the presence of dense prespawning aggregations of the species in the central (deeper) parts of Fortuna Bay, Cumberland Bay and Royal Bay in late March to mid April 1978. No prespawners have been observed in these areas in early February. However, spawning does take place on the shelf at 100 to 125 m depth (Permitin, 1973; Sosinksi, 1985), although its extent is not known. Larvae and 0-group fish have been mostly encountered in nearshore waters (Kock, 1981; Slosarczyk, 1983; North, 1987).

Spawning has also been recorded from the South Orkney shelf along depths over 600 m close to the bottom and from the Elephant Island shelf (Anon, 1985). However, Kock (1989) found little indication for extensive spawning on the Elephant Island shelf during a survey in May/June 1986.

Spawning grounds of the Kerguelen population are located at the 100 m depth contour in the northeastern part of the shelf. On Skif Bank *C. gunnari* spawn along the 200 m depth contour of the southern and western margin of the bank (Duhamel, 1987).

3.4 Spawning Time

Spawning at South Georgia occurs from March to May (Table 1) but may even start in February and extend to June. As commonly observed in many teleosts, bigger (= older) individuals reproduce earlier than first spawners (Lisovenko and Silyanova, 1980).

Spawning in the South Orkney Islands/South Shetland Islands region is later and takes place probably in June to July (CCAMLR, 1985; Kock, 1989).

Spawning of various populations in the Indian Ocean sectors occurs in remarkably different seasons (Table 1): May/June on Skif Bank and August to September at Kerguelen Islands and around Heard Island (Duhamel, 1987; Gerasimchook et al., 1987).

3.5 Fecundity

Fecundity of *C. gunnari* is well studied, in particular around South Georgia. Length/weight-fecundity relationships determined by various authors (Table 1), however, differ significantly from each other especially in the upper part of the curve (Figure 4). Fecundity estimates of Kock, Lisovenko and Silyanova and Sosinksi were based on material collected in 1976 to 1978 whereas Lisovenko and Zakharov refer to samples from 1983/84. The remarkable similarity of Kock's and Sosinski's results on one hand and those of Lisovenko and co-authors on the other hand indicates that methodological differences were most likely to be responsible for these differences but not year-to-year variations in fecundity. Fecundity in the various populations obviously follows a latitudinal trend. Potential and relative fecundity were highest around Kerguelen and lowest around Elephant Island and the South Shetland Islands (Figure 5).

3.6 Discussion

Length at first spawning L_{m50} of *C. gunnari* around South Georgia has remained relatively constant between 1976 and 1985 although the population has undergone considerable fluctuations both in size and composition due to heavy fishing during that period. Estimates of L_{m50} of approximately 25 cm which do not differ significantly between sexes, originate from samples taken during prespawning period in January/February. Fish of this length are approximately 2.6 years old. They do not spawn, however, until April/May when they are of approximately 27 cm length and 2.9 years old.

Mesh size regulations have been widely used to establish a minimum size at first capture l_c. Its rationale is to prevent recruitment overfishing and to protect first spawners. Ideally l_c should exceed l_{m50} to some extent in order to allow fish to spawn at least once. Most often, however, l_c is less than L_{m50}.

A minimum mesh size of 80 mm for *C. gunnari* was among the first conservation measures which were introduced by CCAMLR in 1984 and came into force in 1985 (Conservation Measure 2/III). It was based on regulations which had been in use in the Soviet fishing fleet since 1980. Its scientific basis, however, remained unclear.

Preliminary mesh selectivity experiments resulted in a mean selectivity factor SF=3.01 for research vessel catches in the order of 0.5 tonnes/hour (Anon., 1988a). Minimum size at first capture (l_c=24 cm) would then correspond roughly to L_{m50}=25 cm. However, SF and l_c are most likely to be lower in commercial catches (> 1 to 1.5 tonnes/hour) (CCAMLR, 1988b). This demonstrates that present mesh size regulations do offer little, if any protection to first spawners around South Georgia. In fact, first spawners (i.e. primarily age class 2+) had always formed a substantial part of the annual catches (Kock and Köster, 1989, Figure 11) irrespective of the introduction of minimum mesh sizes in the Soviet fishing fleet since 1980.

Providing that most fish which escape through the meshes do survive, protection of first spawners could only be achieved by a substantial increase of minimum mesh size around South Georgia (e.g. to 110 or 120 mm).

Length at first spawning of 35 cm around the South Orkney Islands and the South Shetland Islands/Antarctic Peninsula region is much higher than around South Georgia although maximum length L_{m50} observed was similar in both regions (Kock, 1989; Table 2). Peak catches of 138 000 tonnes around the South Orkney Islands in 1977/78 were comprised almost entirely of juveniles of the very abundant 1973 and 1974 year classes (Kock and Köster, 1989). Catches of 57 000 tonnes around the South Orkney Islands and in the South Shetland Islands/Antarctic Peninsula region in the subsequent season obviously still consisted of juveniles and first spawners to a large extent (Kock and Köster, 1989, Figures 17 and 18). The two very abundant year classes, 1973 and 1974, were apparently already largely fished out before they were able to contribute significantly to the spawning stock biomass (SSB) of these two populations.

Catches on these two grounds dropped substantially after the 1978/79 season to a few thousand tonnes annually which were mostly taken around the South Orkney Islands. In some seasons these catches were almost entirely comprised of juveniles and first spawners (Kock and Köster, 1989, Figures 17 and 18).

It is evident that present minimum mesh sizes of 80 mm do offer very limited protection to the populations of *C. gunnari* around the South Orkney Islands and in the South Shetland Islands/Antarctic Peninsula region. Due to the large size of fish at first spawning, however, adequate protection of juveniles and first spawners could only be achieved by increasing minimum mesh sizes beyond those proposed for South Georgia (i.e. approximately 140 mm).

SSB and SSB/R (recruitment) calculations in VPA and Y/R (yield/recruitment) analyses are usually based on sexual maturity ogives. Although spawning of *C. gunnari* is likely to take place annually, our results indicate that part of the population(s) does not spawn each year. Present input parameters for VPA (CCAMLR, 1988b; Kock and Köster, 1989) may thus overestimate true SSB by 15 to 25%. It is recommended that in future maturity ogives should be based on spawning maturity instead of sexual maturity data.

Around South Georgia, spawning migration obviously commences in late February/early March. Males tend to migrate to coastal waters earlier than females. Consequently females may stay longer within the region of the fishery. It may thus be advisable to close the fishery from 1 March instead of 1 April onwards (Conservation Measure 10/VI).

Coastal spawning grounds, as far as they are known, seem to be well protected by the prohibition of fishing within 12 miles around South Georgia (Conservation Measure 1/III). Spawning on the shelf, however, should be protected as well. Taking into account that other commercially important species spawn in late autumn (*Notothenia rossii*, *Chaenocephalus aceratus* and *Pseudochaenichthys georgianus*) or in winter (*Notothenia gibberifrons*) it seems to be advisable to establish a closed fishing season for those species permanently during that period similar to the closed season which was established in 1988 by the Conservation Measure 10/VI. This closed season should preferably be extended from 1 March to the end of each year's meeting of CCAMLR which is usually held in late October or early November.

Potential fecundity of *C. gunnari* ranges from 1 500 to 30 000 eggs around South Georgia. It rarely exceeds 10 000 eggs in the other populations. Population fecundity around South Georgia is, however, much lower than suggested by the wide range of potential fecundity as the bulk of the population is formed by age classes 2 to 4. They do not produce more than approximately 1 500 to 7 000 eggs per fish.

Relative fecundity (i.e. egg production per gram of body weight) is highest around South Georgia (and Kerguelen Islands) but is decreasing in the waters of higher latitudes.

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Table 1: Reproductive parameters of *Champsocephalus gunnari*.

Locality	Spawning Time	$L_{m\,50}$ (cm)	Year (s) of Investig.	Length range (cm)	Potential Fecundity		Relative Fecundity	Fecundity in Relation to		Source
					Min	Max		Length (cm)	Weight (g)	
South Georgia	March to May	21-26	1967	33-54	4050	23187	-	-	-	Permitin (1973)
		24.8	1976,1985	22-57	1564	31045	13.7-30.6	$F=0.1292 \cdot L^{3.0145}$	$F=383 + 17.9 \cdot W$	Kock (1979, 1981, Unpubl.)
		24.8	1976,1977 1979	22-51	1700	17338	-	$F=0.2223 \cdot L^{2.8882}$	$F=801 + 16.02 \cdot W$	Sosinski (1981, 1985)
		22-30	1965-1979	25-43	2208	11126	-	$F=1.54 \cdot L^{2.29}$	$F=189.6 \cdot W^{0.59}$	Lisovenko, Silyanova (1980)
		-	1984	22-58	1294	21932	-	$F=3.19 \cdot L^{2.08}$	$F=197.0 \cdot W^{0.58}$ *	Lisovenko, Zakharov (1988)
S. Orkney Islands	June to July	-	1967	43	-	8352	14	-	-	Permitin (1973)
		35.1	1979	31-44	5169	9889	-	$F=0.2574 \cdot L^{2.7744}$	$F=1753 + 10.4 \cdot W$	Sosinksi (1981, 1985)
Elephant Island	June to July	(35)	1981,1985 1986	34-50	3094	11664	8.0-16.7	$F=0.1216 \cdot L^{2.9177}$	$F=1523.1+8.55 \cdot W$	Kock (1989)
S.Shetland Islands	June to July (?)	(35)	1978	32-44	3388	9067	12.4-16.5	$F=0.0454 \cdot L^{3.2235}$	$F=128 + 14.45 \cdot W$	Kock (1982)
			1979	36-47	5710	11753	-	$F=3.774 \cdot L^{2.0487}$	-	Sosinski (1981, 1985)
Kerguelen	August to September		1975	26-38	2000	10645	-	$F=0.055 \cdot L^{3.9498}$	$F=57.14+21.42 \cdot W$	Sosinski (1981, 1985)
		25	1979-1984	26-37	2980	9060	24.2-45.4	$F=0.3027 \cdot L^{2.845}$	-	Duhamel (1987)
Skif Bank	May to June		1979-1984	25-25	1750	5220	17.9-29.2	$F=0.20 \cdot L^{2.869}$	-	Duhamel (1987)

* $F=1.97\ W^{0.58}$ in Lisovenko and Zakharov (1988).

Table 2: Sex ratio in prespawning concentrations of *Champsocephalus gunnari* on the shelf and in fjords of South Georgia (from Kock, 1981).

Date	Sex Ratio (%) F	 M	Location
28/03/78	68.0	32.0	Shelf
30/03/78	70.6	29.4	Shelf
01/04/78	64.0	36.0	Shelf
12/04/76	60.4	39.6	Shelf
15/04/76	71.9	28.1	Shelf
15/04/76	69.8	30.2	Shelf
29/03/78	15.7	84.3	Cumberland W. Bay
02/04/78	25.8	74.2	Royal Bay
02/04/78	46.6	53.4	Fortuna Bay *

* A high gonadosomatic index (mostly > 20) indicates that fish are at prespawning state.

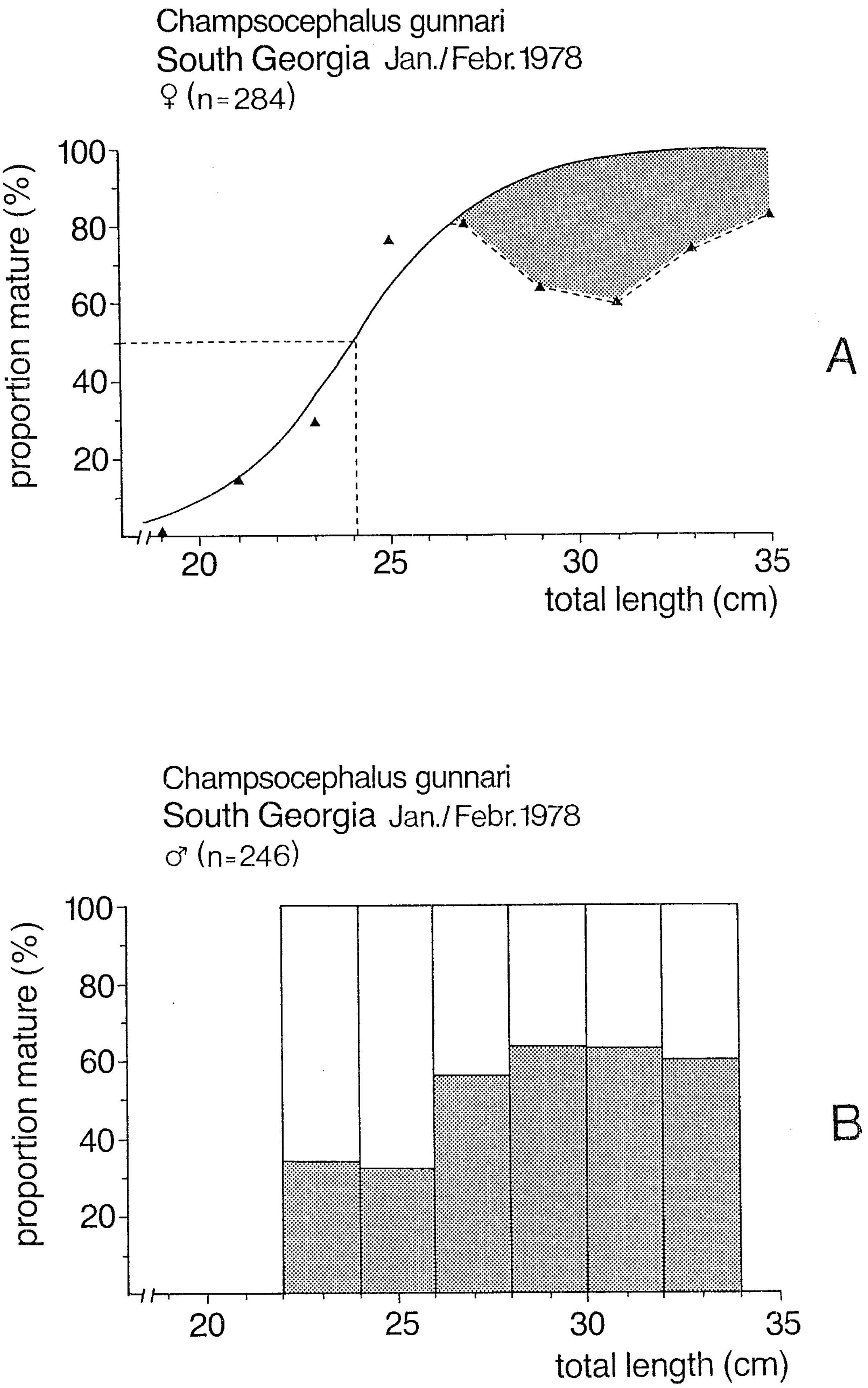

Figure 1: Spawning maturity curves for *Champsocephalus gunnari* around South Georgia in January/February 1978.

A: Females B: Males (Data could not be fitted to a logistic curve).

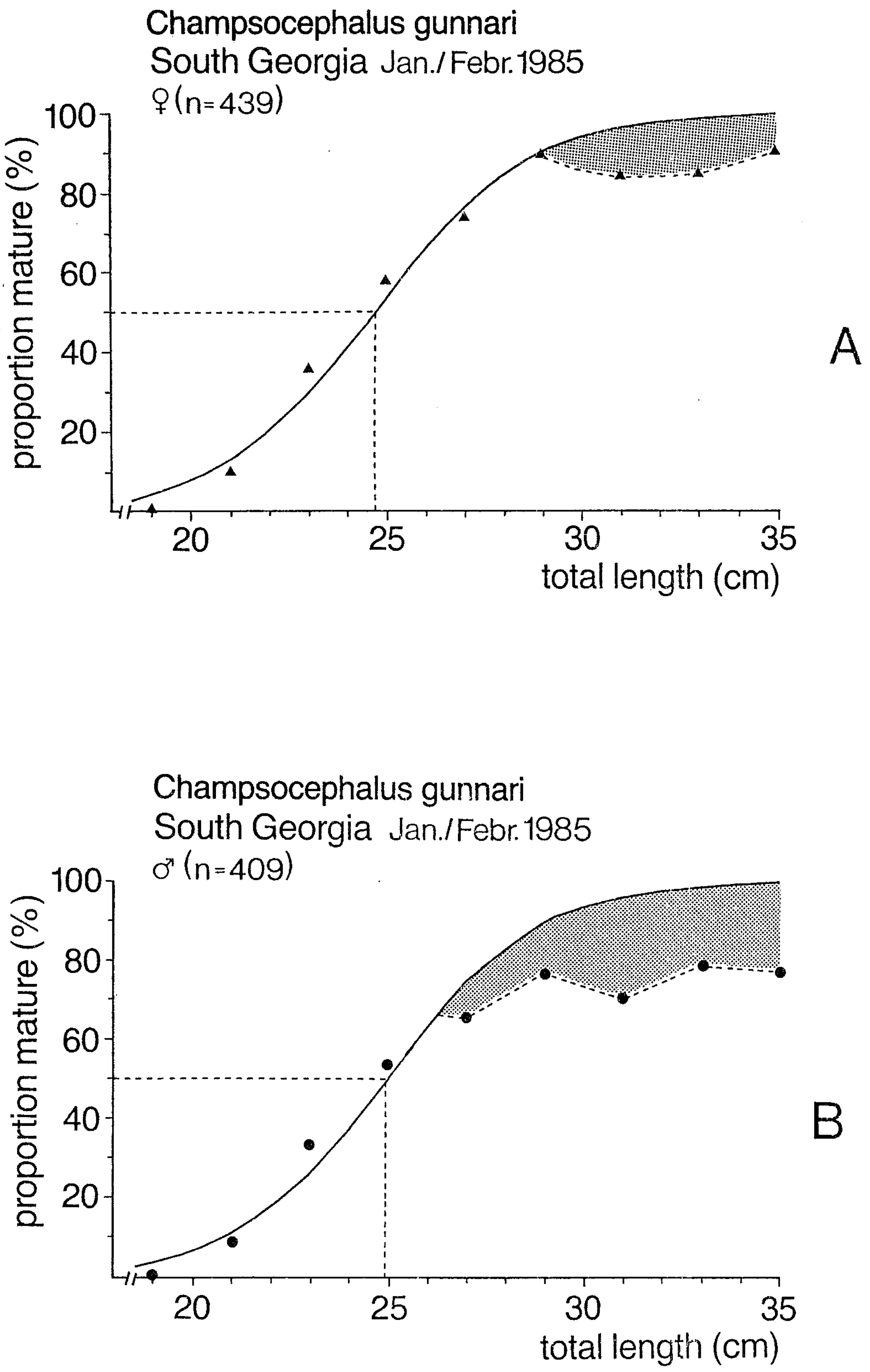

Figure 2: Spawning maturity curves for *Champsocephalus gunnari* around South Georgia in January/February 1985.

A: Females B: Males

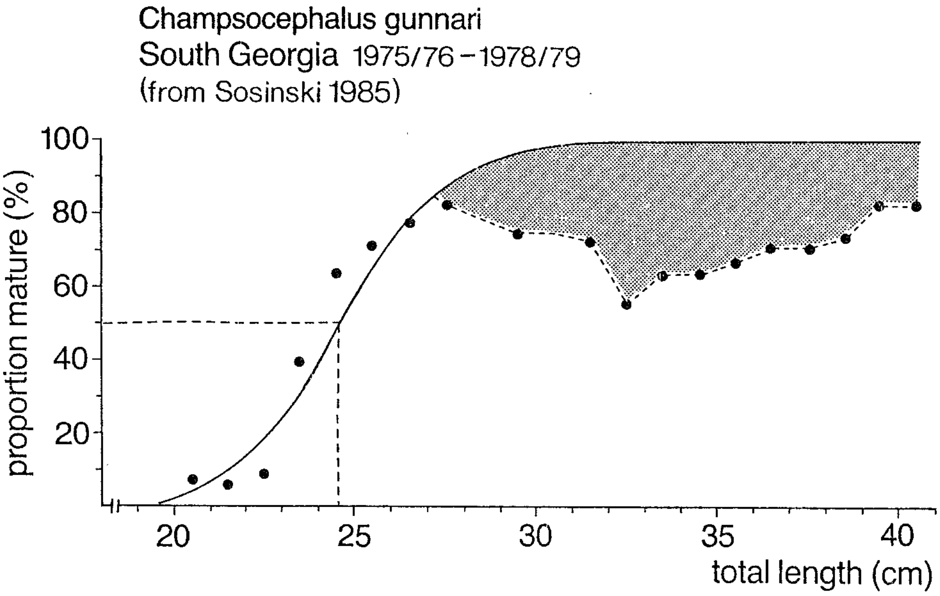

Figure 3: Spawning maturity curve for *Champsocephalus gunnari* (both sexes combined) around South Georgia in 1975/76 (from Sosinski, 1985).

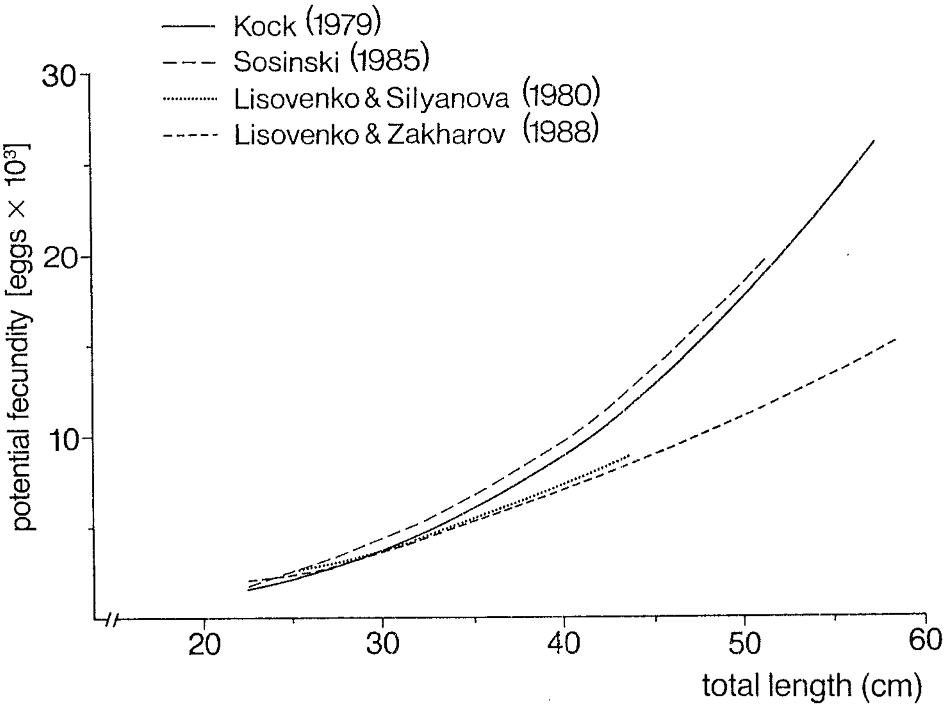

Figure 4: Length versus fecundity curves for *Champsocephalus gunnari* around South Georgia.

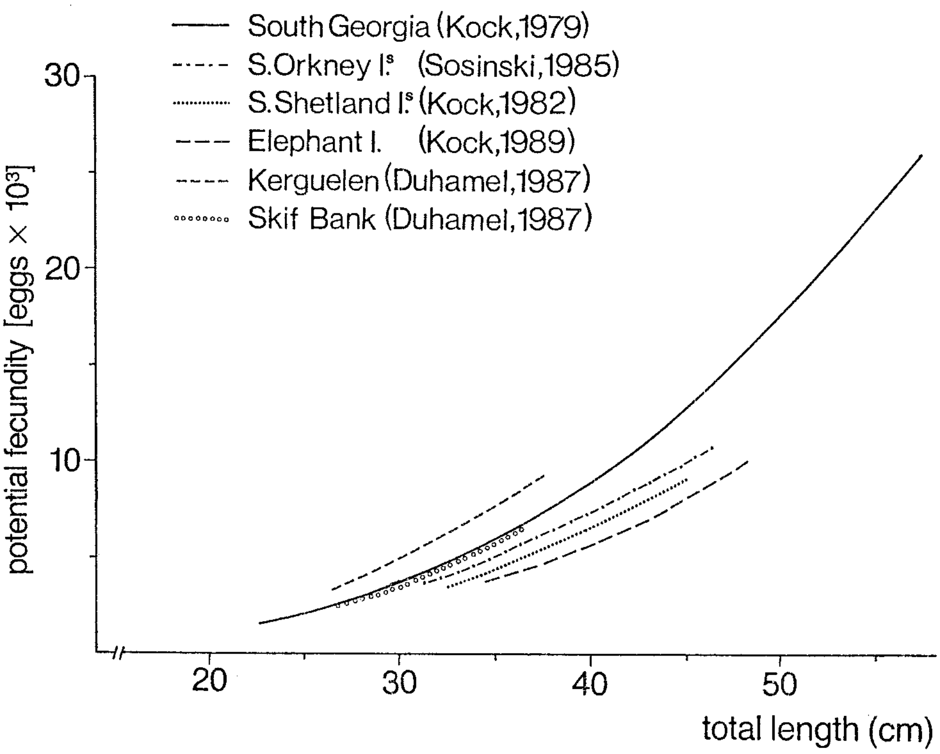

Figure 5: Length versus fecundity curves in six populations of *Champsocephalus gunnari*.

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TRAWL SELECTIVITY FOR *CHAMPSOCEPHALUS GUNNARI*

S.F. Efanov, G.E. Bidenko and V.A. Boronin

Abstract

Data on trawl selectivity for mackerel icefish (*Champsocephalus gunnari* L.), were collected in 1981 in the South Georgia area. The trawl bags tested were made of net webbing with 3.1 mm twine and 88.2 mm mesh size. Trawling speed was 3.5 knots. Icefish comprised 90 to 100% of catches. The logistic selectivity curves were calculated using the collected data. It was found that the selectivity factor for 88.2 mm mesh size was 2.81 and the 50% retention length was 24.8 mm (21.5 to 28.2 mm).

Résumé

Les données sur la sélectivité des chaluts pour le poisson des glaces (*Champsocephalus gunnari* L.) ont été recueillies en 1981 dans la zone de la Géorgie du Sud. Les poches de chalut examinées étaient faites de nappe de filet dont les fils étaient de 3,1 mm et le maillage de 88,2 mm. La vitesse de chalutage était de 3,5 nœuds. Le poisson des glaces formait de 90 à 100% des captures. Les courbes logistiques de sélectivité ont été calculées à partir des données recueillies. Il a été estimé que le facteur de sélectivité pour une taille de maillage de 88,2 mm était de 2,81 et que la longueur de rétention de 50% était de 24,8 mm (21,5 à 28,2 mm).

Резюме

Данные по селективности тралов в отношении ледяной рыбы (*Champsocephalus gunnari* L.) были собраны в районе Южной Георгии в 1981 г. Опробованные кутки были сделаны из сетного полотна с бечеей диаметром в 3,1 мм; размер ячеи 88,2 мм. Скорость траления - 3,5 узлов. Ледяная рыба составила 90-100% уловов. Логистические кривые селективности были рассчитаны на основе полученных данных. Было выявлено, что фактор селективности в отношении ячеи размером в 88,2 мм равнялся 2,81 и, что средняя 50%-ная длина удержания равнялась 24,8 мм (21,5 - 28,2 мм).

Resumen

Datos sobre la selectividad de arrastre para el draco rayado (*Champsocephalus gunnari* L.), se recopilaron en 1981 en el área de Georgia del Sur. Las bolsas de arrastre fueron hechas de un paño de red con un torzal de 3.1 mm y un tamaño de malla de 88.2. La velocidad de arrastre fue 3.5 nudos. Peces de hielo comprendieron entre el 90 y 100% de las capturas. Las curvas de selectividad logística se calcularon usando los datos recopilados. Se encontró que el factor de selectividad para una luz de malla de 88.2 fue 2.81 y la longitud de retención al 50% fue 24.8 mm (21.5 a 28.2 mm).

Rational fishery management with effective fishery regulations guarantees maximum possible yield while at the same time ensuring stability of natural resources and furthering conservation of fish stocks. In the wake of currently increasing fishing intensity the question at hand requires urgent attention. The conservation of juvenile fish is a scientifically based approach to the regulation of fishing activities which allows the stock to be maintained on a sufficiently high level for future exploitation.

In order to rationally exploit resources of the mackerel icefish (*Champsocephalus gunnari*) in the South Atlantic, it was considered necessary to develop measures for increasing the efficiency of fisheries management and to conduct integrated studies into the selective properties of trawls operating on concentrations containing fish of various size groups.

Experimental data on the selective properties of trawls for Antarctic fish were collected by scientists from the AtlantNIRO Research Institute; representatives of the VNIRO Research Institute assisted in processing these data.

Most fishing gear has selective properties. During periods of high fishing intensity the impact of the exploitation on the stock becomes a decisive factor. Establishing an optimal mesh size for commercial trawls is an effective way of guaranteeing that fishing activities are organized with a view to rational exploitation.

The quantitative and qualitative definition of the selective properties of trawls depends on a variety of technical parameters of fishing gear, hydrological conditions, biological features of the exploited species, the design of trawl bags, size, shape and physical-mechanical properties of net material and meshes, patterns of trawling, size of the catch and also characteristics of fish behaviour, the structure and size composition of exploited fish concentrations, morphometric parameters and physiological condition of fish.

In order to analyze the selective properties of trawls for *C. gunnari*, primary data were collected on the number of fish retained in trawl bags and the number passing through the net webbing. A thorough biological analysis of fish was conducted and their physiological condition was evaluated (Table 1). The data were collected on board the RV *Evrika* around South Georgia in September 1981, and assessment of the selective properties of trawl bags was carried out in accordance with standard methods (Treshchev et al., 1986). Trawl bags were made of net webbing with a twine diameter of 3.1 mm and an internal mesh size of 88.2 mm. Trawling speed was 3.5 knots. The duration of trawling varied from 30 to 60 minutes and catch weight did not exceed one tonne. *C. gunnari* accounted for 90 to 100% of the catch.

Processing the experimental data on the selective properties of trawl bags (establishing the analytical dependency of the retention of fish of various lengths, verification of the contingency between experimental and computed data, assessment of the bias at $l_{50\%}$ point) was carried out in accordance with the specially designed algorithm[*] on a mainframe computer using a program for "calculation of logistic selectivity curves" (Kaliningrad, AtlantNIRO, 1982):

$$\text{Logistic function } P = \frac{1}{1 - e^{-(a l_o - b)}}$$

where P = retention of fish by trawl, %;

l_o = total length of fish, cm;

a, b = coefficients.

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[*] Algorithm developed by senior engineer V.F. Ivanova

According to Pearson's test of contingency the curves described by this equation correspond with experimental points at $\beta = 0.95$.

After processing the experimental data the following final logistic formula was worked out for 88.2 mm mesh:

$$P = \frac{1}{1 - e^{(0.265 l_o - 6.58)}}$$

with a 50% retention point for 24.8 cm long fish (Table 2).

The results of experiments with 88.2 mm mesh size give the modal length of fish in trawl catches of 25 cm.

In order to obtain objective data it would be worthwhile conducting research in the major fishing areas. With a view to protecting juvenile *C. gunnari* from overfishing and providing a base for efficient fishing practices, the USSR introduced unilaterally in 1980 the "Fishery Regulations for Antarctic Waters" imposing higher levels of trawl selectivity for the Soviet fleet. In accordance with these regulations, the minimum mesh size in the retaining part of trawls, in particular for *C. gunnari*, was set at 80 mm. This increased mesh size has led to a reduction in the by-catch of immature fish.

Bearing in mind the difference in size composition of fish in various areas, it would seem useful to fix a minimum mesh size for each fishing area individually, which would ensure free passage through the mesh and a high rate of survival for juveniles.

CONCLUSIONS

1. An increase in the level of selectivity by means of using a larger mesh size in trawls (88.2 mm) and a decrease of fishing intensity, will lead to a lower rate of exploitation and a lesser impact on younger age groups of *C. gunnari*.

2. For 88.2 mm mesh size in trawl bags, the percentage of retained *C. gunnari* and selectivity coefficient are 58.9% and 2.81 respectively.

3. The efficiency of the regulations introduced by the USSR in the "Fishery Regulations for the Antarctic Waters" which stipulate higher levels of selectivity, will be secured if commercial trawls of all countries participating in the *C. gunnari* fishery will increase mesh size accordingly.

4. While estimating advantages and disadvantages for the fishery of a conversion to a higher level of trawl selectivity, it would be advisable to carry out selectivity separately in each fishing area.

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Table 1: Catch structure and biological condition of icefish off South Georgia - RV *Evrika*, September 1981.

Size Composition															
cm	12	14	16	18	20	22	24	26	28	30	32	34	36	Total	Mean
No. of specimens	4	15	20	19	63	509	2229	1863	268	117	184	42	7	5340	25.56
%	0.1	0.3	0.4	0.4	1.2	9.5	41.7	34.9	5.0	2.9	3.4	0.8	0.1	100.0	

Size Composition																		
cm	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Total
No. of specimens	4	13	51	153	291	464	359	218	69	18	10	14	15	14	15	15	14	11	1743
Mean weight	45	50	64	70	81	93	104	120	137	157	179	185	202	229	275	303	325	346	

	Stage of Maturity						Fat Content (points)					Stomach Food Volume (points)						
	II	III	Total	II	III	Total	1	2	3	Total	Mean	0	1	2	3	4	Total	Mean
No. of specimens	31	797	828	15	836	851	11	268	1400	1679	2.8	700	364	268	174	167	1679	1.3
%	3.7	96.3	100	1.7	98.3	100	0.6	16.0	83.4	100		41.8	21.8	16.0	10.4	10.0	100	

Table 2: Selectivity parameters of trawls in relation to *Champsocephalus gunnari* (September 1981).

Parameters of trawl bag selectivity	Mesh size 88.2 mm
1. Length of fish, 50% of which are retained in the trawl bag ($l_{50\%}$)	24.8
(a) weight of one specimen, g	80.0
(b) age in years	2.8
2. Selectivity range, cm (Ds)	21.5 - 28.2
3. Selectivity coefficient (Ks)	2.81
4. Modal length of fish, cm (l_m)	25.0
5. Percentage of specimens retained in the bag	58.9

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EFFECTS OF DIFFERENT HARVESTING STRATEGIES ON THE MACKEREL ICEFISH *CHAMPSOCEPHALUS GUNNARI* AROUND SOUTH GEORGIA

F.W. Köster and K.-H. Kock

Abstract

The effects of a number of harvesting strategies on the mackerel icefish (*Champsocephalus gunnari*) have been simulated for a period of 30 years. These were:

- different levels of constant fishing mortality ($F_{0.1}$, F_{max}, $2xF_{max}$);
- harvesting constantly at 50% $F_{0.1}$ with F increasing three or five years after a good recruitment;
- pulse fishing at an interval of three years with no fishing in between; and
- changes in net selectivity resulting in a shift in partial recruitment.

For the projections, recruitment was assumed to follow the historical pattern.

Pulse fishing proved to be the least preferable harvesting alternative. In the absence of regular recruit surveys constant fishing at $F_{0.1}$ is most likely to be the most profitable and least risky harvesting strategy at present. The establishment of a regular recruit survey would offer the possibility of adjusting constant levels of fishing mortality to the strength of the incoming year class. An increase of F, however, should not occur earlier than four years after a good recruitment. A forward shift in partial recruitment values would not alter yield significantly when fishing at $F_{0.1}$ and F_{max} but would lead to a higher spawning stock biomass.

Резюме

Было выполнено математическое моделирование воздействия различных промысловых стратегий на антарктическую ледяную рыбу (*Champsocephalus gunnari*) на протяжении 30 лет. Рассматривались следующие стратегии:

- различные постоянные уровни промысловой смертности ($F_{0.1}$, F_{max}, $2xF_{max}$);
- промысел на постоянном уровне в 50% $F_{0.1}$ при повышении F через 3 года или 5 лет после вступления в запас многочисленного пополнения;
- пульсирующий промысел с интервалом в 3 года при отсутствии промысла в промежутках;

- изменение селективности сетей и связанное с этим изменение частичного пополнения.

При моделировании пополнение было принято за обычное.

Пульсирующий промысел является менее предпочтительным вариантом промысловой стратегии. Вероятно, что в отсутствие регулярных съемок пополнения промысел на постоянном уровне $F_{0.1}$ в настоящее время будет наиболее выгодной и наименее рискованной промысловой стратегией. Регулярное проведение съемок пополнения предоставит возможность регулировать постоянные уровни промысловой смертности в соответствии с мощностью вступающего в пополнение годового класса. Тем не менее, F не должно повышаться ранее, чем через четыре года после многочисленного пополнения. Сдвиг вперед значений частичного пополнения не изменит объема вылова при $F_{0.1}$ и F_{max}, в значительной мере, но приведет к увеличению биомассы нерестующего запаса.

Résumé

Les effets sur le poisson des glaces (*Champsocephalus gunnari*) d'un certain nombre de stratégies d'exploitation ont été simulés pour une période de 30 ans. Ces stratégies sont:

- des niveaux différents de mortalité par pêche constante ($F_{0.1}$, F_{max}, 2 x F_{max});
- une exploitation constante à 50% de $F_{0.1}$ avec une augmentation de F, trois ou cinq ans après un bon recrutement;
- une pêche par à-coups à intervalles de trois ans, sans aucune pêche dans l'intervalle;
- des changements de sélectivité des filets ayant pour résultat un changement du recrutement partiel.

Pour les prévisions, le recrutement était censé suivre le modèle historique.

La pêche par à-coups s'est avérée la solution la moins souhaitable. Faute de campagnes d'évaluation régulières des recrues, il est probable que la pêche constante à $F_{0.1}$ soit la stratégie d'exploitation la plus profitable et la moins hasardeuse à présent. L'établissement d'une campagne régulière d'évaluation des recrues offrirait la possibilité d'ajuster les niveaux constants de mortalité par pêche à l'importance de la nouvelle classe d'âge. Une augmentation de F, cependant, ne devrait avoir lieu qu'un minimum de 4 ans après un bon recrutement. Une augmentation des valeurs de recrutement partiel ne changerait pas de beaucoup le rendement de pêche à $F_{0.1}$ et F_{max}, mais entraînerait une augmentation de la biomasse du stock reproducteur.

1. INTRODUCTION

Since 1976/77 the Antarctic icefish *Champsocephalus gunnari* has become the dominant species in the fishery around South Georgia. Catches were highest at about 93 000 tonnes, 210 000 tonnes and 105 000 tonnes in 1976/77, 1982/83 to 1983/84 and 1986/87 to 1987/88 respectively. During 1976/77 when the fishery was at its first peak 4 and 5 year old fish were the major component of the catch. Stock size is now strongly dependent on the strength of the incoming cohort and the fishery is currently based on age classes 2 and 3 of which age class 2 is not yet fully recruited.

Recruitment is the most important factor determining the size of the population. However, no regular recruit surveys (e.g. on age class 1) have been carried out to estimate the strength of the incoming year class. Advice on the total allowable catch (TAC) in the following season is largely dependent on the abundance estimate of age class 2 derived from Virtual Population Analysis (VPA). Historical recruitment has varied by a factor of up to 19 between seasons. Short-term catch predictions based on mean recruitment values are thus only of limited value (Kock and Köster, 1989).

In its Report of the Seventh Meeting, CCAMLR requested its Scientific Committee to provide advice on management options and their consequences for heavily exploited fish stocks. Such advice should consider, *inter alia*: the likely trajectories of catch and spawning stock biomass under different patterns of fishing mortality including:

- different constant levels of F including $F_{0.1}$; and
- a complete ban, or a low value of F for a short period followed by a higher level.

The Commission further noted that its decisions in respect to fisheries management would be facilitated by alternative management recommendations and their consequences for each of the fisheries requiring management. This should include, beside TACs for the current season, a forecast for catch levels in the following season based upon realistic assumptions about fishing mortality and recruitment (CCAMLR, 1988a, p. 26-27).

In the following we have tried to demonstrate the effect of some of the harvesting strategies mentioned above in the stock of *C. gunnari* around South Georgia. The effects of factors such as stock size, spawning stock size and environment on the size of the recruiting year class are presently not known. We have therefore used the historical recruitment pattern for our simulations. Hennemuth et al. (1987) used a probabilistic model based on recruitment series of 18 fish stocks from various parts of the world in their analysis of South Georgia fish stocks.

2. MATERIAL AND METHODS

Simulations of catch and spawning stock biomass (SSB) under different potential harvesting regimes reflecting the Commission's requests were performed for a period of 30 years (1988/89 to 2017/18) using the ICES Standard Prediction Program (Anon., 1981). Input data such as the preliminary catch and the actual stock size in 1988/89, partial recruitment to fishing mortality values, estimates of natural mortality, maturity ogives and weight-at-age values were those used by Kock and Köster (1989) for their short-term projections (Table 1). Future recruitment was assumed to follow the historical pattern as has been derived from Virtual Population Analysis for the period 1971/72 to 1984/85 (Figure 1) (Kock and Köster, 1989). Growth, maturity, natural mortality and partial recruitment had been assumed not to change over the 30 years.

The first harvesting option included different levels of constant fishing mortality at $F_{0.1}$ (0.252), F_{max} (0.596) and $2xF_{max}$ (1.192) (Kock and Köster, 1989) throughout the whole period (1 a, b, c).

The second option was harvesting constantly at 50% $F_{0.1}$, with an increase of F three years after a good recruitment of age class 1 (> 900 x 10^6 individuals) had been observed. The increase in fishing mortality was adjusted not to exceed the cumulative values of $F_{0.1}$ (7.308), F_{max} (17.284) and $2xF_{max}$ (34.569) for the 30 year period (2 a, b, c).

The third option differed from the second option by a delay in the increase of F to five years after a good recruitment (3 a, b, c).

The fourth option simulated the effects of pulse fishing at an interval of three years without any harvesting in between (4 a, b, c).

Mesh size regulations as a means of protecting juvenile fish and first spawners of *C. gunnari* is under debate in CCAMLR at present (CCAMLR, 1988b; Kock, 1989). A change in net selectivity either by an increase of mesh size and/or the introduction of different mesh types (e.g. square meshes) is likely to occur. This would result in a change in the exploitation pattern. We have therefore simulated the effect of decreased partial recruitment of the youngest age classes by shifting the age-specific mortalities from the VPA one year forward. Partial recruitment values were recalculated for a reference F averaged over age classes 4 to 8 (Table 2). In order to keep results easier to understand we have only presented results for $F_{0.1}$ (recalculated option 1a) and F_{max} (recalculated option 1b) here.

3. RESULTS

Catch and spawning stock biomass projections for different harvesting strategies are presented in Figures 2 to 15. Key results for each projection are given in Table 2. These are: the cumulative catch over the 30 year period; the average spawning stock biomass with corresponding coefficients of variation (CV); and the number of years with a spawning stock biomass of less than 100 000 tonnes, of less than the 1988/89 level of 53 400 tonnes and of less than the lowest spawning stock biomass recorded of 24 800 tonnes.

3.1 Variation of Catch and Spawning Stock Biomass Estimated for Different Harvesting Strategies at Constant Levels of F

Cumulative catch is lowest when harvesting is carried out constantly at 50% $F_{0.1}$ with an increase of F three years after a good recruitment (option 2) (Table 3). Cumulative catch is highest at the same level of F but with an increase of F five years subsequent to a good recruitment (Table 3). Pulse fishing at an interval of three years (option 4) resulted in a cumulative catch higher than that for option 2, but lower than that obtained when fishing constantly at $F_{0.1}$ and F_{max} (option 1) (Table 3).

The lowest average spawning stock biomass is observed at a cumulative F of 7.308 for option 3. Both other levels of F for the same option, however, result in the highest average spawning stock biomass (Table 3). The high coefficients of variation within option 3 a, b, c are due to an increase in spawning stock biomass up to 290 000 tonnes when fishing at 50% of $F_{0.1}$ until five years after a good recruitment. After the increase of F to a level of 0.735, however, spawning stock biomass drops substantially to less than 125 000 tonnes (Figure 4). At a cumulative level of F of 17.286 spawning stock biomass will decrease to less than 100 000 tonnes in 16 of the 30 years. In five out of the 30 years it would even fall below the 1988/89 level (Figure 8). At a cumulative level of F of 34.569 spawning stock biomass would be less than the 1988/89 level in even 10 out of 30 years. This would include two years with spawning stock biomass below the lowest observed level of 24 800 tonnes (Figure 12).

The highest spawning stock biomass is achieved when fishing is carried out constantly at $F_{0.1}$ (option 1a). Both other levels of F within option 1, F_{max} and $2xF_{max}$, lead to the lowest average spawning stock biomass (Table 3). In contrast to option 3, the coefficients of variation in option 1 are considerably lower. At a cumulative F of 17.286 (option 1b) spawning stock biomass is expected to fall below 100 000 tonnes in 12 years out of 30 including five years when spawning stock biomass will fall below the 1988/89 level (Figure 6). At a cumulative F of 34.569 (option 1c) spawning stock biomass will fall below the 1988/89 level in eight out of 30 years including two years below the lowest spawning stock size observed (Figure 10).

Fishing constantly at 50% $F_{0.1}$, with an increase in F three years after a good recruitment (option 2) and pulse fishing (option 4), result in average levels of spawning stock biomass with the lowest coefficients of variations for option 2 compared to relatively high CVs for option 4 (Table 3). Consequently, option 2 leads to the lowest number of extreme spawning stock biomass estimates. At a cumulative level of F of 17.286, for example, spawning stock biomass would never fall below the 1988/89 level (Figure 7). At the same level of F, pulse fishing (option 4) would result in a spawning stock biomass to be less than the 1988/89 level in four out of the 30 years including one year with a spawning stock size below the lowest observed value (Figure 9).

3.2 Variation of Catch and Spawning Stock Size Estimated for Different Levels of F

The cumulative catch is 904 000 to 922 000 tonnes at $F_{0.1}$ (options 1a, 2a, 3a, 4a; Table 3), 1 039 000 to 1 160 000 tonnes at F_{max} (options 1b, 2b, 3b, 4b; Table 3) and 1 044 000 to 1 175 000 tonnes at $2xF_{max}$ (options 1c, 2c, 3c, 4c; Table 3) respectively. Under constant mortality policies (option 1) fishing at F_{max} gives a higher catch than $F_{0.1}$ and $2xF_{max}$ (1 074 000, 922 000 and 1 073 000 tonnes). However, if fishing mortality varies from year to year within the same cumulative total, the picture changes. The highest fishing mortality ($2xF_{max}$) will then give the highest catches, especially if fishing is timed to increase five years after good recruitment.

The corresponding average spawning stock biomass is 168 000 to 172 000 tonnes at $F_{0.1}$, 105 000 to 125 000 tonnes at F_{max} and 69 000 tonnes at $2xF_{max}$ respectively (Table 3). Average spawning stock biomass is thus 26 to 39% at F_{max} and 36 to 60% at $2xF_{max}$ lower than spawning stock size at $F_{0.1}$.

3.3 Variation of Catch and Spawning Stock Biomass for Different Sets of Partial Recruitment Values

Variation of catch and spawning stock biomass due to changes in partial recruitment (= net selectivity, option 5) for harvesting at $F_{0.1}$ and F_{max} constantly are shown in Figures 14 and 15.

For harvesting at $F_{0.1}$ the cumulative catch will be reduced by 4% to 886 000 tonnes if partial recruitment is shifted by one year forward from the present stage. Average spawning stock biomass, however, will increase by 19% to 206 000 tonnes (Table 3). For fishing at F_{max} the cumulative catch will increase by 2% to 1 094 000 tonnes and spawning stock biomass will be raised by 38% to 145 600 tonnes (Table 3). The coefficient of variation will slightly increase after the change in partial recruitment. Spawning stock biomass, however, will be continuously higher throughout the 30 year period (Figures 14 and 15). Consequently, fishing at F_{max} will never reduce spawning stock biomass below the 1988/89 level.

4. DISCUSSION

With the exception of fishing, it is the size of the recruiting year class that effects the future stock size of *C. gunnari* around South Georgia far more than changes in growth, maturity or natural mortality (Hennemuth et al., 1987; Kock and Köster, 1989). Maturity and weight-at-age had not changed significantly in the course of the fishery (Kock, 1989; Kock and Köster, 1989). For this reason we assumed for our projections of future catches and spawning stock size that growth, maturity and natural mortality would not change over time. Partial recruitment values have been assumed to remain constant as well. However, as partial recruitment values are likely to change over a 30 year period of time due to alterations in the fishery, we have investigated that effect in a separate set of simulations by shifting partial recruitment values one year forward.

The aim of our simulations has not been to model or predict future recruitment, but to assess the effect of different harvesting strategies on a stock with highly fluctuating recruitment. Historical recruitment derived from VPA analysis has followed a cyclic pattern (Kock and Köster, 1989) which seemed to be largely independent of spawning stock size. We have therefore assumed that future recruitment will follow the historical pattern instead of applying randomly fluctuating recruitment values estimated from a probabilistic model to our data (see Hennemuth et al., 1987). It is obvious that this should have affected our results, as yield from a series of good year classes should be higher that from a single one. On the other hand a series of poor year classes would likely result in a reduction of spawning stock biomass below the level derived from randomly fluctuating recruitment values.

Article II, 3a of the Convention for the Conservation of Antarctic Marine Living Resources states that "Any harvesting [....] shall be conducted in accordance [....] with the following principles of conservation:

> prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment." (CCAMLR, 1988).

No stock-recruitment relationship seems to be apparent in *C. gunnari* around South Georgia. It is likely, however, that a larger and relatively stable spawning stock would minimize the risk of recruitment failure, in particular since spawning stock sizes derived from VPA analysis tend to overestimate the number of fish actually spawning (Kock, 1989). We have used estimates of average spawning stock biomass, their corresponding coefficients of variations and the number of years when spawning stock size was below a certain level (see Table 3) as a measure of overall level of spawning stock biomass and spawning stock 'stability'.

Of all the options studied, fishing at constant $F_{0.1}$ (option 1a) would result in the second largest cumulative catch and a high and relatively stable spawning stock. Fishing at higher levels of constant F (F_{max} and $2xF_{max}$, options 1 b, c) would produce average cumulative yields and an average stability relative to the other options.

Harvesting at a low constant level of F (50% $F_{0.1}$) and an increase of F three years after a good recruitment (option 2) would result in the lowest cumulative yield of all options, the highest stability of the spawning stock and an average spawning stock size relative to the other options.

Fishing at a constant level of F of 50% $F_{0.1}$ and an increase of F five years after a good recruitment (option 3) would result in the highest cumulative catch of all options coupled with a relatively low stability of the spawning stock.

Pulse fishing (option 4) would produce an average cumulative yield with the lowest stability of all options. Spawning stock size would be at an average level.

Throughout all options fishing at F_{max} would produce a cumulative yield 15 to 19% (= 4 500 to 6 000 tonnes per year) higher and an average spawning stock biomass 26 to 39% lower compared to fishing at $F_{0.1}$. Harvesting at $2xF_{max}$ would increase cumulative yield by 16 to 22% (= 4 700 to 6 600 tonnes per year) and reduce average spawning stock biomass by 36 to 60% compared to fishing at $F_{0.1}$. Stability of the spawning stock would decrease with increasing cumulative F.

Shifting of partial recruitment values one year forward as a result of changes in net selectivity would produce a reduction in cumulative catch by 4% and an increase in spawning stock biomass by 19% relative to the present values when fishing at $F_{0.1}$. If harvesting is maintained at F=0.596 (the present value of F_{max}) then shifting partial recruitment values one year forward will increase cumulative yield by 2% and spawning stock size by 38% relative to the present partial recruitment values.

No regular fishery-independent recruitment surveys have been carried out around South Georgia so far. Information on age class 1 is only available from the VPA and is known to have a high degree of uncertainty, at least for the most recent years in the VPA.

In the absence of any reliable prediction of the strength of the incoming cohort from fishery-independent sources (surveys, recruitment models) the application of a harvesting strategy with a constant low F (50% $F_{0.1}$) and an increase of F three years after a good recruitment (option 2) seems to have little meaning at present.

Abundance estimates of age class 1 from the VPA four years after recruitment (to establish a TAC for five years after a good recruitment) are likely to be more reliable than after two years. This seems to favour option 3. However, this estimate is still entirely based on fishery-dependent information. Any false prognosis would further destabilize the spawning stock which is already less stable than predicted for options 1 and 2.

Pulse fishing had been mentioned as one potential alternative strategy in harvesting Antarctic finfish (Gulland, 1983). Pulse fishing at a three year interval (option 4) would destabilize the spawning stock most, but would only produce average cumulative yields.

In the present state, fishing at a constant level of F is likely to be the most meaningful and least risky harvesting strategy for *C. gunnari* around South Georgia. The most appropriate level of F seems to be $F_{0.1}$. Fishing at F_{max} would produce an annual catch which is only 3 000 tonnes higher relative to fishing at $F_{0.1}$ but an average spawning stock biomass which is 39% less than at the $F_{0.1}$ level. Spawning stock biomass would fall five times below the 1988/89 level, which may bear additional risks for recruitment failure. Fishing at a high spawning stock biomass would be more renumerative (in catch-per-unit-effort) than on a low spawning stock biomass.

A cautious increase of F beyond the level of $F_{0.1}$, however, seems to be feasible if net selectivity experiments are able to demonstrate that an increase in mesh size and/or the introduction of new mesh types would lead to the forward shift in partial recruitment values assumed in our simulations.

After regular fishery-independent recruitment surveys have been established to predict the strength of the incoming cohort, an adjustment of F values to the recruitment of good (or poor) year classes (options 2 and 3) should also be practicable. Fishing mortality should be increased later than three years after a good recruitment (option 3). An increase after only three years (option 2) would not produce a higher yield. As the higher yield in option 3 is coupled with a higher instability of the spawning stock, F should only be increased moderately.

The intention of our paper is to provide a starting point for discussing alternative strategies. However, it should be kept in mind that additional risks exist when converting fishing mortality into TAC. Estimates of stock size are usually derived from research vessel surveys which do have a considerable variability. TACs may therefore miss the target F by a substantial margin.

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Table 1: List of input values for yield and stock projection of *Champsocephalus gunnari* in Subarea 48.3.

The reference F is the mean F for the age-group range from 3 to 7.

Assumed catch in 1988/89 = 23 000 tonnes

Data are listed in the following units:

Number of fish:	numbers x 10^3
Weight by age-group in the catch:	g x 10^3
Weight by age-group in the stock:	g x 10^3

Age	Stock Size	Partial Recruitment	Natural Mortality	Maturity Ogive	Weight in the Catch	Weight in the Stock
1	558816	0.0342	0.3500	0.0000	0.034	0.034
2	385993	0.2591	0.3500	0.7750	0.086	0.086
3	38636	0.7719	0.3500	0.8070	0.153	0.153
4	32682	0.9980	0.3500	1.0000	0.243	0.243
5	25915	1.0568	0.3500	1.0000	0.337	0.337
6	11744	1.0987	0.3500	1.0000	0.482	0.482
7	2202	1.0746	0.3500	1.0000	0.632	0.632
8	210	1.0000	0.3500	1.0000	0.805	0.805
9	43	1.0000	0.3500	1.0000	1.142	1.142

Table 2: Set of partial recruitment values reflecting a change in mesh selectivity in the fishery on *Champsocephalus gunnari* in Subarea 48.3.

Age	Partial Recruitment
1	0.0002
2	0.0364
3	0.2690
4	0.7928
5	1.0143
6	1.0943
7	1.0995
8	1.0709
9+	1.0000

Table 3: Simulated harvesting strategies of *Champsocephalus gunnari* in Subarea 48.3, total catch during the 30 year period of projection, average spawning stock biomass (SSB) and corresponding coefficients of variation (CV) as well as numbers of years with SSB below 100 000 tonnes, below the 1988/89 level of 53 400 tonnes and below the lowest value on record of 24 800 tonnes.

Option	Harvesting Strategy	Cumulative F	Total Catch (tonnes)	SSB	CV	Number of Years with SSB Below:		
						100 000 tonnes	1988/89 level	Lowest Level
1a	Constant fishing at $F_{0.1}$ (0.252)	7.308	922 041	172 749	0.404	6	0	0
2a	Constant fishing at 50% $F_{0.1}$, increased F(0.735) three years after good recruitment	7.308	903 726	170 426	0.344	6	0	0
3a	Constant fishing at 50% $F_{0.1}$, increased F(0.735) five years after good recruitment	7.308	977 841	167 999	0.415	6	0	0
4a	Pulse fishing (F=0.812) with a period of three years	7.308	912 045	170 428	0.435	7	1	0
1b	Constant fishing at F_{max} (0.596)	17.284	1 074 106	105 564	0.418	12	5	0
2b	Constant fishing at 50% $F_{0.1}$, increased F(2.398) three years after good recruitment	17.286	1 039 179	116 482	0.390	12	0	0
3b	Constant fishing at 50% $F_{0.1}$, increased F(2.398) five years after good recruitment	17.286	1 159 527	125 223	0.617	16	5	0

Table 3 (continued)

Option	Harvesting Strategy	Cumulative F	Total Catch (tonnes)	SSB	CV	Number of Years with SSB Below:		
						100 000 tonnes	1988/89 level	Lowest Level
4b	Pulse fishing (F=1.92) with a period at three years	17.280	1 073 940	110 521	0.533	17	4	1
1c	Constant fishing at 2xF_{max}	34.569	1 073 067	69 716	0.461	26	8	2
2c	Constant fishing at 50% three years after good recruitment	34.569	1 044 465	86 567	0.499	21	6	2
3c	Constant fishing at 50% $F_{0.1}$, increased F(4.321) five years after good recruitment	34.569	1 175 421	106 911	0.744	19	10	2
4c	Pulse fishing (F=3.841) with a period of three years	34.569	1 109 625	82 749	0.636	22	9	3
5a	Constant fishing at $F_{0.1}$, changed mesh selectivity	7.308	885 610	206 036	0.412	6	0	0
5b	Constant fishing at F_{max} changed mesh selectivity	17.184	1 094 016	145 580	0.427	10	0	0

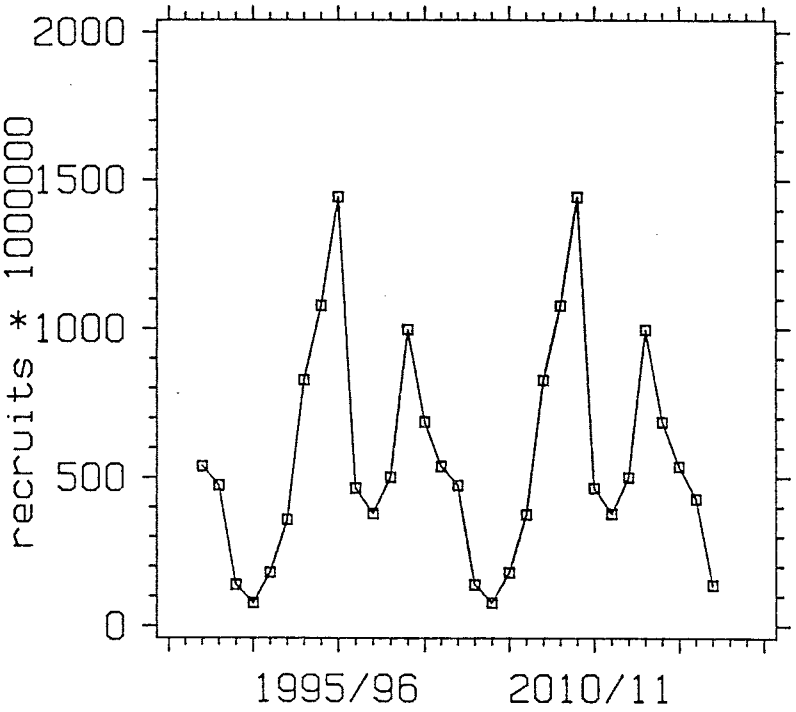


Figure 1: Historical pattern of recruitment in *Champsocephalus gunnari* around South Georgia (from Kock and Köster, 1989) used for the 30 year period of projection.

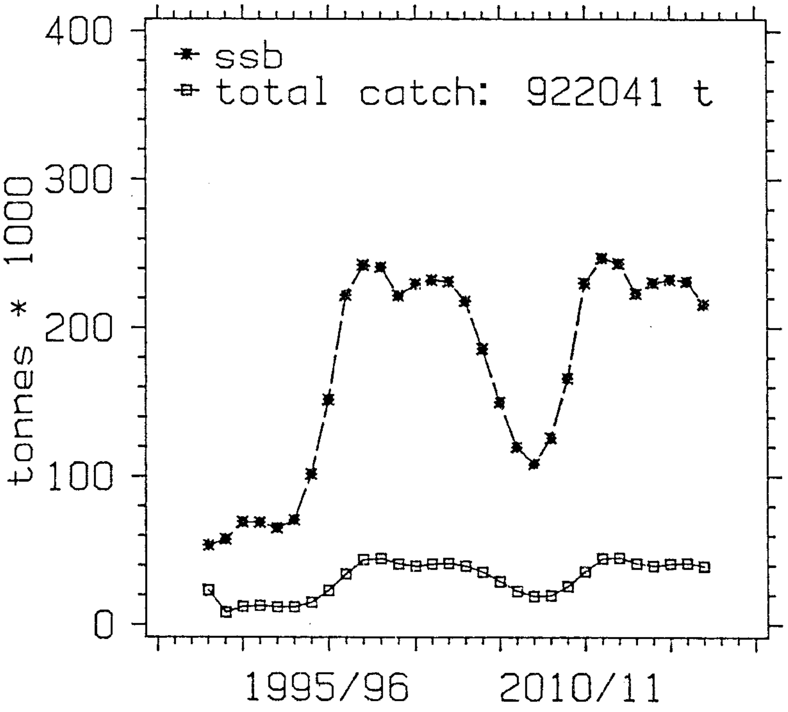


Figure 2: Catch and spawning stock biomass when fishing constantly at $F_{0.1}$ (0.252) (option 1a, Table 3).

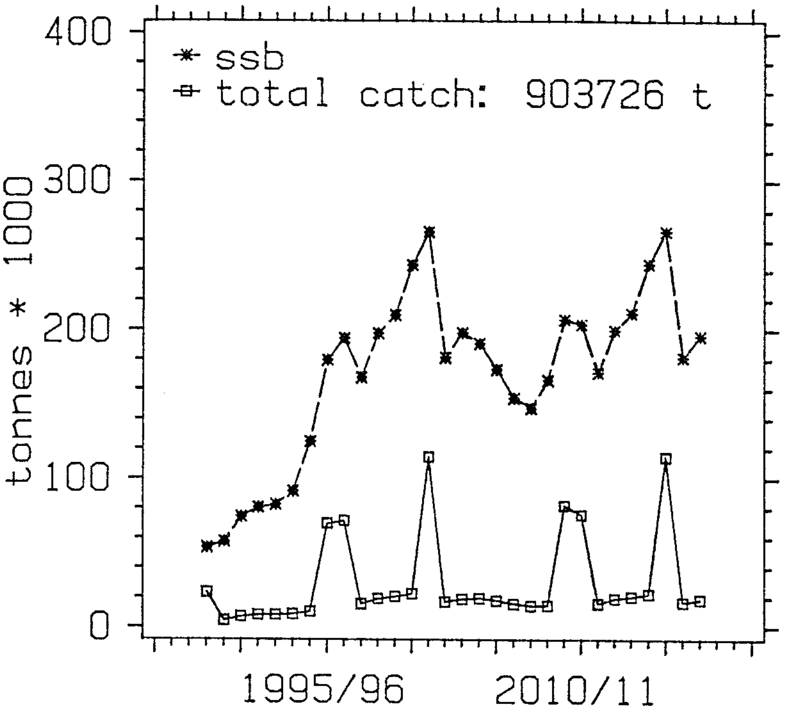


Figure 3: Catch and spawning stock biomass when fishing constantly at 50% $F_{0.1}$, with an increased F (0.735) three years after a good recruitment (> 900 x 10^6 individuals) (option 2a, Table 3).

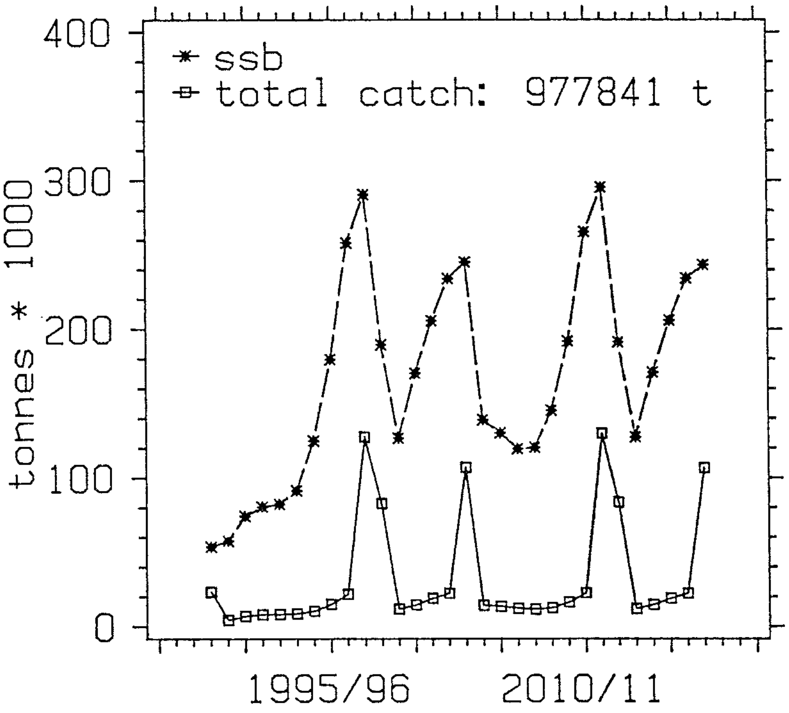


Figure 4: Catch and spawning stock biomass with an increased F (0.735) five years after a good recruitment (> 900 x 10^6 individuals) (option 3a, Table 3).

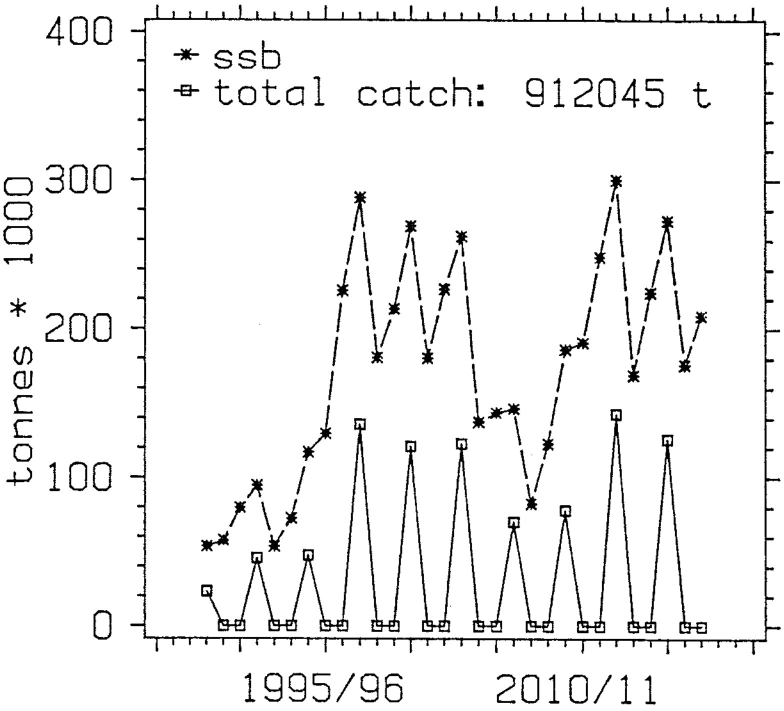
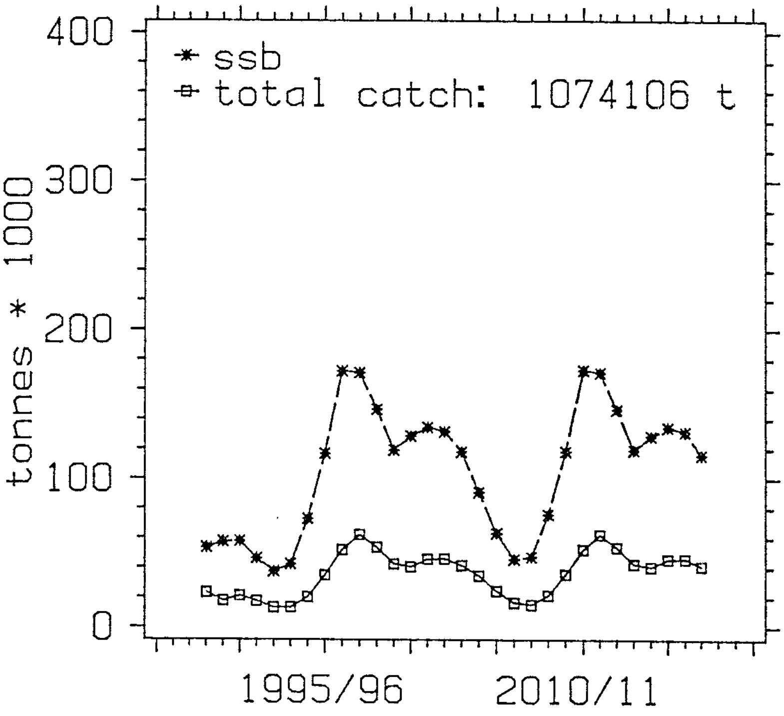


Figure 5: Catch and spawning stock biomass when pulse fishing (F=0.812) at an interval of three years (option 4a, Table 3).



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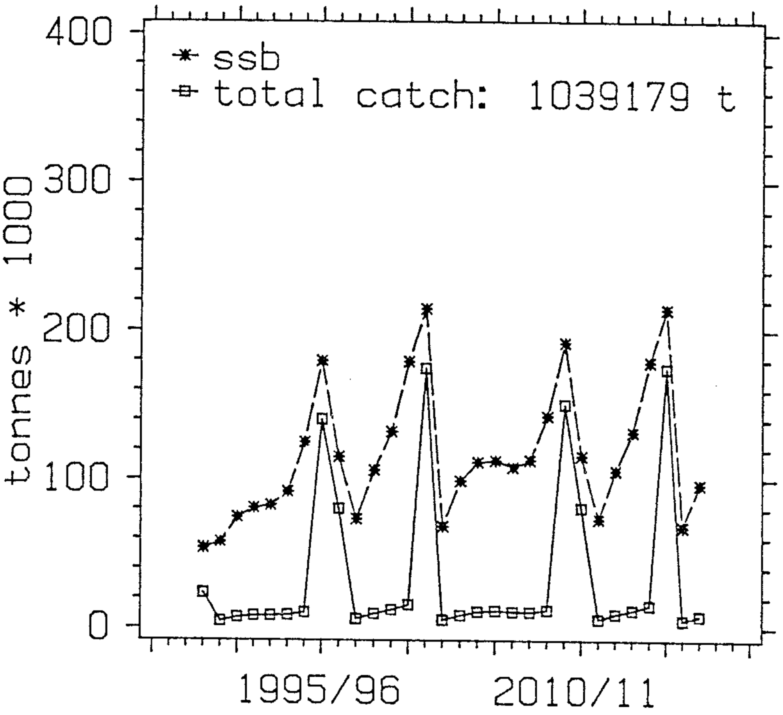

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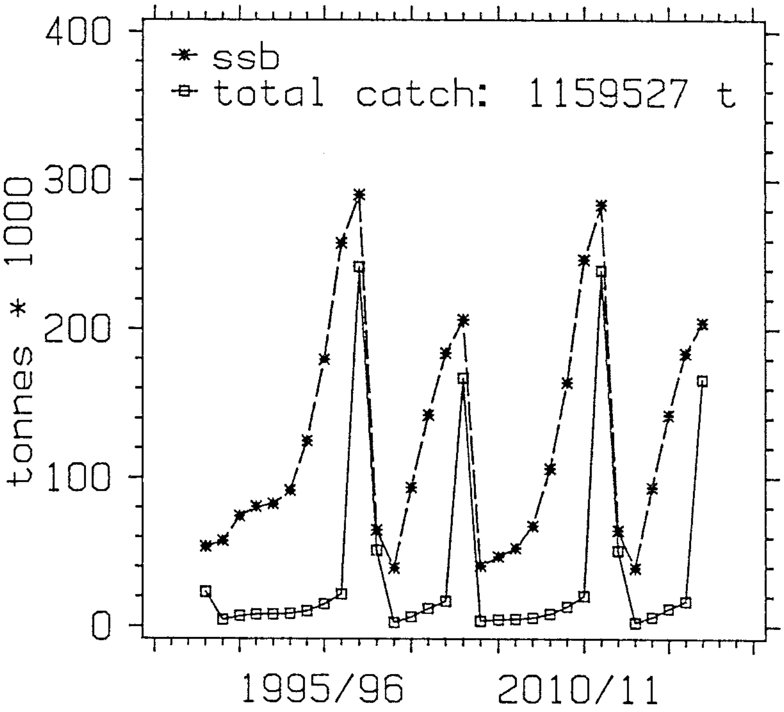

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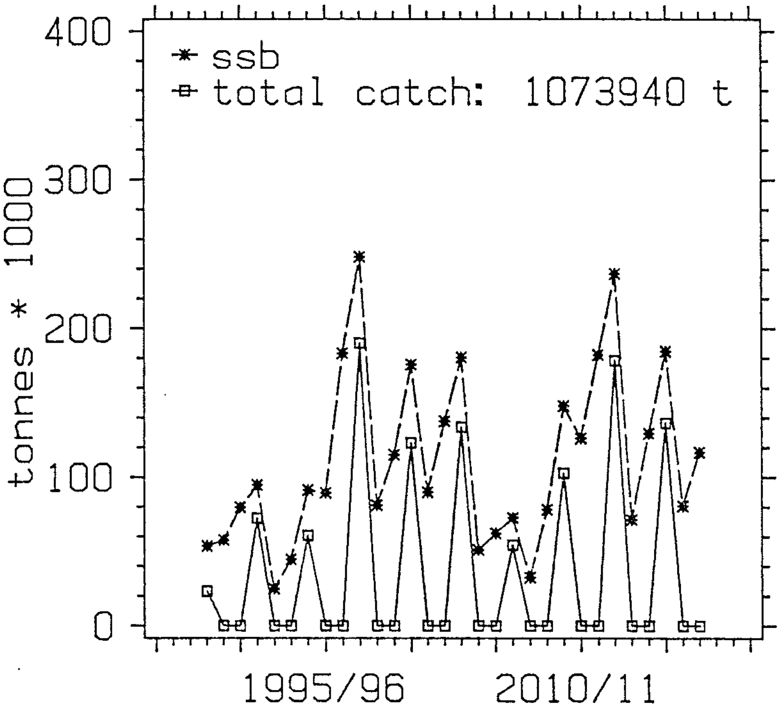

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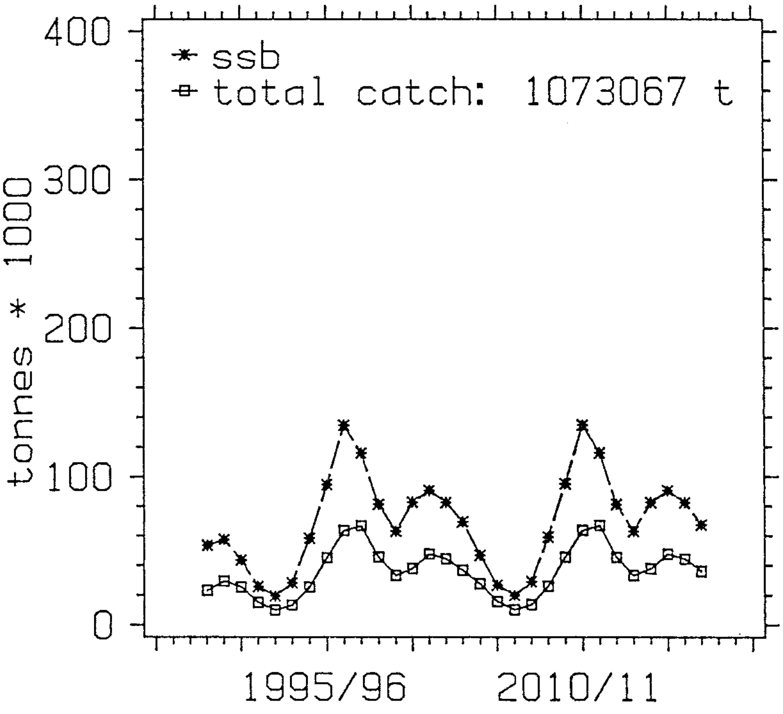

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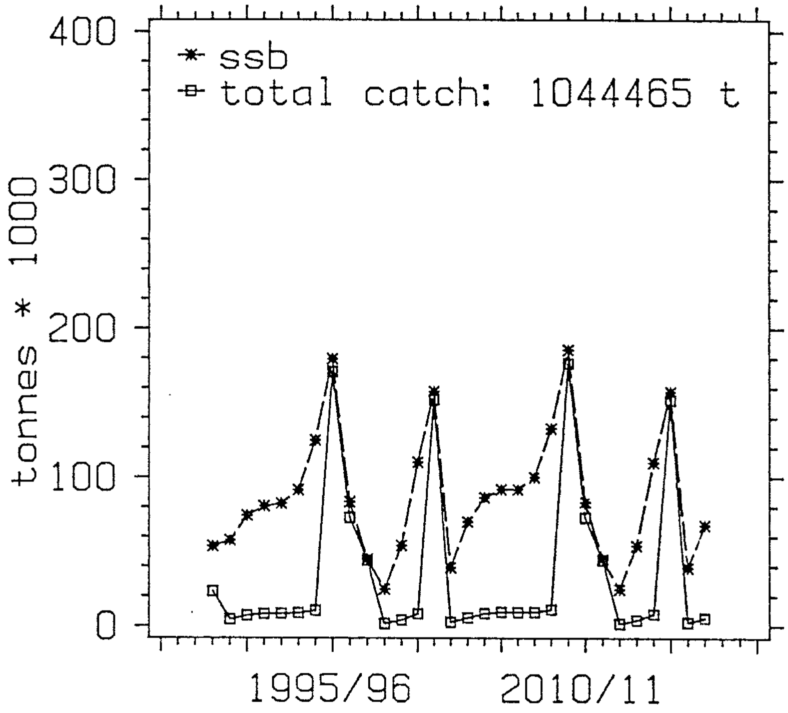

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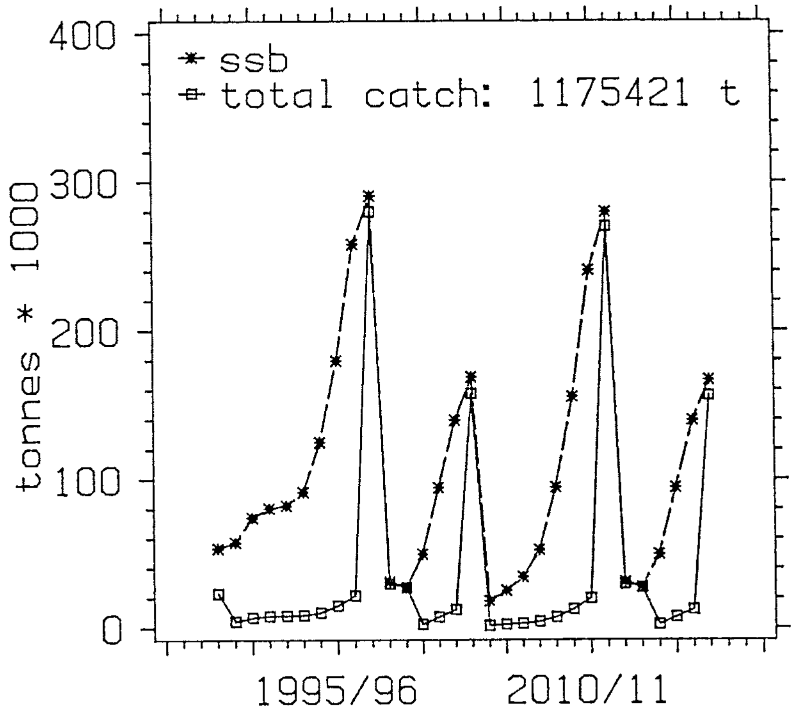

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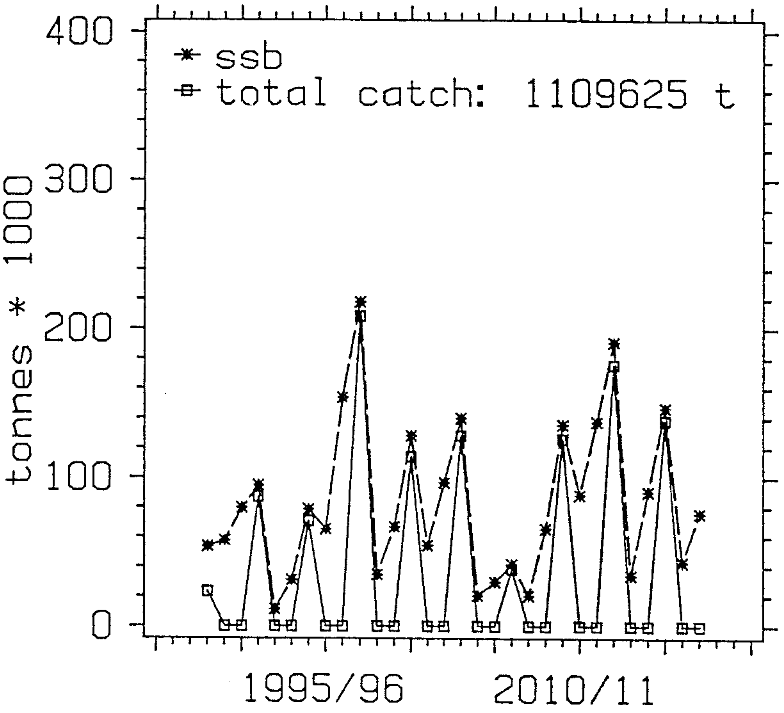

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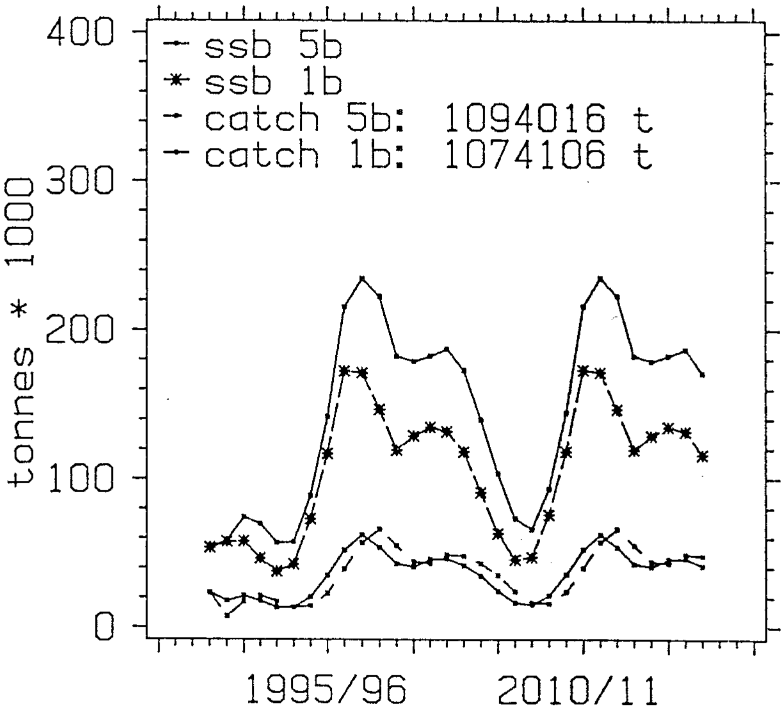

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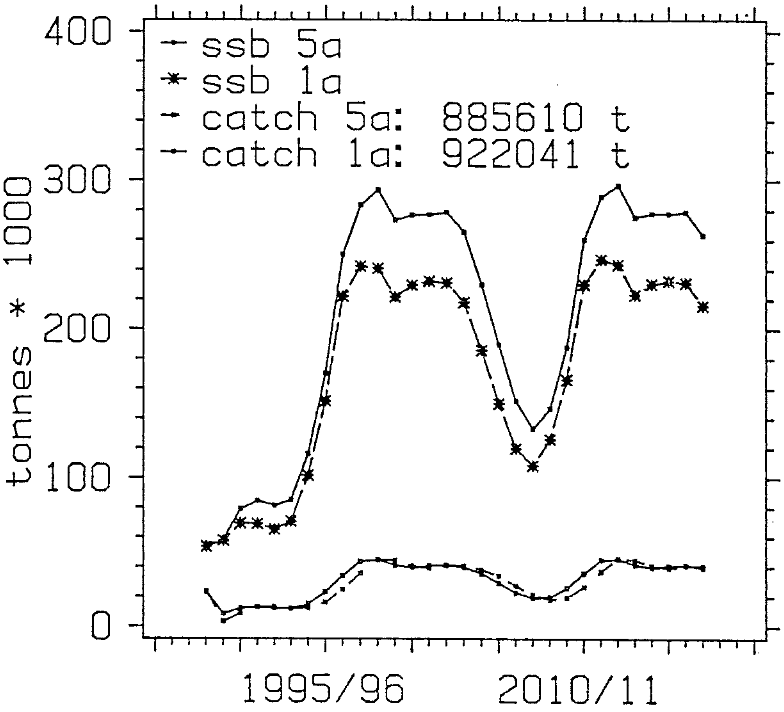

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1989/1990 STOCK STATUS AND TAC ASSESSMENT FOR *PATAGONOTOTHEN BREVICAUDA GUNTHERI* IN SOUTH GEORGIA SUBAREA (48.3)

V.I. Shlibanov

Abstract

The 1989/90 stock status and TAC assessments for *Patagonotothen brevicauda guntheri* from the South Georgia subarea (48.3) have been made using biostatistical material for 1978/79 through 1988/89 collected by Soviet scientists. VPA tuning has been accomplished using the regression equation between fishing mortality and standardized fishing effort for each age-class. Stock has been assessed at 123.1 thousand tonnes with a TAC of 28.3 thousand tonnes for the initial period of 1989/90 fishing season.

Résumé

Le statut du stock et les évaluations du TAC de *Patagonotothen brevicauda guntheri* provenant de la sous-zone de la Géorgie du Sud (48.3), pour l'année 1989/90, ont été réalisés à partir de matériaux biostatistiques rassemblés par les scientifiques soviétiques de 1878/79 à 1988/89. L'ajustement de la VPA a été effectué en utilisant l'équation de régression entre le taux de mortalité par pêche et l'effort de pêche standardisé pour chaque classe d'âge. Le stock a été évalué à 123 100 tonnes avec un TAC de 28 300 tonnes pour la première période de la saison de pêche de 1989/90.

Резюме

На основе биостатистического материала за 1978/79-1988/89 гг. была проведена оценка TAC и состояния запаса *Patagonotothen brevicauda guntheri* в Подрайоне Южной Георгии (48.3) на 1989/90 г. Была проведена настройка VPA при использовании уравнения регрессии коэффициента промысловой смертности и стандартизованного промыслового усилия для каждого годового класса. Размер запаса на исходный период сезона 1989/90 г. был оценен в 123,1 тысячи тонн с TAC в 28,3 тысячи тонн.

Resumen

La evaluación de la condición de las poblaciones en 1989/90 y de la capturas totales permisibles (TAC) de *Patagonotothen brevicauda guntheri* de la subárea de Georgia del Sur (48.3) se ha hecho utilizando material bioestadístico recopilado por los científicos soviéticos desde 1978/79 hasta 1988/89. El ajuste de VPA se ha realizado usando la ecuación de regresión entre la mortalidad pesquera y el esfuerzo de pesca estandarizado para cada clase de edad. Reservas han sido evaluadas en 123.1 mil toneladas, con un TAC de 28.3 mil toneladas para el período inicial de la temporada de pesca de 1989/90.

1. BACKGROUND DATA

1.1 The Fishery

Over a period of eleven years the largest catches of Patagonian rockcod (*Patagonotothen brevicauda guntheri*) occurred during the 1980/81 and 1981/82 seasons (SC-CAMLR-VII, Annex 5). In the following years catches varied from 5 to 16 thousand tonnes but on the whole remained steady within a range of 10.5 to 13.4 thousand tonnes. In 1988/89, since the introduction of catch limits, Soviet vessels landed 13 016 tonnes of *P.b. guntheri*.

1.2 Age Composition of Catches

Data for the 1978/79 to 1987/88 seasons are taken from the document WG-FSA-89/5 from the Working Group on Fish Stock Assessment. Age composition of the 1988/89 catch is calculated using an age/length key for the last quarter of 1988 and comprehensive measurements taken in December 1988 and January 1989. Data on age composition of catches are given in Table 1.

1.3 Catch-Per-Unit Fishing Effort and Fishing Effort

The largest catch-per-unit-effort occurred in 1978/79, the first fishing season (Table 2), followed by a marginal decline in catches to a level which remained steady until 1984/85. The next three years witnessed a decline in catch-per-unit, although in 1988/89 this indicator rose to the average level of previous years.

Soviet BRMT (large refrigerator trawler) was used in assessments as a standard type of fishing vessel. Catch-per-unit-effort data for the seasons 1978/79 to 1988/89 were used. Values for standardized fishing effort are derived from the division of total catch-per-season by the value of catch-per-unit-effort of a standard vessel. These values are presented in Table 2.

1.4 Mean Fish Mass by Age-Group

There are no data on fish mass for the 1979/80 season. Weight values from Bertalanffy's weight-growth equation were used in the calculations for this period. Due to an absence of data for 1984/85, mean mass by age-groups has been taken from the previous season's data. A substantial increase in the fish mass of older age-groups was noted in subsequent years. Weight of fish of age-group one for 1988/89 was corrected to the mean value of previous years (5.3 grams).

The values of mean mass by age and fishing season are given in Table 3.

2. PARAMETERS

2.1 Natural Mortality Rate

Calculations of natural mortality rates by various methods produced the following results (Shlibanov, in press):

Baranov method	0.83
Beverton/Holt method	0.94
Beverton/Holt integral method	0.84
Chapman/Robson method	1.06
Rikhter/Efanov method	0.63
Alverson/Carney method	0.73

The majority of these methods, with the exception of Rikhter/Efanov, are based on length-age composition data on the population of *P.b. guntheri* fished for the first time (i.e. based on identical factual material). Thus M varies from 0.73 to 1.06. For this calculation the value M = 0.9 is assumed.

2.2 Age at Sexual Maturity

According to Lisovenko and Pinskaya's data (1987), 50% of fish reach sexual maturity at a length of 15.6 to 16.5 cm, while semi-mature specimens are first noticed at a length of 11 to 13 cm at an age of two years. Our studies indicate that mass maturation of *P.b. guntheri* occurs in the summer-autumn period when a length of 12 to 14 cm, which corresponds to the age of 2.5 years, is reached.

3. STOCK ASSESSMENT USING VPA

The VPA calculations were tuned by applying the formula of regression between fishing mortality rates and standardized fishing effort. At the final stage of the integration process the coefficients of correlation between these values were:

Age-Group	1	2	3	4	5	6
Coefficient of Correlation	-0.13	0.44	0.71	0.82	0.76	0.81

Calculated fishing mortality rates, abundance and biomass coefficients are presented in Tables 4,5 and 6 respectively.

Abundance estimation of age-group one for the last fishing season has been corrected to the mean value over the previous years.

The stock size of *P.b. guntheri* for 1988/89 has been estimated at 117.5 thousand tonnes.

4. YIELD-PER-RECRUIT

The calculation of yield-per-recruit using Thompson and Bell's method is given in Table 7. The following values were used in calculations:

$$F_{MSY} = 1.90; \; F_{0.1} = 1.12$$

5. TAC ASSESSMENT FOR 1989/90

Calculation of TAC was done with the following assumptions:

- mean fish mass is maintained at the 1989/90 level;
- rate of partial recruitment for 1978/79 to 1988/89 was calculated using fishing mortality rates;
- abundance of age-group one is assumed to be at a level of the mean value over previous years; and
- total fishing mortality rate for 1989/90 will be at a level of $F_{0.1}$.

Results of the TAC assessment are detailed in Table 8.

Within these parameters the stock size of *P.b. guntheri* at the beginning of the 1989/90 season is estimated at 123.1 thousand tonnes. TAC in 1989/90 is 28.3 thousand tonnes.

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SHLIBANOV, V.I. (In print). Growth and Natural Mortality of *Patagonotothen brevicauda guntheri* of the shelf of Shag Rocks.

Table 1: Age composition of catches of *P.b. guntheri* in Subarea 48.3.

Age-Group	Fishing Seasons										
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	33.00	11.80	80.90	34.50	19.10	55.10	84.60	20.80	2.68	4.00	0.71
2	274.90	21.30	467.50	320.30	46.20	36.20	173.70	454.80	57.88	79.90	109.76
3	160.50	91.70	306.70	382.00	43.00	58.90	102.60	77.40	177.31	238.80	102.15
4	97.90	84.70	336.10	232.10	47.30	125.00	83.20	70.10	70.59	95.00	147.55
5	9.90	8.20	60.00	59.70	10.40	36.00	18.90	29.40	15.72	21.10	3.62
6	6.30	0.90	6.10	4.70	1.30	3.20	2.50	5.60	10.37	13.90	0.28

Table 2: Total catch, catch-per-unit fishing effort of a BRMT type vessel and standardized fishing effort by fishing seasons.

Fishing Season	Total Catch (thousand tonnes)	Yield-Per-Recruit	Fishing Effort
1978/79	16.2	50.2	322.8
1979/80	8.6	46.1	186.4
1980/81	40.8	44.7	912.1
1981/82	35.3	43.4	814.3
1982/83	5.7	39.7	143.5
1983/84	12.8	44.9	285.3
1984/85	12.6	42.4	297.3
1985/86	16.2	26.2	617.8
1986/87	13.0	23.4	556.7
1987/88	17.5	19.4	902.9
1988/89	13.0	37.4	348.0

Table 3: Fish mass (g) of *P.b. guntheri* by age-groups for 1978 to 1989.

Age-Group	Fishing Seasons										
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	5.30	5.30	5.30	5.50	6.00	5.70	5.70	4.50	5.30	5.30	10.00*
2	13.50	13.50	14.00	11.50	14.50	13.30	13.30	14.50	20.70	23.30	14.70
3	25.20	25.20	27.30	21.60	28.50	25.80	25.80	22.50	31.60	37.90	32.80
4	39.00	39.00	37.00	42.50	39.00	39.60	39.60	36.30	60.30	59.50	52.00
5	51.70	51.70	46.30	58.50	51.50	52.10	52.10	49.50	95.10	90.00	87.30
6	72.70	72.70	66.30	90.00	69.50	77.30	77.30	57.00	137.20	130.00	120.00

* Determined from one specimen.

Table 4: Fishing mortality rates for *P.b. guntheri* in Subarea 48.3.

Age-Group	Fishing Seasons										
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	0.0057	0.0020	0.0165	0.0074	0.0055	0.0212	0.0231	0.0034	0.0007	0.0013	0.0093
2	0.0867	0.0090	0.2107	0.1749	0.0248	0.0259	0.1792	0.3579	0.0234	0.0560	0.0886
3	0.2330	0.0773	0.3757	0.6122	0.0657	0.0817	0.1988	0.2409	0.5239	0.2689	0.1977
4	0.8894	0.4099	1.1184	1.5359	0.3050	0.6282	0.3428	0.4510	0.8771	1.7980	0.6113
5	0.8723	0.3660	1.6682	1.9344	0.5602	1.0091	0.4012	0.4354	0.3797	2.6476	0.7069
6	0.8820	0.3888	1.3999	1.7440	0.4306	0.8170	0.3730	0.4441	0.6290	2.2266	0.6597

Table 5: Abundance (millions of specimens) of *P.b. guntheri* in Subarea 48.3.

Age-Group	Fishing Seasons										
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	8869.62	9057.55	7472.55	7070.36	5308.27	3981.80	5620.87	9359.16	5450.93	4814.57	116.68
2	4986.05	3585.78	3675.25	2988.29	2853.33	2146.41	1584.96	2233.20	3792.33	2214.53	1954.99
3	1151.11	1858.75	1444.74	1210.42	1019.93	1131.64	850.39	538.70	634.78	1506.22	851.30
4	236.47	370.72	699.49	403.41	266.81	388.31	423.99	283.40	172.13	152.84	468.02
5	24.23	39.50	100.04	92.94	35.31	79.96	84.23	122.35	73.40	29.11	10.29
6	15.30	4.12	11.14	7.67	5.46	8.20	11.85	22.93	32.18	20.41	0.84
Total	15282.80	14916.40	13403.20	11773.10	9489.20	7736.30	8576.30	12559.70	10155.70	8737.70	3402.10

Table 6: Biomass (thousands of tonnes) of *P.b. guntheri* in Subarea 48.3.

Age-Group	Fishing Seasons										
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
1	47.0	48.0	39.6	38.9	31.8	22.7	32.0	42.1	28.9	25.5	35.5
2	67.3	48.4	51.4	34.4	41.4	28.5	21.1	32.4	77.2	51.6	28.7
3	29.0	46.8	39.4	26.1	29.1	29.2	21.9	12.1	20.0	57.1	27.9
4	9.2	14.4	25.9	17.1	10.4	15.4	16.8	10.3	10.4	9.1	24.3
5	1.2	2.0	4.6	5.4	1.8	4.2	4.4	6.1	7.0	2.6	0.9
6	1.1	0.3	0.7	0.7	0.4	0.6	0.9	1.3	4.4	2.6	0.1
Total	154.9	160.1	161.7	122.7	114.9	100.6	97.1	104.3	147.9	148.6	117.5

Table 7: Yield-per-recruit values (Thompson/Bell method).

F	Y/R	F	Y/R
0.20	0.0013	1.15	0.0035
0.40	0.0022	1.20	0.0035
0.50	0.0025	1.30	0.0036
0.60	0.0027	1.40	0.0037
0.70	0.0029	1.50	0.0037
0.80	0.0031	1.60	0.0038
1.00	0.0033	1.70	0.0038
1.05	0.0034	1.80	0.0039
1.10	0.0034	1.90	0.0039

Table 8: Forecast of stock status and TAC calculated using predetermined rates of fishing intensity for *P.b. guntheri* in Subarea 48.3. Fishing intensity in the forecast period is equal to the optimal intensity according to Gulland's method of $F_{0.1}$ calculation: F_{OPT}=1.120.

Age-Group	Natural Mortality Rate	Rate of Partial Recruitment	Average Fish Mass (kg)	1989				1990			
				F	C (millions)	N (millions)	B (thousands)	F	C (thousands)	N (millions)	B (thousands)
1	0.900	0.0132	0.005	0.0093	0.71	6700.42	35.51	0.0148	0.34	6700.42	35.51
2	0.900	0.1827	0.015	0.0884	109.76	1954.72	28.73	0.2046	4.91	2698.97	39.67
3	0.900	1.0000	0.033	0.1977	102.15	851.15	27.92	1.1200	11.48	727.49	23.86
4	0.900	1.0000	0.052	0.6113	147.55	468.05	24.34	1.1200	7.10	283.97	14.77
5	0.900	1.0000	0.087	0.7069	3.62	10.29	0.90	1.1200	4.34	103.26	9.01
6	0.900	1.0000	0.120	0.6597	0.28	0.84	0.10	1.1200	0.12	2.06	0.25
				Total:	364.10	9985.40	117.50	Total:	28.30	10516.20	123.1

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WG-FSA-89/18

GROWTH AND NATURAL MORTALITY OF PATAGONIAN ROCKCOD (*PATAGONOTOTHEN GUNTHERI SHAGENSIS*) FROM SHAG ROCKS SHELF

V.I. Shlibanov

Abstract

The parameters of Bertalanffy's growth equation for Patagonian rockcod (*Patagonothen guntheri shagensis*) were calculated by using age and length-weight data of research and fishery survey cruises in the Shag Rocks area from 1978 to 1986. The natural mortality rate was assessed by six different methods and was within a range of 0.63 to 1.06. The mean value of natural mortality $\bar{M}=0.8$ was used in calculations and the optimal age and length for harvesting Patagonian rockcod were found to be 2.5 years and 12.6 cm.

Résumé

Les paramètres de l'équation de croissance de Bertalanffy, en ce qui concerne la bocasse de Patagonie (*Patagonotothen guntheri shagensis*) ont été calculés en utilisant des données d'âge et de longueur-poids provenant de campagnes d'évaluation menées par des navires de recherche et de pêche dans la région des Shag Rocks de 1978 à 1986. Le taux de mortalité naturelle a été estimé par six méthodes différentes et s'échelonnait entre 0,63 et 1,06. La valeur moyenne de la mortalité naturelle $\bar{M}=0{,}8$ a été utilisée pour les calculs, et l'on constate que l'âge et la longueur optimaux d'exploitation de la bocasse de Patagonie sont de 2,5 années et de 12,6 cm.

Резюме

Параметры уравнения Берталанффи для желтоперки (*Patagognothen guntheri shagensis*) были рассчитаны при использовании данных по возрасту и соотношению длина-вес, полученных в ходе рейсов по проведению научно-исследовательских и промысловых съемок в районе скал Шаг с 1978 по 1986 гг. Оценка коэффициента естественной смертности была проведена шестью различными методами, и его величина варьировалась в диапазоне от 0,63 до 1,06. В расчетах использовалась средняя величина естественной смертности $\bar{M}=0{,}8$, оптимальные промысловые возраст и длина желтоперки равнялись 2,5 годам и 12,6 см соответственно.

Resumen

Los parámetros de la ecuación de crecimiento de Bertalanffy para la trama Patagónica (*Patagonothen guntheri shagensis*) se calcularon empleando los datos de edad y talla-peso obtenidos de los cruceros de investigación y de estudio de pesca realizados en el área de Shag Rocks

desde 1978 a 1986. El índice de mortalidad natural fue evaluado por seis métodos diferentes y se mantuvo dentro de un rango de 0.63 a 1.06. El valor medio de mortalidad natural $\bar{M}=0.8$ se utilizó en las cálculos y la edad y talla óptimos para la pesca de la trama Patagónica se encontró que es de 2.5 años y 12.6 cm.

1. INTRODUCTION

The Patagonian rockcod was first found on the Shag and Black Rocks shelf in 1974 and was classified as a sub-species, *Patagonotothen guntheri shagensis* (Balushkin and Permitin, 1982). Studies of its biology and population dynamics in these areas were initiated in 1973 when commercial catches were first taken there. Although some information on the biology (Lubimova and Shust, 1982; Shust, 1986), feeding (Naumov et al., 1983) and reproduction (Lisovenko and Pinskaya, 1987) of *P.g. shagensis* can be found in current publications, this sub-species still remains a poorly studied commercial fish.

2. MATERIALS AND METHODS

The results of age determination and the data on the length-weight composition of *P.g. shagensis* populations obtained by the Soviet research and exploratory ships over the period from 1978 to 1986 period were used.

The Hohendorf method was used to estimate the Bertalanffy growth equation parameters, and the Kutty and Kasim method was used to determine the optimum length and age of *P.g. shagensis* for harvesting. The calculation of natural mortality rates was carried out by six different methods described in the Methodology Instructions of VNIRO (1984).

3. RESULTS AND DISCUSSION

3.1 Biological Characteristics

P.g. shagensis has distributed locally in the Antarctic waters. It inhabits waters south of the Antarctic Convergence and areas of its distribution are limited by the shelf waters of Shag and Black Rocks to the west of South Georgia Island (Balushkin and Permitin, 1982; Naumov et al., 1983).

This small size notothenia is a near bottom - pelagic species and inhabits depths down to 320 m with temperature ranging from 1.5 to 2.6°C and the salinity from 33.8 to 34.0‰. *P.g. shagensis* forms aggregations during the warm season (December to March). The length of fish in catches is from 8 to 24 cm, the prevailing length is 11 to 18 cm and the weight is between 10 and 120 g with the mean weight of about 40 g.

The maximum age of *P.g. shagensis* is 7 years and fish of 2 to 5 years are most abundant. Sexual maturity is attained by fish at 11 to 13 cm length, 20 to 30 g weight and age of 2 to 3 years. The sex ratio of fish is actually the same in all size classes. Depending on the length, the fecundity of *P.g. shagensis* ranges from 8 000 to 29 000 eggs (Lisovenko and Pinskaya, 1987).

P.g. shagensis is a planktophagous fish and feeds mainly on Antarctic krill, amphipods (mainly *Parathemistro gaudichaudii*) and copepods (Naumov et al., 1983). The feeding intensity is highest during the spring/summer period (October to February). The fish feeds mainly at night. The daily food ration is about 5.3% of the fish weight. Competitors for food are mackerel icefish, marbled rockcod, *Notothenia kempi* and grey rockcod. Among the predators are Patagonian toothfish and marbled notothenia.

4. AGE AND GROWTH

The scales were used for ageing *P.g. shagensis*. This method is less labour-consuming and yields satisfactory results as compared with other methods based on other age-registering structures (Table 1).

From the extensive data, the growth of *P.g. shagensis* was found to be isometric (Figure 1). The weight-length ratio is described by the formula (4.6% accuracy[*]):

$$W = 0.0046\ L^{3.27}$$

The calculations made according to Hohendorf method gave the following parameters of the Bertalanffy equation:

linear growth: $K = 0.3258$, $L = 23.31$ cm, $t_o = 0.1149$
weight growth: $K = 0.3646$, $W = 104.26$ g, $t_o = 0.3838$

The accuracy[*] of these values are 0.90% (linear growth) and 7.25% (weight growth).

5. NATURAL MORTALITY

The natural mortality rate was estimated using the following methods:

(i) Baranov method. The data on age and age/length key (Figure 2) for the second half of 1978 (i.e. prior to the beginning of the fishery) were used. The value of M was estimated by comparing natural logarithms of fish in each age-group (Table 2) and by using the graphic method (Figure 3). In both cases the value of M was 0.83.

(ii) Beverton and Holt method with F=0:

$$M = Z = \frac{1}{\bar{T} - t'} = 0.94$$

where $\bar{T}$ = mean age of fish, 3.42 years
t' = age of year class which is fully represented in catches and does not experience the effect of selectivity of fishing gears used, 2.35 years.

The age composition of *P.g. shagensis* before the beginning of fishing is shown in Figure 2. The mean age of fish was determined from the data on age composition:

$$\bar{T} = 2 \times 0.07 + 3 \times 0.57 + 4 \times 0.24 + 5 \times 0.11 + 6 \times 0.0095 = 3.42 \text{ years}$$

The analysis of the age composition curve shows that not all two year old fish were represented in catches, but only those of a particular length. Using the data of trawl surveys carried out by trawls with small mesh size covers, we managed to evaluate experimentally this length: l'=12.075 cm (n=165). By using this value of l' in the Bertalanffy equation of linear growths, we calculated the age of fish which should be fully represented in catches:

---

[*] A definition of the term "accuracy" is not provided by the author - Ed.

$$t' = t_o \frac{\ln\left(1 - \frac{l'}{L}\right)}{K} = 0.1149 - \frac{\ln\left(1 - \frac{12.075}{23.31}\right)}{0.3259} = 2.35 \text{ years}$$

The calculation of the original equation with estimated values of $\bar{t}$ and t' gave M=0.94.

(iii) Integral method of Beverton and Holt with F=0:

$$M = Z = \frac{(L_\infty - l')\,K}{\bar{l} - l'} = 0.84$$

where $\bar{l}$ = mean fish length in catches taken in the second half of 1978, $\bar{l}$=15.21(n=1470),
l' = length of fish of the youngest age-group fully represented in catches, l'=12.07 cm.

(iv) Method of Chapman-Robson with F=0:

$$M = Z = \ln \bar{t} - \ln\left(1 + \bar{t} - \frac{1}{n}\right)$$

where $\bar{t}$ = assumed mean age of fish in a sample,
n = number of fish in a sample.

The calculations were based on age composition data for the second half of 1978. The calculations were made starting with modal age class of 3 years (Figure 2). For recording the results of age composition the assumed mean age was applied.

The age of the youngest year class which was fully represented in catches, was taken to be zero (Table 3). This routine calculation was used to obtain the sum of years T, (i.e. the number of years lived together by all specimens caught):

$$T = 0 \times 832 + 1 \times 360 + 2 \times 157 + 3 \times 14 = 716 \text{ years}$$

and the assumed mean age:

$$\bar{t} = \frac{T}{n} = 0.525$$

By substituting the values of $\bar{t}$ and t' in the original equation the value of M=1.06 was obtained.

(v) According to the method of Rikhter-Efanov, the following empiric relationship exists between the mean value of M and time of mass maturation (t):

$$M = \frac{1.521}{t^{0.72}} - 0.155 = 0.63$$

Lisovenko and Pinskaya (1987) reported that the length of fish at first maturation is 11 to 13 cm (i.e. 2 years old). According to their data, 50% of fish attain sexual maturity at a length of 15.6 to 16.5 cm.

Our observations showed that mass maturation of *P.g. shagensis* takes place during summer/autumn (January to March) when fish is 12 to 14 cm length. This period corresponds with the age of 2.5 years. According to these data the value of M will be 0.63.

(vi) Method of Alverson-Carney:

$$M = \frac{3K}{e^{tK} - 1}$$

where K = growth coefficient from Bertalanffy equation (0.3646),

T = the age of fish which corresponds with maximum biomass.

In accordance with data from 1978 to 1986, the age of fish which corresponds with maximum biomass ranges from 2 to 4 years depending on the fluctuation of fish abundance. The long-term mean age was estimated at 2.5 years. Hence, with T=2.5 years, the natural mortality rate will be 0.73.

The range of variation of M calculated by different methods is considerable: from 0.63 to 1.06. In the absence of the objective criterion for selecting any of these values the arithmetical mean of the series of calculated values ($\bar{M}=0.8$) was used and some parameters of the optimal stock exploitation were estimated.

The optimal age for harvesting was calculated by the method of Kutty and Kasim:

$$t_{opt} = \frac{ln\ (3K + M) - ln\ M}{K} = 2.5 \text{ years}$$

where K = growth coefficient from the Bertalanffy equation (0.3259).

The optimal length for harvesting was calculated from the Bertalanffy equation:

$$l_{opt} = L\ (1 - e\text{-}K^{(t_{opt} - t_o)}) = 12.6 \text{ cm}$$

where t_o = theoretical time of the beginning of growth (0.1149).

The results presented can be used in stock and TAC assessments for *P.g. shagensis* as well as for the development of recommendations for rational fishery of this fish.

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Table 1: Mean length of *P.g. shagensis* by age-groups in 1978.

Fish Length (cm)	Age (Years)							n
Observed data	6.60	12.03	13.90	16.30	17.98	18.77	21.55	1872
Estimated data	5.84	10.70	14.21	16.74	18.57	19.89	20.84	144

Table 2: Abundance of *P.g. shagensis* by age-groups in catches taken in the second half of 1978.

Age-Groups	2	3	4	5	6	n
Abundance N_i	107	832	360	157	14	1470
ti	4.67	6.72	6.69	5.06	2.64	
n N_i						

Table 3: Age composition of *P.g. shagensis* in catches taken in the second half of 1978 (n=1 363).

Age (years)	Conventional Age (years)	n
3	0	832
4	1	360
5	2	157
6	3	14

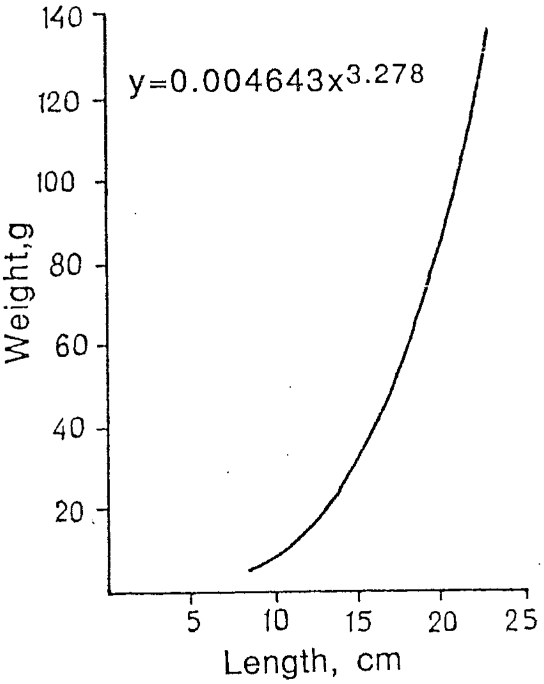

Figure 1: Plot of weight (grams) of *P.g. shagensis* against length (cm).

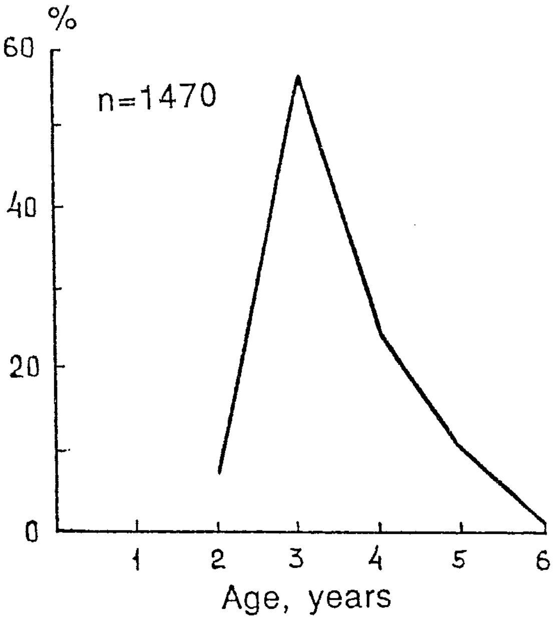

Figure 2: Age composition of *P.g. shagensis* in catches taken in the second half of 1978.

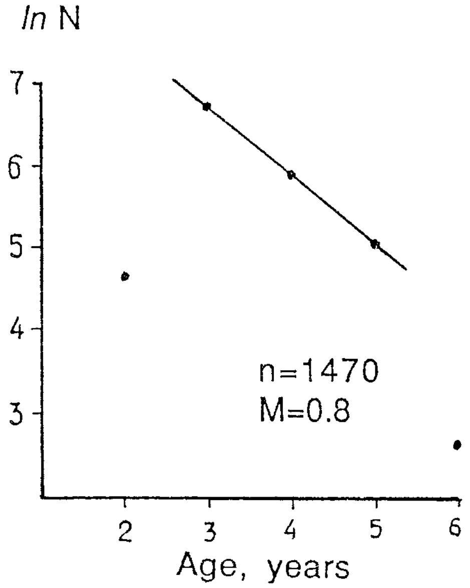

Figure 3: Natural mortality rate for *P.g. shagensis* calculated by the Baranov method.

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GROWTH AND AGE/LENGTH STRUCTURE OF POPULATIONS OF *NOTOTHENIA* (*LEPIDONOTOTHEN*) *SQUAMIFRONS* (*NOTOTHENIIDAE*) IN VARIOUS AREAS OF THE INDIAN SECTOR OF THE SOUTHERN OCEAN

A.K. Zaitsev

Abstract

Age, growth and age/length composition of populations of grey rockcod (*Notothenia* (*Lepidonotothen*) *squamifrons*), inhabiting areas of the Ob and Lena Banks and the Kerguelen Island Shelf, are presented in this paper. It was found that during the first years of life the linear growth rate is 3 to 5 cm per year. It decreases by a maximum of 1 cm during the last years of life. Maximum annual weight increments of 100 to 120 g at the banks and 153 to 188 g in the Kerguelen Island area were recorded for fish at age 6 to 12. Growth parameters were calculated according to Bertalanffy's equation. The dynamics of age/length composition of catches are also examined in this paper. On the Ob and Lena Banks this composition is fairly stable but on the Kerguelen Shelf there is a tendency towards younger fish being more abundant.

Résumé

L'âge, la croissance et la composition âge/longueur des populations de bocasses grises (*Notothenia (Lepidonotothen) squamifrons*) vivant dans les régions des bancs Ob et Léna et du plateau des îles Kerguelen, sont présentées dans ce document. On a découvert que pendant les premières années de vie, le taux de croissance linéaire est de 3 à 5 cm par an. Il diminue d'un maximum de 1 cm au maximum pendant les dernières années de vie. Une augmentation annuelle maximale de poids de 100 à 120 g sur les bancs et de 153 à 188 g dans la région des îles Kerguelen a été relevée pour les poissons des classes d'âge 6 à 12. Les paramètres de croissance ont été calculés selon l'équation de Bertalanffy. La dynamique de composition âge/longueur des captures est également étudiée dans ce document. Sur les bancs Ob et Léna, cette composition est relativement stable, mais sur le plateau de Kerguelen, les poissons plus jeunes ont tendance à être plus abondants.

Резюме

В настоящем документе представлена информация о возрасте, темпах роста и размерно-возрастной структуре популяций серой нототении (*Notothenia (Lepodonotothen) squamifrons*), обитающих в районе банок Обь и Лена, а также шельфа Кергелена. Было установлено, что на протяжении первых лет жизни темп линейного роста входящих в эти популяции особей составляет 3-5 см в год. В течение последних лет жизни он снижается на не более, чем 1 см за год. Максимальный ежегодный прирост веса в пределах 100-120 г и 153-188 г в районе банок и Кергелена соответственно, был отмечен среди особей в возрасте

6-12лет. Параметры роста были вычислены по уравнению Берталанффи. В данной работе также рассматривается динамика размерно-возрастного состава уловов. Состав уловов, полученных в районе банок Обь и Лена, довольно стабилен, в то время как в составе уловов, полученных на шельфе Кергелена, наблюдается тенденция к омоложению.

Resumen

En este documento se presenta la edad, crecimiento y composición de edad/longitud de las poblaciones de tramas grises (*Notothenia* (*Lepidonotothen*) *squamifrons*), que habitan las áreas de los Bancos de Ob y de Lena y la plataforma de la Isla Kerguelen. Se observó que durante los primeros años de vida el índice lineal de crecimiento es de 3 a 5 cm al año, disminuyendo a un máximo de 1 cm durante los últimos años de vida. Se registraron aumentos máximos de peso anual de 100 a 120 g en los bancos y de 153 a 188 g en el área de la Isla Kerguelen en peces de edad 6 a 12. Parámetros de crecimiento se calcularon de acuerdo a la ecuación de Bertalanffy. Las dinámicas de composición de edad/longitud de las capturas también se examina en este documento. En los Bancos de Ob y de Lena esta composición es bastante estable pero en la Plataforma Kerguelen los peces más jóvenes tienden a ser más abundantes.

1. INTRODUCTION

The grey rockcod (*Notothenia* (*Lepidonotothen*) *squamifrons*) is widely distributed in sub-Antarctic waters of the Southern Ocean. There are numerous populations of the Indian Ocean sub-species of this species (*Notothenia squamifrons* Günther, 1880) which inhabits island shelves (Crozet, Prince Edward and Kerguelen Islands) as well as seamounts (Ob, Lena and Skif Banks) (Duhamel, Hureau, Ozouf-Costaz, 1983; Duhamel, Ozouf-Costaz, 1985).

It has been demonstrated that *N. squamifrons* populations of the Ob and Lena Banks are discrete (Zaitsev, 1987 and 1989). Utilization of available resources of this species on these banks must therefore be carried out carefully and all biological features of the species should be taken into account.

Since the impact of fishing has recently become constant, it is increasingly important to examine age, growth rates and the dynamics of age/length composition of each population separately. Research on age structure of the Atlantic sub-species of this species (*N. squamifrons atlantica*, Permitin and Sazonov, 1974) in the South Georgia area was undertaken by Shust and Pinskaya (1978), while a similar study of Indian Ocean sub-species has been carried out by Duhamel and Ozouf-Costaz (Duhamel, 1981; Duhamel, Ozouf-Costaz, 1985). This paper results from the analyses of a large range of material. It supplements to a considerable degree, earlier data on the biology of the Indian Ocean sub-species.

2. MATERIALS AND METHODS

The material was collected by research vessels from the AzCherNIRO Institute and Yugrybpromrazvedka (Southern Fishery Survey Authority) from around the Ob and Lena Banks and the Kerguelen Islands from 1969 to 1987.

The age of fish was determined using standard methods (Chugunova, 1959). To this end, fish scales were used as an age reading structure. Preparations of scales were analyzed with the help of microfiche reading equipment "Microphot 5-PO-1" (materials from the Ob and Lena Banks) and "Microphot-3" AChM-22 (material from the Kerguelen Islands) with 1x20 magnification. Both permanent and temporary preparations were used with "Microphot-3" AChM-22. In the latter case a microfische frame was used as a slide to speed up the process of preparing and analyzing preparations at least twice.

Altogether 536 preparations from the Ob and Lena Banks and 987 from the Kerguelen Islands were studied. Standard length was measured (standard length is from the tip of the snout to the end of the urostyle). Fish weight was determined to the nearest gram. In total, 94 354 specimens of *N. squamifrons* were weighed and measured.

In order to avoid errors in determining the age of *N. squamifrons*, sclerites were counted up to the edge of each annual ring, (i.e. to the point at which the sclerites begin to merge). The results of the count were processed on a computer using a BMDP program package. The hypothesis of normal distribution of sclerite up to the edge of annual rings was tested. Based on the Kolmogorov test, the distributions observed were considered normal at P=0.2. Moreover, single variable statistics of distribution of sclerites in each annual ring were calculated. A polymodal curve was drawn on the basis of these calculations, allowing for a more accurate determination of the age of fish in case of faint annual rings on their scales (Figure 1). A similar curve was used by Boronin and Frolkina (1976) in determining the age of *N. gibberifrons* (Lönnberg) from the South-West Atlantic.

Age composition of catches over the period under study was determined according to the Morozov-Mayorova method using size composition as a starting point

(Chugunova, 1959). Bertalanffy's growth equation was used to calculate parameters of linear and weight growth (Hohendorf, 1966). All calculations were performed on an EC 1035 mainframe computer.

3. LENGTH AND WEIGHT

The equation $W=aL^b$ was used in analyzing the relationship between length and weight where W - weight of fish; L - length; "a" and "b" - parameters statistically calculated from actual data (Ricker, 1979). This equation was calculated for each study area and for male and female specimens separately. A significant positive correlation between length and weight ($r>0.9$) was observed in each instance.

Sexual dimorphism was not apparent within the parameters under examination. The value of coefficient "a", however, varies from area to area (Table 2). Irrespective of the sample, the value of coefficient "b" is close to 3, which enables consideration of the growth of *N. squamifrons* in the areas under investigation as isometric. It also allows the use of these parameters for calculation of growth rates by means of Bertalanffy's equation.

It is worth noting the change in the length-weight ratio of fish in the Kerguelen Islands area from 1969 to 1986. There is a tendency towards weight increase per-unit-length among large fish (more than 25 cm) (Figure 2). These changes are most likely the result of intensive commercial fishing in the area. According to the catch data (Studenetskaya, 1983), the annual catch of *N. squamifrons* has exceeded 50 000 tonnes in some years. It is probable that this substantial yield has improved conditions for feeding and consequently led to a change in the length-weight ratio.

Data obtained from the Kerguelen Island area (1980 to 1986) correspond with those obtained earlier by Duhamel (1981), however it should be noted that Duhamel used total length (L) for calculating the ratio while in our work standard length (SL) was applied.

When comparing the data of different scientists who used either total or standard length, a ratio between these values for *N. squamifrons* was calculated as follows:

$$SL = 0.85L + 7 \text{ (mm)}$$
$$(r = 0.97)$$

4. LINEAR AND WEIGHT GROWTH

Data on growth rate of *N. squamifrons* were obtained from processing age data. This species is characterized by a long life cycle; 15 year old specimens were recorded in our samples. Both sexes of *N. squamifrons* have high linear and weight growth rates while sexual dimorphism was not observed (Table 1). Fish grow at a faster rate in the first half of their life cycle - up to 6 to 8 years (i.e. up until sexual maturity). During this period linear growth is 3 to 5 cm per year. Linear growth decreases by a maximum of 2 cm in mature fish aged 8 to 10 and towards the end of life by a maximum of 1 cm. Maximum increase in weight occurs at age 6 to 10 around the Ob and Lena Banks (100 to 120 g/year) and at age 7 to 12 in the Kerguelen Island area (155 to 188 g/year). It must be noted that retardation of the weight growth rate on the Lena Bank begins at an earlier age than in other areas (Table 1). Weight gain values for the Ob and Lena Bank populations are similar to those obtained for the Atlantic sub-species of *N. squamifrons* in the South Georgia area (Shust, Pinskaya, 1978).

Parameters of linear and weight growth equations (Bertalanffy's equation) were calculated for each area using the data obtained from observations (Table 2).

When comparing the data obtained it can be seen that while the growth rate for all three areas is fairly similar, the calculated values for length and weight of specimens of the same age group are minimal on the Ob Bank and maximal in the Kerguelen Islands area (data for 1980 to 1986) (Table 1). Relative growth rate coefficients (K), calculated using Bertalanffy's equation, are also different (Table 2).

Growth characteristics of *N. squamifrons* in the Kerguelen waters deserve special attention. Material collected before the commencement of exploitation of resources on the Kerguelen Shelf (1969 to 1972), and during the period reflecting the current state of the exploited population (1980 to 1988), has been analyzed. Both empirical and calculated values of length and weight by age for these periods practically coincide. The differences in growth rate coefficients are not significant and are more likely caused by the varied quality of materials than by physiological changes of fish. The results of this research demonstrate, therefore, that despite the impact of the fishery and the slight tendency of the length-weight ratio to change, the general growth pattern of fish in this area has remained virtually constant.

Analysis of the data shows that *N. squamifrons* reaches two-thirds of its theoretical maximum length and one-third of its maximum body weight at the age of 9 years on the Lena Bank, 10 years on the Ob Bank and 11 years in the Kerguelen area.

5. AGE/LENGTH CATCH COMPOSITION

The dynamics of age/length composition of catches may serve as an indicator of the state of exploited populations. Our material makes it possible to assess the age/length catch composition of *N. squamifrons* in each of the areas studied over different years and to note changes that may be occurring.

N. squamifrons taken on the Ob Bank consisted of specimens 8 to 46 cm in length, 4 to 1 400 g in weight and 1 to 15 years old. Specimens of the younger and older age/length groups generally appeared in small numbers. The bulk of the exploited part of the population comprised specimens 20 to 36 cm in length and 4 to 12 years old, the proportion of which varied from 83.8 to 97.6% in different years (Figure 3). The mean age in this area is about 8 years. Earlier it was established that on the Ob and Lena Banks, *N. squamifrons* reaches maturity at the age of 6 to 7 (Zaitsev, 1989), which indicates that primarily mature specimens were fished. Age/length catch composition on the banks is relatively stable, although with the fairly constant mean age of the population over the last two years, the proportion of fish with a mode of 28 to 32 cm aged 8 in catches has increased markedly while the proportion of older specimens has declined (Figure 3). These changes are associated with a concentration in these years of fishing on pre-spawning and spawning aggregations which contain specimens of the above age/length groups.

Age/length catch composition of *N. squamifrons* on the Lena Bank is slightly different from that on the Ob Bank. With similar values for maximum length and age, the mean values of these parameters were lower. The mode was usually 22 to 32 cm and 5 to 8 years while the mean age was approximately 7 years. In recent years there have been no significant changes in age/length structure (Figure 4).

Specimens 8 to 50 cm in length and 7 to 2 200 g in weight were found in trawl catches around the Kerguelen Islands. The age of these fish varied from 1 to 15 years. In the first years of the fishery (1969 to 1972) primarily older aged fish were taken (8 to 13 years), comprising from 67.8 to 92.6% of the total (Figure 5). In the 1980s there was a tendency towards a younger fish in catches with 6 to 7 year old specimens predominating. From 1969 to 1987 the mean age of fish in catches dropped by almost four years. This can be illustrated by the nature of changes in mean length and the range of variation in modal values during the periods being compared. Figure 6 shows a sharp decrease in these parameters from 1969 to 1983 with some stabilization in recent years. Since the majority of fish in the Kerguelen Islands area reach maturity at the age of 7 to 8 and the bulk of the catch for 1985 to 1987 comprised 6 to 7 year olds, it is clear that mainly immature or maturing specimens were targetted by the fishery.

The general trend towards change in the age/length catch composition and a younger population indicates that the fishery in the Kerguelen Islands area must be regulated and managed on the basis of scientific recommendations, made as a result of joint Franco-Soviet research projects.

6. CONCLUSIONS

(i) Growth of *N. squamifrons* in the areas under study is close to isometric since the coefficient "b" of the length-weight ratio is close to 3.0 for both males and females. The relationship between total length (L) and standard length (SL) is expressed by the following equation: SL=0.85L + 7 mm.

(ii) Linear growth rate is from 3 to 5 cm per year in the first years of life to 1 cm in the last years, dependent upon the area. Maximum increase in weight occurs at 6 to 10 years of age in the Ob and Lena Bank areas (100 to 120 g) and 7 to 12 years in the Kerguelen Islands area (153 to 188 g).

(iii) Specimens aged 1 to 15 are taken in trawl catches. The bulk of the exploited part of the population on the Ob bank comprised fish 20 to 36 cm in length, aged 4 to 12 ($\bar{t}=8$ years) and on the Lena Bank - 22 to 32 cm in length, aged 5 to 8 ($\bar{t}=7$ years). At the beginning of exploitation in the Kerguelen Islands area the bulk of the catch consisted of 8 to 13 year old specimens, while in the 1980s, 6 to 7 year olds began to predominate. The mean age of fish in catches dropped by about four years.

(iv) Between-year dynamics of age/length catch composition demonstrated that while *N. squamifrons* populations in the Ob and Lena Bank areas are in a fairly stable condition, the Kerguelen population is experiencing the impact of the fishery which ought to be regulated in this area.

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Table 1: Linear (cm) and weight (g) growth of *N. squamifrons* (calculated according to Bertalanffy's equation).

Area	Sex	Age in years														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Linear growth														
Ob Bank	Females	-	9.3	13.4	17.1	20.5	23.5	26.2	28.7	30.9	32.9	34.8	36.4	37.9	39.2	
	Males	-	8.7	13.3	17.4	20.9	24.1	26.9	29.4	31.6	33.5	35.3	36.8	38.1	39.3	
	Both sexes	-	9.3	13.5	17.3	20.7	23.8	26.6	29.0	31.2	33.2	35.0	36.5	37.9	39.2	
Lena Bank	Females	6.1	10.9	15.2	18.9	22.3	25.3	28.0	30.3	32.5	34.3	36.0			-	
	Males	5.0	10.6	15.4	19.5	23.0	26.0	28.6	30.7	32.6	34.2	35.6			(38.6)	
	Both sexes	5.8	10.9	15.3	19.2	22.6	25.5	28.2	30.5	32.5	34.3	35.9			(39.5)	
Kerguelen Islands (1980-1986)	Females	7.5	12.2	16.5	20.3	23.7	26.8	29.6	32.0	34.2	36.2	38.0	39.6	41.0		(42.7)
	Males	6.2	11.6	16.3	20.4	24.0	27.1	29.9	32.3	34.4	36.3	37.9	39.3	-		-
	Both sexes	7.1	12.1	16.5	20.4	23.9	27.0	29.7	32.2	34.3	36.2	37.9	39.4	40.8		(42.7)
(1969-1972)	Both sexes				20.1	23.3	26.3	29.1	31.7	34.0	36.2	38.3	40.1	41.9	43.5	44.9

Area	Sex	Age in years														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Weight growth														
Ob Bank	Females		12	41	92	163	251	354	468	587	711	835	957	1076	1214	
	Males		12	43	98	176	273	384	506	633	761	888	1012	1130	1242	
	Both sexes		13	44	96	170	262	368	485	609	736	863	989	1111	1228	
Lena Bank	Females	2	18	57	123	210	316	432	556	678	799	914			-	
	Males	1	16	65	146	247	359	472	580	679	767	844			(1028)	
	Both sexes	2	18	61	131	223	330	446	564	679	788	891			(1180)	
Kerguelen Islands (1980-1986)	Females	5	23	64	129	220	336	474	630	800	981	1169	1361	1554		(2001)
	Males	4	22	64	132	227	346	484	637	800	969	1140	1310	-		-
	Both sexes	5	24	65	132	225	341	478	631	796	970	1148	1329	1508		(2001)
(1969-1972)	Both sexes				129	221	337	472	625	792	969	1152	1338	1526	1713	1897

Table 2: Parameters of length-weight equation and Bertalanffy's growth equation for *N. squamifrons*.

Area	Sex	Parameters						
		a	b	L_∞	W_∞	K	t_0	n
Ob Bank	Females	0.01466	3.0831	51.83	2487	0.1015	0.0591	115
	Males	0.00947	3.2209	48.28	2317	0.1235	0.3917	130
	Both sexes	0.01147	3.1600	49.89	2524	0.1115	0.1781	245
Lena Bank	Females	0.00647	3.3250	49.53	1933	0.1166	-0.1350	168
	Males	0.00887	3.2285	43.55	1233	0.1573	0.2182	123
	Both sexes	0.00735	3.2880	47.24	1632	0.1290	-0.0302	291
Lena Bank (Duhamel, Ozouf-Costaz, 1985)	Both sexes	-	-	43.0	1003	0.117	1.0593	
Kerguelen Is (1969-1972)	Both sexes	0.01244	3.1315	63.29	4830	0.0779	-0.9075	309
Kerguelen Is (1980-1986)	Females	0.00293	3.3198	53.59	4755	0.1087	0.3788	281
	Males	0.00262	3.3401	49.39	3547	0.1325	0.0150	295
	Both sexes	0.00314	3.3089	51.31	4157	0.1196	0.2426	576
Kerguelen Is (Duhamel, Ozouf-Costaz, 1985)	Females	0.0025	3.4359	-	-	-	-	627
	Males	0.0032	3.3686	-	-	-	-	683
	Both sexes	-	-	67.0	4470	0.078	0.1075	-

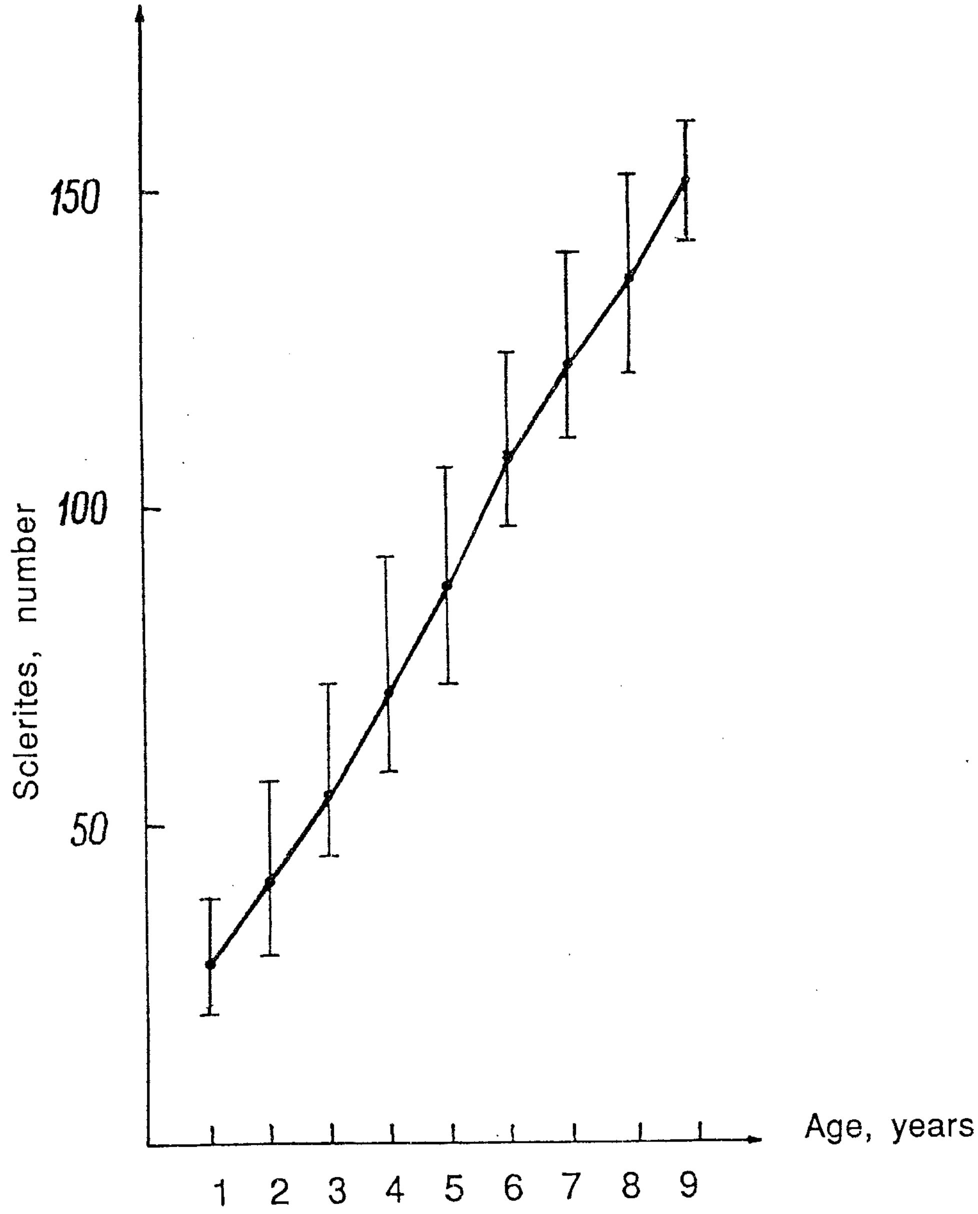

Figure 1: Change in the number of sclerites of *N. squamifrons* of different age.

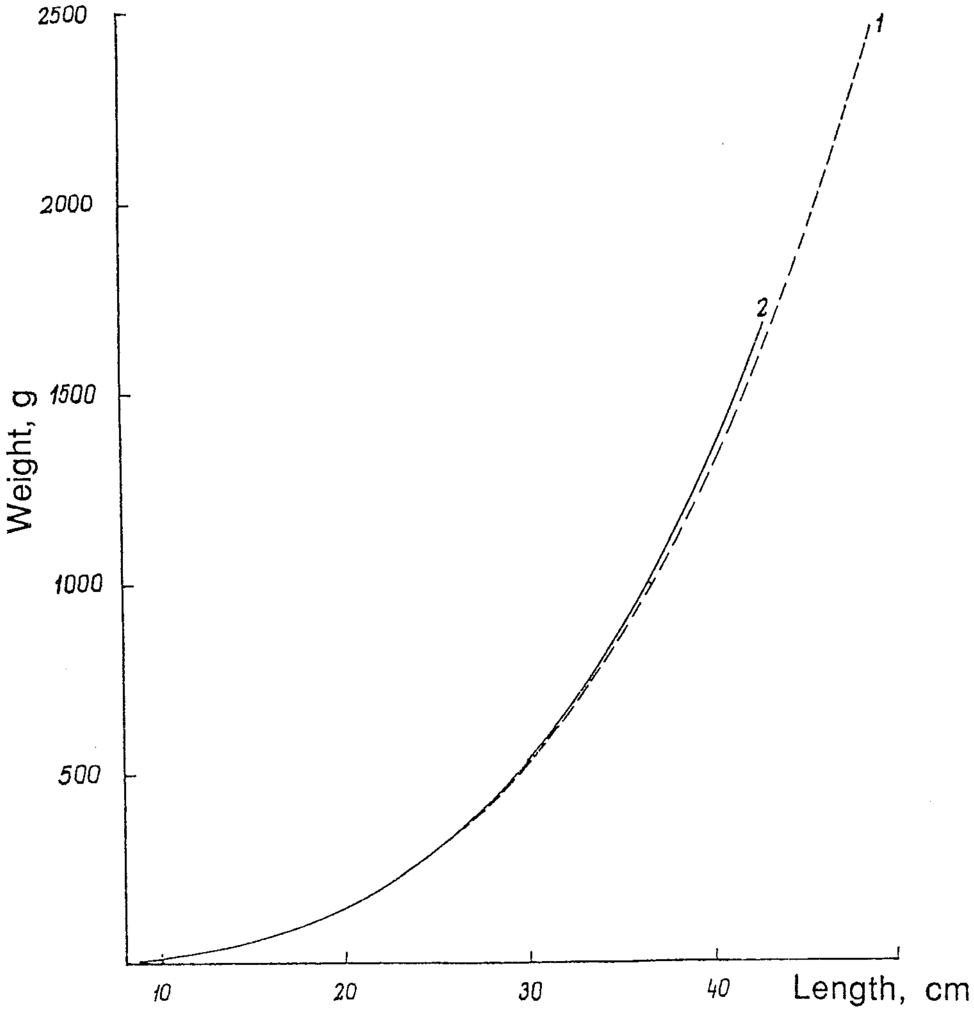

Figure 2: Length-weight ratio of *N. squamifrons* from the Kerguelen Island area: 1=1969 to 1972; 2=1980 to 1986.

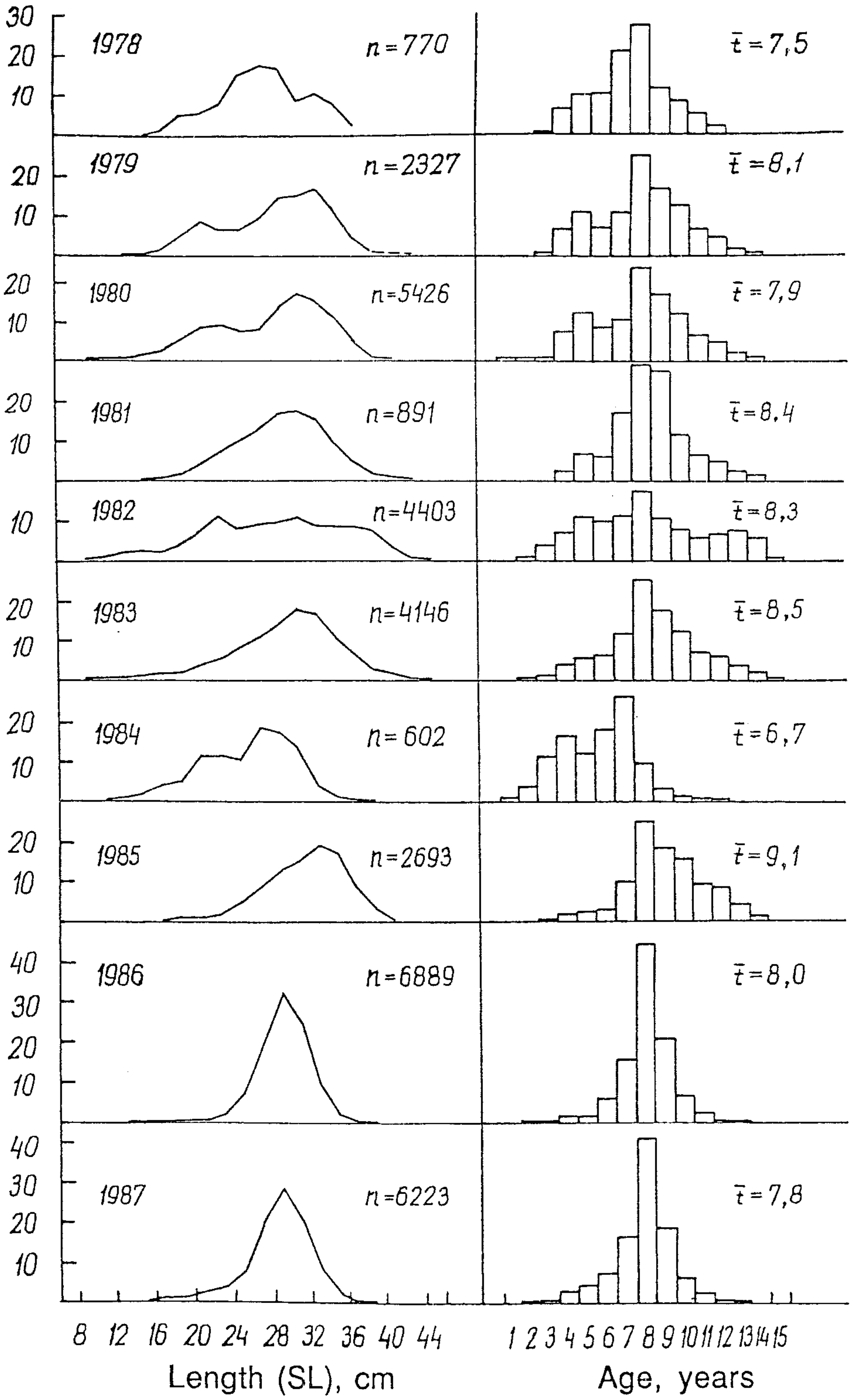

Figure 3: Age/length composition of *N. squamifrons* in the Ob Bank area.

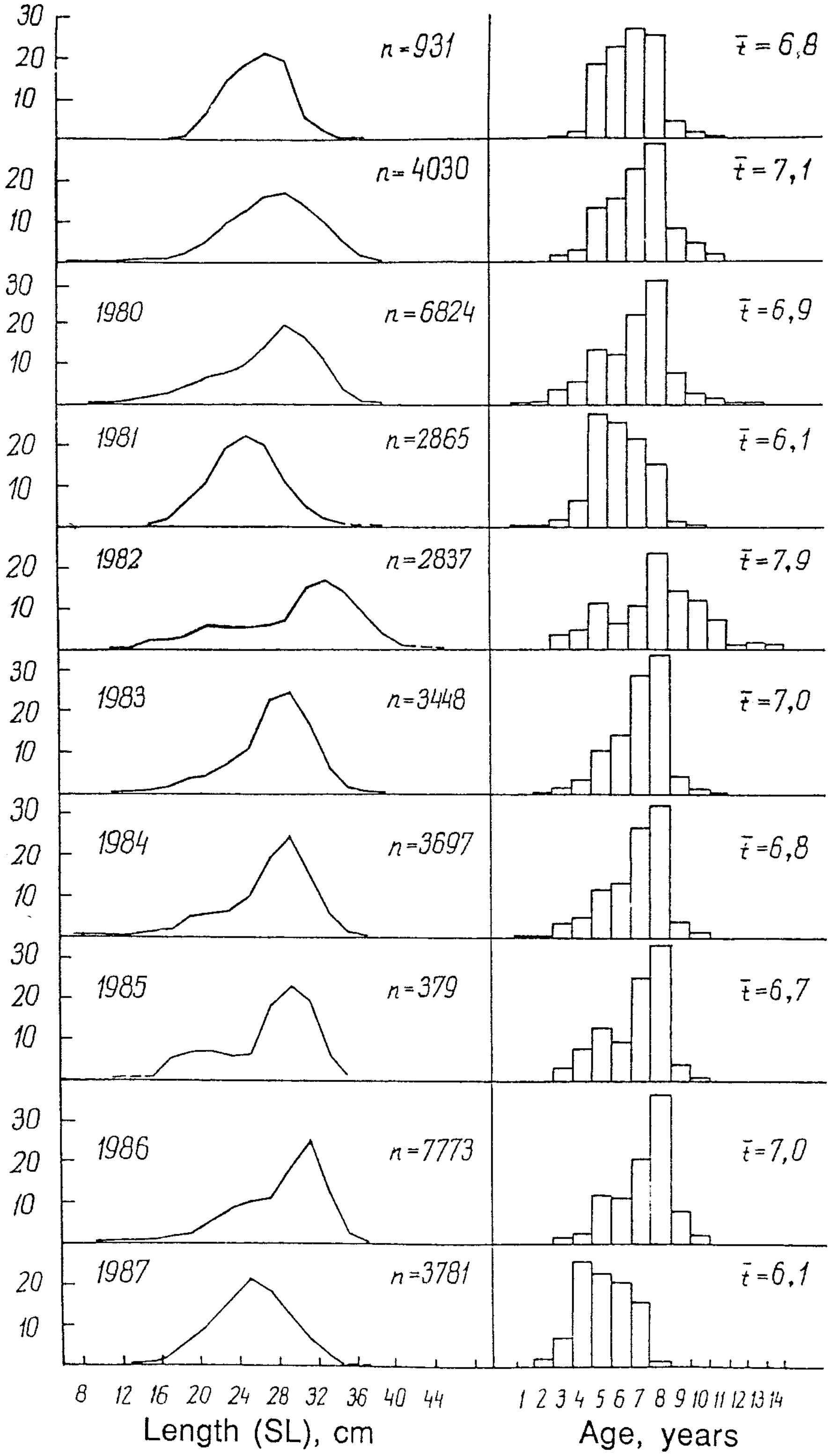

Figure 4: Age/length composition of *N. squamifrons* in the Lena Bank area.

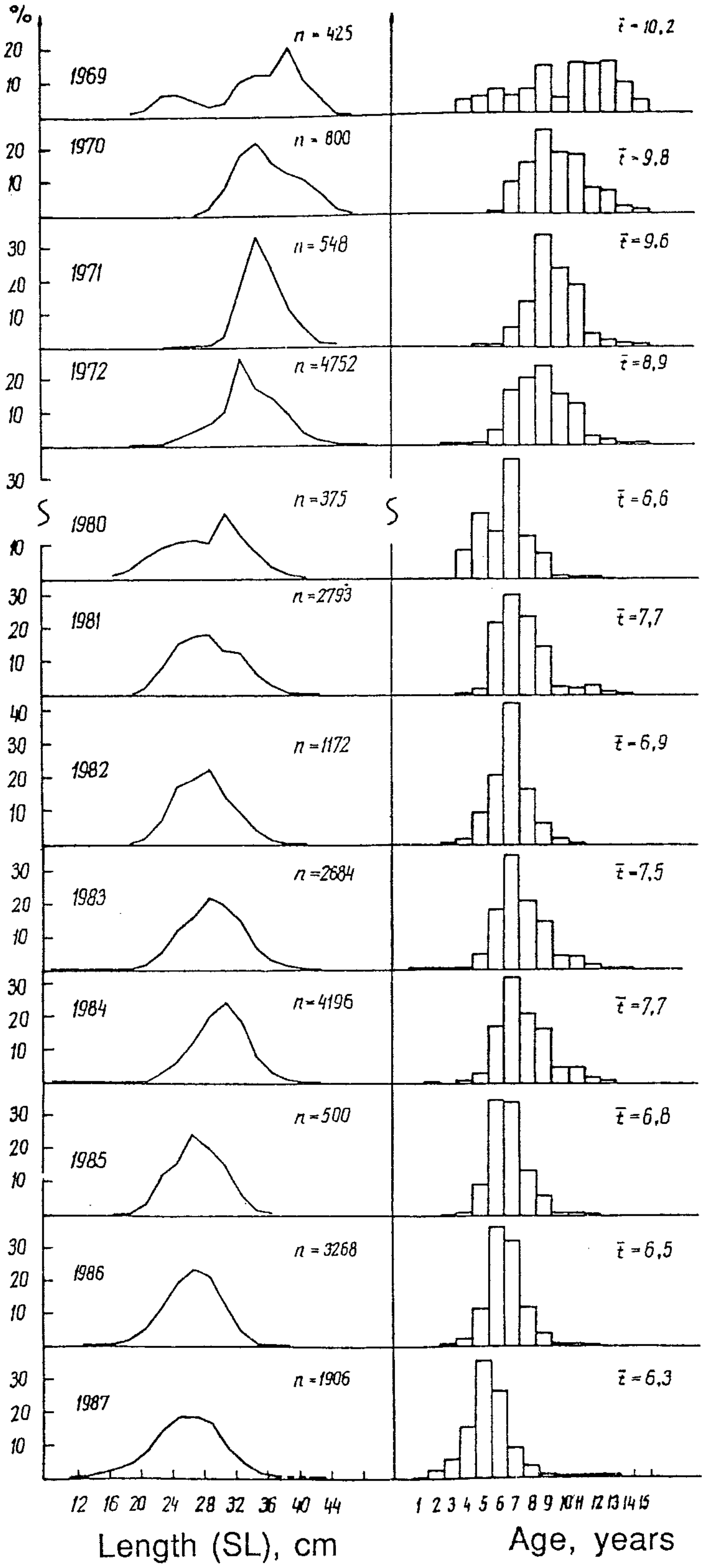

Figure 5: Age/length composition of *N. squamifrons* in the Kerguelen Island area.

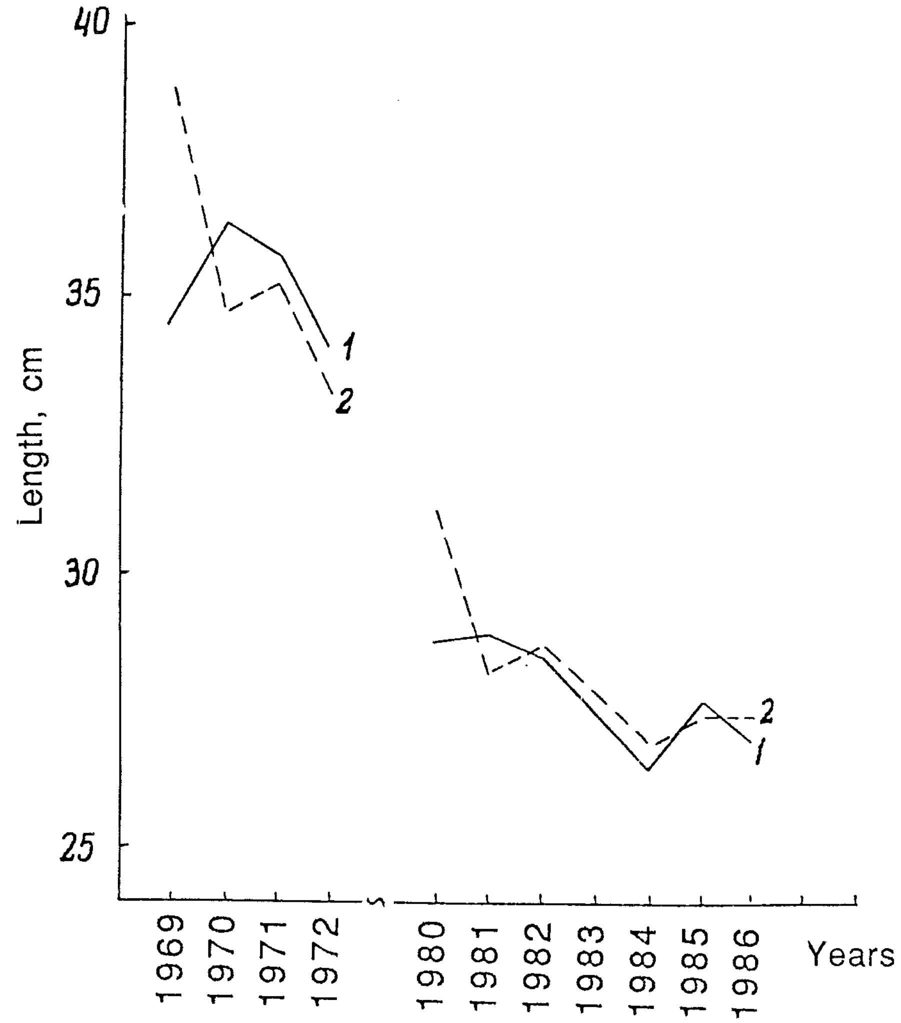

Figure 6: Change in mean and modal length values of *N. squamifrons* in the Kerguelen Island area.

1 - mean length; 2 - modal length

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NATURAL MORTALITY OF GREY ROCKCOD (*NOTOTHENIA SQUAMIFRONS*) IN VARIOUS AREAS OF THE INDIAN SECTOR OF THE SOUTHERN OCEAN

A.K. Zaitsev

Abstract

The rate of natural mortality of grey rockcod (Notothenia squamifrons) on the Ob and Lena Banks and the Kerguelen Shelf were determined using three independent methods. From the values obtained the means were taken to be the most reliable. These were 0.38, 0.36 and 0.33 for the above areas respectively. These values are comparable with those derived for most notothenioids.

Résumé

Le taux de mortalité naturelle de la bocasse grise (*Notothenia squamifrons*), provenant des hauts-fonds Ob et Léna et du plateau de Kerguelen, a été déterminé selon trois méthodes différentes. A partir des valeurs obtenues, on a supposé que les moyennes étaient les plus fiables. Celles-ci étaient respectivement de 0,38, 0,36 et 0,33 pour les zones mentionnées ci-dessus. Ces valeurs sont comparables à celles provenant de la plupart des *Notothenioidei*.

Резюме

При использовании трех различных методов был определен коэффициент естественной смертности серой нототении (*Notothenia squamifrons*) в районе банок Обь и Лена и шельфа Кергелена. Наиболее надежными были признаны средние величины полученных значений. Для вышеупомянутых районов эти величины составили соответственно 0,38, 0,36 и 0,33. Эти значения сопоставимы со значениями, выведеннными для большинства нототениоидных рыб.

Resumen

El índice de mortalidad natural de la trama gris (*Notothenia squamifrons*) en los Bancos de Ob y de Lena y en la plataforma de Kerguelen, se determinó usando tres métodos independientes. De los valores obtenidos, las medias se tomaron como las más fiables. Estas fueron 0.38, 0.36 y 0.33 para estas áreas, respectivamente. Estos valores son comparables con esos derivados para la mayoría de los peces nototenioídeos.

The rate of natural mortality (M) of grey rockcod (*Notothenia squamifrons*) was determined using three independent methods.

The Rikhter-Efanov method uses the empirical relationship between M and age at maturity for most fish (t_n) where 50 or 70% of a population comprises mature specimens (Babayan et al., 1984). The rate of natural mortality (M) is calculated as

$$M = \frac{1.521}{t_n \cdot 0.720} - 0.155 \qquad (1)$$

Values for t_n (70%) were calculated for each area. For specimens on the Ob and Lena Banks these were 6.6 and 6.2 years respectively, while for the Kerguelen Islands area the value was 8.6 years.

The calculated values of M were found to be the lowest among specimens of the Kerguelen populations (0.17), while the "bank" populations gave higher values (0.24 to 0.25).

In order to compare our data with the results obtained by Duhamel (Kock, Duhamel, Hureau, 1985), age at maturity for most fish was determined for a population with 50% of mature fish. The values of t_n were established to be 5.9, 5.2 and 7.6 years. The value for M in the Kerguelen Islands area is comparable to, although slightly higher than that calculated by the French scientists (0.20 as opposed to 0.18) (Table 1).

The Alverson-Carnee method takes into account the age at which fish biomass reaches its maximum (T). This parameter is calculated according to the age of the oldest group in the catches (T_m), comprising not less than 0.5% of the total sample (Babayan et al., 1984). For an exploited population $T=0.38\ T_m$. For *N. squamifrons* T_m is 15 years (Ob Bank), 14 years (Lena Bank) and 15 years (Kerguelen Islands). In this case the natural mortality rate is 0.35 to 0.39.

The Beverton-Holt method is used for previously unexploited populations. The value of M was determined according to the following formula:

$$M = \frac{K\ (l_\infty - l')}{T - l'} \qquad (2)$$

where T = mean length of fish in the catch;
l' = minimum length of fish in the catch;
l_∞ = asymptotic length (i.e. maximum length according to Bertalanffy's growth equation);
K = coefficient of growth of the Bertalanffy growth.

This equation was worked out using data on *N. squamifrons* size composition over the first years of exploitation (i.e. 1978 to 1979 for the Ob and Lena Banks and 1969 to 1972 for the Kerguelen Islands). Data on 2 to 15 year old fish were used in calculations.

Depending on the area, values for M varied from 0.46 to 0.52, which is slightly higher than values obtained using the Rikhter-Efanov and Alverson-Carnee methods.

Because of the considerable difference in instantaneous natural mortality rates, calculated using various methods, and the absence of objective criteria to choose any one of them, the mean arithmetical value of the estimates obtained may be applicable. In this case the mean values of M are 0.38 (Ob Bank), 0.36 (Lena Bank) and 0.33 (Kerguelen Islands) (Table 1).

Natural mortality was also determined using the Pauly method whereby a relationship between growth parameters and environmental temperature is used. The values of "*l*" and "w" from Bertalanffy's equation were applied. The values used are characteristic for the near-bottom layer in each of the areas (Table 1). Pauly's formulae were utilized in the calculations (Pauly, 1980):

$$\lg M = -0.0066-0.279\lg l+0.6543\lg K+0.4634\lg T^{\circ} \qquad (3)$$

$$\lg M = -0.2107-0.0828\lg W-0.6757\lg K-0.4634\lg T^{\circ} \qquad (4)$$

These calculations are presented here purely to compare our results with the data obtained by the French scientists (Kock, Duhamel, Hureau, 1985) in respect of the Ob Bank and the Kerguelen Islands. In our opinion, however, the data obtained has no practical application for notothenioid fish for two reasons. First, the dependence worked out by Pauly referred to tropical fish and secondly, in equations (3) and (4), one of the main components is $\lg T^{\circ}$. However, many species inhabiting the Antarctic near-shelf zone (such as *Pleuragramma antarcticum*, most *Trematomus spp.*, *Channichthyidae* etc.) live in sub-zero temperatures. The impossibility of obtaining a logarithm from a negative number, however, makes the equation mathematically absurd.

A few points must also be made about the applicability of the Rikhter-Efanov method to Antarctic fish. The only variable in the equation (1) is t_m, age at maturity for most fish (70%). This does not take into account primary causes of natural mortality such as ageing, unfavourable abiotic conditions, predation, parasites and illness, changes in food availability. According to Berdichevsky (Berdichevsky et al., 1982), these factors are the main causes of natural mortality. If we calculate M, for example, using the above method for *N. squamifrons* and *Pleuragramma antarcticum* which, like *N. squamifrons* inhabits the Ob and Lena Banks, becomes mature at the age of six, then natural mortality rates will be approximately the same for both species. However, according to Gerasimchook's data (1987), natural mortality rates calculated by the Beverton-Holt method were 1.46 to 1.69 for *P. antarcticum* from coastal Antarctic seas as opposed to 0.46 to 0.52 for *N. squamifrons*. In the author's opinion, the high level of natural mortality (M) of *P. antarcticum* is attributable to a significant pressure of predators.

Therefore, the Rikhter-Efanov method is not always applicable to Antarctic fish in general. However, this method can be used for *N. squamifrons* since predation and the food availability would not appear to have a great impact on natural mortality. This is so because the only predator of adult *N. squamifrons* is the Patagonian toothfish (*Dissostichus eleginoides*) and the food availability largely depends on the topographic features of the banks rather than on other factors. A stable concentration of prey species occurs in areas where bank peaks are within the water gradient zones, formed by water masses of differing quality (Lanin, 1983).

Accepting 0.33 to 0.38 as the most reliable values for M, it may be concluded that the rate of natural mortality of *N. squamifrons* in all three areas is similar and their mean values are comparable with those for the majority of notothenioid fish (Kock, Duhamel, Hureau, 1985; Tankevich, Shlyakhov, 1987; Shlibanov, 1987).

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Table 1: Calculated values of the natural mortality rate (M) of grey rockcod (*Notothenia squamifrons*).

Area	Method							Accepted Mean Value of M
	Rikhter-Efanov		Alverson-Carnee	Beverton-Holt	Pauly			
	M(50%)	M(70%)	M	M	T°	M(l)	M(W)	
Ob Bank	0.27	0.24	0.39	0.52	1.3	0.09	0.08	0.38
Lena Bank	0.31	0.25	0.35	0.47	1.4	0.10	0.10	0.36
Kerguelen Islands	0.20	0.17	0.37	0.46	1.9	0.11	0.10	0.33
Kerguelen Islands (Duhamel, Ozouf-Costaz, 1985)	0.18	-	-		1.9	0.08	-	
Lena Bank (Duhamel, Ozouf-Costaz, 1985)	-	-	-		1.9	0.11	-	

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SUPPLEMENTARY DATA ON EXPLOITED STOCKS IN DIVISION 58.5.1 (KERGUELEN)

G. Duhamel

Abstract

The results of fishing cruises carried out from 1986/87 to 1988/89 in Division 58.5.1 (Kerguelen Island) have made possible a review of the status of the various harvested fish stocks. Since 1984, an average annual growth of 36% has been noted in the abundance of the juvenile section of the stock of *Notothenia rossii*, a species which is at present only fishable as a by-catch. The total biomass of the stock, however, remains very low according to the assessments carried out by the 1987 and 1988 scientific research cruises. The abundant 1985 cohort of *Champsocephalus gunnari* appeared in the shelf stock and it is from this cohort that the fishery achieved its good results in 1988/89, once the cohort had reached legal catch size. The value of the selected abundance index (catch per unit effort expressed in tonnes per fishing hour) is, however, lower than those observed for the two preceding cohorts (1979 and 1982) in a comparable period. The stock of *Notothenia squamifrons* shows a very low biomass value in 1987 and 1988. After a continuous reduction in average length since the creation of the EEZ, a slight increase has been recorded recently, accompanied by an increase in the abundance index, following a reduction in catch and fishing effort. This trend could well be reversed by too high a catch in 1988/89. Finally, it is not possible to accurately estimate the stock status of *Dissostichus eleginoides* because of the lack of recent fishery data.

Résumé

Les résultats des campagnes de pêche 1986/87 à 1988/89 réalisées dans la division 58.5.1 (îles Kerguelen) ont permis de réexaminer le statut des différents stocks de poissons exploités. Pour *Notothenia rossii*, dont la pêche est désormais limitée aux captures accessoires, un accroissement moyen annuel de 36% est noté pour l'abondance de la partie juvénile du stock depuis 1984. La biomasse totale du stock reste cependant encore très faible d'après les évaluations des campagnes scientifiques 1987 et 1988. La cohorte abondante 1985 de *Champsocephalus gunnari* est apparue pour le stock du plateau et c'est sur cette dernière que la pêcherie a réalisé ses bons résultats 1988/89, une fois que la taille légale de capture ait été atteinte. La valeur de l'indice d'abondance retenu (Capture par Unité d'Effort exprimée en Tonnes par heure de pêche) est cependant plus faible que celles observées pour les deux cohortes précédentes (1979 et 1982) à période comparable. Le stock de *Notothenia squamifrons* présente une valeur de biomasse très faible en 1987 et 1988. Après une diminution continue de la longueur moyenne depuis la création de la ZEE on constate une légère augmentation récente accompagnée de celle de l'indice d'abondance, après réduction de la capture et de l'effort de pêche. Cette tendance risque d'être contrariée par une capture trop élevée en 1988/89. Enfin l'état du stock de *Dissostichus eleginoides* ne peut être évalué correctement en raison de son exploitation récente.

Резюме

В результате промысловых рейсов, выполненных на Участке 58.5.1 (остров Кергелен) с 1986/87 по 1988/89 гг., предоставилась возможность сделать обзор состояния различных облавливаемых рыбных запасов. Начиная с 1984 г. средний темп ежегодного роста неполовозрелой части запаса *Notothenia rossii* составлял 36%, в настоящее время этот вид входит исключительно в состав прилова. Тем не менее, по оценкам, сделанным в ходе научно-исследовательских рейсов 1987 и 1988 гг., общая биомасса этого запаса все еще очень низка. В состав шельфового запаса вошла многочисленная когорта *Chamspocephalus gunnari* 1985 г., за счет этой когорты в течение промыслового периода 1988/89 г., когда она достигла установленного промыслового размера, были достигнуты хорошие результаты. Тем не менее, показатель численности (вылов на единицу промыслового усилия, выраженный в тоннах на час промысла) был ниже показателей численности для двух предыдущих когорт (1979 и 1982 гг.) за подобный период. В 1987 и 1988 гг. уровень биомассы запаса *Notothenia squamifrons* был очень низким.Со времени установления экономической зоны наблюдалось постоянное сокращение средней длины. Тем не менее, за недавнее время, вследствие снижения величины уловов и интенсивности промыслового усилия, было отмечено незначительное увеличение средней длины, на ряду с повышением показателя численности. Однако, эта тендеция может быть заменена противоположной в результате слишком высокого объема вылова за 1988/89 г. В заключение, оценить состояние запаса *Dissistichus eleginoides* точно невозможно в связи с отсутствием промысловых данных за самый недавний период.

Resumen

Los resultados de los cruceros de pesca llevados a cabo desde 1986/87 hasta 1988/89 en la División 58.5.1 (Isla Kerguelen) han hecho posible hacer una revisión de la condiciones de las varias poblaciones de peces. Desde 1984, un crecimiento promedio anual de 36% se ha observado en la abundancia de la sección juvenil de las poblaciones de *Notothenia rossii*, una especie la cual es, al momento, capturada sólo como pesca accidental. La biomasa total de la población, sin embargo, permanece muy baja, de acuerdo a las evaluaciones realizadas por los cruceros de investigación científica de 1987 y 1988. El cohorte abundante de 1985 de *Champsocephalus gunnari* apareció en la población de la plataforma y es de este mismo que la pesquería consiguió sus bueno resultados en 1988/89, una vez que el cohorte alcanzó tamaño de pesca legal. El valor del índice de abundancia seleccionado (esfuerzo de pesca por unidad expresada en toneladas por hora de pesca) es, no obstante, más bajo que aquellos observados en los dos previos cohortes (1979 y 1982) en un período comparable. La población de *Notothenia squamifrons* muestra un valor de biomasa muy bajo en 1987 y 1988. Siguiendo una continua reducción en la longitud promedia desde el establecimiento de la EEZ, un pequeño aumento se ha registrado últimamente, acompañado por un

aumento en el índice de abundancia, después de una reducción en el esfuerzo de pesca y captura. Esta tendencia podría cambiar totalmente si se permite una pesca demasiado alta en 1988/89. Finalmente, es imposible hacer una estimación adecuada sobre la condición de la población de *Dissostichus eleginoides* debido a la carencia de datos recientes de pesca.

1. INTRODUCTION

After two seasons (1986/87 and 1987/88) of small catches (7 910 and 850 tonnes), Division 58.5.1 has recorded in 1988/89 a catch level (26 298 tonnes) comparable to that observed from 1979/80 on, when a system for monitoring the fishery was established.

Recent trends in the fishery are marked by a short fishing campaign in the 1987/88 southern winter (four trawlers having carried out 837 trawls) followed by a complete cessation of fishing only interrupted by a joint franco-soviet assessment cruise in the 1988 southern summer. Fishing effort was only resumed in the 1988/89 southern spring (11 trawlers following each other made 3 602 trawls), finishing in April 1989.

The status of exploited stocks was treated at some length by Duhamel (1987) and since then a biomass assessment has been carried in 1987 and 1988 during a joint cruise (Duhamel, 1988). The aim of this contribution is to present, for each of the exploited stocks, some new data which have been acquired since these works.

2. METHODS

The data are from scientific projects involving surveys of fish stocks carried out on trawlers operating in the fishing areas. They are concerned both with statistical (catch and fishing effort) data obtained by analyzing fishing logs (KERPECHE data bank) and biological data (LFD, age, reproductive status), these latter having been collected according to the recommendations for Southern Ocean species.

3. RESULTS

3.1 *Notothenia rossii*

As in South Georgia, a continued decline in catches of *N. rossii* at Kerguelen has been one of the notable features of trends in this fishery. This species was in fact the main resource when harvesting first began, but now only appears as a secondary species. It must be added that the main work of the Scientific Committee has been concentrated on this species up to now.

At Kerguelen, following the establishment of an Integrated Study Region which in turn followed a decade of unregulated exploitation, a continued decline in the abundance index (average CPUE expressed as tonnes per hour of fishing) was ascertained from 1980 to 1982 (Duhamel, 1987). Directed fishing on the only spawning ground on the southeast of the shelf in the southern winter, which corresponds to the reproductive period, has led to the recommendation of a cessation of this practice. A temporary closure of this fishing area has been in effect since 1984. An assessment of the biomass of individuals aged more than three years present over the Kerguelen Shelf was carried out in 1987 and 1988 (Duhamel, 1988). The results obtained provide a value of between 18 000 and 28 000 tonnes which clearly indicates a significant reduction in the biomass since the commencement of exploitation. Simulation tests on the reconstitution of the stock (Hennemuth et al., 1988) allowed for a forecast on the future of the stock following the implementation of some conservation measures. In particular, a low level of fishing effort would correspond to (be followed by) a doubling of the biomass of the stock in five years.

The implementation of conservation measures does not, however, always allow the recovery of the stock, particularly in the case of *N. rossii.* Outside of the reproductive period the adult stock is very widely dispersed, in very random spatial aggregations, which does not allow the abundance index used to reflect the status of the stock. It is therefore essential to have recourse to methods which do not introduce a bias. An analysis of the recruitment of juveniles in the coastal area appears therefore to be most appropriate. Regular experimental fishing with trammel nets in this area would thus allow the measurement of variations in the abundance of this part of the stock which remains limited to the relatively shallow waters of the archipelago for the juvenile growth period (Hureau, 1970; Duhamel, 1987). The observed trend will later have repercussions on the adult stock, with some inertia due to growth, taking into account mortality phenomena.

The results obtained since 1982 in the Morbihan Gulf (Figure 1) (Duhamel and Hureau, in press) show a very low abundance of juvenile stock in 1984, which could be correlated with a noticeable decrease in the adult stock prior to that date. In fact a certain displacement between the abundance of the two stocks is observed, taking into account the fact that these are juvenile fish of age classes 2 and 3, and therefore will have hatched from layings of adult stock of three or four years earlier, which are caught in the trammel nets. Then a gradual increase in abundance with an average annual growth rate of 36.3% is observed, which leads to a doubling in the number of individuals in a little less than three years. The growth in the biomass of the juvenile stock is noted and a deferred impact will be observed on the adult stock with a delay of about four years corresponding to the arrival (at the age of 5 to 6 years) of these juveniles on the shelf.

A catch limited to by-catches has recently been initiated for the *N. rossii* stock fished at Kerguelen in order to assist the recovery of the latter. A perceptible reduction in annual catches of this species since that date (1986/87, 481 tonnes; 1987/88, 24 tonnes; 1988/89, 282 tonnes) is thus to be noted and one can hope for a gradual recovery of the adult stock similar to that observed in coastal areas for juveniles, approximating to that in the simulation model.

3.2 *Champsocephalus gunnari*

Icefish constitute the main catch at present on the Kerguelen Shelf since for the 1988/89 season it represented 86.3% of the 26 697 tonnes caught.

Fishing is carried out, for the shelf stock, on a single cohort hatched in 1985 which began to be harvested once the legal size (25 cm) was reached (1988). Regular sampling in the northern and northeastern parts of the shelf (traditional fishing sectors) permitted the growth of the cohort to be surveyed (Figure 2) as had been done for the cohorts 1979 and 1982 (Duhamel, 1987). The average length observed for the 1988/89 season was 29.2 cm which compares closely with previous data on the same growth sampling period. No other abundant cohort has been able to be detected since the southern winter of 1987 which confirms the hypotheses of an abundant recruitment every three years corresponding to the first reproduction of mature individuals in each cohort. The analysis of length frequency distributions provides three other kinds of information useful for the management of the stock.

- The sex ratio is continuously unfavourable to males (only 37.8% are males) but no significant difference in average length between the two sexes has been noted (Figure 3).

- The annual growth period begins in December and continues throughout the summer (Figure 4).

- There were no differences between sampling carried out on catches made by benthic trawl and that made by semipelagic trawl. The same stock is thus being harvested (Figure 5).

The initial biomass of the 1985 cohort was assessed during the 1988 scientific cruise (Duhamel, 1988) and shows a high abundance. Following the 1988/89 fishing season the abundance index (CPUE in terms of the average number of individuals caught per hour of trawling) gives a value of $3.16 .10^4$, which is lower than the values observed, for an equivalent age, for the 1979 (4.40) and 1982 (3.81) cohorts. An analysis of these three values shows a certain trend towards a decrease in the total biomass of each cohort. Some reservations must however be expressed concerning a potential bias due to a change in fishing methods recorded in the past few years (selective use of semipelagic trawls, trawling strategy taking into account nycthemeral migrations of the species, longer trawling times, cessation of fishing at night) which make standardization of the index more difficult. Thus fishing effort for the target species *C. gunnari* in the northern and northeastern sectors during the 1988/89 season can be divided into benthic trawls (62%) and semipelagic trawls (38%) with respective yields of 4.71 and 4.46 tonnes per hour (Table 1).

These results do not bring out the important differences between the two types of fishing gear as was previously the case (Duhamel, 1987).

The second stock of icefish in Division 58.5.1, that of the Skif Bank at the southwest of the shelf, has not been fished, nor sampled, since April 1988, when the 1987 cohort appeared (Lt=13 cm) following the 1984 cohort whose presence was still recorded (Lt = 33.3 cm). The 1987 cohort will reach sexual maturity in 1990, at the same time as it attains its legal fishing size. Previous studies (Duhamel, 1987) have, however, demonstrated that the biomass of this stock is small in relation to the shelf stock and would not sustain a heavy fishing effort.

3.3 *Notothenia squamifrons*

Unlike *C. gunnari*, the sex ratio for *N. squamifrons* is practically even and no difference is observed between average length in samplings carried out on the Kerguelen Shelf stock for both sexes (Lt=33.3 and 33.5 cm in 1988/89) (Figure 6). After a continued decrease in the average length observed between 1983/84 and 1986/87 (Duhamel, 1987) and which carried through into 1987/88 (Lt=30.8 cm), the value observed in 1988/89 is higher (Lt=33.4 cm), very close to average length at sexual maturity (33.5 and 33.8 cm at the age of 9 years). The length frequency distribution observed in 1988/89 is very close to that observed since 1985/86 with a demographic structure of the exploited population comprising mainly individuals aged between 7 and 11 years.

The biomass of the shelf population was considered to be very low in 1987 and 1988 (between 5 500 and 9 000 tonnes) (Duhamel, 1988) which corroborates/confirms the results of the virtual population analysis (Duhamel, 1987). Catches of *N. squamifrons* were insignificant in 1987/88 (41 tonnes) but in 1988/89 they exceeded (1 825 tonnes) the values recorded in 1986/87 (1 641 tonnes). Values of the abundance index (CPUE in t/h) recorded in 1986/87 in the southern (1.58) and southeastern (0.68) sectors confirm the trend towards a decrease in the biomass, however in 1988/89 there is a certain slowing of the trend in the southern sector (1.38) and a further increase in the southeastern sector (1.08) (Figure 7). Considering this analysis in terms of the annual area of distribution of the stock, this recovery, if noted, is very small. It therefore seems that the effect of a temporary cessation of fishing in 1987/88 has been weakened in 1988/89 by a fishing effort too great for this fragile stock.

A second stock of *N. squamifrons* exists on the Kerguelen-Heard Banks at the border of Divisions 58.5.1 and 58.5.2, and sampling carried out in 1979 and since 1987 prove that the demographic structure observed is close to that of an unexploited population (Lt=43.0 cm in 1989). Some catches of this small stock (138 tonnes in March 1989) have to be remarked on. The lack of regular observations does not allow an evaluation of the size of this resource, which must be limited because of the small size of the available areas, to be made at present.

3.4 *Dissostichus eleginoides*

During the 1984/85 fishing season, a stock of adult *D. eleginoides* was discovered in a deep area of the western sector of the Kerguelen Shelf. Since that date, this sector has become the most exploited sector for the catch of this large-sized species. Fishing effort on this new target species has however fluctuated greatly from one year to the next (Table 2) in relation to the availability of other exploited species, particularly icefish. The fishing season is largely concentrated within the months of October and January and average yields observed (Table 3) are at present (1.96 t/h in 1988/89) greater than those for *N. squamifrons* (1.19 t/h in 1988/89), which is remarkable considering the difficulties encountered in fishing for this species, but do not, however, reach the levels observed for *C. gunnari* (4.46 t/h in 1988/89). It would be premature to assess the status of the exploited stock especially since trends in the abundance index fluctuate greatly and knowledge of the biology of the adults is still very incomplete.

4. CONCLUSION

The status of exploited stocks at Kerguelen requires a regular and continuing survey allowing for the modification of catch sizes and conservation measures in force. The *N. rossii* stock will require maximal protection as long as the biomass of the adult stock fails to increase significantly. Fishing effort on the *C. gunnari* stock should take account of the three-year cycle which has now been revealed, and catch levels should be based on a measurement of the recruitment of each new cohort before it begins to be exploited. The *N. squamifrons* stock is at present being over-exploited and conservation measures should be implemented in order to reverse this. Finally, it is too early to assess the status of the stock of *D. eleginoides*.

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Table 1: Fishing effort, catch and corresponding mean yield for the exploited *Champsocephalus gunnari* stock in the northern to northeastern part of the Kerguelen Shelf in 1988/89.

Semipelagic trawls:	Effort (hours of fishing):	1 896
	Catch (tonnes):	8 923
	Yield (t/h):	4.71
Benthic trawls :	Effort ("):	3 069
	Catch ("):	13 679
	Yield ("):	4.46

Table 2: Fishing effort, catch and corresponding yield for the stock of *Dissostichus eleginoides* harvested in the west of the Kerguelen Island Shelf from 1984/85 to 1988/89.

Fishing season	Fishing effort (hours of fishing)	Catch (tonnes)	Yield (t/h)
1984/85	2 597	6 492	2.50
1985/86	263	370	1.41
1986/87	1 779	3 190	1.79
1987/88	637	497	0.78
1988/89	907	1 496	1.64

Table 3: Fishing effort, catch and yield for the stock of *Dissostichus eleginoides* harvested in the western sector of the Kerguelen Shelf in the southern spring from 1984/85 to 1988/89.

Fishing season	Fishing effort (hours of fishing)	Catch (tonnes)	Yield (t/h)
1984/85	2 026	5 979	2.95
1985/86	263	361	1.37
1986/87	1 756	3 158	1.80
1987/88	(58)	(36)	-.--
1988/89	655	1 286	1.96

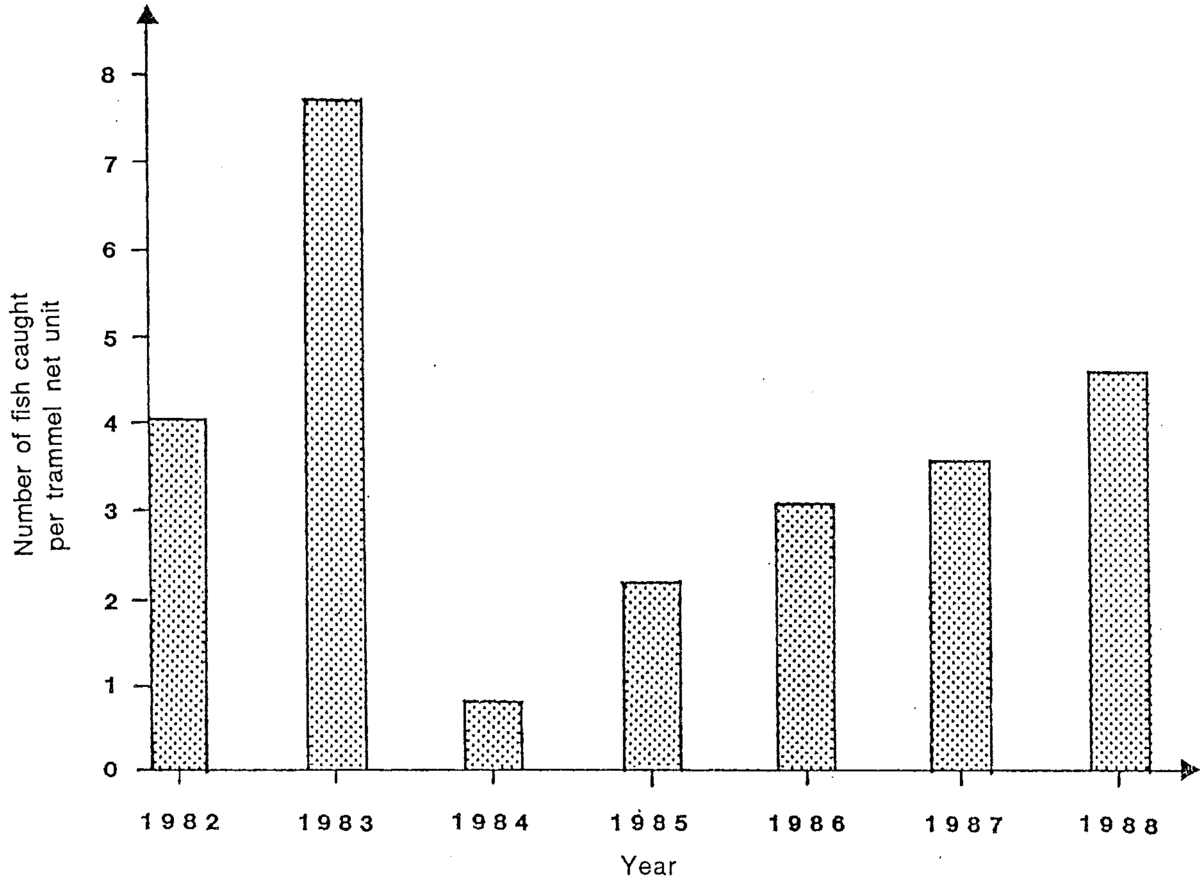


Figure 1: Mean annual abundance (expressed as the number of fish caught per unit trammel net) of juvenile *Notothenia rossii* in the Morbihan Gulf, a coastal area of the Kerguelen Islands, from 1982 to 1988.

Kerguelen shelf, northeast C.gunnari

month.year

month

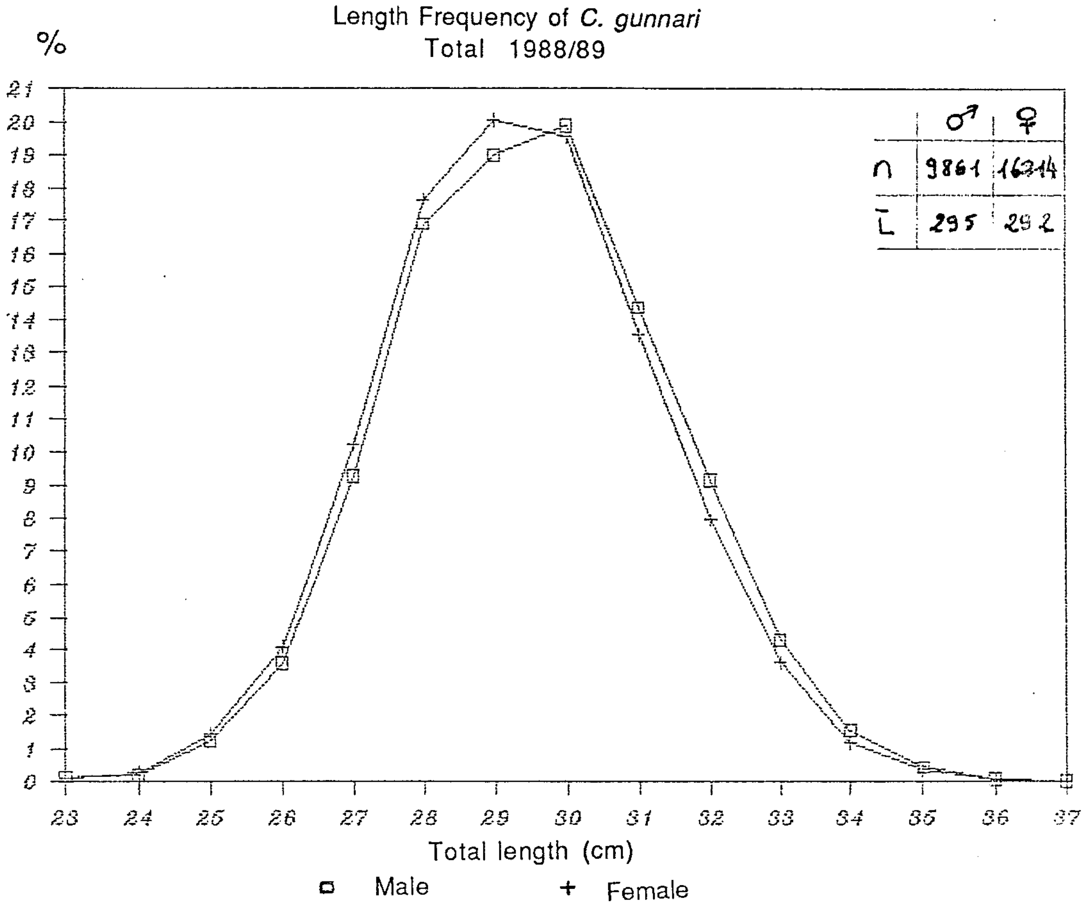
Total length

L.cm	2.87	%	3.87	%	3.87	%	10.87	%	11.87	%	2.88	%	3.88	%	4.88	%	9.88	%	10.88	%	12.88	%	1.89	%	2.89	%	3.89	%
12	1	1.1																										
13	5	5.6																										
14	11	12.2																										
15	15	16.7																										
16	12	13.3																										
17	16	17.8	1		1	0.4																						
18	14	15.6			6	2.4	1	0.8																				
19	12	13.3			14	5.7	5	3.8	1	0.4	2	0.0	1	0.1														
20	3	3.3			43	17.6	10	7.6	5	2.1	2	0.0	2	0.2														
21	1	1.1			43	17.6	27	20.6	26	11.0	14	0.2	1	0.1														
22			2		·72	29.4	23	17.6	36	15.3	73	1.3	6	0.6	7	0.2												
23	90				40	16.3	27	20.6	63	26.7	267	4.7	33	3.4	23	0.6	5	0.1	2	0.1								
24	16.5				15	6.1	20	15.3	49	20.8	643	11.4	78	8.1	114	2.9	15	0.3	12	0.5	1	0.6						
25					9	3.7	12	9.2	34	14.4	1120	19.9	142	14.7	332	8.6	79	1.8	41	1.8	2	1.2	2	0.2				
26	1	3.6			2	0.8	6	4.6	13	5.5	1267	22.5	178	18.4	551	14.2	208	4.8	151	6.8	3	1.8	5	0.4	4	0.2		
27									8	3.4	1154	20.5	220	22.7	827	21.3	557	12.8	346	15.5	12	7.1	25	2.0	8	0.4		
28									1	0.4	685	12.1	166	17.1	861	22.2	944	21.7	575	25.8	33	19.4	79	6.3	31	1.5	5	0.9
29	1	3.6	2	2.1							294	5.2	91	9.4	631	16.3	992	22.8	538	24.1	49	28.8	180	14.3	73	3.6	12	2.1
30	3	10.7	4	4.1							99	1.8	41	4.2	345	8.9	899	20.7	356	16.0	40	23.5	254	20.2	312	15.3	39	6.9
31	3	10.7	7	7.2							14	0.2	9	0.9	148	3.8	457	10.5	148	6.6	19	11.2	304	24.2	352	17.3	78	13.8
32	6	21.4	20	20.6							3	0.1			35	0.9	146	3.4	45	2.0	10	5.9	226	18.0	466	22.8	127	22.5
33	7	25.0	18	18.6							1	0.0			7	0.2	31	0.7	12	0.5	1	0.6	134	10.7	427	20.9	126	22.3
34	3	10.7	21	21.6							1	0.0					6	0.1	2	0.1			42	3.3	242	11.9	108	19.1
35	2	7.1	13	13.4											1	0.0	3	0.1					6	0.5	95	4.7	41	7.3
36	1	3.6	7	7.2											1	0.0									27	1.3	24	4.2
37			3	3.1																					3	0.1	5	0.9
38	1	3.6																										
39			1	1.0																								
40			1	1.0																								
41																												
Number of fish	28		97		245		131		236		5639		968		3883		4342		2228		170		1257		2040		565	
Mean Length	32.4		33.4		21.61		22.47		23.36		26.05		26.61		27.59		28.84		28.50		29.19		30.73		31.97		32.66	

Cohort 1982

Cohort 1985

Figure 2: Length frequency distributions (LFD) of *Champsocephalus gunnari* obtained by monthly sampling in the northeastern zone of the Kerguelen Islands from 1987 to 1989.



	♂	♀
n	9861	16314
$\bar{L}$	295	292

Figure 3: Length frequency distributions (LFD) of male and female *Champsocephalus gunnari* obtained in 1988/89 on the Kerguelen Shelf.

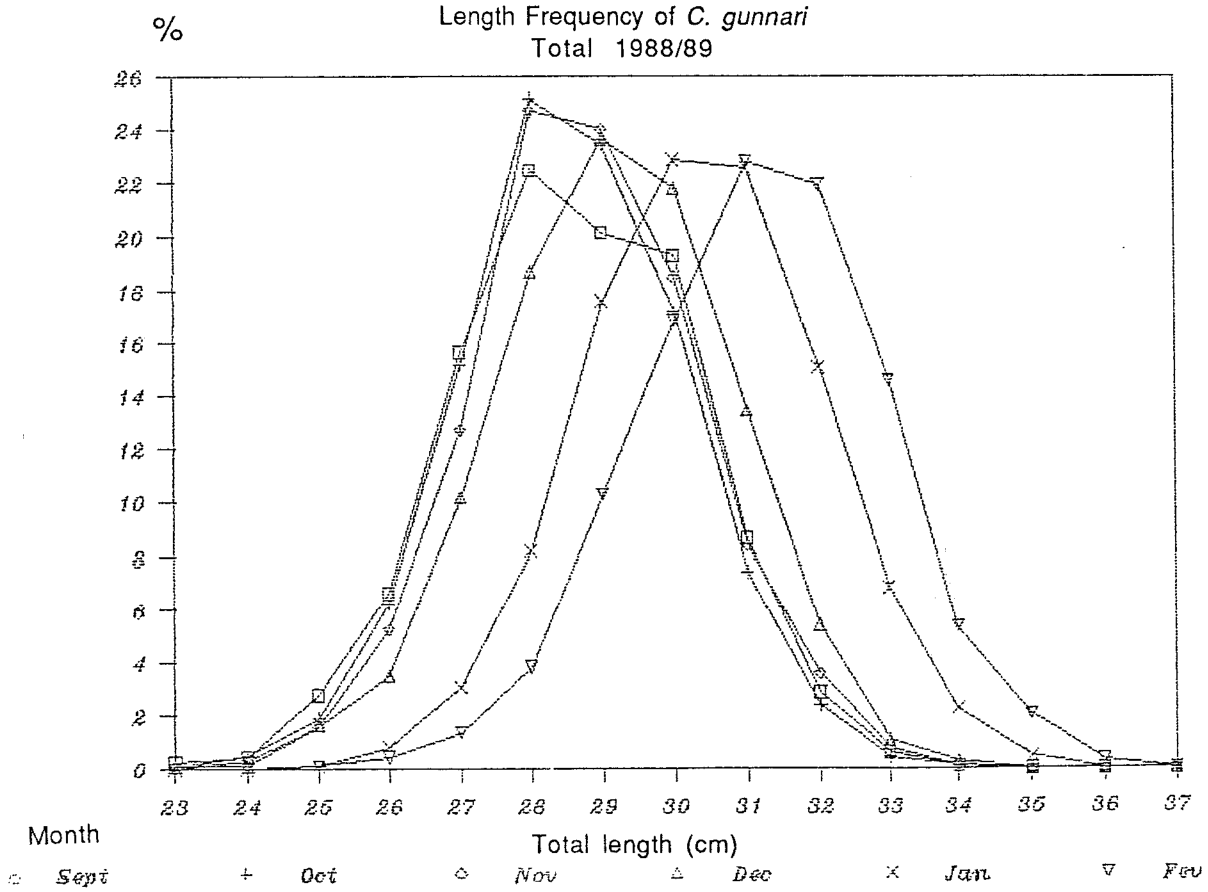


Figure 4: Length frequency distributions (LFD) of *Champsocephalus gunnari* obtained on a monthly basis on the Kerguelen Shelf in 1988/89.

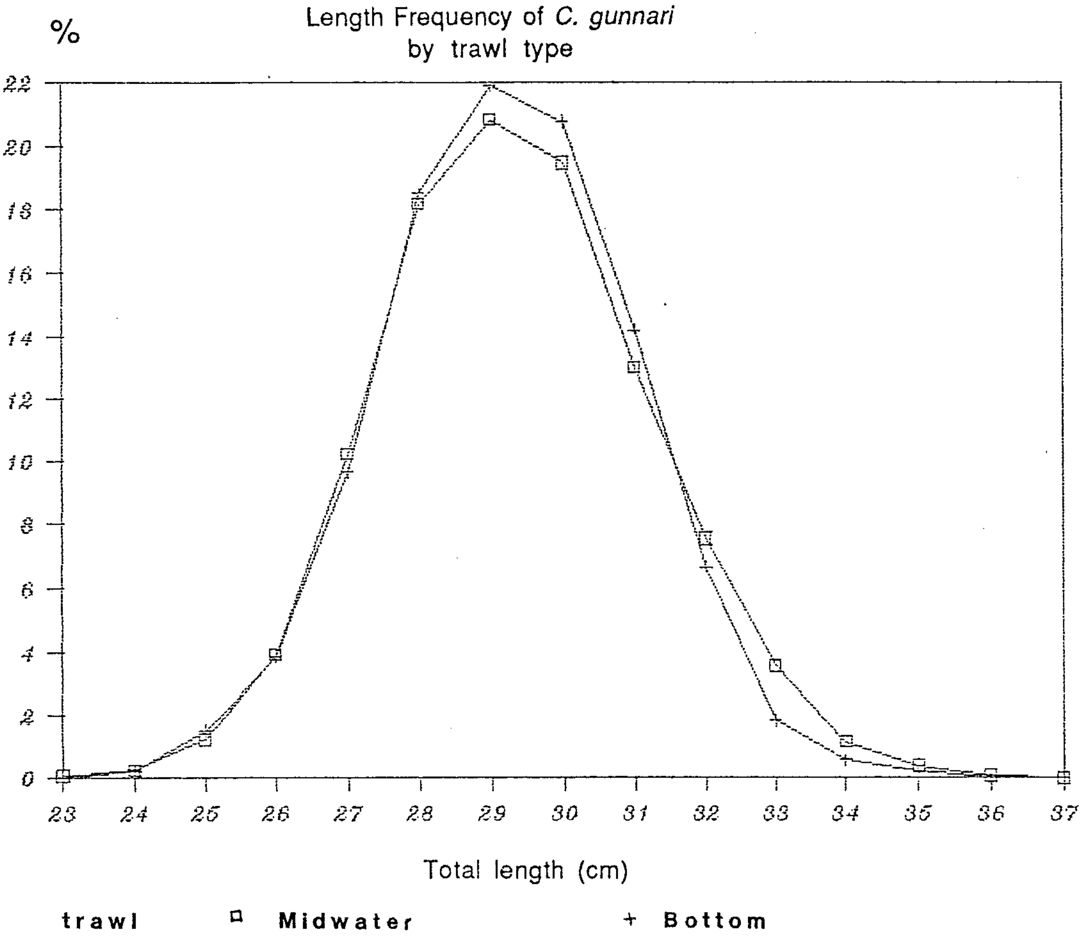


Figure 5: Length frequency distributions (LFD) of *Champsocephalus gunnari* obtained from sampling of catches made by semi-pelagic and benthic trawl in 1988/89.

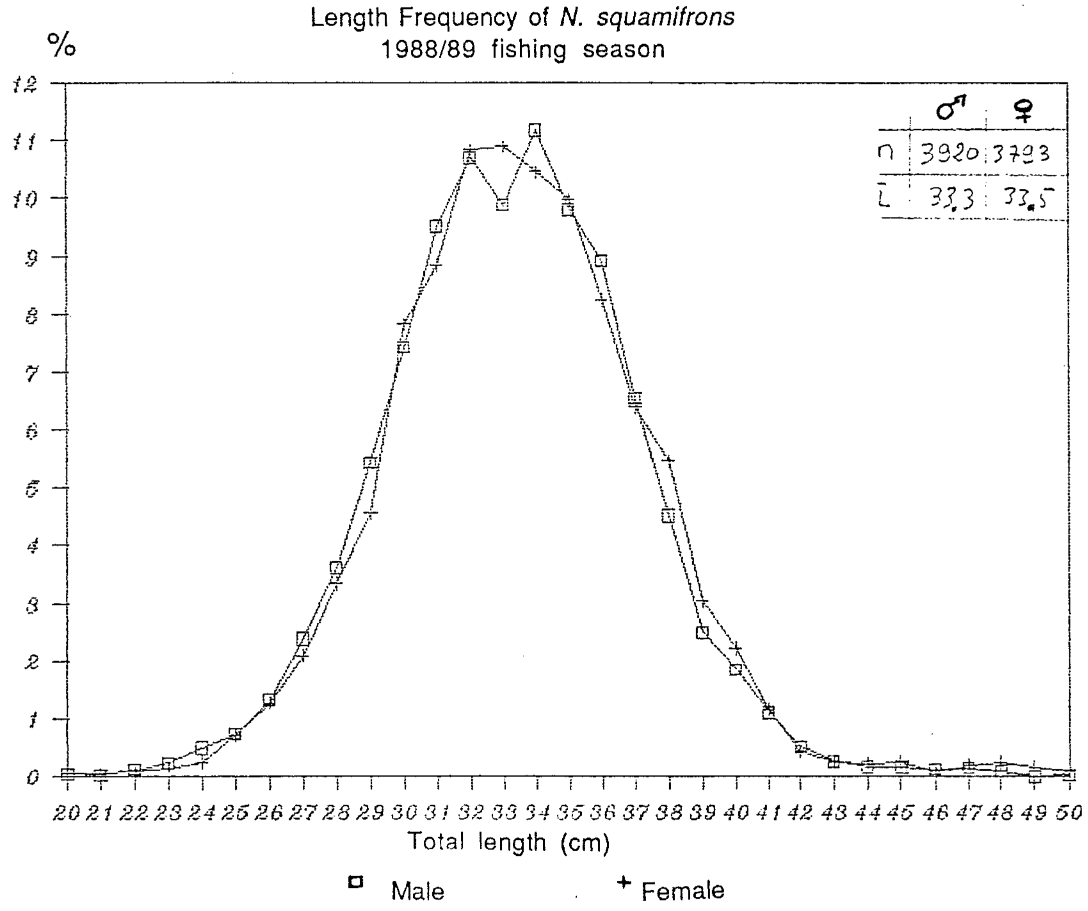


Figure 6: Length frequency distributions (LFD) of male and female *Notothenia squamifrons* obtained during sampling in 1988/89.

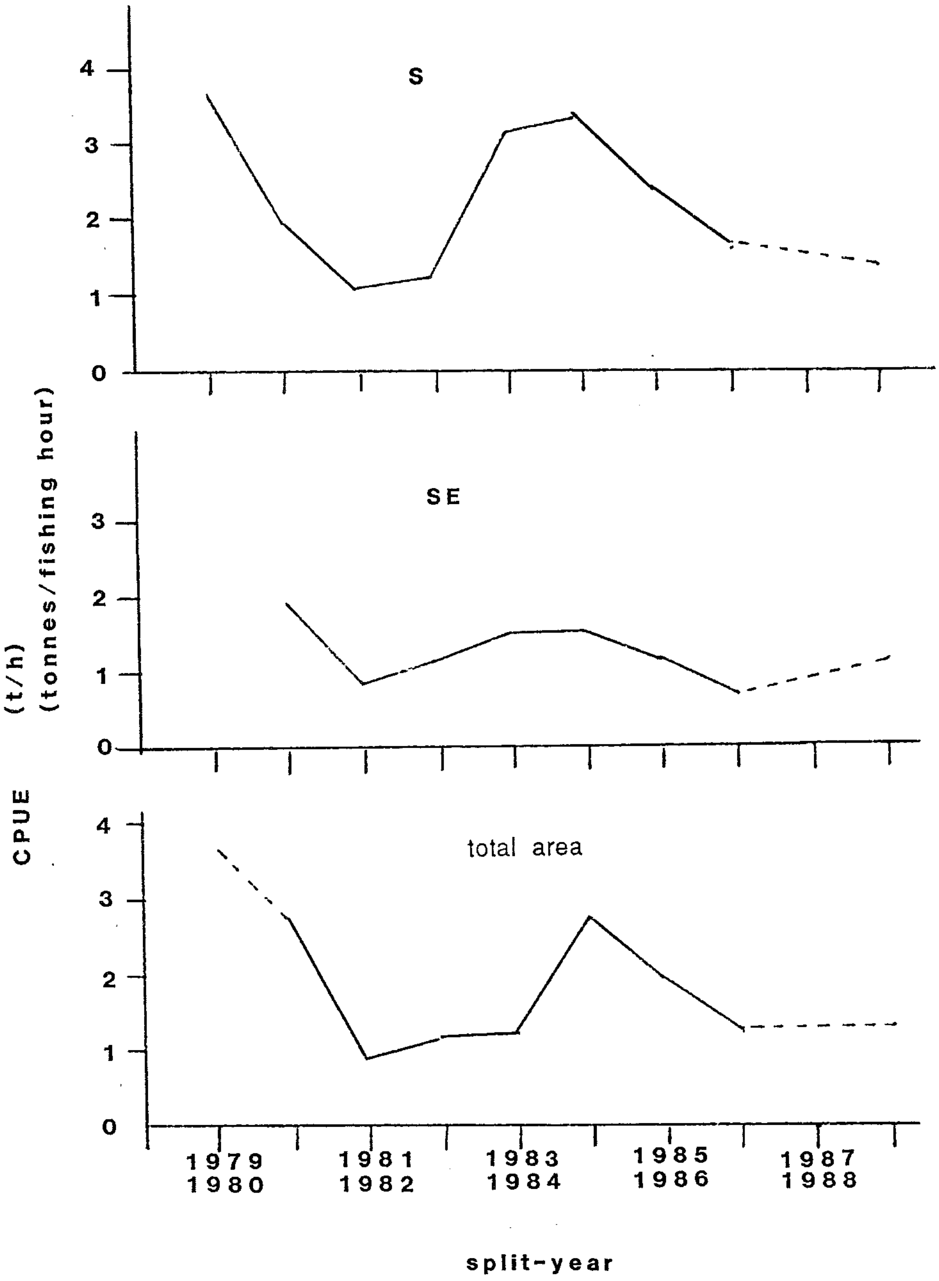


Figure 7: Variation in the abundance index (expressed as tonnes of fish caught per hour of trawling) for the exploited stock of *Notothenia squamifrons* from the Kerguelen Shelf from 1979/80 to 1988/89.

S: Southern sector SE: Southeastern sector

EVALUATION OF THE RESULTS OF TRAWL SELECTIVITY EXPERIMENTS BY POLAND, SPAIN AND USSR IN 1978/79, 1981/82 AND 1986/87

W. Slosarczyk, E. Balguerias, K. Shust and S. Iglesias

Abstract

Trawl selectivity for several species of Antarctic fish was evaluated taking into account additional data obtained by Poland, Spain and USSR during selectivity experiments in Statistical Area 48 in 1978/79, 1981/82 and 1986/87 seasons. These data comprise different characteristics of experimental codends, length frequency distribution of stocks sampled, catch rates and catch composition. Details of these data were analyzed and minimum mesh sizes for several species were calculated. It is recommended that introduction of these mesh sizes should be considered for commercial fishery in Statistical Area 48.

Résumé

La sélectivité des chaluts pour plusieurs espèces de poissons de l'Antarctique a été évaluée, compte tenu des données complémentaires obtenues par la Pologne, l'Espagne et l'URSS au cours des expériences de sélectivité dans la zone statistique 48 pendant les saisons 1978/79, 1981/82 et 1986/87. Ces données comprennent les différentes caractéristiques de culs de chalut expérimentaux, la distribution de fréquences de longueurs des stocks échantillonnés, les taux de capture et la composition des captures. Les détails de ces données ont été analysés et les tailles minimales du maillage ont été calculées pour plusieurs espèces. Il est recommandé que l'introduction de ces tailles du maillage soit considérée pour la pêcherie commerciale dans la zone statistique 48.

Резюме

Селективность трала для нескольких видов антарктических рыб была оценена с учетом дополнительных данных, полученных в ходе экспериментов по селективности в Статистическом районе 48, проводившихся Польшей, Испанией и СССР в течение сезонов 1978/79, 1981/82 и 1986/87 гг. Эти данные включают различные характеристики экспериментальных кутков, частотное распределение длины в запасах, где брались пробы, интенсивность промысла и состав уловов. Был произведен подробный анализ этих данных, и для некоторых видов были вычислены минимальные размеры ячеи. Рекомендуется рассмотреть вопрос о введении этих размеров ячеи для коммерческого промысла в Статистическом районе 48.

Resumen

Selectividad de arrastre para varias especies de peces Antárticos fue evaluada tomando en consideración los datos adicionales obtenidos por Polonia, España y la URSS durante los experimentos de selectividad realizados en el Area Estadística 48 en las temporadas 1978/79, 1981/82 y 1986/87. Esta información comprende diferentes características de los copos de malla experimentales, distribución talla-frecuencia de las poblaciones muestradas, composición y tasas de capturas. Detalles de estos datos fueron analizados y se calculó la luz mínima de malla para varias especies. Se recomienda que la implementación de estas luces de malla deben ser consideradas para la pesca comercial en el Area Estadística 48.

1. INTRODUCTION

Available data on the selectivity of various trawl codends on Antarctic fish were evaluated in the light of additional information presented to the CCAMLR Scientific Committee. This included: parameters of the codends and netting used, the length distribution of fish in the stock sampled, catch rates and catch composition. All these factors may influence the selectivity and should, therefore, be taken into consideration, when selection parameters are calculated. They were, however, not analyzed by authors of the background documents submitted to the Scientific Committee of CCAMLR (Balguerias, 1988; Efanov et al., 1989; Zaucha, 1986 and 1988).

2. COMMENTS ON METHODS

Some differences were noted in methods and equipment used in selectivity experiments. Some of them, such as number of panels in the codend (2 or 4), inside or outside position of fine-meshed liner in relation to bottom panel, were considered to have little or no influence on fish selection. Other attributes such as twine size and haul duration (which affects the amount of fish in codend) and length of fish caught has in some cases a significant effect on selectivity parameters.

In the first Polish experiment (1978/79), the single-layer codend of mesh size 124 mm was made of 7 mm twine. In the second experiment (1986/87), the size of twine in the codend was 4.2 mm. The Soviet (1981/82) and the Spanish (1986/87) selectivity experiments were conducted with 3.1 and 3.0 mm twine respectively. The relationship between the twine diameter and selection factors (SF) for *Champsocephalus gunnari* gives the range of likely change of some selectivity parameters when different twine is used in the codends (Figure 1). It should be noted, that the selection curve for 7 mm twine is not well defined and SF point in Figure 1 is only a rough estimate.

The effect of catch rates on fish selection cannot be properly evaluated on the basis of available data. Polish hauls of 2 to 3 hours resulted in some cases in large catches of 2 to 5 tonnes and thus affected the selectivity of the major species caught (*C. gunnari*). The significant decline of SF and the 50% selection length (L_{50}) was observed (Figure 2). Some data points in Figure 2 were estimated from selection ogives which were not well defined, therefore the presented relationship should be taken with care. Thirty minute hauls in the Spanish experiment gave average catches of 290 to 580 kg and resulted in better conditions for fish selectivity. However, some single hauls with high catches did not result in the reduction of selection parameters of fish sampled (Figure 3; see also Table 1.1 of the Appendix). Similarly, no clear relationship was observed between SF and catch per tow for *Notothenia gibberifrons* in the Polish experiment (Figure 4; see also Table 9.2 of the Appendix). In this case the selection was probably influenced by a large by-catch of benthos (sponges).

An accurate evaluation of another factor, the length distribution of fish caught, was also difficult. Analysis of its effect on selectivity was limited to hauls with comparable catch rates. In general, observations of this relationship were not consistent for *C. gunnari* in both Spanish and Polish data sets. This relationship was, however, noted for *N. gibberifrons* in the Polish records, where gradual decrease of L_{50}, ranging from 33.5 to 23.4 cm, may clearly be related to an increasing amount of small specimens of this species (Figures 5 and 6; see also Table 9.2 of the Appendix).

3. EVALUATION OF THE RESULTS FOR SOME SELECTED, COMMERCIALLY EXPLOITED SPECIES

3.1 *Champsocephalus gunnari*

3.1.1 South Georgia (Subarea 48.3)

Polish, Spanish and Soviet mesh selectivity experiments in 1981/82 and 1986/87 were carried out in comparable conditions. Fish length distributions and catch rates were similar, an amount of *C. gunnari* in catches from 42 to 100%. The length distribution of that species in the South Georgia area in 1978/79 during the first Polish trawl selectivity studies was also close to that observed in 1986/87.

Information about CPUE and catch composition from the first Polish experiment is not available. Hauls of three hours or more in the second experiment resulted in the mean total catch of 2.9 tonnes and catch rate for *C. gunnari* of 0.52 tonnes per hour fished (tonnes/hf). Haul-by-haul information from the Soviet experiment is not available. Tows of 30 to 60 minutes yielded total catches of 0.6 to 1.0 tonnes. Mean catch rate for *C. gunnari* was 0.75 tonnes/hf. In the Spanish experiment 30 minute hauls produced total catches of about 0.3 to 0.6 tonnes on the average. However, several hauls over 1.5 tonnes per tow were also noted (Table 1.1 of the Appendix). Mean catch rates for *C. gunnari* were 0.45 and 0.49 tonnes/hf, similar to those in the Polish experiment.

The catch rates during selectivity experiments resemble those of the commercial fishery. The mean CPUE range observed from 1984 to 1988 for *C. gunnari* was 0.1 to 0.5 tonnes per hour in a mixed fishery and 1.0 to 1.5 tonnes per hour in the fishery targetted at this species. A less than expected increase was observed in L_{50} as a result of enlarging the mesh size from 68 through 88 to 124 mm. The 50% selection length for 88 mm mesh in the Polish experiment was decreased due to a large quantity of fish and benthos in the codend. The 50% selection length for codends having 124 mm and 125 mm meshes and the chafer having 220 mm meshes was estimated from the selection ogives. In the first case, a low L_{50} resulted from using 7 mm polyamide twine which was approximately twice the thickness of that used in the 68 and 88 mm netting. The number of fish sampled from the 125 mm mesh codend was small, so the selection ogives give two values of the 50% selection lengths, 21 and 29 cm. The low L_{50} values for this codend resulted most probably from the 220 mm mesh chafer used to protect the 3.5 mm codend netting.

3.1.2 South Orkney Islands (Subarea 48.2)

The Spanish study was carried out in favourable conditions for fish selection (low catch rate). This resulted in a relatively high SF of 3.11. Because of the low catch rate, however, the experiment does not represent fishery conditions, where CPUE for *C. gunnari* was within the range of 0.3 to 0.9 tonnes per hour fished. Also, the number of fish measured seems to be insufficient: despite the small mesh size, the number of fish retained by a codend is more or less the same as the number of fish in the fine-meshed cover.

Information on CPUE in the Polish experiment is not available, and fish length distribution is different from that in the Spanish studies. Moreover, the Polish codend was protected by the 220 mm mesh chafer. Those differences made interpretation of SF and L_{50} estimates from the Polish selectivity studies difficult.

3.1.3 Elephant Island and South Shetland Islands (Subarea 48.1), Table 3

Fish length distribution in the Elephant Island area did not show any significant changes throughout the whole period of selectivity experiments. Selection factors were relatively high (mean SF=3.05) for all meshes tested. The 50% selection length increased gradually as mesh-size increased.

The low estimate of selectivity parameters for the South Shetland Islands area are most probably related to the availability of juvenile fish in the area.

Selectivity parameters obtained in Subarea 48.1 are, however, not representative of commercial fishing, especially for *C. gunnari*. Catch rates in the Spanish experiment were lower than observed in the commercial mixed fishery (0.1 to 2.0 tonnes/hf) in the area, in 1979 to 1983. Total CPUE in the Polish experiment more closely resembled the CPUE in the mixed fishery, but the percentage of *C. gunnari* was very small (2.5 to 6.5%). Corresponding catch rates for this species were 6 and 24 kg/hf, therefore, they cannot represent selectivity conditions of the commercial fishery.

3.2 *Chaenocephalus aceratus*, Tables 4, 5 and 6

The 50% selection length did not increase significantly over the range of mesh sizes from 68 to 125 mm. Selection factors differed considerably (1.4 to 2.63) and were generally low. All values of L_{50} were much lower than the length at 50% maturity for the South Georgia area of 46 cm for males and 47.4 cm for females (Kock, 1981). The morphology of this species, especially its large and spiny head, as well as its behaviour (stretching opercles in case of danger) seem to be mainly responsible for absence of any meaningful trend in selection characteristics.

3.3 *Pseudochaenichthys georgianus,* Tables 7 and 8

Selectivity data available for this species are insufficient to justify any mesh regulation. It is obvious from the Spanish data (Tables 7 and 8) that 68 mm mesh is far too small. Also 88 mm mesh seems not to be adequate to ensure protection of undersized fish (Zaucha, 1988). As in the case of *C. aceratus*, the morphology and behaviour of this fish seems to be responsible for the low selectivity parameters in both experiments.

3.4 *Notothenia gibberifrons*, Tables 9, 10 and 11

Fish length distribution was different in 1978/79 and 1986/87, and also in the five areas studied. Selection factors varied from 2.02 to 3.04 (mean SF=2.62) for various meshes and codends tested, so it was not possible to reach a clear conclusion about selection of this species. One conclusion emerges, however, from information shown in Tables 9, 10 and 11. All values of L_{50} for South Georgia are well below the length at 50% maturity of 31.7 cm (Boronin and Altman, 1979) or 34 cm (Hoffman, 1982). L_{50} values calculated for South Orkney Islands, Elephant Island and South Shetland Islands were 28.8 cm, 30.0 cm and 30.9 cm respectively (Balguerias et al. 1987). Only in one haul taken in the South Shetland area with a mesh of 110 mm (Table 11, data set (1)), the L_{50} of 31.2 cm was above the length at maturity. However, for the same mesh size in the Elephant Island area (Table 11, data set (3)), when the mean CPUE increased from 241 kg to 993 kg/hf, the L_{50} decreased to 23.6 cm. L_{50} values of 30 cm for mesh size 124 mm (Table 9) and of 29.4 cm for mesh 110 mm (Table 11) are difficult to interpret (rough estimate in the first case and a very low CPUE in the second).

Catch rates for this species in the experiments are more or less the same as those reported in the mixed commercial fishing in the Scotia Sea area from 1979 to 1983 (average CPUE of 0.01 to 0.4 tonnes/hf). It is, therefore, likely that selectivity on the exploited fishing grounds is similar.

3.5 *Patagonotothen brevicauda guntheri*, Table 12

The fish length distribution and catch rates of the Spanish selectivity experiment were similar to those reported for the commercial fishery in this area. The bulk of the Soviet catches consisted of 14 to 17 cm long fish (Shust and Borodin, 1988). Reported CPUE for the 1984 to 1987 seasons were 0.3, 0.4 and 1.6 tonnes/hf (bottom trawl) and 2.1 tonnes/hf (midwater trawl). The average amount of fish in the codend during selectivity experiments was about 580 kg. For this reason the selection factor obtained may be taken as applicable for commercial fishing by bottom trawls. This estimatation is, however, preliminary and further selectivity studies with the mesh size and codends currently in commercial use, should be undertaken. High catch rates by midwater trawls is likely to result in substantially lower selectivity.

4. SUMMARY AND CONCLUSIONS

4.1 *Champsocephalus gunnari*

The selection factor (SF) of 2.95, obtained in the South Georgia area for mesh sizes of 68 and 88 mm, seems applicable for calculations of mesh size in the commercial trawl fishery for *C. gunnari*.

When referred to a nominal mesh of 80 mm, adopted by CCAMLR in 1984 as the minimum mesh size for *C. gunnari*, this value of SF gives L_{50} of 23.6 cm. This length is only slightly above the mean length at 50% maturity for the South Georgia area of 23.1 cm (Kock, Duhamel and Hureau, 1985), and well below the length of first spawning of 27 cm (Kock, 1989). The application of SF=2.95 corresponds in this case to the minimum mesh size of 92 mm. A mesh size of 108 mm would in turn correspond to the age at first capture of 4 years (i.e. around 32 cm), which was proposed as the optimum under conditions of high fishing mortality (Anonymous, 1988).

By using the mean SF from the South Georgia area in calculation of minimum mesh sizes for *C. gunnari* for the South Orkney and South Shetland areas, and applying the length at first spawning of 35 cm (Kock, 1989), the minimum mesh size of 119 mm was obtained.

4.2 *Notothenia gibberifrons*

By assuming the mean SF of 2.62 for *N. gibberifrons* for the entire Statistical Area 48, and using mean lengths at 50% maturity for this species in South Georgia (32.9 cm) as well as South Orkney, Elephant and South Shetland Is (29.9 cm), we obtain mesh sizes of 126 and 114 mm respectively. It should be recalled, however, that SFs for *N. gibberifrons* vary considerably between the areas studied and there is no clear relationship between mesh size increase and L_{50}. For these reasons the above mesh sizes should to be taken as provisional.

4.3 *Patagonotothen brevicauda guntheri*

SF of 3.21 when referred to 16 cm, which is the 50% length at maturity of *P.b. guntheri* (Balguerias and Quintero, 1989; Shlibanov, 1989), gives minimum mesh of 50 mm for this species.

4.4 *Chaenocephalus aceratus* and *Pseudochaenichthys georgianus*

Selection parameters for *C. aceratus* differ considerably for various meshes and codends tested. In general, they are rough estimates resultant from insufficiently defined selectivity ogives. Selectivity data available for *P. georgianus* are inadequate for designation of a minimum mesh size.

4.5 Mesh Regulation

Assuming that the actual size of twine mesh in commercially used codends is on the average 10% greater than the nominal mesh size (Zaucha, 1988), the introduction of the following mesh sizes in the commercial fishery in the Statistical Area 48 should be considered:

(a) Subarea 48.3

- (i) Fishery targeted at *C. gunnari*
  80 mm, to protect immature fish, or
  90 mm, to protect first spawners, or
  100 mm, to give an age at first capture of 4 years;
- (ii) Fishery target at *P. guntheri*
  50 mm, to protect immature fish;
- (iii) Mixed fishery (not targeted at *C. gunnari* or *P.b. guntheri*)
  120 mm, to include *N. gibberifrons, C. aceratus* and *P. georgianus* in addition to *N. rossii* and *D. eleginoides*, which have been covered by this mesh regulation since 1984 - Conservation Measure 2/III), to ensure better protection of immature fish;

(a) Subareas 48.1 and 48.2

110 mm, to ensure protection of first spawners of *C. gunnari* and immature *N. gibberifrons*.

In addition to the above, the provision that topside chafers will not be used and codends will be made not thicker than 4.5 mm should also be included.

4.6 Further Selectivity Experiments

Further research on mesh selectivity is recommended in order to improve the applicability of available selection factors. It is important that such studies reflect selectivity in the commercial fishery and therfore be undertaken using commercial fishing gear and techniques independently from biomass surveys.

It is worthy to note that the mean SF of 3.5 for *C. gunnari* and *N. gibberifrons*, obtained in the first Polish experiment using tape netting of 60 and 100 mm mesh, is considerably higher than that for twine netting currently in use in commercial trawls. One of the properties of the tape netting is constant rectangular shape of meshes (Zaucha, 1986). Satisfactory parameters of fish selection, obtained for this kind of net, should encourage further experiments with the 'open mesh' netting.

There is no information available to evaluate whether or not the mortality of fish passed through nets is a significant problem for Antarctic fish. It is recommended that such studies be undertaken in future selectivity experiments.

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Table 1: Species: *Champsocephalus gunnari*
Area: South Georgia and Shag Rocks (R) (Subarea 48.3)
Month/Year: November to December 1986(1), September 1981(2), December 1978 to March 1979(3)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length cm	Modal Length Range	Number of Fish Measured Codend	Number of Fish Measured Cover	Mean Total Catch Per Hour (kg)	Mean % of *C. gunnari* in Total Catch	Mean Catch of *C. gunnari* Per Hour (kg)
68 (70)(1)	2.94	20.0	26	13 - 37	92770	19854	583	76.9	448
67 (70)(1)R	3.48	23.5	26	17 - 41	8055	4551	1162	41.9	487
88 (80)(1)	2.56	23.0	26	11 - 41	56342	29851	970	56.4	547
88 (80)(2)	2.81	24.8	25	12 - 37	5340*		600-1000*	90-100*	750
124 (120)(3)	(1.77)[e]	(21-23)[e]	25	18 - 49	2864	2274	na	na	na
125 (120)[c](3)	(1.68;2.32)[e]	(21-29)[e]	25	18 - 49	430	421	na	na	na

na Data not available
[e] Estimated value
[c] Codend with the 220 mm mesh chafer
* Codend and cover combined

Table 2: Species: *Champsocephalus gunnari*
Area: South Orkney (Subarea 48.2)
Month/Year: December 1986(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length cm	Modal Length Range	Number of Fish Measured Codend	Number of Fish Measured Cover	Mean Total Catch Per Hour (kg)	Mean % of *C. gunnari* in Total Catch	Mean Catch of *C. gunnari* Per Hour (kg)
68 (70)(1)	3.11	21.3	22; 33	10 - 51	379	329	87	4.6	4
125 (120)[c](2)	(2.56)[e]	(32)[e]	38	31 - 47	2272	1905	na	na	na

na Data not available
[e] Estimated value
[c] Codend with the 220 mm mesh chafer

Table 3: Species: *Champsocephalus gunnari*
Area: Elephant I. and South Shetland Is (Subarea 48.1)
Month/Year: December 1986 to January 1987(1), January to February 1987(2), November to December 1986(3), November 1986 to February 1987(4)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *C. gunnari* in Total Catch	Mean Catch of *C. gunnari* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(1)	3.11	21.3	22;32	19 - 39	4394	1751	121	38.7	47
68 (70)(2)[s]	2.89	19.7	14;23	9 - 36	2666	2730	70	12.8	9
88 (80)(3)	3.22	28.0	22;32	15 - 52	2330	1841	241	2.5	6
110 (100)(4)	2.82	31.1	22-23;32-34	15 - 52	604	1035	369	6.5	24

[s] S. Shetland Islands

Table 4: Species: *Chaenocephalus aceratus*
Area: South Georgia (Subarea 48.3)
Month/Year: November to December 1986(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *C. aceratus* in Total Catch	Mean Catch of *C. aceratus* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(1)	(2.63)[e]	(17.9)[e]	15;25;32	13-67	639	301	615	1.3	8
88 (80)(1)	2.29	20.6	15;25;34;51	13-69	2954	133	966	11.9	115
124 (120)(2)	(1.41)[e]	(17.5)[e]	24	12-68	3490	1161	na	na	na
125 (120)[c](2)	(1.75)[e]	(21.0)[e]	24	12-68	1008	325	na	na	na

na Data not available
[e] Estimated value
[c] Codend with the 220 mm mesh chafer used

Table 5: Species: *Chaenocephalus aceratus*
Area: South Orkney Is (Subarea 48.2)
Month/Year: December 1986(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *C. aceratus* in Total Catch	Mean Catch of *C. aceratus* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(1)	(2.22)[e]	(15.2)[e]	13,20,28,42	11-62	1058	1609	82	14.7	12
125 (120)[c](2)	(1.68)[e]	(21.0)[e]	57	23-70	164	36	na	na	na

na Data not available
[e] Estimated value
[c] Codend with the 220 mm mesh chafer

Table 6: Species: *Chaenocephalus aceratus*
Area: Elephant I. and South Shetland Is (Subarea 48.1)
Month/Year: October to November 1986 and February 1987(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *C. aceratus* in Total Catch	Mean Catch of *C. aceratus* Per Hour (kg)
			cm	Range	Codend	Cover			
88 (80)(1)	2.48	21.5	46	12 - 68	1801	44	241	14.2	34
110 (100)(1)	2.09	23.0	46	12 - 68	1691	125	434	14.4	62
124 (120)(2)	(1.61;2.1)[e]	(20;26)[e]	na		827	106	na	na	na

na Data not available
[e] Estimated value

Table 7: Species: *Pseudochaenichthys georgianus*
Area: South Georgia (Subarea 48.3)
Month/Year: November to December 1986

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *P. georgianus* in Total Catch	Mean Catch of *P. georgianus* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)	2.00	13.8	19;34;48	13-56	382	58	583	1.0	6

Table 8: Species: *Pseudochaenichthys georgianus*
Area: South Orkney (Subarea 48.2)
Month/Year: December 1986 to January 1987

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *P. georgianus* in Total Catch	Mean Catch of *P. georgianus* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)	2.25	15.4	14;27;39;50	12-52	14	230	80	1.7	1

Table 9: Species: *Notothenia gibberifrons*
Area: South Georgia (Subarea 48.3)
Month/Year: November to December 1986(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *N. gibberifrons* in Total Catch	Mean Catch of *N. gibberifrons* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(1)	2.87	19.5	16;38	5 - 49	347	646	556	1.8	10
88 (80)(1)	2.02	18.2	16;40	5 - 51	6814	2198	971	24.1	234
124 (120)(2)	(2.42)[e]	(30.0)[e]	25;40	9 - 51	1663	1093	na	na	na
125 (120)[c](2)	*	*	25;40	9 - 51	1898	979	na	na	na

na Data not available
[e] Estimated value
[c] Codend with the 220 mm mesh chafer used
* All selection estimates were over 50% level

Table 10: Species: *Notothenia gibberifrons*
Area: South Orkney Is. (Subarea 48.2)
Month/Year: December 1986(1), December 1978 to March 1979(2)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *N. gibberifrons* in Total Catch	Mean Catch of *N. gibberifrons* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(1)	3.04	20.8	19	9 - 43	6247	4047	81	36.1	29
125 (120)[c](2)	*	*	na	na	6562	2288	na	na	na

na Data not available
[c] Codend with the 220 mm mesh chafer used
* All selection estimates were over 50% level

Table 11: Species: *Notothenia gibberifrons*
Area: Elephant I., Joinville I. and South Shetland Is (Subarea 48.1)
Month/Year: October to November 1986(1), December 1986 to March 1987(2), January to February 1987(3), December 1978 to March 1979(4)

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *N. gibberifrons* in Total Catch	Mean Catch of *N. gibberifrons* Per Hour (kg)
			cm	Range	Codend	Cover			
68 (70)(2)	2.86	19.6	31	17-46	566	42	121	28.6	35
68 (70)(3)[s]	2.70	18.4	21;32;38	12-49	329	89	69	20.0	14
88 (80)(1)	2.28	19.8	30	11-46	20701	2826	241	71.8	173
88 (80)(1)[s]	2.88	25.0	30	11-47	3217	420	750	74.3	557
110 (100)(1)	2.84	31.2	30	11-47	7053	8526	241	71.8	173
110 (100)(3)	2.10	23.6	29	18-48	3090	1328	993	76.9	764
110 (100)(1)[j]	2.64	29.4	30	11-47	835	761	8	25.8	2
124 (120)(4)[s]	(1.3;1.6)[e]	(16;20)[e]	na		10609	4253	na	na	na

na Data not available
[e] Estimated value
[j] Joinville Is
[s] S. Shetland Is

Table 12: Species: *Patagonotothen brevicauda guntheri*
Area: Shag Rocks (Subarea 48.3)
Month/Year: November 1986

Mesh Size (mm) Measured (Nominal)	Selection Factor	50% Selection Length (cm)	Modal Length		Number of Fish Measured		Mean Total Catch Per Hour (kg)	Mean % of *P.b. guntheri* in Total Catch	Mean Catch of *P.b. guntheri* Per Hour (kg)
			cm	Range	Codend	Cover			
67 (70)	3.27[e]	21.5[e]	12	10 - 22	451	634	1163	57	663

na Data not available
[e] Estimated value

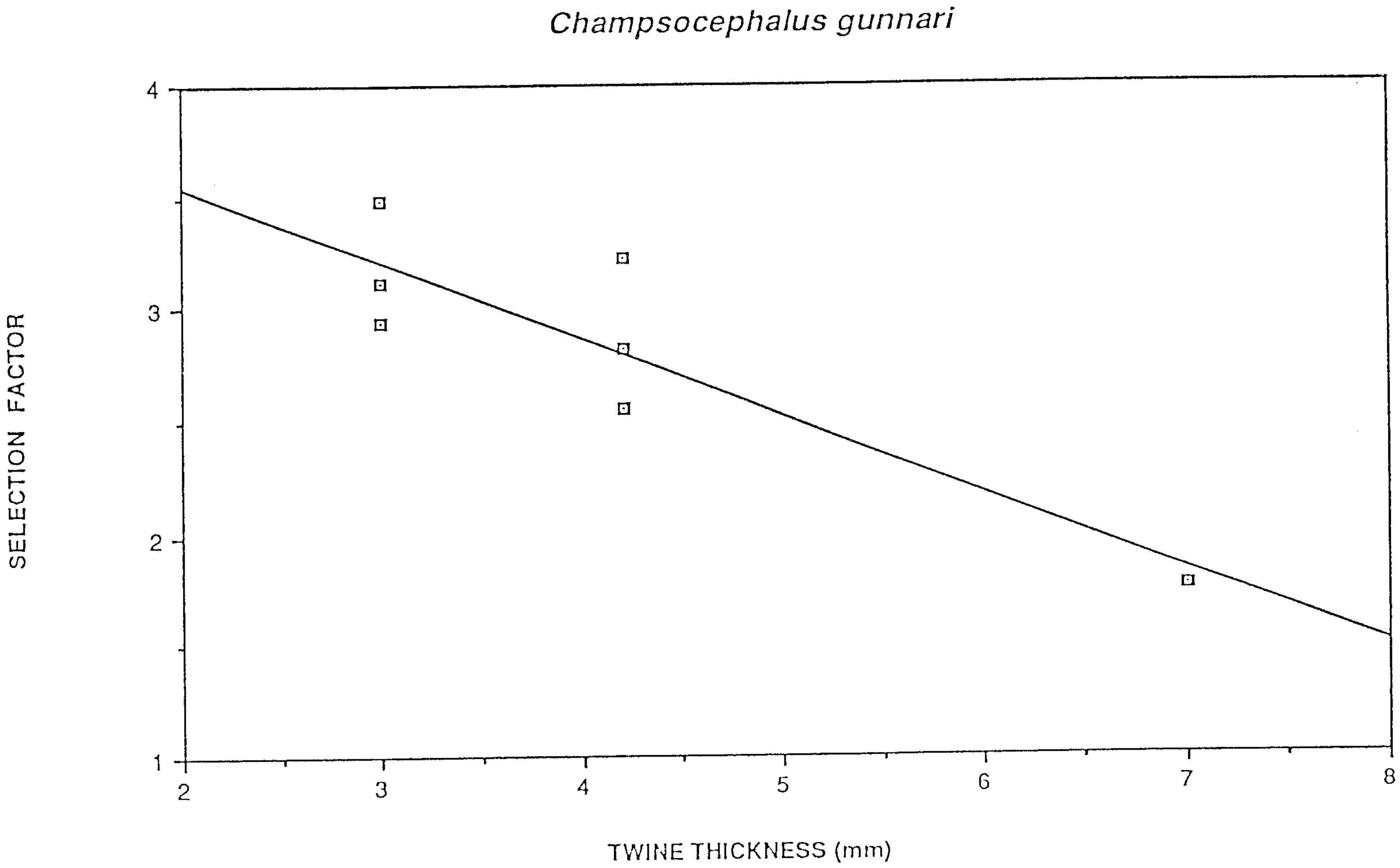


Figure 1: Relationship between the diameter of twine (mm) codends used in the selectivity experiments and the selection factor for *Champsocephalus gunnari*.

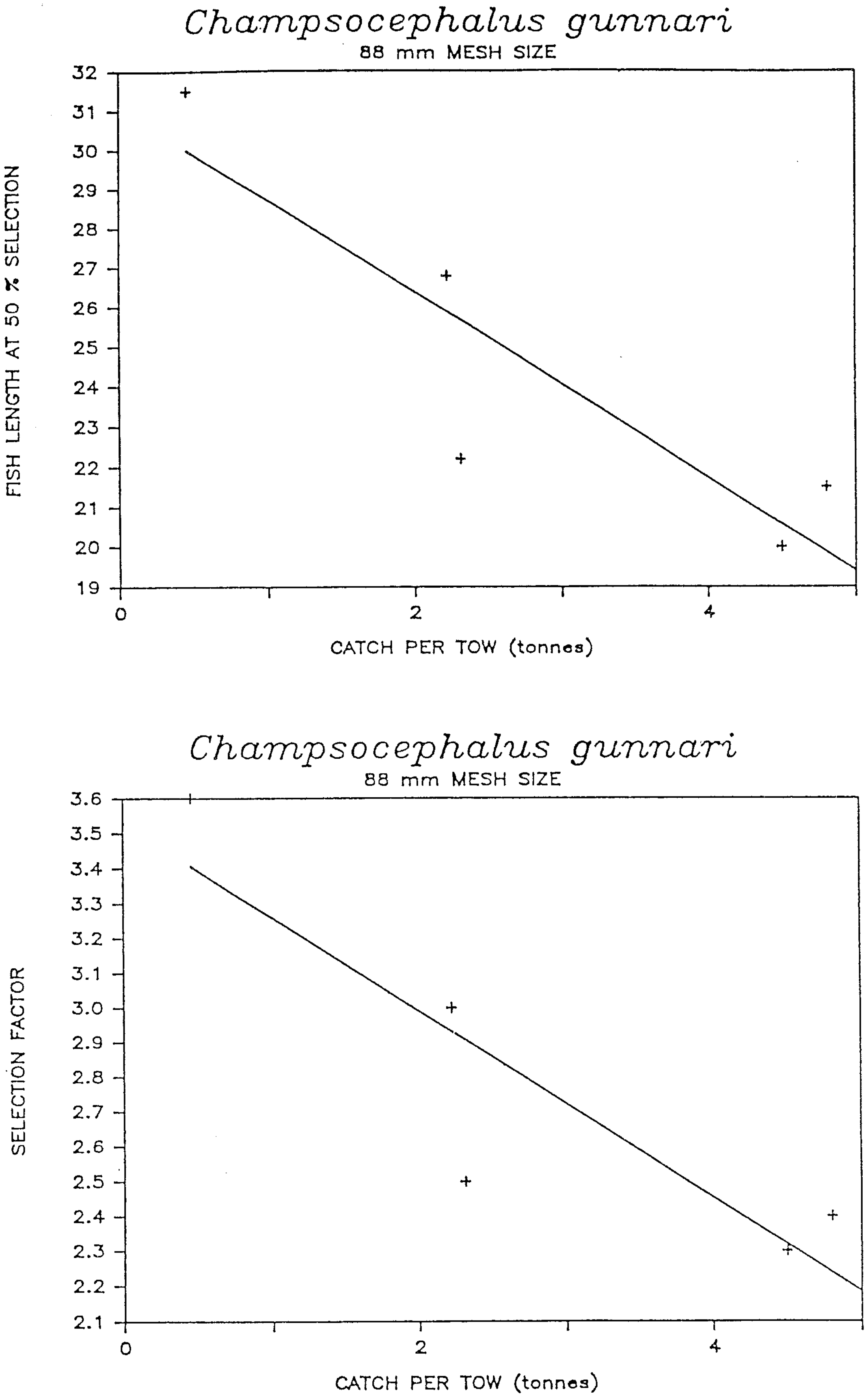


Figure 2: Relationship between the total catch-per-tow and selectivity parameters for *Champsocephalus gunnari* in the Polish experiment.

(a) L_{50}; (b) Selection Factor

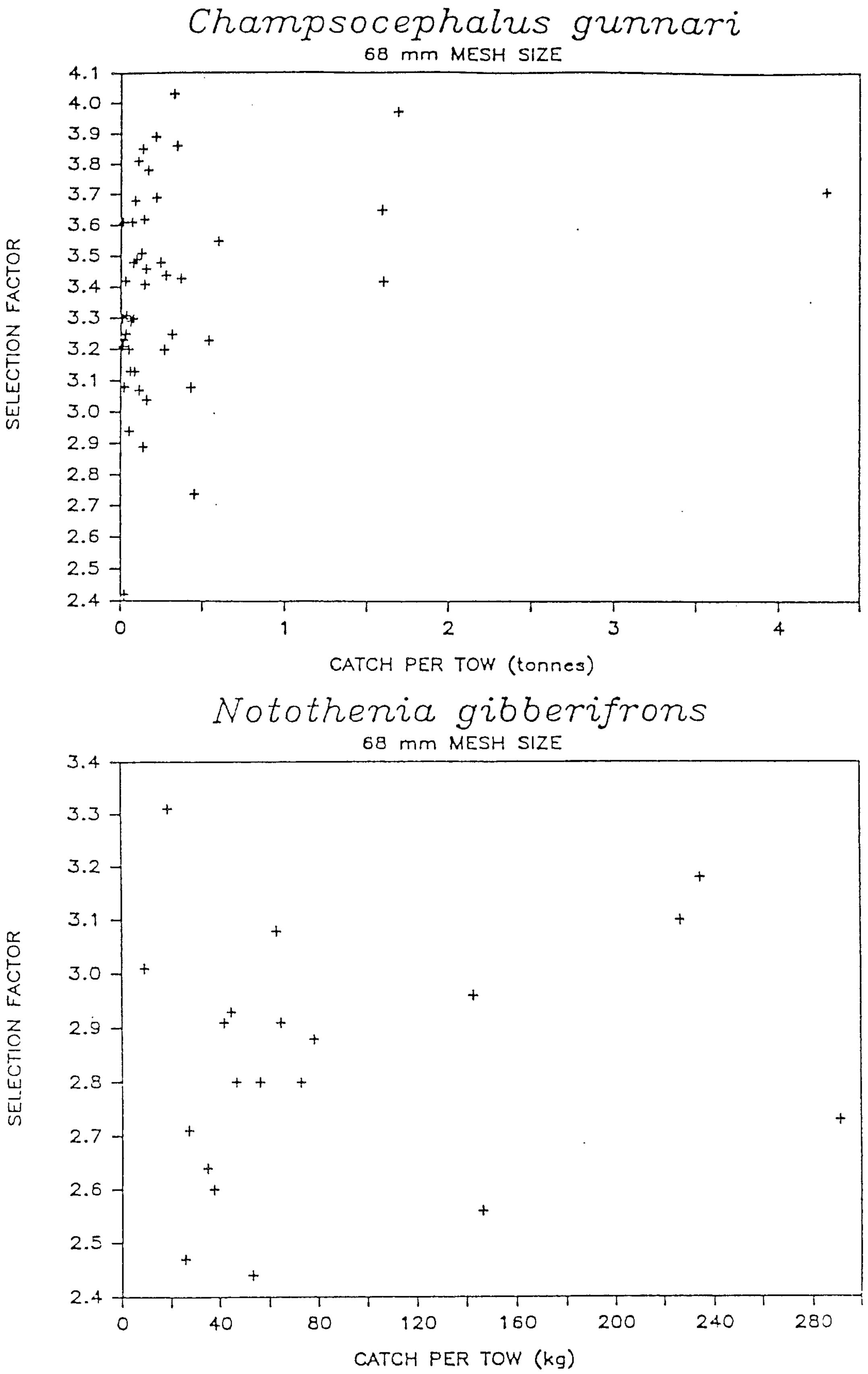


Figure 3: Relationship between catch-per-tow and the selection factors for (a) *Champsocephalus gunnari* and (b) *Notothenia gibberifrons* in the Spanish experiment.

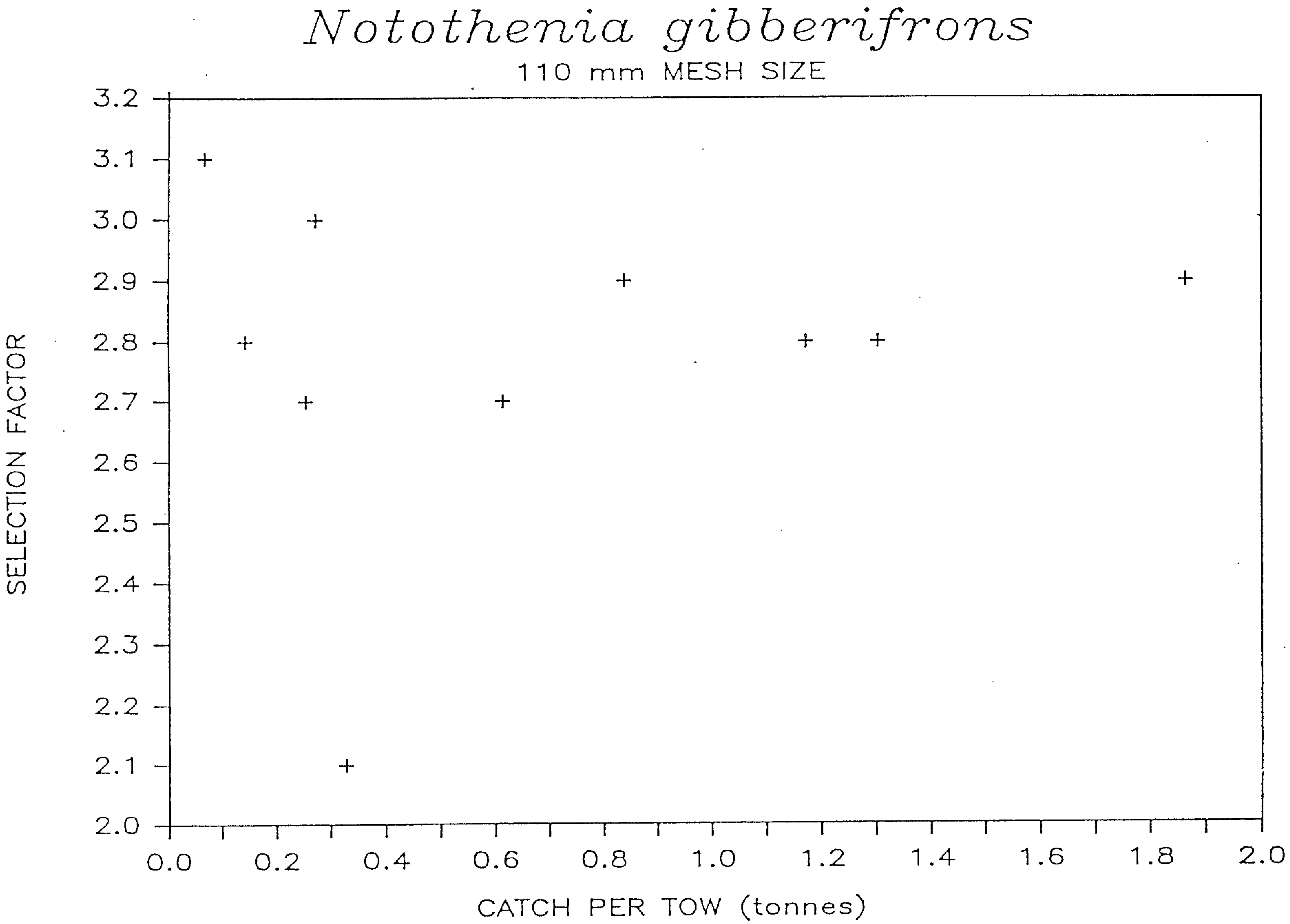


Figure 4: Relationship between catch-per-tow and the selection factors for *Notothenia gibberifrons* in the Polish experiment.

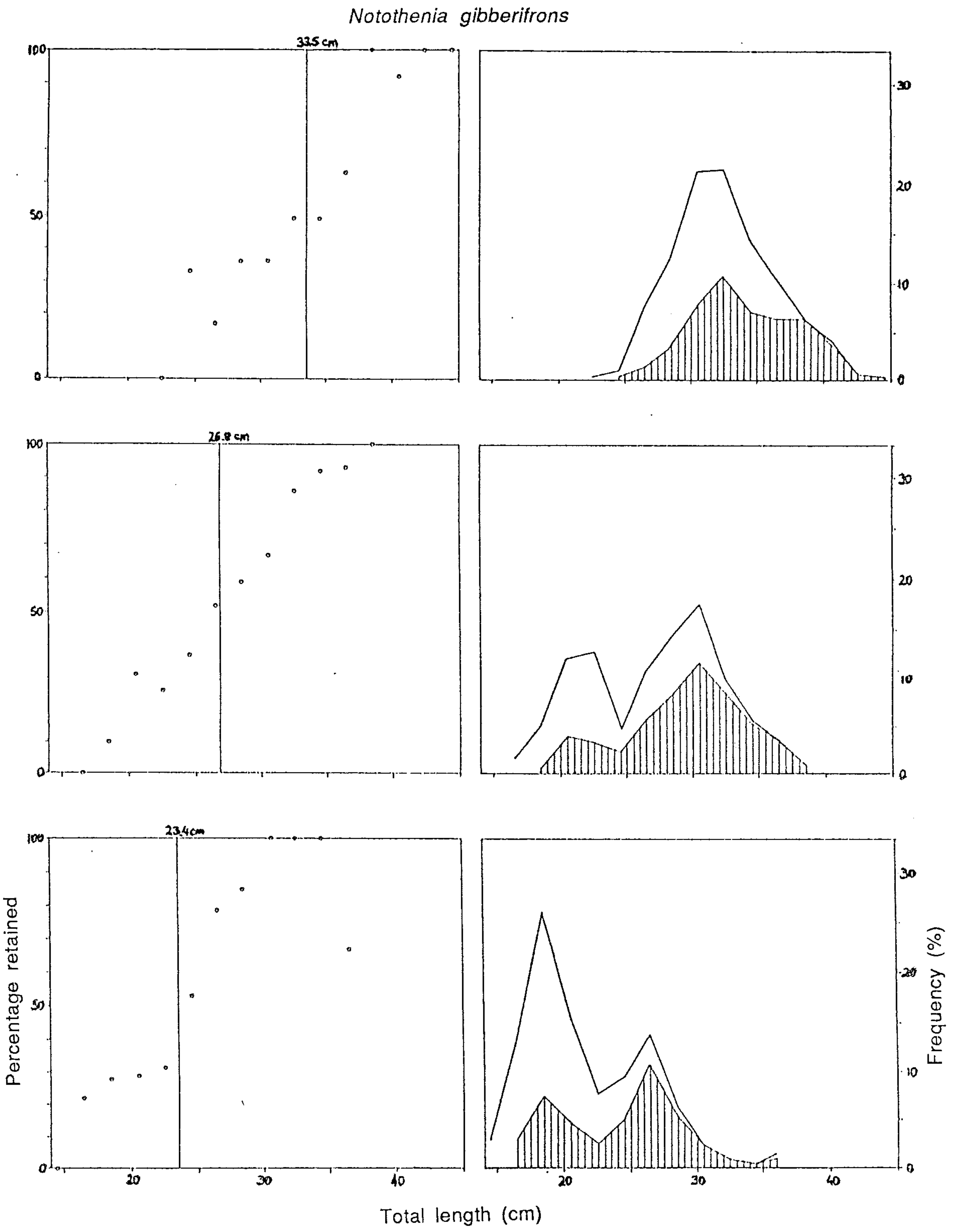
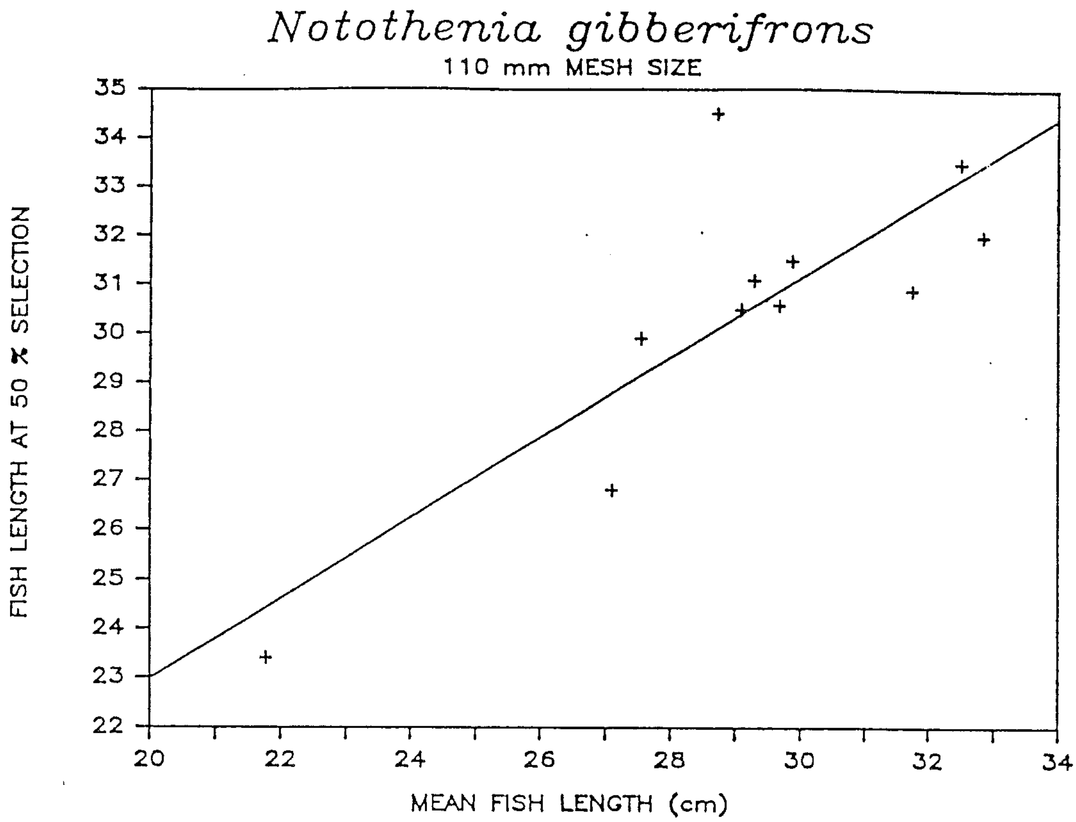

Notothenia gibberifrons

Figure 5: Effect of the length structure of the stock sampled on the 50% selection length of fish in experiments with 110 mm mesh size. Shaded area represents fish retained by the trawl codend. Dots on the left are percentage of fish retained in particular length classes. Vertical lines are L_{50}.



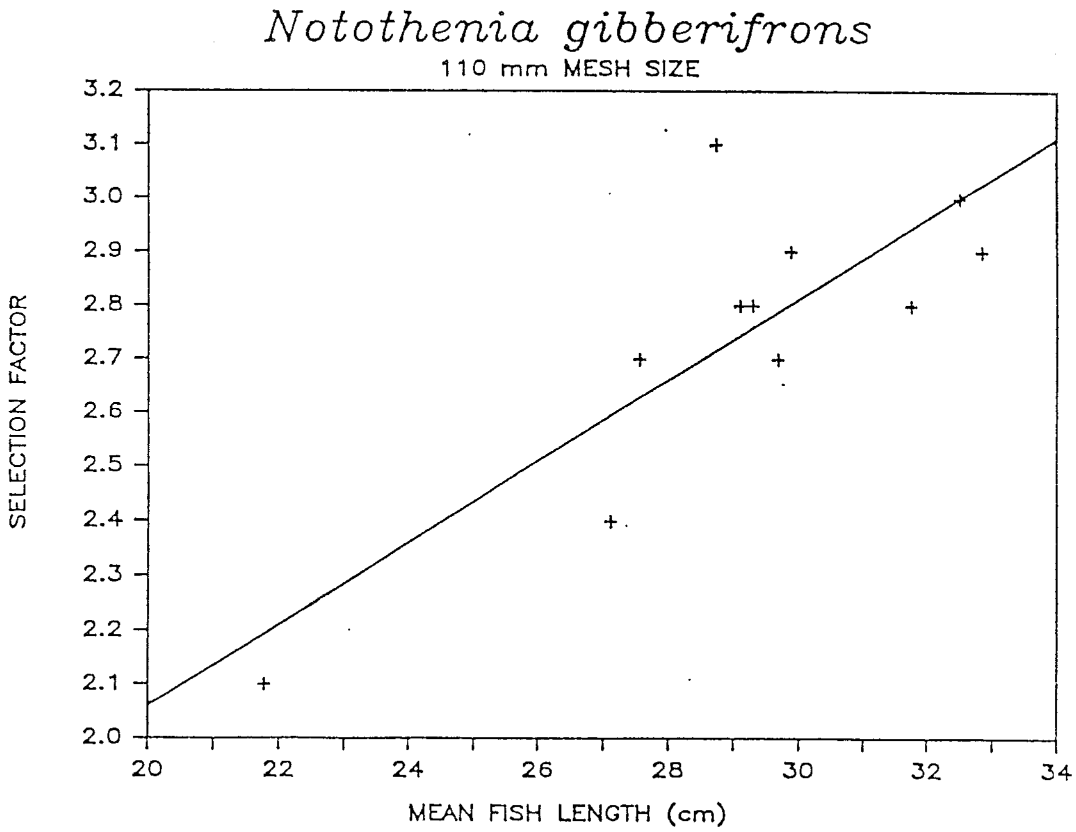


Figure 6: Relationship between mean fish length in the stock sampled and selectivity parameters: the 50% selection length and the selection factor.

APPENDIX

HAUL-BY-HAUL SELECTIVITY DATA OBTAINED FROM THE POLISH AND SPANISH EXPERIMENTS[*]

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[*] Table 1.1 refers to Table 1of this paper
Table 2.1 refers to Table 2 and so on.

Table 1.1: Species: *Champsocephalus gunnari*
Area: South Georgia, Shag Rocks (Subarea 48.3)
Month/Year: November to December 1986
Mesh size (mm):
Measured (nominal): 68 (70) and 67 (70)^r
Twine diameter (mm): 3.0

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
19^r	30	30.22	60.44	9.92	33	56	124	18;24	16-39	3.42	23.06
28^r	30	276.75	553.50	54.70	20	103	62	25	18-40	3.44	23.18
29^r	30	1590.50	3181.00	684.10	43	117	129	25	19-28	3.65	24.60
32^r	30	213.92	427.84	195.00	91	107	112	25	21-32	3.89	26.27
47	30	1687.72	3375.44	1687.70	100	176	68	26;31	22-39	3.97	26.99
48	30	325.16	650.32	325.00	100	170	246	27	16-37	4.03	27.41
55	30	342.55	685.10	250.50	73	93	110	27	22-35	3.86	26.27
62	30	21.64	43.28	20.35	94	89	125	15	13-30	2.42	16.49
69	30	53.79	107.58	17.12	32	150	19	14;28	13-37	2.94	19.98
70	30	428.16	856.32	23.15	5	280	61	23	20-40	3.08	20.95
71	30	32.22	64.44	8.90	28	78	27	15;24	13-39	3.25	22.14
75	30	80.46	160.92	25.90	32	214	144	23	20-31	3.30	22.40
83	30	1599.06	3198.12	211.01	13	135	234	14;23	13-33	3.42	23.20
84	30	1296.00	2592.00	19.50	2	68	112	13;23	12-35	3.66	24.90
97	30	88.32	176.64	41.25	47	88	74	28	19-36	3.68	25.01
105	30	160.34	320.68	9.18	6	69	62	13;27	13-42	3.04	20.68
111	30	598.06	1196.12	590.00	99	120	141	24	19-30	3.55	24.17
112	30	107.91	215.82	93.50	87	83	125	24	21-40	3.81	25.92
113	30	167.54	335.08	112.00	67	97	132	27	20-35	3.78	25.72
120	30	4288.75	8577.50	4258.00	99	155	126	26	21-36	3.71	25.25
122	30	218.85	437.70	45.10	21	60	47	27	21-31	3.69	25.11
124	30	36.38	72.76	3.53	10	100	39	26	14-30	3.31	22.53
126	30	97.40	194.80	69.35	71	86	42	27	20-34	3.49	23.74
127	30	77.35	154.70	17.80	23	73	19	27	21-34	3.48	23.65
128	30	20.30	40.60	3.25	16	32	14	15;24	13-29	3.23	21.98

Table 1.1 (continued)

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
131	30	315.31	630.62	90.60	29	117	154	22	14-29	3.25	22.14
133	30	147.65	295.30	13.20	9	100	58	13;25	13-31	3.41	23.19
147	30	540.79	1081.58	518.00	96	172	159	22	19-29	3.23	21.96
155	30	268.37	536.74	184.00	69	203	116	22	16-36	3.20	21.74
161	30	156.52	313.04	70.00	45	157	109	23	19-36	3.46	23.57
162	30	367.09	734.18	328.00	89	237	123	25	19-38	3.43	23.30
165	30	60.84	121.68	47.00	77	167	92	22	14-35	3.13	21.28
168	30	127.75	255.50	16.10	13	110	164	16;22	14-31	3.51	23.87
169	30	244.83	489.66	22.20	9	162	115	22;25	13-42	3.41	23.70
170	30	113.61	227.22	23.05	20	192	140	15;22	13-50	3.07	20.86
179	30	86.95	173.90	37.30	43	370	88	26	21-34	3.13	21.19
180	30	134.58	269.16	45.40	34	68	70	26	21-31	3.85	26.17
184	30	69.61	139.22	26.50	38	181	69	25;38	15-55	3.61	24.56

[r] Shag Rocks

Table 1.2: Species: *Champsocephalus gunnari*
Area: South Georgia (Subarea 48.3)
Month/Year: December 1986
Mesh size (mm):
Measured (nominal): 88 (80)
Twine diameter (mm): 4.2

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
123	180	2219.3	739.8	1452.5	65	743	1101	23;26	18-47	3.0	26.8
124	180	452.4	150.8	381.6	84	260	410	26	20-35	3.6[e]	31.5[e]
126	180	2306.9	769.0	1249.2	54	352	653	23*;26	19-39	2.5	22.2
127	180	4802.1	1606.3	2053.7	43	298	499	26	18-37	2.4[e]	21.5[e]
128	230	4497.8	1173.3	3100.8	69	535	450	27	21-38	2.3[e]	20.0[e]

[e] Estimated value
* Modal length with high frequency (in polymodal length distributions)

Table 2.1: Species: *Champsocephalus gunnari*
Area: South Orkney (Subarea 48.2)
Month/Year: December 1986 to January 1987
Mesh size (mm):
Measured (nominal): 68 (70)
Twine diameter (mm): 3.0

Station	Haul Time (min)	Total Catch (Per Tow) (kg)	Total Catch (Per Hour) (kg)	Species Catch Per Tow		Number of Fish Measured		M<odal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
347	30	144.44	288.88	32.50	23	164	111	23;34	20-50	3.62	24.77
350	30	12.08	24.16	7.44	62	44	26	23	12-36	3.21	21.94

Table 3.1: Species: *Champsocephalus gunnari*
Area: Elephant I., South Shetland Is. (Subarea 48.1)
Month/Year: January to February 1987
Mesh size (mm):
Measured (nominal): 68 (70)
Twine diameter (mm): 3.0

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
413	30	449.80	899.60	333.00	74	113	162	22;32	19-35	2.74	18.90
434	30	52.33	104.66	27.00	52	57	52	23	21-39	3.20	21.96
448	30	22.05	44.10	18.10	82	147	60	23;26;31	19-38	3.08	21.12
477[s]	30	137.99	275.98	137.60	100	176	180	13;22	12-31	2.89	19.66
479[s]	30	62.23	124.46	62.00	100	162	162	14;19;24	11-27	3.29	22.40
499[s]	30	15.21	30.42	13.80	91	75	141	14;21;25	13-48	3.61	24.59
545[s]	30	15.58	31.16	4.73	30	36	124	14;20;25	12-27	3.30	22.44

[s] S. Shetland Is

Table 3.2: Species: *Champsocephalus gunnari*
Area: Elephant I. (Subarea 48.1)
Month/Year: October to November 1986
Mesh size (mm):
Measured (nominal): 110 (100)
Twine diameter (mm): 4.2

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
I/14	120	1303.0	651.0	29.8	2	79	303	20;30	15-35	2.9	32.0
I/16	180	1864.9	621.0	96.2	5	284	343	20;29	17-44	2.7	30.0
I/41	105	613.3	350.0	17.0	3	37	92	20;30	18-44	3.1	33.7

* Modal length with high frequency (in polymodal length distributions)

Table 7.2: Species: *Notothenia gibberifrons*
Area: South Georgia (Subarea 48.3)
Month/Year: December 1986
Mesh size (mm):
Measured (nominal): 88 (80)
Twine diameter (mm): 4.2

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
123	180	2219.3	739.8	557.2	25	135	56	17*;28;36*-39	9-50	2.6[e]	23.0[e]
124	180	452.4	150.8	38.0	8	25	180	17	12-37		* *
126	180	2306.9	769.0	849.2	37	110	37	11;18*;30;38*	10-49		* * *
127	180	4802.1	1606.3	1708.7	36	201	139	9;17*,40*	8-48		* * * *
128	230	4497.8	1173.3	419.0	9	98	70	16*-20*;37-40	9-42	2.2[e]	19.0[e]

[e] Estimated value
* Modal length with high frequency (in polymodal length distributions)
* * All selection estimates were below 50% level
* * * All selection estimates were over 50% level
* * * * Multiple 50% selection estimates

Table 9.2: Species: *Notothenia gibberifrons*
Area: Elephant I., Joinville I., King George I. (Subarea 48.1)
Month/Year: October to November 1986, February 1987[k] 1986
Mesh size (mm):
Measured (nominal): 110 (100) and 88 (80)[k]
Twine diameter (mm): 4.2

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
I/9	125	327.4	157.0	274.0	84	613	169	24;34*	14-46	2.1	23.1
I/10	120	837.9	419.0	691.0	82	438	644	24;36*	13-46	2.9	32.0
I/11	120	253.8	126.0	201.0	79	315	641	26	11-43	2.7	29.9
I/13	260	67.6	16.0	54.0	80	97	334	29-31	13-39	3.1	34.5
I/14	120	1303.0	651.0	1028.0	79	408	568	29	16-42	2.8	31.1
I/16	180	1864.9	621.0	1601.0	86	948	1278	29	13-44	2.9	31.5
I/17	130	1170.9	540.0	866.2	74	494	1980	30	20-41	2.8	30.5
I/41	105	613.3	350.0	437.0	71	224	297	30	19-43	2.7	30.6
I/42	200	85.1	25.0	71.0	83	96	58	31;35	22-48		
I/33[j]	120	80.7	40.0	23.2	29	88	116	19*;26	14-37	2.1	23.4
I/34[j]	115	888.7	464.0	84.6	10	113	200	22;30	17-39	2.4	26.8
I/36[j]	60	272.0	272.0	100.5	37	153	159	30-32	23-44	3.0	33.5
I/37[j]	100	143.4	86.0	77.0	54	119	95	29-31;37*	18-44	2.8	30.9
IV/7[k]	90	599.7	400.0	440.0	73	361	137	27;41	19-47	3.3	29.0

* Modal length with high frequency (polymodal length distributions)

[j] Joinville I.

[k] King George I.

Table 10.1: Species: *Notothenia gibberifrons*
Area: South Orkney (Subarea 48.2)
Month/Year: December 1986 to January 1987
Mesh size (mm):
Measured (nominal): 68 (70)
Twine diameter (mm): 3.0

Station	Haul Time (min)	Total Catch Per Tow (kg)	Total Catch Per Hour (kg)	Species Catch Per Tow		Number of Fish Measured		Modal Length		Selection Factor	50% Selection Length (cm)
				kg	%	Codend	Cover	cm	Range		
267	30	64.600	129.20	37.09	57	190	60	19;25;30;37	12-37	2.91	19.91
268	30	234.660	469.32	109.40	47	417	206	12;20;29;32	9-38	3.18	21.76
271	30	62.930	125.86	35.80	57	164	190	17;20;25;28	9-38	3.08	20.95
272	30	56.170	112.34	35.95	64	199	124	19;23;28;35	10-40	2.80	19.05
273	30	77.990	155.98	42.95	55	220	198	11;20;27;35	9-38	2.88	19.57
275	30	226.530	453.06	132.00	58	946	149	20;32	11-36	3.10	21.13
276	30	146.380	292.76	80.00	55	399	301	11;19;27;36	9-43	2.56	17.42
278	30	37.485	74.97	16.05	43	110	42	19;26	15-39	2.60	17.72
281	30	53.355	106.71	18.25	34	116	138	11;16;20;24;28;32	10-39	2.44	16.70
282	30	291.315	582.63	86.90	30	451	402	11;18;24;28;32	9-39	2.73	18.59
322	30	72.620	145.24	35.30	49	175	37	21;26;31;35	15-40	2.80	19.15
323	30	44.675	89.35	30.85	69	120	79	12;21;27;34	10-42	2.93	20.02
327	30	34.880	69.76	16.30	47	78	85	10;14;21;27	8-40	2.64	17.95
328	30	41.795	83.59	9.65	23	62	154	14;20	9-41	2.91	19.78
333	30	18.965	37.93	9.85	52	40	164	10;17	8-39	3.31	22.52
340	30	285.155	570.31	7.28	3	40	12	25;30	19-32	3.21	21.93
345	30	9.285	18.57	6.55	71	30	18	18;23;28;32	16-40	3.01	20.51
378	30	142.785	285.57	74.05	52	341	374	11;19	10-39	2.96	20.23
379	30	25.490	50.98	14.80	58	109	85	10;21;27;30	9-38	2.47	16.78
380	30	46.680	93.36	8.80	19	41	41	10;20;26;30	9-40	2.80	19.16
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SC-CAMLR-VIII/BG/46

RESULTS OF THE CCAMLR ANTARCTIC FISH OTOLITHS/SCALES/BONES EXCHANGE SYSTEM

K.-H. Kock

Abstract

An exchange system was established among Members of CCAMLR to compare age determinations for the same species among different laboratories. Four species were included in the exchange: *Notothenia rossii*, *Champsocephalus gunnari*, *Notothenia gibberifrons* and *Pleuragramma antarcticum*. The level of agreement in age determination was highest for scales of juvenile *N. rossii* and for otoliths of juvenile *C. gunnari* from South Georgia and lowest for scales of adult *N. rossii* and *N. gibberifrons* and otoliths of *P. antarcticum*. Agreement between otoliths and scales of individual *N. gibberifrons* was in the order of 50%. There was little indication that agreement between experienced investigators was higher than between experienced and less experienced ones.

Résumé

Un système d'échange a été établi parmi les Membres de la CCAMLR afin de comparer la détermination de l'âge d'une même espèce effectuée par des laboratoires différents. Quatre espèces sont comprises dans ce système d'échange: *Notothenia rossii*, *Champsocephalus gunnari*, *Notothenia gibberifrons* et *Pleuragramma antarcticum*. Le niveau de conformité de détermination de l'âge le plus élevé concernait les écailles de *N. rossii* juvénile et les otolithes de *C. gunnari* juvénile de la Géorgie du Sud. L'écart le plus important concernait les écailles de *N. rossii* et *N. gibberifrons* adultes, et les otolithes de *P. antarcticum*. La conformité entre les otolithes et les écailles d'individus de *N. gibberifrons* était de l'ordre de 50%. Il n'est pas vraiment évident que la conformité parmi les chercheurs expérimentés ait été plus élevée qu'entre les chercheurs moins expérimentés et ceux qui l'étaient.

Резюме

Членами АНТКОМа была создана система обмена информацией по определению возраста одного и того же вида рыбы в различных лабораториях. Эта система охватывала четыре вида: *Notothenia rossii*, *Champsocephalus gunnari*, *Notothenia gibberifrons* и *Pleuragramma antarcticum*. Согласованность результатов была наивысшей при определении возраста молоди *N. rossii* по чешуе и молоди *C. gunnari* по отолитам для района Южной Георгии, тогда как результаты определения возраста по чешуе у половозрелых особей *N. rossii* и *N. gibberifrons*, а также по отолитам *P. antarcticum* имели меньшую степень согласованности. Данные, полученные в результате исследования отолитов отдельных особей *N. gibberifrons* в

50% случаев совпадают с данными, полученными в результате исследований чешуи отдельных особей этого же вида. Не существует значительных свидетельств того, что результаты анализа, проведенного опытными лаборантами, совпадают в большем количестве случаев, чем результаты анализа, выполненного более и менее опытными исследователями.

Resumen

Un sistema de intercambio se estableció entre los Miembros de la CCRVMA para comparar las determinaciones de edad para la misma especie entre los diferentes laboratorios. Cuatro especies fueron incluidas en el intercambio: *Notothenia rossii, Champsocephalus gunnari, Notothenia gibberifrons* y *Pleuragramma antarticum*. El nivel de acuerdo fue alto en relación a la determinación de edad concerniendo las escamas de *N. rossii* juvenil y los otolitos de *C. gunnari* juvenil proveniente de Georgia del Sur. Sin embargo no hubo tanto acuerdo acerca de las escamas de *N. rossii* y *N. gibberifrons* adultos y los otolitos de *P. antarticum*. Acuerdo entre otolitos y escamas de *N. gibberifrons* individuales fue del orden del 50%. Hubo poca indicación de que acuerdo entre los investigadores más experimentados fuese más alto que aquel entre investigadores más y menos experimentados.

1. INTRODUCTION

Following a recommendation of the CCAMLR Fish Age Determination Workshop held in Moscow from 14 to 19 July 1986 (SC-CAMLR-VII/BG/41), an exchange system was established among Members of CCAMLR to examine otoliths, scales and bones of selected species of Antarctic fish. Samples were kindly provided by the USSR, United Kingdom and Argentina. Laboratories of the following Members took part in the exchange: USSR , Poland, German Democratic Republic, Federal Republic of Germany, United Kingdom, Spain, Argentina and Australia. Reports on the progress of the exchange were submitted to the Scientific Committee of CCAMLR in 1987 (SC-CAMLR-VI/BG/26 Rev. 1) and 1988 (WG-FSA-88/30).

The exchange was terminated before 1 August 1989 despite only five of the six samples available having been circulated among all interested Members. The status of one sample is unknown at present.

2. MATERIAL AND METHODS

The following samples were made available for the exchange:

(i) Scales of adult *Notothenia rossii* from South Georgia and the South Shetland Islands (Table 1) mounted on microscopic slides. Sample size: 46. Six slides sent were broken during mailing, therefore only 40 specimens could be included in the exchange. Samples covered the length range of 39 to 70 cm. Sources: VNIRO, AtlantNIRO (USSR).

(ii) Scales of juvenile *N. rossii* from Potter Cove (South Shetland Islands) (Table 2) mounted on microscopic slides. Sample size: 50. Specimens of 23.5 to 44.3 cm length were available. Source: Instituto Antártico Argentino (Argentina).

(iii) Scales of *Notothenia gibberifrons* from South Georgia and the South Shetland Islands (Table 3). Sample size: 58. Five slides were broken during transportation, therefore only 53 specimens could be included in the exchange. Length of the specimens ranged from 10.9 to 46.2 cm. Sources: VNIRO, AtlantNIRO (USSR).

(iv) Scales and otoliths of *N. gibberifrons* from South Georgia (Table 4). Sample size: 81. Otoliths were prepared according to the Bedford method; scales were in vials, but were mounted on microscopic slides by the Convener in the course of the exchange. Both otoliths and scales of 57 specimens were available. Samples covered the length range of 7.7 to 43.2 cm. Source: British Antarctic Survey (UK).

(v) Otoliths of *Champsocephalus gunnari* from South Georgia, the South Orkney Islands and South Shetland Islands (Table 5). Sample size: 70. Four otoliths were lost during transportation, therefore only 66 otoliths were available for the exchange. Specimens of 7.3 to 48.7 (57.5) cm in length were present in the sample. Sources: VNIRO, AtlantNIRO (USSR).

(vi) Otoliths of *Pleuragramma antarcticum* from the Mawson Sea (East Antarctic) (Table 6). Sample size: 50. Two otoliths were broken during transportation, therefore only 48 otoliths were included in the exchange. Size of specimens ranged from 12.4 to 20.6 cm. Source: YugNIRO (AzcherNIRO) (USSR).

Techniques used in various laboratories for ageing Antarctic fish were described in

SC-CAMLR-VII/BG/41 and in various scientific publications. These methods are summarized below:

(i) *Notothenia rossii*: Scales and otoliths were used to age *N. rossii*. Checks observed on both structures were validated to form annuli (scales: Sherbich, 1975; Freytag, 1980; otoliths: Burchett, 1983). Due to the delicacy of the otoliths and the amount of time taken to extract and prepare them, scales are commonly used in most laboratories for routine age determination. Scales located just below the lateral line under the pectoral fin were found to be most suitable for ageing. Scales are usually cleaned by soaking them in 10% ammonia (VNIRO, AtlantNIRO) or in a soap solution (Sea Fisheries Institute, Hamburg) and then mounted wet between two microscopic slides. Scales are then examined with a binocular microscope using transmitted light and various magnifications. Otoliths are prepared in two ways: either 'cracked and charred' (Möller Christensen, 1964) or sectioned after being embedded in polyester resin (Bedford, 1983).

(ii) *Notothenia gibberifrons*: This species is routinely aged by scales prepared similarly to those of *N. rossii* (Boronin and Frolkina, 1976; Skora, 1980; Kompowski, 1983) and by sections of the first ventral fin ray (GDR: Hoffmann, 1982), as described by Gubsch (1980) for *Chaenocephalus aceratus*. Occasionally otolith sections have been used for ageing (North et al., 1980; Clasing et al., 1985). However, so far only the first three to four annuli on scales have been tentatively validated by plotting polymodal curves of the total number of sclerites versus fish age (Boronin and Frolkina, 1976).

(iii) *Champsocephalus gunnari*: Channichthyids lack scales. Routine age determinations are carried out using otoliths (whole otoliths: Kock, 1981; Frolkina unpubl.; cracked: Sosinski, 1981; sections: Kochkin, 1985), vertebrae (Kochkin, 1985) and sections of the first ventral fin ray (Gubsch, 1982). Whole otoliths are kept in alcohol (Frolkina, unpubl.) or glycerine (Kock, 1981). For examination they are placed in camphor oil for a maximum of 10 to 15 minutes, otherwise they become opaque (Frolkina, unpubl.). Whole and sectioned otoliths, vertebrae and sections of the first ventral fin ray are examined either via transmitted light (Frolkina, Kochkin) or reflecting light against a black background (Kock, Gubsch, Sosinski). The first two to three annuli identified on whole otoliths have been validated by distinct peaks in ploymodal frequency curves (Kock, 1981; Slosarczyk, 1987).

(iv) *Pleuragramma antarcticum*: Scales, otoliths and coracoid bones were examined for age determination by Gerasimchook. Scales were found to be unsuitable due to the even distribution of sclerites which were impossible to separate into "fast" and "slow" growth zones. The coracoid was also found to be unsuitable and staining with alizarin did not enhance the internal structures. Poor calcification of the skeleton of *P. antarcticum* is the most probable reason for this lack of distinct rings (Gerasimchook in SC-CAMLR-VII/BG/41).

Sagittal otoliths were proved to be suitable for estimating age. Two different techniques are used for age determination.

(i) Otoliths are examined in glycerine via transmitted light. However, otoliths should not be kept for "long periods" in glycerine because this results in the otoliths becoming irreversibly transparent (Gerasimchook, in SC-CAMLR-VII/BG/41).

(ii) A different technique has been used by Hubold and Tomo (1989). They have examined otoliths in glycerine against a black background under reflected light.

The first two annuli identified by both techniques have been validated by comparing them with prominent peaks in length frequency compositions which are supposed to represent the first two age classes (Gerasimchook, pers. comm.; Hubold and Tomo, 1989).

Analysis of the results of the otoliths/scales/bones exchange was mainly based on the level of agreement either among all investigators or within pairs of investigators. Agreement, however, was not only assumed when 'readers' estimated the same age (e.g. 5 and 5) but also when one of the investigators only gave an approximation (e.g. 5 and 5/6 or 5?). It is obvious that this should lead to an increase of 'positive' results. Agreement among all of the investigators was evaluated under two provisions:

(i) full agreement; and
(ii) full agreement or deviations of not more than one year.

The 'birthday' of Antarctic fish is commonly accepted as 1 July. However, one reader (Barrera-Oro, Argentina) took 1 October as the 'birthday' for *N. rossii* as annuli in its scales were observed as incomplete before that date.

3. RESULTS

3.1 *Notothenia rossii* (Adults)

Results of ageing are set out in Table 1. Three of the four investigators (1, 3 and 4) were experienced in determining the age of the species; one investigator (2) was less experienced.

Age classes 4 to 12/13 were identified from the sample.

Full agreement among all readers: 0
Full agreement among experienced readers: 0

The following table demonstrates the agreement (in %) among all of the investigators:

		Full Agreement (%)			
	Reader	1	2	3	4
Full agreement/ deviation = 1 year (%)	1	X	29.0	28.2	10.3
	2	76.3	X	48.7	35.1
	3	81.1	89.2	X	59.9
	4	66.7	88.5	84.2	X

With the exception of readers 2 and 4, full agreement between two readers was usually much less than 50%. If one allows for a deviation of one year, agreement among most readers was more than 80%. Deviations were more common as length (= age) of fish increased.

Although true age of the specimens was not known, some investigators (2, and 4) tend to attribute higher ages to the specimens than others, irrespective of the length of the specimens (Figures 1 and 2).

3.2 *Notothenia rossii* (Juvenile)

Results of age determinations are set out in Table 2. Two of the three investigators (1 and 2) were experienced and one (3) was less experienced. Age classes 3 to 7 were identified from the samples.

Full agreement among all readers:	37	(74.0%)
Full agreement among experienced readers:	39	(78.0%)
Full agreement or deviation of not more than one year among all readers:	50	(100%)

The following table indicates that agreement between two readers was in the order of 80%. Agreement could have been even higher if 'reader' 1 had not used 1 October as the 'birthday' instead of 1 July. Except in one case, however, no deviation of more than one year was observed.

		Full Agreement (%)		
	Reader	1	2	3
Full agreement/ deviation = 1 year (%)	1	X	78.0	84.0
	2	100.0	X	80.0
	3	100.0	98.0	X

3.3 *Notothenia gibberifrons*

Results of age determinations from scales only are given in Table 3. Three investigators were experienced (1, 4 and 5) and two (2 and 3) had less experienced with the species. Age classes 1 to 14/15 were identified from the samples.

Full agreement among all readers:	0	
Full agreement or deviation of not more than one year among readers:	1	(2.4%)

The following table demonstrates that the level of agreement between two readers was approximately 25%, except in experienced readers when it was 38.0%. Even allowing for one year of deviation among readers, agreement did not reach more than 50 to 60%.

		Full Agreement (%)				
	Reader	1	2	3	4	5
Full agreement/ deviation = 1 year (%)	1	X	24.4	22.9	38.0	12.0
	2	60.0	X	26.2	25.6	7.0
	3	54.2	47.6	X	16.7	6.0
	4	71.2	50.0	55.3	X	20.4
	5	32.0	11.6	24.4	46.9	X

Less experienced readers tended to attribute higher ages to the specimens than did experienced investigators, irrespective of the fish length (Figures 3 and 4).

Results of ageings on a second set of samples containing scales and otoliths are set out in Table 4. Age classes 1 to 15 were identified from the samples.

Comparison of age determination from scales did not reveal results substantially different from those described for the first set. Analysis is therefore confined to a comparison of age determinations from both otoliths and scales. However only three of the five investigators examined both structures. Two (4 and 5) were experienced and one (2) was less experienced.

Full agreement between ages determined from otoliths and scales was observed in 45.5% (reader 2), 52.6% (5) and 67.3% (4) of the samples respectively. One of the investigators (5) attributed generally (87%) higher ages to scales compared to otoliths of the same specimens, whereas the other two did not.

3.4 *Champsocephalus gunnari*

Results of comparative age determinations are given in Table 5. Two of the investigators were experienced (1 and 3), one was experienced in ageing *C. gunnari* by fin ray sections but not by otoliths (2) and one was less experienced. Age classes 0 to 9 were identified from the samples.

Full agreement among all investigators: (Agreement, however, was mostly confined to age classes 0 and 1 and then substantially decreased).	18.0%
Full agreement or deviation of not more than one year:	72.1%

Agreement was mostly confined to the first three age classes (0 to 2).

The following table demonstrates that agreement was highest between readers 2 and 3 (62.3%).

		Full Agreement (%)			
	Reader	1	2	3	4
Full agreement/ deviation = 1 year (%)	1	X	40.6	46.8	41.0
	2	73.4	X	62.3	39.7
	3	78.7	88.3	X	46.3
	4	82.3	91.1	94.2	X

Agreement between pairs of experienced readers and among less experienced readers (except 2 and 3) did not differ considerably.

Readers 1 and 4 tended to attribute higher ages to fish of the same size more so than did readers 2 and 3. This was consistent in all three populations of *C. gunnari* for which material was available (Figures 5 to 7).

3.5 *Pleuragramma antarcticum*

Results of ageings are shown in Table 6. Three investigators (1, 2 and 3) were experienced with the species and one was (4) less experienced. Age classes 2 to 12 were identified from the sample.

Full agreement among experienced readers existed in 20.8% of all samples. Allowing for one year of deviation, agreement increased to 52.1%.

The following table demonstrates the agreement between pairs of readers.

		Full Agreement (%)			
	Reader	1	2	3	4
Full agreement/ deviation = 1 year (%)	1	X	26.2	37.5	4.2
	2	76.2	X	34.2	26.8
	3	78.7	65.9	X	11.1
	4	43.5	42.5	33.3	X

The same difference among experienced and less experienced readers as indicated above is also evident from this table. Less experienced investigators attributed generally lower ages to fish of the same size than did experienced readers (Figure 8).

4. DISCUSSION

Since the beginning of the 1970s, many studies on age and growth of Antarctic fish have been published. Most of them deal with commercially exploited nototheniids and channichthyids. The first comparative age determinations were carried out during two ageing workshops of the BIOMASS Working Group on Antarctic Fish Biology in 1979 and 1982 (Anon, 1980 and 1982).

Results, however, in particular those obtained during the second workshop are not directly comparable to the CCAMLR otoliths/scales/bones exchange as other species (*Dissostichus eleginoides, Nototheniops larseni, Notothenia squamifrons*) were included.

As in fish from temperate waters, otoliths and scales are widely used for ageing Antarctic fish (Kock, Duhamel and Hureau, 1985). Except for cross sections of the first ventral fin ray (Gubsch, 1980; Hoffmann, 1982), other bony structures (vertebrae, coracoid, cleithrum, operculum and hypural) proved to be less successful for the identification of annuli. However, age determination is still far from being reliable and considerable differences exist between findings of different authors for one species. This is clearly underlined by the results of the CCAMLR Age Determination Workshop in Moscow in 1986 and findings of the CCAMLR otoliths/scales/bones exchange.

Agreement among investigators was high for scales of juvenile *N. rossii* from coastal waters of the South Shetland Islands and for otoliths of juvenile *C. gunnari* from South Georgia (age class 0 to 1). Agreement decreased in this species, however, from age class 2 onwards. Agreement was lowest for scales of adult *Notothenia rossii marmorata* and *N. gibberifrons* and otoliths of *P. antarcticum*. Agreement between otoliths and scales of individual *N. gibberifrons* varied from 45.5 to 67.3% depending on the investigator. One of the experienced investigators (5) of *N. gibberifrons* otoliths and scales tended to attribute higher ages to scales compared to otoliths, whereas the other two did not. This may indicate that scales which are subject to replacement and resorption do not necessarily exhibit more 'checks' which would mislead investigators into attributing a higher age to them *per se* (at least in *N. gibberifrons*).

There was little indication that agreement among experienced readers was higher than among experienced and less experienced investigators.

One important reason for the observed low level of agreement among readers of most species is likely to be associated with the scarcity of validation studies in Antarctic fish. Validation of the first age classes is usually carried out using three methods.

(i) Correlation of checks on otoliths and scales with prominent peaks in length frequency compositions.

(ii) Estimation of the onset of scale formation and deduction of age classes from frequency histograms of the number of sclerites.

(iii) Validation of 'checks' as being annual by means of counting daily increments.

Length frequency distributions have been used in *C. gunnari* and other icefish species to validate age classes 0 to 2 successfully (Kock, 1981; Slosarczyk, 1987). This seems to have been generally accepted and was largely confirmed by the results of the exchange. A similar approach was used in *P. antarcticum* from the Weddell Sea (Hubold and Tomo, 1989). Unfortunately, samples of this species used in the exchange did not contain small specimens representing the first age classes.

The first age classes of *N. rossii* and *N. gibberifrons* have been derived from frequency histograms of the number of sclerites (Sherbich, 1975; Freytag, 1980; Boronin and Frolkina, 1976) without, however, estimating the onset of scale formation. Freytag's results (1980) exhibit remarkably good agreement with Burchett's findings (1983) on *N. rossii* otoliths.

Daily ring counts of one of the species involved in the exchange have so far only been carried out for *N. rossii* and *C. gunnari* (Radtke, SC-CAMLR-VI/BG/43). Findings on *N. rossii* agree well with Freytag's (1980) and Burchett's (1983) results, but counts for *C. gunnari* indicate much higher ages in fish of the same size than those estimated by traditional methods.

It is obvious that there is still a need to carry out additional validation studies, in particular on exploited nototheniids, to identify the first annuli more precisely. This may be one way to establish more reliable age determinations in exploited Antarctic fish species. Validation studies should be extended to otoliths which are not subject to replacement and resorption as scales are. Priority should be given to compare age determinations from both structures as has been attempted for *N. gibberifrons* in the exchange.

As commonly observed in age determinations of temperate water fish, agreement among investigators generally decreased with increasing size of the fish. This problem is likely to remain unresolved in the near future. However, further validation studies and the increase in knowledge of the biology of a particular species may reduce that problem. Comparative age determinations on a workshop basis which should be combined with an extensive discussion on the life history of a species may in the future better help to attribute the 'best'* age to a specimen. Establishing additional exchange schemes are unlikely to give more reliable estimates than those obtained during the first exchange.

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* The 'best' age is not necessarily the true age nor is it the majority 'reading' nor the mean of the exchange 'readings'.

The assessment of the state of Antarctic fish stocks within CCAMLR is largely based on age-dependent models. Prerequisites are reliable age determinations. It is evident from the results both of the Age Determination Workshop in Moscow and the otoliths/scales/bones exchange that 'readings' among investigators are not compatible. Age-dependent models should thus be based on age/length keys from one source only to avoid the introduction of additional systematic errors.

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Table 1: Age readings of *Notothenia rossii* scales from South Georgia and the South Shetland Islands.

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings			
					1	2	3	4
South Georgia, November 1971, Source: VNIRO								
1	70.0	5030	M	2	10	12?	nr	13
2	39.5	670	M	1	4+	4	4	5
3	67.0	3740	F	2/3	9	11	10?	12
4	66.0	3280	F	2/3	8	9	10?	12/13
5	53.5	1920	M	2	6	7	6/7	7
6	65.5	3540	M	2	9	10	9/10	12
7	67.0	4130	F	2/3	9	10	10	12
8	57.0	2500	M	2	8	8	8/9	9
9	66.0	3680	F	2/3	8	10	9?	12
10	67.0	3930	F	2/3	9	11	10/11	11
11	66.5	3490	F	2/3	8	-	10	10
12	62.0	3210	F	2/3	9	-	9	10
South Georgia, 1977, Source: VNIRO								
1	56.0	2620	M	3/4	8	-	-	-
2	51.0	1450	M	3/4	7	6	6	6
3	54.0	1980	F	3/4	8	-	-	-
4	53.0	2360	F	3/4	8	-	-	-
5	51.0	1630	M	3/4	7	6	6	7
South Georgia, 1986, Source: AtlantNIRO								
1	41.0	1050	-	-	4+	4	6	5
2	42.0	1100	-	-	4+	5	5/6?	6
3	43.0	1300	-	-	5+	6	6	6
4	42.0	1300	-	-	5+	6	6	6
5	42.0	1300	-	-	5+	5	6	6
6	41.0	1200	-	-	4+	5	5/6?	5
7	42.0	1650	-	-	4+	5	6	5
8	48.0	1340	-	-	4+	6	6	6
9	58.0	2360	-	-	6+	8	8/9	nr
10	56.0	2180	-	-	6+	7	7/8	9
South Shetland Islands, November 1979, Source: VNIRO								
1	38.5	540	F	2	6	5	4	5
2	45.0	1120	F	2	7	6	7	7
3	49.0	1290	M	3	7	-	-	-
4	44.0	920	F	2	7	-	-	-
5	45.5	990	M	2/3	6	-	-	-
6	46.5	1250	F	5	8	7	8	8
7	46.0	1130	M	3	9	7	8/9	8
8	44.0	990	F	2	9	7	9	7
9	40.0	890	M	2	8	6	8	7

Table 1 (continued)

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3	4
South Shetland Islands, November 1986, Source: AtlantNIRO								
1	41.0	860	-	-	5+	5	6	6
2	48.0	1600	-	-	6+	7	8	8
3	48.0	1450	-	-	6+	6	6/7	7
4	46.0	1350	-	-	6+	6	7	7
5	42.0	1070	-	-	5+	6	6	6
6	52.0	2070	-	-	7+	7	9	8
7	45.0	1200	-	-	6+	6	7	7
8	47.0	1610	-	-	7+	7	8	7
9	42.0	1010	-	-	5+	6	6	6
10	39.0	930	-	-	5+	5	6	6

Age readings, source:

1: VNIRO and AtlantNIRO (USSR) respectively
2: U. Hoffman (GDR)
3: E. Barrera-Oro (ARG)
4: K.-H. Kock (FRG)

\- not available, lost
nr not readable

Table 2: Age readings of juvenile *Notothenia rossii* scales from King George Island (South Shetland Islands). Source: Instituto Antártico Argentino.

No.	Capt.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3
1	10/05/83	30.0	-	M	-	4	4	4
2	13/05/83	33.5	-	F	-	4	4	4
3	16/05/83	23.5	-	M	-	3	3	3
4	19/05/83	28.5	-	M	-	3	3	3
5	19/05/83	33.5	-	M	-	5	6	4
6	23/05/83	25.7	-	F	-	3	3	3
7	27/05/83	24.4	-	M	-	3	3	3
8	04/06/83	31.3	-	M	-	4	4	4
9	04/06/83	30.2	-	F	-	4	4	4
10	04/06/83	36.5	-	F	-	5	5	5
11	08/06/83	24.8	-	M	-	3	3	3
12	08/06/83	32.7	-	M	-	5	5	4
13	17/11/83	26.6	-	F	-	3	3	4
14	17/11/83	35.0	-	M	-	5	4	5
15	17/11/83	37.5	-	M	-	6	5	6

Table 2 (continued)

No.	Capt.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3
16	21/11/83	36.6	-	F	-	6	6	6
17	21/11/83	33.9	-	F	-	5	5	5
18	11/04/85	44.3	1118	M	-	6	6	6
19	18/04/85	38.9	665	M	2	5	5	5
20	25/04/85	37.0	635	F	1	5	5	5
21	25/04/85	36.5	592	M	1	5	5	5
22	25/04/85	35.5	570	M	1	5	5	5
23	14/05/85	37.4	757	F	1	5	5	5
24	14/05/85	36.8	597	M	1	5	5	5
25	17/05/85	26.7	258	M	1	3	3	3
26	20/05/85	37.7	727	F	2	5	5	5
27	07/08/85	36.6	606	F	2	5	6	5
28	07/08/85	39.1	818	M	2	6	6	6
29	23/08/85	37.0	673	M	1	5	6	6
30	08/09/85	37.6	658	F	2	5	6	6
31	20/09/85	38.0	617	F	2	5	6	6
32	20/11/85	38.0	656	M	1	6	6	6
33	25/12/85	43.0	879	M	2	7	6	6
34	25/12/85	37.6	739	M	1	6	6	6
35	04/01/86	40.5	952	F	2	6	6	6
36	04/01/86	30.0	392	F	1	4	4	4
37	04/01/86	35.5	576	M	1	6	6	5
38	04/01/86	39.6	728	M	2	6	6	6
39	04/01/86	37.3	654	M	1	6	6	6
40	04/01/86	37.9	714	M	1	6	6	6
41	08/02/86	40.0	824	F	-	6	6	6
42	08/02/86	37.9	770	M	3	6	6	6
43	08/02/86	38.9	803	F	2	6	5	6
44	08/02/86	40.5	830	F	2	6	6	6
45	03/04/86	42.1	1030	F	2	6	6	6
46	07/05/86	38.9	697	M	2	6	5	6
47	07/05/86	38.6	804	F	2	6	5	6
48	06/12/86	23.8	153	F	1	3	3	3
49	06/12/86	23.0	126	F	1	3	3	3
50	29/12/86	24.2	165	F	1	3	3	3

Age readings, source:

1: E. Barrera-Oro (ARG)
2: K.-H. Kock (FRG)
3: U. Hoffman (GDR)

Table 3: Age readings of *Notothenia gibberifrons* scales from South Georgia and the South Shetland Islands.

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3	4	5
South Georgia, March 1985, Source: VNIRO									
1	42.0	740	F	3	11	11/12	9	10	9
2	33.0	355	M	2	7(8)	nr	nr	6	5
3	36.0	500	F	3	8+	nr	7	6	6
4	37.0	460	M	3	11	12/13	10	11	9
5	41.0	650	M	3	10	nr	9	9	8
6	34.0	480	M	3	10	10/11	13	12	7
7	40.0	610	M	3	11	11	9	9	9
8	36.0	500	M	3	10	11	10	9	8
9	40.0	470	F	2	9	nr	9	8	8
10	38.0	530	M	3	9	9/10	9	9	7
South Georgia, September 1986, Source: AtlantNIRO									
1	11.3	8	-	-	1	1	3	1	1
2	10.9	7	-	-	1	1	3	1	1
3	28.7	200	-	-	6	6	6	4	-
4	21.8	70	-	-	4	nr	5	2	-
5	24.0	98	-	-	4	nr	nr	2	3
6	20.6	55	-	-	3	3/4	7	3	3
7	19.0	42	-	-	2	3/4	5	2	-
8	37.0	450	-	-	8	9/10	10	7	7
9	33.0	400	-	-	7	8	10	8	5
10	39.0	650	-	-	9	-	-	-	-
11	31.0	340	-	-	7	7	9	5	5
12	37.0	540	-	-	9	9	11	9	7
13	45.0	960	-	-	11	13/14	11	12	11
14	46.0	1100	-	-	13	14	14	14	11
15	43.0	830	-	-	14	-	-	-	-
16	46.2	1050	-	-	13	-	-	-	-
17	41.8	790	-	-	8	10/11	nr	11	9
South Shetland Islands, March 1985, Source: VNIRO									
1	22.5	100	M	1	4+	5/6	6	4	4
2	36.0	430	F	2	9+	12	8	8	7
3	34.5	350	M	2	8+	10/11	9	8	6
4	39.0	580	F	3	10(9)	-	-	-	-
5	26.0	145	F	1	5+	7	7	6	4
6	30.5	255	F	1	7(8)	9	7	8	5
7	40.0	650	M	3	11	14/15	10	11	8
8	32.0	245	M	1	8+	9/10	8	8	6
9	43.5	740	F	3	12	14	11	10?	10
10	29.0	215	F	2	8+	9	7	8	6
11	28.0	180	F	1	6+	-	-	-	-
12	30.0	220	M	1	7+	9/10	8	7	5

Table 3 (continued)

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3	4	5
South Shetland Islands, March 1985, Source: VNIRO (continued)									
13	39.0	760	F	3	11	nr	9	9	7
14	33.0	350	F	2	9+	11	9	11	6
15	28.5	220	F	1	6(7)	8	8	6	4
16	36.0	440	M	3	8+	13	nr	10	8
17	38.0	610	F	3	9+	13/14	9	11/12	8
South Shetland Islands, November 1986, Source: AtlantNIRO									
1	29.0	230	-	-	7	8/9	9	7	5
2	28.0	220	-	-	7	9	9	6	4
3	27.0	180	-	-	6	8	9	6	5
4	30.0	260	-	-	7	9	11	-	5
5	24.0	140	-	-	5	6/7	8	5	4
6	36.0	520	-	-	8	12	10	8	7
7	37.0	440	-	-	8	nr	10	9	7
8	33.0	350	-	-	9	9/10	10	9	6
9	38.0	625	-	-	9	12	10	11	7
10	35.0	420	-	-	9	10/11	11	9	7
11	40.0	670	-	-	10	11/12	10	9	8
12	41.0	710	-	-	10	11	11	9	8
13	42.0	820	-	-	12	13	nr	10	9
14	41.0	810	-	-	11	12/13	11	11/12	9

Age readings, source:

1. VNIRO and AtlantNIRO (USSR) respectively
2. E. Barrera-Oro (ARG)
3. M.T. Garcia Santamaria, E. Balguerias Guerra (SP)
4. R. Coggan, M.G. White (UK)
5. U. Hoffman (GDR)

Table 4: Age readings of *Notothenia gibberifrons* otoliths and scales from South Georgia.

Source: British Antarctic Survey (UK)									
No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings (otoliths/scales)				
					1	2	3	4	5
88 20 80	39.5	610	F	2	9/-	12/12	-/7	10/9	8/10
20 81	35.6	400	M	1	12/-	10/nr	-/7	9/10	9/10
24,65	43.2	870	F	1	10/-	13/-	-	13/-	-
24 66	33.7	350	M	1	6/-	10/7	-	7/-	6/7
24 80	41.8	720	M	2	7/-	13/10	-/8	10/10	10/11-12
24 82	34.0	350	M	1	5/-	11/10	-/6	8/8	8/9
27 63	35.2	390	M	-	6/-	11/-	-	9/-	9/-
88 49 68	26.0	132	M	2	4/-	7/-	-	5/-	5/-
83	39.0	660	M	2	7/-	11/11	-/8	9/9	9/9
84	40.0	690	F	2/3	7-6/-	12/12	-/8	11/10	9/10
85	40.2	620	M	2	8-7/-	12/12	-/9	11/10	9/10
86	34.5	350	M	1	6/-	9/10	-/6	7/7	6-7/8
87	20.3	70	M	1	4/-	5/6	-/3	4/4	3/3-4
88 60 80	36.5	?	?	?	7/-	10/10	-/6	8/8	7/7-8
81	36.5	475	F	2	6/-	10/10	-/6	?/7	7/7
82	34.5	375	F	1	6-7/-	10/10	-/6	7/7	6/7
83	38.5	550	F	1	7/-	12/11	-/7	8/9	9/9
84	37.5	500	F	2	7/-	-/11	-/7	8/8?	8/10
85	31.0	255	F	1	5/-	9/11	-	6/6	6/6
86	30.0	245	F	1	6/-	8/8	-/5	6/6	5/6
87	30.5	252	F	1	7/-	11/11	-/6	7/6	6/7
88	30.5	236	F	1	9/-	9/9	-/5	7/6	6(5?)/6
89	25.8	210	M	1	7-6/-	8/7	-/4	5/5	5/5
90	23.3	95	M	1	6-8/-	7/7	-/4	4/4	4/4(3?)
88 60 91	23.0	90	M	1	6/-	7/7	-/3	4/4	4/3
92	24.2	120	F	1	(3)/-	-/6	-/4	?/4	3(2?)/4
93	22.2	85	F	1	4/-	6/6	-/3	4/4	3/3
94	22.5	83	F	1	4-7/-	5/6	-/3	4/4	4/4(5?)
15 B 1-1	20.8	64	F	1	3/-	7/-	-/3	4/4	3/5?
1-2	21.5	80	F	1	4/-	6/-	-/3	4/4	3/4?
1-3	30.0	270	F	2	8/-	7/-	-/5	7/6	6/6(7?)
1-4	18.3	37	F	1	?/-	6/-	-/12	4/3	2/3?
15 B 1-5	39.1	560	-	-	11/-	13/-	-	10/-	11/1-
1-6	38.3	520	F	2	9/-	10/-	-/7	9/9	9/(10?)9
1-7	38.0	590	F	1	11/-	10/-	-/7	8/9	9/(10?)9
1-8	40.9	650	M	2	10/-	14/-	-	10/-	9/11
1-9	35.8	530	F	2	11/-	11/-	-/7	8/10	8/10(11?)
1-10	22.4	84	F	1	6/-	7/-	-/3	5/5	(6?)7/3(4?)
89 44 41	19.8	47	F	1	4/-	7/6	-/3	4/4	3/3
42	18.0	42	F	1	4/-	7/7	-/2	4/3	(2?)3/(2?)3
43	16.3	26	F	1	4/-	6/6	-/2	3/3	2/2(3?)
66	31.3	270	F	2	9/-	10/10	-/6	6/6	7/-
68	41.5	770	M	2	13/-	14/11	-/10	11/11	(11?)12/11
69	42.4	850	F	2	13/-	15/15	-/9	11/10	11/11
70	33.2	360	M	1/2	7/-	11/12	-/6	7/8	7/8
71	38.8	540	F	2	9/-	10/11	-/7	8/8	9/9
72	41.3	770	M	2	9/-	12/10	-/8	11/11	10/12
73	35.8	450	F	2	8-9/-	10/11	-/7	8/9	8/(8?)9

Table 4 (continued)

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings (otoliths/scales)				
					1	2	3	4	5
89 44 74	27.0	155	F	1	8/-	8/-	-/4	5/5	5/5
75	25.5	122	M	1	4/-	6/7	-/4	5/4	5/5
76	18.2	41	M	1	3/-	5/6	-/3	4/4	4/3(4?)
77	12.6	11	F	1	2/-	5/4	-/2	2/2	?/?
78	12.3	11	F	1	2/-	4/4	-/1	2/2	2/2
89 45 51	22.0	80	-	1	5/-	6/-	-	4/-	(4?)3/-
52	17.1	32	-	1	3/-	5/-	-	3/-	3/-
53	13.7	16	-	1	3/-	4/-	-	2/-	2/-
54	14.5	20	F	1	3/-	5/-	-	3/-	2-3/-
61	12.2	11	-	1	2/-	3/-	-	2/-	2/-
62	7.7	2	-	1	?/-	2/-	-	1/-	1/-
89 46 38	14.4	21	-	1	2/-	4/-	-	3/-	3/-
39	13.7	19	M	1	3/-	4/-	-	3/-	3/-
40	13.7	17	M	1	3/-	5/-	-	3/-	3/-
41	11.6	10	M	1	2/-	3/-	-	2/-	(3?)2/-
42	12.9	16	M	1	2/-	-/-	-	2/-	2/-
45	43.6	750	F	2	12/-	12/-	-	12/-	12/-
76	43.1	1010	M	3	14/-	12/-	-	12/-	12/-
77	37.8	?	F	1	9-10/-	10/-	-	9/-	(9?)10/-
79	32.9	325	F	1	8-7/-	9/-	-	8/-	8/-
80	23.7	110	F	1	4/-	5/-	-	5/-	5?/-
81	17.6	36	-	1	3-4/-	4/-	-	3/-	3/-
82	14.8	20	-	1	3/-	4/-	-	3/-	3/-
96	40.0	665	F	2	10/-	11/9	-/8	10/10	10/9
97	21.1	64	M	1	4/-	6/6	-/3	4/4	4(5?)/4(5?)
98	31.8	300	M	1/2	7-6/-	8/8	-/5	6/6	6/6
99	23.1	79	M	1	4	5/5	-/3	4/4	4/(3?)4
89 47 00	36.3	450	M	2	8/-	11/9	-/7	8/8	9/8(9?)
01	30.1	219	F	1	6/-	8/-	-/5	6/6	6(5?)/5(6?)
02	39.2	600	M	2	9/-	10/9	-/8	9/9	9(10?)/9
03	31.8	288	F	2	7/-	9/10	-/5	7/7	7/6
04	36.7	490	M	2	9/-	11/10	-/7	9/9	7/8
05	12.0	11	F	1	2-3/-	5/4	-/1	2/2	?/1(2?)

Age readings, source:

1. R. Coggan (UK)
2. M.T. Garcia Santamaria
   E. Balguerias Guerra
   M.E. Quintero Perez (SP)
3. U. Hoffmann (GDR)
4. K.-H. Kock (FRG)
5. K. Skora (POL)

Table 5: Age readings of *Champsocephalus gunnari* otoliths from South Georgia, the South Orkney Islands and South Shetland Islands.

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3	4
South Georgia, Source: VNIRO, AtlantNIRO								
1	7.3	1.1	-	1	0+	0	0	0
2	7.5	1.3	-	1	0+	0	0	0
3	9.0	2.5	-	1	0+	0	0	0
4	18.4	34	-	1	1+	1	1	1
5	20.7	49.2	M	2	1+	1	1	2
6	20.7	49.5	F	2	1+	1	1	2
7	20.8	51.2	M	2	1+	1	1	2
8	22.0	63	M	1	1+	2	2	2
9	27.8	117	M	3	2+	2	2	2
10	28.1	136	M	3/4	2+	2	2	2
11	28.5	118	F	2	2+	2	?	2
12	30.5	165	F	3	3+	3	2	-
13	30.5	186	M	2	3+	3	2	3
14	34.0	276	M	3/4	3+	3	2	?
15	34.5	276	F	3/4	4+	3	3	3
16	36.0	287	F	2/3	4+	3	4	4
17	36.0	307	M	3	4+	4	4	4
18	36.2	344	M	3/4	4+	4	5	4
19	39.6	374	M	2/3	5+	4	?	4
20	40.5	475	M	3/4	5+	-	-	-
21	42.6	450	F	3/4	5+	4	5	5
22	48.7	915	M	3	7+	5	9	-
23	50.5	870	M	3	8+	-	-	-
24	57.5	1720	F	3	11+	-	-	-
South Georgia, December 1984, Source: VNIRO, AtlantNIRO								
1	25.1	90	M	-	3	2	2	3
2	37.4	363	M	-	6	3	4	4
3	37.1	346	F	-	6	3	?	4
4	29.2	175	F	-	4	3	2	3
5	33.2	264	F	-	5	3	3	3
Shag Rocks, October 1985, Source: VNIRO, AtlantNIRO								
6	13.3	12.1	M	-	1	?	?	2
7	24.8	91.6	F	-	3	2	2	3
8	30.0	174.0	M	-	4	3	4	3
9	21.6	66.5	M	-	3	2	2	3
10	13.5	11.2	F	-	1	1	1	2
11	25.1	86.6	F	-	3	-	2	3
12	13.9	10.1	F	-	1	1	1	2
13	22.2	59.7	F	-	3	2	2	2
14	28.9	114.0	M	-	4	2	3?	3
15	15.2	17.8	M	-	1	1	1	2

Table 5 (continued)

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings			
					1	2	3	4
South Orkney Islands, March 1978, Source: VNIRO, AtlantNIRO								
1	13.5	10	-	1	1 +	1	1	1 +
2	20.5	50	F	2	2 +	2	2	2 +
3	22.0	60	-	1	2 +	2	2	3
4	22.0	60	F	2 / 3	3 +	2	2	2
5	24.0	70	M	2	3 +	3	3	2
6	25.0	90	F	3	3 +	3	3	2 +
7	26.5	100	F	3	4 +	3	3	3 / 4
8	27.0	110	M	3	4 +	3	3	3
9	27.0	100	F	2	4 +	3	3	3
10	28.0	110	M	2	4 +	3	3	4 +
11	28.0	120	M	2	5 +	3	3	4 +
12	30.0	160	M	2	5 +	3	3	4
13	30.5	140	F	3	5 +	3	3	4
14	33.0	230	F	3	6 +	4	4	3 +
South Shetland Islands, March 1985, Source: VNIRO, AtlantNIRO								
1	29.5	165	F	2	3 +	3	3	3
2	30.5	165	M	2	3 +	2	3	3 +
3	34.2	-	M	3	4 +	3	4	4
4	34.3	-	F	3	4 +	4	4	7
5	36.2	-	F	3	5 +	-	-	5
6	36.5	260	F	2	5 +	4	5	7
7	40.0	450	F	2	5 +	3	4	6
8	40.0	500	M	3	5 +	4	5	6
9	41.0	740	M	2	5 +	5	5	6
10	47.3	-	M	3 / 4	7 +	>5	8	?
11	47.5	940	F	4	7 +	7	7	6 +
12	51.5	980	M	4	8 +	>6	?	6 +

Age readings, source:

1. VNIRO and AtlantNIRO (USSR)
2. G. Gubsch (GDR)
3. J. Sosinski (POL)
4. R. Coggan/M. White (UK)

Table 6: Age readings of *Pleuragramma antarcticum* otoliths from Mawson Sea, March 1984.

Source: AzcherNIRO

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings			
					1	2	3	4
1	19.3	66.0	F	-	7	9	9	6/7
2	18.2	51.0	F	-	7	5	8	5
3	19.8	80.0	F	-	9	9	7	7
4	18.6	60.0	F	-	8(7)	8	8	6/7
5	16.6	45.0	M	-	7	8	7	5
6	19.1	64.0	F	-	7	?	7	6?
7	17.4	58.0	M	-	7	8	6	6
8	18.4	74.0	M	-	8	9	9	7
9	20.1	90.0	F	-	8	9	9	6/7
10	18.7	74.0	F	-	9(10)	?	9?	5/6
11	19.2	80.0	F	-	7	8	10	5?
12	18.4	70.0	F	-	8	8	9	5/6
13	16.8	49.0	M	-	7	8	8	5
14	18.0	69.0	F	-	7	?	7	5
15	19.6	93.0	F	-	9	10	9	6/7
16	17.2	58.0	F	-	7	9	8	4/5
17	17.8	68.0	F	-	7	7	7	4/5
18	17.3	67.0	M	-	8	6	8	5/6
19	20.6	99.0	F	-	8	7	9	6/7
20	16.9	42.0	M	-	6(7)	?	7?	5
21	16.6	50.0	M	-	6	7	7	4/5
22	14.2	26.0	M	-	5	4	5	3/4
23	15.5	34.0	F	-	5	4	5	?
24	16.6	40.0	F	-	6	4-5	7	4
25	16.0	44.0	M	-	7(6)	7	7	4
26	15.0	30.0	F	-	5	5	5	3/4
27	15.4	38.0	F	-	5(6)	6	5	4
28	16.0	34.0	M	-	5	5?	7	4
29	15.5	32.0	F	-	5	5	5	3
30	14.5	24.0	M	-	5	-	-	-
31	20.5	89.0	F	-	9	7	8	7
32	14.5	26.0	F	-	5	?	7	3/4
33	20.5	80.0	F	-	10?	7	8	6/7
34	14.5	25.0	F	-	5	4	5	4
35	13.4	21.2	F	-	5	3	4	3
36	13.4	22.0	M	-	5	3	4	4
37	12.4	15.0	M	-	4	2-3	-	2/3
38	13.9	18.7	F	-	4	4	4	-
39	12.6	16.5	F	-	4	3	3	2
40	13.6	19.9	F	-	5	-	-	-
41	13.5	21.5	M	-	5	4	6	3
42	19.4	69.8	F	-	8	9	7?	5/6
43	19.3	73.0	M	-	7	12	9	7
44	17.8	56.0	F	-	7	9	7	5

Table 6 (continued)

No.	Length (cm)	Weight (g)	Sex	Maturity Stage	Age Readings 1	2	3	4
45	17.1	52.5	M	-	7	?	5	5/6
46	16.5	44.5	M	-	7	8	5	5
47	15.9	38.9	F	-	6	6	6	4
48	13.8	20.3	M	-	5	5	6	3
49	13.6	18.5	F	-	5	4	4	2
50	18.1	46.8	F	-	6	5	8	5

Age readings, source:

1. V.V. Gerasimchook (USSR)
2. G. Hubold (FRG)
3. R. Williams (AUS)
4. E. Barrera-Oro (ARG)

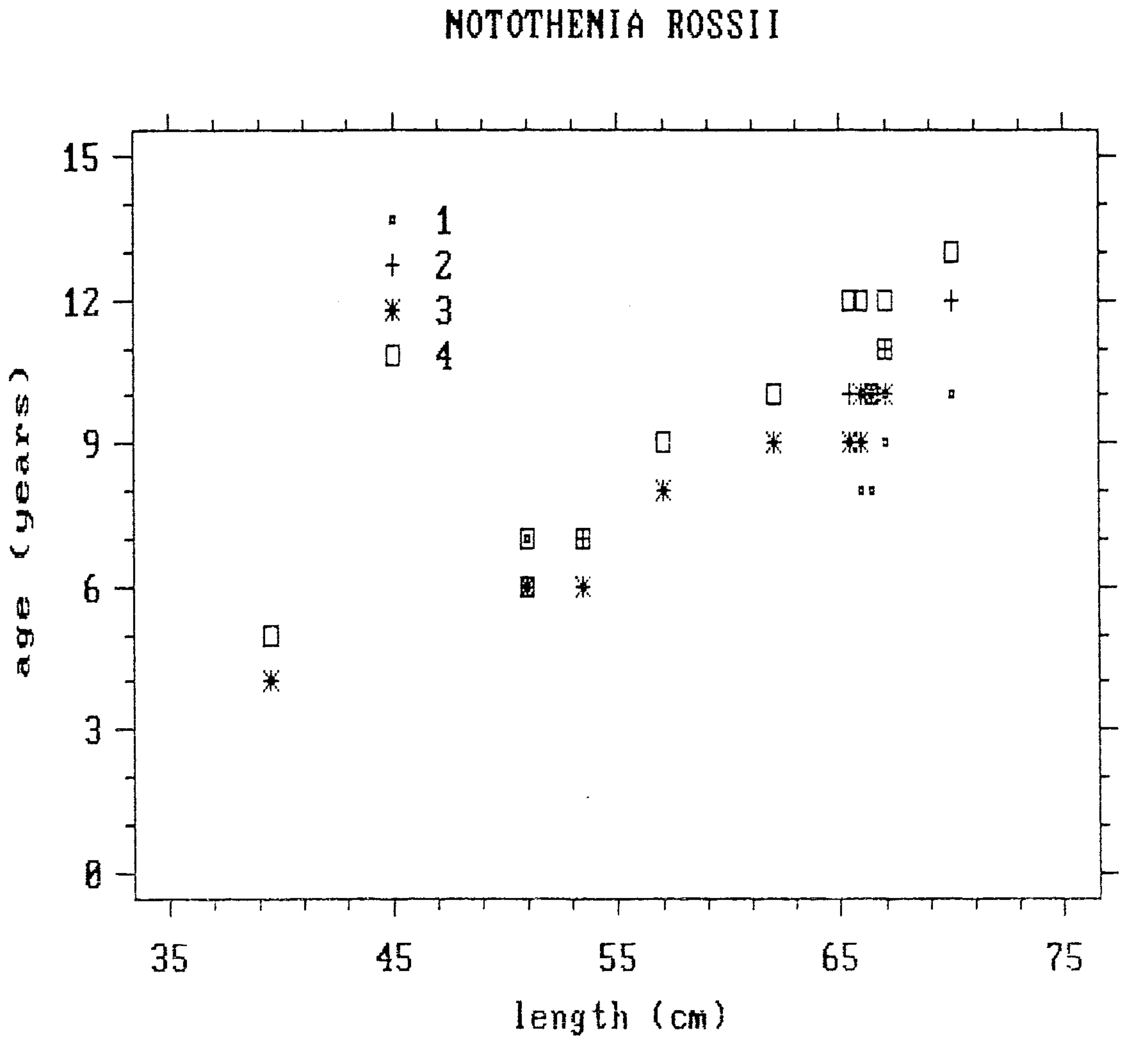

Figure 1: Length versus age plot from comparative age determinations on scales of *Notothenia rossii* from South Georgia. Collected 1971, 1977 by VNIRO (USSR). For readers 1-4 see footnote to Table 1.

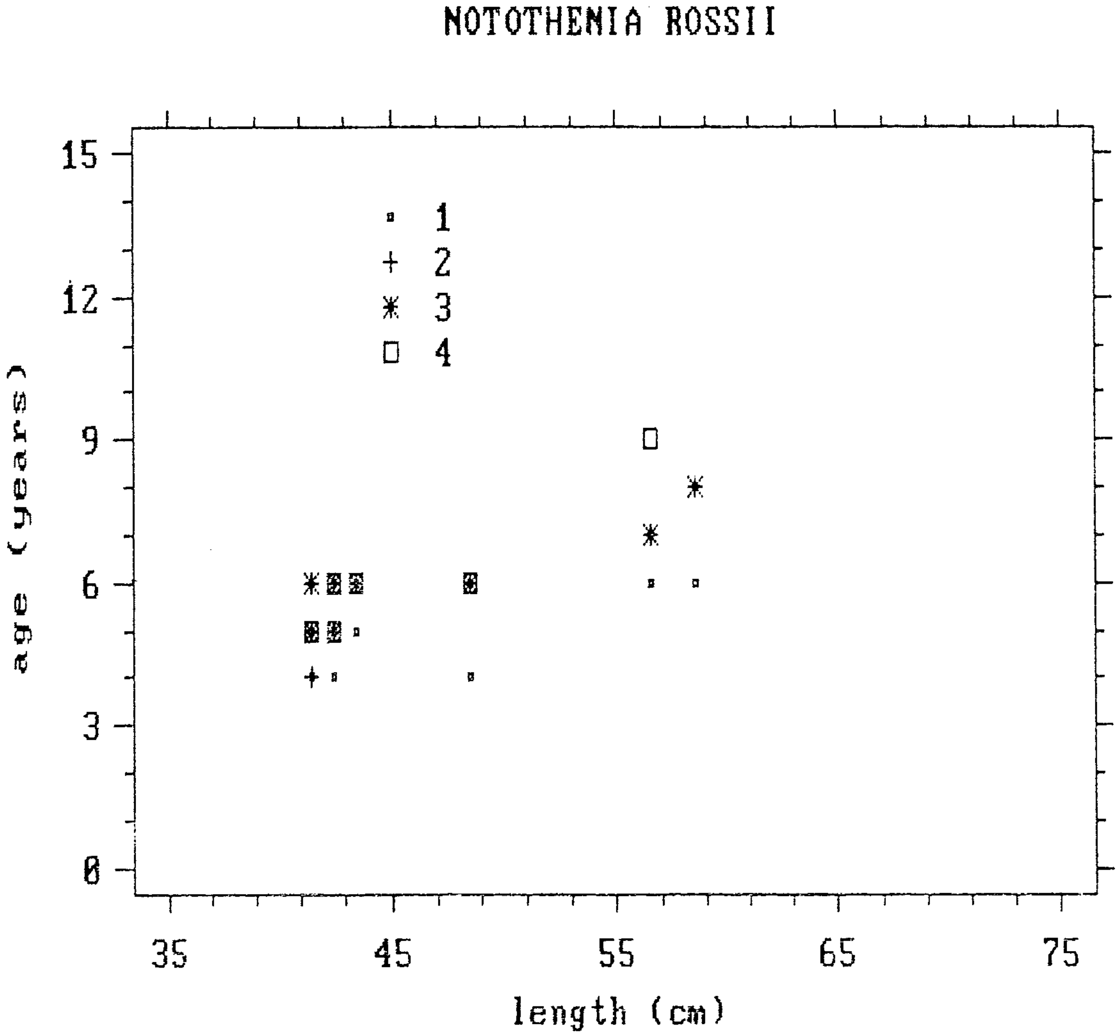

Figure 2: Length versus age plot from comparative age determinations on scales of *Notothenia rossii* from South Georgia. Collected 1986 by AtlantNIRO (USSR). For readers 1-4 see footnote to Table 1.

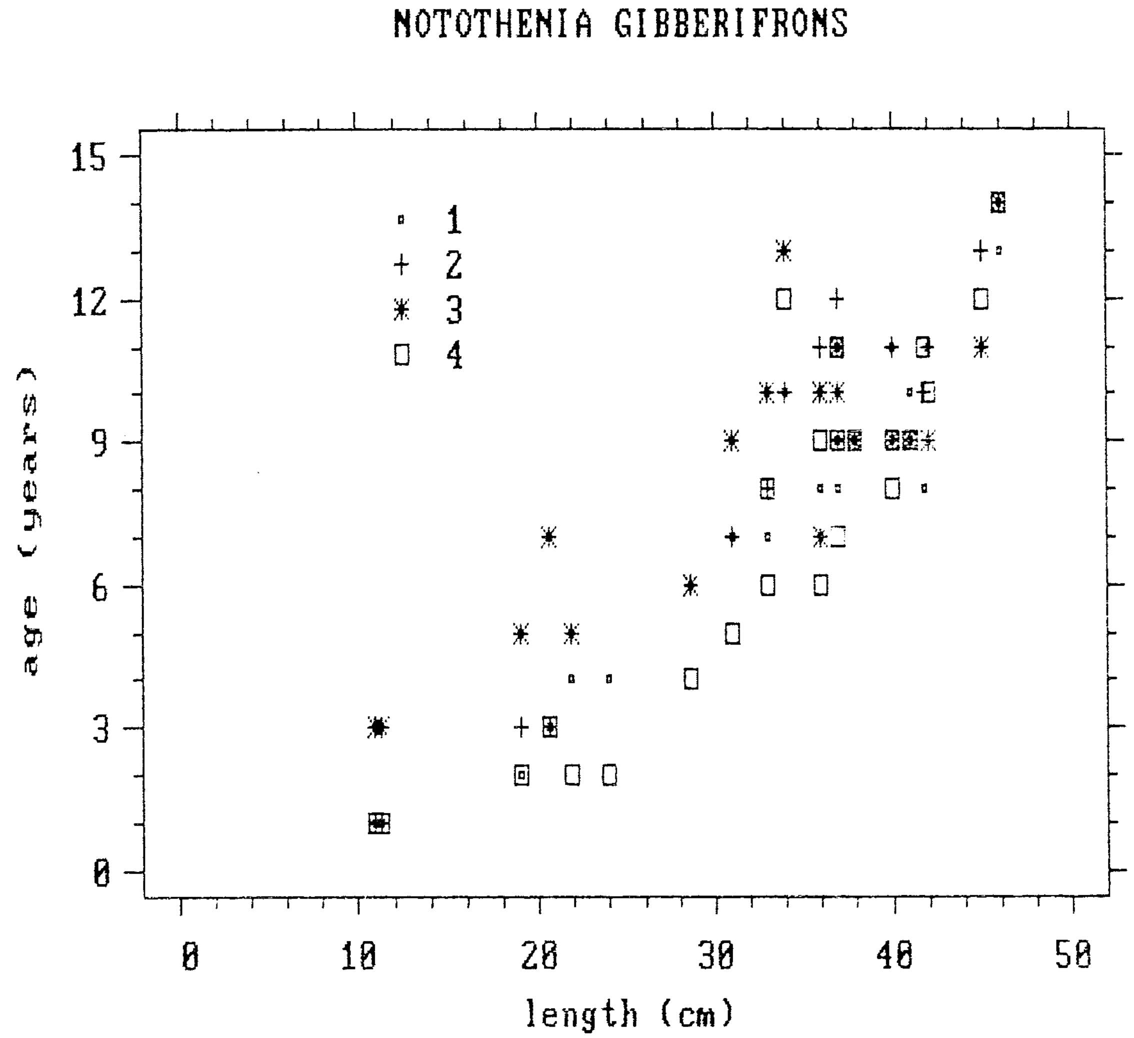

Figure 3: Length versus age plot from comparative age determinations on scales of *Notothenia gibberifrons* from South Georgia. (Data of reader 5 have not been included due to submission after deadline). Collected 1985, 1986 by VNIRO and AtlantNIRO (USSR).
For readers 1-4 see footnote to Table 3.

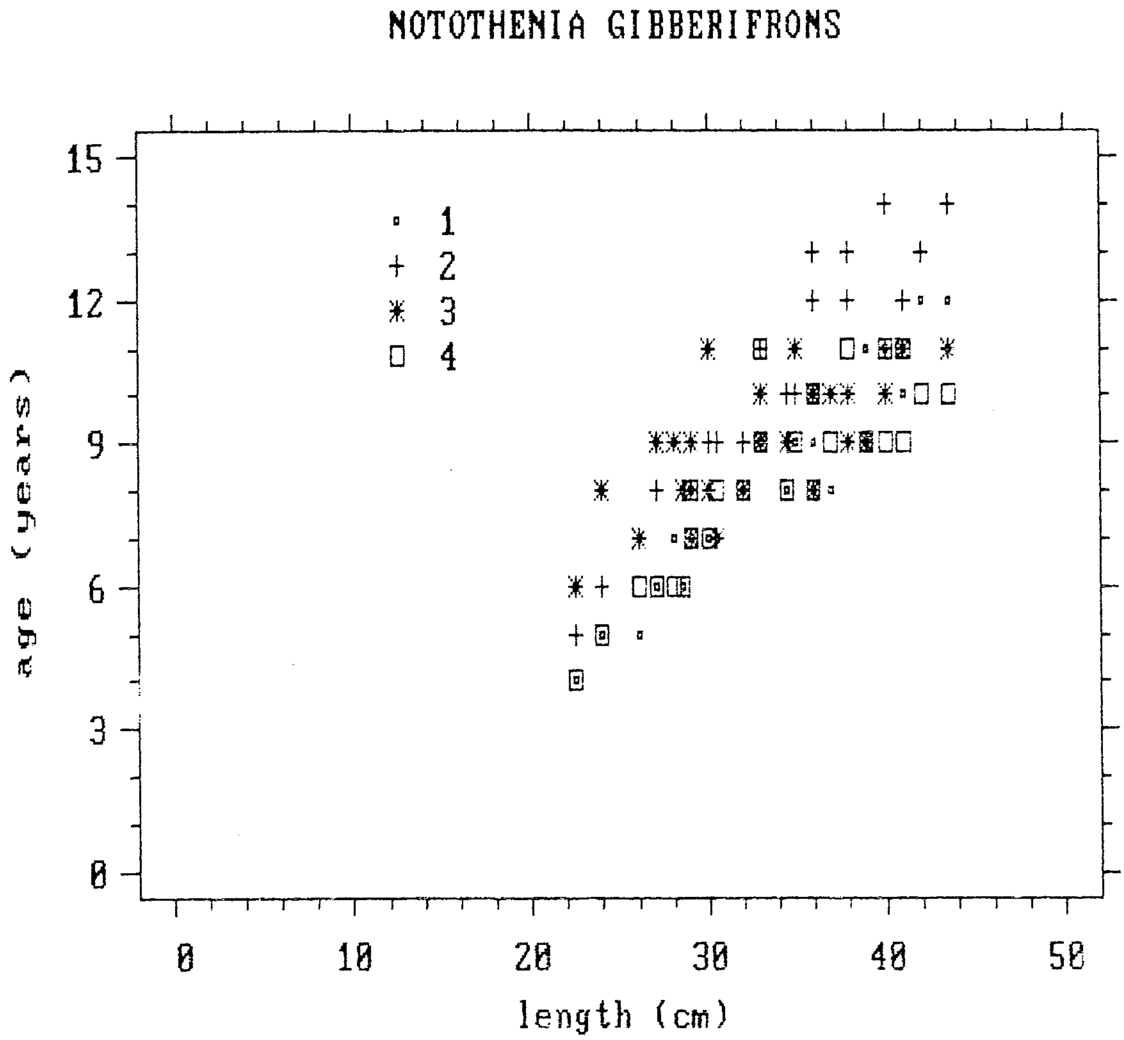

Figure 4: Length versus age plot from comparative age determinations on scales of *Notothenia gibberifrons* from the South Shetland Islands. (Data of reader 5 have not been included due to submission after deadline). Collected 1985, 1986 by VNIRO and AtlantNIRO (USSR).
For readers 1-4 see footnote to Table 3.

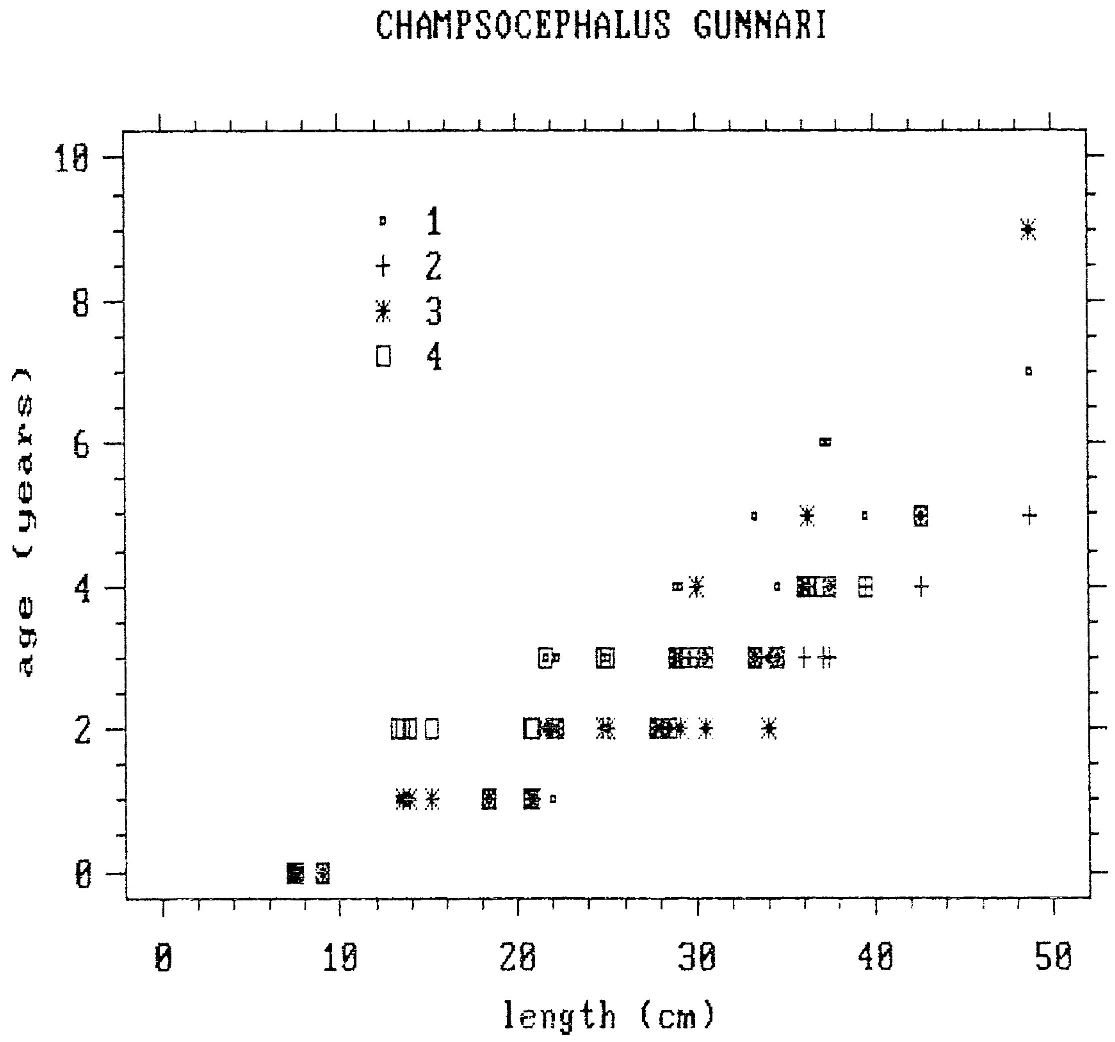

Figure 5: Length versus age plot from comparative age determinations on otoliths of *Champsocephalus gunnari* from South Georgia. Collected by VNIRO and AtlantNIRO (USSR).
For readers 1-4 see footnote to Table 5.

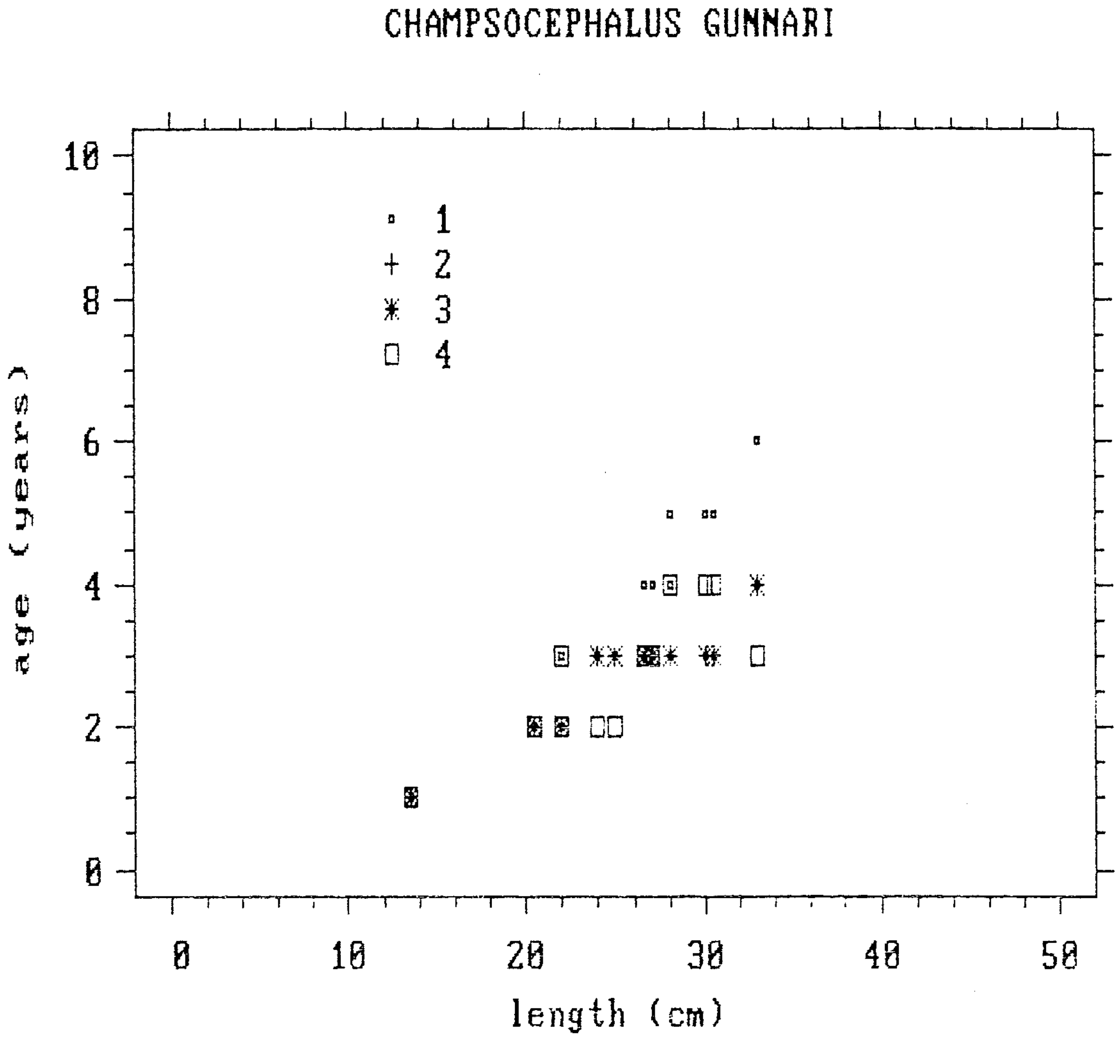

Figure 6: Length versus age plot from comparative age determinations on otoliths of *Champsocephalus gunnari* from the South Orkney Islands. Collected by VNIRO and AtlantNIRO (USSR).
For readers 1-4 see footnote to Table 5.

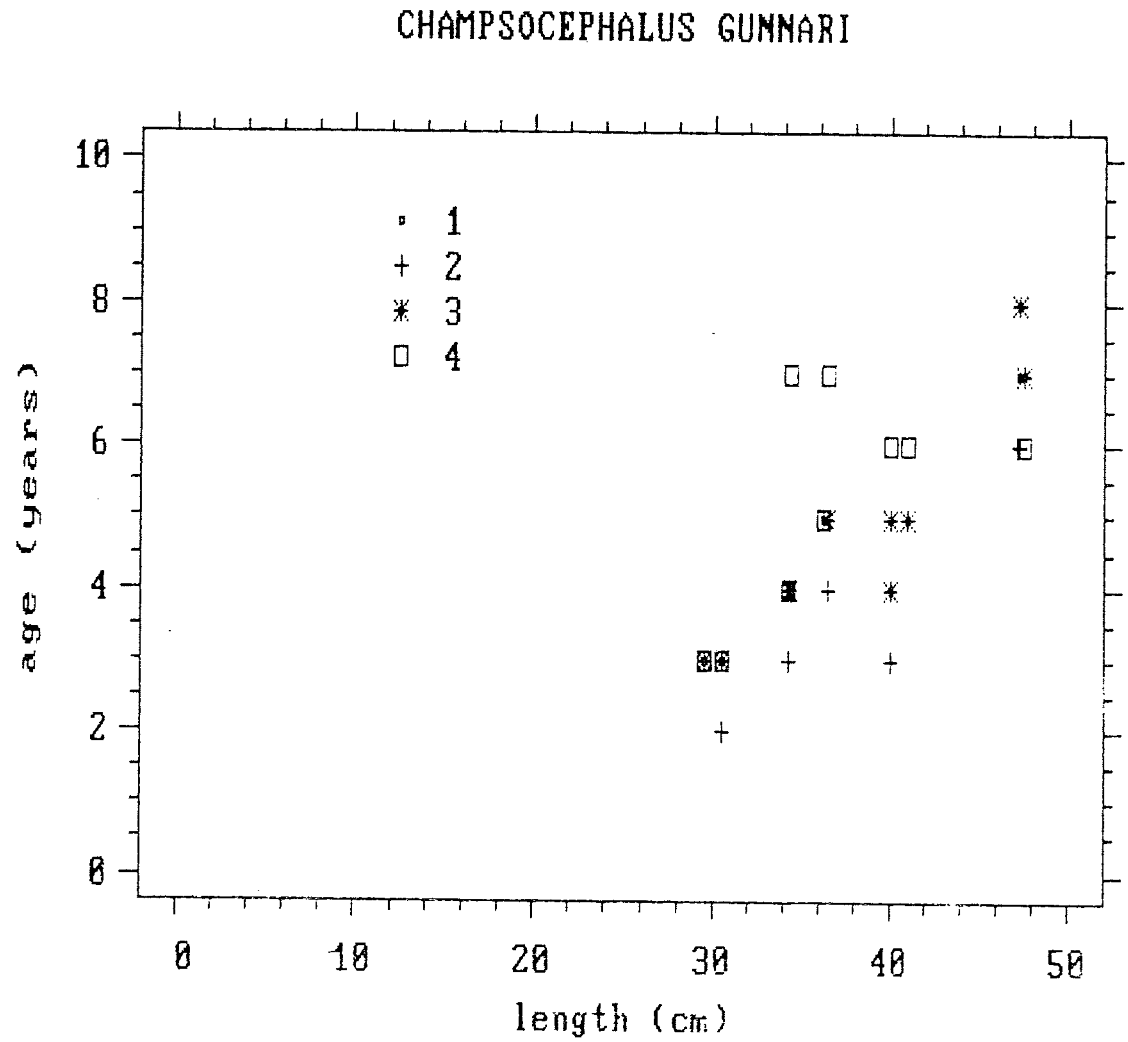

Figure 7: Length versus age plot from comparative age determinations on otoliths of *Champsocephalus gunnari* from the South Shetland Islands. Collected by VNIRO and AtlantNIRO (USSR).
For readers 1-4 see footnote to Table 5.

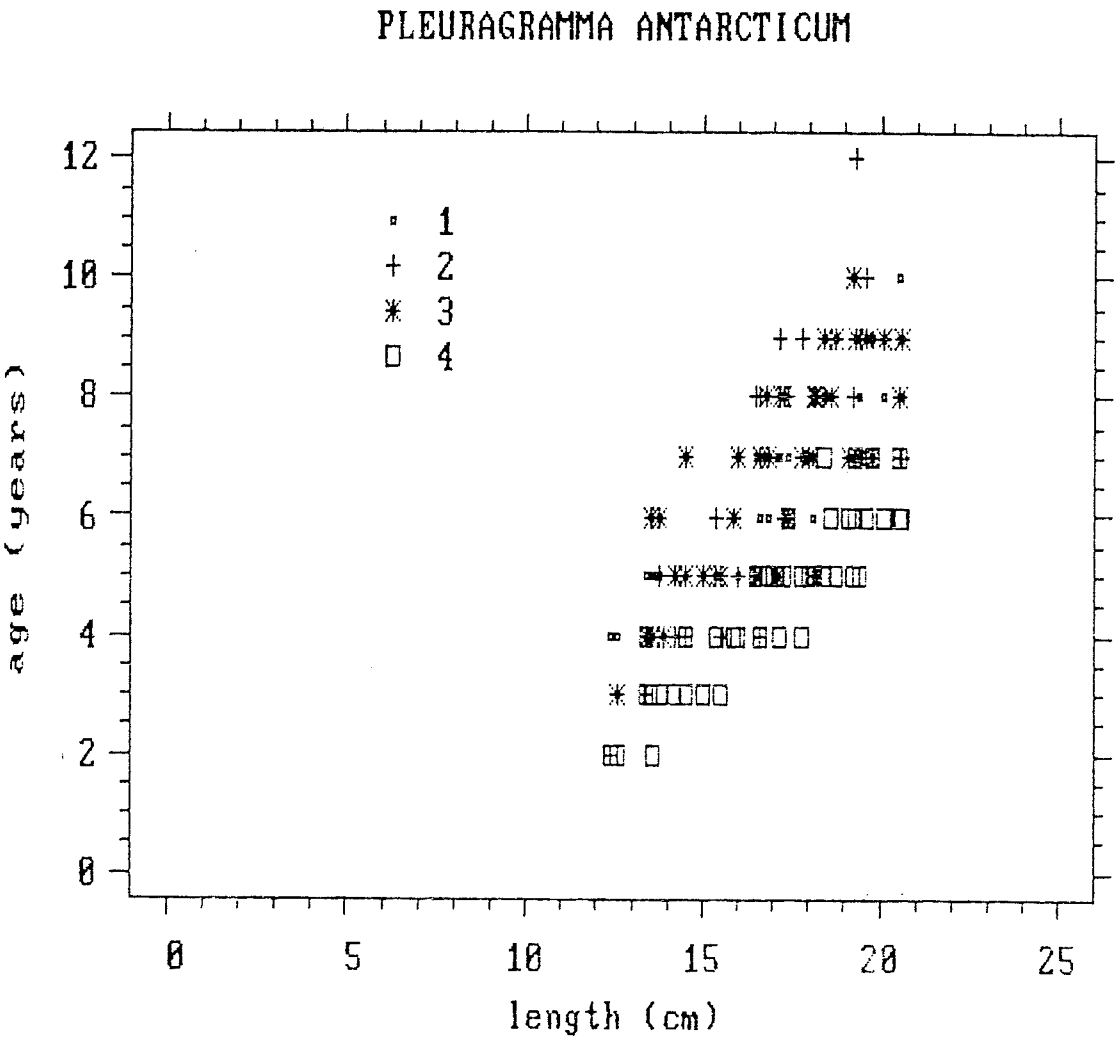

Figure 8: Length versus age plot from comparative age determinations on otoliths of *Pleuragramma antarcticum* from Mawson Sea. Collected by AzcherNIRO (USSR). For readers 1-4 see footnote to Table 6.

II. ANTARCTIC KRILL

SC-CAMLR-VIII/BG/11

COMMERCIAL KRILL FISHERIES IN THE ANTARCTIC, 1973 TO 1988

D.G.M. Miller

Abstract

STATLANT data reported to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) are used to discern observable trends in catch and effort for the Antarctic krill (*Euphausia superba*) fishery between 1972/73 and 1987/88. The annual krill catch rose gradually to a peak of some 500 000 tonnes in 1981/82 before dropping to a low level in 1983/84 and stabilizing at about 400 000 tonnes thereafter. In terms of both catch and effort the Soviet and Japanese krill fisheries in Subareas 48.1, 48.2 and 48.3 prevail in the CCAMLR Convention Area. Monthly fishing patterns (November to April) are similar in all areas, except in Subarea 48.3 where fishing is predominantly confined to the winter months (April to August). Trends in the fishery with respect to independent estimates of krill abundance and minke whale (*Balaenoptera acutorostrata*) catches are discussed.

Résumé

Les données STATLANT présentées à la Commission pour la conservation des ressources marines vivantes de l'Antarctique (CCAMLR) sont utilisées pour discerner les tendances apparentes de capture et d'effort pour la pêcherie du krill antarctique (*Euphausia superba*) entre 1972/73 et 1987/88. La capture annuelle du krill a augmenté petit à petit jusqu'à un maximum de quelques 500 000 tonnes en 1981/82 avant de baisser jusqu'à un niveau faible en 1983/84 et de se stabiliser par la suite, à environ 400 000 tonnes. Il semble qu'en termes de capture ainsi que d'effort, les pêcheries soviétiques et japonaises dans les sous-zones statistiques 48.1, 48.2 et 48.3 dominent l'exploitation du krill dans la Zone de la Convention de la CCAMLR. Les façons de pêcher, par mois (de novembre à avril), sont similaires dans toutes les zones, à l'exception de la sous-zone 48.3 où les activités de pêche sont limitées pour la plupart aux mois d'hiver (d'avril à août). Les tendances dans la pêcherie en ce qui concerne des estimations indépendantes de l'abondance du krill et les captures de petits rorquals (*Balaenoptera acutorostrata*) sont examinées.

Резюме

Данные по STATLANT, представленные в Комиссию по сохранению морских живых ресурсов Антарктики (АНТКОМ) используются для того, чтобы выявить очевидные закономерности изменений уловов и промыслового усилия при промысле антарктического криля (*Euphausia superba*) в течение периода 1972/73 - 1987/88 гг. Ежегодный вылов криля постепенно возрастал до максимума примерно в 500 000 т. в 1981/82 г.; затем вылов находился на низком уровне в 1983/84 г. и впоследствии стабилизировался на уровне около 400 000 т. Имеются свидетельства того, что как в отношении вылова, так и промыслового усилия советский и японский промысел в подрайонах 48.1, 48.2, и 48.3 играют главную роль в эксплуатации криля в зоне действия Конвенции АНТКОМ. Ежемесячный промысловый режим (ноябрь-апрель) подобен во всех районах за исключением Подрайона 48.3, где промысел ведется главным образом в течение зимних месяцев (апрель-август). Рассматриваются направления изменений промысла криля, определенные по независимым оценкам численности криля и размера уловов малого полосатика (*Balaenoptera acutorostrata*).

Resumen

Los datos notificados a la Comisión para la Conservación de los Recursos Vivos Marinos Antárticos (CCRVMA) en formularios STATLANT se utilizan para distinguir tendencias visibles en la captura y esfuerzo para la pesca de krill Antártico (*Euphausia superba*) entre 1972/73 y 1987/88. Hubo un aumento gradual en la captura anual de krill llegando a un máximo de 500 000 toneladas durante un tiempo en 1981/82, antes de disminuir a un nivel mínimo en 1983/84 para estabilizarse alrededor de 400 000 toneladas de ahí en adelante. En términos de captura y esfuerzo, las pesquerías de krill soviética y japonesa en las Subáreas 48.1, 48.2 y 48.3 predominan en el Area de la Convención de la CCRVMA. Los patrones mensuales de pesca (noviembre a abril) son semejantes en todas las áreas, excepto en la Subárea 48.3 donde la pesca es limitada principalmente a los meses de invierno (abril a agosto). Se debaten las tendencias en la pesquería con respecto a estimaciones independientes sobre la abundancia de krill y rorcual aliblanco (*Balaenoptera acutorostrata*).

1. INTRODUCTION

During the past three decades a growing demand for protein from the sea combined with increasingly restricted access to historical fishing grounds has resulted in the development of many "unconventional" fisheries (cf Robinson, 1982; Budzinski et al., 1985). In particular, such development has been focussed on the Antarctic krill (*Euphausia superba* Dana).

Krill has long been recognised as a key component of many Antarctic marine food webs (cf Marr, 1962; Everson, 1977; Knox, 1984 amongst others) and exhibits several attributes which enhance its potential as an exploitable resource. These include:

- high global abundance estimates (Everson, 1977; Gulland, 1983);
- high nutritional value (Grantham, 1977; Budzinski et al., 1985); and
- relative ease of capture arising from the species' tendency to aggregate (Eddie, 1977; El-Sayed and McWhinnie, 1979).

Exploratory fishing for krill as a commercial resource commenced in the early 1960's and initially catches were relatively small (Table 1). The build-up of annual catches was slow and it was not until the 1973/74 season that exploitation of krill could in any way be considered to have been on a commercial basis.

The primary aim of this paper is to review krill catches over the past fifteen years. Catch statistics will be used to indicate areas where the fishery has been most active and from which the largest catches have been taken. Discernible trends in the catches will be considered in the light of available theories on krill distribution and some attempt will be made to provide insights into possible relationships between krill fisheries and the species' distribution. As a secondary aim, some attempt will be made to assess possible links between the information provided by the fisheries data and available knowledge on krill predators. It is hoped that this approach will contribute to current efforts aimed at assessing the role of the minke whale (*Balaenoptera acutorostrata*) as an indicator of krill stock dynamics.

2. THE KRILL FISHERY

2.1 Available Data

Krill catches are reported from three major statistical areas in the Antarctic. Originally defined by the FAO, these areas have been subsequently adopted by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (CCAMLR, 1988a). They are termed the Atlantic (Statistical Area 48), Indian Ocean (Statistical Area 58) and Pacific Antarctic (Statistical Area 88), and for convenience have been further subdivided into various subareas and divisions (Figure 1).

Summary catch and effort data are supplied annually to CCAMLR using the STATLANT A and B formats. For reporting purposes, catches are summarized by split-years; a split-year being the twelve month period from 1 July in one year to 30 June in the next. The catch year is designated according to the second of the two split-years. Krill STATLANT data contain information on catch with respect to year, month, major gear type, vessel type and geographical subarea.

Both STATLANT A and B data are considered in this paper, although only data where krill were specified as the target or only species caught have been used to analyze fishing effort. The bulk of catches taken during the period under consideration (1973 to 1988) were by the Soviet fishery (see below). Prior to 1983, however, Soviet catch data in all areas were not ascribed by month, and effort data (e.g. hours fished) are only available from that year onwards. Fine-scale catch and effort data (taken in groups by 10-day period and 0.5° latitude x 1° longitude) have been available since 1985/86 for Subareas 48.1 and 48.2 only. Such data have not been considered to any great extent in the analyses reported here.

2.2 Trends in Catches

2.2.1 Annual catch

During the period 1973 to 1988 (Figure 2) annual krill catches in the CCAMLR Convention Area rose steadily from 19 785 tonnes in 1973/74 (with a minor reduction of 28 891 tonnes, from 477 023 tonnes to 448 132 tonnes, between 1979/80 and 1980/81) to a peak of 528 201 tonnes in 1981/82. After 1982, catches declined sharply to a trough of 130 875 tonnes in 1983/84; a level close to that observed in 1977/78 (132 349 tonnes) during the early expansion of the fishery. Thereafter, annual catches gradually increased to a second peak of 445 673 tonnes in 1985/86 and subsequently levelled off at about 370 000 tonnes in the remaining years. From Figure 2 it is also apparent that the Soviet Union (±85% total) and Japan (±14% total) are by far the two major krill fishing nations, together accounting for about 99% of all catches.

2.2.2 Annual Catch By Area and Subarea

The annual catch in Statistical Area 48 is consistently larger (except for the 1975/76 season when no krill were taken in this area) than in Statistical Areas 58 and 88 for any one year (Figure 3). This trend has been especially obvious since the 1983/84 season.

Trends in the annual catch from the three areas (Figures 4 to 6) show slight differences, although Soviet and Japanese catches remain dominant. In Statistical Area 48 (Figure 4) the overall catch trend is similar to that for all three areas combined (Figure 3), which is not surprising given that Statistical Area 48 accounts for the major proportion of the annual catches. Gradually increasing catches in Statistical Area 58 peaked in 1980/81 (155 030 tonnes), at a much lower level than the 1985/86 peak (425 871 tonnes) in Statistical Area 48, before falling to consistently lower levels (±20 000 tonnes) thereafter (Figure 5). Sporadic catches in Statistical Area 88 reached a peak of 10 637 tonnes in 1982/83 and exhibited a subsequent decline similar to that in Statistical Area 58 (Figure 6). The 1983/84 season yielded the lowest post-peak catch levels in Statistical Areas 48 and 88 (104 680 and 641 tonnes respectively), which occurred (5 932 tonnes) in Statistical Area 58 two seasons later (1985/86).

Plots of cumulative catch by subarea (Figures 7 and 8) again illustrate the relatively large catches in Statistical Area 48 compared with the other two areas, despite the fact that both Statistical Areas 58 and 88 are substantially larger than Statistical Area 48. It is also apparent that prior to 1979/80 substantial catches in Statistical Area 48 were reported from subareas "unknown". These were predominantly taken by the Soviet fishery and suggest that the total catch from Statistical Area 48 over the years is substantially greater than that reflected in the designated subarea data presented.

The accumulated catches were greatest in Subareas 48.2 (1 161 678 tonnes) and 48.3 (977 118 tonnes) (Figures 7a and 7b) as were annual catches (Figure 9). Similarly, the pattern of both the underlying annual trend in catches and a low 1983/84 catch in these two subareas closely resembles the overall trend for Statistical Area 48 illustrated in Figure 4. Given the relative importance of catches from Statistical Area 48, therefore, the following analyses have tended to concentrate on Subareas 48.1, 48.2 and 48.3.

2.2.3 Catch By Subarea and Month

Although monthly Soviet catches are not available prior to 1983, it is possible to plot total catches by month for various subareas and time periods (Figure 10). Monthly catch trends are remarkably similar in Subareas 48.1 and 58.4 and Area 88 as a whole (Figures 10a, 10d and 10e). Fishing commences in early spring (i.e. October/November) and is followed by a gradual increase in catches until peak levels are reached in early to mid-summer (January/February). Catches then decrease until cessation of fishing in April/May. In Subarea 48.2, on the other hand, fishing commences at a similar time but large monthly catches are taken over a much longer period (January through to April) and peak slightly later (March/April) (Figure 10b). By contrast, the fishing pattern in Subarea 48.3 is entirely different (Figure 10c). Although catches may be taken the whole year round, the highest catch levels occur between April and August (i.e. in late autumn through winter) with peak catches in June. This observed trend has been independently confirmed by Dolzhenkov et al. (1988) and in the absence of further information it must by concluded that the observed pattern of fishing in Subarea 48.3 reflects a re-direction of effort northwards as a result of the seasonal encroachment of pack-ice in Subareas 48.1 and 48.2.

A further breakdown of catches by subarea, split-year and month is shown in Figure 11. Although data are scarce prior to 1983 in Statistical Area 48 (Figures 11a to 11c), both the annual and monthly tends described above are still observable. Similarly, even though catch data are far fewer and the underlying trend more erratic, this holds true for Subareas 58.4 (as illustrated by Division 58.4.1, Figure 11d) and 88.1 (Figure 11e).

2.3 Trends in Catch-Per-Unit of Fishing Effort

2.3.1 Annual Trend

Both Shimadzu (1985a) and Everson (1988) have concluded that the most appropriate index of catch-per-unit of fishing effort for krill (particularly for the Japanese fishery) is derived from catch/hour spent fishing. Using STATLANT B data, it is possible to calculate three annual indices of catch (tonnes)/hour fished (CPH). These are:

- total CPH/year (i.e. total catch/total hours fished/split-year);
- mean CPH/fishing season (i.e. mean monthly CPH for the months when fishing took place); and
- mean CPH/year (i.e. mean monthly CPH for a full 12 month split-year).

Values for the above three indices in Statistical Area 48 are shown for the period 1982 to 1988 (both Soviet and Japanese fishery combined) in Figure 12. Indications are that despite fluctuations from year to year, all three indices illustrate a gradual increase in CPH over the past seven years, particularly in Subareas 48.1 and 48.2 (see Figures 12a and 12b). (N.B. It must be noted that a large catch of 89 tonnes in one hour reported by the Japanese fishery in Subarea 48.2 during October 1982 (see below) has been omitted from this and, unless specifically mentioned otherwise, subsequent analyses. Although there are no indications that this particular result was invalid, its inclusion would serve to magnify fluctuations in CPH and would not conform with the underlying trend indicated by the total CPH/year (see Figure 12b)). It is also apparent that the greatest returns per unit of fishing effort were from these two subareas.

Plotting CPH for the Japanese fishery (Figure 13), including "mother ship" operations between 1977/78 and 1981/82 (cf Shimadzu, 1985a; Shimadzu and Ichii, 1985; Everson, 1988), it can also be seen that although there are wide year to year fluctuations the annual catch-per-unit of fishing effort has increased markedly, at least up until the three most recent seasons (i.e. 1985/86 to 1987/88). It must also be noted that there was a marked decline in CPH during the 1983/84 season which can be compared to the decline in total catch for that season (see Figure 2). Since 1985/86, catch rates have stabilized and this is probably attributable to the rigid operational characteristics of the Japanese fishery, particularly the commitment of a limited number of vessels to specific areas (cf Shimadzu, 1985b).

2.3.2 Trends By Area and Subarea

CPH indices for both the Japanese and Soviet fisheries by subarea are given in Table 2 for all years for which data are available. From this table and data presented in Figure 14, it would appear that the Japanese catch rate is markedly better than that of other nations. With respect to the Soviet fishery, however, two factors caution against unqualified acceptance of this conclusion. First, there is a marked difference between the operational characteristics of the two fisheries (cf Ichii, 1987; Dolzhenkov et al., 1988) and, second, Soviet effort data are only available from 1983 onwards. Nevertheless, it is apparent from the CPH values given in Table 2 that Subareas 48.1 and 48.2 are the most productive for both the Soviet and Japanese fisheries, an observation supported by the catch figures already discussed.

2.3.2.1 Japanese Fishery

Monthly CPH values for the Japanese fishery in Subareas 48.1 and 88.1, and Division 58.4.1 are plotted in Figures 15a to 15c for split-years 1977 to 1988. Overall trends in the fishing pattern are similar to that observed in the catches from each area (see Figure 11).

From comparison of Figures 16 and 15b, it can be seen that the fishery in Subarea 58.4 moves southwards as the season progresses. Everson (1988) has concluded that this is a consequence of the retreat of the pack ice into the East Wind Drift zone. In addition, it is apparent that individual monthly CPH values fluctuate widely and no dominant trend is visible. Everson (1988), citing Sugimito (1977), attributes the high CPH in Division 58.4.2 (see also Figure 16a) during December 1976 to the result of fishing on a large aggregation of krill or “super-swarm”. A similar effect may have produced the high CPH observed in Subarea 48.2 for October 1982 (see below).

Shimadzu (1985a) showed that during 1977 Japanese operations extended eastwards into Statistical Area 88 (Figure 15c). Subsequently, monthly CPH values in this area and Division 58.4.1 are comparable, suggesting some similarity in the type of fishing operation being undertaken and in the catchability of the krill encountered.

The Japanese krill fishery moved into Statistical Area 48 from the 1980/81 season (Shimadzu, 1985a; Everson, 1988) and both Figure 15a and Table 2 indicate that CPH was very much higher here than elsewhere. Monthly CPH values from 1981 to 1988 for the Japanese fishery in Statistical Area 48 are shown in Figure 17. These tend to follow a similar pattern to the monthly catch figures (i.e. as shown in Figures 11a and 11b), although it can be seen that since 1985/86 the fishing season in Subarea 48.1 has been extended to include April (Figure 17).

Patterns in Japanese fishing effort to a large degree reflect trends in the catch, both within and between years, already discussed. Unlike the general trend in CPH shown in Figures 12 and 13, a gradual increase and levelling off of effort in both Subareas 48.1 and 48.2 during the past three years is not apparent (Figure 18). In fact effort has declined in Subarea 48.2 since 1984/85, while increasing effort in Subarea 48.1 from 1982/83 was broken by a marked decline in the 1984/85 season. In the absence of further information, this would tend to suggest some operational change in the fishing pattern during 1984/85. Based on a report contained in the official proceedings of the CCAMLR Scientific Committee (SC-CAMLR, 1985, paragraph 5.26), there does in fact appear to have been a reduction in the number of Japanese vessels operating in both subareas during that particular season.

Other than these general trends, it is not possible to discern any clear pattern in Japanese fishing effort in the two subareas under consideration. However, as Everson (1988) has noted, the presence of fishing activity in what are effectively two adjacent subareas should allow some comparison (both between and within seasons) to be made between Subareas 48.1 and 48.2. Comparing seasonal mean CPH in the subareas (Figure 19), however, indicated that they have little in common. Similarly, plotting mean CPH in Subarea 48.1 compared with Subarea 48.2 for all fishing months and for mid-season months alone (December to February) (Figure 10) supports this observation. On the other hand, if values from the same month are compared (Figure 21) there is a tendency for a high CPH in Subarea 48.1 to be associated with a high CPH in Subarea 48.2. Everson (1988) has concluded that this suggests some link between the catchability of krill in the two subareas and given the currently expanded data set (compared with that originally analyzed by Everson) probably indicated a "real effect".

2.3.2.2 Soviet Fishery

Available Soviet CPH data (1983 to 1988) from Area 48 are confined to Subareas 48.2 and 48.3, and as for the Japanese fishery, the seasonal mean indicates a gradual increase in CPH since data became available in 1983 (Figure 22). This increase was most marked, however, from 1985/86 onwards and especially in Subarea 48.3.

Trends in the mean monthly CPH for the Soviet fishery in Subareas 48.2 and 48.3 (Figure 23) indicate a similar pattern to that of the catches (Figures 10b and 10c), namely high CPH in Subarea 48.3 from April to October compared with high values in Subarea 48.2 from December through to May. This observation is borne out by both monthly fishing effort (Figure 24) and CPH values (Figure 25) over the past six seasons, particularly high catch-per-unit effort between January and April of the 1986/87 season. In this connection it should be noted that it was during 1986 that CCAMLR restrictions on directed fishing for *Notothenia rossii* in Subarea 48.3 came into force (CCAMLR, 1988a). Plotting monthly fishing effort on an annual basis indicates a substantive increase in effort for krill during January to April, 1987 (Figure 26). It is also interesting to note that 1986/87 was the only season during which fishing occurred all year round in Subarea 48.3 and subsequently the annual mean fishing effort was highest (Table 3).

As with the Japanese fishery in Subareas 48.1 and 48.2, comparison of Soviet CPH in Subareas 48.2 and 48.3 indicates little association between krill catchability in the latter two subareas (Figure 27). Furthermore, differences in the pattern of fishing limit a comparison of CPH values from similar months in Subarea 48.2 and Subarea 48.3. As such, similarities in krill catchability observed for the Japanese fishery in Subareas 48.1 and 48.2 were not evident (i.e. comparing Figures 21 and 28).

2.4 Comparison of Fishery Dependent Data With Other Sources of Information

A number of fishery-independent surveys of krill abundance have been undertaken in the same areas and at the same time as the fisheries data described above were collected. The two methods principally employed during these surveys were acoustics (i.e. using calibrated echo-sounders) and systematic net sampling with relatively small scientific nets (Table 4). As Everson (1988) has emphasized, the data in Table 4 indicate that incongruities between survey-based estimates of krill abundance are reflected in similar estimates based on catch and effort data from the fishery. As such, CPH indices do not exhibit any clear trend relative to acoustic or net estimates.

3. DISCUSSION

In terms of CCAMLR, knowledge concerning the amount(s) of krill removed by commercial fishing operations *per se* is unlikely to be of substantial application in the management of the fishery. As both Butterworth (1986) and Everson (1988) have emphasized, there are two major reasons for this. Firstly, the Convention requires that krill resources be managed on a sustainable basis and despite information on krill removed by the fishery, knowledge concerning the long-term proportionate mortality from fishing, predation and other natural causes is still incomplete. Such knowledge is vital in ascertaining whether particular stocks can sustain themselves in the face of exploitation. Secondly, the stipulation that krill harvesting should not prejudice the potential productivity of dependent species (i.e. predators) requires careful consideration of functional relationships between predator and krill population dynamics.

Krill's large-scale distribution has been extensively discussed by various authors and a number of theories for observed patterns exist (e.g. Marr. 1962; Makarov et al., 1970; Mackintosh, 1973; Lubimova et al., 1982; Miller and Hampton, 1989). The present analyses confirm that although major concentrations of krill may be distributed throughout the CCAMLR Convention Area, commercial fishing operations have tended to concentrate in so called "hot spots" in the Atlantic (Statistical Area 48) and Indian Ocean (Statistical Area 58) sectors. Of these, both catch and catch-effort statistics indicate Statistical Area 48 to have been the most productive for most of the fishery's available history. Both these observations do not substantially contradict any of the current theories on krill distribution.

Although there is little doubt that developments in the krill fishery have been closely governed by logistic (e.g. the possible connection between restrictions on finfish and increased krill harvesting discussed for Subarea 48.3) and economic constraints (cf Shimadzu, 1985a; Everson, 1988), it would appear from the catch/effort data analyzed here and from similar analyses undertaken by Everson (1988) that there is a large natural variation in the abundance of exploited krill stocks. As far as CCAMLR is concerned, the major difficulty is that such variability cannot be adequately quantified or separated from fishery-related variation. Nevertheless it would appear that a number of unifying principles link abundance, catch and fishing effort. Such factors are demonstrated by low catches and reduced CPH for the Japanese fishery during the 1983/84 season, the relatively high "catchability" of krill in the Atlantic sector (Statistical Area 48) and some anomalously high values for catch in terms of effort (e.g. during October 1982). These results tend to confirm one of the major conclusions of the CCAMLR sponsored Krill Simulation Study, namely that catch and effort data only provide a reasonable index of krill abundance in the immediate vicinity of the fishing fleet.

Both the Soviet (Dolzhenkov et al., 1988) and to some extent the Japanese (Ichii, 1987; Butterworth, 1988) fleets tend to focus their activities on krill concentrations and swarms[1]. In this context, fishing a super-swarm (such as observed in October 1982 or described in Sugimito, 1977) would represent an extreme case of such activity. Therefore, in order to realistically determine abundance over a wider area, some measure of "search time" by the fishery is necessary to assess the spatial heterogeneity of the krill stock(s) being fished (cf Butterworth and Miller, 1987; Butterworth, 1988; Mangel, 1988). According to recommendations forthcoming from the recently held Workshop on the CCAMLR

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[1] For definition of what constitutes a krill "concentration" and "swarm" refer to Butterworth and Miller (1987) and the "patch-within-patch model" developed by Butterworth (1988).

Krill CPUE Simulation Study this would require documentation of the start and end times of fishing (specifically for the Japanese fishery) as well as classification of the type of krill aggregation being fished (CCAMLR, 1989). Only very detailed catch/effort data on a fine-scale are likely to provide such potentially important information. Similarly, crucial information on both krill swarms and concentrations (particularly for the Soviet fishery) would be best collected acoustically (CCAMLR, 1989).

As far as dependent species (i.e. krill predators) are concerned, Murphy et al. (1988) have emphasized that a first step in determining the effects of possible interactions between krill and other species requires definition of the temporal and spatial scales over which such interactions occur. An important consequence of this approach is that in a manner analogous to catch/effort data for the fishery, localized predator population processes are unlikely to provide a suitable index of krill abundance over a wide area (Everson, 1988).

Croxall et al. (1988) have fully discussed the problems inherent in monitoring warm-blooded predators to obtain some indication of variability in krill abundance. They make the point that even if krill harvesting was to increase markedly, it would be difficult to exclude the possibility that reductions in the rate of increase of seabird and seal populations are, independently of krill harvesting, attaining the natural carrying capacity of the environment. In addition, many monitoring programs are likely, for logistic reasons, to be confined to predators that are accessible at specific times (e.g. during breeding ashore). Such circumstances tend to restrict studies of krill variability as related to predator parameters within relatively confined temporal and spatial boundaries (i.e. the foraging ranges of land-based predators). This has been recognized by Bengtson (1984) as a major shortcoming in any attempt to assess possible relationships between krill and predators over the former's greater distributional range. For this reason the CCAMLR Ecosystem Monitoring Program (SC-CAMLR, 1986) has to come to recognize the potential importance of assessing the impact of feeding over a wide area by mobile krill predators. The minke whale is a specific example of such a predator.

Returning to the fisheries data analyzed in this paper, it can be seen that despite the fact that the fishery is essentially circumpolar it is predominantly confined to three major localities, of which Subareas 48.1, 48.2 and 48.3 appear to be most important. These particular subareas already contain a number of key monitoring sites for land-based krill predators (CCAMLR, 1988b) and it remains to be seen how important these specific subareas may be with respect to more wide-ranging krill predators, such as the minke whale.

The minke whale is one of the six rorqual (*Mysticeti*: family *Balaenopteridae*) species which has been least affected by commercial whaling (Tonnessen and Johnsen, 1982; Mizroch, 1984). Like the other species of the family, the minke whale is characterized by unique anatomical adaptations which facilitate filter-feeding on krill swarms by "gulping" or "engulfment" (Nemtot, 1959). In fact it is the swarming of krill which allows minke whales to feed on krill over almost the same spatial and temporal scales as those of its own habitat (cf Murphy et al., 1988). From this, it could be assumed that if the krill fishery is also geared towards exploiting swarms (see above), then some congruence between fisheries activities and minke whale distribution could be expected.

Information on the distribution of minke whale catches is shown (Figure 29) for the months of December to March and between 1972/73 and 1979/80. It can be seen, however, that there are only relatively few similarities between whale catches and data from the krill fishery.

To a large extent, whaling during the period under consideration was predominantly confined to the Indian Ocean (Statistical Area 58) and Pacific (Statistical Area 88) sectors. In contrast, krill fishing was primarily undertaken in the west Atlantic (Statistical

Area 48). Although there may be logistic reasons for this, the overall lower catch-per-unit of effort for the krill fishery in Statistical Areas 58 and 88 (Figure 15) suggest that (for whatever reason) minke whales were in fact being harvested in areas where krill were being fished. Such conclusions, however, are reached in the absence of detailed information from the major krill fishery (i.e. that of the Soviet Union) which only became available from 1983 onwards. In this connection, it is interesting to note that Ichii (1987) has reported considerable variability in observed associations between minke whale sightings and the presence of krill swarms.

Despite the above observations, some similarities exist between the geographic distribution of minke whale and krill catches by month. It can be seen that as the austral summer progresses, whale catches are taken farther south, particularly in the Indian Ocean (i.e. Statistical Area 58). This is directly analagous to the southward movement of the krill fishery in the same area (Figure 16). Furthermore, there is a steady decline in the number of whales caught between January and March which is similar to the decline in krill catches (Figures 10d and 10e) over the same period in Statistical Areas 88 and 58. Given the state of the available data, however, it is not possible to draw more specific associations between the distribution of krill fishing and minke whale catches.

It must be concluded therefore that in view of the demonstrated incompatibilities between the krill fishery and minke whale catch data, there is little to be gained in terms of understanding minke whale-krill interactions from coarse comparisons of the kind undertaken here. This is not to say that plotting the temporal and spatial associations of krill fishing and whale catches on a finer scale may not lead to some insight(s) into the form of the functional relationship(s) between krill distribution and whale feeding. It is difficult, however, to see how such information could be realistically applied in the absence of minke whale stomach contents data at a similar level of resolution as fine-scale information from the fishery. Finally, in attempting to monitor the recovery of whale stocks (also a requirement of CCAMLR) in the face of krill exploitation, considerably more information is required on the functional relationship(s) between krill aggregation and whale distribution at a variety of scales. In this connection, comparison of contemporaneous minke whale sightings (particularly on feeding animals) with both fisheries-dependent and independent survey data on krill distribution/abundance, especially acoustic information on aggregations, should be encouraged.

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Table 1: Annual krill catches prior to 1973/74 (from Everson, 1978 and Bengtson, 1984).

Season	Catch (t)	Comments	Reference
1961/62	4	krill	Burukovskiy and Yaragov (1967)
1963/64	70	krill	Stasenko (1967)
1964/65	306	krill	Nemoto and Nasu (1975)
1966/67	?	krill	Nemoto and Nasu (1975)
1967/68	>140	krill	Ivanov (1970)
1969/70	100	UMC*	FAO (1976)
1970/71	1300	UMC*	FAO (1976)
1971/72	2100	UMC*	FAO (1976)
1972/73	7459	krill	FAO (1976) Nemoto and Nasu (1975)

* Catches of "Unspecified Marine Crustacea" for areas closely adjacent to the Antarctic are assumed by Everson (1978) to be krill.

Table 2: Total catch/hour fished/year (1), mean catch/hour fished/fishing season (2), and mean catch/hour fished/year (3) for the Soviet and Japanese krill fisheries by subarea. All data are given in t/hr; for explanation of indices of effort refer to text.

	48.1	48.2	48.3	58.4	58.4.1	58.4.2	88.1
Japanese fishery							
1	12.13	18.89	- - - -	- - - -	5.81	5.73	5.32
2	12.96	14.80	- - - -	- - - -	4.18	4.67	5.54
3	4.55	5.62	- - - -	- - - -	1.97	1.71	1.21
Year*	81-88	82-88	- - - -	- - - -	76-87	74-83	77-87
Soviet fishery							
1	- - - -	6.20	5.69	3.88	- - - -	- - - -	- - - -
2	2.44	5.20	4.85	4.05	- - - -	- - - -	3.43
3	- - - -	3.44	3.16	1.55	- - - -	- - - -	- - - -
Year*	83	83-88	83-88	83-88**	- - - -	- - - -	87

* Split-year

* * Excluding 1986 (no data)

Table 3: Mean annual (/12 month period) and seasonal (/months fished) fishing effort (hours fished) for the Soviet krill fishery in Subarea 48.3, 1983 to 1988.

Year	Mean annual effort (hours fished)	Mean seasonal effort (hours fished)
1983	170.92	683.67
1984	576.50	1383.60
1985	726.92	1744.60
1986	2233.50	2978.00
1987	3635.83	3635.83
1988	2913.92	3885.22

Table 4: Updated version of Table 3 in Everson (1988) comparing CPH and independent survey estimates of abundance during the same months and in approximately the same areas. Data pairs in brackets are the result of different analyses on the same data sets.

Date	Location of study	Subarea	Biomass (tonnes)	Density (published)	Density estimated (g/m^2)	CPUE (Japan)	Ref for survey
Acoustic surveys (FRG)							
Oct/Nov 1983	SIBEX I	48.1	51680	$7.2 g/10^3 m^3$	0.72	10.25, 13.75	Klindt 1986
Nov/Dec 1984	SIBEX II	48.1	379750	$54.8 g/10^3 m^3$	5.48	9.89, 18.15	Klindt 1986
Mar/Apr 1985	SIBEX II	48.1	16490	$2.6 g/10^3 m^3$	0.26	(9.46 Feb)	Klindt 1986
Acoustic surveys (Poland)							
Feb/Mar 1981	FIBEX (Drake Pass.)	48.1	(1195572	$28.9 t/nm^2$	8.40*)	20.08 -	Kalinowski 1982
			(62000		)	20.08 -	BIOMASS 1986
	FIBEX (Drake Pass.)	48.1	(70827	$34.0 t/nm^2$	9.93*)	20.08 -	Lillo & Guzman 1982
			(182000	$7.2/m^3$	715.00)	20.08 -	BIOMASS 1986
	FIBEX (Bransfield St)	48.1	(2271000	$346.0 t/nm^2$	100.00*)	20.08 -	Kalinowski 1982
			(136000	$4.7 g/m^3$	468.00)	20.08 -	BIOMASS 1986
	FIBEX (Bransfield St)	48.1	(448795	$76.2 t/nm^2$	22.26*)	20.08 -	Lillo & Guzman 1982
			(800000	$32.2 g/m^3$	3225.00)	20.08 -	BIOMASS 1986
Dec/Jan 1983/84	SIBEX I (Drake Pass.)	48.1	122470	$4.0 t/nm^2$	1.17*	18.15, 10.70	Kalinowski et al. 1985
	SIBEX I (Bransfield Strait)	48.1	70593	$3.0 t/nm^2$	0.88*	18.15, 10.70	Kalinowski et at. 1985

* Assumes one tonne per nautical square mile = $0.292 g/m^2$. All density values assume a depth range of 100 m.

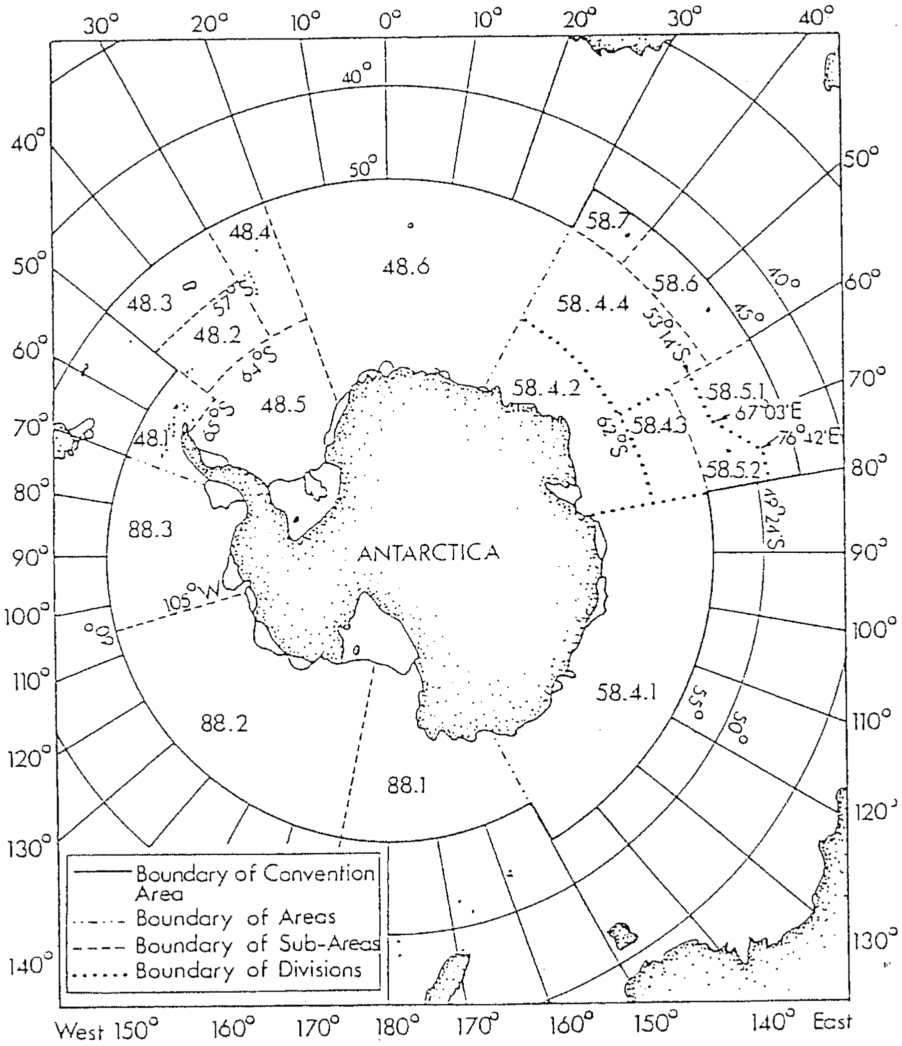
* * Daytime data only.

Table 4 (continued)

Date	Location of study	Subarea	Biomass (tonnes)	Density (published)	Density estimated (g/m^2)	CPUE (Japan)	Ref for survey
Acoustic surveys (Australia, France, Japan, South Africa)							
Feb/Mar 1981	FIBEX (Prydz Bay Bouvet Is.)	58.4.2 48.6	4512000	-	1.97	4.24, 3.60	BIOMASS 1986
Feb/Mar 1985	SIBEX II (Prydz Bay)	58.4.2	124000	48.0g/m^3	0.48	- -	Miller 1987
Jan/Mar 1981	FIBEX (Prydz Bay)	58.4.2	**1600000	1.1g/m^2	-	3.30, 4.24, 4.60	Higginbottom et al. 1988
Jan/Feb 1984	ADBEX (Prydz Bay)	58.4.2	**3500000	2.7g/m^2	-	-	Higginbottom et al. 1988
Jan 1985	SIBEX II (Prydz Bay)	58.4.1	**3700000	2.9g/m^2	-	5.04	Higginbottom et al. 1988
Net haul surveys							
Oct/Nov 1983	SIBEX I	48.1	723000	103.2g/10^{3}m^3	10.32	10.25, 13.75	Nast 1986
Mar/Apr 1984	SIBEX I	58.4.2	550000	34.8g/10^{3}m^3	3.48	- -	Miller 1986
Nov/Dec 1984	SIBEX II	48.1	25200	36.0g/10^{3}m^3	3.60	- , 106	
Mar/Apr 1985	SIBEX II	48.1	164000	23.4g/10^{3}m^3	2.34	(9.46 Feb)	Nast 1986

* Assumes one tonne per nautical square mile = 0.292 g/m^2. All density values assume a depth range of 100 m.

* * Daytime data only.



AREA 48	ATLANTIC ANTARCTIC AREA	
	48.1	Peninsula Subarea
	48.2	South Orkney Subarea
	48.3	South Georgia Subarea
	48.4	South Sandwich Subarea
	48.5	Weddell Subarea
	48.6	Bouvet Subarea
AREA 58	INDIAN OCEAN ANTARCTIC AREA	
	58.4	Enderby-Wilkes Subarea
	58.4.1	Enderby-Wilkes Division 1
	58.4.2	Enderby-Wilkes Division 2
	58.4.3	Enderby-Wilkes Division 3
	58.4.4	Enderby-Wilkes Division 4
	58.5	Kerguelen Subarea
	58.5.1	Kerguelen Division
	58.5.2	McDonald-Heard Division
	58.6	Crozet Subarea
	58.7	Marine-Prince Edward Subarea
AREA 88	PACIFIC ANTARCTIC AREA	
	88.1	Eastern Ross Subarea
	88.2	Western Ross Subarea
	88.3	Amundsen Sea Subarea

Figure 1: Statistical areas, subareas and divisions of the CCAMLR Convention Area (CCAMLR, 1988a).

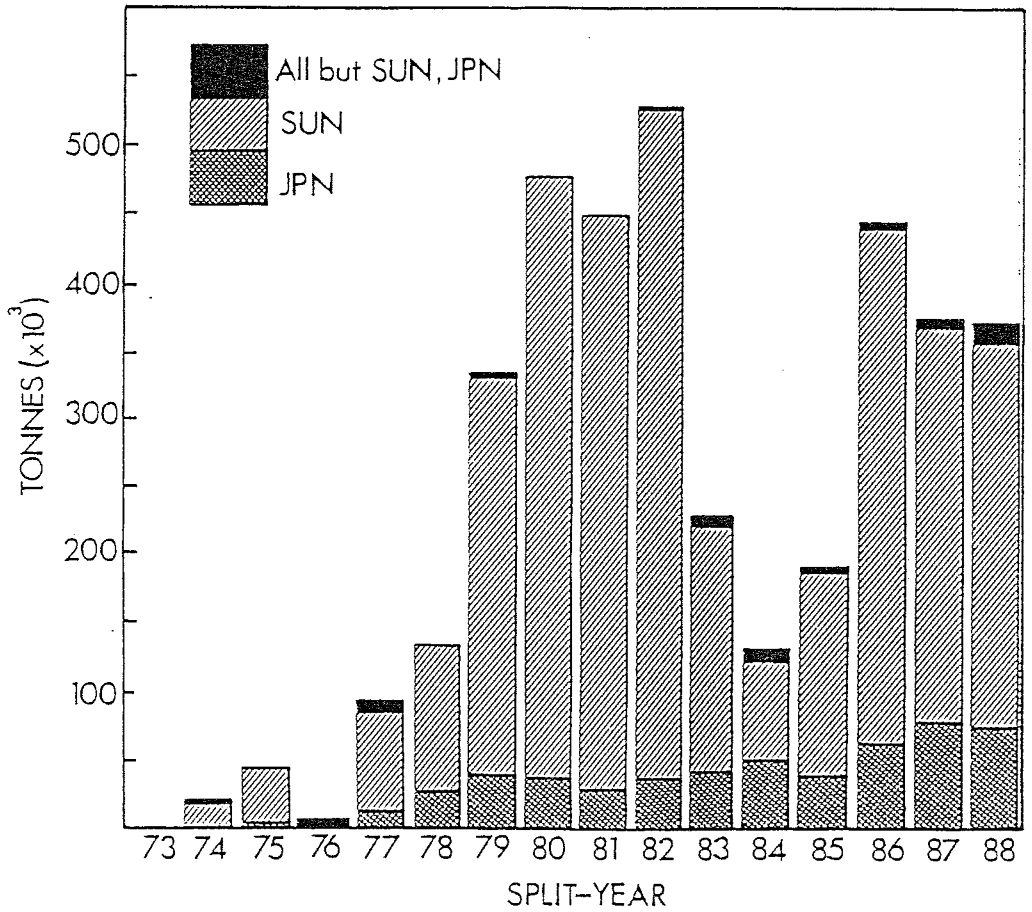


Figure 2: Reported annual krill catches by country from the CCAMLR area (SUN = Soviet Union, JPN = Japan. All but SUN, JPN = Brazil, Chile, GDR, Korea and Poland).

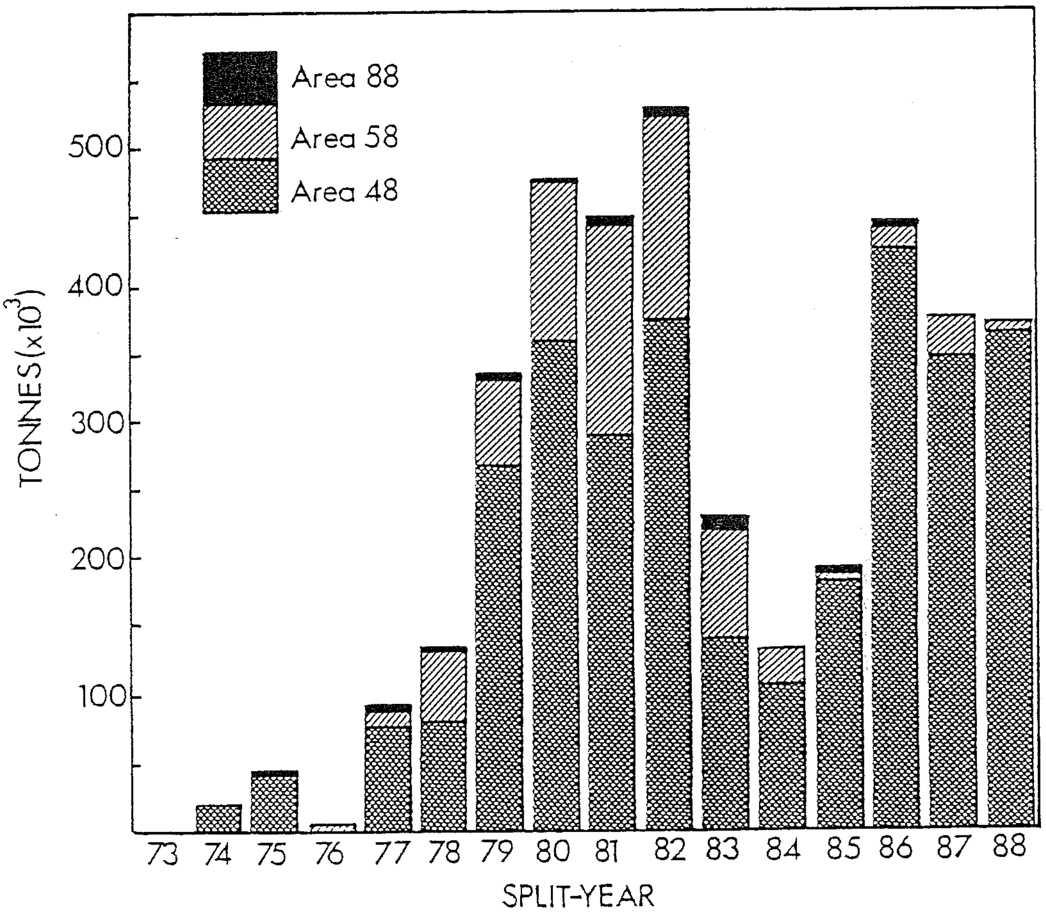


Figure 3: Reported annual krill catches by statistical area from the CCAMLR Covention Area.

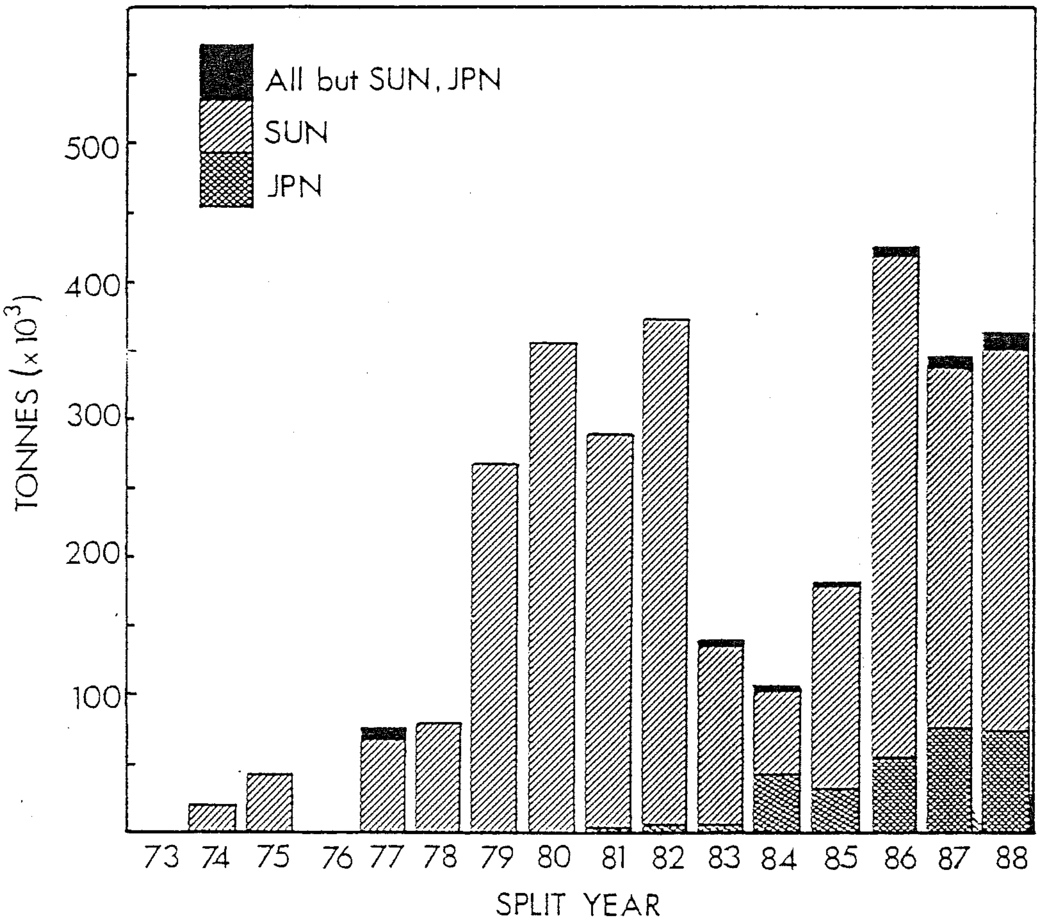


Figure 4: Reported annual krill catches by country in Statistical Area 48.

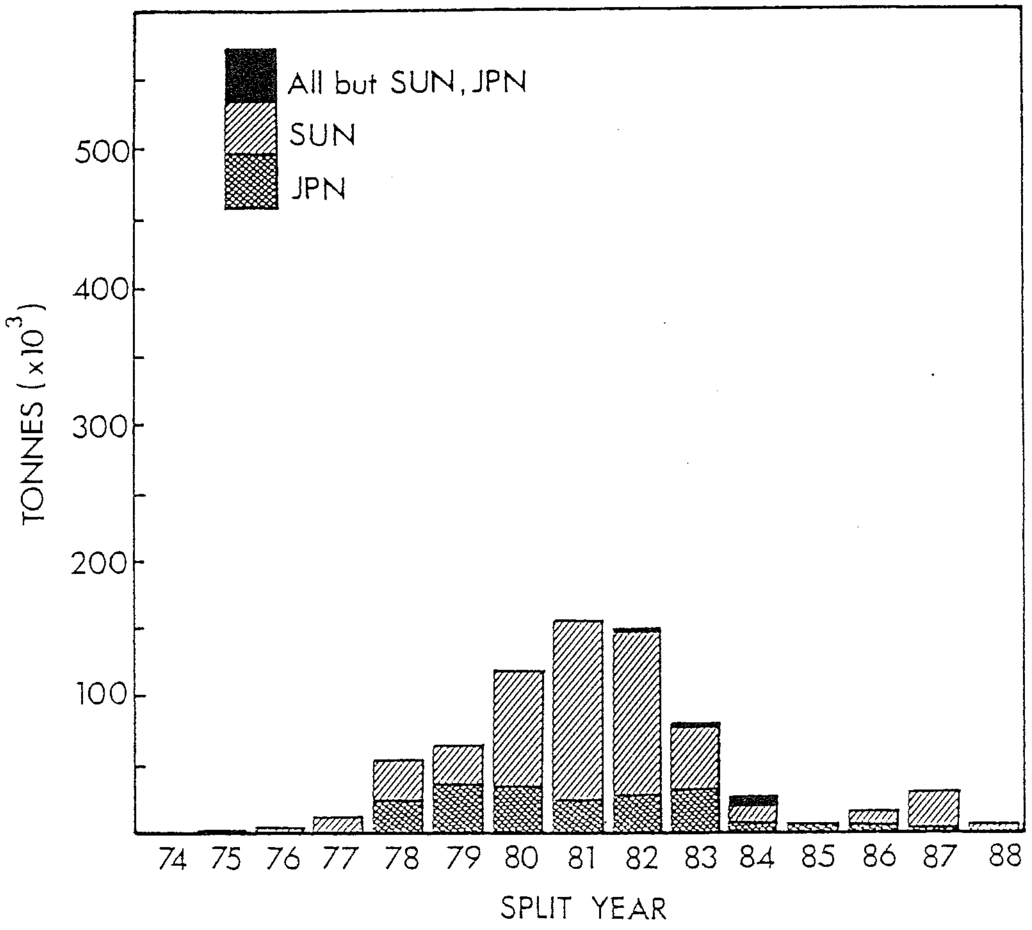


Figure 5: Reported annual krill catches by country in Statistical Area 58.

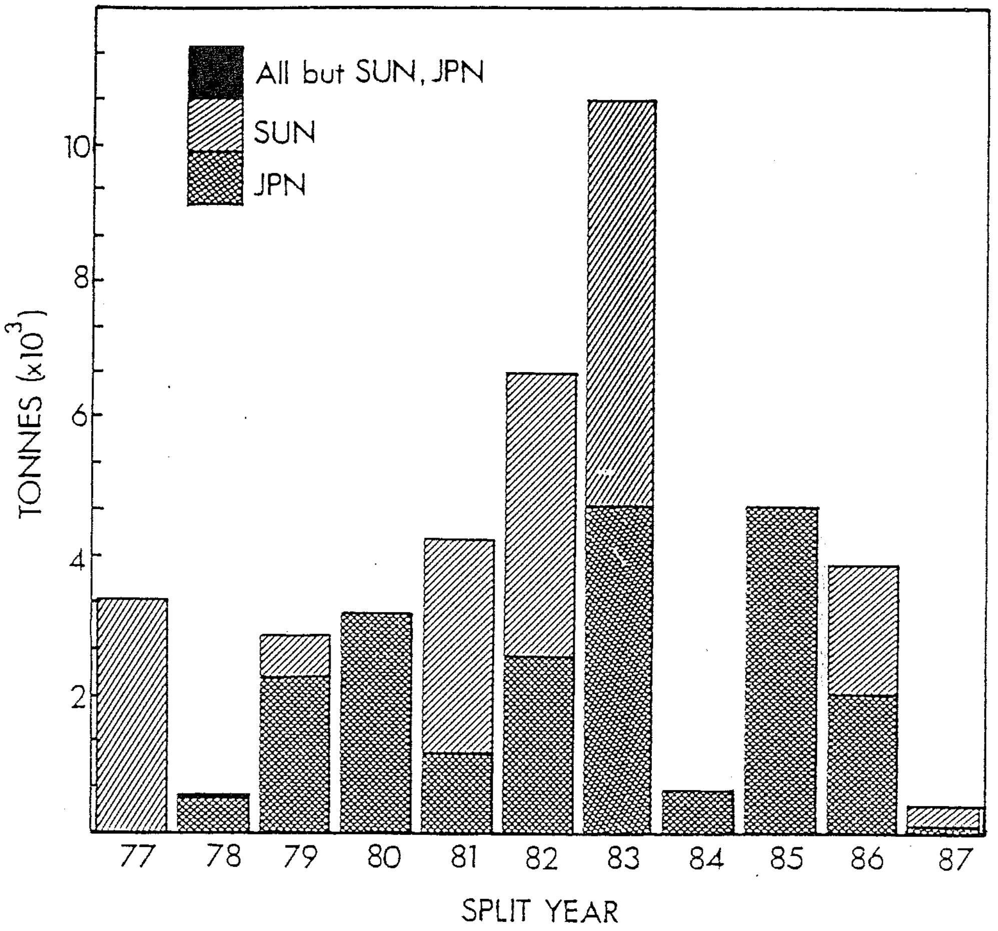


Figure 6: Reported annual krill catches by country in Statistical Area 88.

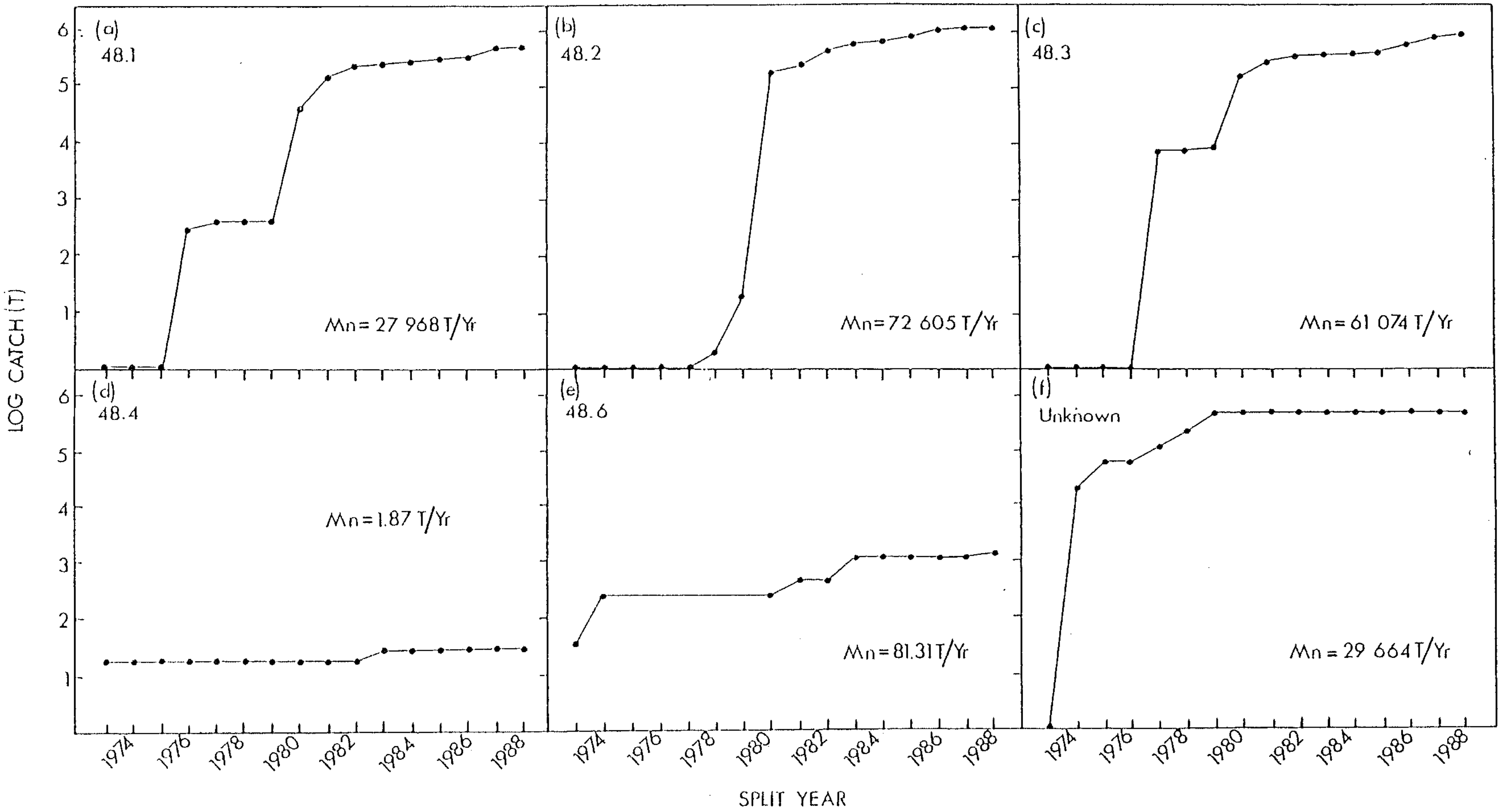


Figure 7: Cumulative krill catches from Subareas (a) 48.1, (b) 48.2, (c) 48.3, (d) 48.4, (e) 48.6 and (f) "unknown".

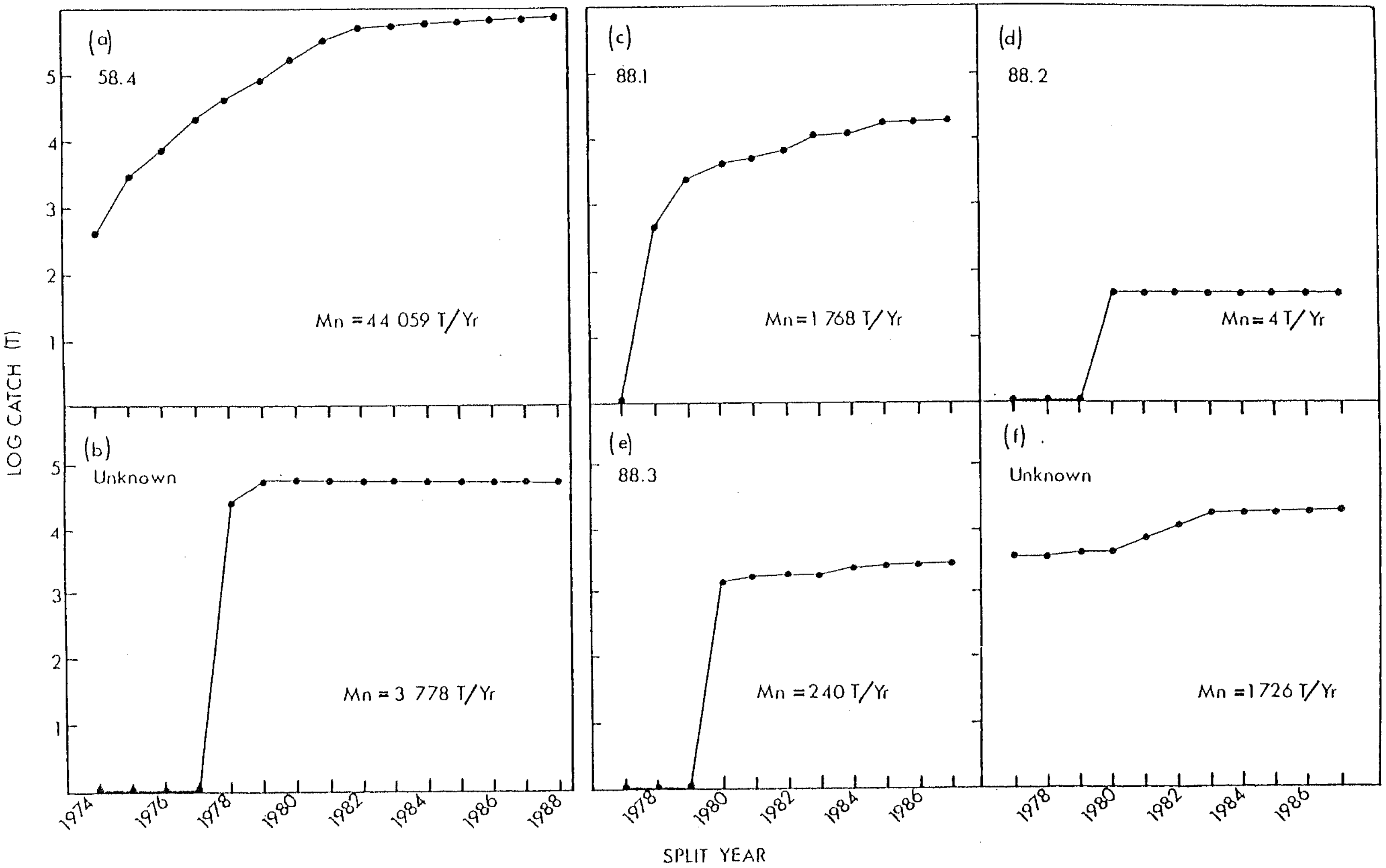


Figure 8: Cumulative krill catches from Subareas (a) 58.4, (b) 58 "unknown", (c) 88.1, (d) 88.2, (e) 88.3, and (f) 88 "unknown".

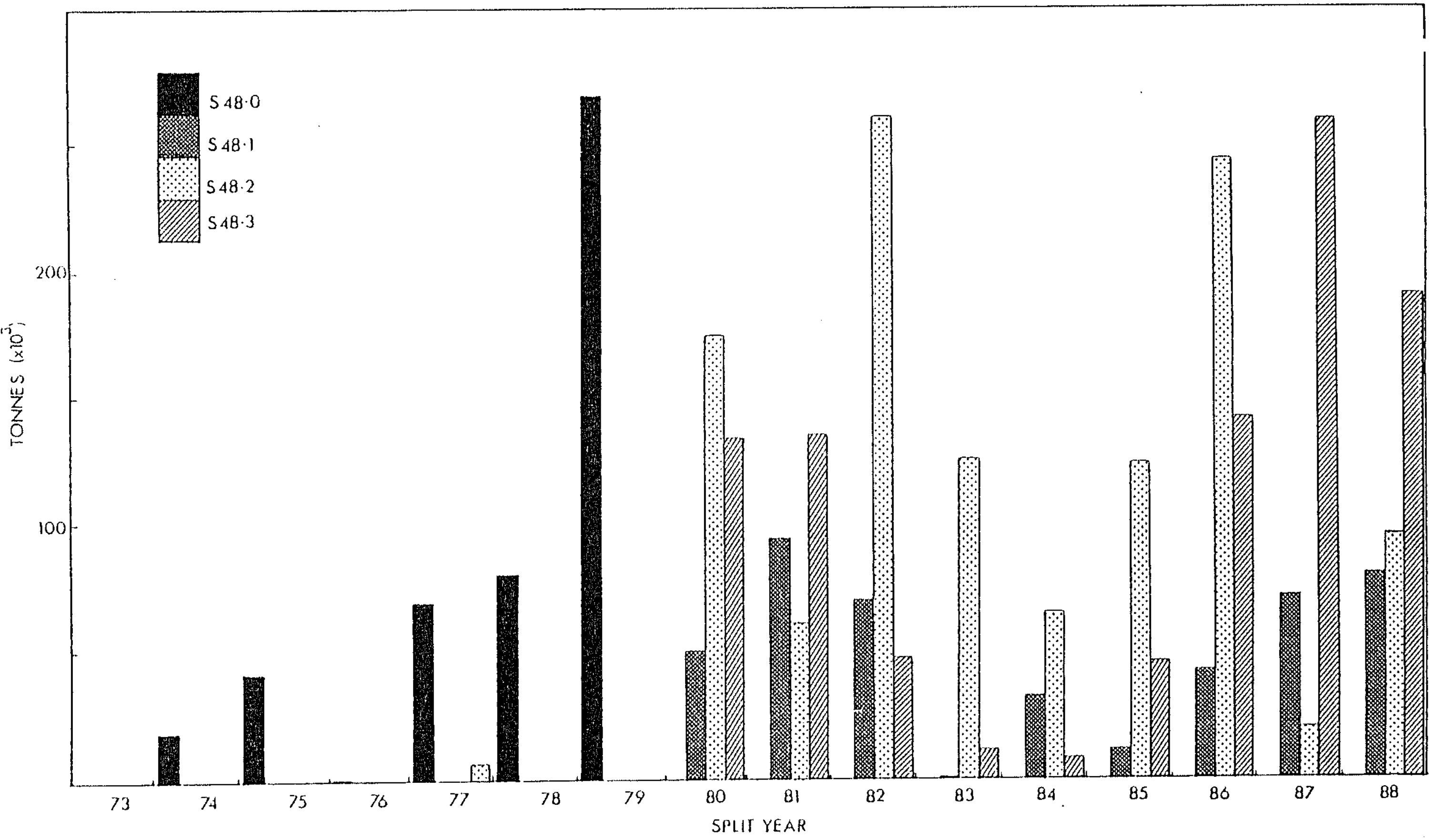


Figure 9: Annual krill catches from Statistical Area 48 by selected subarea.

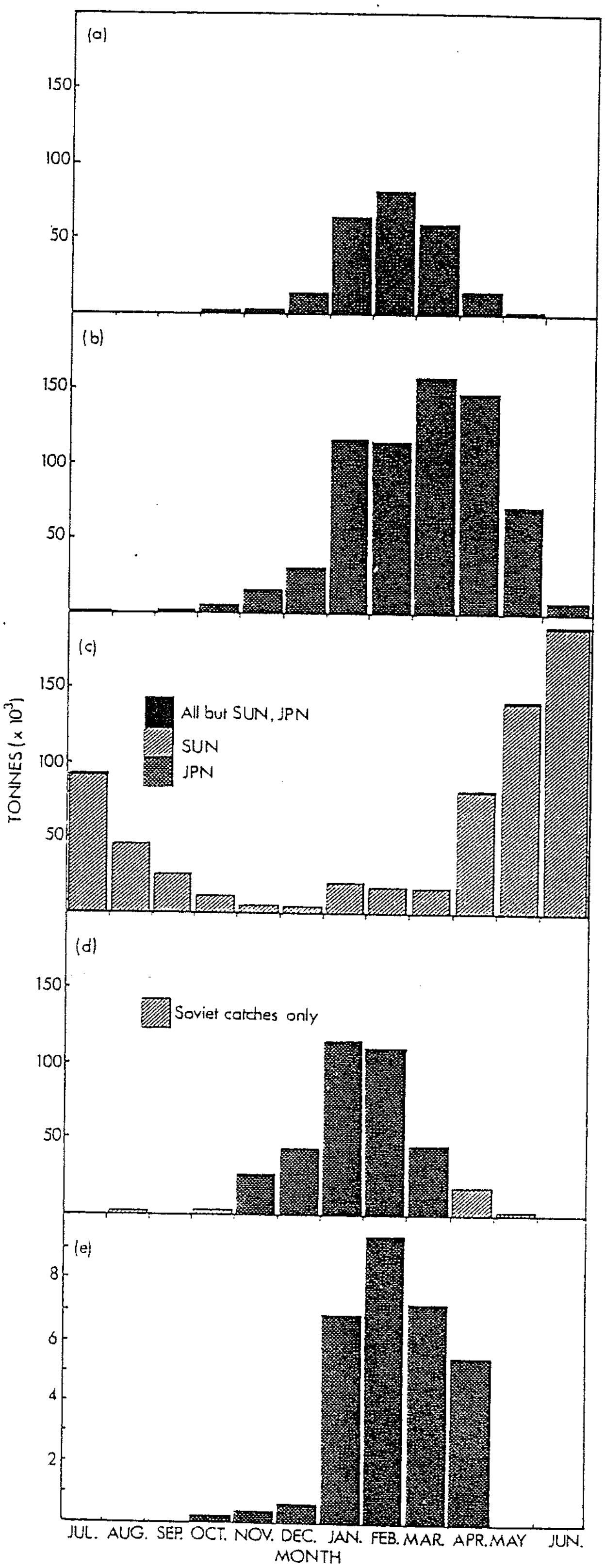


Figure 10: Krill catches by month in Subareas (a) 48.1, (b) 48.2 and (c) 48.3 (1982/83 to 1987/88), and in Areas (d) 58 (1973/74 to 1987/88 - Soviet data from 1982/83 only) and (e) 88 (1976/77 to 1986/87 - Japanese data only).

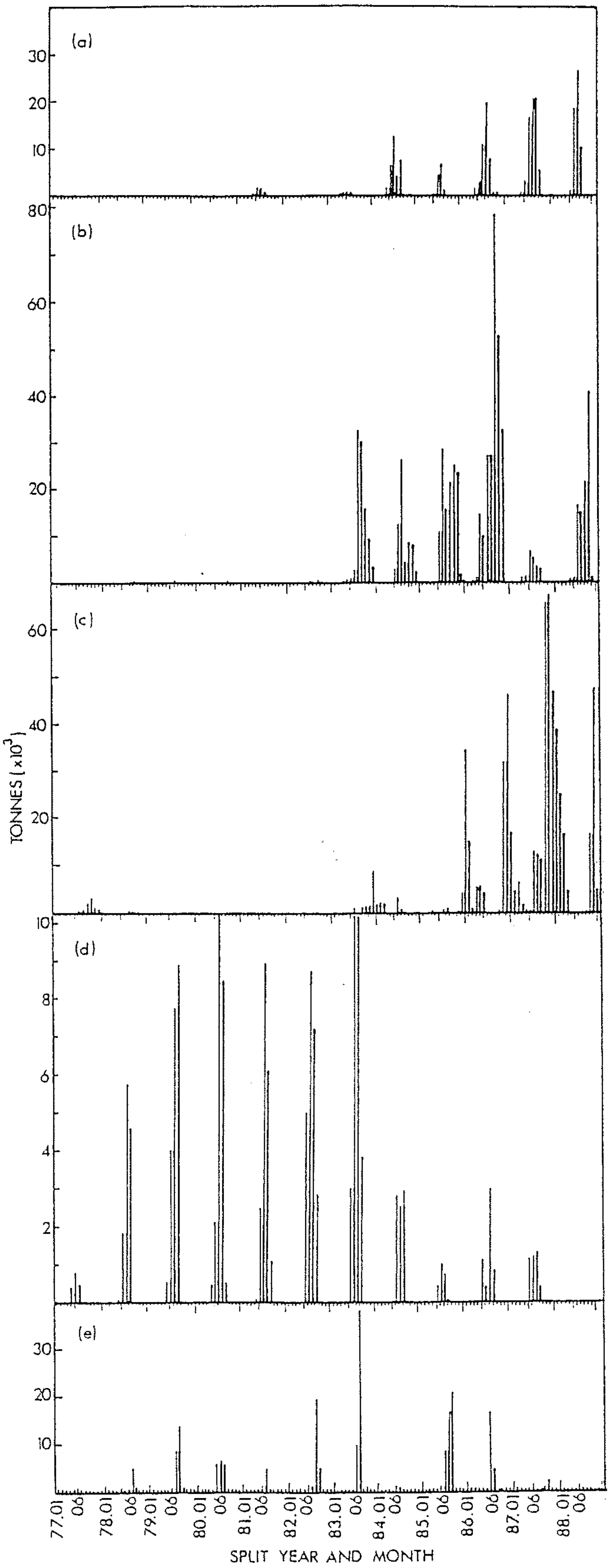


Figure 11: Krill catches by split-year and month for the period 1976/77 to 1987/88 in Subareas (a) 48.1, (b) 48.2 and (c) 48.3, (d) Division 58.4.1 (Japanese data only) and (e) Subarea 88.1 (Japanese data only). Months are numbered according to split-year (e.g. 88.03 on the horizontal axis means the third month of the 1987/88 split-year, i.e. September) - see text for further details.

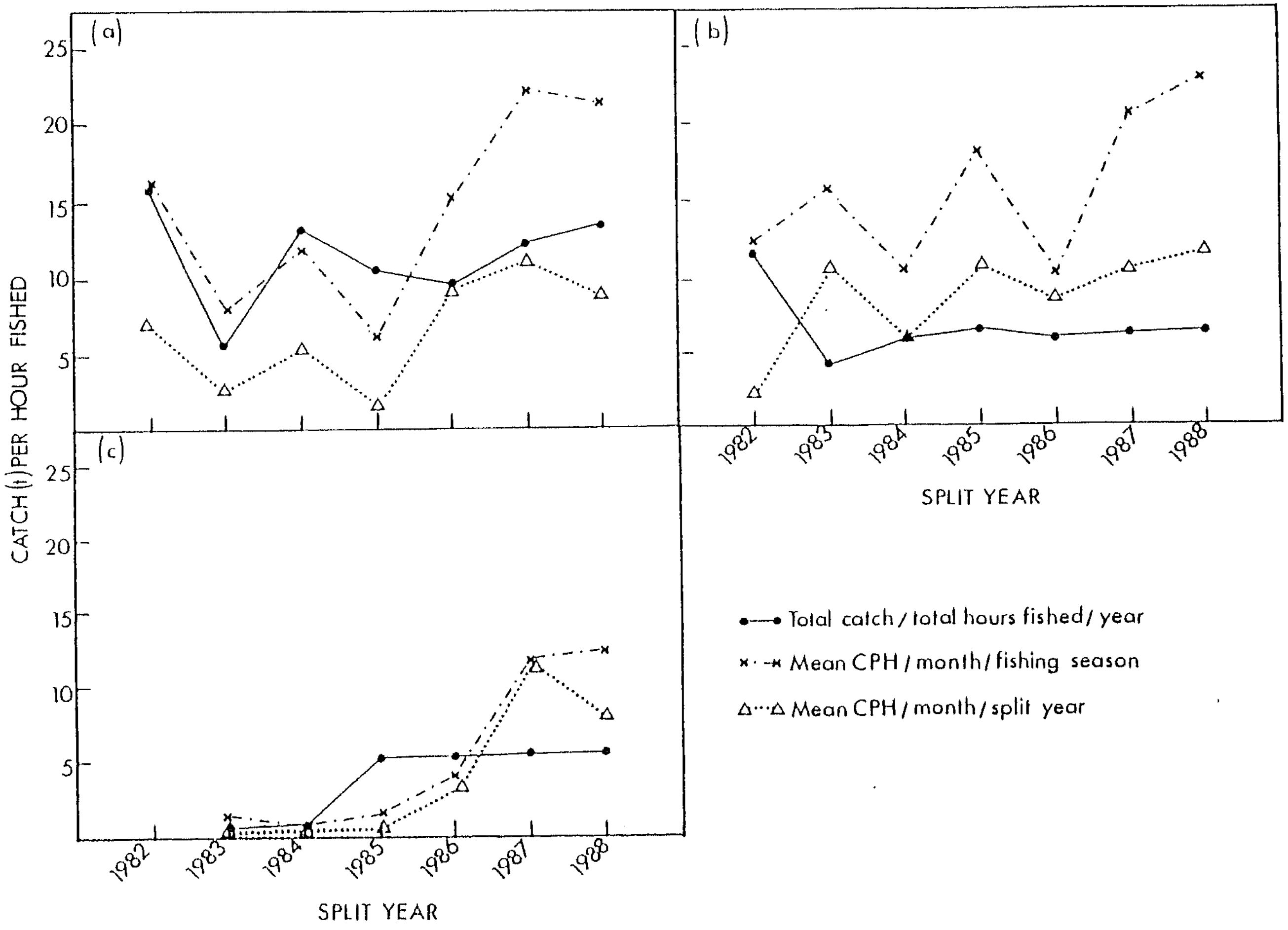


Figure 12: Krill catch (tonnes) per hour fished (CPH) indices in Subareas (a) 48.1, (b) 48.2 and (c) 48.3.

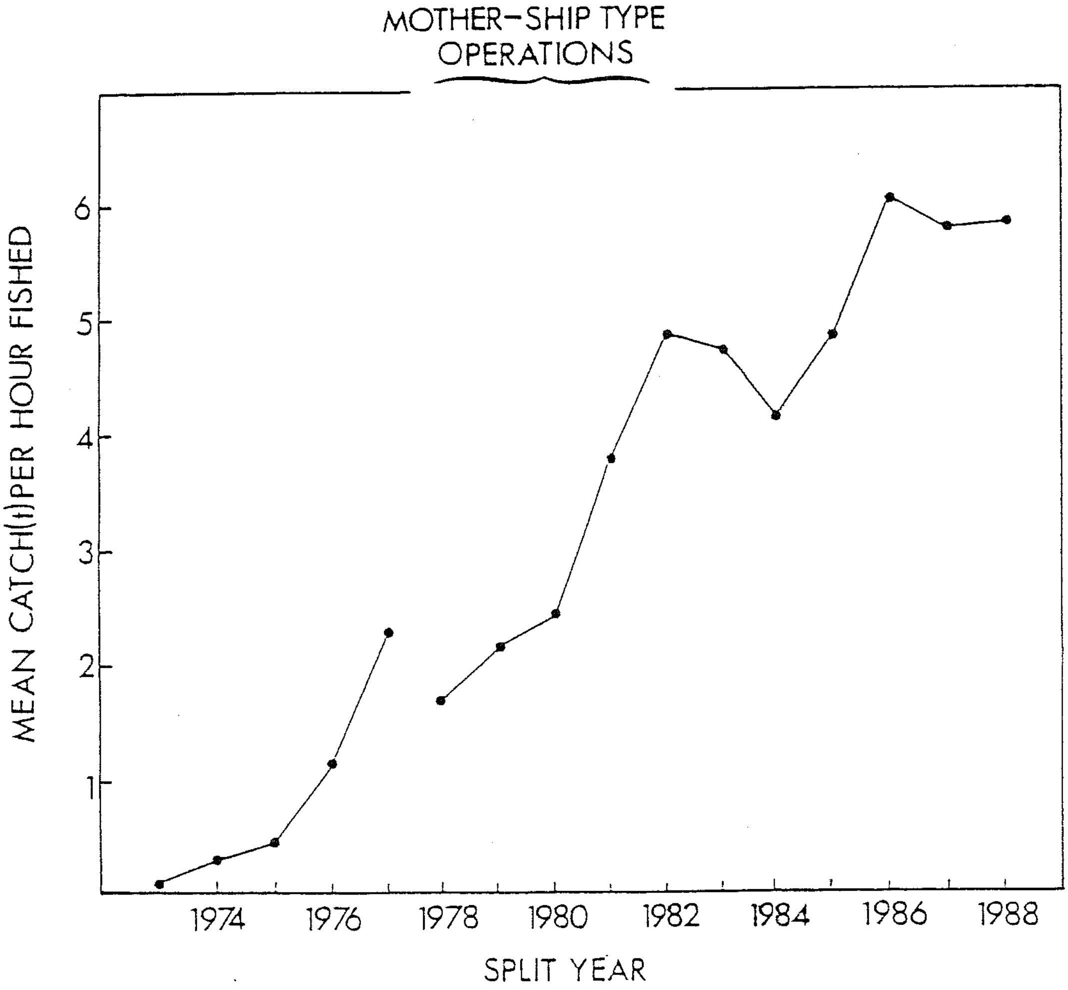


Figure 13: Mean CPH for the Japanese krill fishery between 1972/73 and 1987/88.

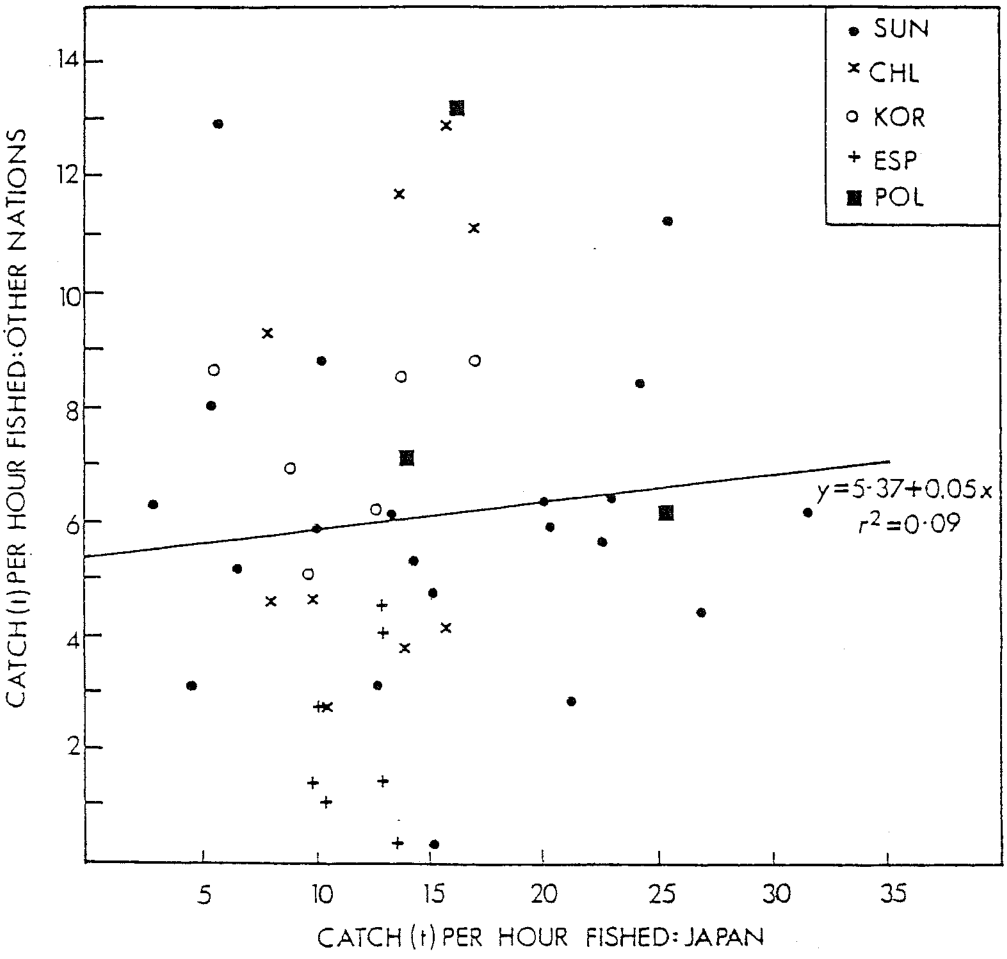


Figure 14: Comparison of CPH values for the Japanese fishery with those for other nations in the same subarea and during the same month.

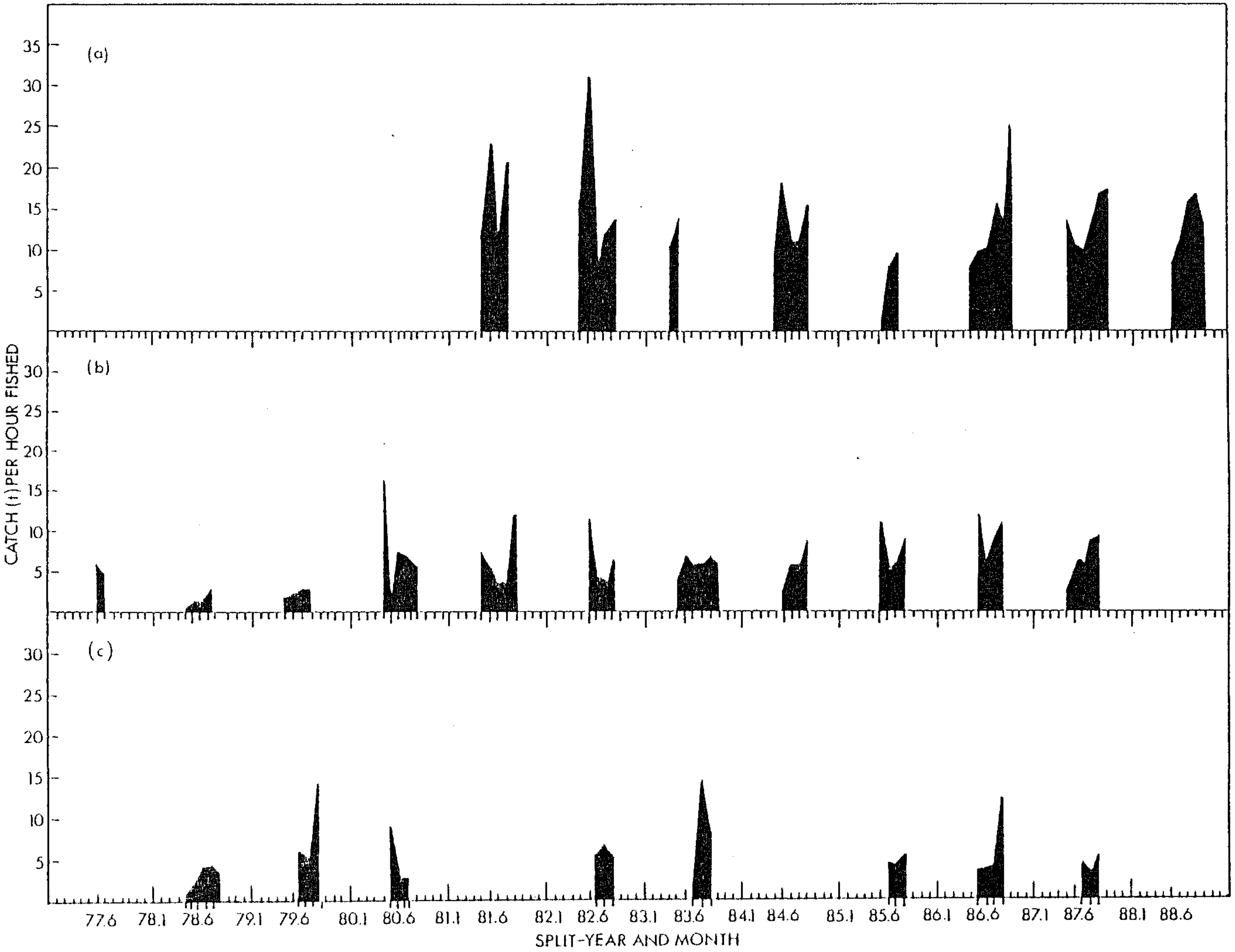


Figure 15: Monthly CPH values for the Japanese krill fishery in (a) Subarea 48.1 (1980/81 to 1987/88), (b) Division 58.4.1 and (c) Subarea 88.1 from 1976/77 to 1987/88.

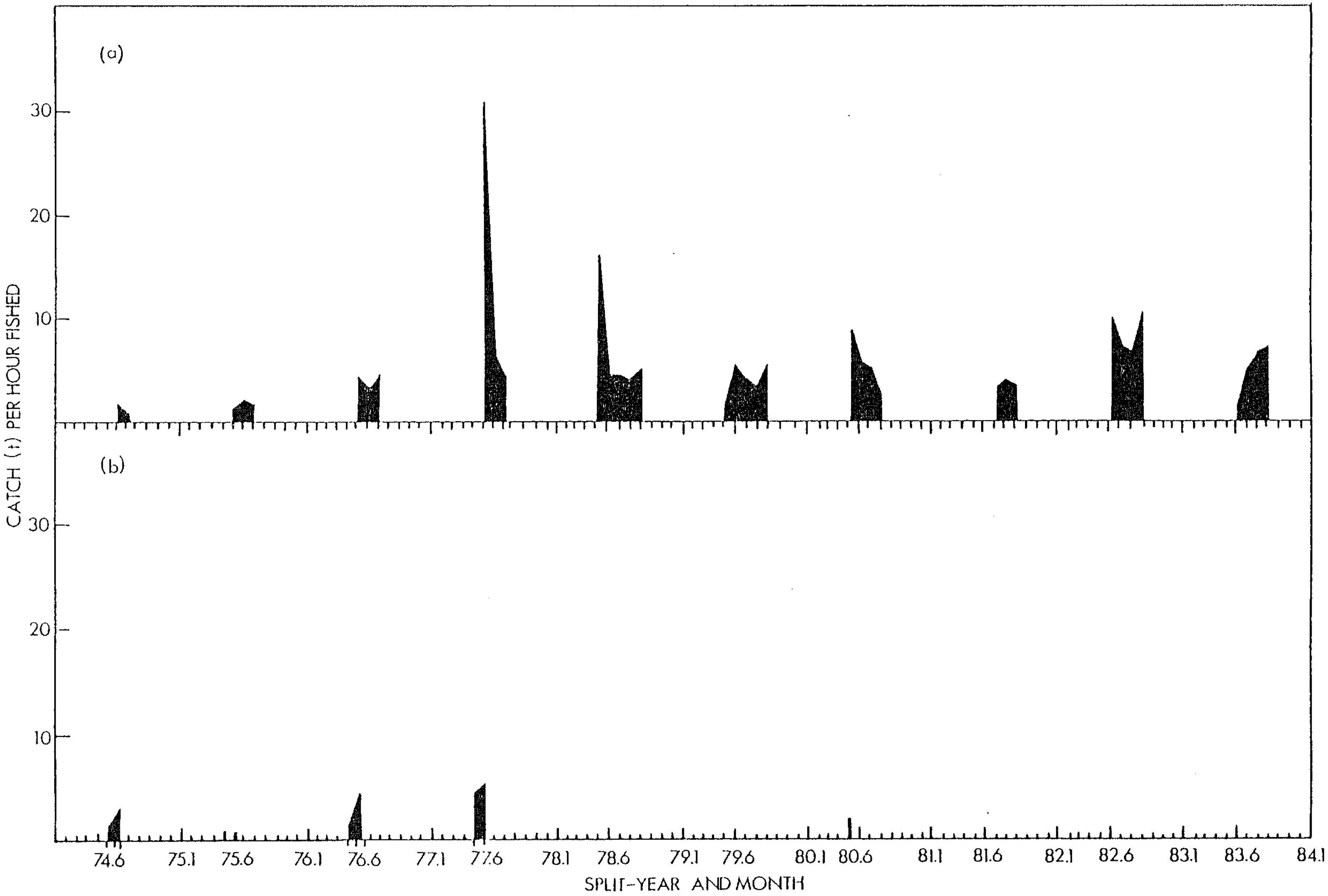


Figure 16: Monthly CPH values for the Japanese krill fishery in Divisions (a) 58.4.2 and (b) 58.4.4 from 1973/74 to 1982/83.

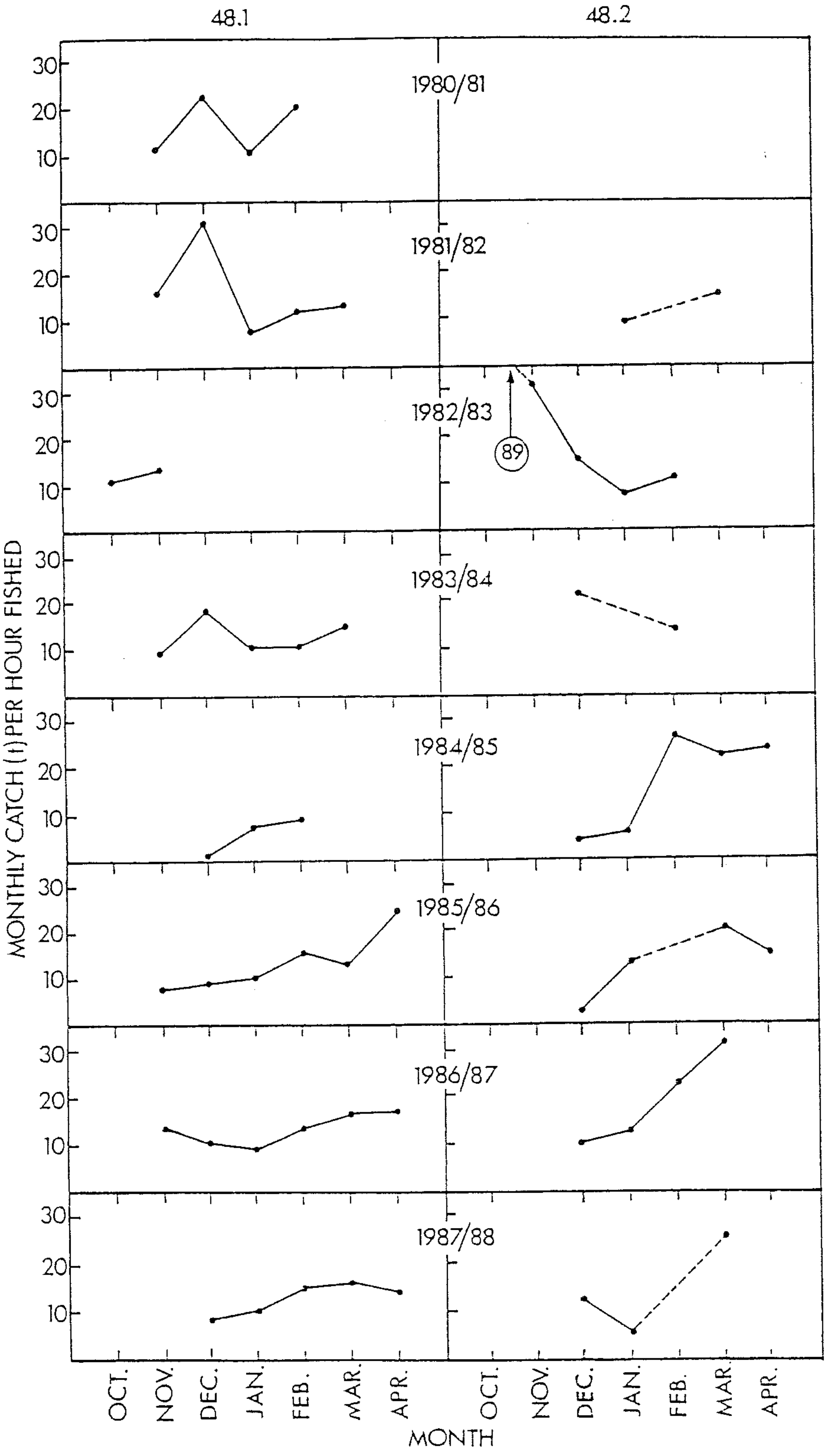


Figure 17: Monthly CPH values for the Japanese krill fishery in Subareas 48.1 and 48.2 for the period 1980/81 to 1987/88.

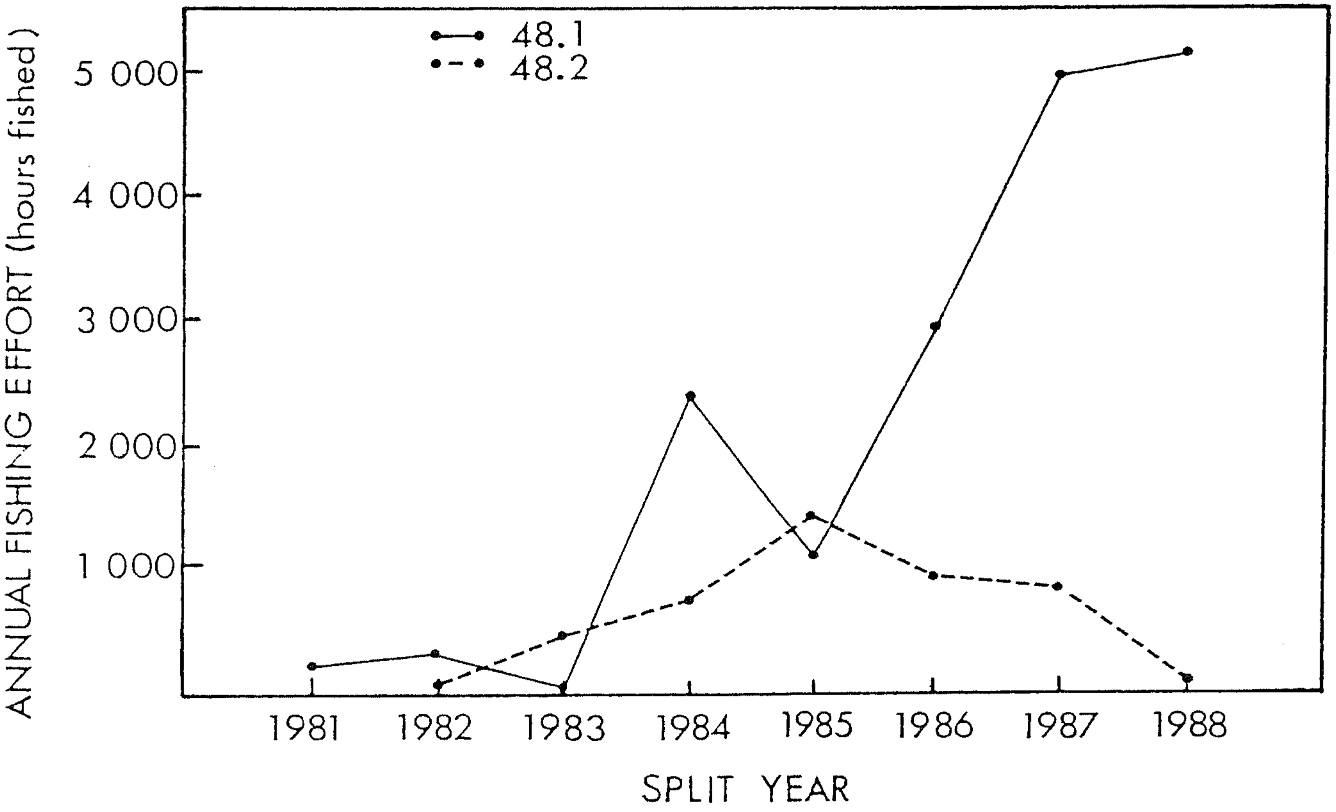


Figure 18: Annual fishing effort (hours fished) by the Japanese krill fishery in Subareas 48.1 and 48.2 (1980/81 to 1987/88).

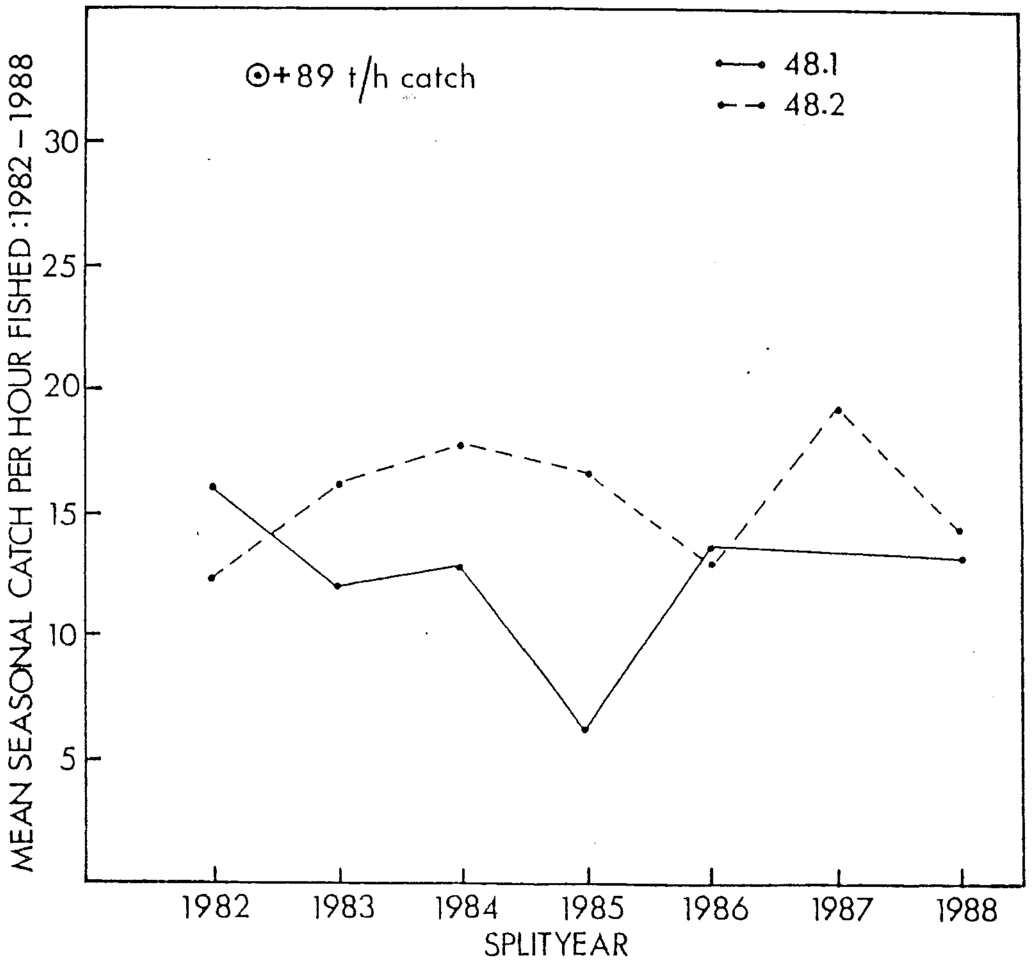


Figure 19: Seasonal mean CPH of the Japanese fishery in Subareas 48.1 and 48.2 (1980/81 to 1987/88).

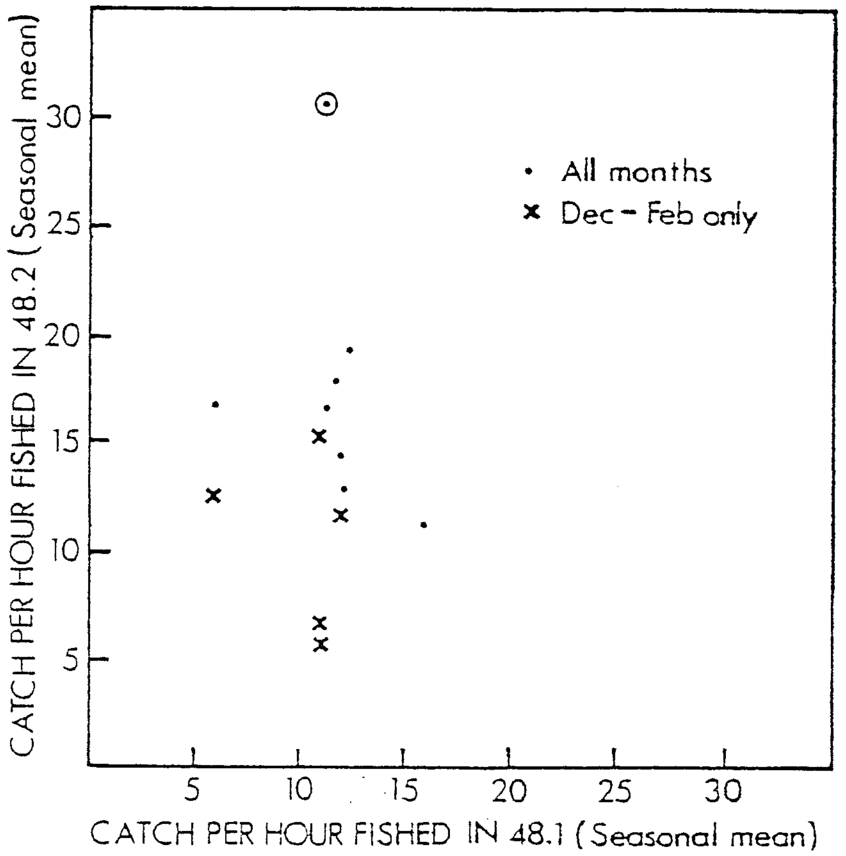


Figure 20: Comparison of seasonal mean CPH for the Japanese krill fishery in Subarea 48.1 versus Subarea 48.2.

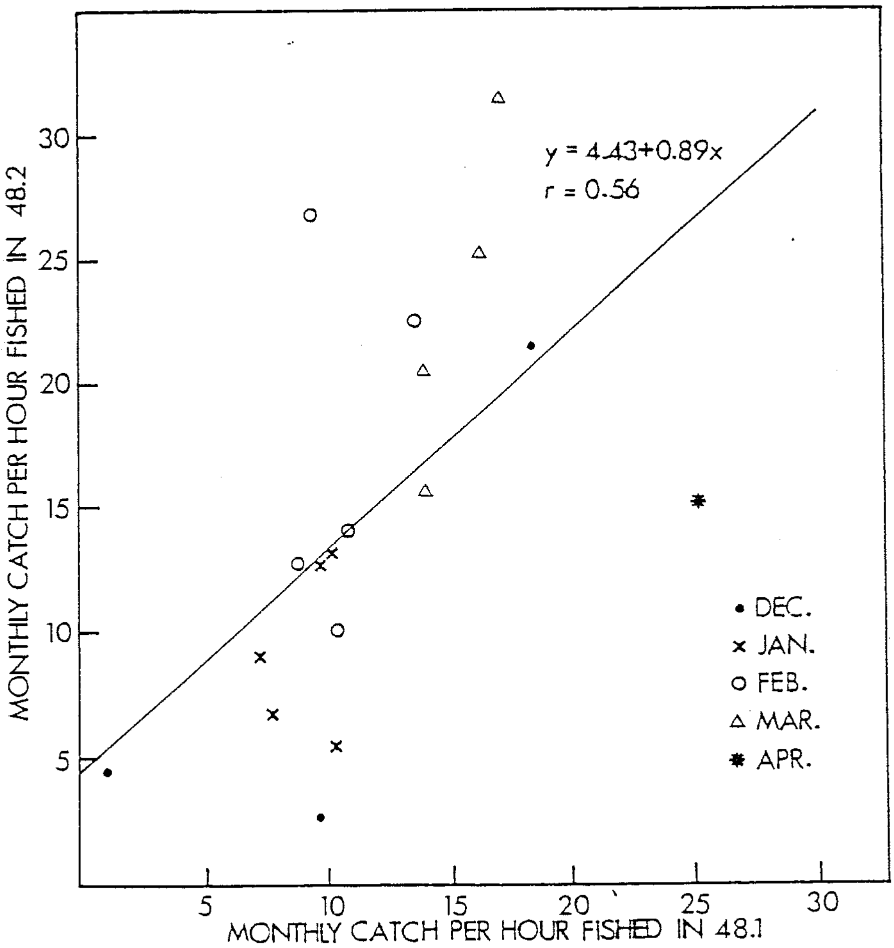
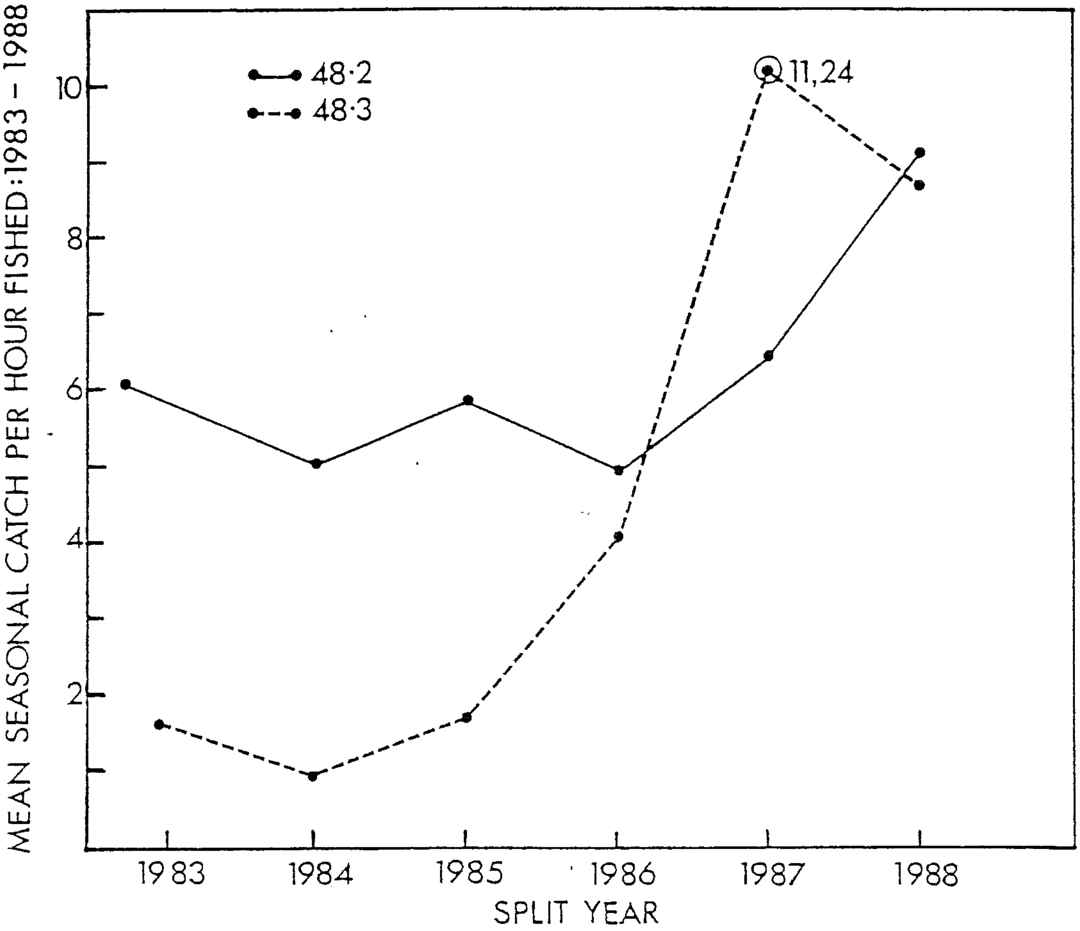


Figure 21: Comparison of CPH values for the Japanese krill fishery in the same months between December and April for Subarea 48.1 versus Subarea 48.2.



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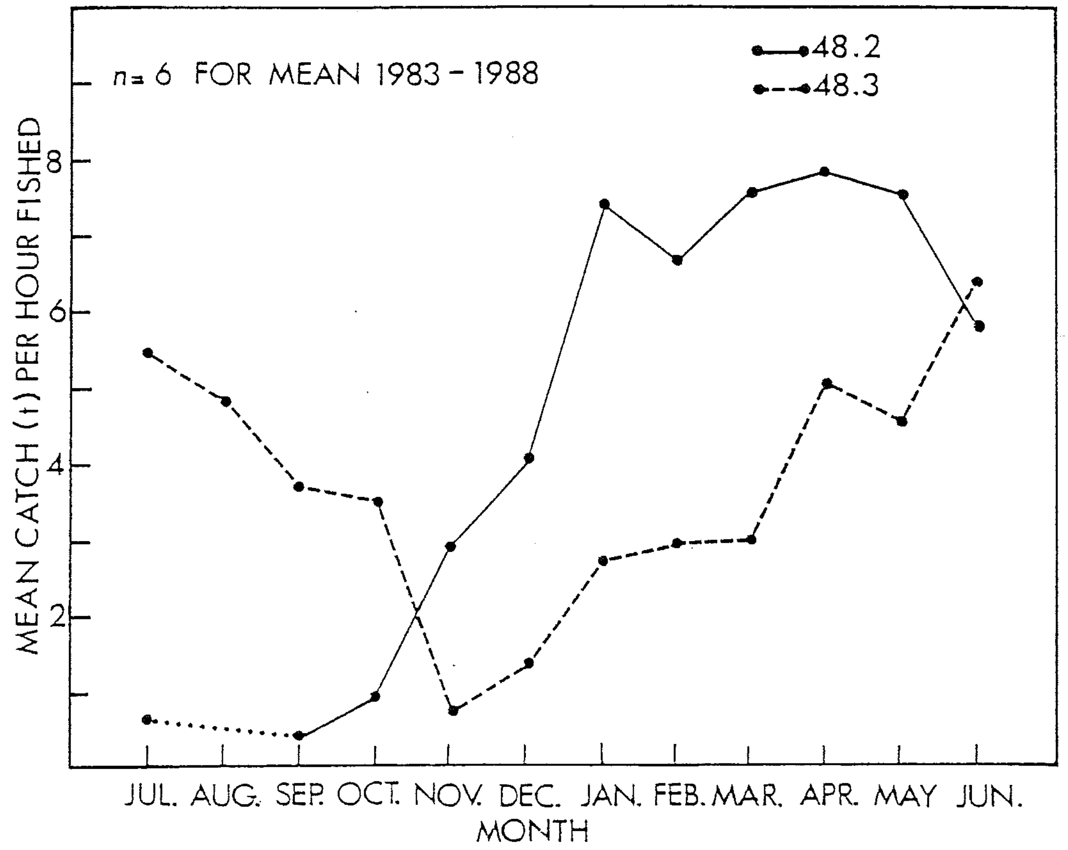

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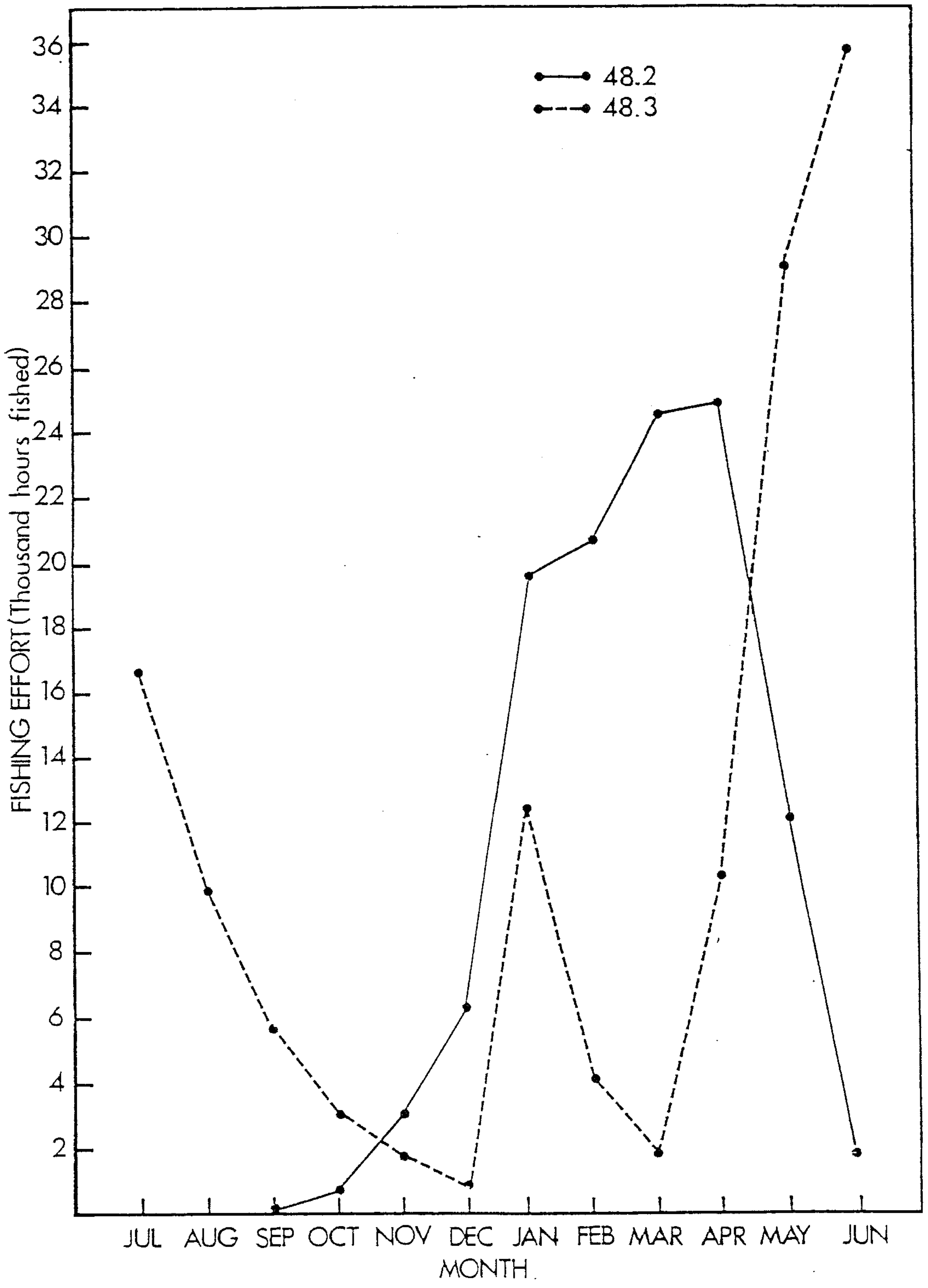

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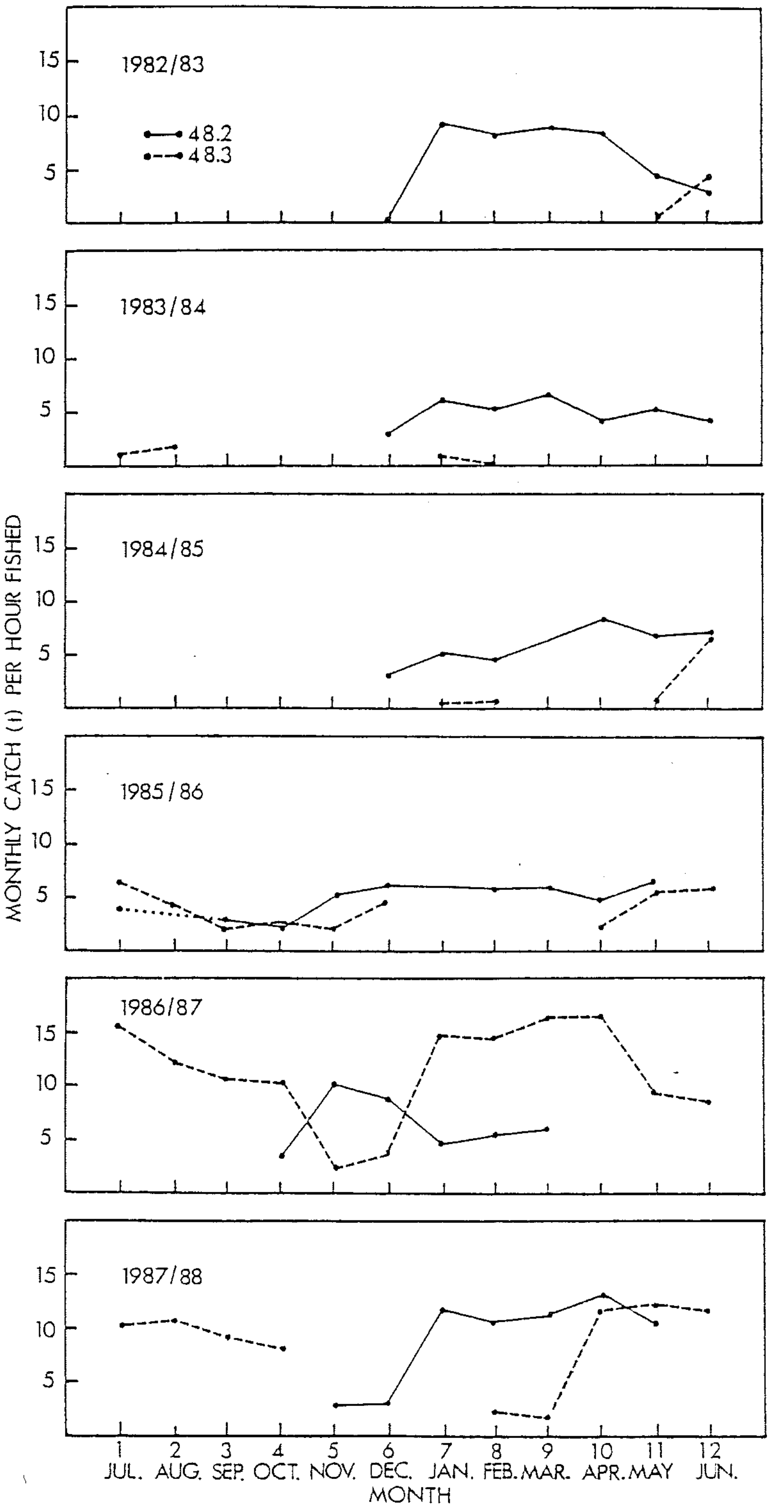

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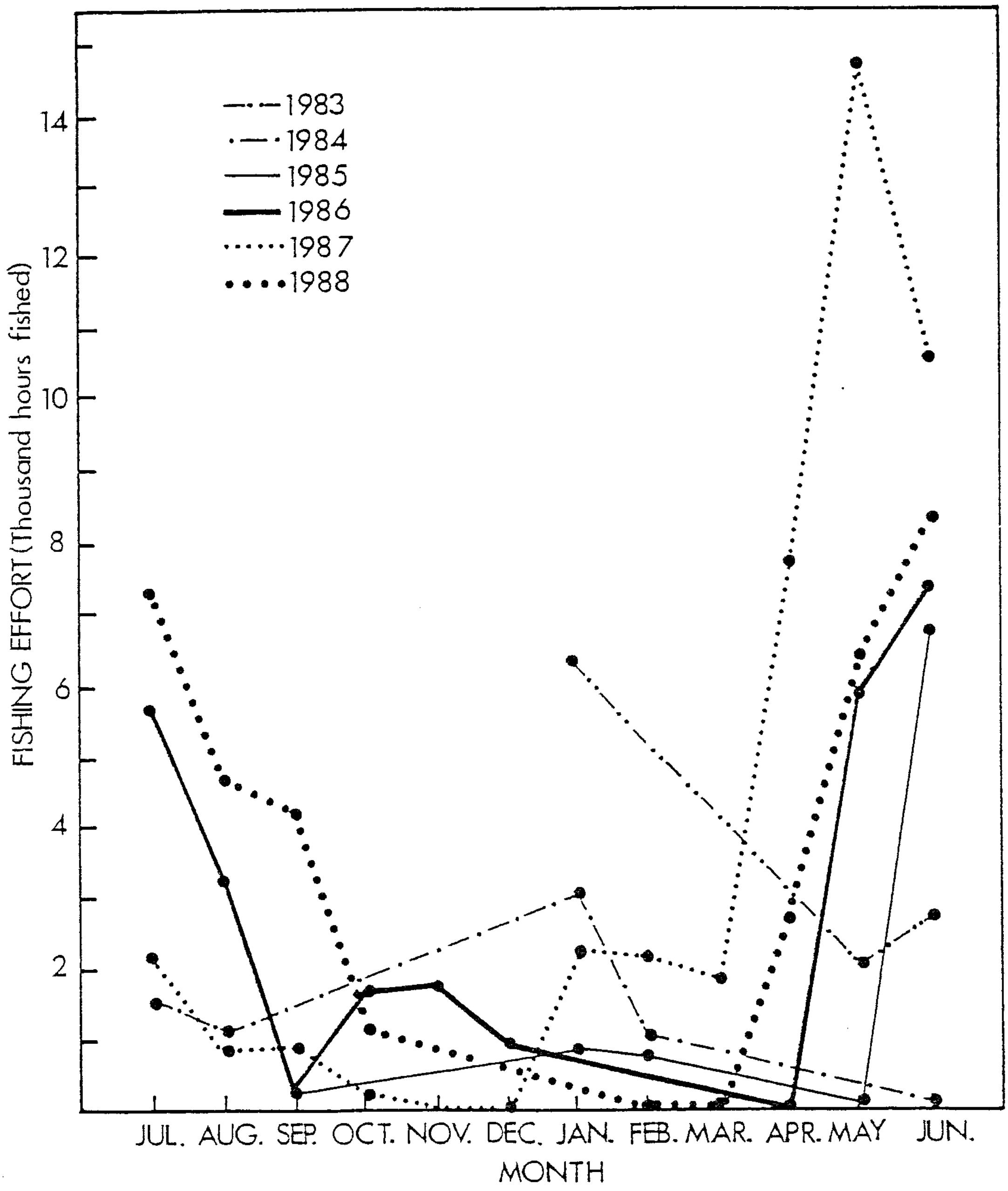

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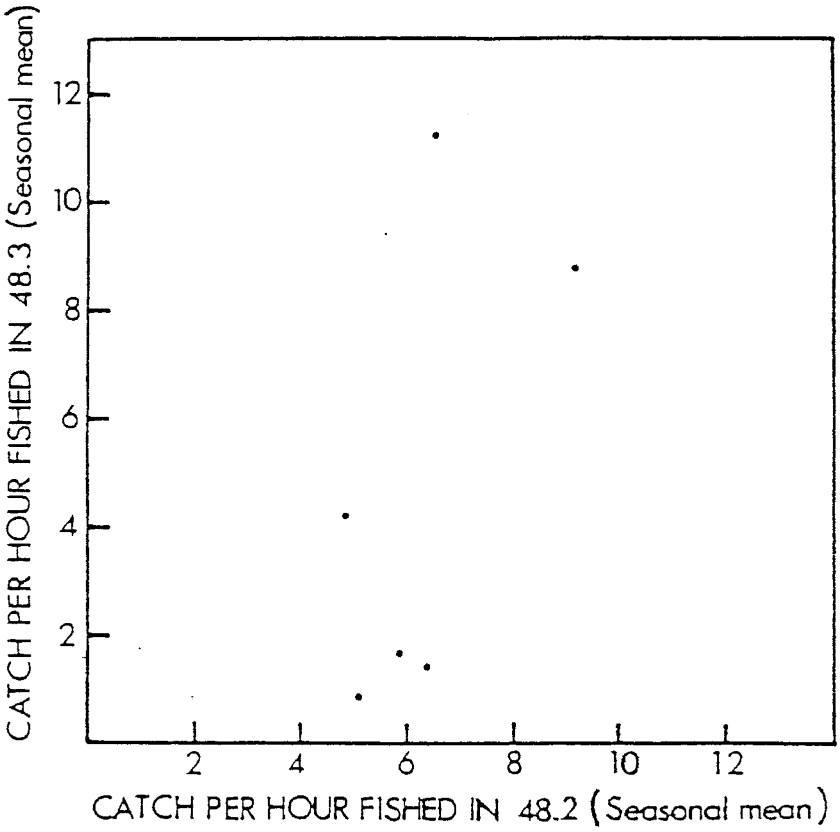

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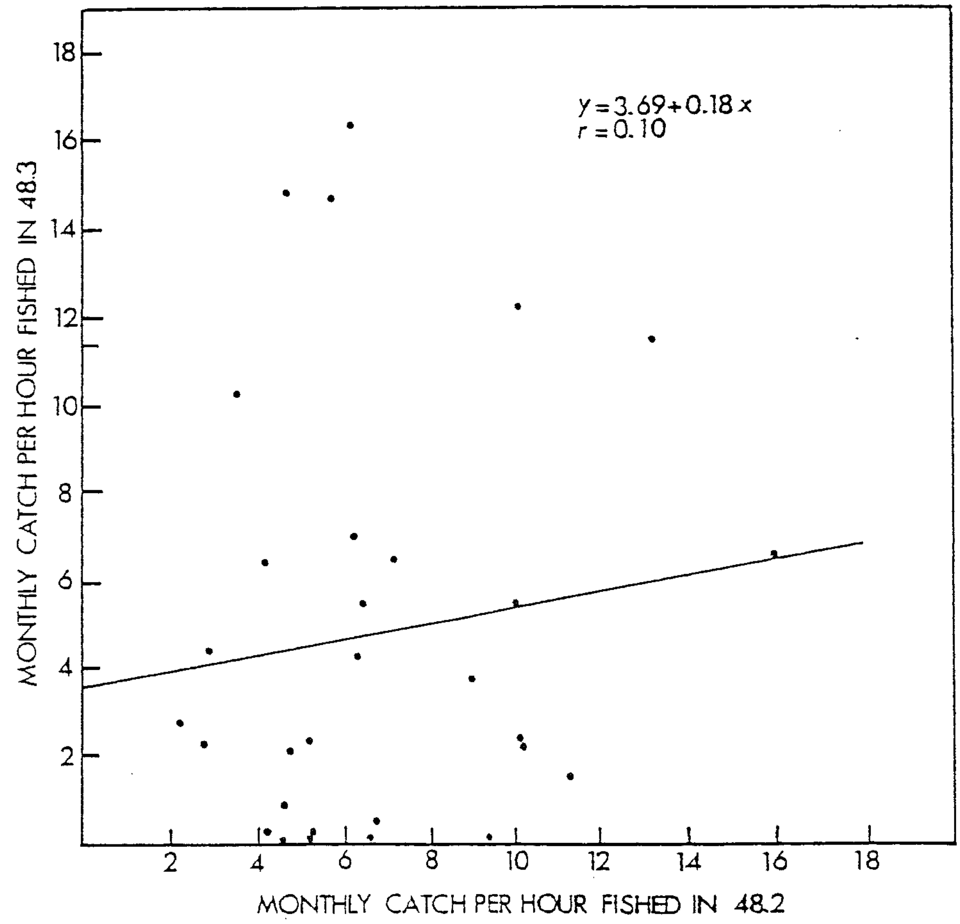

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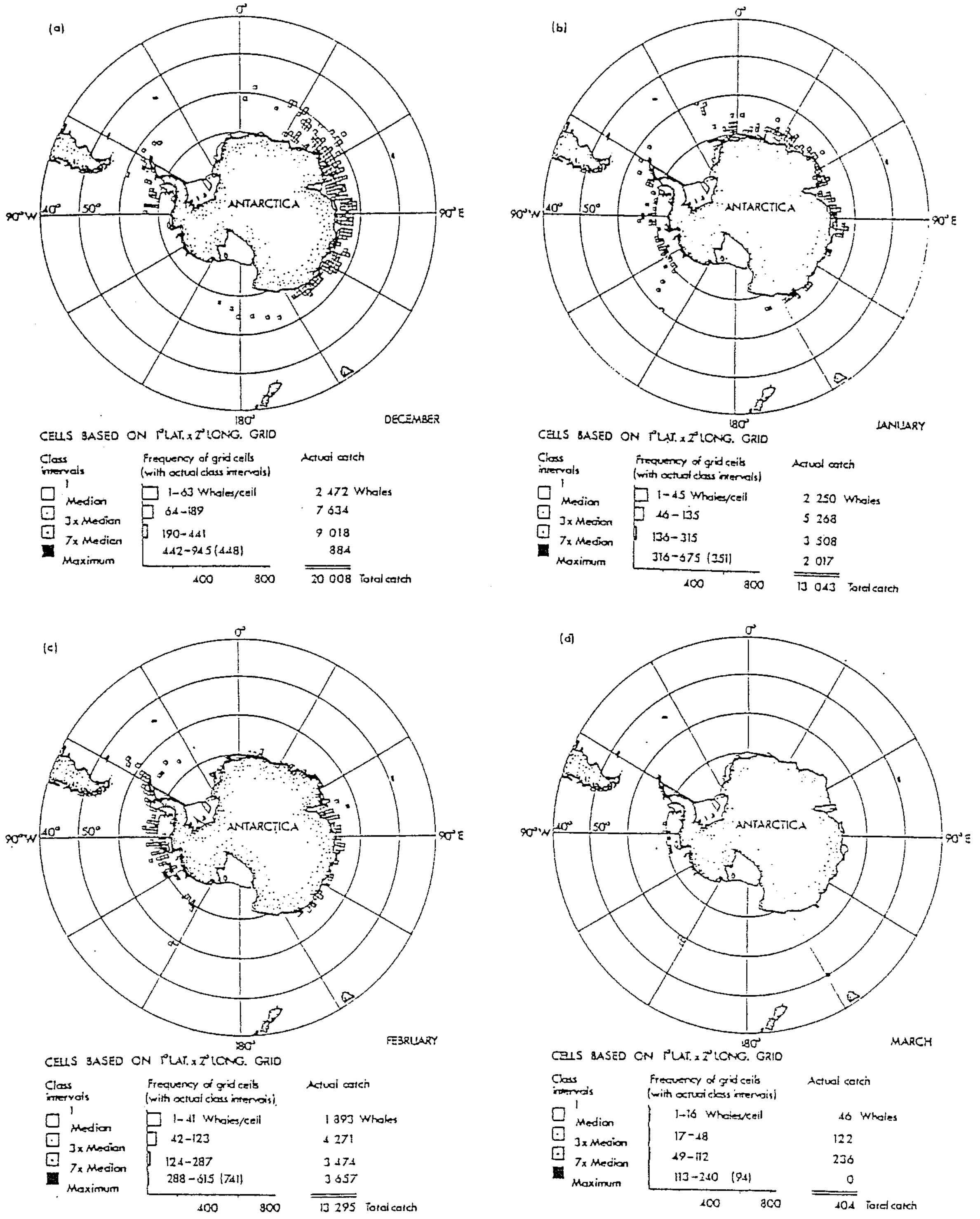

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ANALYSIS AND MODELLING OF THE SOVIET SOUTHERN OCEAN KRILL FLEET, II: ESTIMATING THE NUMBER OF CONCENTRATIONS AND ANALYTICAL JUSTIFICATION FOR SEARCH DATA

M. Mangel

Abstract

In this paper, I show how data that are routinely collected by survey vessels can be used to estimate the number of concentrations of krill (Butterworth, 1988; Mangel, 1988) in a given region of the Southern Ocean. Sample computations are performed, using data collected by Soviet research/survey vessels in the early 1980s. These examples highlight the need for a navigational log as well as a fishing log in order to make accurate inferences. In the appendix, a method for correcting for the bias in the detection of concentrations is described.

Résumé

Dans ce document, je démontre comment des données qui sont habituellement recueillies par les navires de prospection, peuvent être utilisées pour estimer le nombre de concentrations de krill Butterworth (1988), Mangel (1988) dans une région donnée de l'océan Austral. Des exemples de calculs sont faits, utilisant des données recueillies par des navires de recherche/de prospection au début des années 80. Ces exemples soulignent le besoin d'un journal de navigation tout autant que d'un carnet de pêche dans le but de tirer des conclusions précises.

Резюме

В настоящей работе мною показано, каким образом данные, которые регулярно собираются поисковыми судами, могут быть использованы для оценки количества концентраций криля (Butterworth, 1988; Mangel, 1988) в каком-либо определенном районе Южного океана. При выполнении пробных расчетов были использованы данные, собранные в начале 80-х годов советскими научно-исследовательскими и поисковыми судами. Приведенные примеры указывают на то, что для вынесения точных заключений на борту судов должен иметься как навигационный судовой журнал, так и промысловый судовой журнал. В приложении описывается метод внесения поправки на погрешность в обнаружении концентраций.

Resumen

En este documento, muestro como la información recopilada rutinariamente por los navíos de investigación puede usarse para estimar el número de concentraciones de krill (Butterworth, 1988; Mangel, 1988) en una región dada del oceáno Austral.

Cálculos de muestras se realizan usando datos coleccionados por los navíos soviéticos de investigación/estudio al principio de los años 1980. Estos ejemplos subrayan la necesidad de mantener un diario de navegación además de un cuaderno de pesca para hacer deducciones adecuadas.

1. INTRODUCTION

This paper is an extension of Mangel (1989) and complements both that paper and Butterworth (1989), who suggested that krill abundance could be monitored through fishery based data if the data are properly chosen. The distributional model used in those reports was supported by the analysis of field data (Levin et al., 1989); the notation used in the models will be adopted here. In this description, individual krill (spatial scale 50 mm) aggregate into *swarms* of krill (spatial scale 100 m) which then aggregate into *concentrations* of krill (spatial scale 10 nm) in a large sector of the southern ocean (spatial scale 600 nm). Although there remain questions concerning this distributional model and its relation to other data sets (Miller and Hampton, 1988), the preliminary results are sufficiently encouraging to begin considering actual (vs. simulated) abundance estimates from the krill fisheries data.

At the meeting of the Scientific Committee for the Conservation of Antarctic Marine Living Resources in 1988, Dr J.R. Beddington proposed that the Soviet Union provide data from research vessels that can be used to estimate the number of concentrations in a sector of the ocean and that Japan provide data from commercial vessels that can be used to estimate within concentration properties of krill. Both kinds of information are needed to construct abundance indices that are responsive to change in krill abundance and have reasonable variances.

In this paper, I present examples of how research vessel data routinely collected by the Soviet Union could be used to estimate the number of concentrations in a given area. The data used in these examples are the same data analyzed in Mangel (1989). They were not collected with the intent of this estimation, so that additional assumptions are needed in order to construct the estimates. These assumptions are discussed in detail in the next section.

The conclusions are:

- The types of movement by vessels in search for concentrations of krill are important and skippers should record the nature of movement and encounters. Essentially, accurate and effective inference for the number of concentrations requires information from a navigational logbook as well as a fishing logbook.

- There is considerable variability in concentration properties (radius, catch, trawling time); coefficients of variation range between 50% and 100%.

- The distributional model used by Butterworth (1989) and Mangel (1989), in which concentration radii are uniformly distributed between 6 nm and 22 nm may be inappropriate. In particular, the distribution of concentration radii may be skewed, with a long tail, rather than uniform as assumed previously. The difficulty in drawing a conclusion is that there is a bias in detection: the radii of detected concentrations are, on average, larger than the average radius of all concentrations (see Appendix for further details).

- In general, data collected by research or survey vessels (both navigational log-book and fishing logbook information) can be effectively used to estimate the number of concentrations in a sector of the ocean. In particular, there is a need for operational data and logbooks including echo sounder information. A navigational logbook will provide two kinds of data. First, from the navigational log, one can determine whether krill are present in regions between fishing hauls. Second, the navigational log can be used to set the boundaries of the region being searched.

- Using the methods described in this paper, no inferences can be made about stock size regions that are not searched. A Bayesian approach is needed to answer that question.
- In order to determine if concentrations are double counted, it is important to know the temporal persistence of concentrations of krill.

2. THE SEARCH FOR CONCENTRATIONS OF KRILL

The motion between-concentrations (rather than within-concentrations) can be broadly divided into three types:

(i) True search for a new concentration. In this case, the fleet leaves the current concentration and begins true search for another concentration. Here "true search" means that the search path is not highly directed in that the vessel has limited information about where to search. Even if the vessel executes a directed search path, it may be reasonable to expect that the overall search will be random (e.g. Washburn 1981 for justification).

(ii) Direct movement to a new region, followed by true search. In this case, the fleet exits the current concentration and moves directly to a new region (e.g. a historically known fishing ground) and then begins a true search within this new region. That is, the initial movement of the vessel is directed, based on specific information about where to search. The total time between concentrations then consists of a portion corresponding to directed motion (in which concentrations may be discovered accidentally) and a portion corresponding to true search.

(iii) Following oceanographic conditions. Since krill swarms may move passively according to prevailing currents, a fleet might simply follow an existing concentration as it is advected by the current.

3. SOURCES FOR DATA AND DESCRIPTION OF ANALYSIS

The data used here are the same as in Mangel (1989) and correspond to research vessel (RV) cruises between 1980 and 1984.

The pertinent information for these analyses are:

(i) vessel location at the start of trawling;
(ii) time of the start of trawling;
(iii) time of end of trawling; and
(iv) krill catch.

Each combination of location, start and end times and catch is called a record.

From these, we can compute the time between trawls (TBT) and movement between trawls (MBT). Mangel (1989) analyzed 12 different data sets; four of these were selected for further analysis in this paper. They are listed in Table 1. The approximate areas of the survey are shown in Figure 1.

4. PRELIMINARY ANALYSIS: SPATIAL LOCATION OF HAULS

Since the data used here were not explicitly collected for the purpose of estimating the number of concentrations, there is no indication in the data of the type of movement, as described above, or whether the vessel moved into a new concentration or encountered concentrations during transit. Thus, before any estimation procedures were applied, the data had to be analyzed to determine the number and location of concentrations. Figures 2 to 5 show the spatial location of hauls, ignoring the timing of hauls, for each of the data sets. In these plots, hauls were separated into those less than 1 000 kg of krill and those greater than or equal to 1 000 kg of krill. Although these figues give a sense of the spatial location of survey activities (e.g. hauls may be along the shelf edge or follow the ice edge), they do not give any temporal sense of the hauls. In order to do that, one must adopt rules for defining concentrations.

5. DEFINING CONCENTRATIONS BY VESSEL MOVEMENT

In the distribution model used by Butterworth (1989) and Mangel (1989), the radius of a concentration is uniformly distributed over (5.6 nm, 11.2 nm). This means that the maximum diameter of a concentration is about 22 nm and thus a movement of 50 nm corresponds to twice the maximum diameter of a concentration. Hence, the following rule was adopted for the analysis

> New Concentration Rule: When the vessel moved more than 50 nm between trawls, I assumed that the vessel moved to a new concentration.

Given this rule, it is possible to divide each data set into groups of records corresponding to fishing in different concentrations. From the records in each concentration, we can construct the east-west extent and north-south extent of the concentration and thus estimate the area of the concentration. One degree of latitude is assumed to be 60 nm and one degree of longitude is assumed to be 30 nm.

Figures 6 to 9 show the results of the application of the rule concerning movement to a new concentration. In some cases (e.g. Figure 6 or Figure 9) nearly all hauls were made in a concentration and the path of the vessel between concentrations can be visually determined simply by considering the concentrations defined by the 50 nm rule. In other cases (e.g. Figure 7 or Figure 8), vessel movement between concentrations is indicated as well.

Corroborative data for the 50 nm rule can be obtained by considering vessel speed between hauls. One would expect that this speed would be larger between concentrations (assuming random search) than within concentrations. For example, for the data from RV *Odyssey* in 1981, the average vessel speed between concentrations determined by the 50 nm rule is 4.8 kt ($\sigma=5.3$) and the average vessel speed within concentrations is 1.8 kt ($\sigma=3.0$). Application of the Mann Whitney U-Test (Siegel 1956) to the data showed that the two distributions were different at the 0.001 level.

One conclusion from Figures 6 to 9 is that it is easy to "double count" concentrations in a *post hoc* analysis such as the one being performed here. For example, in Figure 6 it is likely that concentrations 3,5, and 6 and concentrations 4 and 7 are, in fact, the same concentration. It is not as clear if concentrations 1 and 2 are indeed the same concentration. Possible double counting of concentrations becomes important in the estimation of the number of concentrations in a given area.

6. DEFINING CONCENTRATIONS AS FOCI OF HAULS

An alternative definition of concentrations ignores the temporal distribution of hauls and simply considers the location of hauls. If concentrations persist for very long periods of time, this approach makes sense. In this case, one can use the spatial distribution of hauls and try to group hauls that appear to "naturally" aggregate. Figures 10 and 11 show the results of this approach. Although circles are drawn in these figures, the disparity in vertical and horizontal scales means that the concentrations defined in this way are, in fact, ellipses.

On a finer scale, however, it is not clear at all if the presumed smooth geometrical shape for a concentration is appropriate. For example, Figures 12-15 provide examples of the finer scale distribution of hauls. In some cases, the "shape" of the concentration is apparent, but in others it is not clear at all. In addition, Figure 15 provides an excellent example of why echo sounder information is needed. That figure shows two foci for fishing krill with a gap between them. Without echo sounder information, it is impossible to tell in post hoc analysis if the region between the two sets of hauls contained krill and the skipper was attempting to determine the boundary of the concentration or if the region between the two sets of hauls was devoid of krill.

7. THE EFFECTIVE RADII OF CONCENTRATIONS

The distributional model used by Butterworth (1989) and Mangel (1989) assumes circular concentrations. Let $\langle A \rangle$ denote the average area of the concentrations computed from the east-west and north-south extent. The simplest estimate for the radius of the concentration is then $r=(\langle A \rangle/\pi)^{1/2}$. We can construct a better estimate, however, by noting that concentration radii and areas are random variables. Write $r=f(A)$, where $f=(A/\pi)^{1/2}$ and Taylor expand the expectation of r (Seber 1982):

$$E\{ r \} = E\{ f(A) \} = f(E\{A\}) + (1/2) f''(E\{A\}) \operatorname{Var}\{ A\} \qquad (1)$$

We estimate the expected value of A by $E\{ A \}=\langle A \rangle$ and the variance of A by the sample variance $\operatorname{Var}_s(A)$ to obtain

$$E\{ r \} = (\langle A \rangle/\pi)^{1/2} - (1/8)\pi^{-1/2} \langle A \rangle^{-3/2} \operatorname{Var}_s\{ A\} \qquad (2)$$

It should be noted, however, that there is a more serious bias in the estimation of the effective radii of concentrations. Larger concentrations are more likely to be detected than smaller concentrations. Thus, the average radius of detected concentrations is larger than the average radius of all concentrations. One can show (e.g. Feller 1971, p. 371; also see the Appendix) that

$$E\{\text{radius of detected concentrations}\}/E\{\text{radius of all concentrations}\} = (sM_1+ M_2)/(s + M_1) \qquad (3)$$

where s is the detection width of the vessel's sonar,
M_1 is the first moment (average) of the radius of concentrations, and
M_2 is the average of the squared radius of concentrations.

That is, if $f(r)$ is the probability density for concentration radii and r_{max} is the largest possible radius, then $M_k = \int_0^{r_{max}} r^k f(r)\, dr$. For the situation being considered here, this bias is not too severe. For example, running the survey portion of the model developed in Mangel (1989) showed that the bias was only about 10%.

8. ESTIMATING THE NUMBER OF CONCENTRATIONS

The number of concentrations in the region being surveyed can be estimated by use of the random search formula (Mangel, 1985; Mangel and Beder, 1985)

$$N = [\ n_c\ /\ (1\text{-}\exp(-Wvt_s/A_s)\ ] \qquad (4)$$

In this equation, N is the estimated number of concentrations in a sector of area A_s, **[z]** is the integer part of **z**, n_c is the number of concentrations encountered by the vessel, W is the detection width of the vessel and v is the speed of the vessel while searching.

For the majority of computations reported below **v=10 kt**; the other parameters are determined by the data. The search time t_s is the time between the last trawl in one concentration and the first trawl in the next concentration for which the movement between trawls is at least 50 nm.

The detection width **W** is set equal to twice the average radius of concentrations (thus ignoring the contribution from the detection width of the vessel's sonar). Since concentrations vary in size, **W** is a random variable and the estimate given in Equation (4) will be biased. Proceeding in a manner similar to Equation (1) shows that

$$E\{N(W)\} = N(E\{W\}) + (1/2)N_{ww}(E\{W\})Var(W) \qquad (5)$$

where E{W} and Var{W} are the mean and variance of W (estimated from the data); and N_{ww} is the second derivative of N(W) given in Equation (4), and is

$$N_{ww} = (vt_s/A_s)^2 \exp(-Wvt_s/A_s)n/(1- \exp(Wv_s/A_s)^2 + 2(vt_s/A_s)^2 \exp(-2Wvt_s/A_s)n/(1- \exp(Wvt_s/A_s)^3 \qquad (6)$$

The general properties of the estimate **N** can be determined by examination of Equation (4). The parameters enter into Equation (4) in such a way that the estimated number of concentrations only depends upon the combination Wvt_s/A_s. From this, we see that:

(i) An increase in any of **W**, **v**, or t_s will decrease the estimated number of concentrations **N**; and

(ii) An increase in A_s will increase the estimated number of concentrations. For this reason, it is important to have navigational logbook information that can be used to determine the boundaries of the region being searched.

As the combination Wvt_s/A_s increases, the estimated number of concentrations **N** approaches the number of discovered concentrations n_c. As the combination Wvt_s/A_s decreases, the estimated number of concentrations increases without bound (as long as $n_c>0$).

For the results reported below, the following procedure was adopted:

Step 1. Use the 50 nm rule to determine concentrations and the spatial extent of concentrations. The east-west extent of concentration **i** in data set **j** is denoted by EWE_{ij} and the north-south extent of the same concentration is denoted by NSE_{ij}.

Step 2. Compute the effective radius of concentrations using Equations (1 and 2). In addition, compute the radius of concentration **i** in data set **j**, denoted by

r_{ij}, from the formula $r_{ij}=(EWE_{ij}NSE_{ij}/\pi)^{1/2}$. Compute the mean $<r>_j$ radius of concentrations in data set **j** and the variance of radii.

Step 3. Set the detection width in data set j equal to $W_j=2<r>_j$. Apply Equations (5 and 6) to these data. In doing this, since $W=2r$, then $Var(W)=4\ Var(r)$. (Figure A6 of Appendix 5 of the Krill CPUE Working Group Report contains an error for the curve in which bias is included. That error is corrected here.)

Tables 2 to 5 show the results of Step 1 of this process. Note the following limitations in trying to post-hoc interpret the data:

(i) Although the new concentration rule specifies that movements greater than 50 nm correspond to new concentrations, vessels can cover much larger areas by making smaller, directed movements within a concentration. For example, three movements of 40 nm each could cover 120 nm, but under the 50 nm rule, the vessel would still be "in the same concentration". Such records probably correspond to more than one concentration, but there is no way of determining how many different concentrations were really present.

(ii) Another interpretation of large concentration areas is that the concentration radius is not uniformly distributed as assumed by Butterworth (1989) and Mangel (1989), but has a skewed distribution with a long tail. The large concentrations might also represent the detection bias described previously.

(iii) There are instances in which very long trawl times are reported in concentrations for which the catch is very small. It is possible that the vessel was actually doing operations other than fishing during some of this time, but there is no way to tell if this is true (or what the operations were) from the logbooks. Additional annotations in logbooks are needed.

Table 6 contains results of Steps 2 and 3 for the estimated number of concentrations in the region and the radius of the concentrations. Two radii are given. The first is the effective radius, based on Equations (1 and 2). The second is the simple average $<r>_j$ computed in Steps 2 and 3. Table 7 shows summary statistics for catch and trawling times. Concentrations were divided into "poor" concentrations and "good" concentrations: a concentration with CFT (catch per fishing time) less than 500 kg/hour is considered poor. From these tables, we see that the coefficients of variation of concentration properties are very large - typically between 50% and 100%.

Since concentrations are not marked in any way upon encounter, they might be re-encountered and viewed as a new concentration. For example, some concentrations actually overlap in space but not in time (e.g. 4 and 7 in Figure 2). Table 8 shows the possible double counts and the time between the encounters of the double counts.

I presume that when consecutively numbered concentrations are nearly contiguous in space, they are probably being doubled counted. The question is more difficult for non-consecutive concentrations. These are concentrations 3, 6 and 4, 7 for the data collected by the RV *Professor Derugin*, concentrations 1,4 for the data collected by the RV *Odyssey* and concentrations 4, 8 and 1, 14 for the data collected by the RV *Mys Tihiy*. The times between the last trawl in one concentration and the first trawl in the possibly double counted concentration range from 101.4 hrs to 1 290.4 hrs, with a mean of 565.6 hrs. The only way in which we can determine if these are really different concentrations is to know the time scale on which concentrations persist. (In the models used by Butterworth (1989) and Mangel (1989) concentrations are presumed to persist for the entire fishing period of14 to 30 days.)

9. A MORE DETAILED ANALYSIS OF THE DATA FROM RV *MYS TIHIY*

Figure 16 shows a histogram of the radii of concentrations encountered by RV *Mys Tihiy*. In order to obtain an idea of how the estimated number of concentrations depends upon the area of the sector $\mathbf{A_s}$, Equation (4) was used to compute **N** as a function of varying $\mathbf{A_s}$, using **W=2<r>**. The results are shown in Figure 17 (which corrects Figure A6 in Appendix 5 of the Krill CPUE Workshop Report (see CCAMLR, 1989)).

10. CONCLUSIONS

The results presented in this paper lead to the following conclusions:

- The types of movement by vessels in search for concentrations of krill are important and skippers should record the nature of movement and encounters. Essentially, accurate and effective inference for the number of concentrations requires information from a navigational logbook as well as a fishing logbook.

- There is considerable variability in concentration properties (radius, catch, trawling time); coefficients of variation range between 50% and 100%.

- The distributional model used by Butterworth (1989) and Mangel (1989), in which concentration radii are uniformly distributed between 6 nm and 22 nm may be inappropriate. In particular, the distribution of concentration radii may be skewed, with a long tail, rather than a uniform distribution as assumed previously. The difficulty in drawing a conclusion is that there is a bias in detection: the radii of detected concentrations are, on average, larger than the average radius of all concentrations.

- In general, data collected by research or survey vessels (both navigational logbook and fishing logbook information) can be effectively used to estimate the number of concentrations in a sector of the ocean. In particular, there is a need for operational data and logbooks including echo sounder information. The navigational logbook will provide two kinds of data. First, from the navigational log, one can determine whether krill are present in regions between fishing hauls. Second, the navigational log can be used to set the boundaries of the region being searched.

- Using the methods described in this paper, no inferences can be made about stock size regions that are not searched. A Bayesian approach is needed to answer that question.

- In order to determine if concentrations are double counted, it is important to know the temporal persistence of concentrations of krill.

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ESTIMATING THE BIAS IN THE SIZE OF DETECTED CONCENTRATIONS

Since a large concentration is more likely to be detected than a small concentration, there will be a bias in estimating concentration size from the dimensions of concentrations that are encountered.

In this appendix, I show how to calculate the bias. Assuming that the survey vessel runs a straight tack, one need only consider a problem in one dimension. Assume that concentration centers are uniformly placed across an interval of length **$2R$** and that the survey vessel sits at the center of this interval with detection width **$2s$**.

Let **C** denote the location of the center of a concentration and **W** the radius of a concentration. Thus **C** is uniformly distributed on **$[-R,R]$** and **W** has a density function **$f_0(w)$**, so that **$\mathrm{Prob}\{\ w \leq W \leq\ w + dw\} = f_0(w)dw$**. A concentration is assumed to be detected if part of it falls within the detection width of the survey vessel. Thus

$$\begin{aligned}&\mathrm{Prob}\{\text{ concentration of radius } W \text{ is detected}\}\\ &\quad = \mathrm{Prob}\{\ C< 0,\ W+C >-s\} + \mathrm{Pr}\{\ C> 0,\ C-W < s\} \end{aligned} \qquad \text{(A1)}$$

Since the concentrations are uniformly distributed over the interval, the joint probabilities can be rewritten as

$$\begin{aligned}&\mathrm{Prob}\{\ C<0,\ W+C> -s\} = (1/2)\mathrm{Prob}\{W+C>-s|\ C <0\}\\ &\mathrm{Prob}\{\ C>0,\ C-W< s\} = (1/2)\mathrm{Prob}\{C-W< s|\ C >0\}\end{aligned} \qquad \text{(A2)}$$

Because of the symmetry of the problem, **$\mathrm{Prob}\{W+C > -s|C <0\} = \mathrm{Prob}\{C\ W < s|\ C> 0\}$** so that

$$\mathrm{Prob}\{\text{concentration of radius } w \text{ is detected}\}= \mathrm{Prob}\{C < s+w \mid C > 0\} = (s+w)/R \qquad \text{(A3)}$$

Strictly speaking, the term **$(s+w)/R$** in (A3) should be replaced by **$\min(1, (s+w)/R)$**; I assume that **$s+w< R$** always. This can always be achieved by assuming that **$f_0(w)$** vanishes at some finite value of w which is less than **$R-s$**.

Equation (A3) gives the probability that a concentration of radius W will be detected. We want to compute, however, the probability that a concentration has radius approximately **w**, given that it is detected. This can be found by an application of the definition of conditional probability:

$$\begin{aligned}&\mathrm{Prob}\{\text{ concentration has radius approximately } w, \text{ given that it is detected}\}\\ &\quad = \mathrm{Prob}\{\text{concentration has radius approximately } w \text{ and it is detected}\}/\\ &\qquad \mathrm{Prob}\{\text{ concentration is detected}\}\end{aligned} \qquad \text{(A4)}$$

The numerator in (A4) is **$f_0(w)\ dw\ (s+w/R)$** and the denominator is the integral of the numerator over all possible values of **w**.

Hence

Prob{ concentration has radius approximately w, given that it is detected}

$$= (s+w)\ f_0(w)\ dw / \int f_0(w)[(s+w)]dw$$

$$= (s+w)f_0(w)dw/(s + E\{W\}) \qquad (A5)$$

where **E{W}** is the expected radius of a concentration. The expected value of the radii of detected concentrations is then

E{ radii of detected concentrations}

$$= \int [sw + w^2]f_0(w)\ dw/(s+ E\{W\}) \qquad (A6)$$

$$= (s\ E\{W\} + M_2)/(s + E\{W\}) \qquad (A7)$$

where M_2 is the second moment of the concentration radii.

Since $M_2 = \mathrm{Var}\{W\} + E\{W\}^2$, (A7) can be rewritten as

E{radii of detected concentrations }

$$= (s\ E\{W\} + E\{W\}^2 + \mathrm{Var}\{W\})/ (s + E\{W\}) \qquad (A8)$$

This result is derived, in general, by Feller (1971, p. 371).

A nondimensional measure of the bias caused by detection of larger concentrations is

E{radii of detected concentrations}/E{radii of all concentrations}

$$= (s\ E\{W\} + E\{W\}^2 + \mathrm{Var}\{W\})/ (s\ E\{W\} + E\{W\}^2) \qquad (A9)$$

The quantity in (A9) can easily be evaluated. For example, if **W** is uniformly distributed on the interval $[0,\alpha R]$, then

E{radii of detected concentrations}/E{radii of all concentrations}

$$= (2/3)\ [\ 2(\alpha R/s) + 3\ ]/[\ (\alpha R/s) + 2] \qquad (A10)$$

Alternatively, one can consider the case in which s is vanishingly small (i.e. the detection width of the survey vessel is very small, compared to the radii of concentrations). In that case, (A9) becomes

E{radii of detected concentrations}/E{radii of all concentrations}

$$= (E\{W\}^2 + \mathrm{Var}\{W\})/ (E\{W\}^2)$$

$$= 1 + CV(W)^2 \qquad (A11)$$

where **CV{W}** is the coefficient of variation of the concentration radius distribution.

Table 1: Data sets used for the analysis.

Vessel Name	Period of Survey	Region of Survey	Number of Records
1. *Professor Derugin*	18.02.82 - 05.05.82	61.2°E - 112.4°E 62.9°S - 67.1°S	118
2. *Oydssey*	09.01.81 - 19.03.81	35.3°W - 55.7°W 53.6°S - 61.3°S	39
3. *Mys Dalniy*	07.02.84 - 29.04.84	105.6°E - 163.9°E 64.3°S - 77.9°S	65
4. *Mys Tihiy*	02.01.81 - 08.04.81	116.7°E - 167.6°E 65°S - 68.4°S	155

Table 2: Analysis of data for the cruise by RV *Professor Derugin*.

Concentration	Extent East-West (nm)	Extent North-South (nm)	Krill Catch (kg)	Trawl Time (hrs)	Search Time* (hrs)	CFT**
1	24	2	15 000	19.2	19.3	781
2	41.5	26	178 000	151	5.3	1 179
3	23.5	5	69 500	60.7	9.8	1 145
4	38	15	54 510	57.7	14.2	945
5	81.5	10	156 600	197.5	17.6	793
6	49	33	364 800	209	10.9	1 746
7	41.5	10	247 200	204	9.1	1 212

* Trawl time is the total time spent trawling in the concentration.
Search time is the time between the last trawl in the ith concentration and the first trawl in the i+1st concentration.

* * CFT = Catch-per-fishing time = Catch/Trawl Time. Units are kg/hour.

Table 3: Analysis of data for the cruise by RV *Odyssey*.

Concentration	Extent East-West (nm)	 North-South (nm)	Krill Catch (kg)	Trawl Time (hrs)	Search Time* (hrs)	CFT**
1	15.5	20	53 412	285.6	304.3	187
2	24	42	15 000	174.6	135.4	85.9
3	51.5	39	3 100	79.7	23.8	38.9
4	8.5	9	27 802	105.8	57.5	262.8

* Trawl time is the total time spent trawling in the concentration.
Search time is the time between the last trawl in the i^{th} concentration and the first trawl in the $i+1^{st}$ concentration.

* * CFT = Catch-per-fishing time = Catch/Trawl Time. Units are kg/hour.

Table 4: Analysis of data for the cruise by RV *Mys Dalniy*.

Concentration	Extent East-West (nm)	 North-South (nm)	Krill Catch (kg)	Trawl Time (hrs)	Search Time* (hrs)	CFT**
1	48.5	16	17 500	60.2	133.8	291
2	0.5	1	6 000	4	112	1 500
3	10.5	6	21 000	30.9	167.2	680
4	12.5	9	30 200	58.4	223.8	517
5	56	25	7 900	55.7	183	142
6	53.5	24	56 200	118.7	37.5	474

* Trawl time is the total time spent trawling in the concentration.
Search time is the time between the last trawl in the i^{th} concentration and the first trawl in the $i+1^{st}$ concentration.

* * CFT = Catch-per-fishing time = Catch/Trawl Time. Units are kg/hour.

Table 5: Analysis of data for the cruise by RV *Mys Tihiy*.

Concentration	Extent East-West (nm)	 North-South (nm)	Krill Catch (kg)	Trawl Time (hrs)	Search Time* (hrs)	CFT**
1	9	28	1 173	28.7	61.3	40.9
2	12	4	22 800	14.9	65.6	1 530
3	16	6	28 000	78	18.7	359
4	83.5	44	118 200	134.5	41.6	879
5	39	17	43 700	48.2	2.58	907
6	182.5	68	13 400	72.8	114	184
7	39	78	24 700	46.5	252	531
8	54.5	71	171 050	272	157.7	629
9	4.5	1	9 000	9.8	49.3	918
10	43	13	4 500	11.4	61.2	395
11	24	21	35 000	28	21.7	1 250
12	4.5	5	29 500	51	28.4	578
13	7.5	0.3	650	104.3	110.7	6.2
14	43	43	16 200	46.2	35	351

* Trawl time is the total time spent trawling in the concentration.
Search time is the time between the last trawl in the i^{th} concentration and the first trawl in the $i+1^{st}$ concentration.

* * CFT = Catch-per-fishing time = Catch/Trawl Time. Units are kg/hour.

Table 6: Estimates for the number of concentrations and concentration properties.

Vessel	Estimated Number of Concentrations	Concentration Radii Equations (1 and 2) (nm)	 Average $<r>_j$ (nm)
Professor Derugin	20; 24*	14.6	13.2 (6.16)**
Odyssey	12; 38	16.7	15.1 (7.06)
Mys Dalniy	34; 52	13.9	11.3 (8.04)
Mys Tihiy	25; 42	24.7	17.9 (17.1)

* The first value pertains to Equation (5); the second includes the bias.

* * Standard deviations are shown in parentheses.

Table 7: Summary of catch and trawling time data.

Vessel	Concentration Properties		Concentration Types	
	Catch (kg)	Trawling Time (hrs)	Poor	Good
Professor Derugin	155 087 (0.73)*	128 (0.58)*	None	All
Odyssey	24 829 (0.75)	161 (0.49)	All	None
Mys Dalniy	23 133 (0.73)	54.6 (0.64)	1,5,6	2,3,4
Mys Tihiy	36 991 (1.26)	72.8 (0.92)	1,3,6,10 13,14	2,4,5 7,8,9,11,12

* Coefficient of variation is shown in parentheses.

Table 8: Possible double counting of concentrations and the time between encounters.

Number of concentrations that might be double counted	Time between last trawl in one concentration and first trawl in the next
3,5,6	89.5 hrs (3-5), 10.9 hrs (5-6)
4,7	444 hrs
Odyssey	
1,4	296.4 hrs
2,3	23.8 hrs
Mys Dalniy	
4,5	182.6 hrs
Mys Tihiy	
2,3	18.9 hrs
4,8,9	693.6 (4-8), 61.2 (8-9)
1,14	1 290.4

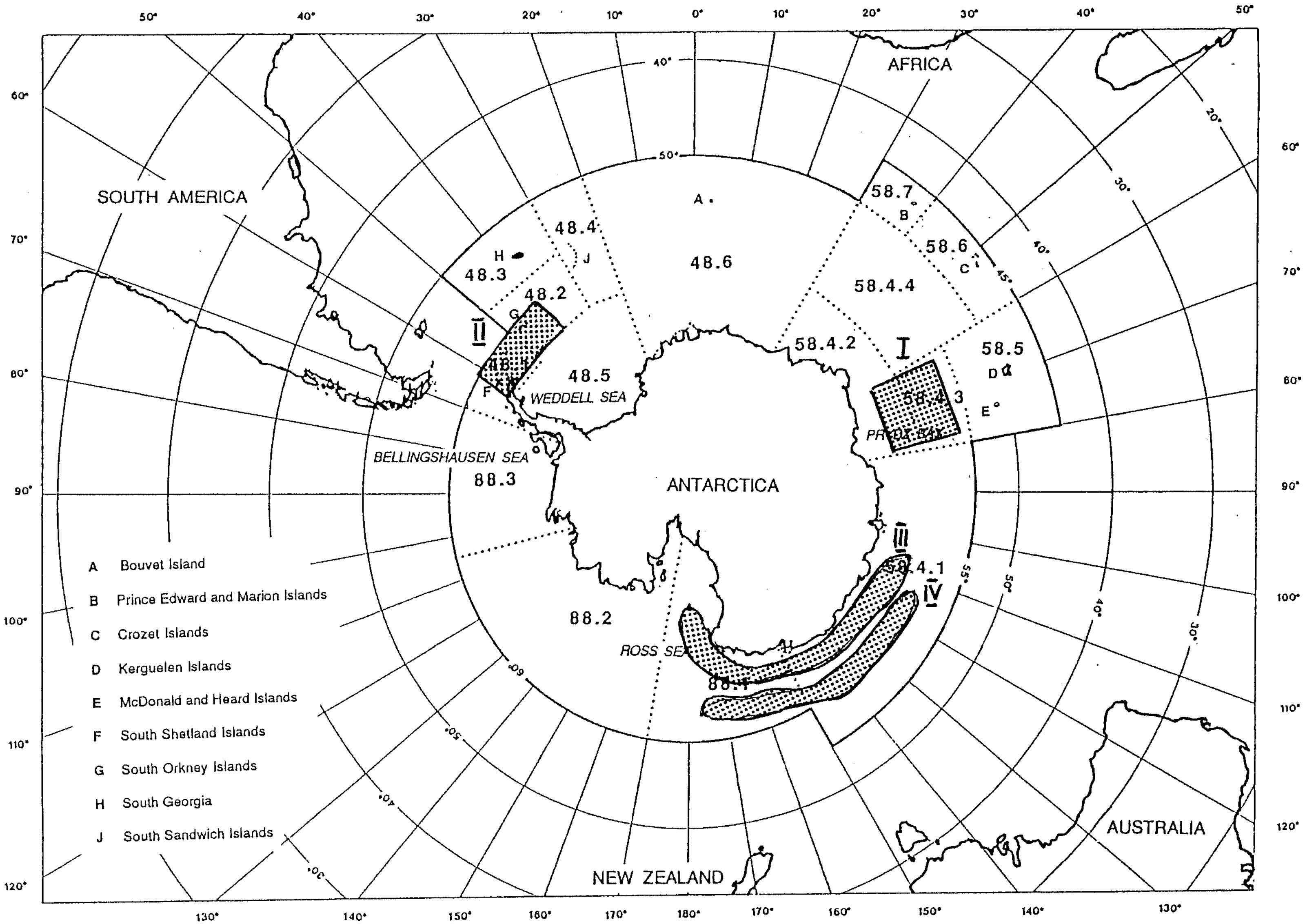


Figure 1: Approximate location of the four survey vessel activities, superimposed upon CCAMLR areas, subareas and divisions. The scale of the survey activity has been slightly enlarged to enhance viewing.

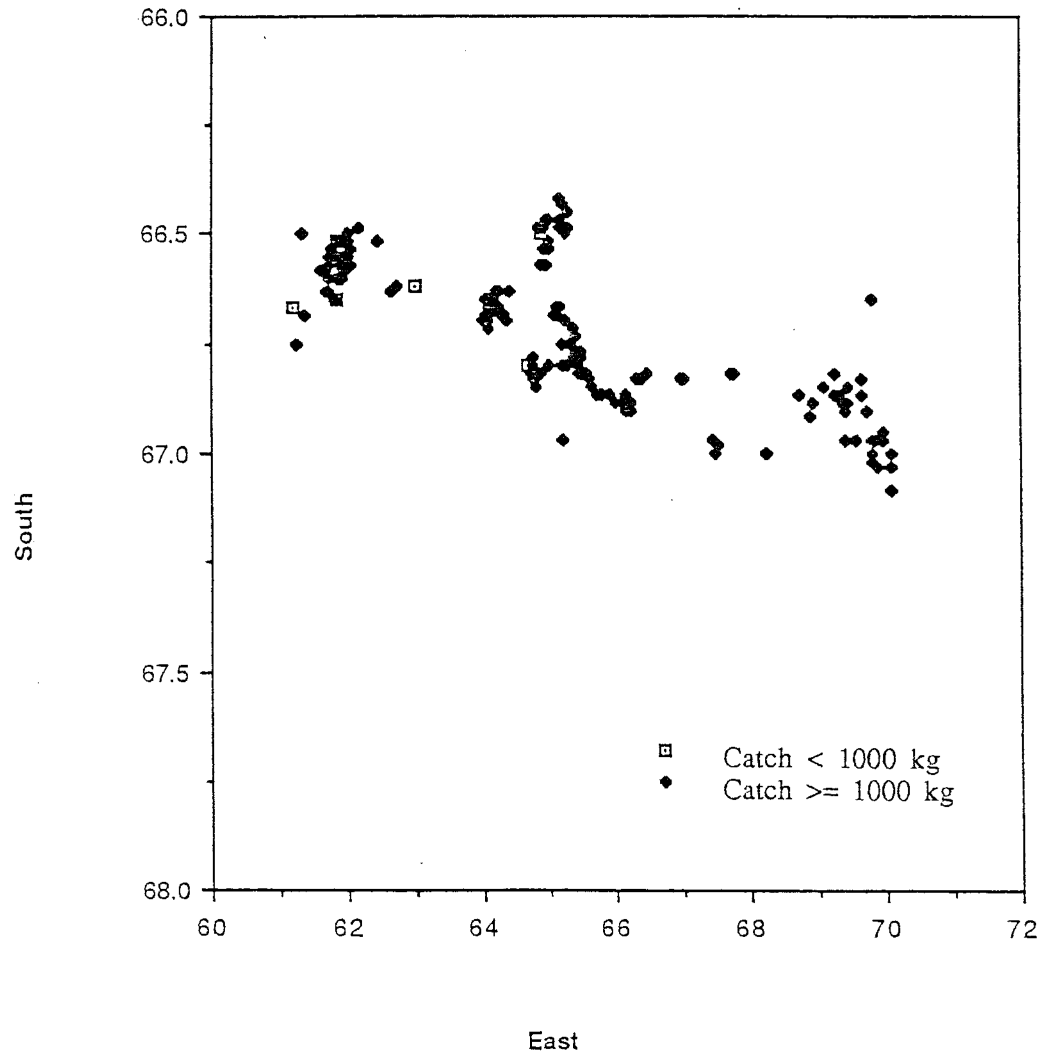


Figure 2: Spatial location of hauls by RV *Professor Derugin*. Hauls are separated according to the size of catch. On this scale there is almost a continuous series of hauls.

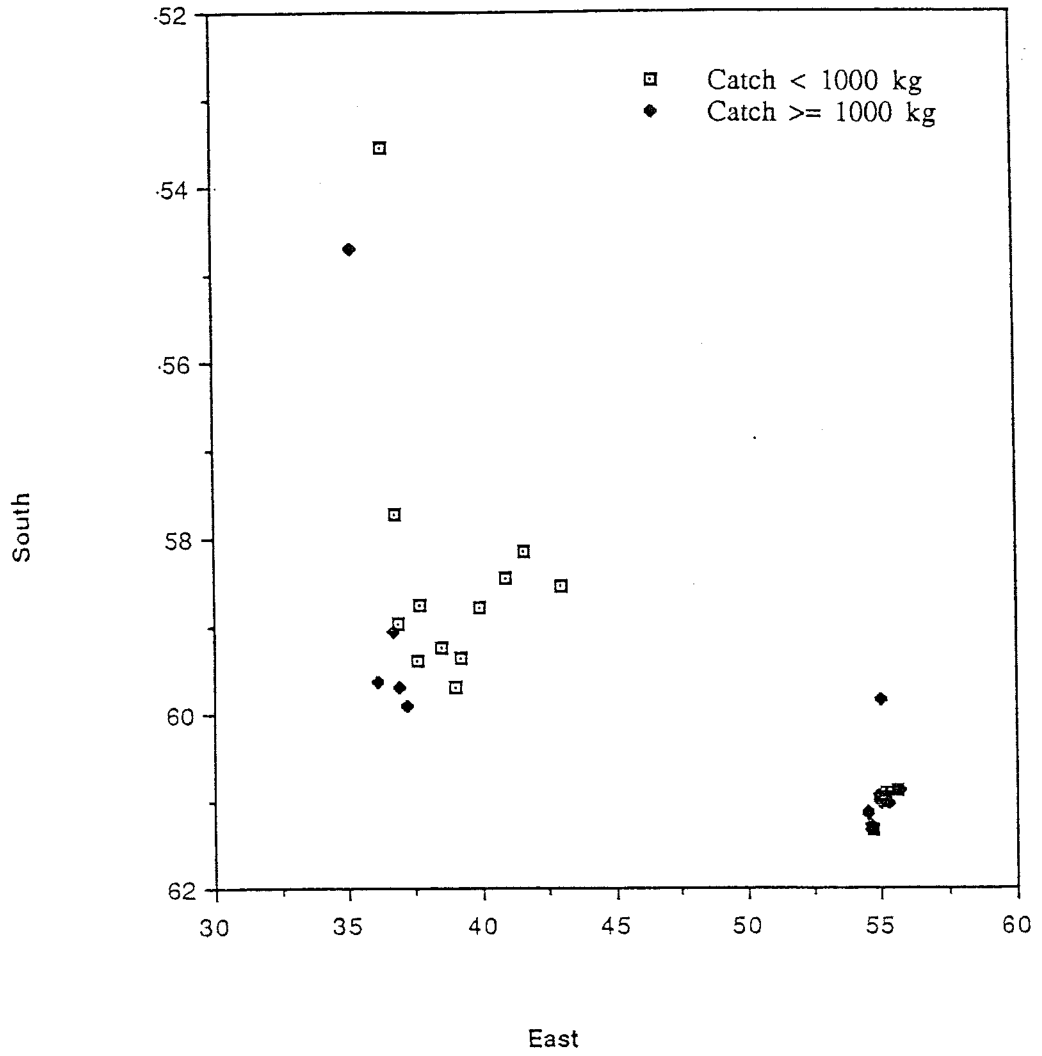
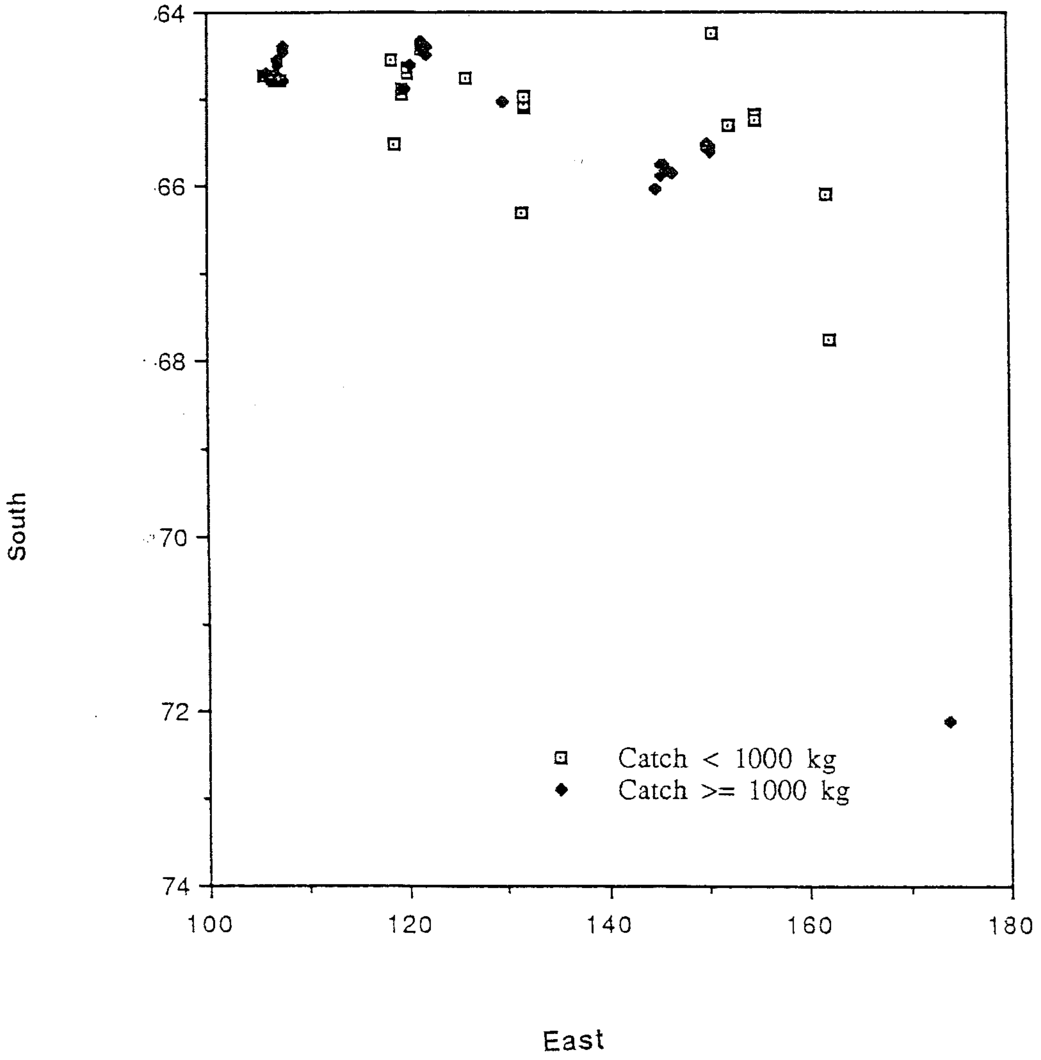


Figure 3: Spatial location of hauls by RV *Odyssey*. Hauls are separated according to the size of catch. Note the large number of hauls with relatively small catch and the spatial dispersion of fishing activity.



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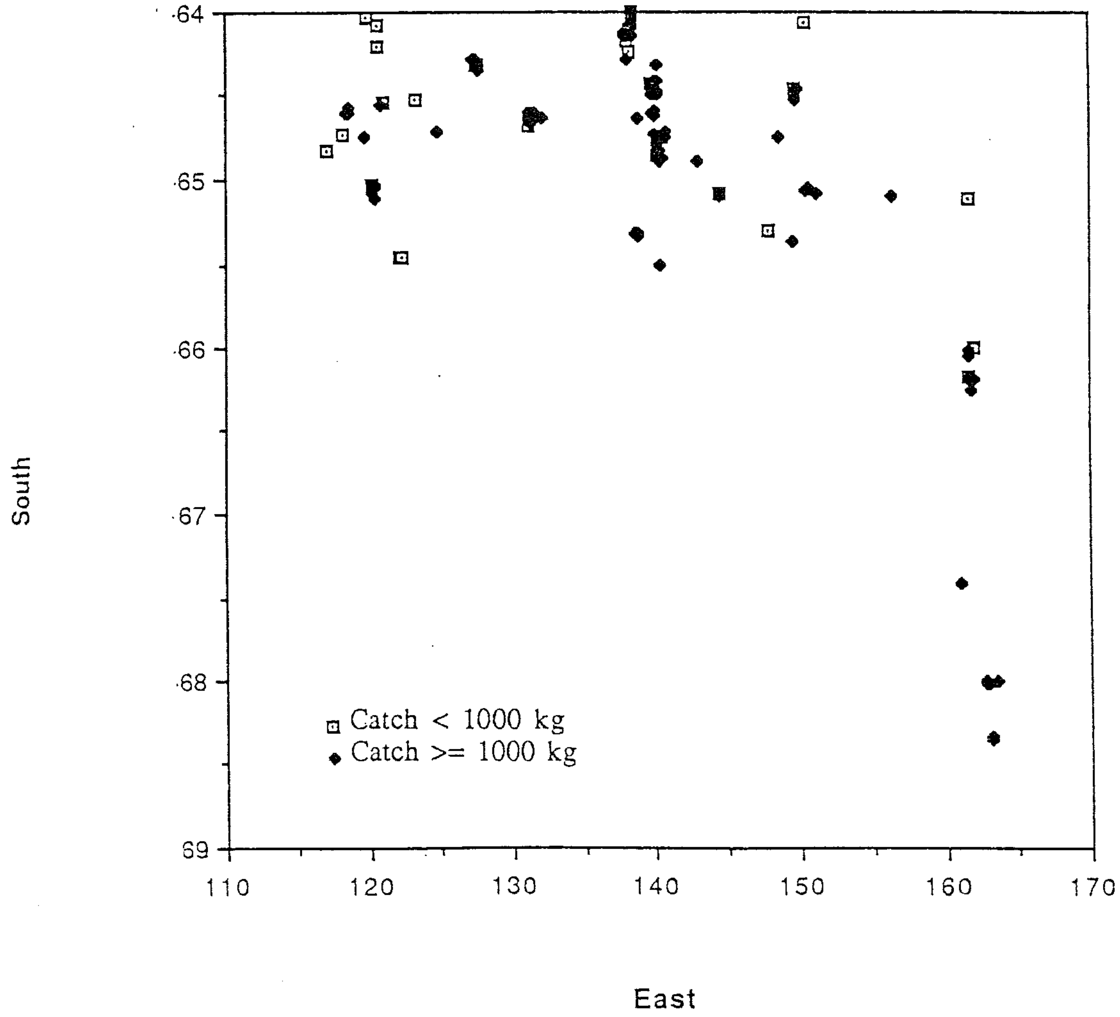


Figure 5: Spatial location of hauls by RV *Mys Tihiy*. Hauls are separated according to the size of catch.

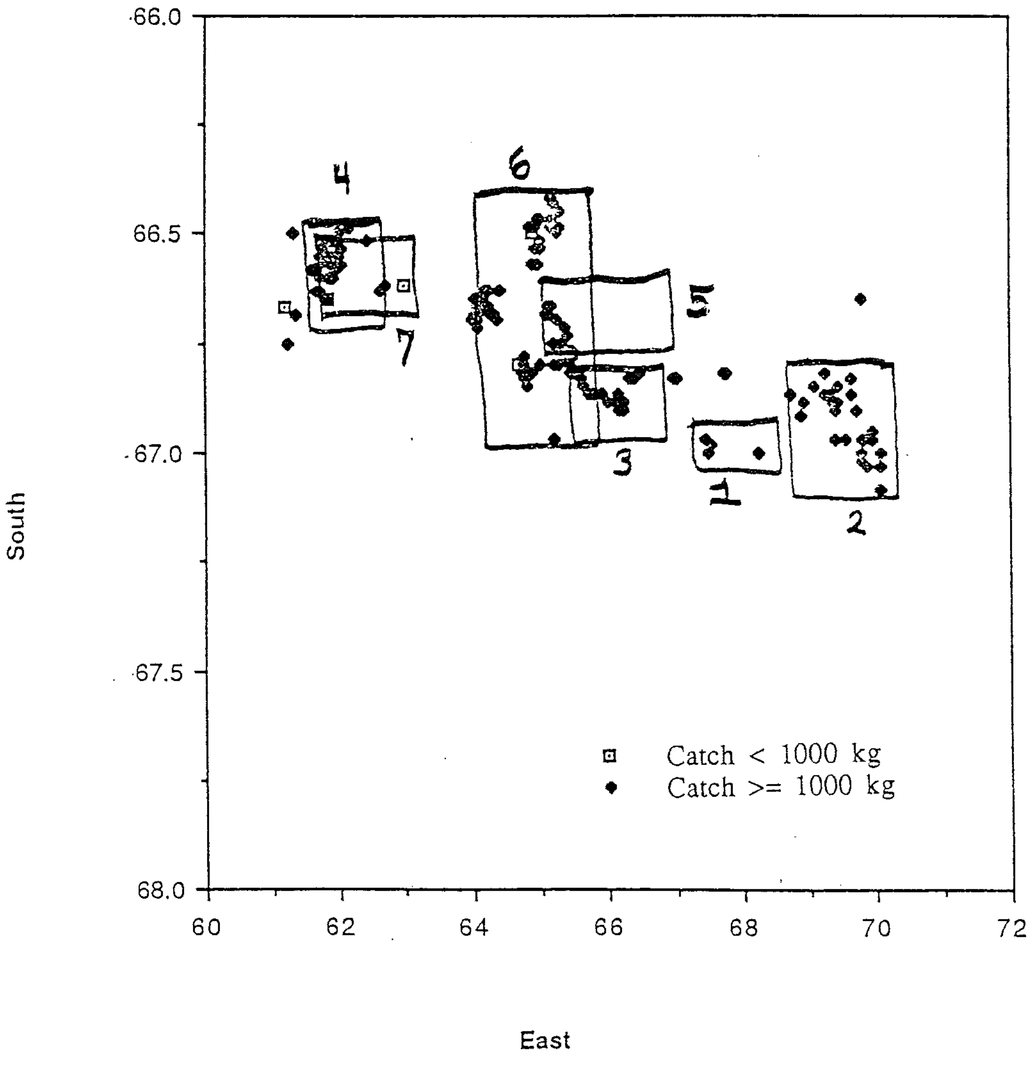


Figure 6: Spatial location of hauls by RV *Professor Derugin*, showing concentrations determined by the 50 nm rule. Concentrations are drawn approximately to scale. It is likely that concentrations 3, 5, and 6 and 4 and 7 are the same, but were encountered in a temporarl sequence that makes a firm conclusion difficult.

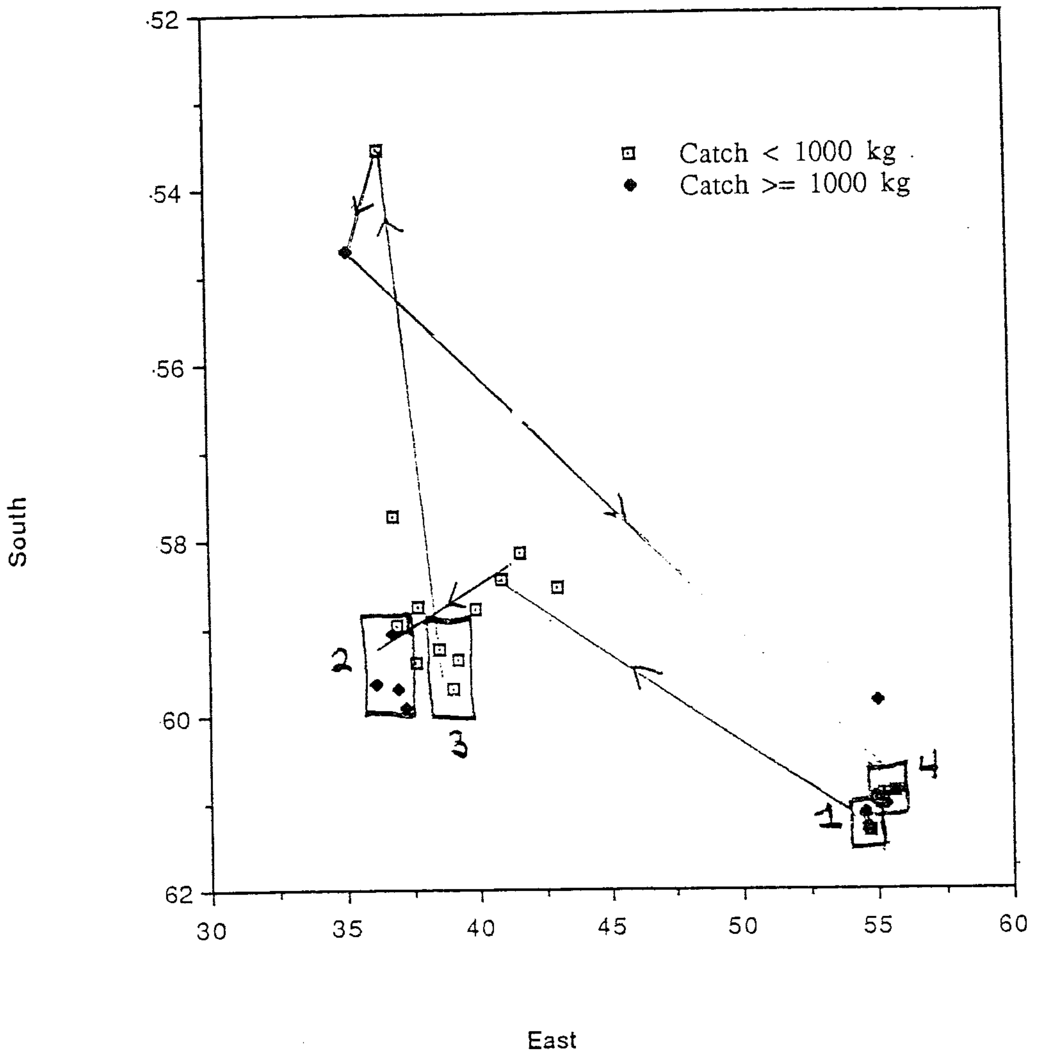


Figure 7: Spatial location of hauls by RV *Odyssey*, showing concentrations determined by the 50 nm rule. Concentrations are drawn approximately to scale. In addition, the vessel path between concentrations is shown. It is likely that concentrations 1 and 4 are the same and that 2 and 3 are in fact part of a larger concentration.

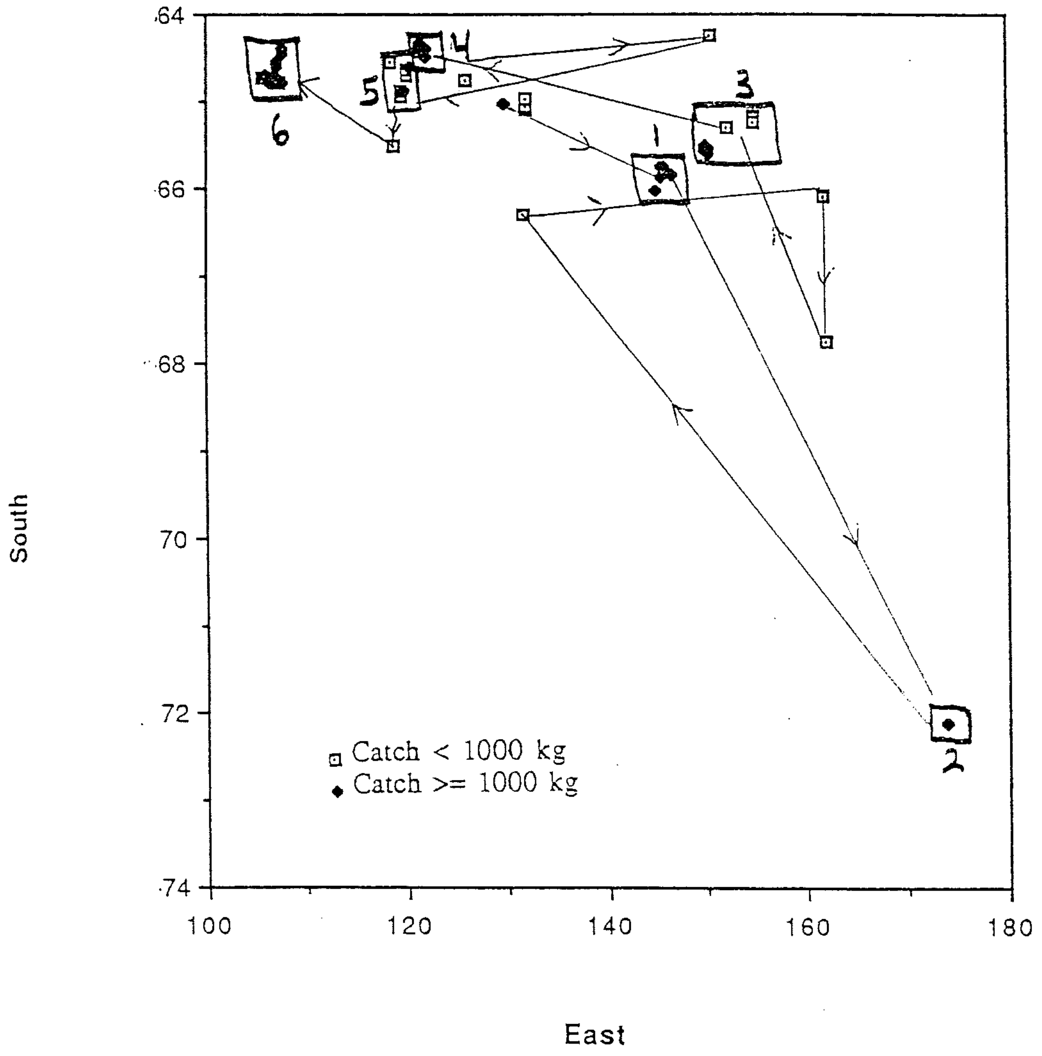
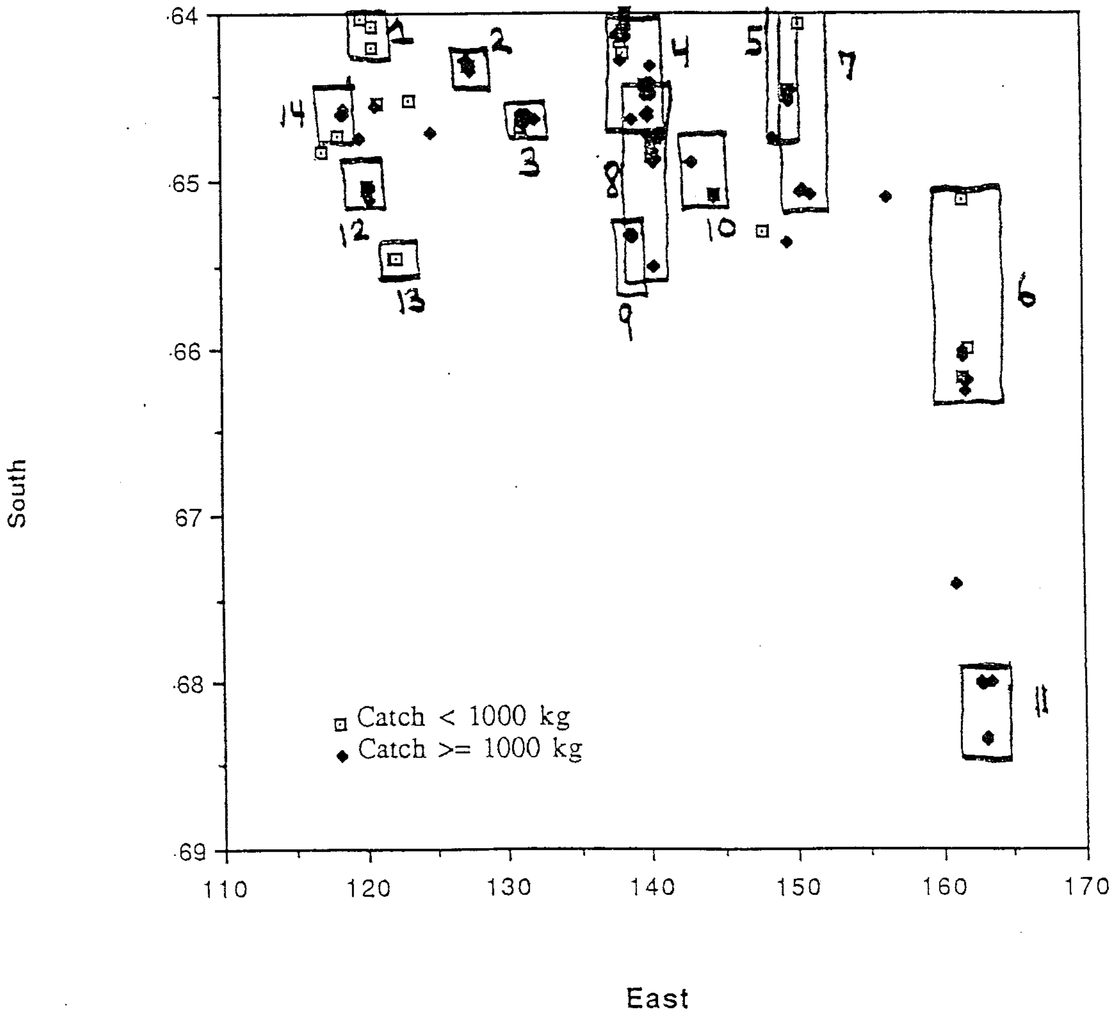


Figure 8: Spatial location of hauls by RV *Mys Dalniy*, showing concentrations determined by the 50 nm rule. Concentrations are drawn approximately to scale. In addition, the vessel path between concentrations is shown.



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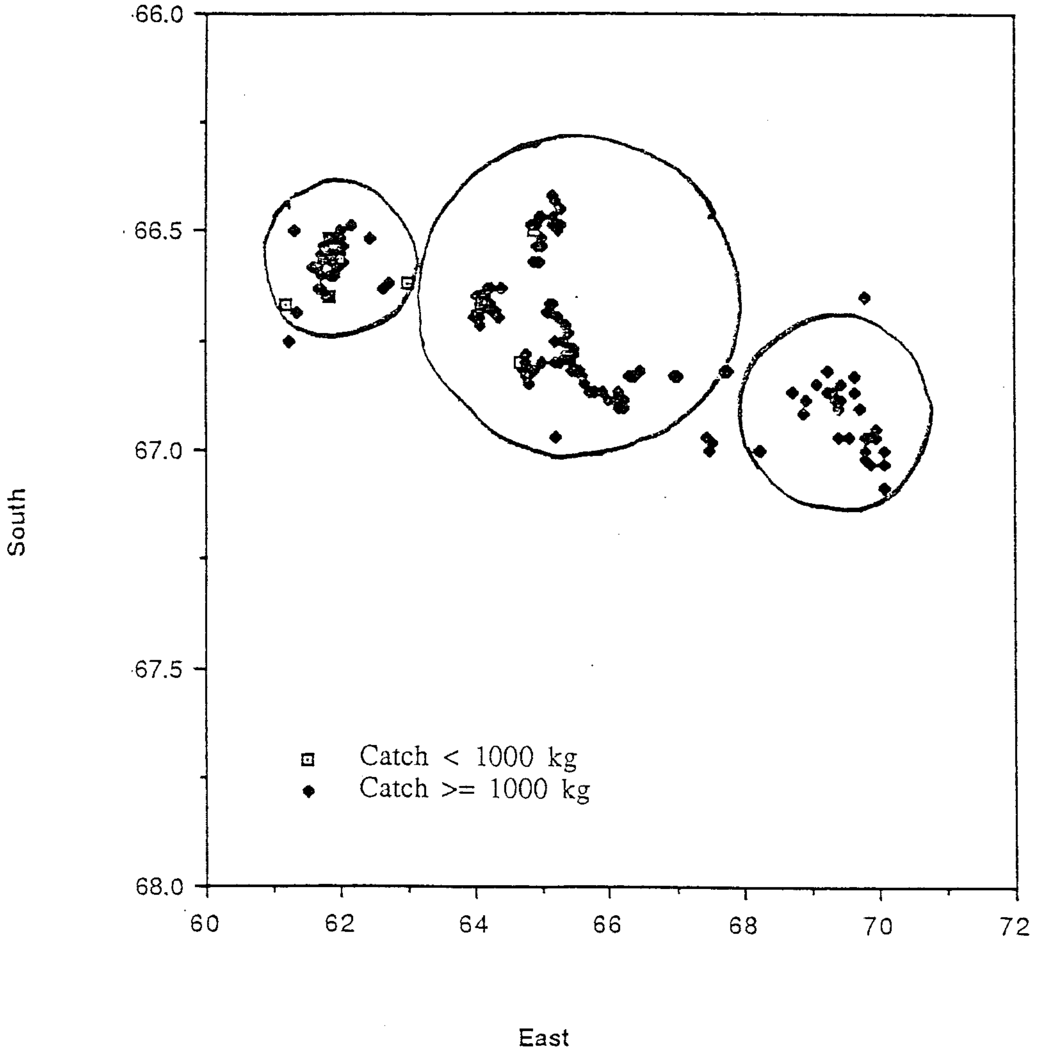


Figure 10: An alternate definition of concentrations, for the data from RV *Professor Derugin*. Circles were drawn around collections of points that appear to "aggregate" naturally. Because of the difference in spatial scales, the actual shape of the concentrations would be elliptical.

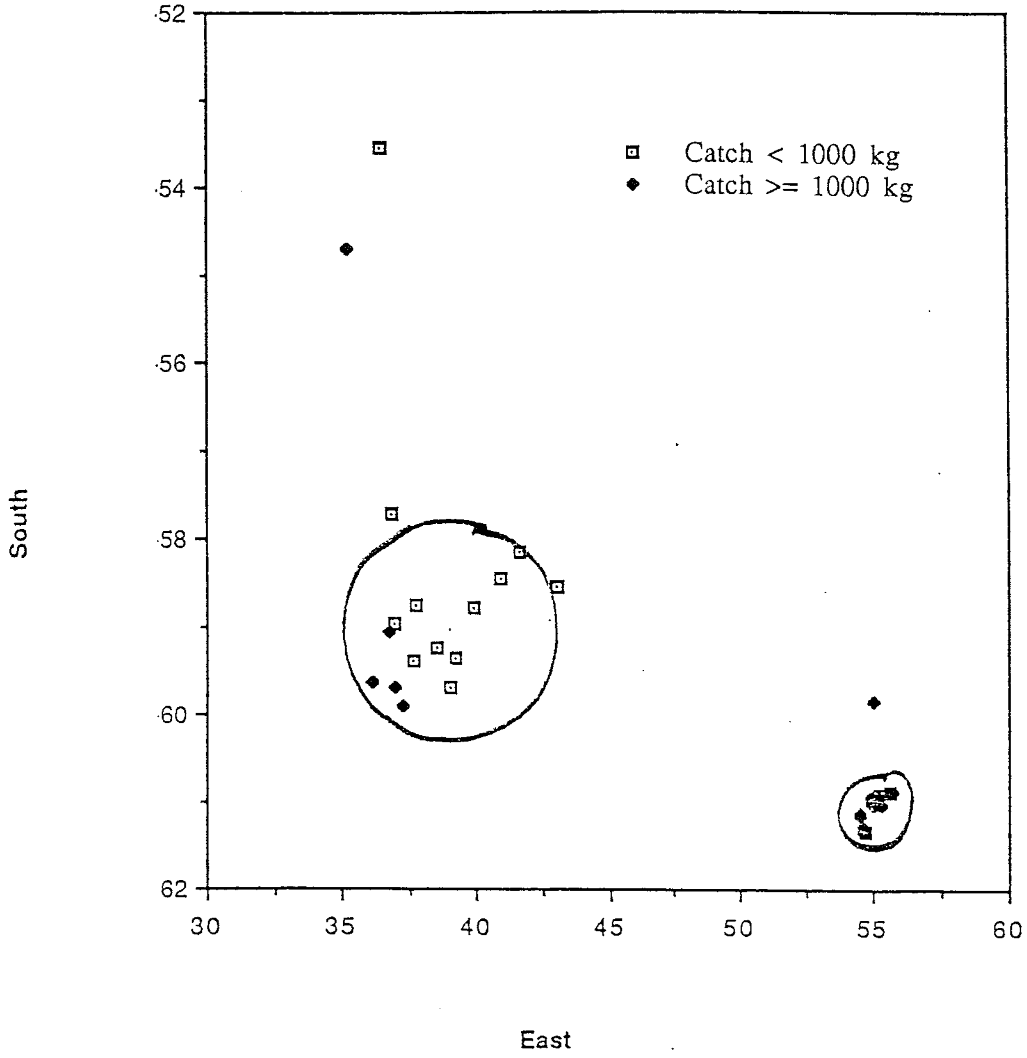
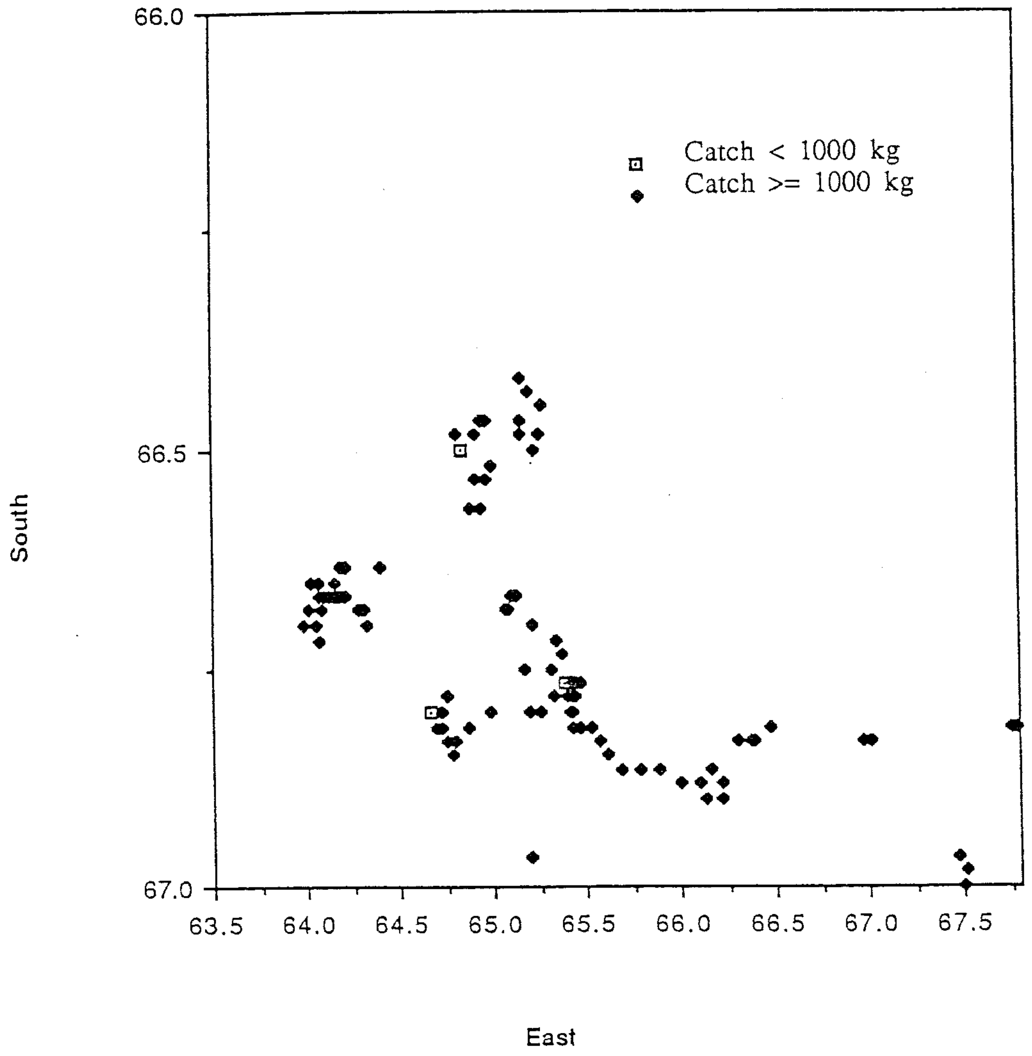


Figure 11: An alternate definition of concentrations, for the data from RV *Odyssey*. Circles were drawn around collections of points that appear to "aggregate" naturally. Because of the difference in spatial scales, the actual shape of the concentrations would be elliptical.



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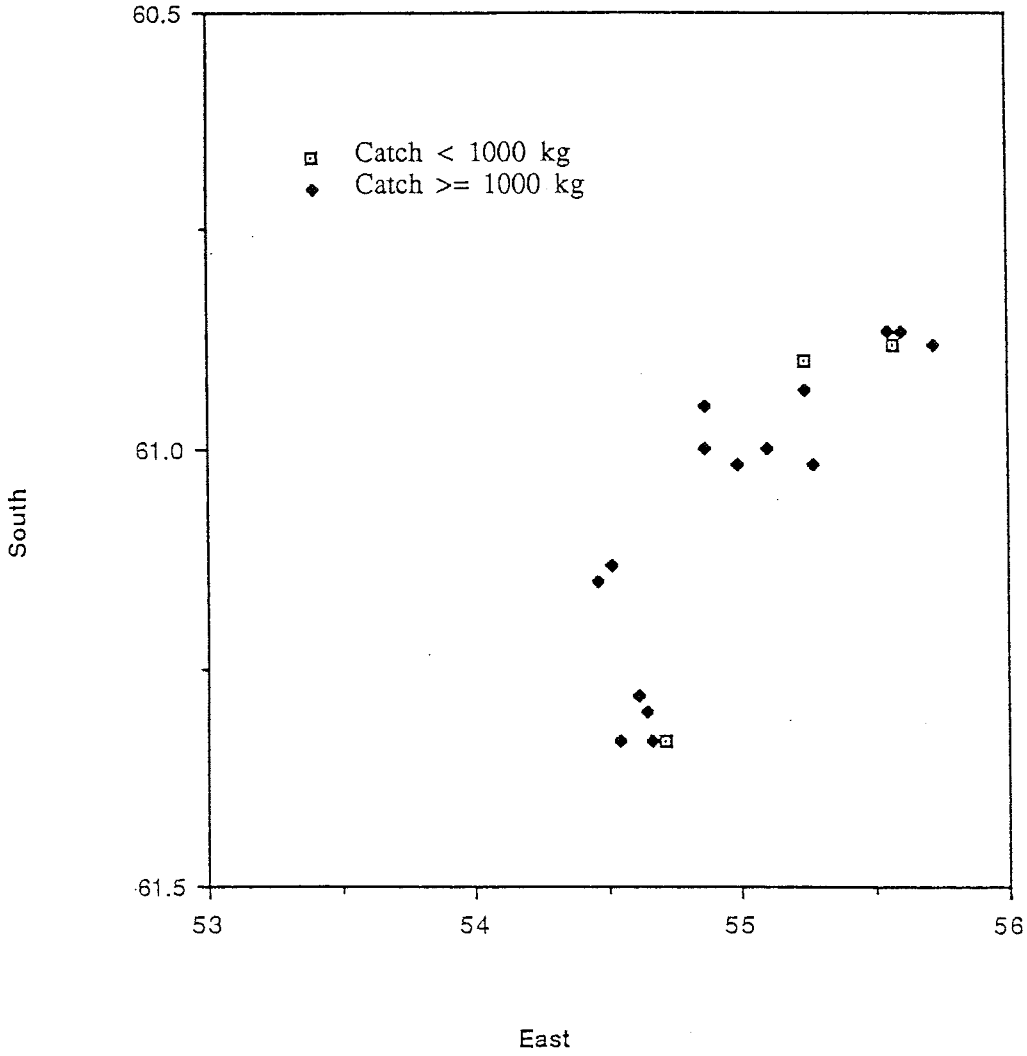

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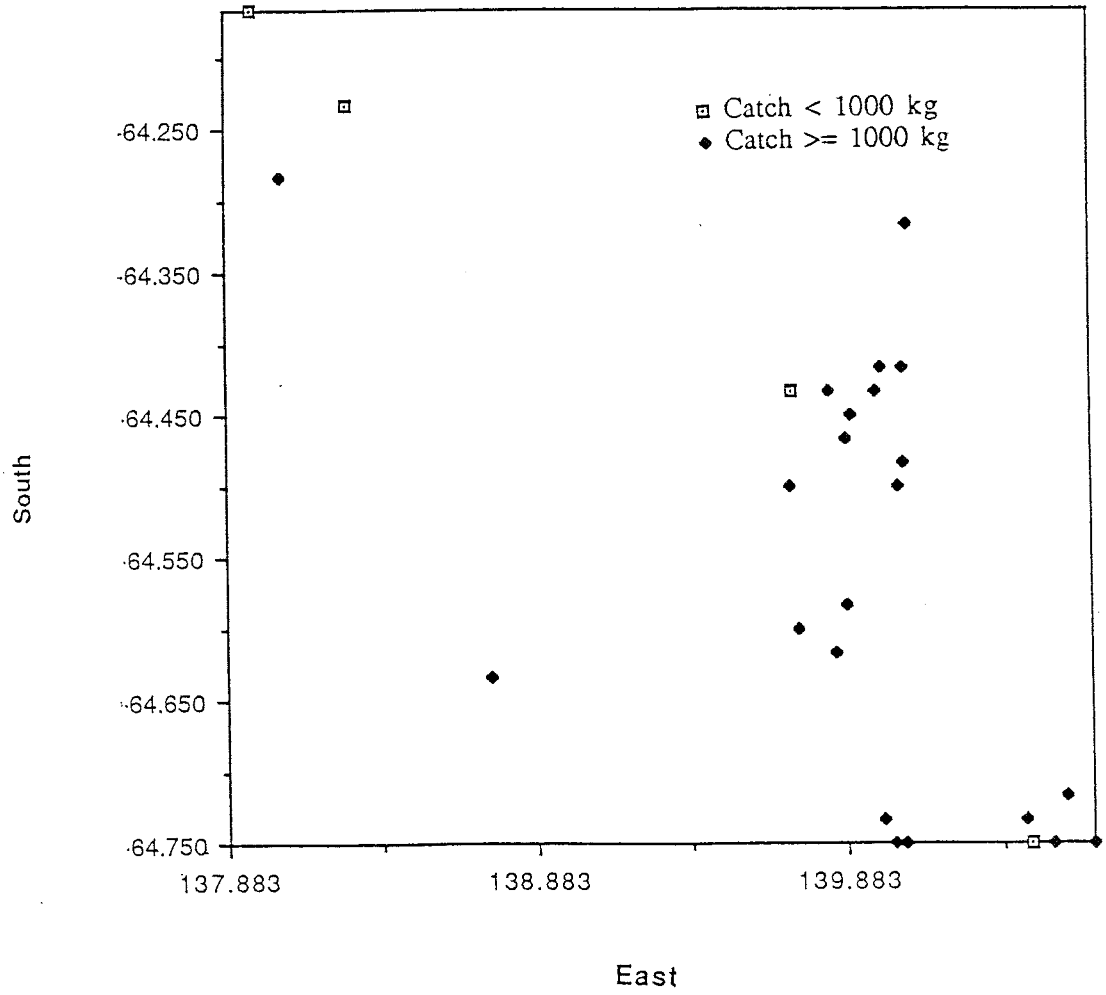

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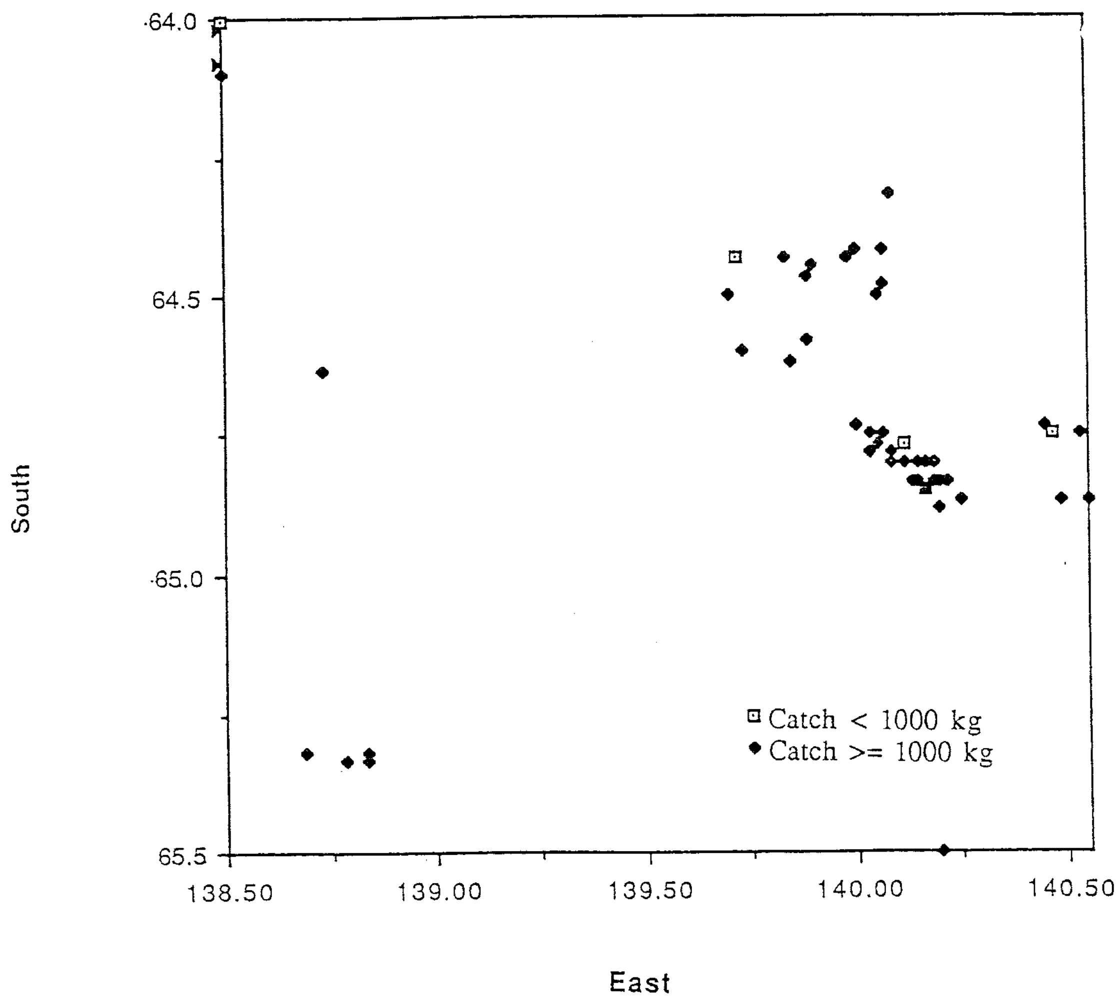
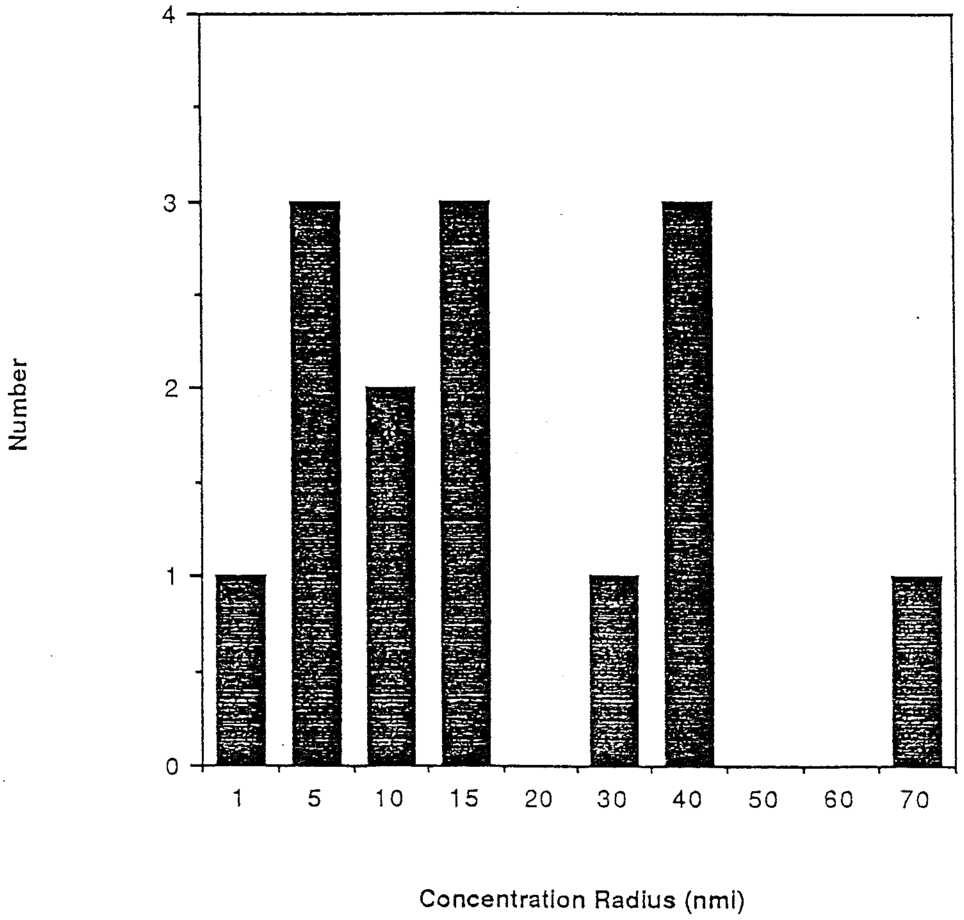


Figure 15: A finer scale spatial plot of hauls by RV *Mys Tihiy* in concentration 8. Note the large gap in fishing activity. From log-book data it is impossible to tell if krill were present in this region and no fishing was attempted because the boundary of the concentration was being delineated or if krill at fishable levels were absent from the region.



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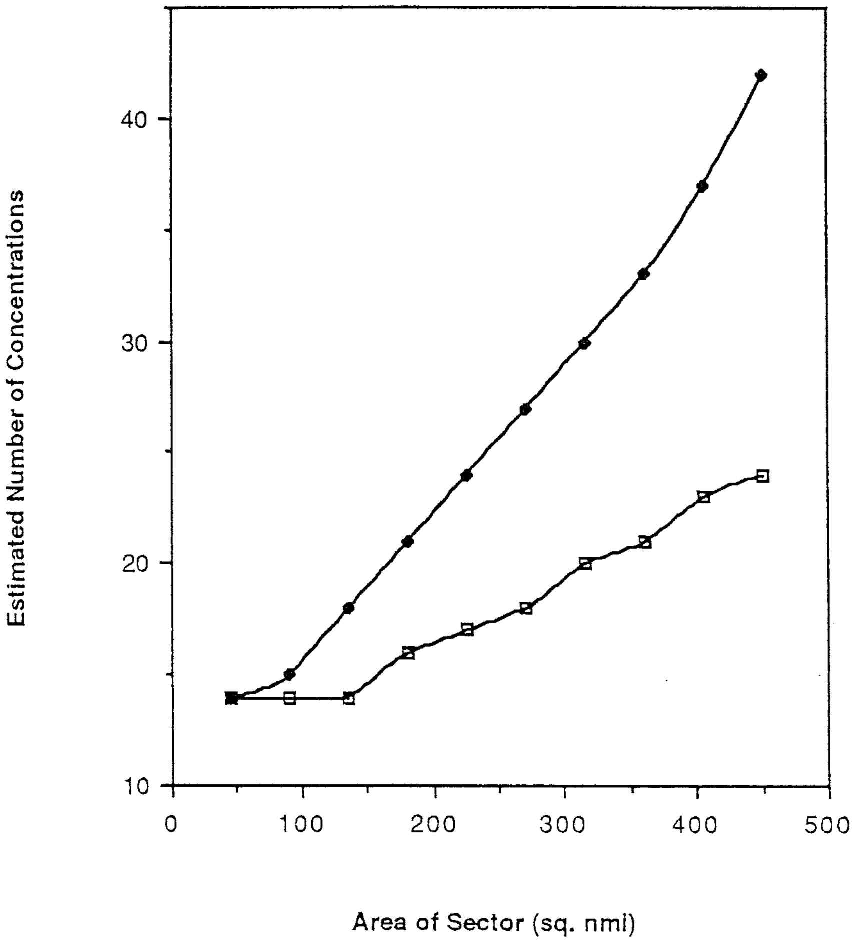

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Figure 9: Position spatiale des chalutages du navire *Mys Tihiy*, montrant des concentrations déterminées par la règle des 50 milles nautiques. Les concentrations sont dessinées approximativement à l'échelle. De plus, le trajet du navire entre les concentrations est montré. Il est probable que les concentrations 1 et 14; 4, 8 et 9; et 5 et 7 soient les mêmes, mais elles ont été rencontrées dans une succession temporelle qui rend une telle identification difficile.

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Figura 11: Una definición alternativa de las concentraciones, para los datos proveniente del navío *Odyssey*. Círculos se han dibujado alrededor de grupos de puntos que parecen "agregarse" naturalmente. Debido a la diferencia en las escalas espaciales, la configuración verdadera de las concentraciones sería elíptica.

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WS-KCPUE-89/8

CPUES, BODY LENGTH AND GREENNESS OF ANTARCTIC KRILL DURING 1987/88 SEASON IN THE FISHING GROUND NORTH OF LIVINGSTON ISLAND

Y. Endo and T. Ichii

Abstract

In order to identify whether or not there was a marked change in two kinds of CPUEs, body length and greenness of krill during the fishing season, these parameters were examined for each 10-day period of the Japanese krill fishery in the northern waters of Livingston Island in the 1987/88 season. It appears that Japanese trawlers have not fished krill concentrations to the extent that a decrease in krill biomass in this area can be detected from these data. The percentages of "Egui" as an indicator of greenness of krill were too variable among trawlers to be an objective indicator at present.

Résumé

Deux sortes de CPUE, la longueur du corps et la teinte verte du krill ont été examinées pour chaque période de 10 jours, pendant la saison 1987/88, pour la pêcherie japonaise de krill dans les eaux au nord de l'île Livingston, afin de démontrer si elles dénotent un changement significatif pendant la saison de pêche. Les CPUE et la longueur du corps du krill n'ont pas changé pendant la saison de pêche. Par conséquent, il semblerait que les chalutiers japonais n'ont pas pêché les concentrations de krill à un point tel que la diminution de la biomasse du krill dans cette région puisse être décelée de ces données. Les pourcentages d'"Egui", comme indicateur de la teinte verte du krill, étaient trop variables d'un chalutier à l'autre pour qu'il soit à l'heure actuelle un indicateur objectif.

Резюме

Два вида CPUE, данные по длине и степени зелености криля, полученные по каждому десятидневному периоду ведения промысла Японией в водах к северу от о-ва Ливингстон в течение 1987/88 г., были рассмотрены для того, чтобы обнаружить, изменялись ли эти элементы в значительной мере в течение промыслового сезона. Изменения CPUE и длины криля в течение промыслового сезона отсутствовали. Полученные данные указывают на то, что промысел криля Японией в этом районе не привел к сокращению его биомассы. Величины "Egui" слишком варьировались от траулера к траулеру и в настоящее время не могут служить надежным показателем зелености криля.

Resumen

Para determinar definitivamente si hubo un cambio notable en dos tipos de CPUE, longitud del cuerpo y verdor del krill durante la temporada de pesca, se examinaron estos parámetros para cada período de 10 días de pesca de krill japonesa en las aguas nortinas de la Isla Livingston en la temporada 1987/88. Parece que los buques de arrastre japoneses no han capturado concentraciones de krill hasta el punto de que una disminución en la biomasa de krill en esta área se pueda detectar en estos datos. Los porcentajes de "Egui" como un indicador del verdor del krill, fueron muy variados entre los buques de arrastre para dar una indicación objetiva al momento.

1. INTRODUCTION

The northern waters of Livingston Island were amongst the largest fishing grounds for the Japanese krill fishery in the 1987/88 season. Fishing operations in this area were conducted from early January to late March 1988. It was in this area that RV *Kaiyo Maru* conducted a co-operative survey with a Japanese trawler on the target strength of krill. Additionally, after the co-operative survey, krill biomass on this fishing ground was estimated by an echo integrator.

Two kinds of CPUEs, body length and greenness of krill were examined for each 10-day period from early January to late March as a case study to identify whether or not they show a marked change during the fishing season.

2. MATERIALS AND METHODS

We defined the fishing ground north of Livingston Island as the area between 59°30'W and 61°30'W and between 61°30'S and 62°30'S (Figure 1). Two kinds of CPUEs, catch/tow and catch/towing time (minute), were computed from the data recorded on log books of Japanese trawlers. A CPUE incorporating searching time was not collected and there were no essential searching activities (primary searching time of Butterworth,1988), at least during the co-operative study. Trawlers sail against the wind, trawl on the wind and spend time searching while waiting to finish processing (secondary searching time).

Each ship was required to measure body lengths, from the tip of rostrum to the posterior end of telson, of 50 animals from one haul per day.

Condition of "Egui" or greenness of krill has become an item to be recorded routinely since the 1987/88 season. Only those catches in which animals showed greenness to the extent that they are not suitable even for production of boiled and frozen products were checked.

Data on the above items, coming from trawls made in the area between 59°30'W and 61°30'W and between 61°30'S and 62°30'S, were examined.

3. RESULTS AND DISCUSSION

Trawling positions in January were distributed from the waters about 30 n miles north of Livingston Island to the waters north of Elephant Island (Figure 2). From early February to mid-March, fishing efforts were concentrated in the waters northwest of Livingston Island. In late March, the major fishing ground moved to the waters west of Elephant Island.

There was no significant difference in both catch/tow and catch/towing time among 10-day periods from early January to late March for each of seven trawlers which participated in krill fishing in this season (ANOVA, Figures 3 and 4). Catch/tow values showed little change during the fishing season. Trawlers which mainly produce peeled krill tended to show larger catch/tow values. Catch/towing time values, however, showed a somewhat irregular pattern compared with catch/tow values. Three trawlers recorded a maximum value in February, but one trawler in late March.

Length frequency distribution of krill from all the trawlers is shown in Figure 5 for each 10-day period. Although mean body length in early January was rather small, 41.8 mm, compared with those in later seasons, 45.1 to 46.7 mm, there was no significant difference in mean body length between each 10-day period during the 1987/88 season (ANOVA).

Percentages of "Egui" catches were highly variable among trawlers. No "Egui" was recorded in any 10-day period in three out of seven trawlers. One trawler, however, scored 100% "Egui" for three 10-day periods in January. Higher percentages tended to occur in January. "Egui" percentage does not seem to be an objective indicator of greenness at present. The last trawler did not leave the fishing ground but stayed there. Therefore, although Butterworth (1988) recommended collection of data on the greenness of krill to improve the abundance indices, we do not think routine collection of the data is useful.

A total of 41 905 tonnes of krill was caught in this area, which equals 57% of the total Japanese catch in the 1987/88 season. The estimated biomass of krill by the echo integrator on board RV *Kaiyo Maru* was 601 297 tonnes in the upper 200 m in the s-shaped co-operative survey area (Figure 1). After the co-operative survey between RV *Kaiyo Maru* and a trawler in late January, the fishing ground shifted southward to the continental shelf just north of Livingston Island. If we assume that the krill concentration in the co-operative survey area moved as a whole and assume no advection from adjacent areas, approximately 7% of the biomass was fished by Japanese trawlers. If krill advected from adjacent areas, the percentage would be lower.

Considering that CPUEs and the mean body length of krill did not change during the fishing season, two options are poossible: Japanese trawlers do not appear to have fished krill concentrations to the extent that a decrease in krill biomass can be detected from CPUE data in the area north of Livingston Island, or krill with similar body length were advected from adjacent areas.

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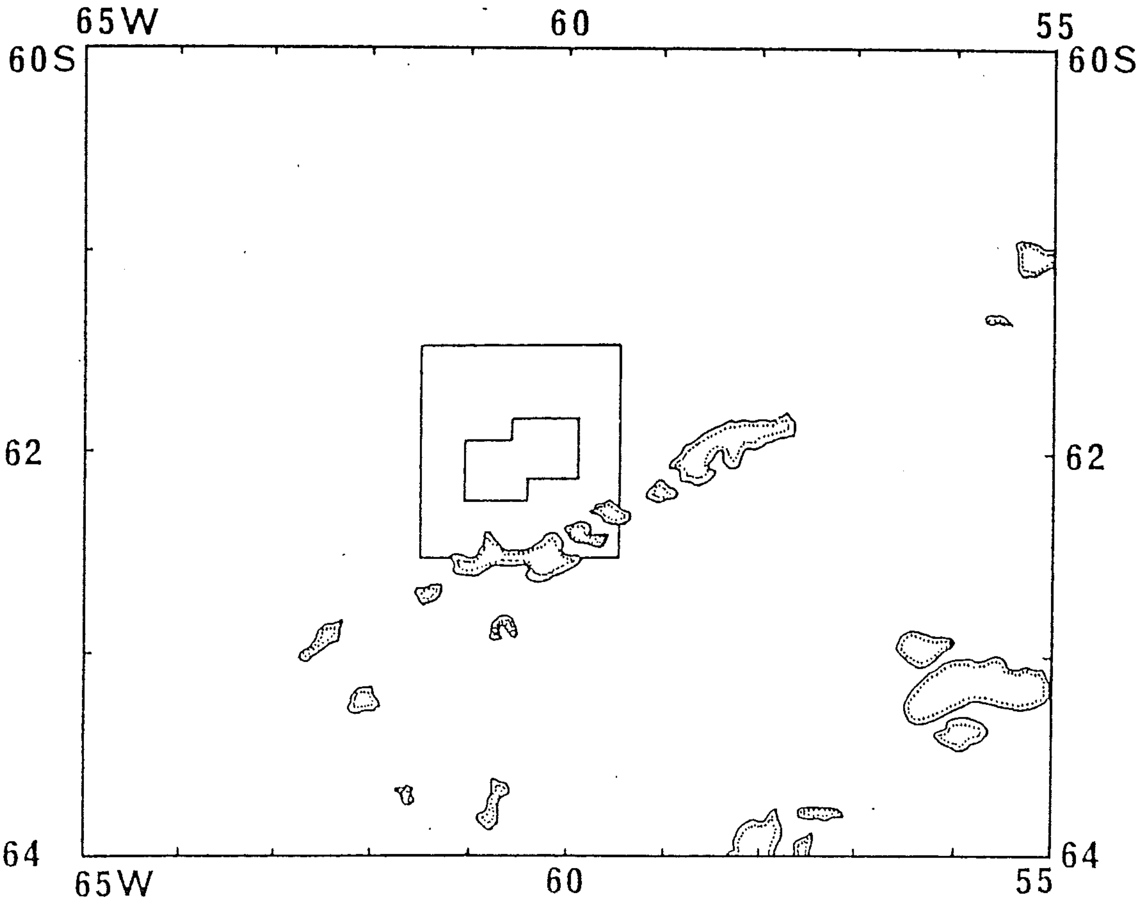


Figure 1: The fishing ground north of Livingston Island (square) and the area surveyed by RV *Kaiyo Maru* and a Japanese trawler (s-shaped area in the square).

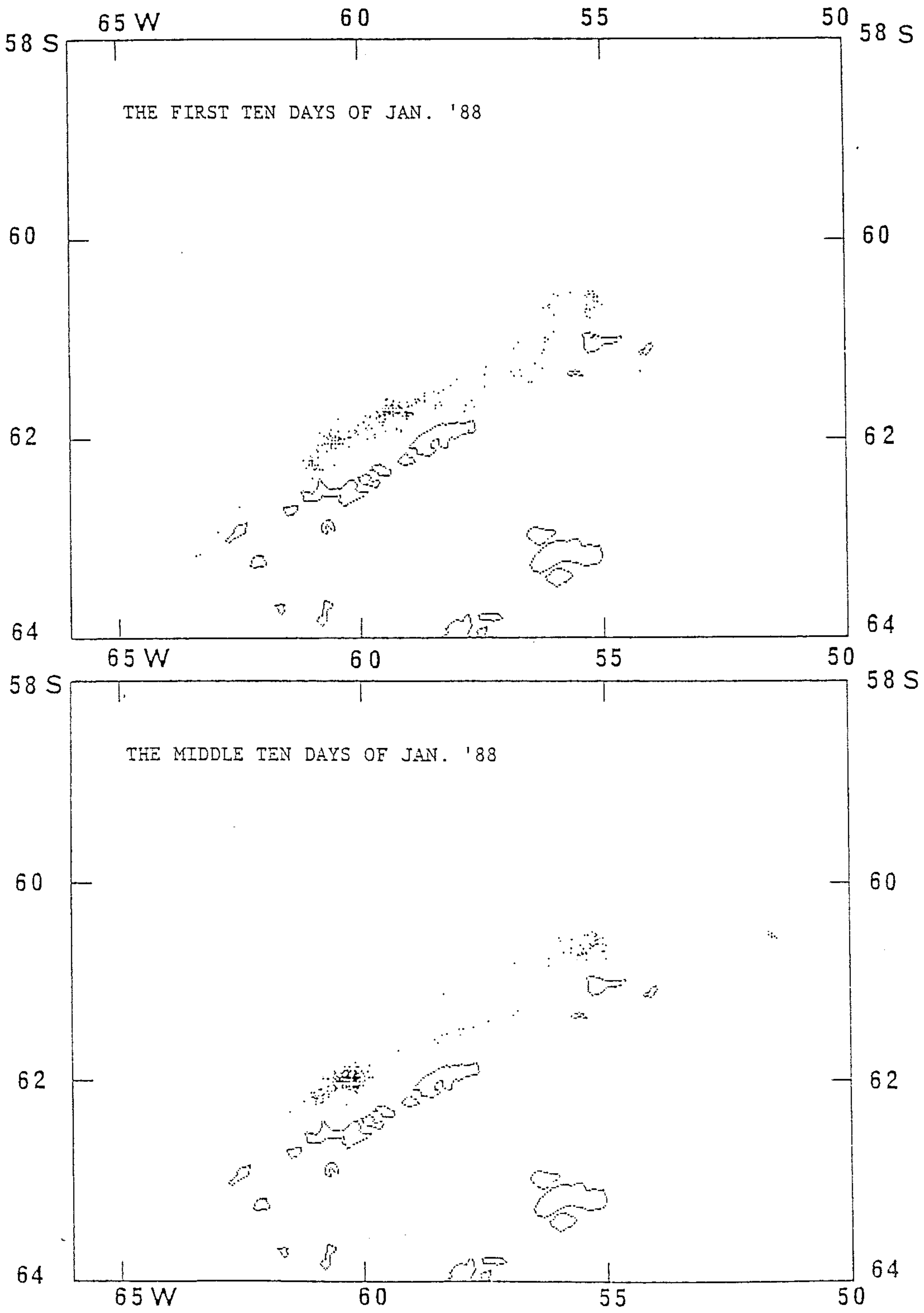


Figure 2a: Trawling positions of Japanese trawlers in the first and middle 10 days of January in the 1987/88 season.

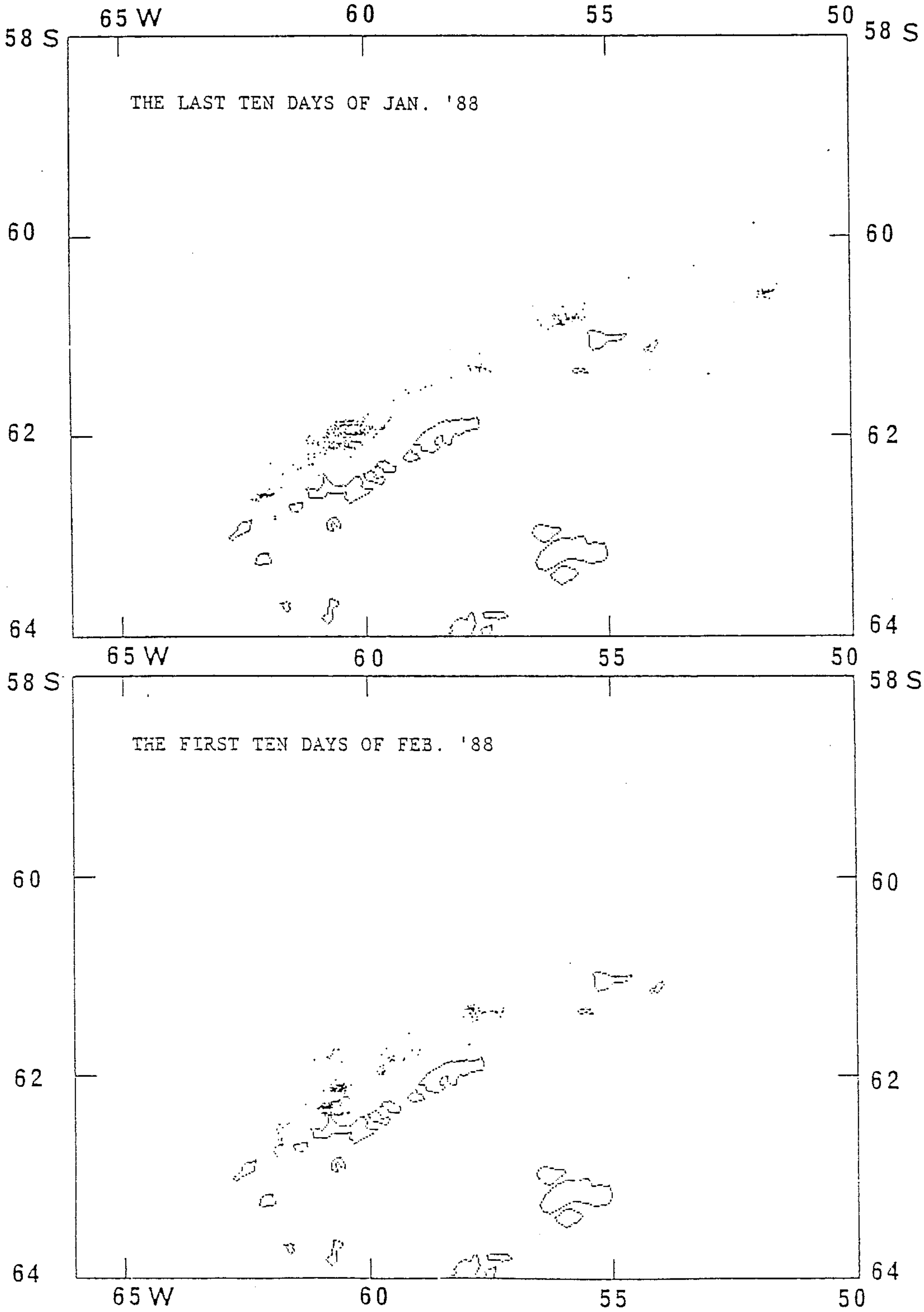
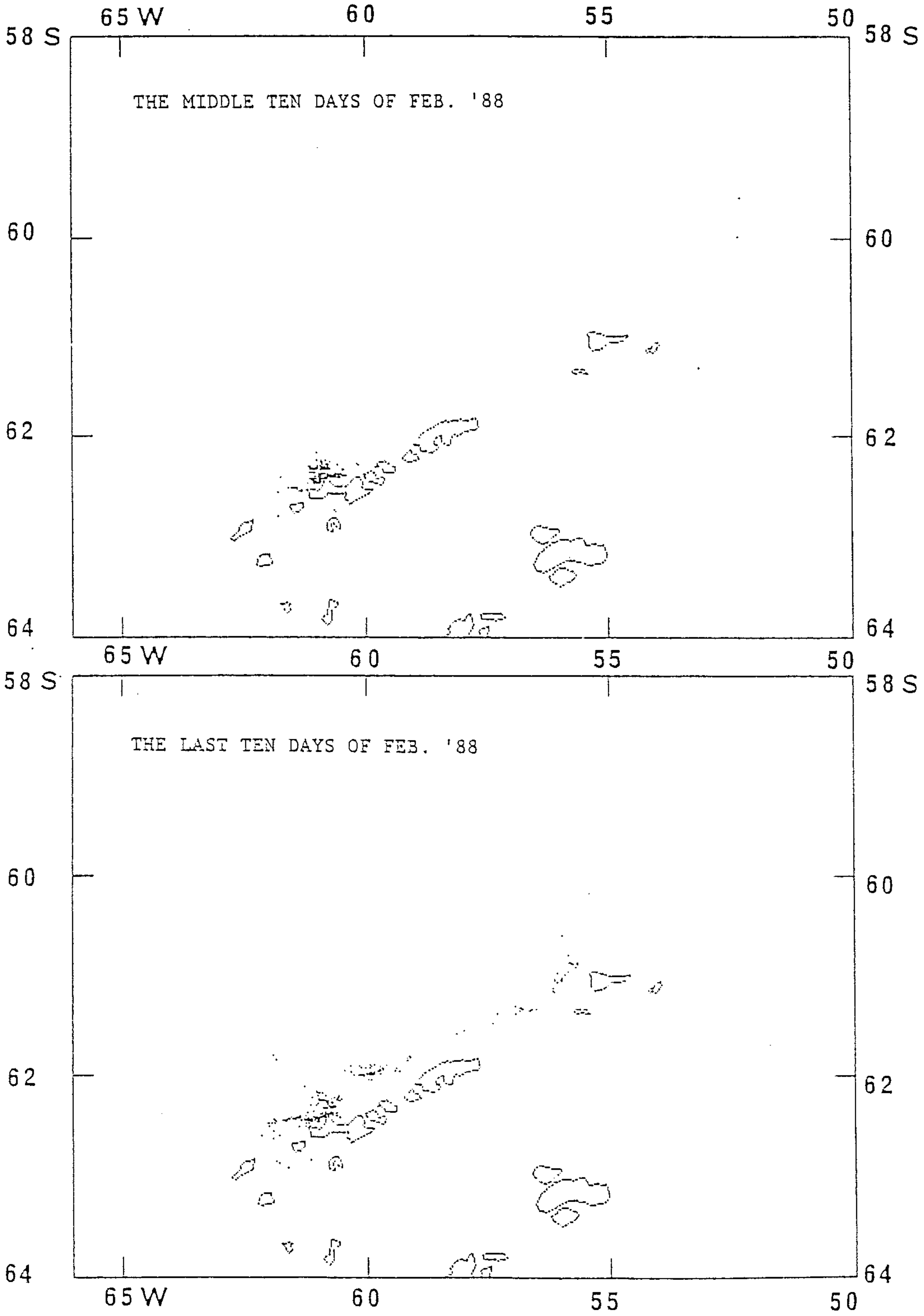


Figure 2b: Trawling positions of Japanese trawlers in the last 10 days of January and the first 10 days of February in the 1987/88 season.



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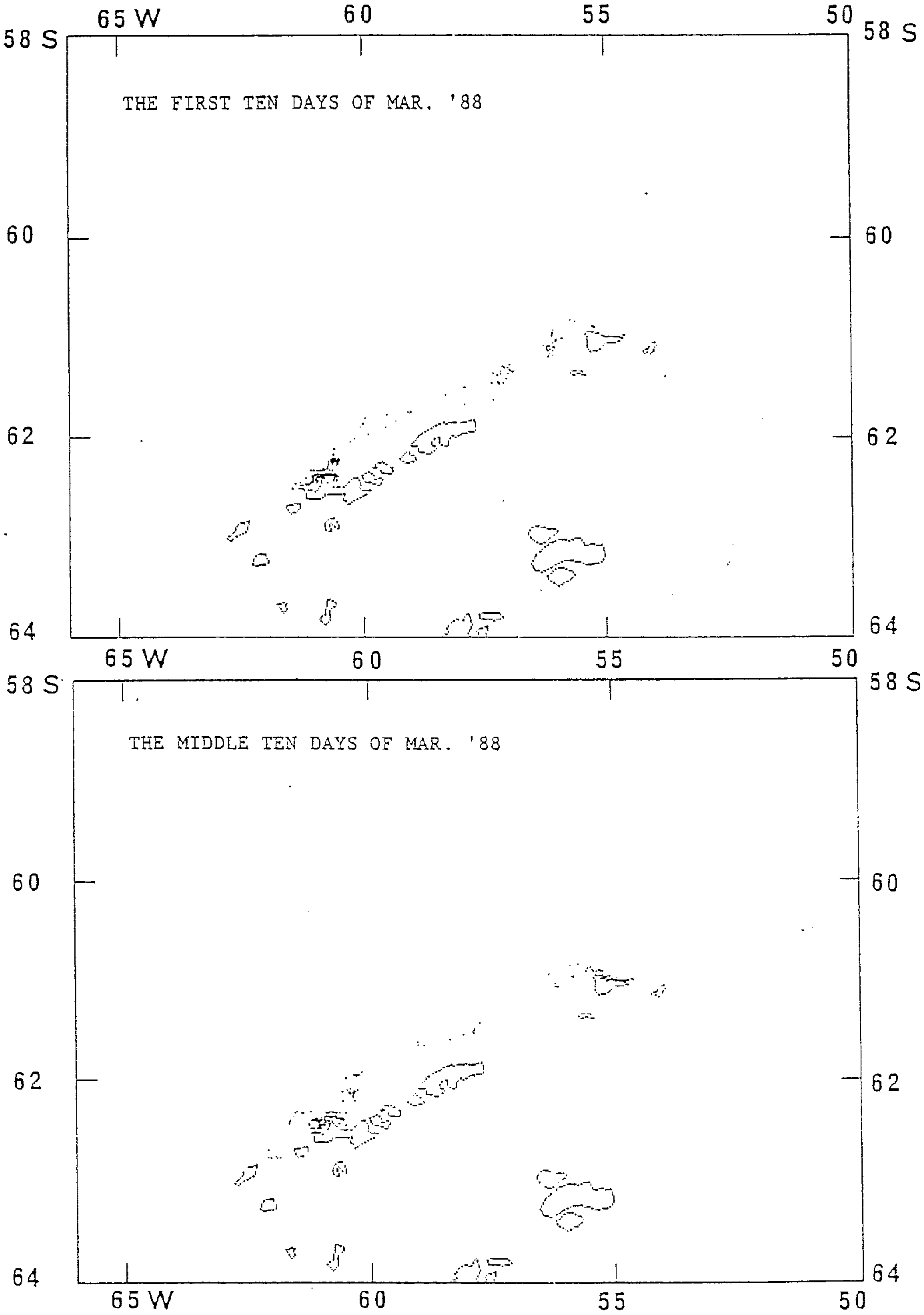

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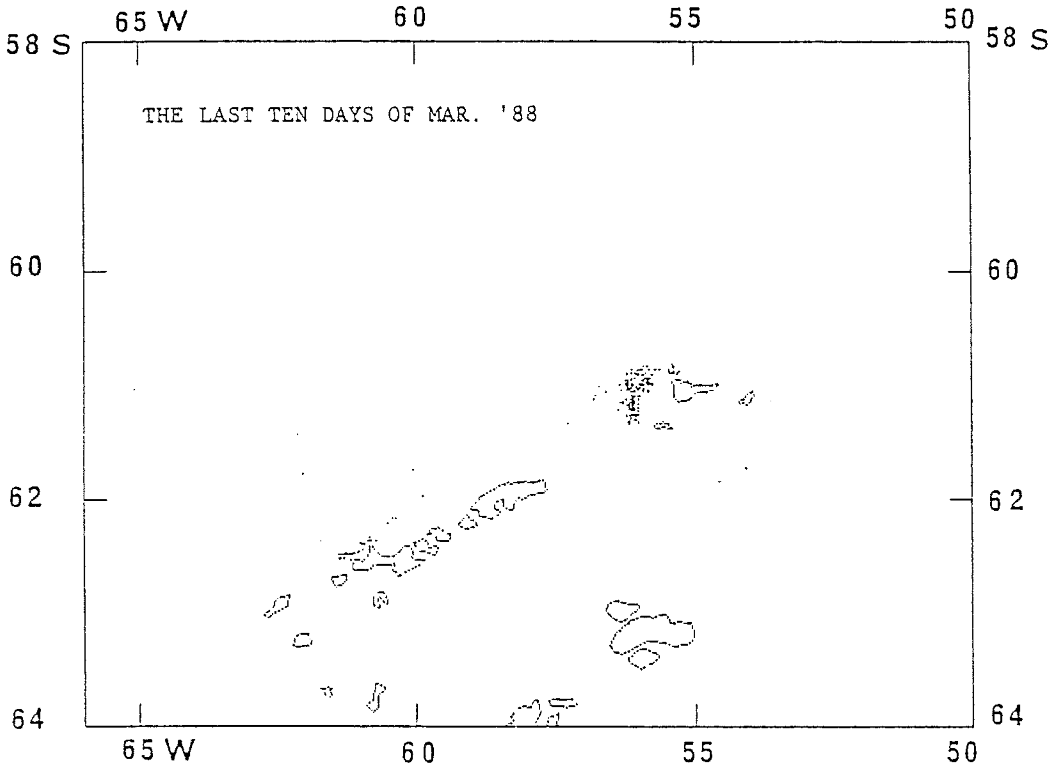
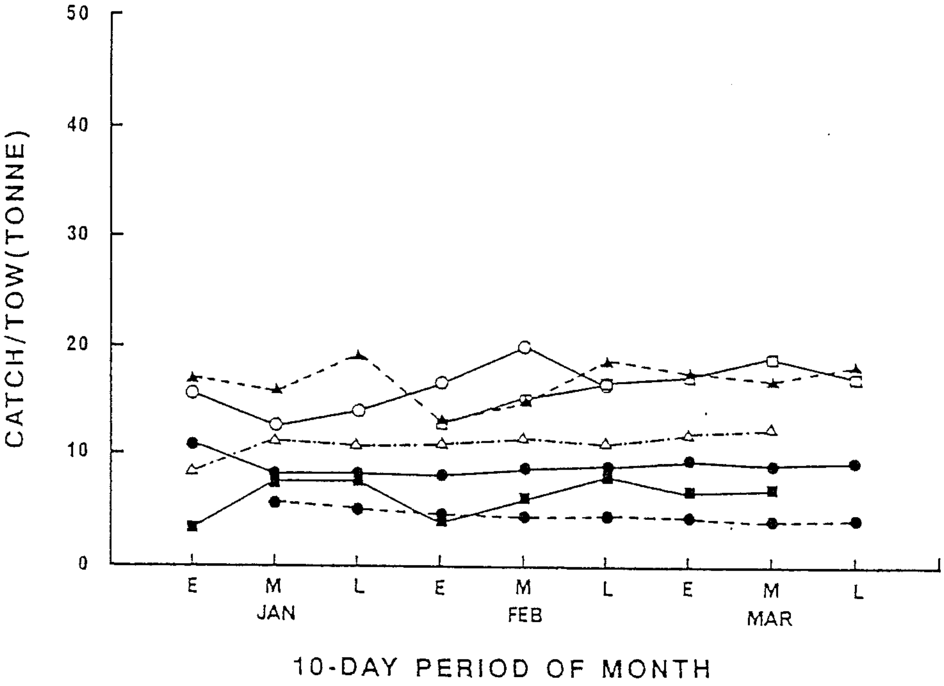


Figure 2e: Trawling positions of Japanese trawlers in the last 10 days of March in the 1987/88 season.



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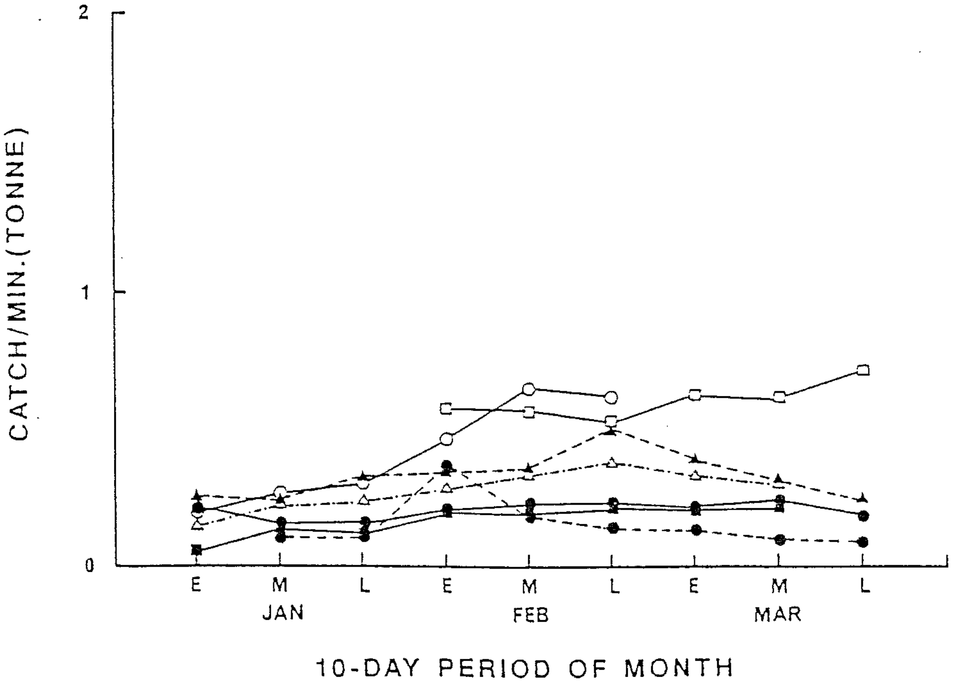

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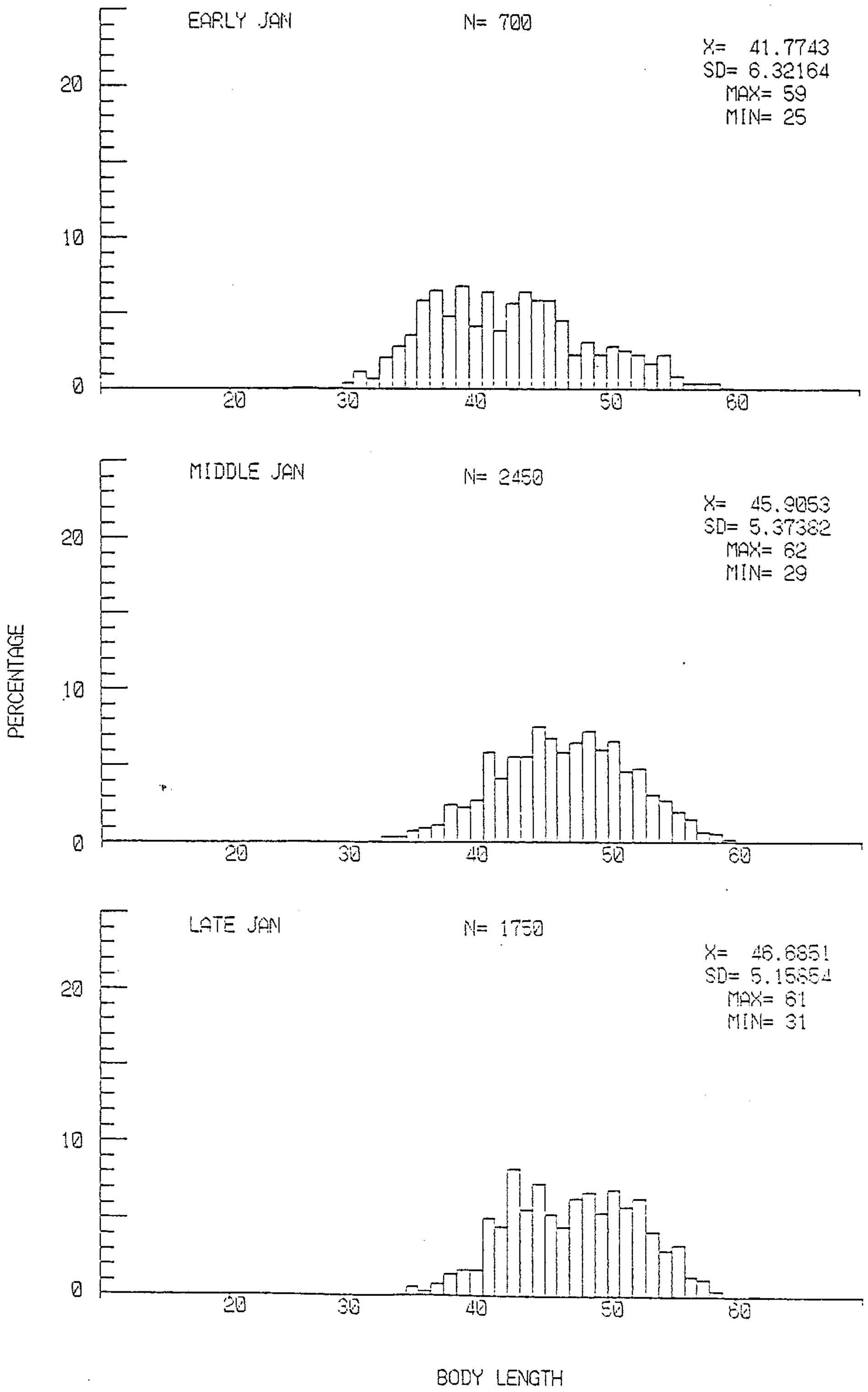

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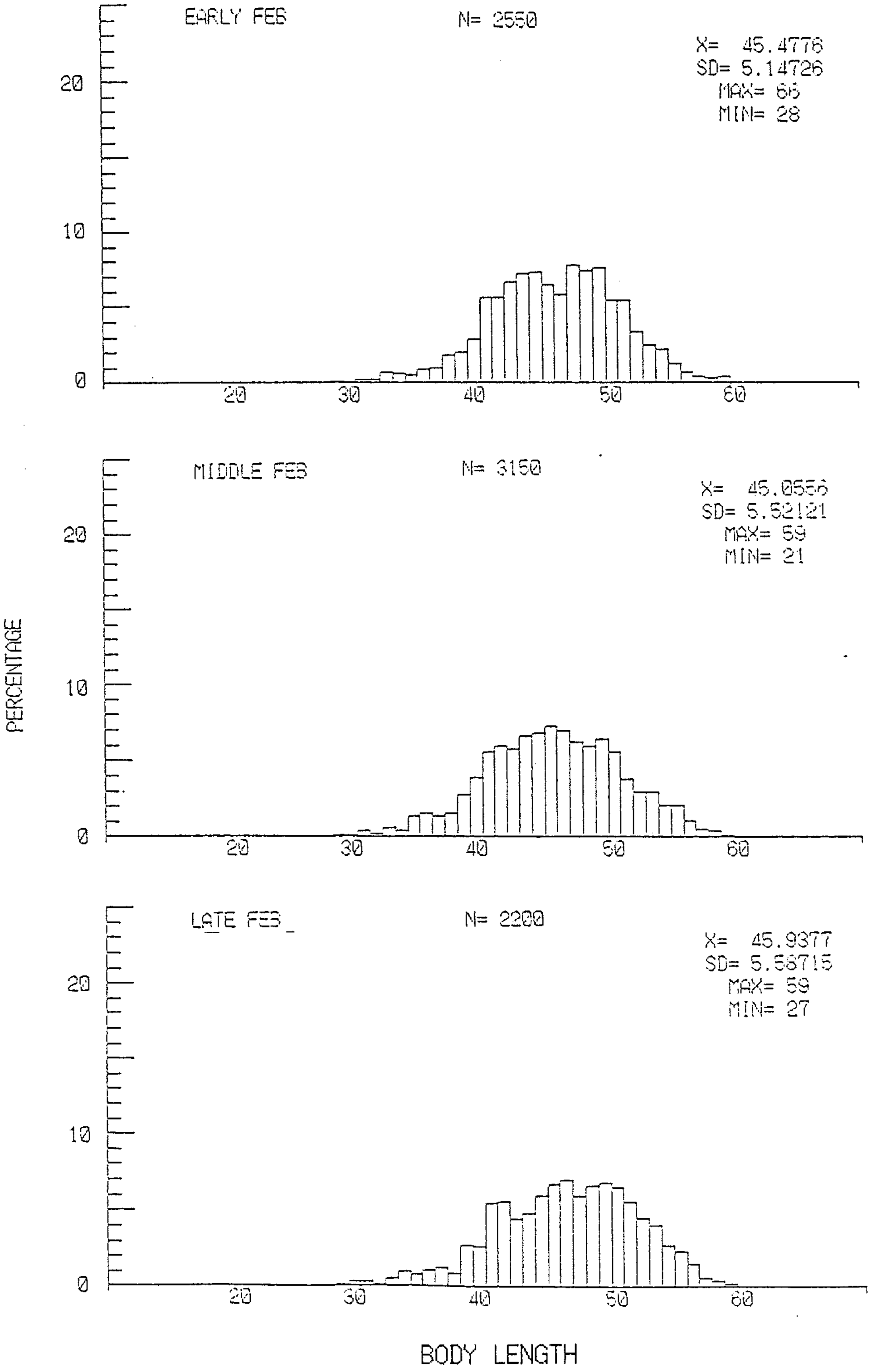
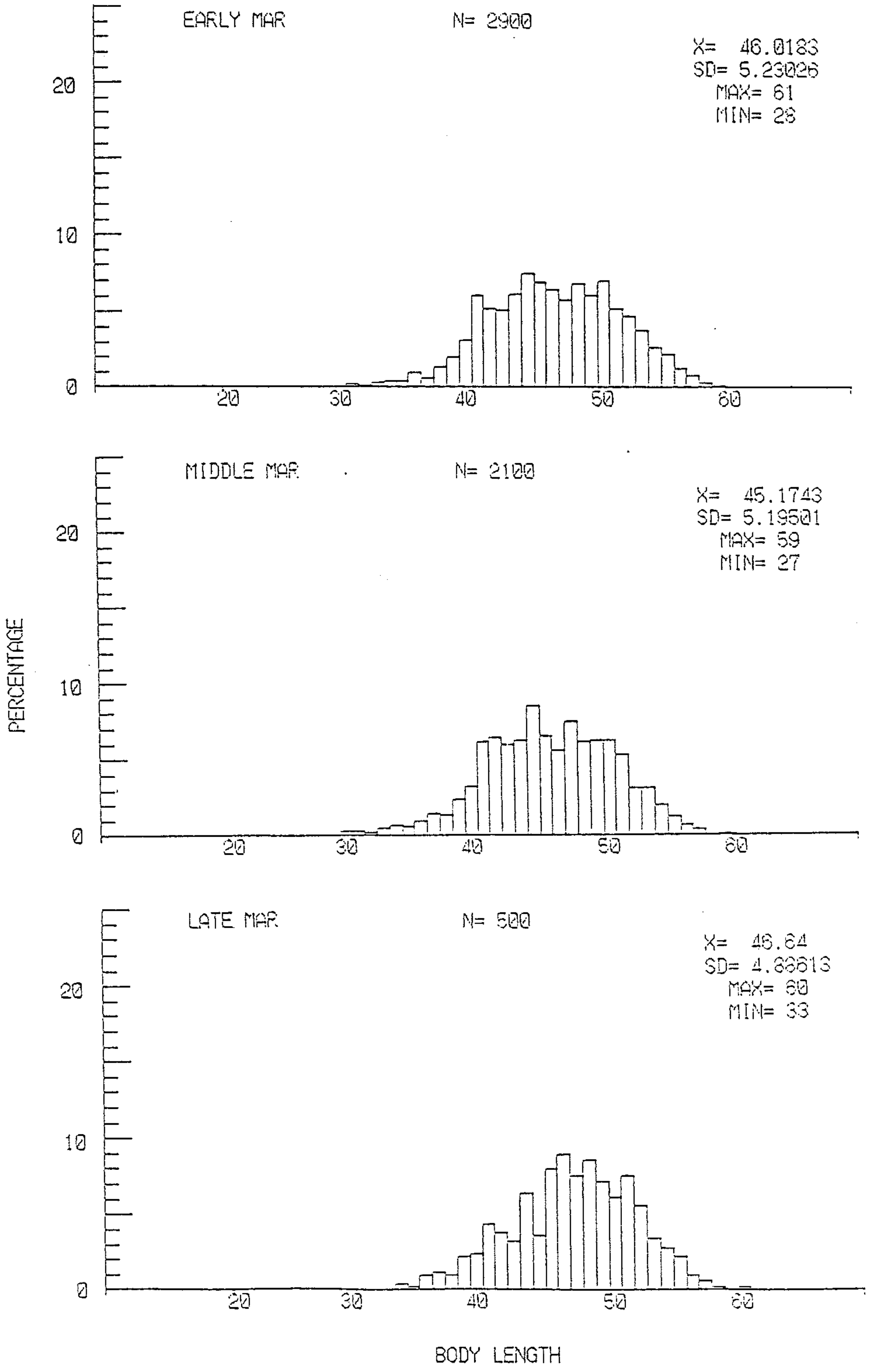


Figure 5b: Length-frequency histograms of krill in February 1988.



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SIZE AND DENSITY OF KRILL LAYERS FISHED BY A JAPANESE TRAWLER IN THE WATERS NORTH OF LIVINGSTON ISLAND IN JANUARY 1988

Y. Endo and Y. Shimadzu

Abstract

The size and density of fishable krill layers in the northern waters of Livingston Island were determined during the co-operative survey carried out by RV *Kaiyo Maru* and a Japanese trawler. The mean values of layer length, thickness and surface density were 3.25 km, 13.3 m and 228.0 g wet weight/m^2, respectively. The krill layers fished by the trawler during the co-operative survey were 44.5 times longer and 2.7 times thicker but 25% less dense than the typical swarms encountered during FIBEX surveys.

Résumé

L'étendue et la densité des couches exploitables de krill dans les eaux du nord de l'île Livingston ont été déterminées lors de la campagne d'évaluation coopérative effectuée par le navire de recherche *Kaiyo Maru* et un chalutier japonais. Les valeurs moyennes de longueur, d'épaisseur et de densité à la surface des couches étaient respectivement de 3,25 km, 13,3 m et 228,0 g de poids humide/m^2. Les couches de krill pêchées par le chalutier au cours de la campagne d'évaluation coopérative étaient de 44,5 fois plus longues, 2,7 fois plus épaisses mais de 25% moins denses que les essaims types rencontrés lors des campagnes d'évaluation de la FIBEX.

Резюме

Данные по размеру и плотности слоев криля были получены в ходе совместной съемки, выполненной НИС *Kaiyo Maru* и японским траулером. Средняя длина слоя равнялась 3,25 км, толщина слоя - 13,3 м и плотность у поверхности - 228,0 г. сырого веса/м^2. Протраленные в ходе совместной съемки слои были в 44,5 раза длиннее, 2,7 раза толще, но на 25% менее плотны, чем типичные скопления, обнаруженные при проведении съемок по программе FIBEX.

Resumen

La densidad y tamaño de las capas explotables de krill en las aguas al norte de la Isla Livingston, fueron determinadas durante el estudio co-operativo llevado a cabo por un buque de arrastre japonés y el RV *Kaiyo Maru.* Los valores medios de la longitud de la capa, grosor y densidad de la superficie fueron 3.25 km, 13.3 m y 228.0 g peso húmedo/m^2, respectivamente. Las capas de krill explotadas por el buque de arrastre durante el estudio co-operativo fueron 44.5 veces más largas y 2.7 veces más gruesas pero 25% menos densas que los cardúmenes típicos encontrados durante los estudios FIBEX.

1. INTRODUCTION

Extensive information on size, shape and density of Antarctic krill aggregations has been obtained by research vessels (e.g. BIOMASS, 1986). Information on harvestable aggregations, however, is scarce, although this is necessary in order to estimate the possible effect of fishing on krill abundance.

This paper provides information on the layers fished by a Japanese trawler during the co-operative survey with RV *Kaiyo Maru* on the fishing ground north of Livingston Island in January 1988.

2. MATERIALS AND METHODS

The co-operative survey between RV *Kaiyo Maru* and a Japanese trawler was conducted from 17 to 20 January 1988 on the fishing ground north of Livingston Island (Figure 1). A total of 30 experiments on TS measurement and net calibration were carried out during the survey. Information on 34 trawling operations including 30 co-operative experiments, was provided by the trawler.

The number of krill aggregations per tow and their shape and dimension were determined from the echogram of a fish finder on the trawler (50 kHz). Since most of the aggregations were long and stratified layers, the thickness of an aggregation was measured at its densest part every five minutes on the echogram.

The density of each layer was estimated from the catch, mouth area of the net (560 m^2) and towing time. The towing time in this case denotes the time from the moment when the aggregation entered the net, which can be ascertained by a net recorder, to the moment when the net started to be raised. The net volume density was calculated by dividing the density by the ratio of thickness of the layer to the net height (28 m), which was recorded on a net recorder chart.

3. RESULTS AND DISCUSSION

The number of aggregations per tow were: one (30 instances); two (one instance); three (two instances); and six (one instance). All the aggregations were layers except the last instance where six swarms were fished. A typical layer recorded by an echogram is shown in Figure 2. Note the stratified appearance of the layer.

The towed layer length ranged from 241 m to 6.0 km with a mean of 3.25 km (N=38, SD=1.66 km) (Figure 3a). The intersected length of six swarms encountered in a tow ranged from 37 to 370 m with a mean of 135.8 m (SD=122.5 m).

The mean thickness of the layer(s) of each tow ranged from 6.1 to 22.8 m with the overall mean of 13.3 m (N=33, SD=3.96 m) (Figure 3b).

The density of each layer was calculated for those tows during which a layer did not end. The density thus calculated ranged from 1.43 to 52.07 g/m^3 with a mean of 7.17 g/m^3 (N=30, SD=8.84 g/m^3). The net density ranged from 4.49 to 73.33 g/m^3 with a mean of 17.14 g/m^3 (N=30, SD=12.70 g/m^3) (Figure 3c). The mean ratio of layer thickness to net height was 0.43. As the net height was 28 m, the layer thickness must be 12 m, which is close to the value obtained from the echogram, 13.3 m. The surface density of layers can be calculated by multiplying 17.14 g/m^3 by the mean thickness, 13.3 m. Thus 228.0 g/m^2 was gained.

Butterworth (1988) assumes that about five swarms are fished per haul in his modified simulation model. In this study, however, one layer was fished per haul in 88% of hauls.

The mean towed layer length was 3.25 km (the mode was 4.5 km) (Figure 3a), which is 44.5 times longer than that obtained from SIBEX surveys (BIOMASS, 1986) and used for a base case model by Butterworth (1988), 73 m. The value of 3.25 km, however, does not seem unusual because Ichii (1987) reported higher values in the fishing ground off Wilkes Land during the 1985/86 season.

The combined results from FIBEX give a mean swarm thickness of 5 m (BIOMASS, 1986), which is less than half that obtained in this study, 13.3 m.

In this study, the mean surface density of krill within a layer was 228.0 g/m^2. This value is less than that calculated by Butterworth from FIBEX data, 300 g/m^2.

As shown above, the krill layers fished by the trawler during the co-operative survey were 44.5 times longer and 2.7 times thicker but 25% less dense than the typical swarms encountered during FIBEX surveys. Fishing vessels were selecting larger aggregations than the average-sized ones found by research vessels.

Towed length and thickness of layers were underestimated because the trawler curtailed the haul before the layer ended in 30 out of 34 hauls and because the trawl net could not fish the deeper parts of the layers in at least 16 out of 34 hauls.

Catch per tow ranged from 1.1 to 23.0 tonnes during the co-operative survey.

After the co-operative survey with the trawler, RV *Kaiyo Maru* sailed around the fishing ground in order to estimate krill biomass by means of an echo integrator (Figure 1). Layers were the main form of aggregation along the track lines except the southern area, lines G-J, where swarms were recorded on the echogram. On lines B-F, L and N, layers never ended. The longest layer was recorded on line C which is more than 18.5 km long. The survey area of RV *Kaiyo Maru* was too small to cover the horizontal extent of the concentration. The longitudinal length of the concentration proved to be more than 52 km (from 60° to 61° W at 62°S).

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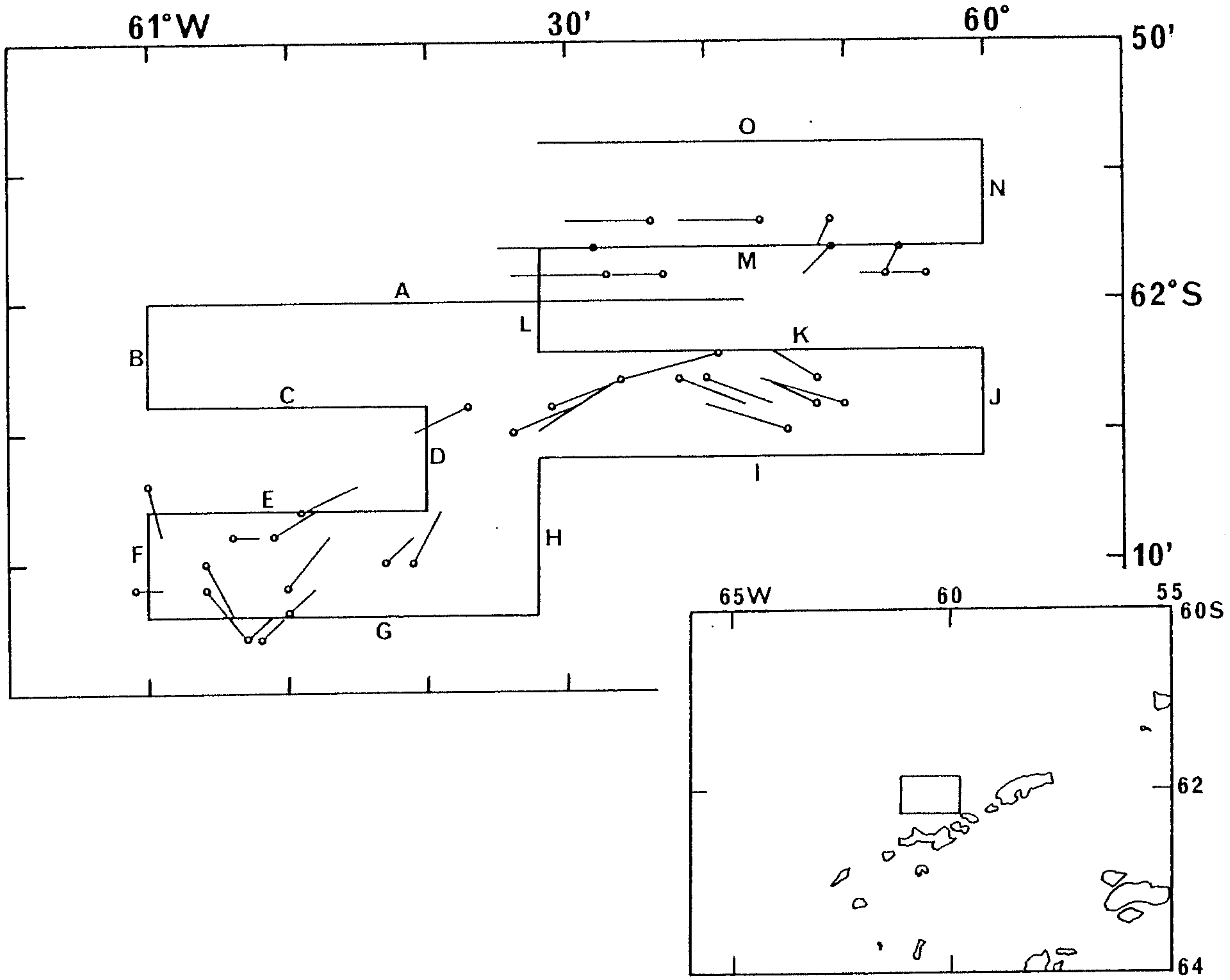
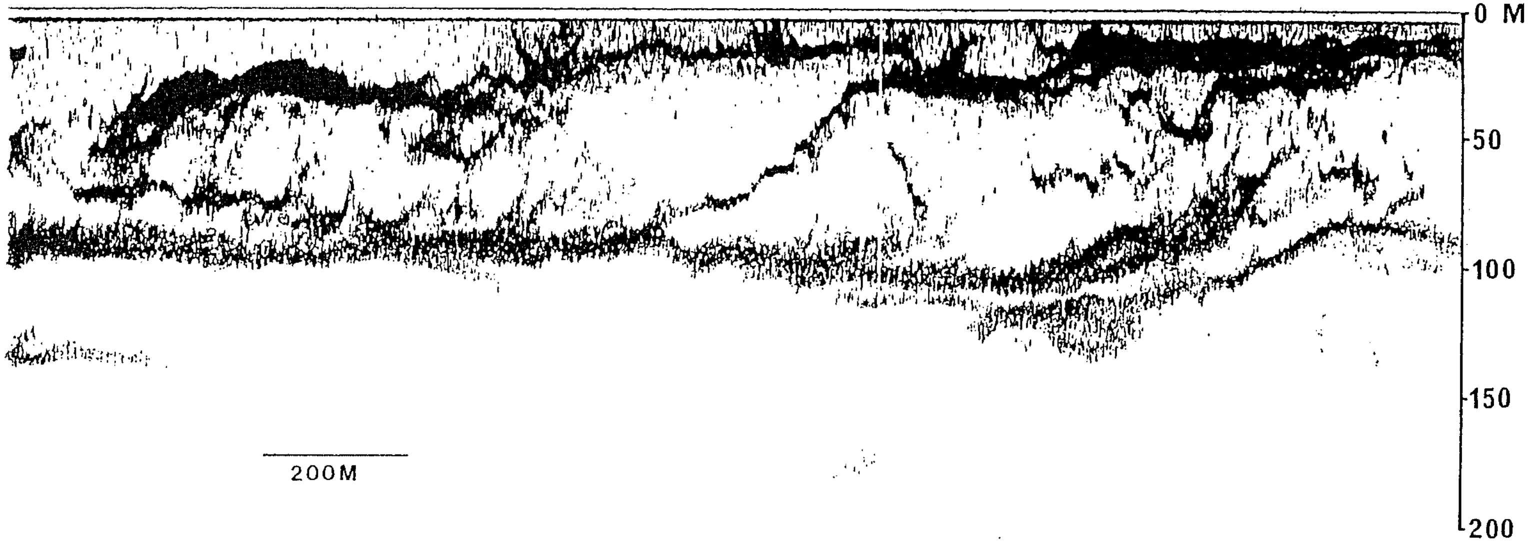


Figure 1: The fishing ground north of Livingston Island. The position and course of 34 trawls carried out by a Japanese trawler during the co-operative survey and RV *Kaiyo Maru*'s track line to estimate krill biomass are shown.



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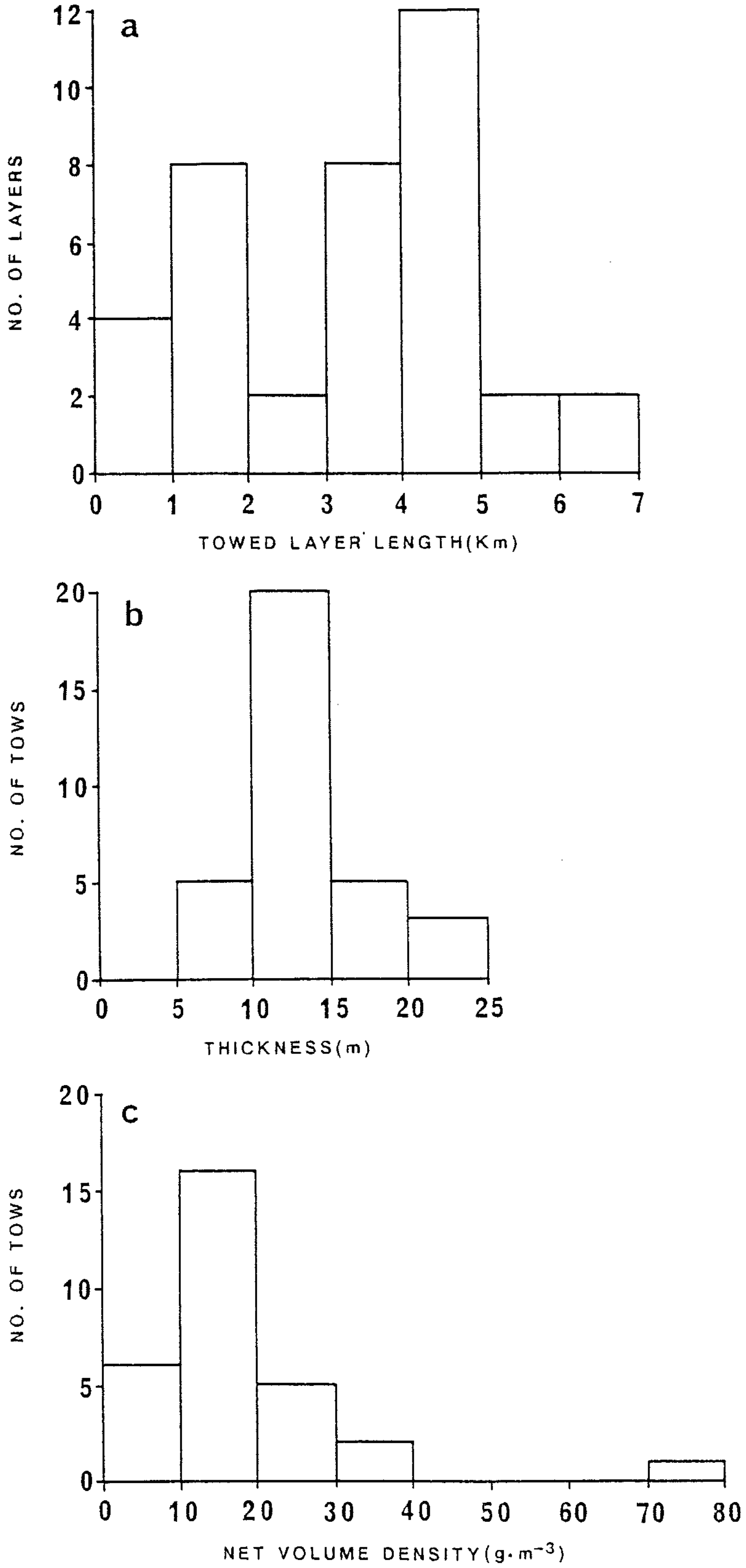

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WS-KCPUE-89/7

BRIEF COMMENTS ON THE SIMULATION STUDY MADE BY PROF. BUTTERWORTH ON KRILL FISHING BY AN INDIVIDUAL JAPANESE TRAWLER

T. Ichii and Y. Endo

Abstract

In this paper, three essential questions are raised concerning the simulation study of the Japanese krill fishery carried out by Butterworth (1988). Firstly, the simulation study used krill distribution parameter values based on the FIBEX results, whereas Japanese vessels often operate on layers which are much larger than the swarms detected during FIBEX surveys. Since very little searching time is spent on layers, the utility of searching time data appears doubtful. Secondly, the utility of indices based on the sum of primary and secondary searching times (PST+SST) is also doubtful because SSTs are markedly dependent upon the type of products being produced, and the demand for each product varies substantially from one season to the next. Finally, attention is drawn to the unrealistic behaviour of the simulation model with respect to the values used for the minimum catch rate per overall elapsed time. It is suggested that an improvement in our knowledge of krill distribution is necessary before the routine implementation of searching time data collection is considered.

Résumé

Dans ce document, trois questions essentielles sont soulevées concernant l'étude par simulation de la pêcherie japonaise de krill effectuée par Butterworth (1988). Tout d'abord, l'étude par simulation utilise les valeurs des paramètres de distribution du krill basées sur les résultats FIBEX alors que, souvent, les navires japonais opèrent en couches qui sont beaucoup plus étendues que les essaims détectés pendant les campagnes d'évaluation FIBEX. Vu le temps de recherche très réduit passé sur les couches, l'utilité de données de temps de recherche semble discutable. En second lieu, l'utilité d'indices basés sur la somme des temps de recherche primaire et secondaire (PST+SST) est également douteuse car les SST dépendent nettement du type de produit en cours de production, et la demande pour chaque produit varie considérablement d'une saison sur l'autre. Enfin, le comportement irréaliste du modèle de simulation a été souligné, en ce qui concerne les valeurs utilisées pour le taux minimum de capture par temps total écoulé. Il est recommandé d'approfondir notre connaissance sur la distribution du krill, avant d'établir la collecte régulière des données sur le temps de recherche.

Резюме

Нами были поставленны три существенных вопроса, относящиеся к исследованию крилевого промысла Японии методом математического моделирования, проведенному Батеруортом (1988 г.). Во-первых, при исследовании методом математического моделирования использовались величины параметров распределения криля, основанные на результатах Программы FIBEX, в то время как японские суда часто ведут промысел в слоях, размер которых намного превышает размер скоплений, обнаруженных в ходе проведения съемок Программы FIBEX. В связи с тем, что поиск при промысле в слоях занимает очень мало времени, полезность данных по времени поиска подвергается сомнению. Во-вторых, мы сомневаемся в полезности показателей, полученных на основе суммы величин времени первичного и вторичного поиска (PST+SST), так как значения SST в значительной мере зависят от вида продукциизк при этом спрос на каждый вид продукции колеблется в значительной степени из сезона в сезон. В заключение, нами было указано на ненадежное поведение модели в отношении минимальной интенсивности лова за общее время промысла. Было предложено расширить знания о распределении криля до начала регулярного сбора данных по времени поиска.

Resumen

En este documento se plantea tres cuestiones esenciales en relación con el estudio simulado japonés de pesca de krill llevado a cabo por Butterworth (1988). Primeramente, el estudio simulado utilizó valores de parámetros de distribución de krill basados en los resultados de FIBEX, mientras los buques japoneses operan a menudo en capas las cuales son mucho más grande que los cardúmenes detectados durante los estudios FIBEX. Debido a que muy poco tiempo de búsqueda se emplea en capas, la utilidad de los datos de tiempo de búsqueda parece dudosa. Segundamente, la utilidad de los índices basados en en la suma de tiempos de búsqueda primarios y secundarios (PST+SST) es también dudosa porque SSTs son notablemente dependientes en el tipo de productos que son producidos y la demanda para cada producto varía substancialmente de una temporada a otra. Finalmente, se llama la atención al comportamiento ilusorio del modelo de simulación con respecto a los valores utilizados para el índice mínimo de capturas por tiempo transcurrido global. Se sugiere que un perfeccionamiento en nuestro conocimiento de la distribución de krill es necesario antes de considerar la ejecución rutinaria de recopilación de datos de tiempo de búsqueda.

Butterworth (1988) made a thorough examination of the usefulness of catch-per-unit-effort (CPUE) data from the Japanese fishery, and suggested that the collection of within-concentration searching times might improve the utility of the data. We commend his efforts in making the simulation as meaningful as possible by using most of the information available at present. His model, however, presents several essential questions and we do not think that CPUEs from the Japanese krill fishery are useful in estimating the change of within-concentration krill abundance even if searching times could be obtained. We present the reasons in the following paragraphs.

(i) As he pointed out, the krill distribution model is based on parameters determined primarily from FIBEX surveys which did not cover the fishing grounds of Japanese trawlers. This causes a major inconsistency in addition to the FISHT problem (in reality, haul times are four to five times greater than in the model). In the peak season, krill usually occur in the form of layers which may be several kilometres in length, or in numerous large swarms (100 to 1 000 m wide) in harvestable concentrations so that primary searching time is usually considered to be nil. So while newly-caught krill are being processed, trawlers move around to kill time, thus finding many swarms. When the processing is about to finish, trawlers begin launching their nets aiming at the swarm(s) which have just been found. When no swarm is found in the vicinity of trawlers at that time, they return to the swarm(s) which were previously detected and marked on the chart. Searching times may not, therefore, have been suggested as being useful had krill distribution parameters been obtained from surveys covering fishing grounds.

(ii) Prof. Butterworth concluded that the best index of krill abundance is TC/TFISHT/PST. Since it is not practical to collect PST (primary searching time), he suggested that TC/TFISHT/(PST+SST) might be useful, but its effectiveness is slightly less than that of the best index. We are, however, doubtful whether (PST+SST) can be an alternative to PST because SST (secondary searching time) differs according to the type of products being produced (such as boiled and frozen, fresh and frozen, peeled krill and meal). Moreover, the demand for each product can be seen to change from year to year. We do, therefore, agree with him that before considering the routine implementation of collection of searching times, small-scale experiments to test the practicality of collection of this data, as well as further tests of the model to determine the robustness of PST-based indices to errors in recording should be carried out (Butterworth, 1988, p. 43).

(iii) In Butterworth's model the decision whether or not to leave a concentration is made on the basis of CRmin (the minimum catch rate per overall elapsed time). Over a range of 1 to 3 t/h for CRmin, his model shows some inconsistency in that the lower the CRmin, the more a trawler can catch during the fortnightly period, leading to the extreme of remaining in the concentration first found rather than moving between concentrations (Butterworth, 1988, p. 42 and Figure 8i). He suggested that there is a need to take into account temporal variability of distribution parameters and krill quality considerations in order to cover this weakness. We consider, however, that this weakness was caused by an underestimation of variability in within-concentration krill abundance and the searching ability of trawlers. In the model, within-concentration krill distribution parameters are assumed to be more or less the same from concentration to concentration and/or the searching abilities of trawlers are assumed to be not high, which results in the extreme of remaining in the concentrations first found, and makes movement between concentrations a waste of time. In reality, there seem to be a few harvestable concentrations among many unharvestable ones. Also if trawlers set the CRmin at an unreasonably low level, they would obtain a poor total catch. Actually, trawlers set the

CRmin criterion 2 to 2.5 t/h (Butterworth, 1988, p. 22) and manage to detect concentrations (based on information such as the historical distribution of harvestable concentrations) which meet that CRmin criterion. This reinforces the argument that the krill distribution model needs to be improved.

Collecting information on searching times is a burden for fishermen and its usefulness is still doubtful at this stage. Instead, as he strongly suggested, we first need to improve our krill distribution model.

REFERENCE

BUTTERWORTH, D.S. 1988. A simulation study of krill fishing by an individual Japanese trawler. *Selected Scientific Papers, 1988 - Part 1. SC-CAMLR-SSP/5*: 1-108.

III. ECOSYSTEM MONITORING

SC-CAMLR-VIII/9

USE OF INDICES OF PREDATOR STATUS AND PERFORMANCE IN CCAMLR FISHERY MANAGEMENT

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Abstract

This paper investigates how data on, or related to, reproductive performance of seabird and seal predators, collected as part of the CCAMLR Ecosystem Monitoring Program (CEMP) could be used in the management, by CCAMLR, of commercial fisheries. It reviews reasons why it is important for CCAMLR formally to use such data in its fishery management operations and discusses the constraints inherent in the CEMP data, both from predator monitoring and harvesting perspectives. An outline of a specific approach is provided, involving an assessment procedure and recommendations for management action. The three elements of the assessment are determining the magnitude and significance of changes in individual parameters, evaluating overall patterns of change within species, sites and areas and reviewing factors potentially influencing or correlated with the changes. The relative merits and feasibilities of recommendations for restrictions on the magnitude, timing and location of harvesting are reviewed, taking account of likely operational constraints on fisheries.

Résumé

Ce document étudie la manière dont la CCAMLR pourrait se servir, dans la gestion des pêcheries commerciales, des données relatives ou ayant rapport à la performance reproductive des oiseaux de mer et des phoques prédateurs, recueillies dans le cadre du Programme de contrôle de l'écosystème de la CCAMLR (CEMP). Il examine les raisons pour lesquelles il est important que la CCAMLR utilise officiellement de telles données dans ses opérations de gestion des pêcheries et traite des contraintes internes des données du CEMP, tant du point de vue du contrôle des prédateurs que de celui de l'exploitation. Les grandes lignes d'une méthode d'attaque spécifique sont fournies; cette dernière nécessite une procédure d'évaluation et des recommandations de gestion. Les trois éléments de l'évaluation sont : la détermination de l'ampleur et de la portée des changements des paramètres individuels, l'évaluation des tendances générales des changements au sein d'espèces, de sites et de régions, et l'étude des facteurs qui risquent d'influer sur ces changements, ou qui sont en correlation avec eux. Les mérites et les applications pratiques de recommandations relatifs, aux restrictions sur l'ampleur, à la période appropriée et à l'emplacement de l'exploitation sont examinés, compte tenu des contraintes opérationnelles probables sous lesquelles opèrent les pêcheries.

Резюме

В настоящем документе рассматривается вопрос о том, каким образом собранные в ходе работ по Программе АНТКОМа по мониторингу экосистемы (CEMP) данные по эффективности воспроизводства хищных морских птиц и тюленей, и связанные с ними данные, могут быть использованы АНТКОМом при управлении коммерческим промыслом. В документе рассматриваются причины, по которым АНТКОМу следует в официальном порядке использовать такие данные при управлении промыслом. В документе также рассматриваются ограничения применимости данных CEMP как при мониторинге хищников, так и при управлении промыслом. Предлагается обзор конкретного подхода, включающий процедуру оценки и рекомендации в отношении управления. Процедура оценки состоит из трех элементов, которые определяют величину и значение изменений отдельных параметров, оценивают общие закономерности процесса изменения видов, участков и районов и рассматривают факторы, оказывающие потенциальное воздействие или связанные с изменениями. Рассматриваются относительные преимущества и пригодность рекомендаций по ограничению объема, времени ведения и места ведения промысла, при этом во внимание принимаются вероятные оперативные ограничения промысла.

Resumen

Este documento investiga como los datos acerca de, o relacionados con, la acción reproductora de las aves marinas y focas depredadoras, recopilados como parte del Programa de Seguimiento del Ecosistema de la CCRVMA (CEMP) podrían ser utilizados en la administración de pesca comercial por la CCRVMA. Este examina las razones por las cuales es importante que la CCRVMA use estos datos oficialmente en sus operaciones de administración de pesca y debate las obligaciones intrínsecas en los datos del CEMP, según las perspectivas de pesca y también del seguimiento de animales depredadores. Se provee un resumen de un enfoque específico, incluyendo un procedimiento de evaluación y recomendaciones para la administración. Los tres elementos de esta evaluación determinan la magnitud e importancia de los cambios en parámetros individuales, interpretación de los patrones generales de los cambios en ciertas especies, localidades y factores de análisis que potencialmente influyen o son correlacionados con estos cambios. Los méritos relativos y viabilidad de las recomendaciones para las limitaciones impuestas en la magnitud, coordinación y localidad de la pesca son examinados, tomando en cuenta las posibles restricciones operacionales a las pesquerías.

1. INTRODUCTION

1.1 Background

An important part of the uniqueness of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) is the concern that exploitation of resources should not be detrimental to natural consumers (see Article II, paragraph 3(b)). This obligation has led the Commission for the Conservation of Antarctic Marine Living Resources to develop, through its Scientific Committee, an Ecosystem Monitoring Program (CEMP) whose aims are "to detect and record significant changes in critical components of the ecosystem, to serve as the basis for the conservation of Antarctic Marine Living Resources. The monitoring system should be designed to distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological" (SC-CAMLR-IV, paragraph 7.2). The program's terms of reference are set out in SC-CAMLR-III, paragraph 9.27.

The approach followed has been to start a system of regular recording of selected ecologically-orientated parameters of the populations of selected species of seals and seabirds and to try to develop schemes for monitoring harvested species and relevant environmental variables. This paper is concerned chiefly with the monitoring of predator species.

The choice of predator species has been based on reasonably objective criteria whose definition has evolved over several years (see SCAR 1979, p. 306; BIOMASS 1980, p. 16; BIOMASS 1982, p. 6; SC-CAMLR-IV, p. 172; SC-CAMLR-V, p. 149) and were most recently summarized by Croxall et al. (1988) as:

"(a) important components (in terms of prey consumption) of the Southern Ocean system;

(b) specialist predators on harvestable prey, especially krill;

(c) have broad geographical breeding ranges including sites near to and far from areas likely to be subject to intensive fishing;

(d) readily accessible at breeding sites and tolerant of human presence and activity."

Only very recently has attention started to focus on the objective selection of parameters according to criteria of accuracy (feasibility of repeatedly making accurate and precise measurements), relevance (closeness of linkage to and degree of dependence upon harvestable resources) and detectability (sensitivity of parameter to changes in food availability) (see Croxall et al. 1988, pp. 277-278).

So far, however, no attention has been directed to arguably the most important point of all, how the data resulting from the monitoring program are to be used by CCAMLR in its management of the commercially exploited resources. This paper reviews why we should be trying to do this and suggests some approaches that might facilitate constructive progress towards realistic goals.

1.2 Why Does CCAMLR Need to Use Results from the CEMP in its Fishery Management Strategies?

I believe that there are at least two main reasons for doing this. First, in the eyes of many participants in and perhaps most observers of CCAMLR work, the main positive element of this Convention is its explicit concern that exploitation of resources should not adversely effect natural consumers.

It is this that chiefly distinguishes CCAMLR from conventional fishery management agreements. Dissatisfaction with the latter stems from their repeated failure in the past to prevent gross over-exploitation, to the detriment of exploited stock and natural consumer alike, often despite the existence of appropriate scientific data and/or advice. By the time such over-exploitation was officially recognized (i.e. accepted by all parties), it usually proved impossible adequately to restore either the harvestable stock or the depleted population of natural consumers - especially in situations where there is pressure for continuing exploitation.

From many vantage points, the success of CCAMLR rests on whether it can provide more sensitive, balanced and effective management policies than most existing fishery management agreements. A particular issue, not explicitly addressed in Article II, is where the "burden of proof" rests. It is apparently implicit at present that detrimental changes to predators must be proved to result from harvesting before action can be taken. It would be equally logical, however, to assert that commercial harvesting should only continue as long as it can be proved that it has no significant adverse effect on natural predators.

Second, there is limited point in Members of CCAMLR making the substantial commitments of time and money necessary to carry out the CEMP unless CCAMLR has specific plans for using the results in a constructive way.

It would surely be a serious mistake for CCAMLR to be seen to wait until a proven crisis for predator populations is identified before instituting any protective measures. This applies irrespective of whether harvesting is a direct or indirect contributor to the situation. What is needed is (a) to develop contingency plans now, and (b) to ensure that action (i.e. some restriction on harvesting) is taken when the first danger signals appear.

2. GENERAL APPROACH TO THE USE OF PREDATOR INDICES

2.1 Introduction

What would seem to be required is the development by CCAMLR of a balanced and flexible way of using the results of the CEMP predator studies to influence CCAMLR's management (including short-term policy) of commercial fisheries. It is crucial that this aim be achieved with the active support of those involved in current and prospective harvesting and that it is developed in a way that is sensitive to the commercial and logistic constraints which such operations entail. Any scheme will involve compromise. Thus it will obviously include provision for restraint on harvesting under some circumstances; conversely it will inevitably provide less than absolute protection for all consumers under all foreseeable circumstances.

What are some of the obvious problems and considerations involved in the development of such a scheme? I advance below some views, from the different perspectives of predator monitoring and commercial harvesting, which need to be taken into account.

2.2 Predator Monitoring Perspective

The possible aims of CEMP predator monitoring might include any or all of the following.

(i) To detect changes in indices of the status (in either demographic or physiological (e.g. condition) respects) and/or reproductive performance of seabirds and seals.

(ii) To relate these changes to indices of prey (at present krill) abundance and availability (to the predators).

(iii) To use predator indices, on the basis of relationships between predators and prey developed above, as a measure of (a) prey availability (to the predators) and (b) prey stock abundance.

(iv) To use the predator indices to detect changes in food availability that result from commercial harvesting as distinct from changes due to natural fluctuations in the biological and physical environment.

In my judgement a realistic assessment of these aims is that:

(i) should be possible for many species, sites and circumstances;

(ii) may be possible for certain species at certain sites under favourable circumstances;

(iii) (a) might be possible under optimum conditions;

(b) is unlikely to be possible even under optimum conditions; and

(iv) is unlikely to be possible, unless under exceptional circumstances.

We should accept that proof, in terms of scientific evidence which would pass rigorous scrutiny, of commercial harvesting causing detriment to predators, is very unlikely. Even if it were obtained, it would probably come so long after the start of the causal problem as seriously to prejudice reversal of the situation within two to three decades (as required by Article II of the Convention).

We should also accept that, with our present knowledge of the dynamics of predator-prey interactions in the marine environment, evidence for short-term changes (year-to-year differences or trends over three to five years) will rarely be available even at 90%, let alone 95% levels of statistical significance (Croxall et al., 1988).

In addition, not all predator indices are equally important because not all parameters fulfil equally the criteria of relevance, accuracy and detectability. Furthermore, as more knowledge accumulates and/or more parameters are added to the CEMP, the relative importance of indices may change. Also, as more CEMP data become available there is likely to be a better chance of meaningful trends being detected. Important though such results may be, they will not replace the need for some kind of short-term assessment, permitting a finer-scale tuning of management policy.

Finally, it might not be too difficult (in theory) to incorporate predator indices into the management approaches being developed for fisheries directed at existing target species, where there are adequate data available to CCAMLR coming from the fishery itself. A fishery starting for a completely new target species would be a different matter, because there will be few, if any, data on which to base rational management. It is, therefore, not unreasonable to plan to take greater note of changes in relevant predator indices concurrent with the start of a new fishery.

2.3 Harvesting Perspective

Commercial harvesting, especially in the Southern Ocean, is a difficult and costly operation, where, nowadays, profit margins are usually small. Restrictions on the timing, location, or permitted catch levels of fishing may interfere with sensible, safe or effective fishing practice to the point where the fishery becomes uneconomic and therefore unsustainable. This may also eliminate one of the main sources of data for monitoring future trends in the prey.

Indices of predator status/performance derived from study sites on the Antarctic Continent and perhaps Antarctic Peninsula are likely to be as much, if not more, affected by changes in the physical, rather than biological, environment (Croxall et al., 1988). Resulting difficulties in interpretation may, therefore, reduce their direct relevance to fisheries management.

Even if we accept that predator indices can theoretically reflect prey abundance/availability, in practical terms they do so over areas that are often not congruent with those for which prey stock assessments are carried out. Furthermore, prey abundance/availability and predator status/performance are unlikely to be coupled in linear fashion. Therefore, predator indices may be a poor guide to prey abundance/availability, except perhaps at more extreme values.

There is evidence that some predator populations in the Southern Ocean are currently increasing in numbers. If, as is likely, density-dependent factors ultimately limit population size (Croxall and Rothery, in press), indices of status and performance may show a negative trend when this happens. Uncritical interpretation could easily attribute such a trend to adverse effects of harvesting.

Finally, climatic trends have already been detected in the Antarctic and are likely to be an important feature of the next decades. The responses of predators and prey are likely to involve changes in abundance and reproductive performance. This will significantly complicate detecting any effects which might be ascribed to harvesting.

2.4 Conclusions

Taking both sets of perspectives into account, what might be a reasonable set of conclusions for a sensible general approach?

First, if we wish to use indices of predator status/performance to influence fishery policy on a year-to-year basis, we need to develop a system that takes notice of changes where the likelihood of correctness is less than 95%, provided the required responses make appropriate allowance for our reduced certainty.

Second, it may be most profitable initially to develop a policy for incorporating predator indices into CCAMLR fisheries management for sub-Antarctic and Antarctic Peninsula areas. This may avoid much of the problem concerning the relative importance of physical and biological influences and would also concentrate on locations where significant harvesting is regularly occurring at present.

Third, the initial focus of attention should be on krill and krill-eating predators. This interaction is the most closely coupled of those available and must offer the best chance of developing a sensible policy. Doing this would facilitate extending the policy to less closely linked trophic interactions (e.g. between seabirds/seals and fish), including those hitherto largely unstudied (e.g. involving squid).

Fourth, it is important that estimates of prey abundance/availability to predators be forthcoming as soon as possible and that these be as congruent as possible with the areas generating the predator indices. There is a particular need to ensure that broad-scale data (e.g. at the "stock" level) are complemented by fine-scale data (e.g. $1° \times {}^1/_2°$ squares), because it is the latter which are of greater relevance in assessing predator-prey interactions.

Fifth, until the nature of relationships between predator indices and prey abundance/availability are established, we need to be prepared to proceed on the assumption that changes in predator indices are reflecting changes in food availability, unless there is clear evidence to the contrary. Evidence from a wide variety of marine ecosystems provides examples of indices of predator population status and reproductive performance correlating with various indices of prey stock availability and abundance (see reviews in Croxall, 1987; Furness and Monaghan, 1987; Croxall and Rothery, in press). Such relationships certainly need investigating in more detail and there may be special problems where physical and environmental factors regularly exert stronger influences than biological ones, but the above assumption is probably a suitably conservative one from which to proceed.

Sixth, we should accept that there is a need to avoid harvesting exacerbating a situation where predator indices tell us that populations are performing poorly - even when there is no evidence that harvesting is, or has been, a contributory factor. The logic for this is that if predator populations are in trouble, any level of harvesting, if conducted at critical times and places, may have significant adverse effects.

3. SPECIFIC APPROACHES

It is not intended to develop here a detailed formal scheme. Rather, the aim is to suggest one possible approach, which can then serve as a basis for discussion and development.

Consideration is confined to krill-eating predators and, inevitably, the perspective is chiefly that gained from work at Bird Island, South Georgia over the last 14 years. The emphasis is entirely on the detection and evaluation of short-term change.

3.1 Outline of Approach

3.1.1 Preparation

(i) Rank or group parameters according to relevance criteria.

(ii) Also, using information on accuracy and detectability criteria, define the lowest level of significance that would constitute evidence of change for each parameter or group of parameters.

The process of formal ranking of parameters and definition of level at which changes would be regarded as significant will inevitably be somewhat arbitrary, especially in the present state of our knowledge. One alternative would be to take into account the information on relevance, accuracy and detectability at the assessment stage.

(iii) For each parameter, calculate magnitude of change, compared with last year and with average(s) of previous years. Determine level of statistical significance of change.

3.1.2 Assessment

(i) For each species at each site, examine magnitude (and direction) of all significant changes and determine overall nature of predators' response to that years environmental circumstances.

(ii) For each species at all sites (particularly within the same general area) and for all species monitored at each site, review overall pattern of responses.

3.1.3 Recommendations

Make recommendations for appropriate management action. This, and the preceding assessments, will obviously need to take into account additional information on:

(i) the biological environmental background (e.g. current/recent diet of monitored species, current/recent prey stock assessments and level of commercial catches in each subarea);

(ii) the physical environmental background (weather and climate prevailing during monitoring period); and

(iii) the current status of the monitored species (e.g. population trend, latest demographic information, etc.).

3.2 Evaluation of Parameters

The approach outlined here requires that, at some stage, parameters be evaluated. Croxall et al. (1988, pp. 278-281) assessed a variety of parameters, including all those currently selected by CCAMLR (1988). Based on this, parameters might be classified, in relation to their potential for detecting short-term changes, as follows.

(i) Potentially high relevance and of appropriate accuracy and detectability

   (a) foraging trip duration;
   (b) offspring growth rate and/or weight at independence (fledging/weaning).

(ii) Potentially high relevance but with large interannual variation and/or difficult to acquire enough data

   (a) diet;
   (b) breeding success.

(iii) Potentially lower relevance (because reflects a variety of influences over rather longer timespans) but easy to measure accurately

   (a) adult weight (e.g. at arrival).

(iv) Potentially lower relevance (reflects a variety of influences over much longer timespans) and difficult to obtain very accurate data

   (a) demographic variables;
   (b) breeding population size.

Detailed demographic (including population trend) studies, however, should receive high priority; evidence of statistically significant trends (especially in vital rates) should be considered, in the context of the CEMP, as soon as it is available.

(v) Potentially high relevance, but apparently rather insensitive to environmental change

(a) clutch size;
(b) incubation shift duration (see Davis and Miller, in press);
(c) onshore attendance in fur seals.

An informal use of this, or any other parameter classification would simply give greater weight to changes in some parameters than others, particularly when considering the overall picture at the species and site level. A more formal approach would be to assign levels of significance at which changes in each parameter (or parameter group) would be accepted. Categories (ii) and (iv) above might be best regarded simply as vital background information.

3.3 Recommendations for Management Action

The assessment procedure has three distinct elements. First, the evidence for change in monitored parameters is considered individually. Second, the overall pattern of changes within species, sites and areas is evaluated. Third, factors possibly influencing or correlated with these changes are reviewed.

Recommendations for management action are only likely to follow when there is evidence either of a broad scale general effect or of an acute effect at a more local level. The content of recommendations is likely to involve restrictions on the magnitude, timing and location (or some combination of these, perhaps involving effort limitation) of krill harvesting (Table 1).

Restricting the total catch in an area requires regular reporting of catches by all vessels and a system for informing them of the rate of progress towards the target catch. Checking the accuracy of catch reports is very difficult and imposing a catch limit, even in a subarea, is unlikely to be the most effective way of improving conditions for predators. Limiting the timing and location of fishing is easier to do, easier to monitor and, by avoiding times and places of greater likely impact on predators, more likely to have a significant effect.

Restricting fishing within the foraging radius of breeding fur seals and penguins, or confining fishing to areas downstream of the main predator breeding concentrations in a subarea, would be obvious possible actions. Closing the fishery at particular times could be used to avoid harvesting occurring simultaneously with times of critical energy requirements by predators. One such time might be while adults have dependent offspring. Critical periods for adults may also occur just before breeding starts and for juveniles when they become independent. Winter may generally be a time of reduced food availability. However, most predators are well dispersed at this time and it is difficult to identify any management actions which could be implemented effectively in winter.

Limitations on the timing of fishing may well be the most difficult for commercial operations to cope with. Thus fishing conditions may be better in some seasons than others; also fishing fleets have timetables involving fishing for other resources in other areas at fixed periods. Their capacity for flexibility may be severely limited and more so than in respect of modifying the location of fishing.

The recommendations themselves need to be flexible in terms of the magnitude of the restriction they seek to impose. Some possible examples are shown in Table 2. The degree of restriction would obviously depend on the magnitude of the perceived problem but in many circumstances it would be prudent to start with a relatively modest restriction and adopt more severe ones if there are no signs of a change for the better.

3.4 General

If CCAMLR adopts any strategy involving the evaluation of the results of predator monitoring in order to consider these in the context of fisheries management, then WG-CEMP will need annually to review and evaluate the predator data. They would provide detailed advice for the Scientific Committee to consider, as a basis for making appropriate recommendations to the Commission.

ACKNOWLEDGEMENTS

I thank Inigo Everson, John Gulland, Mike Harris and John Heap for helpful comment and discussion.

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Table 1: Practical considerations relating to applying restrictions on commercial harvesting.

Restriction on Catch	Feasibility of Implementation	Feasibility of Monitoring Compliance	Consequences for Fishery	Probability of Aiding Predators
Size	Moderate-difficult	Difficult	Moderate	Low
Timing	Easy	Moderate	Serious	Moderate
Location	Easy	Moderate	Moderate	Moderate-good

Table 2: Examples of measures of differing degrees of restriction on commercial harvesting.

Restriction on Catch	Increasing Intensity of Restriction		
	1	2	3
Size	30% reduction	60% reduction	Zero
Timing	Not Jan-Mar	Not Dec-April	Closed
Location	Downstream in subarea	Close subarea	Close area

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THE USE OF ANALYSIS OF PENGUIN STOMACH CONTENTS IN SIMULTANEOUS STUDY OF PREY AND PREDATOR PARAMETERS

E. Marschoff and B. González

Abstract

Size selectivity of krill by penguins is shown to be highly sensitive to the statistical assumptions made during the analysis of data. The nested ANOVA method is proposed as being the correct approach for analysis because lack of independence between krill specimens found in the stomach of a given penguin prevents the pooling of krill lengths from different samples. Samples taken in Bahía Esperanza were used to illustrate the different approaches to this analysis. A highly significant linear regression between krill size and time of sampling was found.

Full use of information obtained from analysis of penguin stomach contents requires block sampling designs. Replicating samples from the same penguin or studying portions of stomach samples at different stages of digestion are proposed as alternative methods.

Résumé

La sélectivité de la taille de krill par les manchots est démontrée comme étant très sensible aux hypothèses statistiques sur lesquelles l'analyse des données est fondée. Il est proposé de considérer que la méthode correcte est celle des modèles ANOVA à emboîtements, étant donné que le manque d'indépendance entre les spécimens de krill trouvés dans l'estomac d'un manchot donné empêche de regrouper les longueurs du krill provenant d'échantillons différents. Les échantillons prélevés dans la Bahía Esperanza sont utilisés pour expliquer les différentes approches à cette analyse. Une régression linéaire très significative entre la taille du krill et l'époque d'échantillonnage a été observée.

L'utilisation intégrale des informations provenant de l'analyse des contenus stomacaux des manchots nécessite l'emploi de modèles d'échantillonnage en bloc. La reproduction des échantillons provenant du même manchot ou l'étude de portions du contenu stomacal à différents stades de digestion est proposée comme autre méthode possible.

Резюме

Селективность пингвинов в отношении размера потребляемого ими криля проявляет высокую чувствительность к статистическим допущениям, сделанным при анализе данных. В качестве верного подхода предлагается гнездовой метод анализа (ANOVA), поскольку данные по длине криля, полученные по отдельным пробам, невоможно свести воедино в связи с тем, что в желудке пингвина криль в значительной степени перемешан. Пробы, взятые в районе залива Эсперанза, используются в качестве иллюстрации различных подходов к такому анализу. Была выявлена важная линейная регрессивная зависимость между размером криля и временем сбора проб.

Для извлечения максимального количества информации при исследовании содержимого желудков пингвинов необходимы схемы проведения групповой выборки. В качестве альтернативных методов предлагаются многократные пробы содержимого желудка одного и того же пингвина и изучение фрагментов содержимого желудка различной степени переваренности.

Resumen

La selectividad del tamaño del krill hecha por los pingüinos demuestra ser sumamente sensible a las suposiciones estadísticas hechas en el análisis de datos. El método inclusivo ANOVA se propone como el correcto enfoque para análisis, porque la falta de separación entre los especímenes de krill que se encuentran en el estómago de un cierto pingüino evita hacer un agrupamiento de datos sobre medidas del krill de diferentes muestras. Muestras tomadas en la Bahía Esperanza se utilizan para ilustrar los diferentes aproches a este análisi. Se encontró una regresión linear sumamente significante entre el tamaño del krill y tiempo.

Se necesita un conjunto de diseños de muestreo para lograr la utilización completa de la información obtenida de los contenidos estomacales. Se proponen como métodos alternativos, la reproducción de muestras de un mismo pingüino o estudiando porciones del contenido estomacal que presenten diferentes niveles de digestión.

A study of penguin diet conducted simultaneously with monitoring prey parameters would be clearly advantageous. It would enable interpretation of changes observed in predator parameters by taking into account changes in monitored prey parameters. It would also allow prediction of possible consequences for predators of changes in prey parameters. Such a simultaneous approach is fundamental to the CCAMLR Ecosystem Monitoring Program.

It would be difficult to design an experiment which combines simultaneous measurement of prey and predator parameters (e.g. measurement of krill size distribution and abundance within the foraging range of a monitored colony of predators during their breeding season). Sampling of krill introduces the problem of net selectivity which, together with krill swarming behaviour, makes it extremely difficult to ensure that the area of sampling coincides accurately with the foraging range of penguins.

A study of krill length frequency distribution in samples taken from penguin stomachs provides a great deal of important information on prey and predators. If designed properly, a study of this type may be used for evaluating the variability of some prey parameters.

The value of this study would depend on selectivity properties of penguins as krill samplers; whether or not a length frequency distribution of krill in their stomachs reflects changes in food availability. If penguins do have selectivity properties, would it be possible to define which characteristics of penguins (e.g. sex, age, etc.) may be considered as representative selection factors and also, would it be possible to define groups of penguins lacking selectivity?

Some published studies on size selectivity of krill describe penguins as highly selective predators. A statistically significant difference was found in length distribution of krill in samples taken from penguins of different sex and size. In these studies, all krill taken from stomachs of a particular group of penguins were pooled together in order to estimate the mean size of krill which in turn, was tested against the variance of the pooled samples. These analyses imply that an individual krill was independent from the remaining krill in the same penguin stomach. This assumed independence does not take note of krill swarming behaviour and is therefore incorrect.

In our study we made comparative analyses of 41 stomach samples of penguins from Bahía Esperanza, randomly divided into two groups (Table 1). Obviously, the highly significant F-statistic means only that the assumption of independence is incorrect, and demonstrates that differences between groups of penguins cannot be tested against the "krill in penguins variance" because such tests will yield misleading results.

The nested ANOVA method is the correct statistical procedure for this type of analysis. This method of analysis demonstrated that there was an insignificant F-statistic for the random groups, but a highly significant F-statistic for penguins within the random groups (Table 2).

At this stage it seems reasonable to assume that the question of size selectivity of krill by penguins is at least open to question.

Results shown in Table 3 are much more interesting. When samples were grouped according to their collection dates, the resultant statistics were insignificant both for the dates and "penguin within dates" groups. It is now evident that individual penguins feed on krill of different sizes; but krill size is also affected by the date of collection.

The "penguin within dates" component is, at least partially, a consequence of patch distribution of krill. A fraction of this component might reflect particular characteristics of penguins (e.g. sex, age, etc.), which may be responsible for their preference for krill of a particular size.

It should be stressed that unless any grouping by date is tested against the appropriate variance (between dates), erroneous results will be obtained. One example is shown in Table 5: samples from penguins have been classified in accordance with the day of the week of collection (e.g. Monday, Tuesday, etc.). The resulting nested ANOVA does not take into account "between dates" variability and shows a significant result. Obviously, penguins do not observe religious fasts stipulating that only smaller krill be eaten on Wednesdays and Fridays. This result illustrates that penguins included in any weekday group are not independent but related through sampling dates, and this dependence should be reflected in the analysis.

The regression analysis demonstrates a positive trend in mean sizes of krill with time (Table 4 and Figure 1). In view of this significant regression, it is reasonable to assume that the variance component due to date is the result of differences in krill population parameters during the sampling period. It may be argued that some pertinent component may result from the changing preferences of penguins (e.g. due to their varying needs throughout the creche period). The complex nature of these possible changes prevents the comparison of colonies to test the existence of more general trends.

The important point here is that data as currently collected will not contribute towards resolving this difference. A random block design is needed to separate penguin dependent sources of variation from those depending on krill availability, and increasing a number of samples in order to include adults is desirable.

Blocks might be defined in different ways, but the most interesting would be a swarm of krill. Unfortunately it would be technically very difficult, if not impossible, to identify the swarm on which individual penguins feed. Another useful set of blocks would be obtained by replicating samples from the same individual. This procedure would provide the "within blocks" degree of freedom needed for the independent testing of hypotheses about selectivity and prey parameters and can be obtained simply by replication of samples from the same individual, by comparison of differently digested portions of the same sample or by a combination of both methods.

Other definitions of blocks based on penguin characteristics (sex, age, beak size, reproductive condition, etc.) can be used, but results would be difficult to interpret because the distribution of penguins at sea is basically non-random.

The proposed methodology would also be useful for krill studies. When preferences of penguins are evaluated and discounted, the remaining effects of variations in prey parameters will provide valuable information about krill populations. Krill length distributions might be considered as resulting from environmental conditions within the area continuously sampled by penguins in the foraging range of a colony, thus opening the possibility for combining ship and land-based studies using powerful and well designed dynamic models.

ACKNOWLEDGEMENTS

Data were provided by Lic. Ruben Coria and Hugo Spairani. Lic. Ingrid Mozetich drew our attention to the size selectivity problem.

Table 1: One factor ANOVA for two random groups of penguins. See text for discussion.

Analysis of Variance					
Source of Variation	DF	Sum of Squares	Mean Square	F_s	Probability
Random groups	1	611.46	611.46	8.01	0.004772
Krill (within group)	2238	170824.75	76.33		

Table 2: Nested ANOVA for two random groups of penguins. See text for discussion.

Analysis of Variance					
Source of Variation	DF	Sum of Squares	Mean Square	F_s	Probability
Random groups	1	611.46	611.46	0.32	0.57913
Penguins in groups	39	73702.28	1889.80	42.79	0.0
Krill (within group)	2199	97122.39	44.17		

Components of Variance	
Source of Variation	Percentage
Random groups	0.0
Penguins in groups	45.07
Krill (within group)	54.93

Table 3: Nested ANOVA for groups of penguins sampled on the same day. See text for discussion.

Analysis of Variance					
Source of Variation	DF	Sum of Squares	Mean Square	F_s	Probability
Dates	9	56052.57	6220.06	10.57	0.0
Penguins in dates	31	18261.16	589.07	13.34	0.0
Krill (within group)	2199	97122.39	44.17		

Components of Variance	
Source of Variation	Percentage
Dates	37.50
Penguins in dates	11.82
Krill (within group)	50.68

Table 4: Regression of krill mean size consumed by penguins as a function of collection date.

		Analysis of Variance			
Source of Variation	DF	Sum of Squares	Mean Square	F_s	Probability
Between dates	15	1043.63	69.58	4.43	0.00055
Linear regression	1	908.46	908.46	57.81	0.0
Constant regression	1	52911.36	52911.36	3367.10	0.0
Deviation from regression	14	135.17	9.66	0.61	0.82842
Error within groups	25	392.86	15.71		
Total sum of squares	40	1436.49			
Uncorrected total	41	54347.84			

Table 5: Nested ANOVA for groups of penguins sampled on the same weekday. See text for discussion.

		Analysis of Variance			
Source of Variation	DF	Sum of Squares	Mean Square	F	Probability
Between days of the week	5	39299.13	7859.83	7.86	0.000055
Penguins in weekday	35	35014.61	1000.42	22.65	0.0
Krill (within group)	2199	97122.39	44.17		

	Components of Variance
Source of Variation	Percentage
Between days of the week	26.84
Penguins in groups	21.70
Krill (within group)	51.46

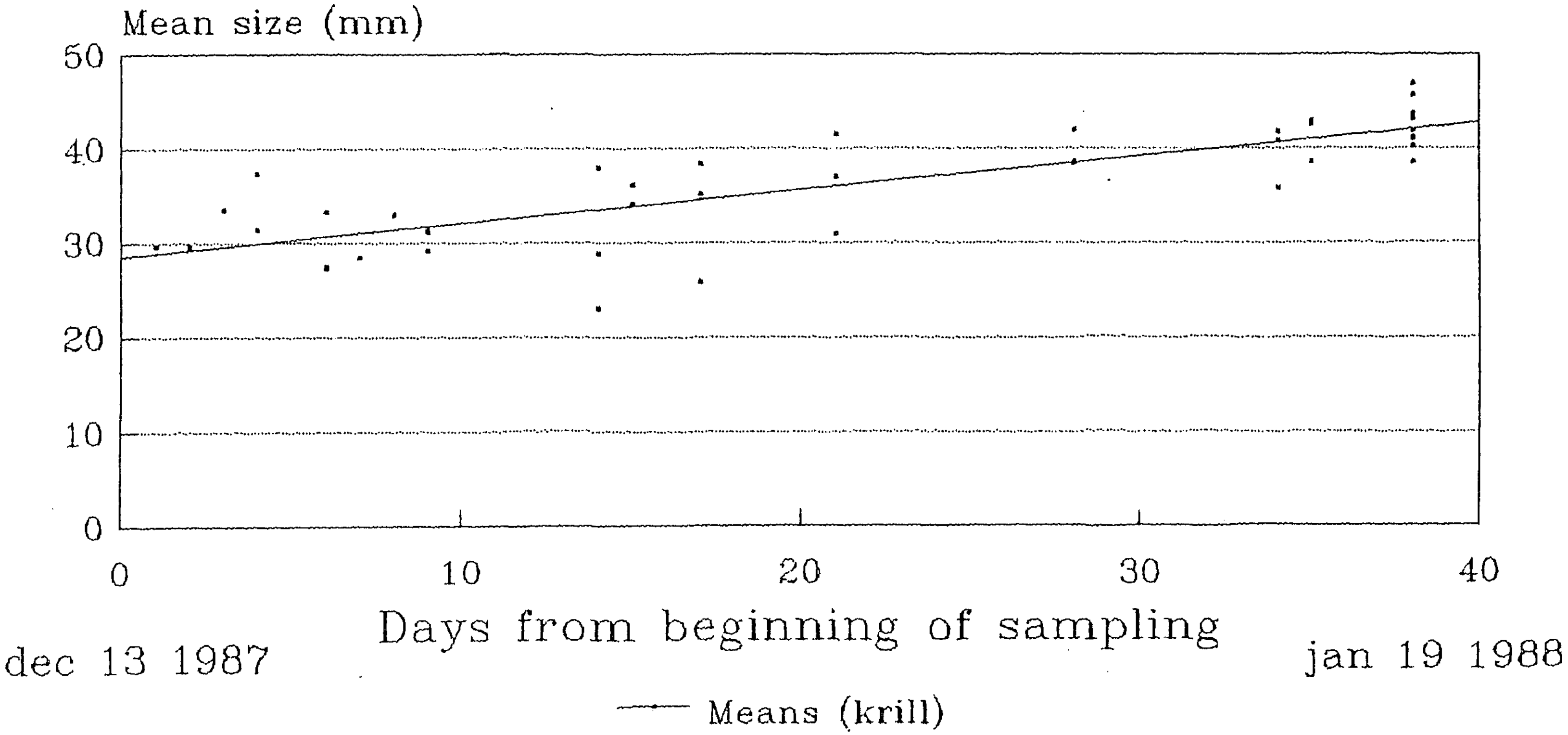

Figure 1: Krill size as a function of time of sampling. Krill consumed by penguins in Bahía Esperanza. Observed trend in the size of krill consumed by penguins. See Table 4 for statistical analysis.

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Tableau 3: ANOVA à emboîtements pour des groupes de manchots échantillonnés le même jour. Voir le texte pour discussion.

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ON THE POWER TO DETECT CHANGES USING THE STANDARD METHODS FOR MONITORING PARAMETERS OF PREDATORY SPECIES

P. Boveng and J.L. Bengtson

Abstract

The CCAMLR guidelines (CCAMLR, 1989) for analyzing the statistical power to detect changes are applied using variance estimates from studies at the South Shetland Islands of lengths of first incubation shifts by penguins (Standard Method A2.1), duration of penguin foraging trips (A5.1), penguin breeding success (A6.1), penguin chick diet (A8.1), and fur seal foraging trip duration (C2.0). The other Standard Methods are not evaluated because the power analysis in the CCAMLR guidelines is inappropriate (fur seal pup growth rate C1.0), and/or because data from the studies considered here are insufficient for conducting power analyses (penguin arrival weight A1.1, trend in penguin population size A3.1, penguin demography A4.1, penguin fledging weight A7.1). Alternative forms for analyses of the power of Standard Methods A3.1, A5.1, C1.0, and C2.0 are proposed.

Résumé

Les lignes directrices de la CCAMLR (CCAMLR,1989) concernant l'analyse de la puissance statistique de détection des changements sont mises en application en utilisant des estimations de variance provenant d'études faites aux îles Shetland du Sud. Celles-ci portent sur la durée du premier tour d'incubation des manchots (Méthode standard A2.1), la durée des sorties alimentaires des manchots (A5.1), la réussite de la reproduction des manchots (A6.1), le régime alimentaire des jeunes manchots (A8.1) et la durée des sorties alimentaires des otaries (C2.0). Les autres Méthodes standard ne sont pas évaluées, l'analyse de la puissance dans les lignes directrices de la CCAMLR étant impropre (taux de croissance de jeunes otaries C1.0), et/ou les données provenant des études prises en considération dans ce document étant insuffisantes pour effectuer des analyses de la puissance (poids du manchot à l'arrivée A1.1, tendances dans la taille de la population de manchots A3.1, démographie des manchots A4.1, poids des jeunes à la première mue A7.1). D'autres formes d'analyses de la puissance des Méthodes standard A3.1, A5.1, C1.0 et C2.0 sont proposées.

Резюме

Руководства АНТКОМа (CCAMLR, 1989) по анализу статистической мощности при выявлении изменений применяются с использованием оценок продолжительности первой инкубационной смены пингвинов (Стандартный метод A2.1), продолжительности периодов кормления пингвинов в море (Стандартный метод A5.1) репродуктивного успеха пингвинов (Стандартный метод A6.1), рациона птенцов пингвина (Стандартный метод A8.1) и продолжительности периодов кормления морского котика (Стандартный метод C2.0), полученные в ходе исследований на Южных Шетландских островах. Остальные Стандартные методы не оцениваются в связи с тем, что приведенный в руководствах АНТКОМа анализ мощности неприменим (темп роста щенков морского котика C1.0), и/или в связи с тем, что данных, полученных в результате рассматриваемых исследований, недостаточно для выполнения анализа мощности (вес пингвинов по прибытии в колонию A1.1, тенденции изменения размера популяции пингвинов A3.1, демография пингвинов A4.1, вес пингвинов при оперении A7.1). Предлагаются альтернативные формы анализа мощности Статистических методов A3.1, A5.1, C1.0 и C2.0.

Resumen

Las directivas de la CCRVMA (CCAMLR, 1989) para analizar la capacidad estadística para detectar cambios, se aplican utilizando estimaciones de variación procedente de los estudios realizados en las Islas Shetland del Sur sobre las duraciones de los primeros turnos de incubación de pingüinos (Método Estándar A2.1), duración de los viajes de alimentación de los pingüinos (A5.1), éxito en la reproducción de pingüinos (A6.1), dieta de los polluelos de pingüinos (A8.1), y duración de los viajes de alimentación de los lobos finos (C2.0). Los otros Métodos Estándar no están evaluados porque la capacidad de análisis de las directivas de la CCRVMA no es apropiada (índice de crecimiento de los cachorros de lobo fino C1.0), y/o porque datos de los estudios considerados aquí son insuficientes para conducir análisis de capacidad (peso de llegada de los pingüinos A1.1, tendencias en el tamaño de la población de pingüinos A3.1, demografía de pingüinos A4.1, peso de pingüinos al emplumaje A7.1). Se proponen maneras alternativas para los análisis de la capacidad de los Métodos Estándar A3.1, A5.1,C1.0 y C2.0.

1. INTRODUCTION

Members of the Working Group for the CCAMLR Ecosystem Monitoring Program (CEMP) have been asked to conduct "sensitivity analyses" of existing data on predator parameters. Those analyses, perhaps more properly called "power analyses", should provide information about the power of the standard methods to detect changes in parameters monitored for predators.

Guidelines for conducting one type of power analysis were compiled by the CCAMLR Secretariat (CCAMLR, 1989). That paper described the method for estimating the sample size required to detect a specified difference (δ) between or among years, subject to acceptable probabilities of rejecting a true null hypothesis (α) or accepting a false null hypothesis (β). The required input for the analysis is an estimate of the standard deviation (s) if δ is in the same units as the mean, or the coefficient of variation (*cv*) if δ is expressed as a percentage of the typical mean value.

The analysis described in CCAMLR (1989) provides information about the power to distinguish between the mean values of parameters obtained in two or more years. We may also wish to know what sample size is required in an annual monitoring effort to detect a linear or log-linear trend in a parameter. Methods for such analysis were presented by Gerrodette (1987). When the parameter values are proportions, the sample sizes required to detect a specified slope can be obtained as described by Nam (1987). The quantities required in a power analysis for detecting trends are essentially the same as those required for the previous analysis, though the formulae are slightly different. The quantity δ must be expressed as the minimum detectable slope of a regression.

For some parameters the monitoring design is such that neither analysis mentioned above is strictly appropriate. Because of the complexity of some of the designs, there may be no general formula for evaluating power or determining a required sample size. For those parameters we advocate using numerical simulations to assess the ability to detect changes.

In the remainder of this paper, we first suggest several changes to the guidelines suggested in CCAMLR (1989). Then we consider each of the standard methods for monitoring parameters of predatory species. For each method we discuss appropriate techniques for evaluating the power to detect changes or for determining required sample sizes. For some of the parameters, we apply those techniques to existing estimates of the uncertainty in the parameter. We consider unpublished data from the US AMLR monitoring program at Seal Island, Elephant Island (60°59.5'S, 55°24.5'W), and from the study by Trivelpiece et al. (1989) at Admiralty Bay, King George Island (62°10'S, 58°30'W).

2. COMMENTS ON CCAMLR (1989)

First, we note that there was a typographical error in equation (1) of CCAMLR (1989) by the omission of an exponent on the sum of the t-values. The corrected form of the equation is reproduced here as

$$n \geq 2(s/\delta)^2\{t_{\alpha,[v]}+t_{2(1-P),[v]}\}^2 \qquad (1)$$

where n = the required sample size,

s = the standard deviation computed from the raw or transformed data,

δ = the smallest true difference that it is desired to detect,

v = degrees of freedom for error in the ANOVA or t-test [$v=r(n-1)$ where r is the number of years or replicates],

P = desired probability that a difference will be found if it is as large as δ (P is the statistical power),

$t_{\alpha,[v]}$ = value from a two-tailed t-table with v degrees of freedom and corresponding to probability α, and
$t_{2(1-P),[v]}$ = value from a two-tailed t-table with v degrees of freedom and corresponding to probability 2(1-P).

We also suggest that an additional column be added to the table described in paragraph 19 of CCAMLR (1989). The additional column should contain the sample sizes required when $\alpha = \beta = .05$. For many of the parameters, these conditions will not be attainable due to logistic impracticalities, so α and β may need to be reduced. However, unlike situations typically presented in statistical textbooks, we suggest that in a conservation context, type 2 errors (β errors) may be at least as important as type 1 errors (α errors). For example, failure to detect a decrease in penguin reproductive success that actually occurred (type 2 error) may be equally or perhaps more serious than detecting an apparent, but false, decrease (type 1 error).

The probabilities of committing the two types of errors have a direct bearing on the circumstances under which decisions are taken to impose conservation measures. If one were required to choose between the types of error that one would be willing to accept, a conservative approach might suggest that it would be preferable to take protective action when there was an apparent but false need rather than failing to take protective action when there was a true but undetected need for conservation measures.

Finally, the suggestion that members compute estimates of required sample sizes for both two and five years of monitoring seems unnecessary. The question addressed by equation (1) simply uses the estimated variance of a parameter to determine how small a change (δ) could be detected between or among years with a given sample size. The number of years monitored will have little effect on the size of the change that is detectable. Therefore, the required sample sizes will differ by very little, if at all, for estimates based on two years or five years of monitoring (though for detecting a trend, the number of years will be very important). This can be seen in the table presented in paragraph 19 of CCAMLR (1989). In the following analyses, we present only estimates of sample sizes required assuming two years of monitoring.

3. METHODS FOR PENGUINS

3.1 Weight on Arrival at Breeding Colonies (A1.1)

As shown in CCAMLR (1989), the standard method for estimating the population mean weight on arrival at the rookery is incomplete because it does not account for seasonal variation in rates of arrival. No data were available, from the sources mentioned above, to evaluate the variability in this parameter. Croxall et al. (1988) evaluated the power to detect changes in this parameter for macaroni and gentoo penguins at Bird Island and for Adélie and chinstrap penguins at Signy Island.

3.2 Length of First Incubation Shift (A2.1)

Trivelpiece et al. (1989) measured the durations of first incubation shifts of male and female Adélie penguins for five years and of male and female chinstrap penguins for four years at King George Island. Although a separate analysis could be conducted to determine the statistical power which could be achieved by routine monitoring at the actual sampling intensity attained in each year, a more useful approach would combine the standard deviations from all five years (four years for chinstraps) into a single statistic that would be more representative of the variation in this parameter. Then the analysis suggested in CCAMLR (1989) would be performed to investigate the trade-off between sample size and the power to detect changes in the parameter.

One appropriate statistic for estimating the standard deviation of a parameter when several years' data are available is the "mean-squared-error" (MSE) term from a one-way analysis of variance with years representing treatments. The square root of the MSE term is a "pooled" estimate of the quantity s of equation (1). Given the resulting value of s and specified levels of acceptable type 1 and 2 errors (alpha and β respectively), the minimum detectable difference δ can be expressed as a function of sample size, or vice-versa.

The MSE within years for first incubation shifts by male Adélie penguins was 6.92 and for female Adélies was 13.07. Using the square-root of the MSE as an estimate of the typical standard deviation in this parameter, we used equation (1) to compute the requisite sample sizes for detecting changes of 10%, 20% and 30% of the mean value (males, 12.4 days; females, 10.0 days) for the 5 years studied (Table 1).

For chinstrap penguins, the MSE for length of first incubations by males was 9.0 and for first incubations by females was 5.5. The mean length of first incubations by males was 5.8 days and by females was 3.9 days. The requisite sample sizes for detecting changes of 10%, 20% and 30% of the mean values are shown in Table 2.

No data on this parameter were available from the study at Seal Island.

3.3 Trends in Breeding Population Size (A3.1)

There were no suitable estimates of variance for the data on breeding population size from the two studies considered here. This will likely be a problem for other studies as well. Some techniques for abundance estimation result in particular and known relations between the mean and variance of the estimate (Gerrodette, 1987). For studies utilizing such techniques, a range of reasonable guesses about the variance in the estimates could be applied to the formulae presented by Gerrodette (1987) to make a preliminary assessment of the power to detect trends. As an initial upper bound to the range of variance, one might simply use the variance between several recently obtained annual censuses. We have not done such an analysis for the data considered here. Alternatively, replicate counts (at least three replicates) of colonies in future seasons would allow estimating the variance.

3.4 Demography (A4.1)

The parameters to be monitored by method A4.1 are annual survivorship, age at first reproduction, and cohort strength. The banding program in "Method A" will provide estimates of the average survival of adult breeding birds. "Method B" will provide age-specific survival estimates as well as estimates of the age at first reproduction. Cohort strength is not well defined in the method's description but presumably involves some measure of the size of a cohort relative to that of adjacent cohorts.

Estimates for any of the three parameters will be available only after several years of monitoring. Estimating the variability of the parameters may require an even longer period, though some of the methods for estimating survival rates and age at first reproduction in a mark-resight study are associated with theoretically derived analytic estimates of variance. Sufficient data for evaluating the variability in any of the three demographic parameters were not available from either of the two studies considered here.

3.5 Duration of Foraging Trips (A5.1)

The design for monitoring the duration of foraging trips is a nested, or hierarchical, experiment. That is, for any particular year, several breeding birds are chosen (at random) for monitoring and the lengths of foraging trips by each bird are measured. In general, the sample of birds monitored one year is not the same as the sample monitored the next year. Thus, each sample of birds is said to be "nested" within years when two or more years are being compared. The analysis must take into account that some of the variation between or among years is simply due to the fact that the birds used were not the same every year.

In addition to the complication of a nested design, the standard method for monitoring foraging trip duration may be complicated by an inverse relationship between trip duration and number of trips. That is, if a bird with a propensity to make long trips tends to make fewer of them than a bird which makes short trips, the usual statistical tests will not be reliable. The usual methods for unbalanced (unequal sample size) nested ANOVA assume that sample size and magnitudes of the items in the sample are independent.

The consequence of the problems mentioned above is that there is no simple or general formula analogous to equation (1) to produce the required sample size for effective monitoring of foraging trip duration. Existing estimates of the variance of trip duration for an individual bird, the covariance of trip duration with number of trips, and the variance between birds could be used in numerical simulations to assess the power of the method or to choose reasonable sample sizes. Such an exercise is beyond the scope of this paper. Until such time as those simulations are conducted, we advocate the following as a first approximation to a power analysis of the standard method for foraging trip duration.

The problem of correlation between trip duration and numbers of trips can be avoided by computing a mean trip duration separately for each bird and giving equal weight to the mean for each bird when computing the annual mean. Then the sample size is simply the number of birds, without regard to the number of trips made by individual birds. Likewise, the variance is the variance between the means of individual birds, without regard for the variance of the lengths of trips made by individual birds. Applying existing estimates of the between-bird variance to the formula in equation (1), yields the approximate required sample sizes, in terms of numbers of birds.

Trivelpiece et al. (1989) used visual monitoring of pairs of Adélie and chinstrap penguins to estimate average foraging trip durations for each species at King George Island in the 1981/82 and 1982/83 seasons. The mean trip duration for 37 pairs of Adélie penguins in the two years was 24.3 hr. The mean duration of trips made by 47 pairs of chinstrap penguins was 16.7 hr. The MSE for duration of trips was 20.5 for Adélies and 40.7 for chinstraps. Sample sizes, estimated by the approximation method described in the previous paragraph, for detecting changes of 10%, 20%, and 30% of the mean values are shown for Adélie and chinstrap penguins in Table 3.

The data on durations of chinstrap and macaroni penguin foraging trips at Seal Island, monitored with radio-transmitters, were not summarized in time for analysis in this report. However, a comparison of data obtained using visual and radio-transmitter methods would be useful in determining whether sample sizes required for these techniques differ.

Finally, we note that the scheme presented in CCAMLR (1989) for computing an annual mean trip duration (paragraphs 28 and 29) ignores the problems of nested design and correlation between trip duration and number of trips. That scheme gives equal weight to each foraging trip made during a particular year. The simplification we presented above partially avoids that problem, but ignores the five-day stratification scheme which may be necessary to account for systematic changes in trip duration within a season.

3.6 Breeding Success (A6.1)

The reproductive success of 150 pairs of chinstrap penguins was monitored at Seal Island in 1987/88, though the field work was begun on 25 December, well after the first egg was laid. Assuming no egg loss occurred prior to the study, the mean number of chicks raised to creche age per pair was 1.26, with a standard deviation of 0.87. If those numbers are typical, the minimum number of nests which would have to be monitored to detect changes of 10% to 30% of the mean value are shown in Table 4*.

Breeding success was monitored in 33 pairs of macaroni penguins at Seal Island in 1987/88. Because the number of macaroni chicks raised per pair can only equal zero or one, the data can be treated as binomial proportions. Fleiss (1981, pp. 41-42) gives the appropriate formulae for the sample sizes required to detect a specified difference between two proportions. Table 5 presents estimated minimum sample sizes to detect a change from the observed mean of 0.91 chicks per pair to each of several new values for the reproductive success parameter. Note that the sample sizes in Table 5 are generally much larger than the 33 pairs used to estimate the mean for the analysis. Therefore, this analysis is presented more as an example of the method than as a true power analysis.

The reproductive success of Adélie penguins, measured as the number of chicks fledged per breeding pair was monitored by Trivelpiece et al. (1989) at Admiralty Bay, King George Island. During each of six years (not all consecutive), several hundred breeding pairs were observed. Therefore, a mean and standard deviation of the number of chicks fledged per pair is available for each of the six breeding seasons. However, at the time of this writing we were unable to adequately interpret those data because the quoted standard deviations were larger than is possible for a variable which can only take on values of zero, one, or two.

3.7 Chick Fledging Weight (A7.1)

As shown in paragraphs 9 and 10 of CCAMLR (1989), the standard method for estimating the population mean fledging weight may not yield a reliable annual index if the true average fledging weight varies between five-day periods. The average weights of chinstrap penguins fledging in consecutive five-day periods differed significantly at Seal Island in 1989. If this result is confirmed for other species, sites, and years, the standard method will need to be revised to include a strategy for weighting the mean from each five-day period by the number of chicks fledged in that period.

One potential method for obtaining an index of the numbers of chicks fledged in each 5-day period would be to keep daily counts of the numbers of chicks (unfledged) remaining in several discrete, small or peripheral colonies. Adding up the daily decrements in chick numbers might yield a satisfactory estimate of the relative numbers fledging in the several 5-day periods. The daily decrements will include mortality, but if the rate of mortality is small relative to the rate of fledging and if the mortality rate is not dramatically different between different five-day periods, the estimates should still be reliable.

3.8 Chick Diet (A8.1)

The data from the standard methods for monitoring penguin chick diet will consist of total wet weights of the contents of individual stomachs or of more detailed information such

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* E. Marschoff (personal communication) has suggested that changes in the individual proportions of pairs raising zero, one or two chicks might be detectable using sample sizes much smaller than those apparently required to detect changes in the mean number of chicks raised.

as the proportion of the total weight comprising a particular prey taxon. We consider here only the data on total weight, deferring analysis of the proportion data to another paper evaluating the different types of analysis appropriate for proportions.

Trivelpiece et al. (1989) measured meal sizes of Adélie and chinstrap penguin chicks during three years at King George Island. The average meal size for Adélie penguins was 533 g and the average for chinstraps was 443 g. Pooling the variances as described above, the square-root of the MSE for meal size of Adélie penguins was 191.8 and for chinstrap penguins the square-root of the MSE was 219.8. Using the square-root of the MSE as the typical standard deviation, we estimated the sample sizes required to detect changes of 10%, 20%, and 30% of the mean values for Adélie and chinstrap meal size (Table 6). Because of the relatively high variability in this parameter, the samples required to detect a modest change in the mean are very large.

4. METHODS FOR FUR SEALS

4.1 Fur Seal Pup Growth (C1.0)

The data from this method consist of periodic weights of a marked sample of pups or of random samples of pups. The resulting index will be the value of the slope of a regression of pup weight versus date. The techniques for comparing the slopes of two or more regressions are well established, and found in most introductory statistics texts. However, several aspects of this technique should be considered in more detail before a formal power analysis is conducted.

As discussed in CCAMLR (1989), the assumptions for linear regression analysis (homogeneity of variance, fit to linear model) should be investigated. Assuming that those investigations reveal that linear regression is appropriate, a power analysis will still be more difficult than one which relies on equation (1) for the following reason.

There are two measures of sample size which must be considered in designing a test for differences between pup growth rates among several years. The first is the number of pups to be weighed on a particular date. The second is the number of dates within the pup-rearing season on which pup weights are to be sampled. The issue of how many times samples of pups should be weighed is further complicated by consideration of the time intervals between successive weighings. Weights taken on each of four consecutive days will not provide the "contrast" afforded by weights collected at four one-week intervals. A thorough analysis of the power to detect changes in pup growth rates will likely require numerical simulations in which the response of the parameter to systematic changes in numbers of pups and in numbers and spacing of weighing dates is explored. Because good estimates of the "within-date" variance of pup weights are available from two years at Seal Island, we intend to pursue this topic in the near future.

4.2 Foraging/Attendance Duration (C2.0)

As we discussed above in the section on penguin foraging trip duration, this monitoring scheme is a nested design with the complication that trip duration and number of trips made by an individual are inversely related (Figure 1). One approach, to prevent undue weighting of females which tend to make short trips, would be to weight the mean trip duration for each female equally when computing the overall mean trip duration for the year. Using that method on data from Seal Island, the following results were obtained.

The average of the mean trip durations of 19 fur seal females at Seal Island in 1986/87 was 59.7 hr, with a standard deviation of 43.6 hr. In 1988/89, the average from 13 females was 52.4 hr, with a standard deviation of 44.4 hr. With coefficients of variation of about 80%, it would clearly be very difficult to detect differences between years using this type of analysis. This is shown in Table 7, by the very large sample sizes which would be required (again calculated by using a pooled estimate of variance and equation (1)).

The data shown in Figure 2 suggest an explanation for the low statistical power obtained by the previous method: the lengths of foraging trips tend to decrease as the season progresses. Therefore, some of the "within-year" variation may be due to differences between the dates on which different females' trips were made. Modifications to the standard method, such as stratifying foraging data by calendar date or using analysis of covariance to remove the effect of date, will likely reduce the within-year variation, thereby reducing the size of the sample of females required to detect a specified difference between years.

Other modifications, addressing the problems we described above, to the standard method for fur seal foraging trip length are also possible. For example, another way to give equal weight to the mean of each female's trip durations would be to use only a specified number, say the first 5, of her postpartum foraging trips. That strategy may also partially remove the "date effect", by reducing the portion of the season during which trips are measured. In any case, a thorough investigation of the power of standard method C2.0, with the modifications we described above, is beyond the scope of this paper. We will use the data from Seal Island to conduct such an analysis, making the results available to the Working Group as soon as they are completed.

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Table 1: Estimates of the minimum sample sizes (number of birds) required to detect a change of magnitude equal to δ in the mean lengths (days) of Adélie penguin first incubation shifts are presented for a range of values for desired statistical power. All estimates are for tests conducted after two years of monitoring. Data are from Trivelpiece et al. (1989) Table 11.

Incubation shifts by males:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
1.24 (10%)	119	96	72	46
2.48 (20%)	31	25	19	13
3.72 (30%)	15	12	9	7
For α = 0.10:				
1.24 (10%)	99	79	57	34
2.48 (20%)	26	21	15	10
3.72 (30%)	12	10	8	5

Incubation shifts by females:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
1.00 (10%)	341	276	207	130
2.00 (20%)	86	70	53	34
3.00 (30%)	39	32	24	16
For α = 0.10:				
1.00 (10%)	284	225	163	95
2.00 (20%)	72	57	42	25
3.00 (30%)	33	26	19	12

Table 2: Estimates of the minimum sample sizes (number of birds) required to detect a change of magnitude equal to δ in the mean lengths (days) of chinstrap penguin first incubation shifts are presented for a range of values for desired statistical power. All estimates are for tests conducted after two years of monitoring. Data are from Trivelpiece et al. (1989), Table 12.

Incubation shifts by males:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
0.58 (10%)	698	564	422	264
1.16 (20%)	176	142	107	67
1.74 (30%)	79	64	48	31
For α = 0.10:				
0.58 (10%)	581	460	332	194
1.16 (20%)	146	116	84	50
1.74 (30%)	66	52	38	23

Incubation shifts by females:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
0.39 (10%)	953	771	576	360
0.78 (20%)	239	194	145	91
1.17 (30%)	107	87	65	41
For α = 0.10:				
0.39 (10%)	794	629	454	265
0.78 (20%)	200	158	114	67
1.17 (30%)	89	71	52	31

Table 3: Estimates of the minimum sample sizes (number of birds) required to detect a change of magnitude equal to δ in the mean duration (hours) of chinstrap and Adélie penguin foraging trips are presented for a range of values for desired statistical power. All estimates are for tests conducted after two years of monitoring. Data are from Trivelpiece et al. (1989), Table 9.

Adélie penguins:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
2.43 (10%)	92	74	56	36
4.86 (20%)	24	20	15	10
7.29 (30%)	12	10	8	6
For α = 0.10:				
2.43 (10%)	77	61	44	26
4.86 (20%)	20	16	12	8
7.29 (30%)	10	8	6	4

Chinstrap penguins:

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
1.67 (10%)	382	309	231	145
3.34 (20%)	97	78	59	37
5.07 (30%)	44	36	27	18
For α = 0.10:				
1.67 (10%)	318	252	182	107
3.34 (20%)	81	64	47	28
5.07 (30%)	37	29	21	13

Table 4: Estimates of the minimum sample size (number of pairs) required to detect a change of magnitude equal to δ in the mean number of chinstrap chicks raised to creche age per breeding pair are presented for a range of values for desired statistical power. All estimates are for tests conducted after two years of monitoring. Data are from Seal Island, 1987/88.

	Statistical Power (1-β)			
δ	0.95	0.90	0.80	0.60
For α = 0.05:				
0.129 (10%)	1185	958	716	448
0.258 (20%)	297	241	180	113
0.387 (30%)	133	108	81	51
For α = 0.10:				
0.129 (10%)	986	782	564	329
0.258 (20%)	248	196	142	83
0.387 (30%)	111	88	64	38

Table 5: Estimates of the minimum sample sizes (number of pairs) required to detect a change in macaroni penguin reproductive success from a value of 0.91 chicks raised per pair to each of the new values (P2) listed below. The usual quantity δ would be the difference between P2 and 0.91. All estimates are for tests conducted after two years of monitoring. Data are from Seal Island, 1987/88.

	Statistical Power (1-β)			
P2	0.95	0.90	0.80	0.60
For α = 0.05:				
0.95	1104	902	686	446
0.85	792	647	492	319
0.80	281	231	177	117
0.75	152	125	97	65
0.70	98	81	63	43
For α = 0.10:				
0.95	927	744	551	341
0.85	665	533	394	243
0.80	236	191	143	90
0.75	128	104	79	51
0.70	83	68	52	34

Table 6: Estimates of the minimum sample sizes required to detect a change of magnitude equal to δ in the average wet weight of Adélie and chinstrap penguin chick meals (grams) are presented for a range of values for desired statistical power. All estimates are for tests conducted after two years of monitoring. Data are from Trivelpiece et al. (1989), Table 6.

Adélie penguins:

		Statistical Power (1-β)			
δ		0.95	0.90	0.80	0.60
For α = 0.05:					
53.3	(10%)	338	273	205	128
106.6	(20%)	86	69	52	33
159.9	(30%)	39	32	24	16
For α = 0.10:					
53.3	(10%)	281	223	161	95
106.6	(20%)	71	57	41	25
159.9	(30%)	33	26	19	12

Chinstrap penguins:

		Statistical Power (1-β)			
δ		0.95	0.90	0.80	0.60
For α = 0.05:					
44.3	(10%)	641	519	388	243
88.6	(20%)	162	131	98	62
132.9	(30%)	73	59	44	28
For α = 0.10:					
44.3	(10%)	534	423	306	179
88.6	(20%)	135	107	77	46
132.9	(30%)	61	48	35	21

Table 7: Estimates of the minimum sample sizes (number of females) required to detect a change of magnitude equal to δ in the mean duration (hours) of fur seal foraging trips are presented for a range of values for desired statistical power. These estimates are likely to be too high because they do not account for the "within-year" variation of the type shown in Figure 2. All estimates are for tests conducted after two years of monitoring. Data are from Seal Island, 1986/87 and 1988/89 seasons.

		Statistical Power (1-β)			
	δ	0.95	0.90	0.80	0.60
For α = 0.05:					
5.67	(10%)	1558	1261	942	589
11.35	(20%)	391	316	237	148
17.02	(30%)	175	141	106	67
For α = 0.10:					
5.67	(10%)	1298	1029	742	433
11.35	(20%)	326	258	186	109
17.02	(30%)	146	115	84	49

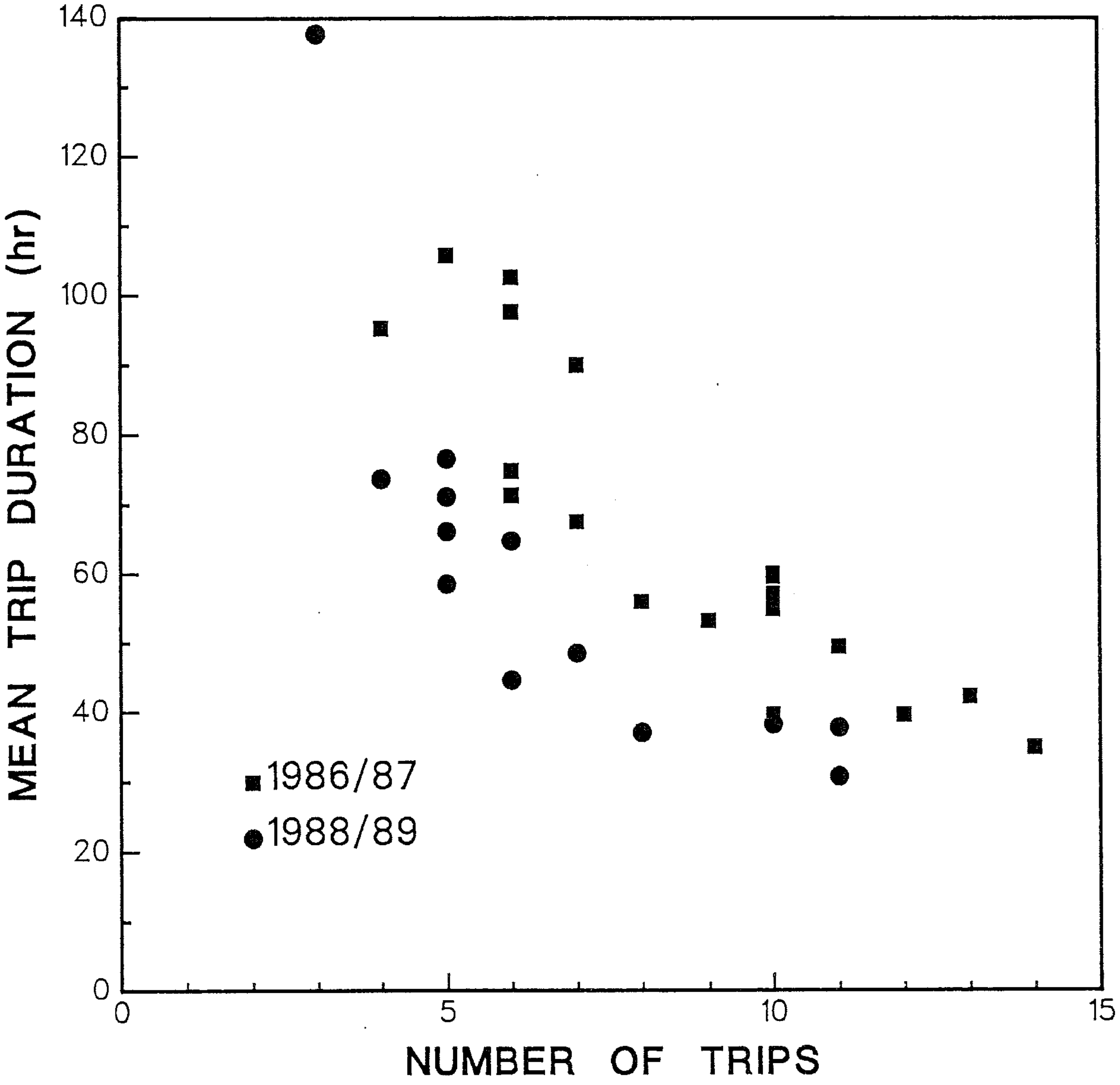

Figure 1: Relationship of individual duration and total number of foraging trips to sea made by female Antarctic fur seals at Seal Island, South Shetland Islands, Antarctica. Data from the 1986/87 season sampled trips from late December to mid-February; 1988/89 data sampled trips from mid January to late February.

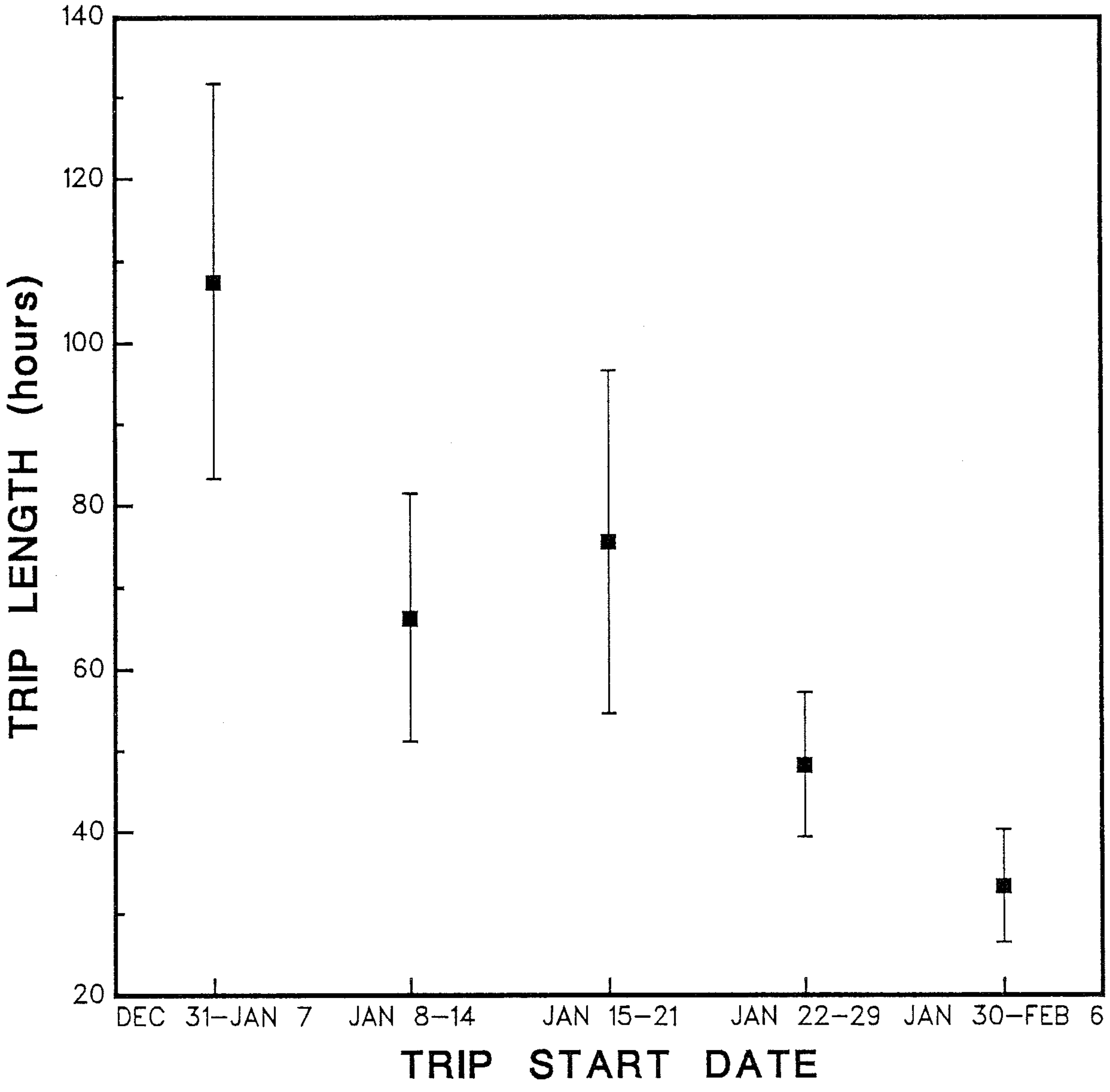

Figure 2: Within-season changes in the duration of foraging trips to sea made by female Antarctic fur seals at Seal Island, South Shetland Islands, Antarctica. Data are from the 1986/87 season.

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STATISTICAL POWER TO DETECT CHANGES IN GROWTH RATES OF ANTARCTIC FUR SEAL PUPS

P. Boveng, J. L. Bengtson and M. E. Goebel

Abstract

Numerical simulations were used to investigate the power of methods for detecting changes (between years) in pup growth rates, the loss of power associated with obtaining weight samples on only three dates in a season, and potential means of increasing the power of the CCAMLR Ecosystem Monitoring Program Standard Method C1 (B). Using estimates of variance in pup weights obtained at Seal Island (60°59.5'S, 55°24.5'W), the simulations suggest that following the protocol of the Standard Method (50 pups of each sex, weighed on four dates at 28-day intervals) would result in the ability to detect a 17% change in the growth rate with a 10% chance of committing Type 1 or Type 2 errors. If only three samples (50 pups, 28-day intervals) are obtained, the detectable change increases to about 34% under the same conditions. Slight gains in power can be obtained in some cases, without increasing the total number of pups weighed in a season, by decreasing the time between weighings.

Résumé

Des simulations numériques ont été utilisées pour examiner l'efficacité des méthodes de détection des changements (entre années) dans les taux de croissances des jeunes, la perte d'efficacité liée au fait que les échantillons de poids n'ont été obtenus que trois fois par saison, et les moyens potentiels d'augmenter l'efficacité des Méthodes standard du Programme de contrôle de l'écosystème de la CCAMLR C1 (B). En se basant sur les estimations de variance de poids des jeunes, obtenues à l'île Seal (60°59,5'S, 55°24,5'W), les simulations suggèrent qu'en suivant le protocole de la Méthode standard (50 jeunes de chaque sexe, pesés à quatre dates espacées de 28 jours), l'on pourrait déceler un changement de 17% dans le taux de croissance, avec 10% de chances de commettre des erreurs de type 1 ou 2. Si l'on n'obtient que trois échantillons (50 jeunes, à intervalle de 28 jours), les changements décelables augmentent d'environ 34%, dans les mêmes conditions. Dans certains cas, l'efficacité peut être légèrement augmentée sans augmentation du nombre total de jeunes pesés en une saison, en diminuant le temps passé entre les pesées.

Резюме

При исследовании эффективности методов в выявлении (межгодовых) изменений темпа роста щенков, рассмотрении снижении эффективности вследствие получения данных по весу только за три дня в течение сезона и потенциальных путей повышения эффективности Стандартного метода C1 (B), являющегося частью Программы АНТКОМа по мониторингу экосистемы, было использовано математическое моделирование. В результате применения при моделировании полученных на острове Сил (60°59,5'ю.ш., 55°24,5'з.д.) оценочных величин изменчивости веса щенков, было сделано заключение о том, что при следовании процедуры Стандартного метода (50 щенков каждого пола взвешиваются четыре раза с интервалом в 28 дней) можно выявить 17%-ное изменение темпа роста, при этом существует 10%-ная вероятность допущения погрешности типа 1 или 2. При получении лишь 3 проб (50 щенков в каждой с интервалом в 28 дней) при таких же условиях можно выявить более значительное, 34%-ное изменение. В некоторых случаях эффективность может быть повышена в некоторой степени при отсутствии увеличения количества щенков, взвешенных в течение одного сезона за счет сокращения интервала между взвешиваниями.

Resumen

Simulaciones numéricas se utilizaron para investigar la capacidad de los métodos para detectar los cambios (entre años) en el índice de crecimiento de los cachorros, la incapacidad asociada con la obtención de muestras de peso en sólo tres fechas en una temporada, y maneras potenciales de aumentar la capacidad del Método Estándar C1 (B) del Programa de Seguimiento del Ecosistema de la CCRVMA. Usando estimaciones de variación en el peso de los cachorros obtenidas en la Isla Seal (60°59,5'S, 55°24.5'W), las simulaciones sugieren que siguiendo el protocolo del Método Estándar (50 cachorros de cada sexo, pesados en cuatro fechas a intervalos de 28 días) resultaría en la habilidad de detectar un 17% en el índice de crecimiento, con una posibilidad de 10% de que se cometan errores del Tipo 1 o Tipo 2. Si sólo se obtienen tres muestras (50 cachorros, intervalos de 28 días), el cambio detectable aumenta aproximadamente 34% bajo las mismas condiciones. Leves aumentos en veracidad se pueden obtener en ciertos casos, sin aumentar el número total de cachorros pesados en una temporada, disminuyendo el tiempo entre cada pesaje.

1. INTRODUCTION

The CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method C1 describes two techniques for estimating growth rates of Antarctic fur seal (*Arctocephalus gazella*) pups. Method (A) requires weighing each member of a sample of individually marked pups several times between birth and weaning. Method (B) requires weighing samples of 50 male and 50 female pups at monthly intervals beginning about 30 days after mean pupping date and concluding prior to weaning, when pups are about 110 days old. The analysis presented here pertains to the statistical power to detect changes in pup growth rate using Method (B), deferring a similar treatment of Method (A).

Boveng and Bengtson (1989) suggested that the effective sample size for estimating power to detect changes in growth rates depends not only on the total number of pups weighed, but on the number of weighing dates and the time intervals between them. Method B does not specify clearly the number of dates on which pups should be weighed. If the first sample is weighed 30 days after mean pupping date, three additional samples at monthly (say 28-day) intervals would conclude on the 114th day after mean pupping. Thus, it seems that no more than four samples of pups will be weighed following this method and that possibly three or fewer samples might be obtained.

A monitoring program in which pups are weighed on only three dates may not attain acceptable statistical power to detect changes in pup growth rate. Furthermore, the ability to detect non-linearity in the growth curve is minimized when only three samples are available. This paper presents an investigation into the power of the standard method to detect changes in pup growth rates, the loss of power associated with obtaining only three weight samples, and possible means of increasing the power of the standard method.

2. METHODS

Antarctic fur seal (*Arctocephalus gazella*) pups were weighed on four dates in 1988 and three dates in 1989, at Seal Island, Elephant Island (60°59.5'S, 55°24.5'W). Linear regressions (Sokal and Rohlf, 1981, pp. 480-482) of pup weight versus date, were computed separately for each sex and year. Bartlett's test was used to evaluate heterogeneity of variances. For each sex, pooled (i.e. weighted average) estimates of the slope and of the mean squared error (MSE) from both years were formed for use in a power analysis.

Monte Carlo simulations were used to investigate the effects of number and spacing of sampling dates, and number of pups weighed per date, on the power to detect changes of 5 to 50% of the observed mean pup growth rates. The simulations proceeded as follows:

(i) A simulated data set, with a specified number and spacing of sampling dates and number of pups weighed per date, was drawn at random from normal distributions with means determined by our observed growth rate and variances equal to our observed MSE (the "null" data);

(ii) A second data set was drawn under similar conditions to the first, except that the underlying growth rate differed by a specified amount from the first (the "alternative" data);

(iii) Linear regressions were computed for each of the data sets ("null" and "alternative"), and the regression coefficients compared (Sokal and Rohlf 1981, pp. 499-506);

(iv) Steps (i) to (iii) were repeated 500 times with the same input parameters, recording the number of times that the growth rates in the two data sets were significantly different. The number of significantly different results divided by 500 is an estimate of the power to detect a change in the growth rate from the null value to the alternative value.

(v) Steps (i) to (iv) were repeated for several alternative growth rates, ranging from 1.0 to 1.5 times the null rate.

Simulations were conducted to estimate the effects of using three versus four weighing dates at 28-day intervals, of sampling smaller numbers of pups at more frequent intervals, and of the choice of α for comparisons of regression coefficients.

3. RESULTS AND DISCUSSION

The weighing dates, numbers of pups weighed, mean weights, and standard deviations of weights from Seal Island are shown for each sex and year in Table 1. There were no significant differences in variances of pup weights among dates, for either sex in either year ($P > 0.13$ in all cases). Table 2 shows estimates of growth rates from linear regressions of Seal Island pup weights versus date. Male pups grew faster and had more variable weights than females (Table 2). Tests for departures from linearity were all non-significant ($P > 0.25$ in all cases). Because the weighing periods at Seal Island were shorter than specified in the standard method, this result is not a confirmation of the pup growth curve being generally linear.

Figure 1 shows the statistical power achieved in a simulated monitoring program following Standard Method C1 (B), and assuming that the typical growth rate and within-date variance in pup weights are equal to the weighted averages of those observed in females at Seal Island (Table 2). If four samples of 50 pups each are weighed at 28-day intervals, there would be a 90% chance of detecting a 17% change in the true growth rate (using α equal to 0.10 for comparing rates). Figure 1 also shows the reduction in statistical power that would occur if samples of 50 female pups were weighed each year on three rather than four dates, again at 28-day intervals. The lower power obtained in a program sampling on only three dates is a result of the smaller total number of pups weighed (150 versus 200), as well as the shorter duration of the weighing period.

Figure 2 shows that if the duration of the weighing period is limited (e.g. by logistic or other constraints), weighing smaller samples of pups more often can result in higher statistical power, even though the total number of pups weighed is not increased. No such increase in power, however, was observed in simulations of a monitoring program in which pups are weighed at intervals shorter than 28 days for the entire available weighing period. For example, if samples of 28 pups are weighed on seven dates at 14-day intervals, so that total sample size and duration of the weighing period are nearly identical to those in the standard method, there is no increase in the power to detect changes. Therefore, the power of a monitoring program that utilizes the entire available weighing period can be increased only by increasing the total number of pups weighed or by accepting a lower value of α for comparing growth rates.

Figure 3 shows the effect of the choice of α, the acceptable risk of a Type 1 error, on the power to detect a change in growth rate. As expected, the simulations show that a monitoring program using a relatively high α-level for comparing regression coefficients (growth rates) will be more sensitive (i.e. will have higher power to detect a significant departure from the typical growth rate) than a program using a lower α-level. Boveng and Bengtson (1989) suggested that α and β (the risk of a Type 2 error) probabilities should be equal in some resource conservation contexts. The magnitude of change detectable with α and β probabilites equal, are shown for all simulations in Figures 1 to 3.

If the relationships between the growth rates for males and females and between the variance in weights of males and females observed at Seal Island are typical, the power to detect a proportional change in growth rate will be similar for both sexes. This is because the ratio of the standard deviation of weights to the growth rate is similar for both sexes. Though simulations were conducted using data from both sexes, only the results from female pup weights have been presented here.

The simulations were used to verify that the power curves are symmetric for positive and negative deviations from the typical growth rate. Therefore, the statistical power shown in Figures 1 to 3 pertains to increases or decreases in the growth rate.

LITERATURE CITED

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Table 1: Dates, sample sizes, means, and standard deviations of male and female fur seal pup weights measured at Seal Island in 1988 and 1989.

Date	Males n	Males mean weight (kg)	Males s.d.	Females n	Females mean weight (kg)	Females s.d.
1988:						
2 Jan	30	9.91	1.60	20	8.78	1.13
15 Jan	40	11.28	1.64	26	9.50	1.49
27 Jan	41	12.91	1.64	20	10.76	1.15
12 Feb	36	15.91	2.22	35	12.38	1.66
1989:						
17 Jan	21	10.65	1.94	29	9.19	1.81
31 Jan	26	12.81	1.88	24	10.62	1.70
13 Feb	30	14.42	1.77	35	12.61	1.42

Table 2: Results of linear regressions of pup weight versus data. Growth rates, standrd errors and estimated "within-date" variance in pup weights (MSE) are shown separately for each year and as weighted averages of both years.

		Growth Rate (kg/d)	Standard Error of Growth Rate	MSE
Males,	1988:	0.147	0.0147	3.21
Males,	1989:	0.139	0.0089	3.45
Males,	wt. ave.:	0.145	- -	3.29
Females,	1988:	0.092	0.0077	2.04
Females,	1989:	0.127	0.0130	2.67
Females,	wt. ave.:	0.108	- -	2.34

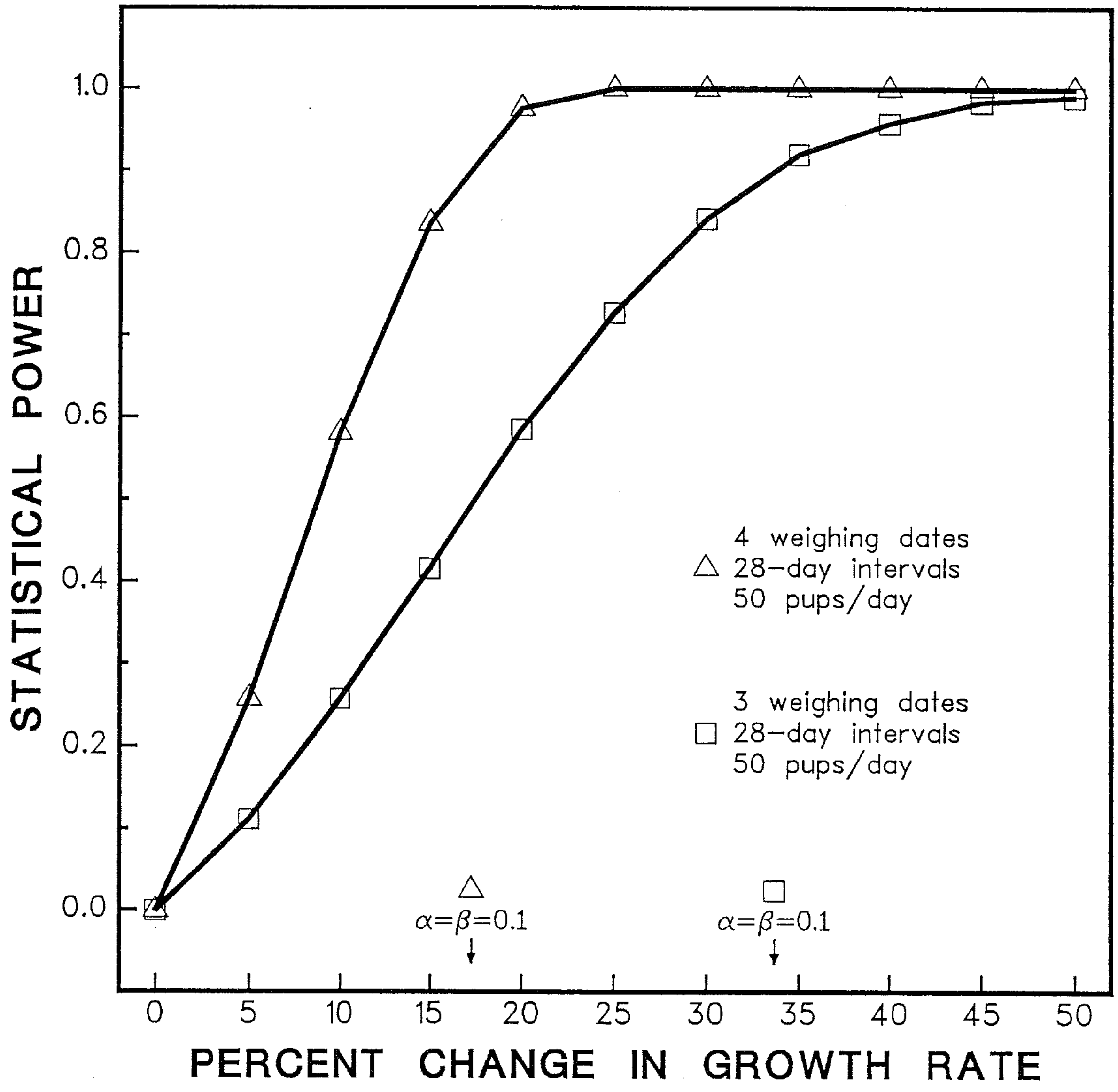

Figure 1: Difference in power to detect changes in fur seal pup growth rate using Standard Method C1 (B) when three or four samples of pups are weighed. The typical growth rate, or "null" rate, used in the simulation was 0.108 kg/d, the average rate observed for females at Seal Island in 1988 and 1989. The mean-squared-error for pup weights was 2.336, the average for females at Seal Island.

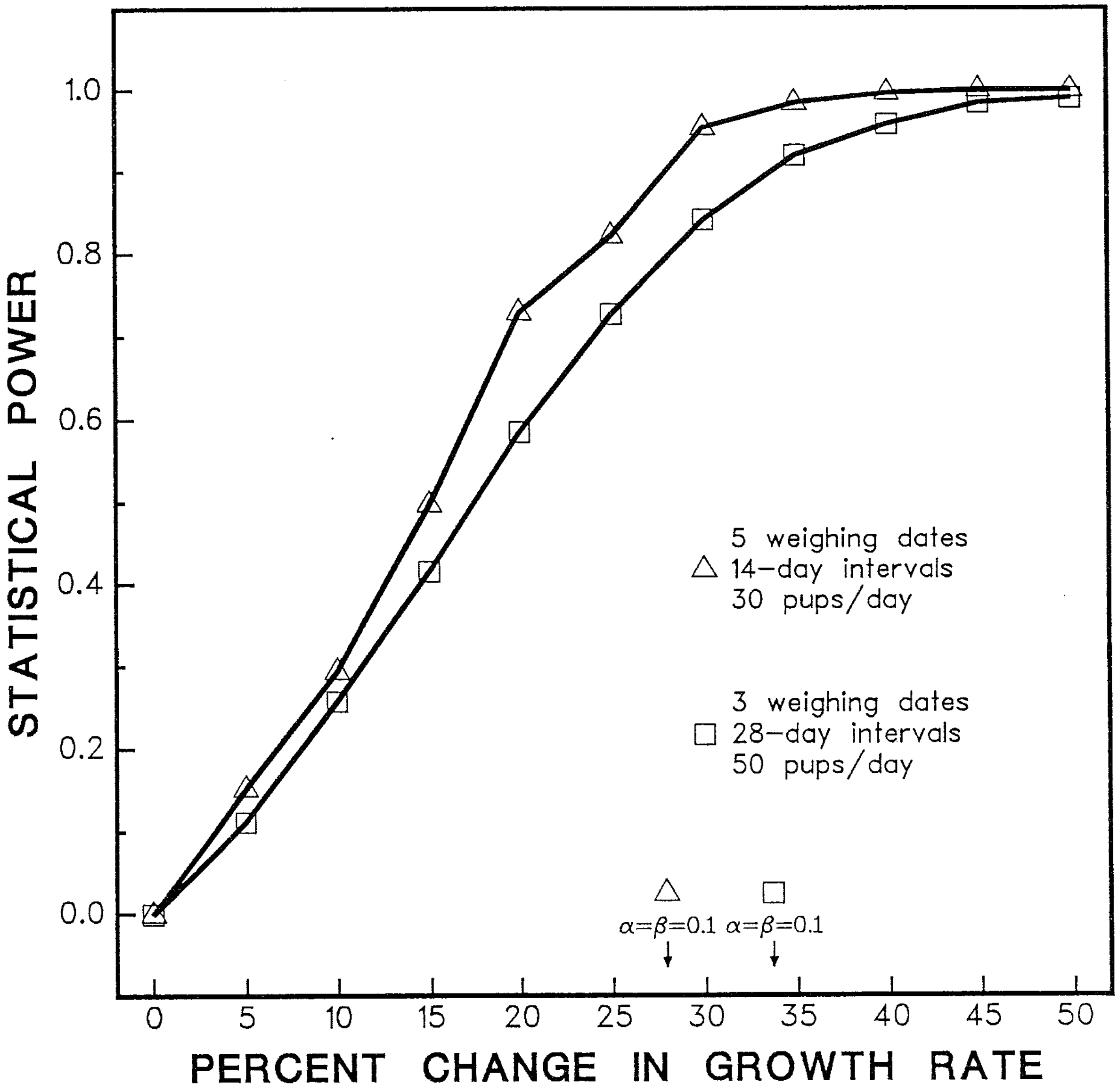

Figure 2: If the weighing period is limited to approximately 60 days, a slight increase in power can be obtained by weighing smaller samples of pups at more frequent intervals than specified in the Standard Method. As in Figure 1, null growth rate equals 0.108 kg/d, mean-squared-error equals 2.336.

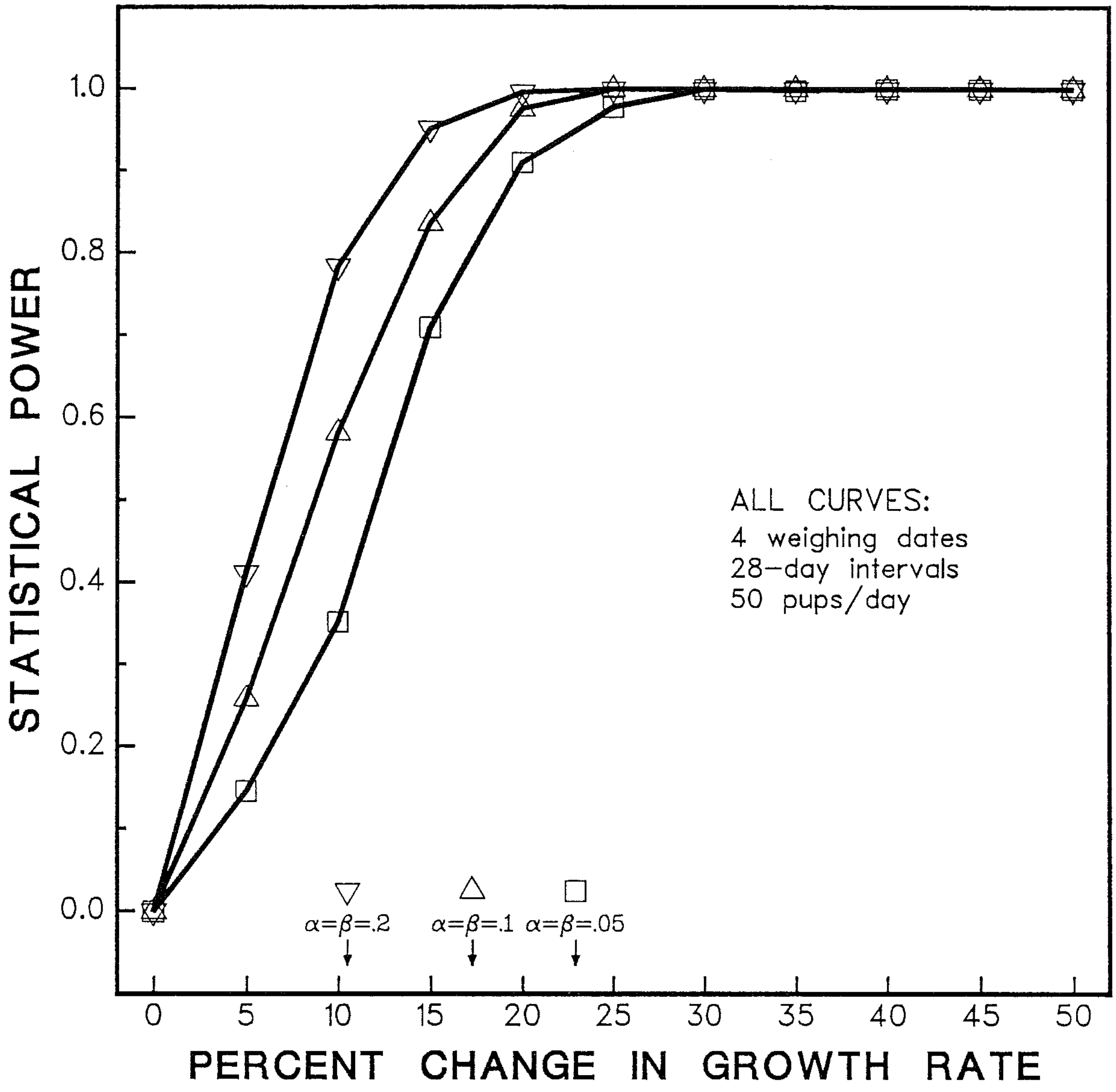

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Figure 2: Si la période de pesée est limitée à environ 60 jours, une légère augmentation de puissance peut être obtenue en pesant des échantillons plus petits de jeunes à des intervalles plus courts que ceux spécifiés dans la méthode standard. De même que dans la Figure 1, le taux de croissance nul est égal à 0,108 kg/jour, et l'erreur quadratique moyenne est égale à 2,336.

Figure 3: L'effet du choix de α pour comparer les coefficients de régression (taux de croissance), à la puissance à détecter les changements. De même que dans la Figure 1, un taux de croissance nul est égal à 0.108 kg/jour, et l'erreur quadratique moyenne est égale à 2,336.

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WG-CEMP-89/7

SENSITIVITY ANALYSIS FOR PARAMETERS OF PREDATORY SPECIES CCAMLR ECOSYSTEM MONITORING PROGRAM

M.D. Whitehead

Abstract

Following the request of the Scientific Committee of CCAMLR to conduct sensitivity analyses on existing data regarding predator breeding biology parameters, this report presents such a treatment of data obtained at the Magnetic Island Adélie penguin colony in Prydz Bay in the 1987/88 and 1988/89 breeding seasons.

The data on the following parameters were analyzed:

- adult weight on arrival at breeding colonies;
- duration of first incubation shift;
- duration of adult foraging trips;
- breeding success; and
- chick fledging weight.

Résumé

A la demande du Comité scientifique de la CCAMLR portant sur la conduite d'analyses de sensibilité sur les données existantes concernant les paramètres biologiques de reproduction des prédateurs, ce rapport présente un tel traitement de données obtenues à la colonie de manchots Adélie de l'île Magnetic, dans la baie de Prydz, pendant les saisons de reproduction 1987/88 et 1988/89.

Les données se rapportant aux paramètres suivants ont été analysées:

- poids des adultes à l'arrivée aux colonies de reproduction;
- durée du premier tour d'incubation;
- durée des sorties alimentaires des adultes;
- réussite de la reproduction; et
- poids des jeunes à la première mue.

Резюме

В ответ на просьбу Научного комитета АНТКОМа о проведении анализа чувствительности параметров воспроизводства хищников с учетом существующих данных, в настоящей работе представлены результаты такого анализа данных по колонии пингвинов Адели, полученных на острове Магнетик в заливе Прюдс в течение сезонов размножения 1987/88 и 1988/89 гг.

Были проанализированны данные по следующим параметрам:

- вес взрослых особей по прибытии в гнездовую колонию;
- продолжительность первой инкубационной смены;
- продолжительность периодов кормления взрослых особей;
- репродуктивный успех; и
- вес птенцов при оперении.

Resumen

Siguiendo la solicitud hecha por el Comité Científico de la CCRVMA para conducir análisis de sensibilidad en los datos ya existentes con relación a los parámetros biológicos de reproducción de los depredadores, este informe presenta tal tratamiento de datos obtenidos en las colonias de pingüinos Adelia en la Isla Magnetic, Bahía de Prydz, durante las temporadas reproductivas de 1987/88 y 1988/89.

Se analizó la información de los siguientes parámetros :

- peso del ejemplar adulto a la llegada a la colonias de reproducción;
- duración del primer turno de incubación;
- duración de los viajes de alimentación como adulto;
- éxito en la reproducción; y
- peso del polluelo al emplumaje.

1. INTRODUCTION

Since the establishment of the Biological Investigation of Marine Antarctic Systems and Stocks (BIOMASS) program, vertebrate predators have been considered potentially useful environmental monitors, assuming that their populations are sensitive to conditions within their foraging ranges (e.g. BIOMASS, 1982).

This interest in the use of vertebrate predators in environmental monitoring continued in discussions of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and its Scientific Committee (SC-CAMLR). In 1988 this culminated in the publication by the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP) of a handbook entitled Standard Methods for Monitoring Parameters of Predatory Species (CCAMLR, 1988).

This booklet summarized the parameters recommended for monitoring studies of penguins and seals. Previous meetings of CCAMLR had identified a range of breeding biology parameters likely to be sensitive to perturbations in the marine environment, which could act as indicators of marine conditions when monitored annually. A few species were deemed most likely to be useful in this capacity, based on their population sizes and accessibility, and on their likelihood of reflecting fluctuations within the krill-based ecosystem. Species identified included the Adélie penguin *(Pygoscelis adeliae).*

The monitoring methods which seemed the most likely to yield useful results were selected for each identified species. The methodology proposed is in many cases based on few data. It is important therefore to determine whether the scope and precision of the observations are sufficient to monitor the vertebrate population parameters of interest with acceptable reliability.

To comment on the suitability of the sampling methodologies proposed, it is necessary to have an idea of some characteristics of the data generated; most importantly, the degree of variance around the mean. While data sets can be simulated, and variances estimated if no real data exist, the use of actual data with 'real' variance enables estimates of required sample sizes for specified detection capabilities to be made with greater confidence. This was recognised by the Scientific Committee (SC-CAMLR-VII, paragraph 5.22 (i) and (ii)) and led to the instructions for sensitivity analysis set out by the CCAMLR Secretariat and Convener of CEMP.

This report summarizes some preliminary data on various Adélie penguin breeding biology parameters, collected at the Magnetic Island colony in Prydz Bay (68°33'S, 77°54'E) in the 1987/88 and 1988/89 breeding seasons.

Though assessed and presented under the parameter headings given by CCAMLR (1988), it should be realised that differences did exist between methods of data collection recommended for the Ecosystem Monitoring Program (CCAMLR,1988) and those used for the analysis in this report. In most instances the data were collected in conjunction with other research programs with their own specific aims. The characteristics of the data upon which the subsequent 'sensitivity' analyses are based are described in the following section.

2. DATA ACQUISITION AND CHARACTERISTICS

2.1 Parameter A1 - Weight on Arrival at Breeding Colonies

This parameter is considered likely to reflect pre-breeding season conditions within the penguins foraging range. The CEMP Standard Methods Sheets (CCAMLR, 1988) recommend the capture and weighing of between 50 and 75 (depending on whether sex can be determined) adults every five days during the occupation period.

The data presented here are based on the weighing of 100 unsexed adults on 17 October 1987 and again on the 17 October 1988. Adults were captured as they moved across the sea-ice toward their colonies, and weighed to the nearest 25 g.

The distribution of the data did not differ significantly from normality in either year (Kolmogorov-Smirnov one-sample test (K-S); z=0.037, p=0.354 and z=0.071, p=0.239 for 1987 and 1988 respectively). The means and variances of the data were similar for both years (Figures 1a and 1b) and sample size analysis was based on the 1987 data.

2.2 Parameter A2 - Length of the First Incubation Shift

The length of the first incubation shifts has been shown to be very closely related with Adélie penguin breeding success (Davis, 1982). This parameter is considered likely to be sensitive to variable food availability during the foraging trip of the incubating bird's partner. The CEMP Standard Methods Sheets (CCAMLR, 1988) recommend that 100 nests be monitored daily and the length of the first incubation shift by both members of the pair be recorded.

I recorded attendance of a sample of male and female Adélie penguins at two colonies on Magnetic Island. Checks of marked nests were made every two days, and the presence of either male or female recorded. The length of the first incubation shift was recorded for both male and female of 26 pairs, and male only at an additional 31 nests, at the Turner colony. At the East colony, length of the first incubation shift was recorded for both male and female of 79 pairs, and male only at an additional 22 nests. Length of incubation shift was calculated assuming that changeovers occurred midway between observation periods.

Distribution of data on first incubation shift length did not differ significantly from normality for either sex at either study colony (K-S; p > 0.120 in all cases) (Figures 2a to 2d). There was no significant difference between the study colonies in length of either male or female first incubation shifts (t=0.261, p=0.791 and t=0.880, p=0.615 respectively), so data from each colony were pooled, and sensitivity analyses conducted for each sex. Pooled data did not differ significantly from normality for either males (K-S; z=0.088, p=0.134) or females (K-S; z=0.133, p=0.086) (Figures 2e and 2f).

2.3 Parameter A5 - Duration of Foraging Trips

This parameter is considered sensitive to the availability of food during the foraging trip. The CCAMLR Standard Methods Sheets indicate that changes in this parameter can only be satisfactorily detected by precise monitoring of adult attendance patterns using radio transmitters and a continuous scanning receiver/logger.

Data collected for this study were from direct observation of two study colonies at Magnetic Island. At the Turner colony, 21 nests were monitored and at the East colony, 68 nests were monitored. Nest sites were visited daily and the attendance of either adult of the pair recorded. Foraging trip length was calculated assuming that changeover occurred midway between observation periods. This strategy was only effective until the end of the guard-stage, after which time both parents began to feed simultaneously, and colony attendance could not be monitored without 24 hour watches or automatic recording devices.

The data used here were the estimated foraging trip lengths of the first post-hatching (of first egg) foraging trip for each nest site. At the Turner colony this comprised nine male and 12 female foraging trips, and at the East colony it comprised 36 male and 32 female foraging trips. Foraging trips are relatively short during early chick rearing, so detection of fluctuation in this parameter at this stage may require larger sample sizes (but more importantly more frequent sampling), than when trips are longer. There was no significant difference between estimated length of foraging trips for either sex at either location (ANOVA; F=0.747, p=0.527), so data were pooled for sensitivity analysis. Although the distribution of these data did differ significantly from normality (K-S: z=0.219, p=0.019) (Figure 3), it was used for the sensitivity analysis.

2.4 Parameter A6 - Breeding Success

This parameter probably reflects the perturbations in food availability integrated over an entire breeding season. The CEMP Standard Methods Sheet suggests that three separate counts be made of adults and/or chicks in study colonies, so that a measure of the variation in counting accuracy may be obtained. It recommends counting a sample of discrete colonies from the entire breeding site, though not as replicates.

In this study, adults and chicks at four colonies on Magnetic Island were counted, however, replicated data (from independent counters) were only available for chick counts. Between three and five independent counts were made of the number of chicks surviving in these study colonies in late January (Table 1). As sample sizes were small ($n \leq 5$ in all cases), the distribution of the data were not examined. Sensitivity analyses were conducted on data from colonies 3 and 4.

2.5 Parameter A7 - Fledging Weight

It is suggested that the weight of chicks at fledging in any particular season may reflect food availability over the whole of that season. WG-CEMP recommends that 100 fledglings be weighed every five days during the fledging period.

Chicks fledging from the Magnetic Island colony were weighed daily from the commencement of fledging (early February) in the 1987/88 season until 21 February 1988, when the author departed the area. This period encompassed the majority of the fledging period. Chicks were weighed (to the nearest 25 g) as they milled around the waters edge, marked with dye and released.

These data were pooled into five-day periods. The frequency distribution of each data set corresponded closely with normality (K-S; $p > 0.235$ in all cases)(Figures 4a to 4d) and the mean fledging weights of the four sequential fledging periods were not significantly different (ANOVA; F=1.782, p=0.150), so data were pooled for sensitivity analysis. The frequency distribution of the combined data set conformed closely with normality (K-S; z=0.037, p=0.278) (Figure 4e).

There was clearly discrepancy between the methods stipulated for CEMP data (CCAMLR data) and the data upon which the analyses in this report were based. In some cases our methods were about as rigorous as those required by the CEMP (e.g. parameters A1, A7), while in others they were not (e.g. parameter A5). As a result, the variances upon which the sensitivity analyses were based were not always representative of the variances had the data been collected according to the CEMP. This should be taken into account when considering the recommended sample sizes.

3. SAMPLE SIZE (='SENSITIVITY') ANALYSES

From these data it is possible to decide what sample size would be necessary if we wished to detect a true fluctuation in the mean of any of these parameters, at some stipulated significance level, with a specified probability of the significance being found. It is important to realize that such an analysis of the data presented here gives an indication of the sample size necessary to detect a given parameter fluctuation if the data collected have a variance the same as that upon which the sensitivity analysis was based. If a sampling methodology different to that used here was employed, the variance would be effected, and the necessary sample size would be different. These data do however give an indication of real variance and allows fairly realistic estimates of sample size.

The appropriate formula for calculating the necessary sample size to detect a given 'true' difference between means is:

$$n \geq 2(sd/\Delta)^2 \{t_{a,[v]} + t_{(1-P,[v]}\}^2$$

where n = the required sample size (samples per year per site)
sd = true standard deviation
Δ = the smallest true difference that is desired to detect
v = degrees of freedom for error in the ANOVA or t-test [$v=r(n-1)$, where r is the number of years or replicates]
a = significance level (i.e. probability of rejecting a true null hypothesis of no difference among years)
P = desired probability that a difference will be found if it is large as Δ (P is the statistical power)
$t_{a,[v]}$ = value from a two-tailed t-table with v degrees of freedom and corresponding to probability a, and
$t_{2(1-P),[v]}$ = value from a two-tailed Student's t-table with v degrees of freedom and corresponding to probability $2(1-P)$

(Sokal and Rohlf, 1981)

This equation is solved iteratively, and calculations of the necessary sample sizes for detecting differing degrees of change in the mean, at different levels of statistical significance and power are given for these various parameters in the Tables 2 to 7. The effect of number of years of sampling on the required sample size is also considered.

4. SUMMARY

Before continuing field work aimed at providing monitoring information it is important to assess with whatever data available the degree of annual variation in these breeding biology parameters. This will assist in deciding the minimum change in any parameter that it is desirable to be able to detect. Some information has recently become available in this respect (see Croxall et al., 1988) and should be considered as future monitoring strategies are considered. With information such as that provided in this report it is possible to then decide on the sample sizes required to detect changes in specific parameters.

The development of annual indices for each parameter, on which to base comparisons, was discussed in the "Instructions for the Preparation of Sensitivity Analyses" provided by CCAMLR. For monitored parameters that give five-day running means (Parameters A1, A5 and A7), it is suggested that the annual index derived should reflect the importance of each five-day period in calculation of the annual mean. In this report, the only parameter for which data were collected over five-day periods was Parameter A7 (fledging weight). As no significant difference was detected among five-day periods, the mean value from randomly weighed fledglings or from a single five day period will probably serve as a suitable annual index. Further data and analysis is required before a suitable annual index for the other two parameters in this category can be decided.

For Parameters A2 and A6 the suggested annual index upon which to base comparisons was the mean of the data. This was the basis of the sensitivity analysis for these two parameters in this report and is the obvious index to use.

The sensitivity analyses presented here provide those sample sizes for arbitrarily chosen levels of fluctuation, however, the variances of the parameters themselves will enable calculation for any desired level of detection.

ACKNOWLEDGEMENTS

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Table 1: Counts of surviving chicks in Magnetic Island study colonies - late January 1989. Number of independent counts (n), mean (x), and standard deviation (sd) are indicated.

Colony	n	x	sd
1	5	162	3.03
2	3	53	1.00
3	4	104	6.38
4	4	74	3.74

Table 2: Parameter A1: Adult weight on arrival at breeding colony (1987 data). Sample size = number of arriving penguins that must be weighed.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
	(5%)	42	66	88
Smallest Difference (d)	(10%)	12	19	25
(% Current Value)	(20%)	5	5	7
	(30%)	2	3	4
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(5%)	30	51	71
(% Current Value)	(10%)	9	14	20

Table 3: Parameter A2: Length of the first incubation shift (males). Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	34	54	72
(% Current Value)	(20%)	9	14	19
	(30%)	5	7	9
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(10%)	33	53	71
(% Current Value)	(20%)	9	14	18
	(30%)	4	6	8

Table 4: Parameter A2: Length of the first incubation shift (females).
Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	24	38	51
(% Current Value)	(20%)	7	10	14
	(30%)	4	5	7

Table 5: Parameter A5: Duration of foraging trips (post-hatching trip 1).
Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	165	264	352
(% Current Value)	(20%)	42	67	89

Table 6: Parameter A6: Breeding success.
Sample size = number of independent counts of colony that must be made.

		Statistical Power (P)		
		0.6	0.8	0.9
Colony 3 - late January chick counts				
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	5	7	9
(% Current Value)	(20%)			3
Colony 4 - late January chick counts				
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(10%)	4	5	7
(% Current Value)	(10%)			2

Table 7: Parameter A7: Chick weight at fledging (2 to 21 February 1988). Sample size = number of fledging chicks that must be weighed.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
	(5%)	71	113	150
Smallest Difference (d)	(10%)	21	33	43
(% Current Value)	(20%)	6	8	10

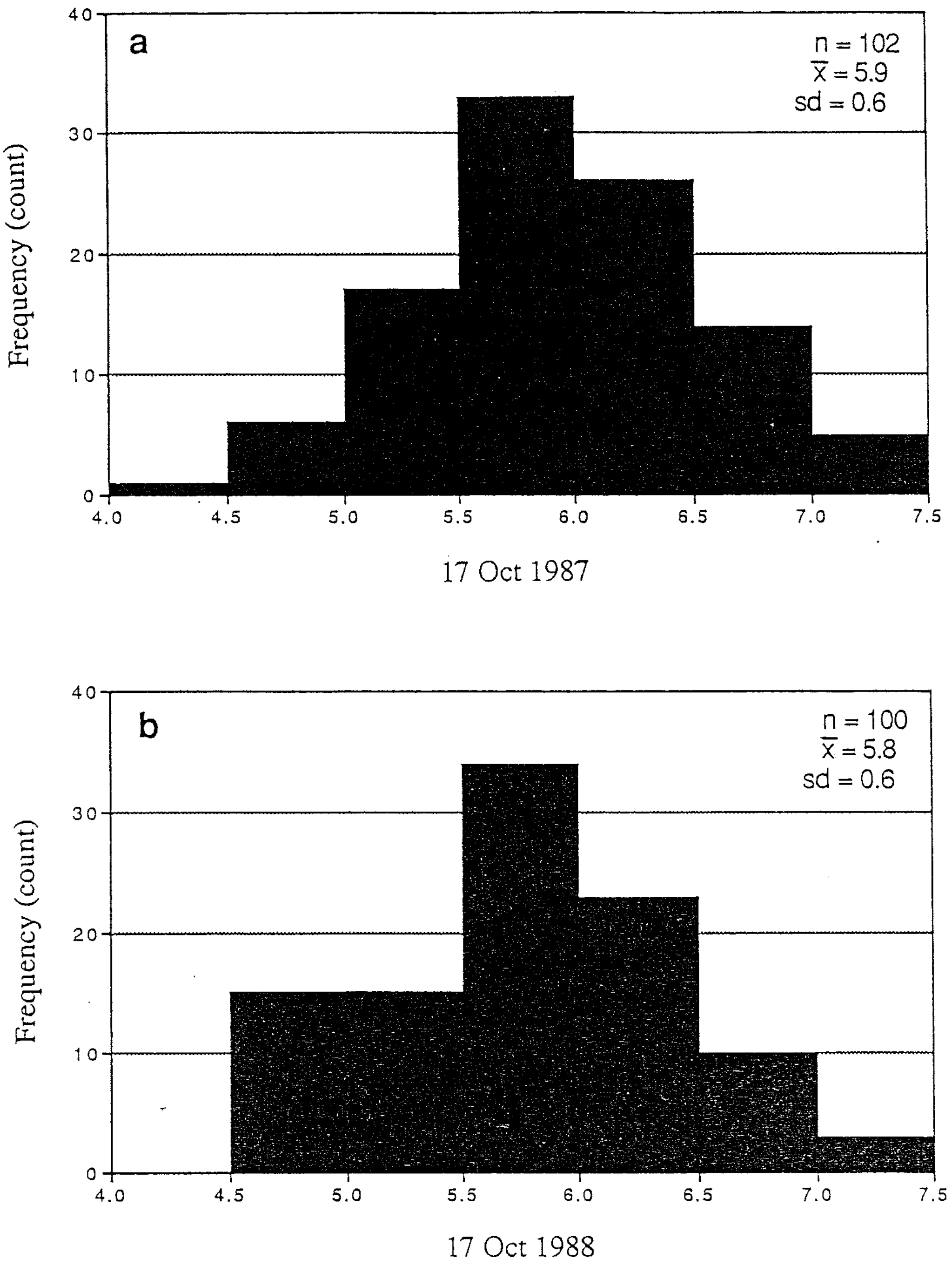
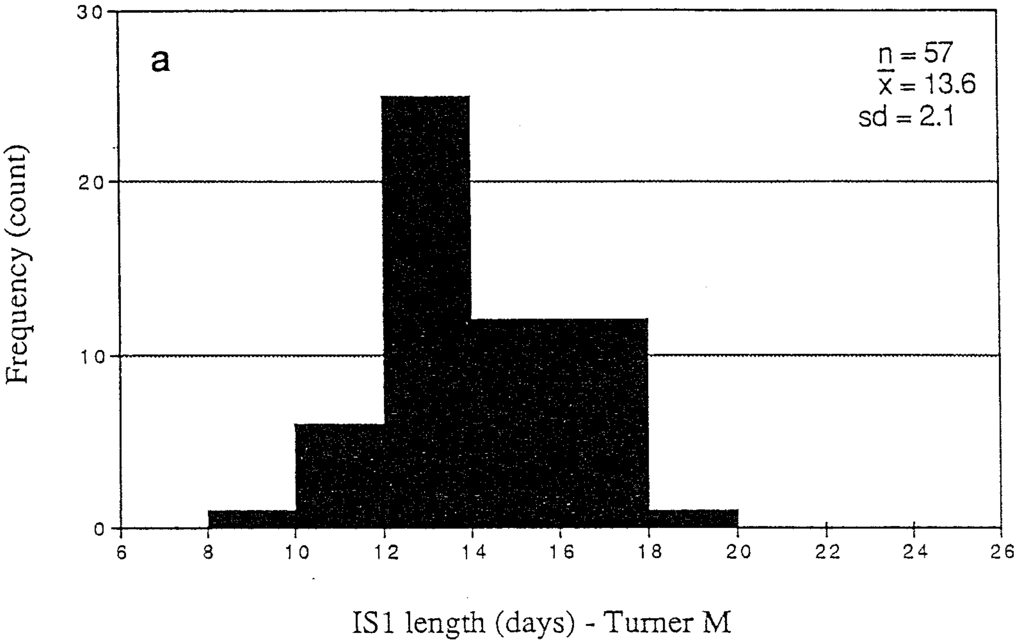


Figure 1: Frequency distribution of Adélie penguin arrival weight data (kg).

a. 17 October 1987
b. 17 October 1988



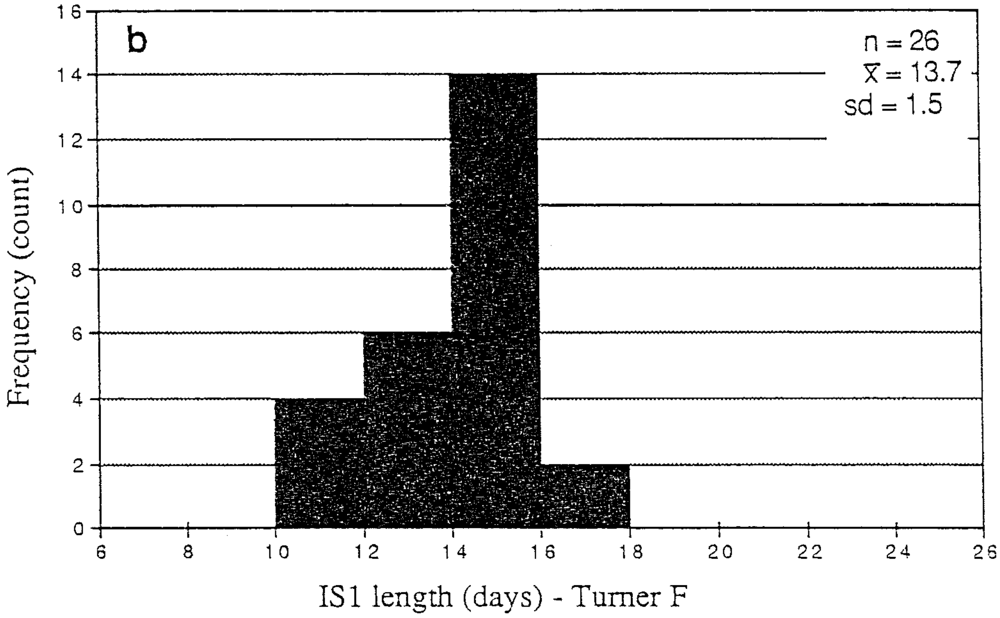


Figure 2: Frequency distribution of Adélie penguin first incubation shift lengths (days).

a. Turner colony - male
b. Turner colony - female
c. East colony - male
d. East colony - female
e. Both colonies - male
f. Both colonies - female

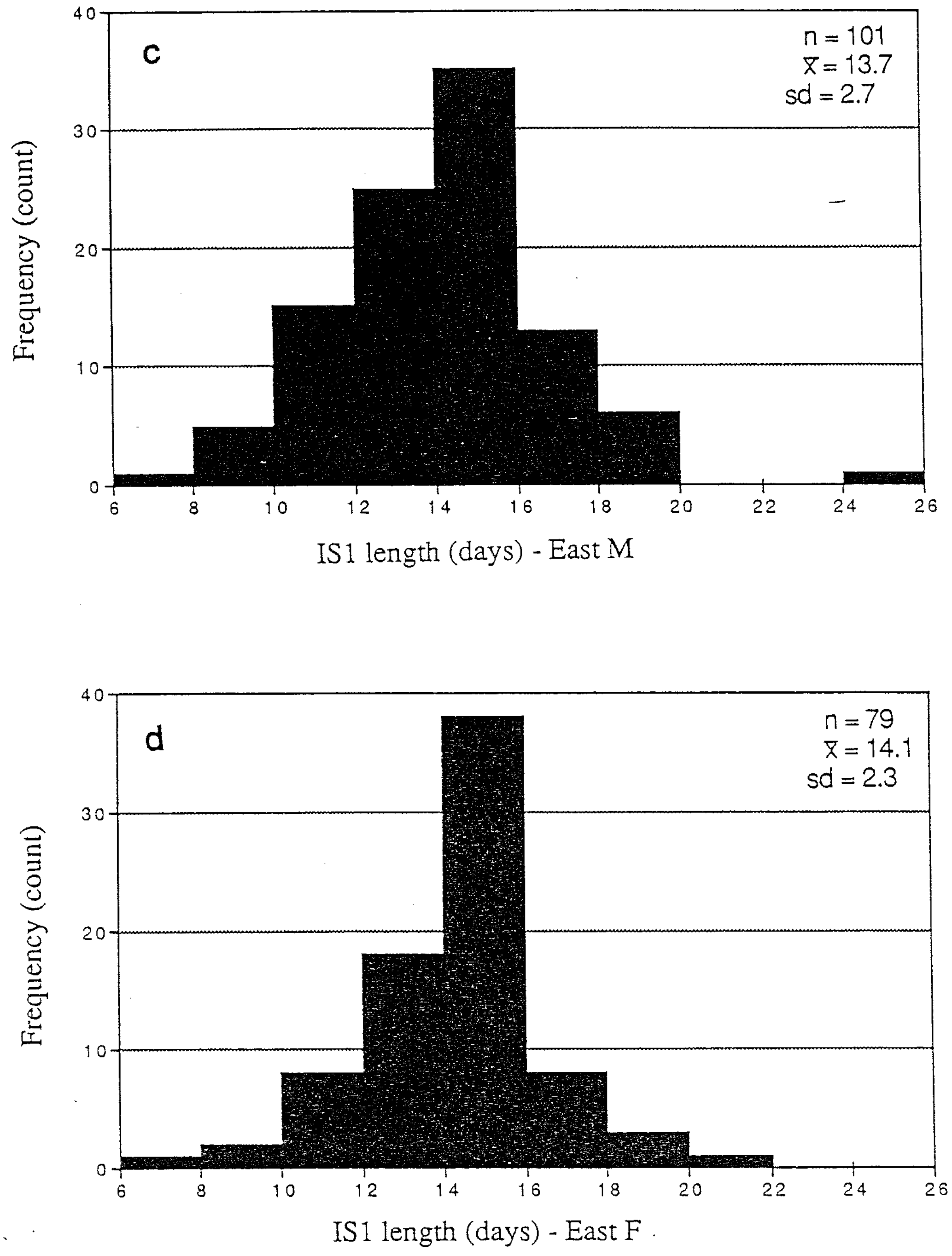
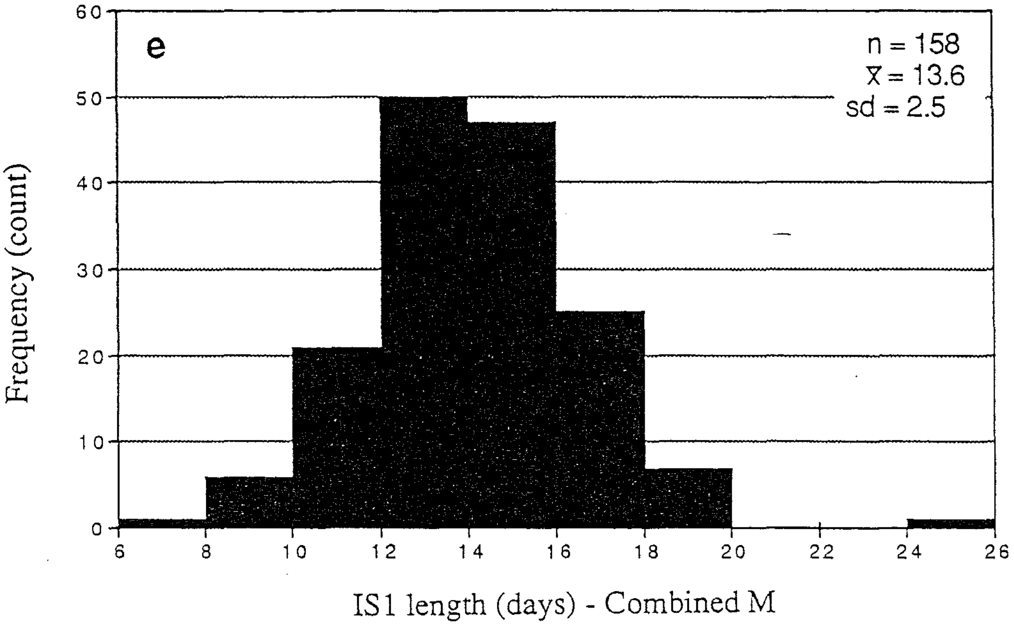


Figure 2 (continued)



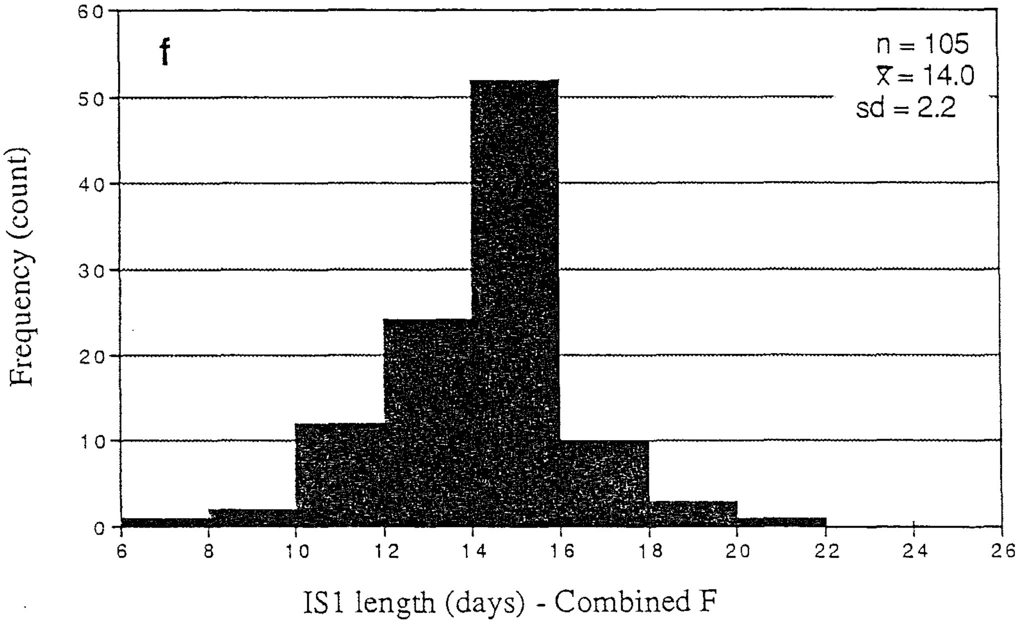


Figure 2 (continued)

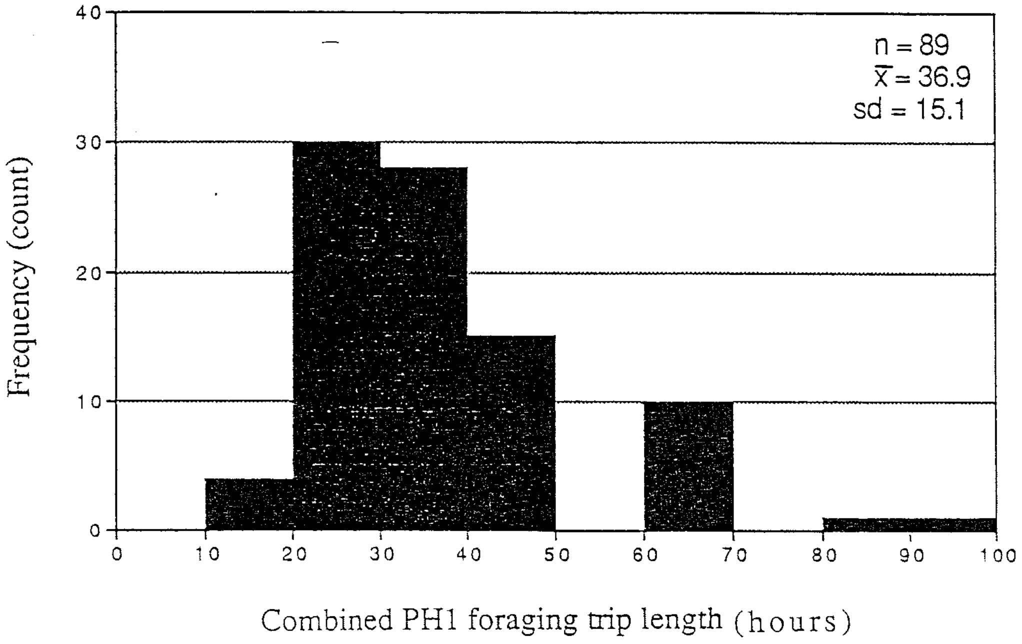
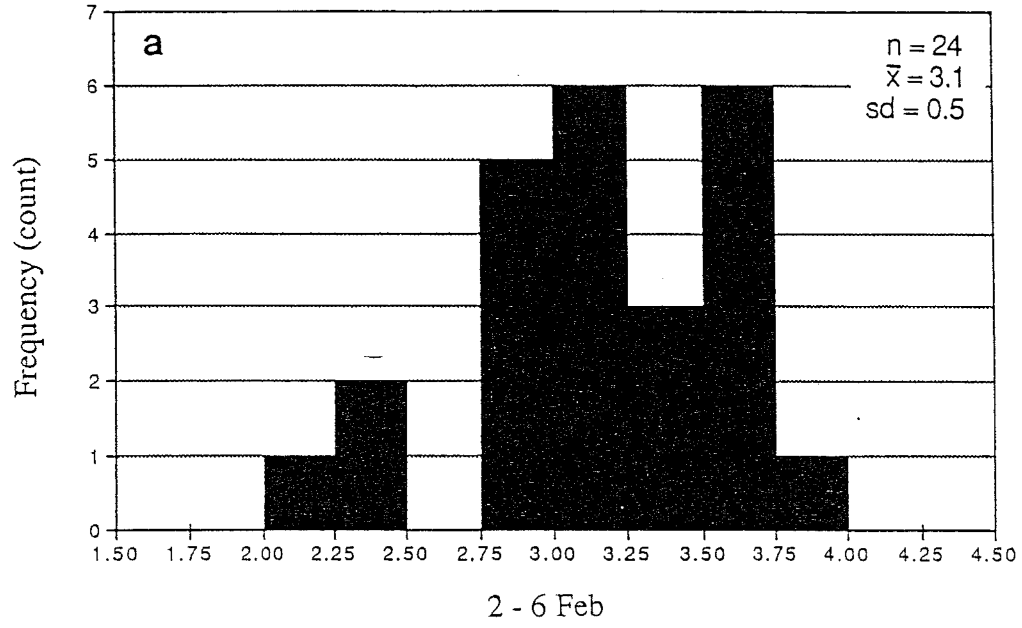


Figure 3: Frequency distribution of Adélie penguin first post-hatch foraging trip lengths. Sexes and colonies combined.



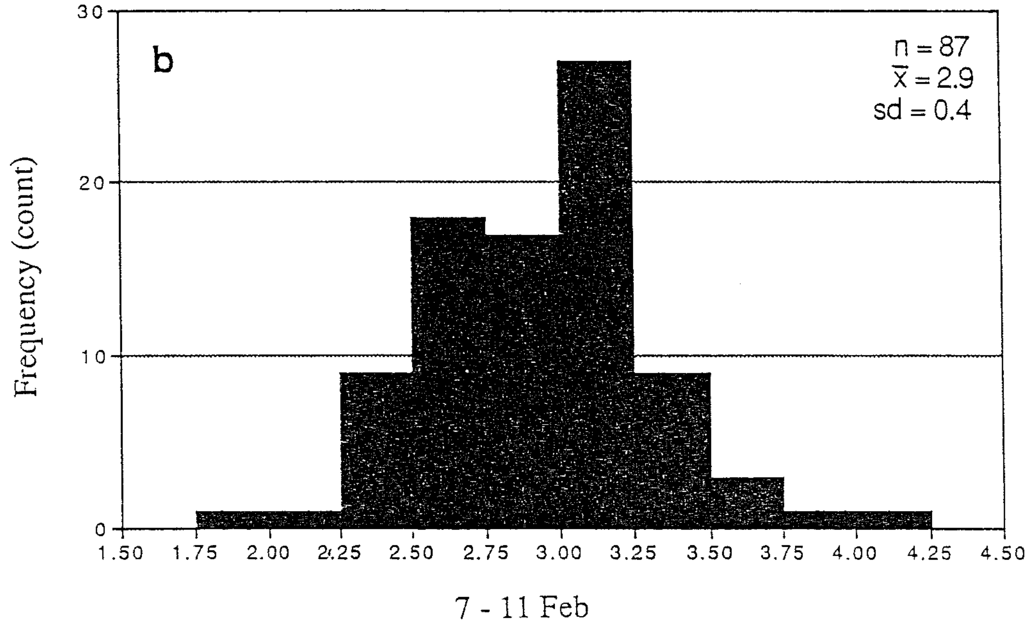
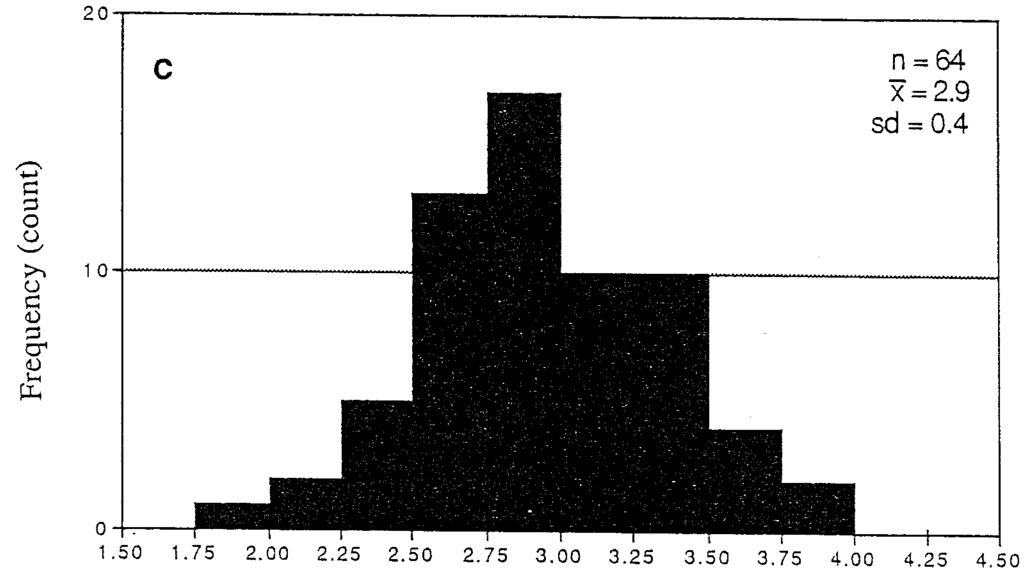
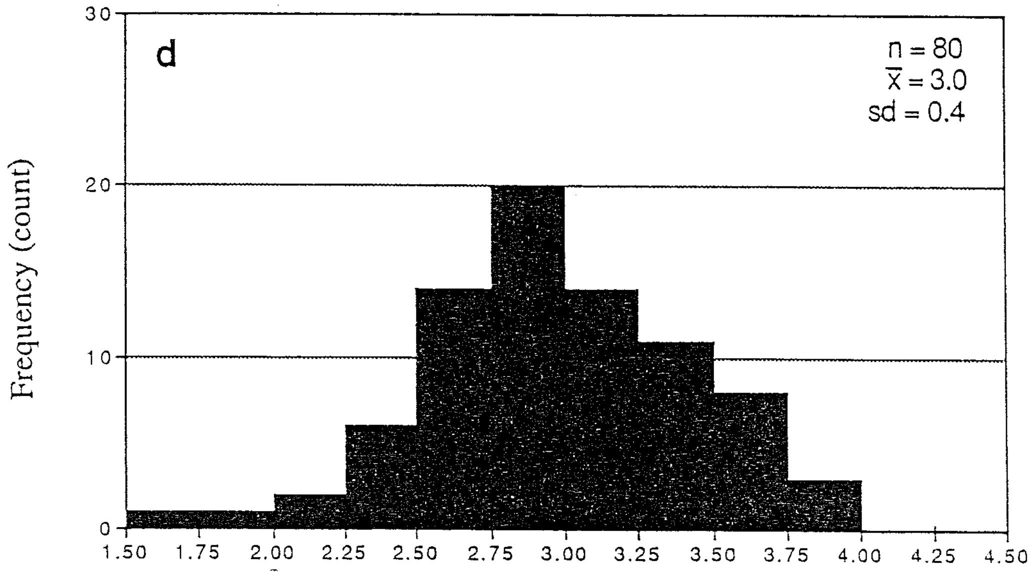


Figure 4: Frequency distribution of Adélie penguin chick fledging weights (kg).

a. 2 to 6 February 1988
b. 7 to 11 February 1988
c. 12 to 16 February 1988
d. 17 to 21 February 1988
e. 2 to 21 February 1988 combined

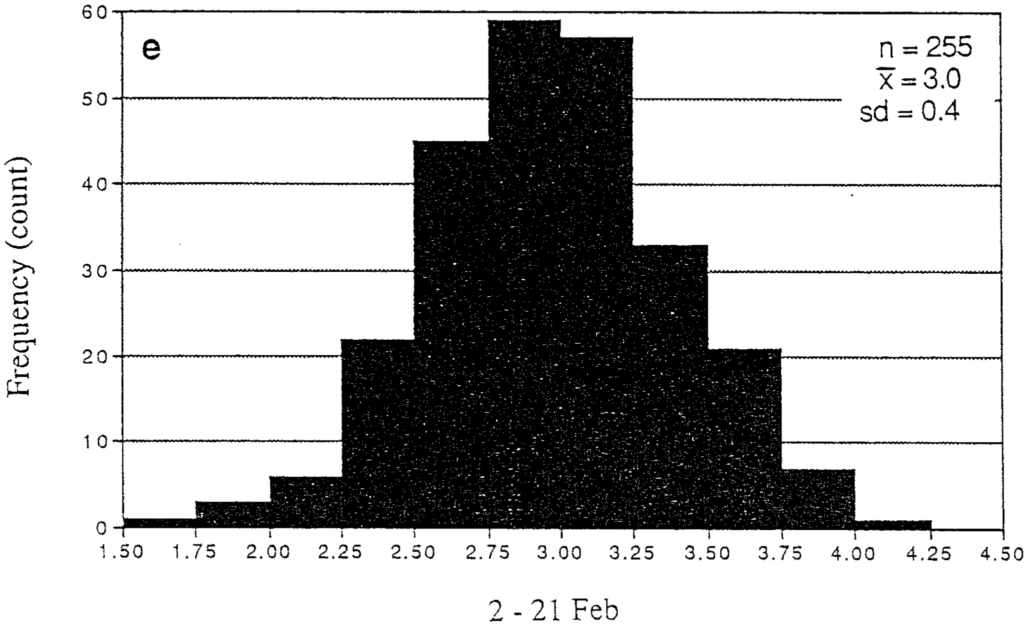


12 - 16 Feb



17 - 21 Feb

Figure 4 (continued)



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Размер пробы = число гнезд, за которыми следует вести наблюдения.

Таблица 4: Параметр A2: продолжительность первой инкубационной смены (самки).

Размер пробы = число гнезд, за которыми следует вести наблюдения.

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Размер пробы = число гнезд, за которыми следует вести наблюдения.

Таблица 6: Параметр A6: репродуктивный успех.

Размер пробы = необходимое количество отдельных подсчетов численности колонии.

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d. колония Восточная - самки
e. обе колонии - самцы
f. обе колонии - самки.

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d. colonia Este - hembra
e. ambas colonias - macho
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d. 17-21 feb. 1988
e. 2-21 Feb. 1988 combinados.