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CHANGES IN BIOMASS OF EIGHT SPECIES OF FINFISH AROUND THE SOUTH ORKNEY ISLANDS (SUBAREA 48.2) FROM THREE BOTTOM TRAWL SURVEYS

C.D. Jones
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
US Antarctic Marine Living Resources Program
PO Box 271, La Jolla, Ca. 92038, USA

K.-H. Kock
Institut für Seefischerei
Bundesforschungsanstalt für Fischerei
Palmaille 9, D-22767 Hamburg, Germany

E. Balguerías
Instituto Español de Oceanografía
Centro Oceanográfico de Canarias
Apartado de Correos 1373
Santa Cruz de Tenerife, España

Abstract

Stocks of finfish exploited around the South Orkney Islands (Subarea 48.2) suffered substantial declines from split-year 1977/78 to 1989/90. The biomass of several species of finfish has been monitored through scientific bottom trawl surveys within the 500 m isobath of the South Orkney Islands, most recently by the Federal Republic of Germany in 1985, Spain in 1991 and the USA in 1999. From these surveys, estimates of total stock biomass were computed for the eight species of finfish which were most abundant in catches. Biomass levels and size composition from the March 1999 trawl survey were compared to previous surveys conducted in February 1985 and January to February 1991. Species examined were *Gobionotothen gibberifrons, Lepidonotothen squamifrons, Pseudochaenichthys georgianus, Champsocephalus gunnari, Chaenocephalus aceratus, Chionodraco rastrospinosus, Notothenia rossii* and *Lepidonotothen larseni*. Despite substantial variability in point estimates, biomass levels of most species appear to be unchanged or may have declined slightly since 1991. The stock of *C. gunnari* is currently extremely low, while there appear to be strong signs of recovery for *N. rossii*. However, overall levels of biomass indicate very little potential for commercial exploitation at this time.

Résumé

Les stocks de poissons exploités autour des îles Orcades du Sud (sous-zone 48.2) ont affiché une baisse importante entre les années australes 1977/78 et 1989/90. La biomasse de plusieurs espèces de poissons a été contrôlée par des chalutages de fond scientifiques dans l'isobathe 500 m des îles Orcades du Sud. Les dernières campagnes d'évaluation, réalisées par la République fédérale d'Allemagne en 1985, l'Espagne en 1991 et les USA en 1999, ont permis d'estimer la biomasse totale du stock des huit espèces de poissons les plus abondantes dans les captures : *Gobionotothen gibberifrons, Lepidonotothen squamifrons, Pseudochaenichthys georgianus, Champsocephalus gunnari, Chaenocephalus aceratus, Chionodraco rastrospinosus, Notothenia rossii* et *Lepidonotothen larseni*. Les niveaux de biomasse et la composition en tailles observés lors des chalutages de mars 1999 ont été comparés aux campagnes d'évaluation précédentes datant de février 1985 et de janvier–février 1991. Malgré une variabilité significative des estimations ponctuelles, les niveaux de biomasse de la plupart des espèces semblent inchangés, voire en légère baisse depuis 1991. À l'heure actuelle, le stock de *C. gunnari* est extrêmement peu abondant alors que celui de *N. rossii* est clairement en cours de récupération. Pourtant, dans l'ensemble, les niveaux de biomasse n'offrent que très peu de possibilités d'exploitation à ce stade.

Резюме

За 1977/78–1989/90 разбитые годы существенно сократились эксплуатируемые запасы рыб у Южных Оркнейских о-вов (Подрайон 48.2). Мониторинг биомассы нескольких видов рыб проводился посредством научных донных траловых съемок, осуществлявшихся у Южных Оркнейских о-вов в пределах изобаты 500 м ФРГ в 1985 г., Испанией в 1991 г. и США в 1999 г. По результатам этих съемок были рассчитаны оценки общей биомассы запаса 8 наиболее многочисленных в уловах видов рыб. Было проведено сравнение уровня биомассы и размерного состава по траловой съемке марта 1999 г. с предыдущими съемками, проведенными в феврале 1985 г. и январе–феврале 1991 г. Рассматривались следующие виды: *Gobionotothen gibberifrons*, *Lepidonotothen squamifrons*, *Pseudochaenichthys georgianus*, *Champsocephalus gunnari*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Notothenia rossii* и *Lepidonotothen larseni*. Несмотря на существенную изменчивость точечных оценок, с 1991 г. уровень биомассы большинства видов почти не изменился или немного снизился. Запас *C. gunnari* в настоящее время очень низкий, в то же время многое указывает на восстановление запаса *N. rossii*. В целом, уровни биомассы в настоящее время слишком низки для коммерческого промысла.

Resumen

Las poblaciones de peces explotadas alrededor de las islas Orcadas del Sur (Subárea 48.2) disminuyeron substancialmente entre los años emergentes de 1977/78 y 1989/90. El seguimiento más reciente de la biomasa de varias especies de peces ha sido efectuado mediante prospecciones científicas de arrastre de fondo dentro de la isóbata de 500 m alrededor de las Islas Orcadas del Sur, por parte de la República Federal de Alemania (1985), España (1991) y Estados Unidos (1999). A partir de los resultados de estas prospecciones se estimó la biomasa total del stock para las ocho especies de peces más abundantes en las capturas. Se comparó el nivel de la biomasa y la composición por tallas de la prospección de arrastre realizada en marzo de 1999 con los resultados de las prospecciones anteriores realizadas en febrero de 1985 y de enero a febrero de 1991. Las especies estudiadas fueron *Gobionotothen gibberifrons*, *Lepidonotothen squamifrons*, *Pseudochaenichthys georgianus*, *Champsocephalus gunnari*, *Chaenocephalus aceratus*, *Chionodraco rastrospinosus*, *Notothenia rossii* y *Lepidonotothen larseni*. A pesar de la gran variación de las estimaciones puntuales, se ha observado que la biomasa de la mayoría de las especies no ha cambiado, o bien ha disminuido levemente desde 1991. El nivel actual del stock de *C. gunnari* es extremadamente bajo, mientras que se ha observado un repunte del stock de *N. rossii*. El nivel de la biomasa en general sin embargo indica que, por ahora, las posibilidades de una explotación comercial no son buenas.

Keywords: stock biomass, finfish, trawl surveys, Subarea 48.2, CCAMLR

INTRODUCTION

Commercial exploitation for finfish in the South Orkney Island chain (Subarea 48.2) was conducted from 1977/78 to 1989/90. The main species caught in this region during this period were *Champsocephalus gunnari*, *Gobionotothen gibberifrons* and *Notothenia rossii* (CCAMLR, 1990). Also taken were *Lepidonotothen squamifrons*, *Pseudochaenichthys georgianus*, *Chaenocephalus aceratus*, *Dissostichus eleginoides* and unspecified finfish species. The first year of fishing yielded a catch of almost 140 000 tonnes of *C. gunnari*, supported mainly by 1973/74 and 1974/75 cohorts (Kock, 1991). Both cohorts were largely exhausted within two years, and overall catches declined by almost two orders of magnitude within a few years (Figure 1). Catches increased slightly in the mid-1980s, primarily as a result of the 1980/81 cohort, and decreased substantially thereafter once this cohort was exhausted. The rapid declines of catch and catch rates led CCAMLR to impose a moratorium on all directed fishing for finfish in the South Orkney Islands in 1990/91. This moratorium remains in effect (Conservation Measure 73/XVII; see CCAMLR, 1999).

Six scientific trawl surveys have been conducted in the region of the South Orkney Islands, four of which occurred prior to the closure of the fishery. Three of these were bottom trawl surveys conducted by the Federal Republic of Germany (Kock, 1986) in 1976, 1978 and 1985. However the 1976 and the 1978 surveys were limited in scope, covering only a small part of the seabed area within the 500 m isobath. The fourth survey was conducted by Spain in 1986/87 (Balguerías et al., 1987), and used a semipelagic trawl with dimensions substantially different to other surveys. Hence, these three surveys are not considered here. Since closure of the region to bottom trawling, there have been two scientific surveys: one by Spain in 1991 (Balguerías, 1991), and one by the US Antarctic Marine Living Resources (US AMLR) Program in 1999. The three surveys examined in this study (1985, 1991 and 1999) used similar commercial-size bottom trawls and were comprehensive in scope.

This paper uses information collected during the 1999 US bottom trawl survey and compares results to the German surveys conducted in 1985 and the Spanish survey conducted in 1991. Independent analyses of two previous surveys (Kock, 1986; Balguerías, 1991 respectively) used different assessment techniques and different areas of seabed in computations. Here, we give identical analytical treatment to all surveys for more direct comparison of estimates. A total of eight Antarctic finfish species are examined: *G. gibberifrons*, *L. squamifrons*, *P. georgianus*, *C. gunnari*, *C. aceratus*, *Chionodraco rastrospinosus*, *N. rossii* and *L. larseni*.

METHODS AND MATERIALS

Sample strategies for all surveys examined were based on random stratified designs. Sampling sites were stratified by depth, and were positioned to cover a wide geographic range. All surveys had three designated depth strata: 50–150, 150–250 and 250–500 m. The proportion of fishing effort allocated to each stratum was similar for each survey, with the fewest hauls in the 50–150 m strata and the greatest number in the 250–500 m stratum. The gear types used for each of the surveys were similar commercial-size bottom trawls, although there were some differences in gear configuration.

During the US AMLR survey in March 1999, trawling operations were conducted aboard the RV *Yuzhmorgeologiya*. Station coordinates for this survey are plotted in Figure 2. The fishing gear used to conduct the survey was the Hard Bottom Snapper Trawl (HBST) with vented V-doors, both manufactured by Net Systems Inc. (Bainbridge Island, Wa., USA). The overall length of the trawl was about 63 m, with an average horizontal mouth width of about 20 m and mouth height of about 9 m. The footrope was rigged with a tyre-gear bosom approximately 5.8 m in length and 61 cm in diameter. The belly and wings were constructed with 12.7 cm mesh; the intermediate section with 10.16 cm mesh, and a 40 mm mesh liner was installed in the codend. In addition, we used a Netsweep 325 net sonar system (Ocean Systems Inc.) to record the net mensuration (height and width of the trawl mouth), as well as the trawl interaction with the bottom. Hauls were made only after initial acoustic reconnaissance verified that bottom conditions were suitable for trawling. A total of 64 hauls were taken: 7 in the 50–150 m stratum, 24 in the 150–250 m stratum, and 33 in the 250–500 m stratum.

The Spanish survey was conducted aboard the FV *Naroch* from mid-January to mid-February 1991. The trawl used had a horizontal mouth opening of about 26 m, a vertical mouth opening of 8 m, a 35 mm mesh liner in the codend, and polyvalent doors. Additional information from this survey is presented in Balguerías (1991). This survey was by far the most extensive of the three examined, with a total of 139 hauls made: 20 in the 50–150 m stratum, 42 in the 150–250 m stratum and 77 in the 250–500 m stratum.

The 1985 Federal Republic of Germany survey was conducted in January 1985 aboard the FV *Walther Herwig*. The bottom trawl used was approximately 43 m long with a horizontal mouth width of about 23 m, a net height of about 5 m, and a 40 mm mesh liner installed in the codend. The footrope was rigged with a steel-bobbin bosom configuration. Additional details about this survey are presented in Kock (1986). A total of 30 hauls were made: 3 in the 50–150 m stratum, 9 in the 150–250 m stratum and 18 in the 250–500 m stratum.

For all surveys, similar levels of catchability and insignificant differences in size selectivity of the trawls were assumed. All hauls were conducted during daylight hours. The target time for a haul was 30 minutes, with any haul less than 20 minutes considered invalid and discarded. Trawling started as soon as the footrope made contact with the bottom. Once contact with the bottom was made, position, time, ship speed, bearing, headrope depth, bottom depth and net mensuration were recorded. In the 1999 study, recordings were made every five minutes, giving a total of seven observations for each haul. Supplementary data collected for each haul included ship course, sea-surface temperature and salinity, bottom temperature and salinity, air temperature, wind direction and speed, weather, cloud conditions, sea state, light and ice conditions.

During the 1999 survey, the contents of the trawl were emptied onto the deck and transferred to a sorting table. Where catches were large (>500 kg), a subsample of the catch of approximately 500 kg was taken. All fish were separated into species and placed into individual species baskets. Organisms other than fish (benthos and other by-catch) were removed. Baskets were

Table 1: Summary of seabed areas (n miles^2) around the South Orkney Islands, from Jones (2000).

Strata	Seabed Area (n miles^2)
50–150 m	624.24
150–250 m	1 523.50
250–500 m	6 471.82
50–500 m	8 619.55

Table 2: Total nominal yield in weight (kg) for nine species caught around the South Orkney Islands during the US AMLR 1999 survey.

Species	Strata			Total
	50–150 m	150–250 m	250–500 m	
G. gibberifrons	1 084.10	2 438.06	1 539.41	5 061.57
L. squamifrons	-	65.45	4 957.84	5 023.29
P. georgianus	26.65	2 397.43	159.32	2 583.40
C. aceratus	353.83	896.46	203.87	1 454.16
C. rastrospinosus	23.43	85.57	814.92	923.92
C. gunnari	76.92	341.39	84.11	502.42
N. rossii	8.17	14.01	251.12	273.30
L. larseni	6.71	15.56	10.89	33.15
Total	1 579.81	6 253.93	8 021.48	15 855.21

weighed to obtain total catch weights by species. For all species, up to five fish per individual centimetre group and sex were weighed (accuracy to 1 g) over the whole length range in order to obtain an equal distribution of weights and a representative length–weight relationship.

For each haul, total weight of individual species caught was standardised to 1 n mile^2 of area swept using the average trawl mouth width and bottom distance covered. Estimates of standing stock biomass were computed by stratum using the delta-lognormal maximum likelihood estimator (Pennington, 1983; de la Mare, 1994). Jones (2000) computed seabed areas within the South Orkney Islands for this analysis (Table 1).

RESULTS

During the 1999 survey, a total of 16 167.53 kg (38 356 individuals) of 42 species was caught. The eight species considered in the paper represented about 98% of the total yield (Table 2). All surveys exhibited similar geographic distribution of yields, with highest yields generally to the west and north of the South Orkney Island chain (Figure 3) and around the Inaccessible Islands, although the distribution of standardised density varied with species (Figure 4). The distribution of catches by species was highly dependent on depth strata, with average yields and variability of yields per haul greatest in the 150–250 m depth stratum and lowest in the 50–150 m stratum. The average standardised (kg/n mile^2) nominal catch per haul for the eight species combined increased with each survey, with 4 124 kg/n mile^2 in 1985, 13 219 kg/n mile^2 in 1991 and 18 173 kg/n mile^2 in 1999. The species with the highest yield in both the 1985 and 1999 surveys was *G. gibberifrons*, followed by *L. squamifrons*, although the 1991 survey was dominated by *C. gunnari*. Yield from the 1999 survey comprised largely *P. georgianus* and *L. squamifrons*, although yields of these species were the result of encountering very dense aggregations in limited areas to the north and west of the islands.

Trends in estimated standing stock biomass for the eight species combined are presented in Figure 5a. Point estimates increased substantially from the 1985 to the 1991 survey, and then showed signs of a slight decrease in the 1999 survey. In all surveys, 95% confidence limits of the estimates overlap, with the greatest uncertainty in 1985 and the least in 1991. The direction of change in the point estimates of overall biomass is driven primarily by the catches of *G. gibberifrons* and *L. squamifrons*. Levels of uncertainty around these estimates were also driven by these two species. However, point estimates of several other species demonstrated a general pattern of increase in 1991 and slight decrease in 1999. Estimates by species that drive the overall patterns are presented in Table 3.

Table 3: Estimates of biomass (tonnes) and 95% confidence intervals by stratum for the South Orkney Islands for the three surveys examined.

Species	Strata (m)	Survey 1985		Survey 1991		Survey 1999	
G. gibberifrons	50–150	458	(237–675)	2 089	(640–15 999)	6 248	(2 304–49 329)
	150–250	2 865	(1 396–10 585)	4 141	(2 741–7 241)	10 173	(5 960–22 700)
	250–500	15 642	(7 702–50 121)	47 252	(22 042–134 375)	22 479	(12 840–50 640)
	Total	18 965	(10 637–53 483)	53 483	(27 924–140 646)	38 900	(26 091–82 780)
L. squamifrons	150–250	215	(11–489 534)	57	(17–448)	875	(160–22 497)
	250–500	5 858	(1 308–93 944)	14 099	(5 373–56 560)	50 059	(14 345–372 432)
	Total	6 073	(1 444–495 401)	14 156	(5 429–56 617)	50 934	(15 129–373 309)
C. gunnari	50–150	326	(96–7 643)	74	(29–343)	501	(320–1 002)
	150–250	273	(129–1 073)	2 415	(1 040–8 526)	1 249	(757–2 591)
	250–500	4 225	(1 764–18 647)	21 132	(10 087–58 918)	1 267	(551–4 280)
	Total	4 824	(2 297–18 318)	23 621	(12 274–61 450)	3 016	(2 027–6 073)
C. aceratus	50–150	108	(56–156)	928	(201–15 606)	1 859	(887–7 594)
	150–250	1 119	(491–5 313)	4 014	(2 423–8 155)	5 962	(2 994–17 599)
	250–500	3 949	(2 004–11 510)	11 089	(6 707–21 490)	2 610	(1 344–7 012)
	Total	5 175	(2 997–12 203)	16 031	(10 897–31 093)	10 431	(6 628–22 220)
C. rastrospinosus	50–150	12	(3–40)	10	(4–34)	153	(73–623)
	150–250	386	(179–1 599)	605	(367–1 191)	399	(282–640)
	250–500	4 586	(1 890–20 846)	14 795	(8 751–29 750)	12 881	(7 373–29 114)
	Total	4 983	(2 254–15 640)	15 410	(9 353–30 368)	13 434	(7 921–28 796)
P. georgianus	50–150	25	(na)	2	(na)	167	(48–1 425)
	150–250	156	(50–1054)	349	(159–1 121)	6 504	(2 350–35 071)
	250–500	4 557	(1 173–55 578)	18 498	(8 975–50 461)	2 057	(910–6 836)
	Total	4 739	(1 319–42 432)	18 847	(9 316–50 810)	8 728	(4 138–36 461)
N. rossii	50–150	-		2	(0–308)	58	(14–532)
	150–250	22	(4–57)	27	(13–59)	61	(25–126)
	250–500	140	(60–268)	384	(128–2 257)	3 160	(675–61 159)
	Total	163	(77–293)	412	(155–1 719)	3 278	(790–60 672)
L. larseni	50–150	4	(2–9)	3	(1–17)	45	(14–474)
	150–250	141	(42–1 635)	40	(21–96)	91	(47–249)
	250–500	301	(151–909)	412	(215–1 005)	151	(105–241)
	Total	446	(239–1 945)	455	(255–1 049)	288	(205–718)

Gobionotothen gibberifrons

During the 1999 survey, *G. gibberifrons* was the most abundant species both in terms of weight and numbers and among the most encountered species in the whole South Orkney Island chain (Table 2). Fish were found in all regions, with concentrations in the western and northern sectors of the island chain (Figure 4a). Catches throughout the rest of the island chain and offshore were relatively consistent, with greatest average weight and numbers per haul in the 50–150 m stratum.

Comparing all surveys, the lowest estimated standing stock of biomass was in 1985, followed by a substantial increase in 1991 (Figure 5b). The 1999 point estimate of standing stock biomass estimates (Table 3) was 38 900 tonnes (SE = 9 261), with a relatively moderate 95% confidence interval. Although this represents a 27% decrease in point estimate biomass from the 1991 survey (53 483 tonnes; SE = 19 268), the confidence limits and standard errors are large enough that no significant change in biomass from these two surveys can be established. The length-frequency distribution (Figure 6a) demonstrates a shift to slightly larger proportions from 1985 to 1991, and this remained essentially unchanged in the 1999 survey.

Lepidonotothen squamifrons

L. squamifrons was the second most abundant species in terms of catch (5 023.29 kg, 6 875 individuals) during the 1999 survey, although it displayed the most patchy distribution. When standardised to 1 n mile^2, this species demonstrated the highest localised densities (Figure 4b). This was mainly the result of encountering dense spawning or pre-spawning aggregations during hauls in the western sectors of the island chain.

Regions in the south yielded relatively small and less variable catches. In all surveys, fish were encountered only within the 150–250 and 250–500 m depth strata, with the highest average yields per haul in the 250–500 m stratum.

Total standing stock biomass estimates for *L. squamifrons* (Table 3; Figure 5c) were the highest of any species during the 1999 survey, although this was not the case for previous surveys. However, due to the skewed distribution of catches, the uncertainty of biomass levels was also greatest, particularly in the 250–500 m stratum for the 1991 and 1999 surveys, and the 150–250 m stratum for the 1985 survey. Estimates from the 1985 survey are particularly problematic, mainly due to a very large catch at one station in the 250–500 m stratum and no catch at several stations in the 150–250 m stratum. Nevertheless, catches for most hauls during the 1985 survey were very small. Subsequent to this, mean standardised yield per haul has substantially increased with each survey (693 kg/n mile^2; 1 942 kg/n mile^2; 6 736 kg/n mile^2 for 1985, 1991 and 1999 respectively). Even with the uneven distribution of yields of *L. squamifrons* during each survey, the increase in point estimate biomass levels for this species suggests an increase in population levels from 1985 to 1999. Like *G. gibberifrons*, there appeared to be a shift in size composition to larger animals from 1985 to 1991 (Figure 6b), with no differences identified between 1991 and 1999.

Champsocephalus gunnari

A remarkably low number of *C. gunnari* were encountered during the 1999 survey (502 kg, 761 individuals) relative to other species. Most fish were found to the north and east of the island chain (Figure 4c), with the majority of fish taken in the 150–250 m depth stratum. With the exception of the small nototheniid *L. larseni*, this was the least abundant of the eight species caught. Unlike all previous surveys, there were few fish encountered within the 250–500 m stratum in the 1999 survey.

The small catches resulted in a very small 1999 point estimate of total standing stock biomass (Table 3; Figure 5d). The 1999 estimate of 3 016 tonnes was the lowest of the three surveys examined, about 87% lower than the estimate from the 1991 survey, where the importance of *C. gunnari* in terms of overall biomass was second only to *G. gibberifrons*. Confidence limits were roughly equivalent for the three surveys, with the 1985 survey the widest. Length compositions from the three surveys are similar (Figure 6c), with a slight shift towards larger animals apparent from samples taken during the 1999 survey.

Chaenocephalus aceratus

Specimens of *C. aceratus* caught during the 1999 survey (Table 2) were encountered around the island chain in all depth strata, with the highest average concentrations per haul in the 50–150 m stratum and fewer catches offshore (Figure 4d). There was a substantially lower overall proportion of fish encountered in the 250–500 m stratum compared to the 1985 and 1991 surveys.

The total standing stock biomass estimate from the 1999 survey (Table 3; Figure 5e) was 10 431 tonnes, about 35% lower than the 1991 estimate. However, current point estimates are about twice that of the 1985 estimate. Because confidence limits overlap for all survey biomass estimates, there is little evidence to suggest that biomass for this species has increased substantially since the closure of the fishery. The length-frequency plots (Figure 6d) show a shift to larger sizes from 1985 to 1991, and a smaller representation of larger animals in the 1999 survey.

Chionodraco rastrospinosus

Although there were no reported catches of *C. rastrospinosus* while the fishery in the South Orkney Islands was operational, this species was encountered on a very consistent basis for all surveys. This was the only species that was caught at every station during the 1999 survey. There were relatively consistent yields across most stations, and most fish were taken in deeper waters (250–500 m depth stratum) and offshore (Figure 4e). Catches of *C. rastrospinosus* from the 1985 and 1991 survey were similarly distributed around the South Orkney Islands.

The 1999 biomass estimate for *C. rastrospinosus* (Table 3) was the third highest of any species considered, although it does not appear to have increased since the 1991 survey. Confidence limits about the estimates are similar for both surveys (Figure 5f). Biomass appears to have increased relative to the 1985 survey. Length compositions were similar in the 1985 and 1991 survey, and appear to have shifted to smaller size classes in the 1999 survey (Figure 6e).

Pseudochaenichthys georgianus

Of the 2 583 kg of *P. georgianus* captured in the 1999 survey, most (63%) were caught at two stations north of Coronation Island (Figure 4f). Large catches were also taken at another station in the northwestern sector. The extreme unevenness in spatial distribution of the species was probably due to dense pre-spawning aggregations. As a result, the distribution of *P. georgianus* was the second most skewed (after *L. squamifrons*), based on the variability of catch on a haul-by-haul basis, with a similar geographical distribution observed during the 1985 and 1991 surveys. The highest average yields were encountered in the 150–250 m stratum, and most offshore yields were relatively small.

Due to the variability of catches by haul, estimates of biomass from all surveys demonstrate correspondingly high variability, particularly from the 1985 survey. Nevertheless, it is reasonable to conclude that the stock of *P. georgianus* does not appear to have substantially increased across the surveys (Figure 5g). One thing that has remained quite consistent for all surveys is the size structure (Figure 6f), which demonstrates a remarkably consistent distribution.

Notothenia rossii

A total of 273 kg of *N. rossii* was caught in 1999, mostly in the eastern and western sectors (Figure 4g). Most catches were encountered at two stations, both in the 250–500 m stratum. Although this represents a very low proportion of the overall catch during the survey, average yields during 1999 were the highest of any survey.

Variability of computed biomass estimates is high from all surveys due to sparse yields. However, point estimates (Table 3; Figure 5h) demonstrate a considerable biomass increase for the 1999 survey compared to previous surveys. Due to limited yields from all surveys, a comparison of length compositions would not be meaningful and is not presented here.

Lepidonotothen larseni

Due to its small size, *L. larseni* was the only species for which there was no reported catch while the fishery was in operation. Fish were encountered at all depths and most geographic regions sampled within the 500 m isobath (Figure 4h), with highest average yields per haul in the 50–150 m depth stratum. Yields (Table 2) and standing stock biomass estimates (Table 3; Figure 5i) were the lowest of any species considered here. The current estimated levels of total biomass appear to have dropped slightly, although 95% confidence limits overlap in all surveys. Length composition in 1999 appears to have shifted to slightly larger animals compared to the 1985 survey.

DISCUSSION AND CONCLUSION

One must exercise caution when directly comparing estimates of biomass from the 1999 US AMLR survey to those of any previous survey in the South Orkney Islands region. Although the survey designs were similar for all three surveys, there were differences in the types of bottom trawl deployed. However, all were of commercial size, and catch composition both in terms of numbers and proportions of species in the catch was similar. We have therefore assumed that the influence of differences in net design was not substantial.

We assumed a catchability of 100% from all hauls, although it is unlikely that this was met in all three surveys and for all species. A measure of departure from this assumption could allow estimates to be adjusted such that biomass could be directly compared. Correction factors of that kind would probably have to be species-specific, and could only be estimated in an experiment comparing the three nets. This was not possible with these three surveys, which were conducted independently and 14 years apart. However, length-frequency plots suggested no substantial differences in catchability of the three nets, and all size classes appeared to be adequately represented.

There are two ways to approach the question of continuity of biomass estimates when using different ships and different net designs in the surveys. Firstly, one can assume that all surveys provide an accurate representation of stock status for all species considered, allowing us to directly compare biomass estimates from all surveys. Secondly, given differences in vertical opening among nets, we can surmise that a two-panel net with a lower net opening, such as the German 200′ bottom trawl, will catch bentho-pelagic species less effectively than four-panel nets, such as the Spanish and American nets which have a higher net opening. The trawl used during the 1985 survey had a mouth height of about 5 m, which was about 3 to 4 m less than in other surveys.

Although little information exists regarding the vertical distribution of the different species, in general Antarctic fish are found very close to the bottom or even at the bottom, and leave the near-bottom layers only at night. There is some information on *C. gunnari* from the South Orkneys in 1977/78 (Tarverdiyeva, 1982), as well as observations from Elephant Island from 1977/78 (Kock, unpubl.), where in certain cases *C. gunnari* were assembled 5–15 m above the bottom in dense concentrations even during the day and could only be taken by bentho-pelagic trawls or bottom trawls with a high vertical opening. However all other species, as well as *C. gunnari*, seem to follow the general pattern of sticking to the bottom fairly closely during the day. They are just as likely to be caught in a 5 m high net as in a 9 m high net. Until better data are collected, it is reasonable to assume that the nets catch the species with great efficiency, with the possible exception of *C. gunnari* in cases where they form very dense concentrations.

Other factors that warrant caution when directly comparing different surveys include: (i) potential differences in the likelihood of hitting a concentration in a stratum; (ii) the time since substantial commercial fishing has lapsed; (iii) intra-annual and interannual changes in spatial distribution of certain species; and (iv) differences in sample size by survey. In the last case, the 1985 survey around the South Orkney Islands consisted of 30 stations, while in 1991 more than 139 hauls were conducted, and the 1999 survey comprised 64 stations. The likelihood of hitting a concentration of fish increases substantially when conducting 139 stations compared to 30 stations. This may explain why biomass estimates of the different species for the 1991 survey were substantially higher than in 1985. Variability of the combined biomass estimate (as well as those of most species examined separately) was roughly inversely proportional to the number of tows by survey, with the 1985 survey (30 hauls) the most variable, the 1991 survey (139 hauls) the least variable, and the 1999 survey (64 hauls) roughly midway for most species. One factor that was reasonably consistent across all series was the relative continuity of catch composition.

However, one should bear in mind that the 1985 survey was conducted only a few years after a substantial fishery in the area, and fishing was still permitted at the time. The 1991 survey was conducted one year after the closure of the area for finfishing and about 10 years after the peak of commercial fishing, between 1977/78 and 1980/81. By 1991, stocks should have recovered to a large extent, which may not have been the case in 1985. Intra-annual differences are likely to be very small, as all surveys were within a month of each other in their respective years. Interannual changes in spatial distribution of certain species may have occurred and may have influenced biomass estimates. However, all three surveys are consistent in showing most fish biomass occurring in the northern and northwestern parts of the shelf. An exception has been the *C. gunnari* fishery in 1977/78, which operated primarily to the southeast of Laurie Island. Discrepancies resulting from these considerations are likely to be small.

Despite these shortcomings, some important general patterns do emerge. While the paucity of information from this region does not allow precise changes in overall biomass to be measured, it appears as though there have been shifts in the abundance of several species. Given that all surveys represent reasonable measures of biomass, and point estimates are the most accurate levels, there was little shift in overall biomass of the eight species between the 1991 and 1999 surveys. In both of these surveys, however, there is a substantial increase in biomass over the 1985 survey. The 1985 survey followed three to four years of the highest directed effort toward finfishing in the region; limited fishing was conducted during 1985. The increase in overall biomass from the 1985 survey to the 1991 survey was potentially the result of low effort directed at finfish in the region after 1982/83 and the final closure of the area to finfishing after 1989/90. The fishery shifted from the South Orkney Islands back to South Georgia where concentrations of *C. gunnari* were exploited in the 1980s. The similarity of estimates in 1991 and 1999 indicated the stocks had recovered to some degree by then, and little change in the stocks has taken place since the beginning of the 1990s.

On an individual species basis, there may have been some substantial shifts in levels of biomass from the three surveys. For all species except *L. larseni* and *C. gunnari*, biomass levels have increased in the 1991 and 1999 surveys over the 1985 survey. However, biomass levels for only two species increased in 1999 over the 1991 survey, and there was an apparent decrease in biomass for all other species in 1999, particularly *C. gunnari*. The lack of *C. gunnari* encountered during the 1999 survey is noteworthy, as this species drove the commercial fishery during the 1970s and early 1980s. It is unlikely that with 64 hauls we simply missed a large aggregation during sampling. If 1999 biomass levels are accurate, even the upper 95% confidence limit is roughly at 4% of pre-exploitation levels (Kock et al., 1985) around the South Orkney Islands.

N. rossii, and possibly *L. squamifrons*, appear to show signs of population increase since earlier surveys. Historically, there is no indication that a large population of *N. rossii* existed in the South Orkney Islands relative to *C. gunnari* and *G. gibberifrons*, as was the case at South Georgia and Elephant Island. This species had been largely by-catch from 1977/78 to 1980/81 and 1983/84 to 1984/85, with more substantial catches in 1979/80 and 1983/84. Although current biomass levels of *N. rossii* are still small relative to other species, the apparent increase in biomass of this species is encouraging.

A region of the Southern Scotia Arc that has had a similar history of exploitation and resource depletion is the South Shetland Island chain, particularly Elephant Island. The South Orkney and South Shetland Islands have broadly similar ichthyofaunal communities, particularly within the lesser-Antarctic species group, which consists of all species examined here with the exception of *C. rastrospinosus*. However, there is recent evidence that suggests a greater proportion of high-Antarctic species are found around the South Orkney Islands compared with the Elephant Island region (Kock et al., 2000), although this group comprised a very small proportion of the total catch in all surveys. Kock et al. (2000) found no substantial differences in other biological characteristics such as length–weight relationships, length at sexual maturity, and gonadosomatic indices for most individual species between the two regions.

It is difficult to compare standing stock biomass between the South Orkney and the South Shetland Islands unless surveys are conducted during the same season. A biomass survey of the South Shetland Islands was conducted by the US AMLR Program in 1998 using the same ship and trawl, and similar sampling design (Jones et al., in press). Comparing estimated biomass of the same eight species, we computed about twice the biomass in the South Orkney Islands in 1999. From a German survey of Elephant Island one year earlier, Kock's (1998) estimate of biomass around Elephant Island was similar to that estimated in the 1998 US AMLR survey of the region. This suggests a stronger signal of recovery in the South Orkney Islands, although stock sizes are now likely to fluctuate around a mean value. Differences from year to year may be largely due to changes in year-class strength, since abundance of a species is always increasing when one or two strong year classes are passing through the stock. At present, however, most fish stocks are probably not in a state that could withstand even limited exploitation.

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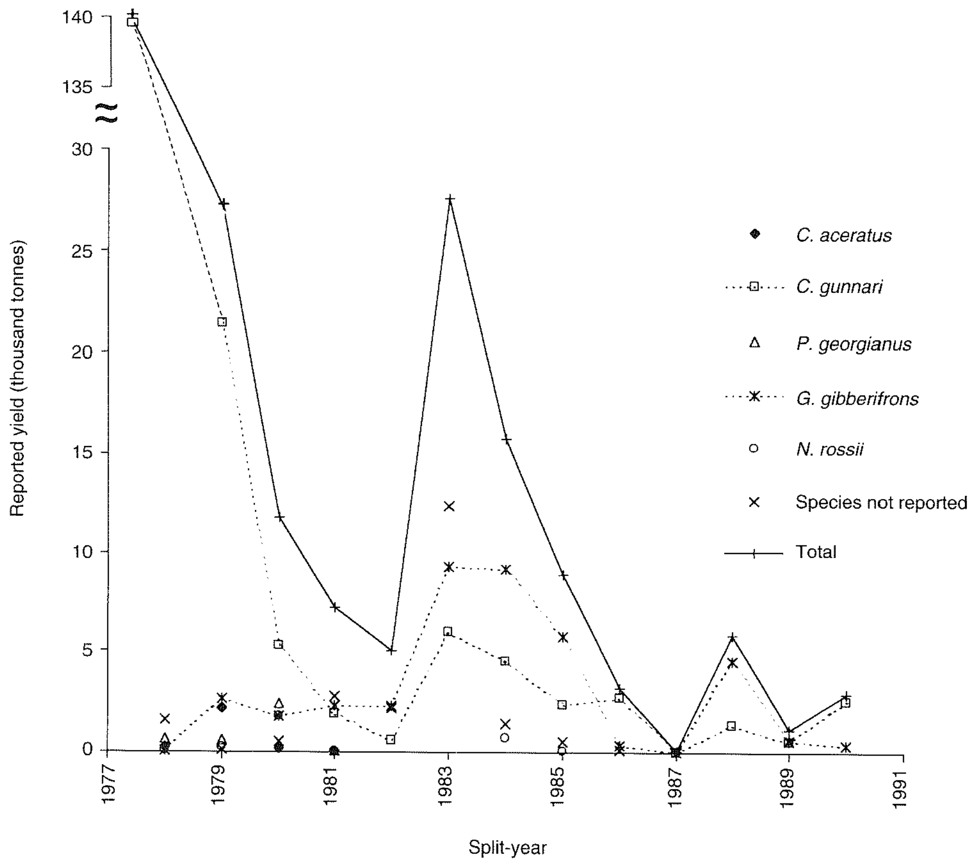


Figure 1: Nominal catches of species around the South Orkney Islands (Subarea 48.2). Catches of *Gobionotothen gibberifrons* from 1980 to 1983 were adjusted according to SC-CAMLR, 1990.

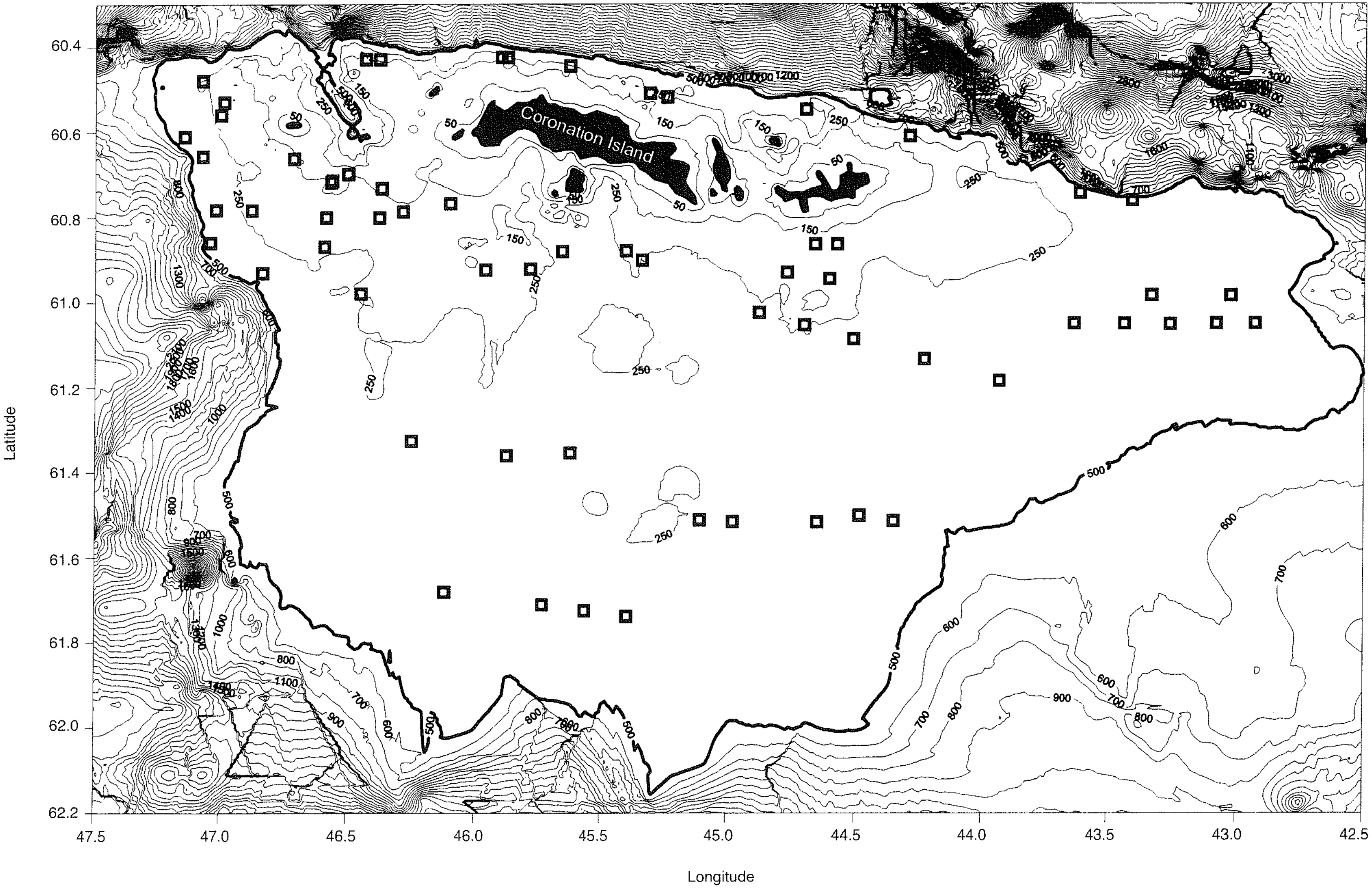


Figure 2: Map of station coordinates from the 1999 US AMLR survey of the South Orkney Islands.

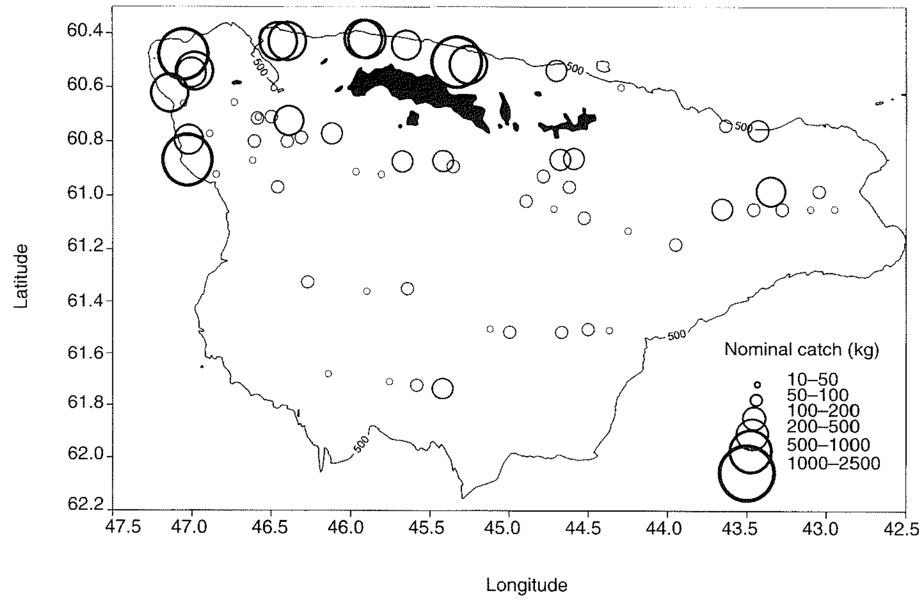
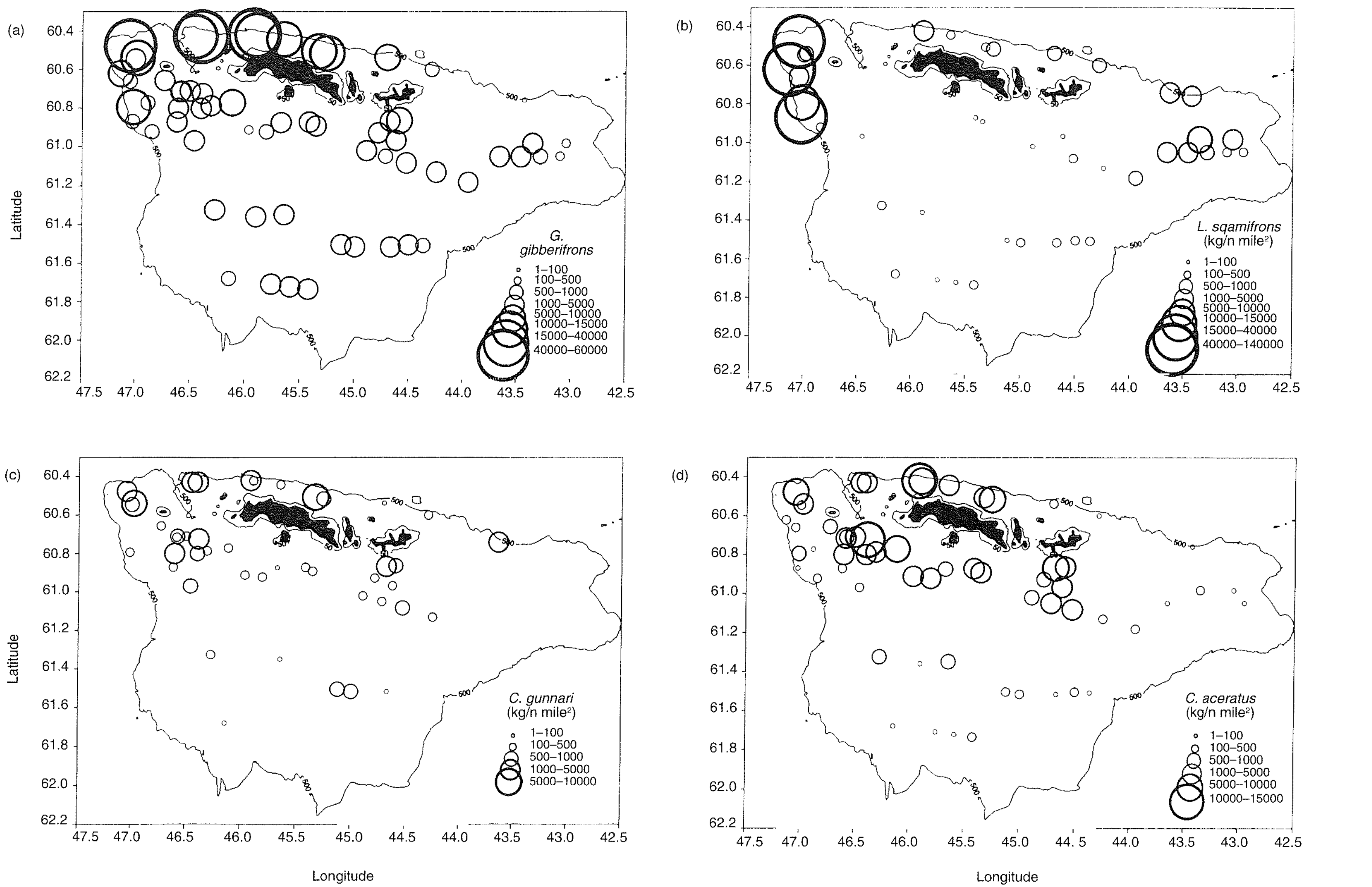


Figure 3: Map of nominal catches for all species combined from the 1999 US AMLR survey of the South Orkney Islands.


(a)
G. gibberifrons
1–100
100–500
500–1000
1000–5000
5000–10000
10000–15000
15000–40000
40000–60000
(b)
L. sqamifrons
(kg/n mile²)
1–100
100–500
500–1000
1000–5000
5000–10000
10000–15000
15000–40000
40000–140000
(c)
C. gunnari
(kg/n mile²)
1–100
100–500
500–1000
1000–5000
5000–10000
(d)
C. aceratus
(kg/n mile²)
1–100
100–500
500–1000
1000–5000
5000–10000
10000–15000
Latitude
Longitude
60.4
60.6
60.8
61.0
61.2
61.4
61.6
61.8
62.0
62.2
47.5
47.0
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44.5
44.0
43.5
43.0
42.5
500
50

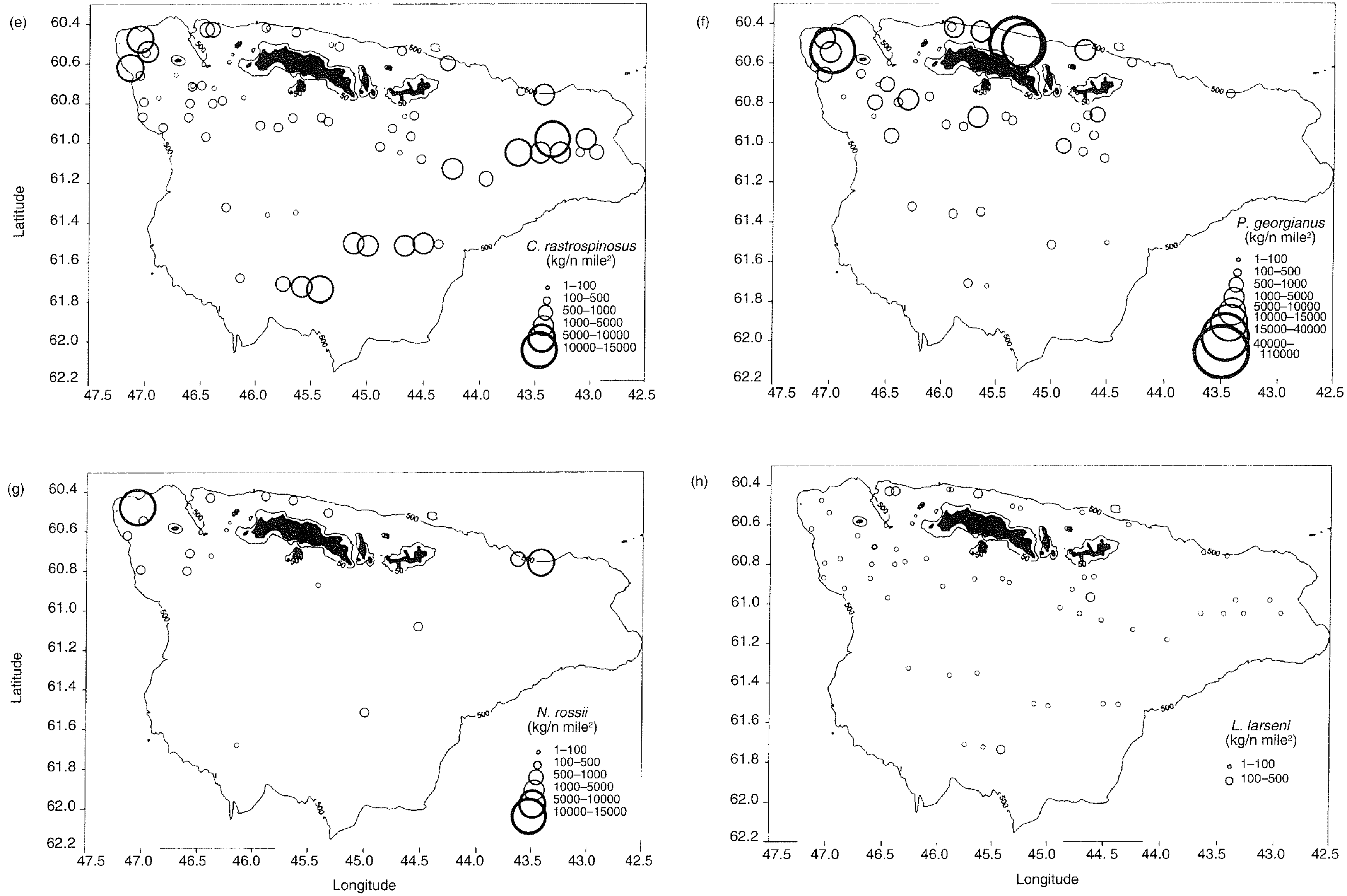
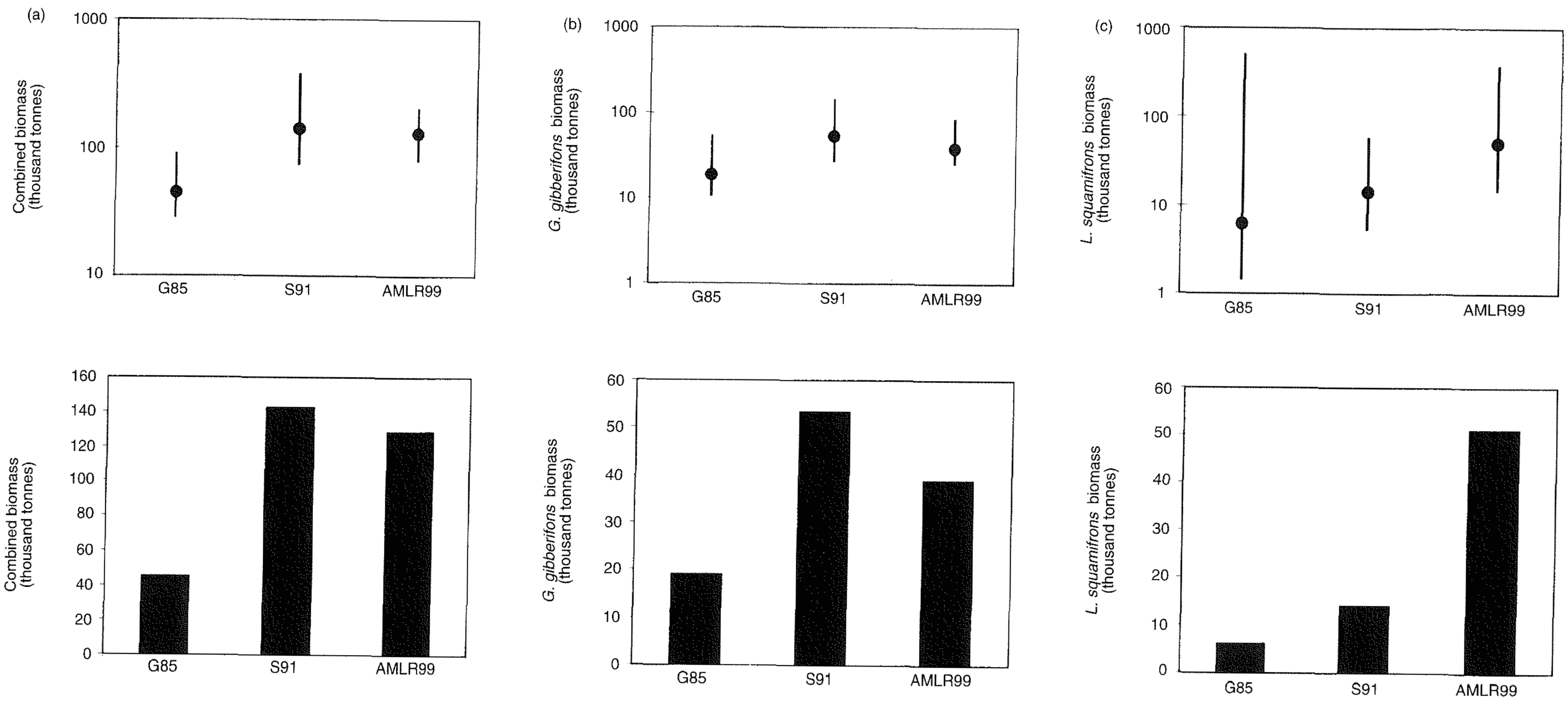


Figure 4: Map of catches (standardised to 1 n mile^2) for (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus*, (g) *Notothenia rossii* and (h) *Lepidonotothen larseni*, from the 1999 US AMLR survey of the South Orkney Islands.



(a)
Combined biomass (thousand tonnes)
1000
100
10
G85
S91
AMLR99
(b)
G. gibberifons biomass (thousand tonnes)
1000
100
10
1
G85
S91
AMLR99
(c)
L. squamifrons biomass (thousand tonnes)
1000
100
10
1
G85
S91
AMLR99
Combined biomass (thousand tonnes)
160
140
120
100
80
60
40
20
0
G85
S91
AMLR99
G. gibberifons biomass (thousand tonnes)
60
50
40
30
20
10
0
G85
S91
AMLR99
L. squamifrons biomass (thousand tonnes)
60
50
40
30
20
10
0
G85
S91
AMLR99

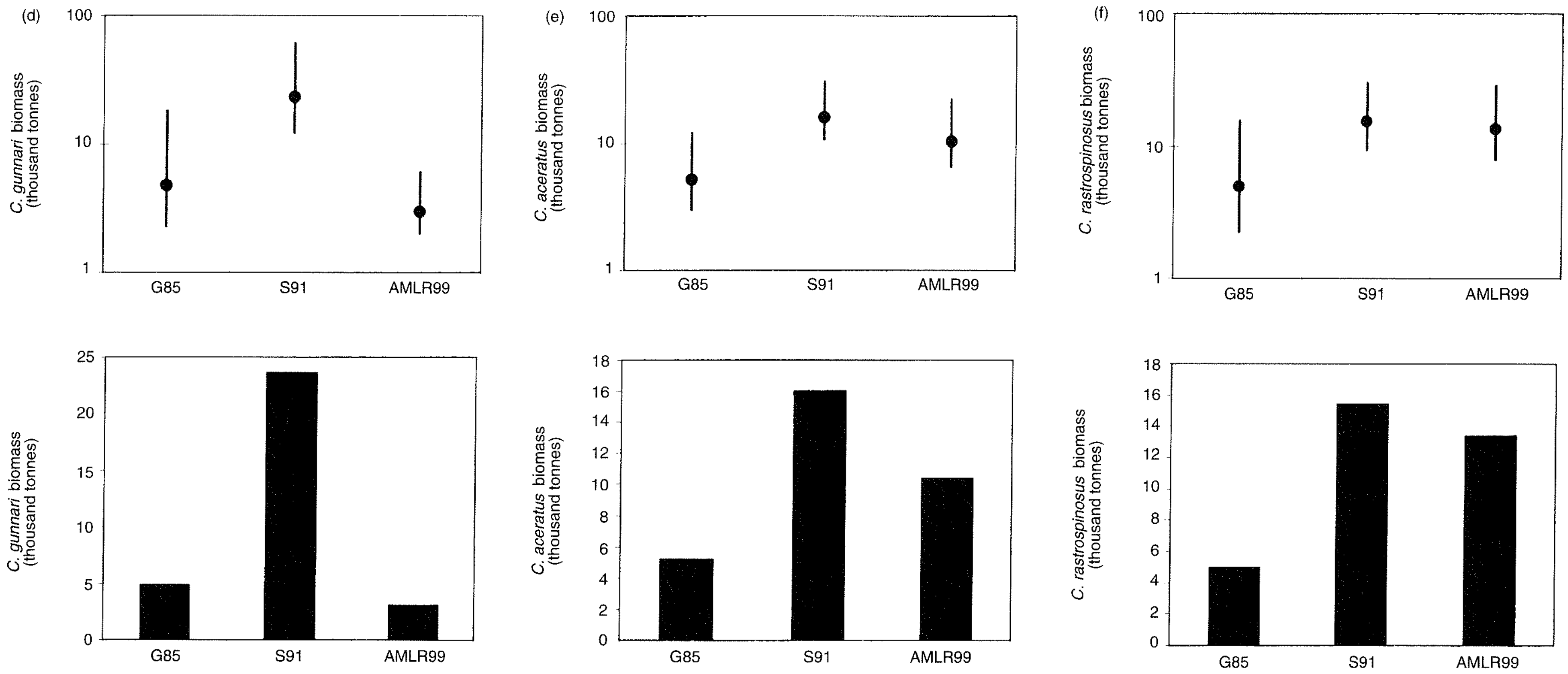


Figure 5: Total biomass estimates for (a) eight species combined, (b) *Gobionotothen gibberifrons*, (c) *Lepidonotothen squamifrons*, (d) *Champsocephalus gunnari*, (e) *Chaenocephalus aceratus*, (f) *Chionodraco rastrospinosus*, (g) *Pseudochaenichthys georgianus*, (h) *Notothenia rossii* and (i) *Lepidonotothen larseni* within the 500 m isobath of the South Orkney Islands from bottom trawl surveys conducted in 1985, 1991 and 1999. Upper plots include 95% confidence limits on a log scale; lower plots are point estimates on a normal scale.

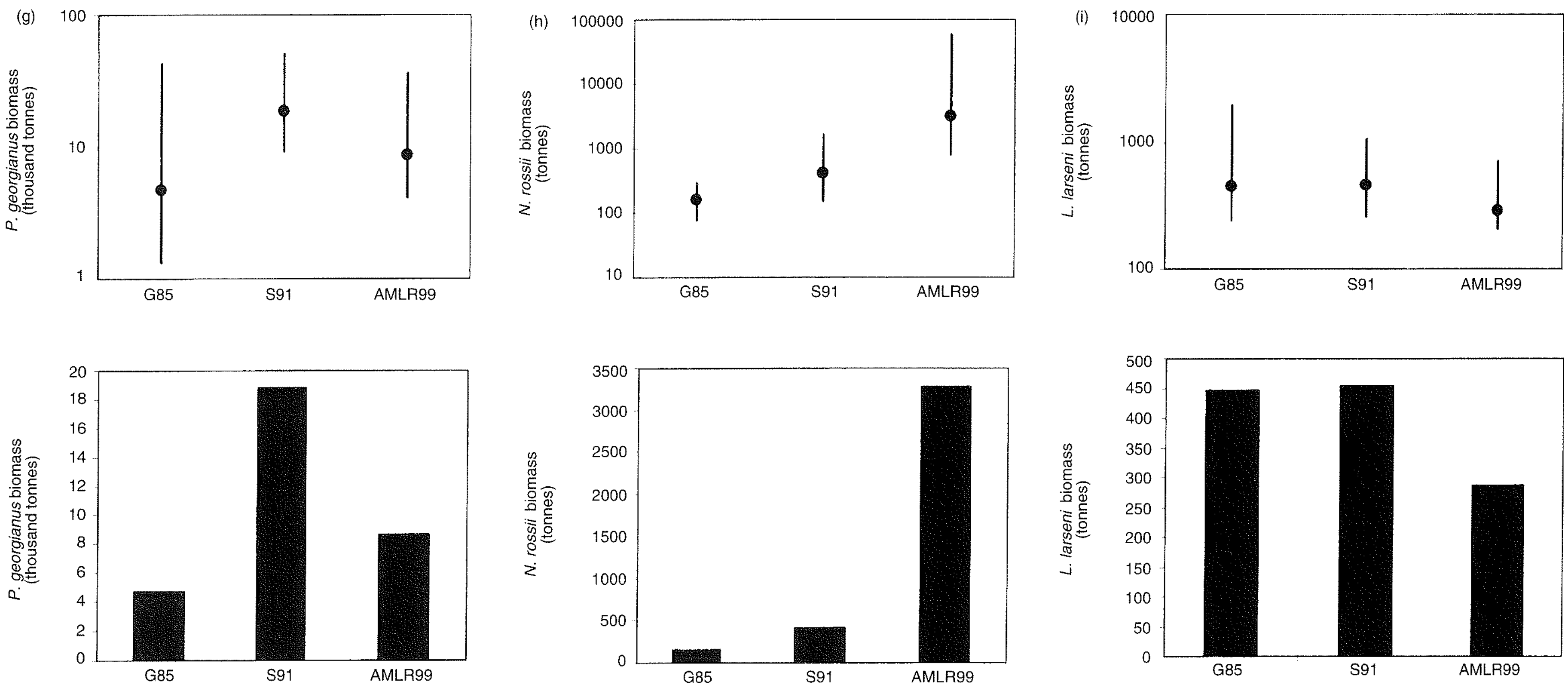


Figure 5 (continued)

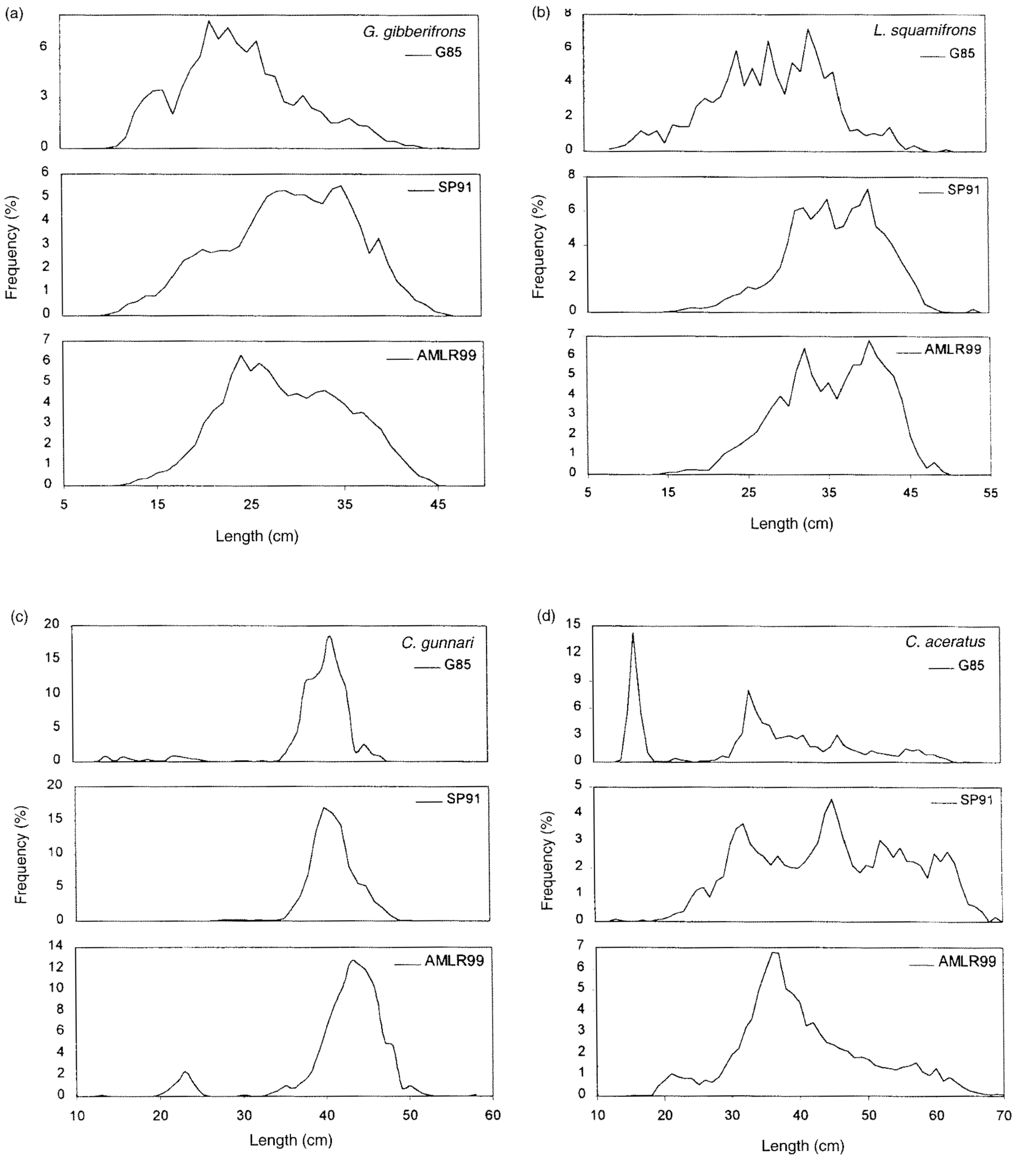


Figure 6: Length-frequency histograms for (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus* and (g) *Lepidonotothen larseni* from bottom trawl surveys of the South Orkney Islands conducted in 1985, 1991 and 1999. Data for *L. larseni* from the 1991 survey were unavailable.

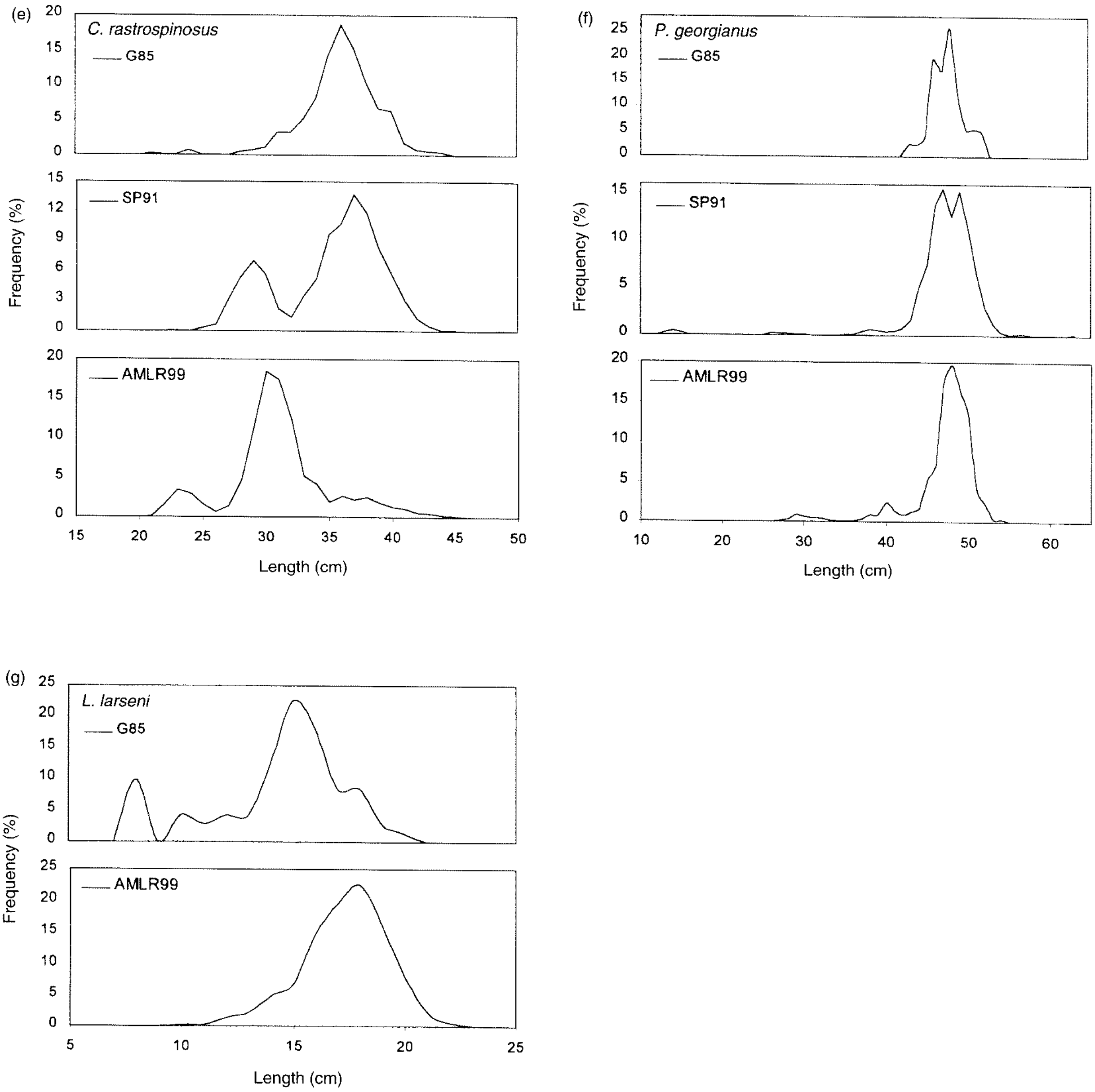


Figure 6 (continued)

Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Рис. 3: Карта суммарного номинального вылова всех видов в ходе американской съемки AMLR в районе Южных Оркнейских о-вов, 1999 г.

Рис. 4: Карта уловов (стандартизованных к 1 мор. миле^2) (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus*, (g) *Notothenia rossii* и (h) *Lepidonotothen larseni* по результатам американской съемки AMLR в районе Южных Оркнейских о-вов, 1999 г.

Рис. 5: Оценки общей биомассы (a) 8 видов вместе, (b) *Gobionotothen gibberifrons*, (c) *Lepidonotothen squamifrons*, (d) *Champsocephalus gunnari*, (e) *Chaenocephalus aceratus*, (f) *Chionodraco rastrospinosus*, (g) *Pseudochaenichthys georgianus*, (h) *Notothenia rossii* и (i) *Lepidonotothen larseni* у Южных Оркнейских о-вов в пределах изобаты 500 м по результатам донных траловых съемок 1985, 1991 и 1999 гг. На верхнем графике также показаны 95%-ные доверительные интервалы в логарифмическом масштабе; нижние графики показывают точечные оценки в нормальном масштабе.

Рис. 6: Гистограммы частотного распределения длин для (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus* и (g) *Lepidonotothen larseni* у Южных Оркнейских о-вов по результатам донных траловых съемок 1985, 1991 и 1999 гг. Не имелось данных по *L. larseni* за 1991 г.

Lista de las tablas

Tabla 1: Resumen de las áreas de lecho marino (millas náuticas^2) alrededor de las islas Orcadas del Sur, de Jones (2000).

Tabla 2: Rendimiento nominal total en peso (kg) de nueve especies capturadas alrededor de las islas Orcadas del Sur durante la prospección estadounidense AMLR realizada en 1999.

Tabla 3: Estimación de la biomasa (en toneladas) e intervalo de confianza del 95% por estrato en las islas Orcadas del Sur, para las tres prospecciones del estudio.

Lista de las figuras

Figura 1: Captura nominal de las especies alrededor de las islas Orcadas del Sur (Subárea 48.2). Se ajustaron las capturas de *Gobionotothen gibberifrons* desde 1980 a 1983, de conformidad con SC-CAMLR, 1990.

Figura 2: Mapa de las coordenadas de las estaciones de la prospección estadounidense AMLR realizada en 1999 alrededor de las islas Orcadas del Sur.

Figura 3: Mapa de la captura nominal combinada de todas las especies obtenido de la prospección estadounidense AMLR realizada en 1999 alrededor de las islas Orcadas del Sur.

Figura 4: Mapa de las capturas (normalizadas a 1 milla náutica^2) de (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus*, (g) *Notothenia rossii* y (h) *Lepidonotothen larseni*, obtenido de la prospección estadounidense AMLR realizada en 1999 alrededor de las islas Orcadas del Sur.

Figura 5: Estimaciones de la biomasa total para (a) ocho especies combinadas, (b) *Gobionotothen gibberifrons*, (c) *Lepidonotothen squamifrons*, (d) *Champsocephalus gunnari*, (e) *Chaenocephalus aceratus*, (f) *Chionodraco rastrospinosus*, (g) *Pseudochaenichthys georgianus*, (h) *Notothenia rossii* y (i) *Lepidonotothen larseni* dentro de la isóbata de 500 m alrededor de las islas Orcadas del Sur derivadas de las prospecciones de arrastre de fondo realizadas en 1985, 1991 y 1999. El gráfico superior incluye el intervalo de confianza del 95% en escala logarítmica; el gráfico inferior corresponde a estimaciones puntuales en una escala normal.

Figura 6: Histogramas de las frecuencias de tallas correspondientes a: (a) *Gobionotothen gibberifrons*, (b) *Lepidonotothen squamifrons*, (c) *Champsocephalus gunnari*, (d) *Chaenocephalus aceratus*, (e) *Chionodraco rastrospinosus*, (f) *Pseudochaenichthys georgianus* y (g) *Lepidonotothen larseni* derivadas de las prospecciones de arrastre de fondo realizadas en las islas Orcadas del Sur en 1985, 1991 y 1999. No hubo datos disponibles para *L. larseni* de la prospección de 1991.