CCAMLR Science, Vol. 2 (1995): 1-20

FISH DISTRIBUTION AND BIOMASS IN THE HEARD ISLAND ZONE (DIVISION 58.5.2)

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Abstract

Division 58.5.2 encompasses the southern part of the Kerguelen plateau, and contains Heard Island and the McDonald Islands, an Australian Territory around which a 200-mile EEZ has been declared. In order to assess the potential of this area for commercial fishing, and to obtain some preliminary data for its management, three random stratified surveys were conducted to investigate the distribution, abundance and biology of the most important species, covering a number of years and seasons. Five species were found to be abundant. There were two consistent areas of aggregation of *Champsocephalus gunnari*, but total abundance varied greatly between years. *Channichthys rhinoceratus* has a similar distribution, but abundance is lower and less variable with location and between surveys. *Dissostichus eleginoides* is widespread over those parts of the plateau where waters are more than 300 m deep, but is nowhere very abundant, although the total biomass is relatively high by virtue of the large area it occupies. There was one aggregation area of *Lepidonotothen squamifrons* on an outlying bank during two surveys, but this had disappeared by the third survey. Rays were widespread and moderately abundant in waters shallower than 300 m. From these results, it seems that a small fishery of a few hundred tonnes each for *C. gunnari* and *D. eleginoides* may be possible.

Résumé

La division 58.5.2, représentée par la partie méridionale du plateau de Kerguelen, comporte un Territoire australien constitué des îles Heard et McDonald autour duquel a été déclarée une ZEE de 200 milles. Afin d'évaluer les ressources halieutiques potentielles de cette région et d'obtenir des données préliminaires en vue de sa gestion, trois campagnes d'évaluation stratifiées et aléatoires, couvrant un certain nombre d'années et de saisons, ont été menées dans le but d'étudier la répartition géographique, l'abondance et la biologie des espèces les plus importantes. Il a été constaté que cinq espèces étaient abondantes. Des regroupements de *Champsocephalus gunnari* ont été repérés régulièrement en deux secteurs, mais l'abondance totale variait considérablement d'une année à l'autre. La répartition de *Channichthys rhinoceratus* est similaire, alors que son abondance est plus faible et qu'elle présente moins de variations d'un emplacement et d'une campagne à l'autre. *Dissostichus eleginoides* est fréquemment rencontré dans les secteurs du plateau de plus de 300 m de profondeur. Sans toutefois présenter de regroupements d'une forte densité, cette espèce se caractérise pourtant par une biomasse relativement élevée en vertu de l'étendue de son habitat. Au cours de deux campagnes, on a pu observer, sur un banc isolé, un regroupement de *Lepidonotothen squamifrons*, mais à la troisième campagne, celui-ci avait disparu. A moins de 300 m de profondeur, des raies sont fréquemment observées, d'une abondance pourtant modérée. Il semblerait ainsi possible d'envisager des captures limitées, de quelques centaines de tonnes, tant de *C. gunnari* que de *D. eleginoides*.

Резюме

Участок 58.5.2 содержит южную часть плато Кергелен, а также о-в Херд и о-ва Макдональд, являющиеся австралийской территорией, в отношении которой была объявлена 200-мильная экономическая зона. Для того, чтобы оценить возможности коммерческого промысла в данном районе, а также получить некоторые предварительные данные для управления этим районом, на протяжении ряда лет и сезонов проводилось три случайно стратифицированных съемки с целью изучения распределения, численности и биологии наиболее важных видов. Встречалось пять многочисленных видов рыб. Наблюдалось два

района, содержащие подобные агрегации *Champsocephalus gunnari*, однако общая численность в значительной мере отличалась от году к году. Распределение *Channichthys rhinoceratus* было схожим, однако численность этого вида была более низкой и более стабильной от места к месту и между съемками. Район распределения *Dissostichus eleginoides* в тех частях плато, где вода глубже 300 м, очень широк, но этот вид нигде не встречается в больших количествах, хотя общая его биомасса относительно высока благодаря тому, что он охватывает большую площадь. В ходе двух съемок встречалась одна зона скопления *Lepidonotothen squamifrons* на внешней банке, однако в ходе третьей семки этой зоны уже не наблюдалось. Скатовые охватывали большую площадь и характеризовались средней численностью в водах мельче 300 м. Судя по этим результатам, кажется, что здесь может оказаться осуществимым небольшой промысел, дающий по нескольким сотням тонн *C. gunnari* и *D. eleginoides*.

Resumen

La División 58.5.2 abarca el extremo sur de la plataforma de Kerguelén y un territorio australiano que incluye a las islas Heard y McDonald, alrededor de las cuales se ha declarado una ZEE de 200 millas. A fin de evaluar el potencial pesquero comercial del área y de obtener datos preliminares acerca de su utilización, se llevaron a cabo tres prospecciones estratificadas al azar durante un cierto número de años y de temporadas para investigar la distribución, abundancia y biología de las especies más importantes. Se encontraron cinco especies abundantes. Se observó que los cardúmenes de *Champsocephalus gunnari* se congregaban regularmente en dos sectores pero su abundancia total variaba considerablemente de un año a otro. *Channichthys rhinoceratus*, por otro lado, presentó una distribución similar, pero su abundancia fue menor y menos variable entre sectores y prospecciones. *Dissostichus eleginoides* está distribuido ampliamente en la plataforma donde la profundidad del agua supera los 300 m. Si bien la biomasa total es relativamente alta debido a la gran área que ocupa, en ninguna parte se presenta en abundancia. Se observó un cardumen de *Lepidonotothen squamifrons* en un banco aislado durante dos de las prospecciones, pero éste desapareció en la tercera prospección. Las rayas estaban distribuidas ampliamente y en moderada abundancia en aguas de profundidad menor de 300 m. Según estos resultados, parecería factible efectuar capturas de unos cientos de toneladas de C. *gunnari* y *D. eleginoides*.

Keywords: Heard Island, *Dissostichus eleginoides*, *Champsocephalus gunnari*, biomass survey, CCAMLR

INTRODUCTION

Division 58.5.2 encompasses the southern part of the Kerguelen plateau and contains Heard Island and the McDonald Islands, an Australian territory around which a 200-mile EEZ has been declared. It abuts Division 58.5.1 (Kerguelen) to the north, in which substantial catches of *Notothenia rossii*, *Lepidonotothen squamifrons*, *Champsocephalus gunnari* and *Dissostichus eleginoides* have been taken on the plateau since the early 1970s by Soviet, French and Ukrainian vessels. Nowadays only *C. gunnari* and *D. eleginoides* have sufficiently large populations to support a fishery. In the Heard Island division, the fish fauna is virtually identical to that in the Kerguelen division, but there has been no recorded harvesting from this area except for some exploratory Polish fishing in 1975 (Slosarczyk and Wysokinski, 1980; Sosinski, 1985), and the possibility that some of the Soviet catch of *C. gunnari* from the early 1970s was from this area before separate statistics were kept for each division (Kock *et al.*, 1985).

In order to assess the potential of this area for commercial fishing, and to obtain some preliminary data for its management, a series of biomass surveys were conducted in this division of the Kerguelen plateau to investigate the distribution, abundance and biology of the most important species, covering a number of years and seasons. This paper reports on the findings of these surveys and discusses the fishery potential of the area.

MATERIAL AND METHODS

Three surveys were conducted (Table 1), as far as possible with the same equipment and techniques.

Table 1: Details of the survey cruises to Heard Island.

Cruise	Survey Start	Survey End	Number of Trawls
Autumn 1990	22 May 1990	23 June 1990	79
Summer 1992	23 January 1992	13 February 1992	68
Spring 1993	29 August 1993	28 September 1993	66

For all cruises the following technical data apply:

Vessel -

Aurora Australis, icebreaker/research vessel
93 m long
3 893 tonnes
power: 10 000 kw maximum, usually 4 500 kw in fishing mode.

Fishing gear -

Bottom trawl, 36.9 m headline length, with 50 mm mesh cod end liner. All meshes 'diamond' pattern. Ground gear with 35.6 cm rubber or steel bobbins, 2.4 x 1.5 m vee doors, 35 m bridles and 25 m sweeps.

Net performance was monitored with a Simrad FS3300 net surveillance sonar. This provides continuous real-time video information on the shape and size of the net mouth, temperature and depth at the headline and confirmation that the net was in contact with the bottom.

Survey design -

Estimates of abundance were derived from a swept-area trawl survey according to a random stratified survey design. For the first cruise (autumn 1990), stratification was simply by depth, with the following depth intervals being designated strata: 0-100 m, 100-200 m, 200-300 m, 300-500 m and 500-700 m. In all future references to these strata, they are named according to their deepest limit, i.e. the 300-500 m stratum is referred to as stratum 500. These strata form irregular but concentric zones around Heard Island. In addition, there are some shallow banks (less than 300 m deep), at some distance from the shallow shelf surrounding the islands, which were also designated as strata. These were Shell, Pike, Coral and Aurora Banks which are separated from the main plateau by water greater than 700 m deep, and Discovery Bank which is a high point on the central plateau (Figure 1). The depth zone between 300 and 500 m around Shell Bank (Shell500) was also designated as a separate stratum. The number of trawls allocated to each stratum was proportional to its area, with the proviso that no stratum had less than five trawls. Within each stratum, trawl sites were chosen at random by computer, with the minimum distance between sites of 5 n miles. For each stratum a list of reserve sites was compiled by the same method, to be used if any of the primary sites were unsuitable owing to rough ground etc.

For the second survey (summer 1992), the same stratification was used, with the following amendments:

- the 100 stratum was combined with 200 because of the small size of 100, difficult trawling conditions so close to the coast, and the similarity of the results from these two strata in autumn 1990;
- the minimum number of trawls on Discovery, Pike, Coral and Aurora Banks was reduced to three because of the small trawlable areas on these banks, less total time available on this survey, and the generally low fish densities during autumn 1990;
- a small stratum on Gunnari Ridge (GR300) was excised from the 300 stratum because of the high density of *C. gunnari* found there during autumn 1990 and on the joint Soviet/Australian survey in 1987 (Gerasimchook *et al.*, 1988). It was allocated more trawls than were proportional to its area;
- a similar stratum, GR500, at 300-500 m depth was established around GR300 to allow for the presence of *C. gunnari* at this depth;
- the 750 stratum was not sampled because of lack of time and the low densities of most species during autumn 1990.

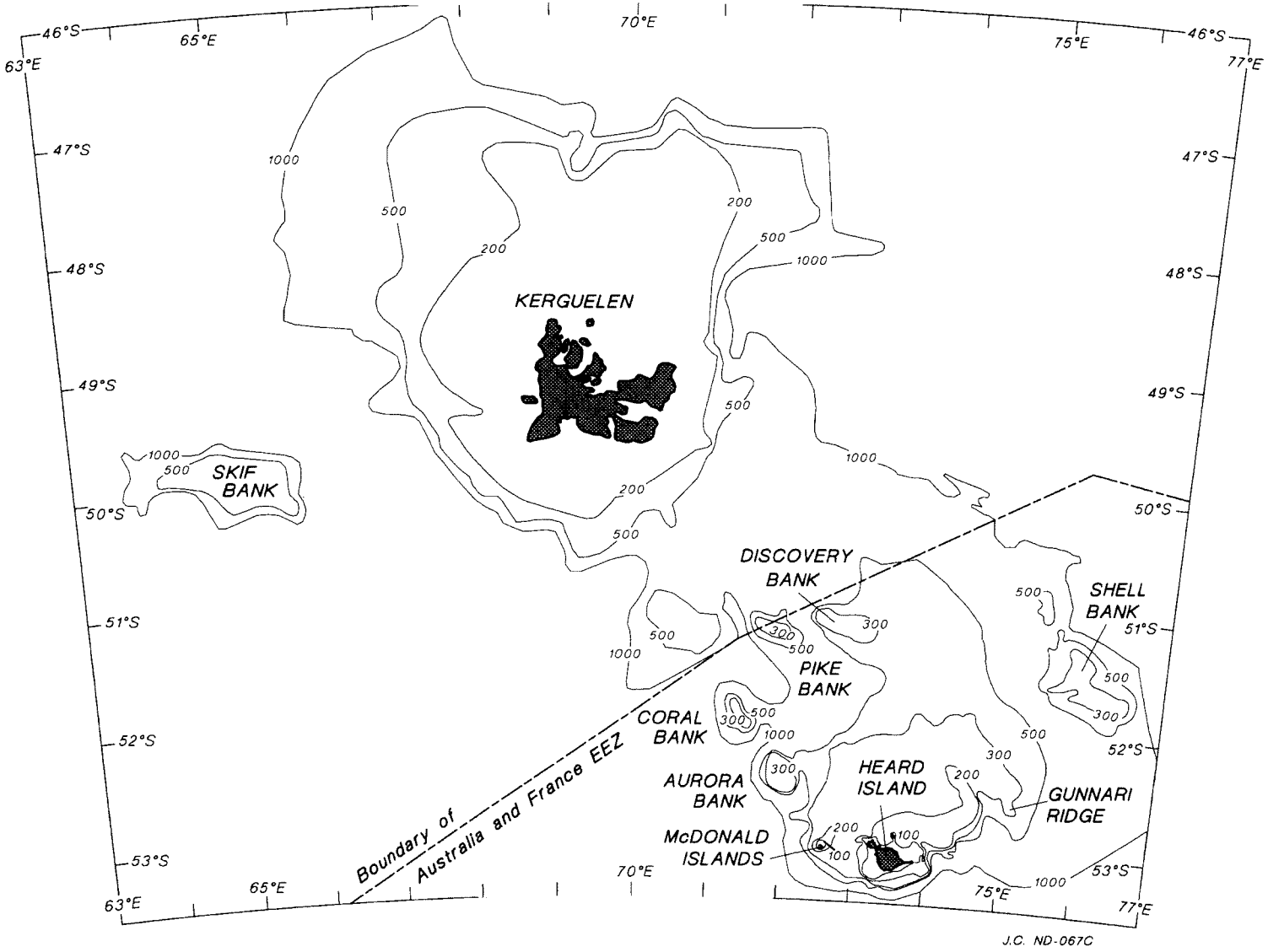


Figure 1: Map of the Kerguelen-Heard area showing principal features.

Table 2: Number of trawls planned and actually performed (in parentheses) during each cruise.

Stratum	Autumn 1990		Summer 1992		Spring 1993	
100	3	(2)				
200	6	(6)	10	(9)	3	(3)
300	16	(16)	10	(11)	9	(9)
GR300			10	(10)	15	(15)
500	24	(20)	5	(6)	15	(14)
GR500			10	(10)		
750	10	(9)			12	(10)
Shell	5	(7)	7	(7)	15	(15)
Shell500	5	(3)	3	(3)		
Discovery	5	(5)	3	(3)	3	(0)
Pike	5	(4)	3	(3)	3	(0)
Coral	5	(4)	3	(3)	3	(0)
Aurora	5	(3)	3	(3)	3	(0)

For spring 1993, the following changes were made with respect to summer 1992:

- the 750 stratum was sampled;
- the GR300 stratum was expanded northwards slightly from Gunnari Ridge and allocated more trawls in proportion to its area because of the high density of fish;
- Shell was likewise allocated more trawls because of high density of *C. gunnari* and *L. squamifrons*;
- GR500 and Shell500 were subsumed back into 500 because catch rates were not substantially different from the rest of the 500 stratum;
- although it was originally planned to sample Discovery, Pike, Coral and Aurora Banks, they were not fished because of great loss of time due to bad weather.

Discrepancies from planned numbers of trawls per stratum arose from sites being in a different stratum from expected, insufficient availability of trawlable ground, and time lost through bad weather.

Trawl sites during summer 1992 were repeats of those sampled during autumn 1990, except for the newly-created strata of GR300 and GR500 where new sites had to be designated. Otherwise, one site in Pike, two in 200, one in 300 and one in 500 were new. There is a danger, when successive surveys use the same sampling sites, of the results being biased, especially if the distribution of fish shows a consistent pattern. To balance this with the practical advantage of repeating sites, we used new locations for half the sites in all strata in the spring 1993 survey.

Each haul was for 30 minutes duration on the bottom, and towing speed was 3 knots. GPS positions were recorded at the start and finish of trawling, and from these, the distance travelled by the net over the bottom was calculated. From the trawl surveillance sonar, the mean width of the net (wingtip to wingtip) during the haul was established, and this multiplied by the towing distance gave the area swept.

For each cruise, catch-per-haul data by species and stratum were analysed using the minimum variance unbiased estimators (Pennington, 1983) of density and abundance of each species per stratum. Confidence intervals were calculated using the method of de la Mare (1994). Initially all strata were treated separately, irrespective of whether they were sampled during all cruises or not. However, in the results set out below, data from strata 100 and 200 have been amalgamated and re-analysed, as have those for strata 500 and Shell500, because trawls per area and fish densities were similar. Although only sampled during one cruise, data for stratum GR500 have not been amalgamated with stratum 500 because the sampling density was very high. In strata where a particular species occurs in one trawl only, it is impossible to calculate confidence limits to the density and abundance estimates. In these cases the data were not analysed.

For biological examination of the common species, 200 specimens were selected at random from each trawl (or the entire catch if less than 200 specimens were present), measured (total length and standard length) and weighed. The first 25 of these were also examined for sex, gonad maturity state, gonad weight and stomach contents, and scales and/or otoliths were taken.

RESULTS AND DISCUSSION

The appendix gives the list of species taken during the three surveys. The fauna is typical of islands south of the Sub-Antarctic Front, and is virtually identical to that of the Kerguelen zone.

Only five species were sufficiently abundant to warrant detailed study: *C. gunnari*, *Channichthys rhinoceratus*, *L. squamifrons* and rays, the latter comprising *Bathyraja murrayi*, *B. eatoni* and a few *B. irrasa*. Details of the density and abundance of these species are given in Tables 3a and 3b.

Total Abundance of Major Species

Figure 2a shows the total abundance of each major species calculated for each cruise. The abundance of *C. rhinoceratus* is quite low and consistent between cruises (2 019 and 2 766 tonnes). The other species have large differences in abundance between cruises. *C. gunnari* abundance was 3 112 and 4 584 tonnes during autumn 1990 and summer 1992 respectively, but increased almost tenfold to 31 701 tonnes during spring 1993. Most of this increase was the result of a very high figure from stratum 300. In fact, the stratum where the highest abundances were seen during autumn 1990 and summer 1992, GR300, had a lower abundance during spring 1993. *D. eleginoides* had similar abundances during autumn 1990 and spring 1993, 17 716 and 11 881 tonnes respectively, but a much lower figure (3 181 tonnes) during summer 1992. This was largely due to the 750 stratum not being fished in summer 1992, although the greatest abundance of this fish occurred there during the other two cruises. For *L. squamifrons* the converse is true. There were very low

Table 3a: Estimates of fish density by stratum for each survey.

Stratum	*C. gunnari*	*C. rhinoceratus*	*D. eleginoides*	*L. squamifrons*	Rays
Autumn 1990			Density (kg/km2)		
200*	36.7	41.6	39.7	16.9	156.3
300	69.4	61.4	158.4	5.3	176.9
GR300	5642.5	142.1	57.8	-	92.5
500**	36	18.7	71.6	26.3	57.4
GR500	NS	NS	NS	NS	NS
750	-	-	295.2	2.5	-
Shell	26.5	21.7	287.6	718.8	-
Discovery	5	34.6	75.5	44.3	16.9
Pike	-	44.7	491.3	76.6	-
Coral	-	8.1	33.4	23.4	-
Aurora	10.6	92.5	1604.3	224.9	-
Summer 1992					
200*	52.4	190.7	113	57.9	122.2
300	31.6	41.3	35.6	1	429.2
GR300	5105.8	1211.4	90.4	3.2	529.9
500**	-	2.3	42.2	1.7	53.6
GR500	1.9	27.7	117.1	9.1	184.2
750	NS	NS	NS	NS	NS
Shell	168	197.1	223.1	19619.7	478.3
Discovery	-	5.5	70.6	17.1	-
Pike	-	35.9	178.8	68.9	-
Coral	-	27.2	42.4	13.9	-
Aurora	-	85.8	-	14.4	-
Spring 1993					
200*	11.5	36.7	47.2	2.5	-
300	1680.8	81.4	112.9	2.7	123.3
GR300	1555.9	782.4	-	1.6	6.7
500**	-	2.4	169.2	0.5	13.3
GR500	NS	NS	NS	NS	NS
750	-	-	143.6	6.9	-
Shell	1642.5	59.3	55.1	14.6	-
Discovery	NS	NS	NS	NS	NS
Pike	NS	NS	NS	NS	NS
Coral	NS	NS	NS	NS	NS
Aurora	NS	NS	NS	NS	NS

* Includes a 100 stratum combined after sampling for autumn 1990
** Includes a 500 stratum around Shell Bank combined after sampling for autumn 1990 and summer 1992

Table 3b: Estimates of fish abundance by stratum for each survey. Figures in parentheses are CV%.

Stratum	*C. gunnari*	*C. rhinoceratus*	*D. eleginoides*	*L. squamifrons*	Rays
Autumn 1990	Abundance (tonnes)				
200*	188 (90.9)	213 (47.7)	204 (48.9)	87 (69.9)	802 (29.8)
300	1142 (46.0)	1009 (43.0)	2605 (27.7)	87 (62.1)	2911 (58.2)
GR300	2178 (37.8)	55 (18.7)	22 (28.7)	-	36 (92.4)
500**	1005 (63.5)	522 (47.7)	1997 (21.1)	734 (54.4)	1601 (53.7)
GR500	NS	NS	NS	NS	NS
750	-	-	10224 (40.7)	85 (81.3)	-
Shell	55 (85.6)	45 (47.5)	600 (42.8)	1499 (74.0)	-
Discovery	6 (99.1)	44 (54.6)	97 (37.9)	57 (39.0)	22 (81.9)
Pike	-	36 (85.6)	393 (57.9)	61 (80.3)	-
Coral	-	6 (34.9)	27 (68.5)	19 (59.4)	-
Aurora	10 (34.9)	89 (70.1)	1547 (87.0)	217 (51.8)	-
Total	4584	2019	17716	2846	5372
Summer 1992					
200*	269 (94.6)	978 (70.5)	580 (58.7)	297 (86.7)	627 (55.4)
300	520 (49.0)	679 (36.4)	586 (25.7)	17 (73.1)	7061 (26.7)
GR300	1971 (80.9)	468 (71.3)	35 (40.6)	1 (68.2)	205 (47.8)
500**	-	63 (81.3)	1138 (40.0)	46 (93.2)	1446 (71.5)
GR500	2 (88.7)	26 (61.7)	109 (54.3)	8 (58.3)	171 (64.1)
750	NS	NS	NS	NS	NS
Shell	350 (92.1)	411 (64.0)	465 (25.8)	40907 (88.0)	997 (44.6)
Discovery	-	7 (37.8)	91 (53.2)	22 (87.4)	-
Pike	-	29 (30.9)	143 (59.3)	55 (70.3)	-
Coral	-	22 (47.3)	34 (51.5)	11 (44.1)	-
Aurora	-	83 (59.6)	-	14 (51.4)	-
Total	3112	2766	3181	41378	10507
Spring 1993					
200*	59 (91.9)	188 (11.1)	242 (75.9)	13 (55.3)	-
300	27194 (92.8)	1317 (33.9)	1827 (34.4)	44 (73.2)	1995 (62.0)
GR300	1024 (72.4)	515 (61.1)	-	1 (86.4)	4 (85.6)
500**	-	67 (35.9)	4722 (34.1)	13 (47.6)	371 (56.0)
GR500	NS	NS	NS	NS	NS
750	-	-	4975 (27.5)	238 (63.8)	-
Shell	3425 (82.3)	124 (35.7)	115 (35.0)	30 (40.5)	-
Discovery	NS	NS	NS	NS	NS
Pike	NS	NS	NS	NS	NS
Coral	NS	NS	NS	NS	NS
Aurora	NS	NS	NS	NS	NS
Total	31701	2220	11881	335	2370

* Includes a 100 stratum combined after sampling for autumn 1990
** Includes a 500 stratum around Shell Bank combined after sampling for autumn 1990 and summer 1992

abundances during autumn 1990 and spring 1993 (2 846 and 335 tonnes respectively), but a very high abundance during summer 1992. This was almost entirely due to large catches of this species at a few stations on Shell Bank.

Patterns of Density and Abundance of Major Species and Aspects of their Biology

Figures 2b to 2d shows the abundance of the major species by stratum for each cruise. Each major species has its own characteristic distribution pattern.

C. gunnari, as elsewhere within its range (South Georgia, Kerguelen), is found mostly in the depth range 200-300 m (Kock *et al.*, 1985), although occasional small catches were taken in the shallower parts of stratum 500. However, the density of this fish is patchy, with highest densities being found on or near Gunnari Ridge and Shell Bank. It was never encountered on Coral or Pike Banks, even though these are at similar depths to the other banks. High densities were consistently found in stratum GR300 (1 555 to 5 642 kg km^{-2}), but in the only other strata to have high densities of this species there were marked variations between cruises. On Shell Bank the density ranged from 26.5 kg km^{-2} during autumn 1990 to 1 642 kg km^{-2} during spring 1993. Stratum 300 only had a high density of *C. gunnari* during spring 1993, when it reached 1 680 kg km^{-2}. During autumn 1990 and summer 1992, over half the total abundance was accounted for by GR300, with the remainder from strata 300,

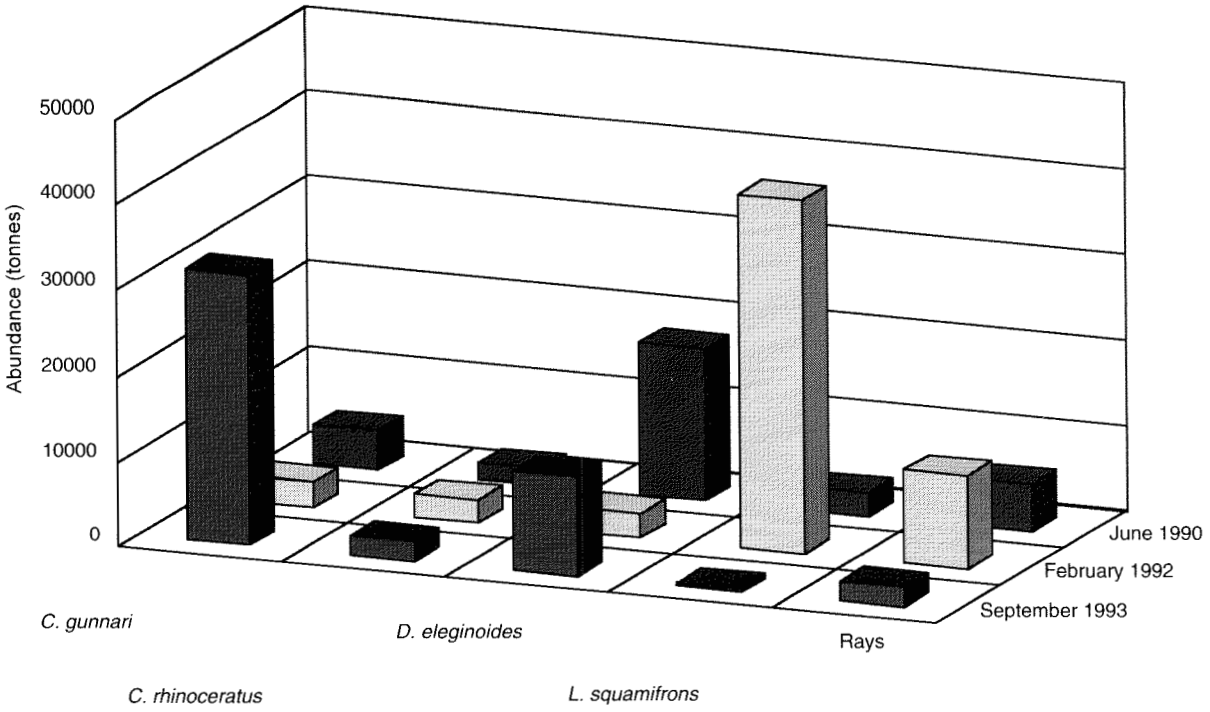


Figure 2a: Total abundance of selected fish species by cruise.

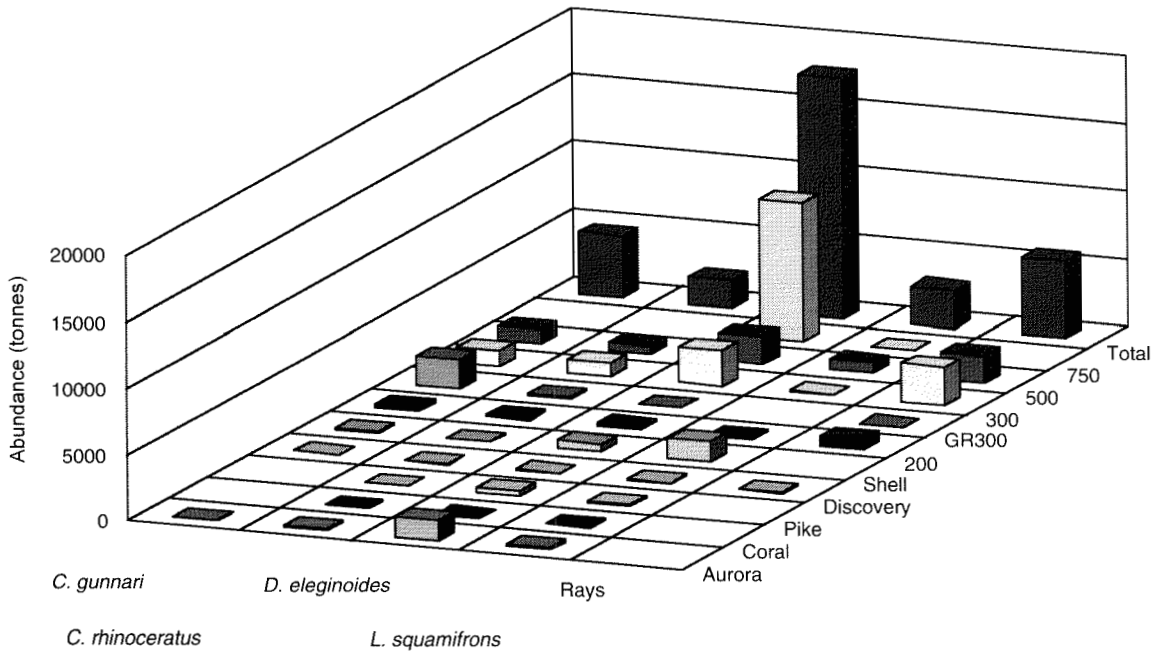


Figure 2b: Abundance of selected fish species by stratum for autumn 1990 (May/June 1990).

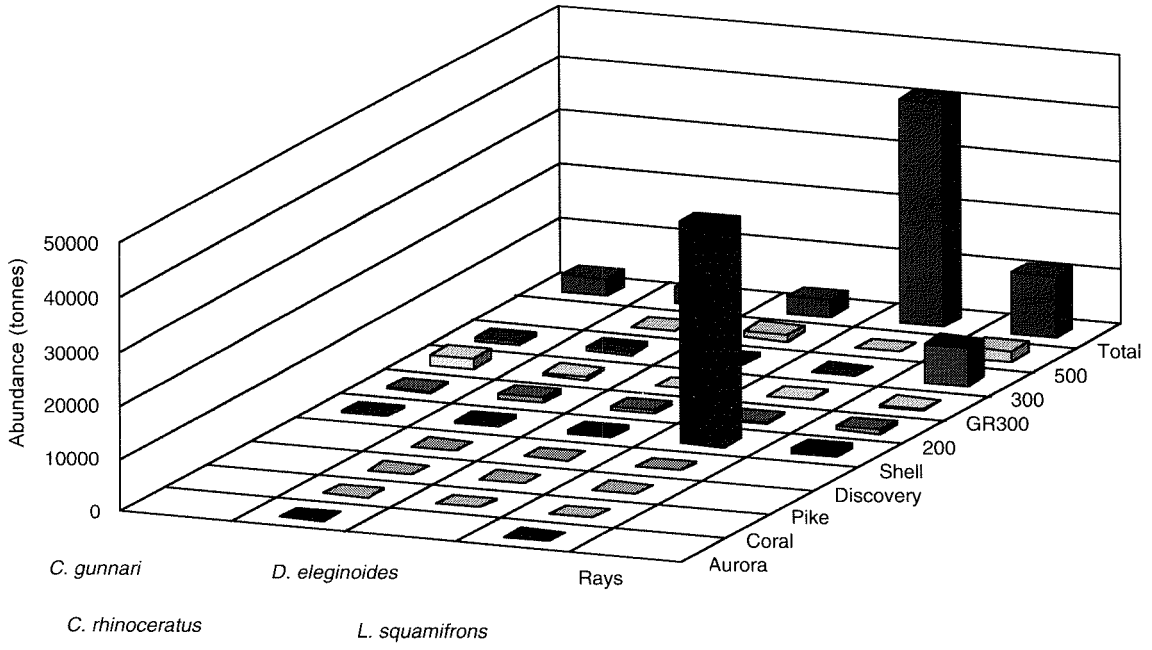


Figure 2c: Abundance of selected fish species by stratum for summer 1992 (January/February 1992).

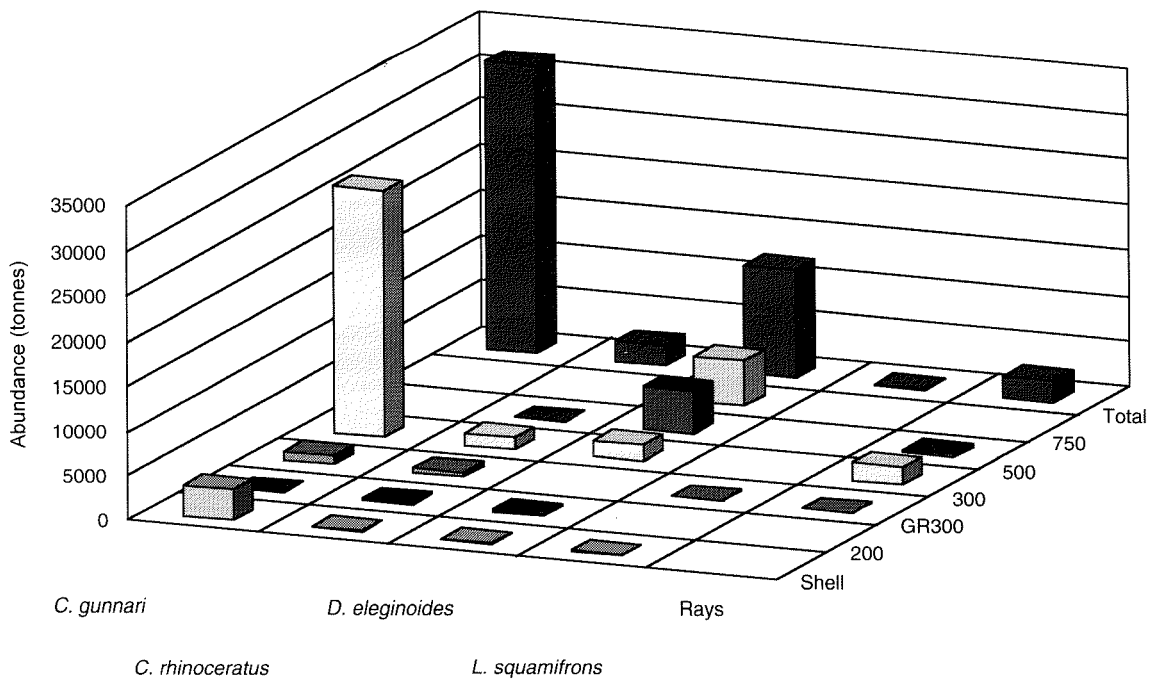


Figure 2d: Abundance of selected fish species by stratum for spring 1993 (September 1993).

Shell and 200 in decreasing order of importance. During spring 1993 nearly 90% of the much larger total abundance was contained in stratum 300, which reflects the high fish density and large area of this stratum. The high fish density was caused by a few large catches taken in what appears to be a spawning ground in the region just outside GR300. As these fish were all in spawning condition, whereas fish of similar size on Gunnari Ridge were all pre-spawners or spent, it is probable that this area is the spawning ground for Gunnari Ridge fish. The remaining area of stratum 300 had low catches, similar to the previous cruises, and this is reflected in the higher CV during spring 1993 (92.75%) for stratum 300 compared to those from autumn 1990 and summer 1992 (45.99% and 48.95%). The abundance in the GR300 stratum (Gunnari Ridge) calculated from these three cruises (1 024 to 2 178 tonnes) is considerably less than the 7 451 ± 3 383 tonnes found in May to July 1987 by Gerasimchook *et al.* (1988). While demonstrating that the Gunnari Ridge aggregation appears to be a permanent feature, other comparisons with the survey of Gerasimchook *et al.* are difficult because they did not perform a random stratified survey, and had only 26 bottom trawls and 8 midwater trawls on which to base their results.

The evidence from length frequency distributions and gonad maturity states indicates that fish on Shell Bank have a different reproductive timetable from the remainder of the population. Fish from Gunnari Ridge and the central plateau area close to Heard Island spawn in September, at the same time as Kerguelen fish, but the length frequency distribution is quite different (Figures 3a to 3c). As is well known from other localities, the density of *C. gunnari* populations is very variable over time (Duhamel, 1991a). Gunnari Ridge and Shell Bank were the only two localities consistently to have reasonably high densities, but showed up to ten-fold variability in density over the three years of sampling, and these variations were not in phase with each other. Duhamel (1991a) has demonstrated a three-year cycle of abundance in the neighbouring Kerguelen zone derived from every third cohort being dominant in the population. A similar general situation may apply in the Heard zone, although the different length frequency distributions indicate that the same cohort is not responsible for the peaks in density in all areas. Slosarczyk and Wysokinski (1980) reported average catches of over 6 tonnes per hour from Pike Bank in April 1975. If these catches were taken from a short-lived cohort confined to Pike Bank which was not replaced, it may explain the lack of fish there during the present surveys.

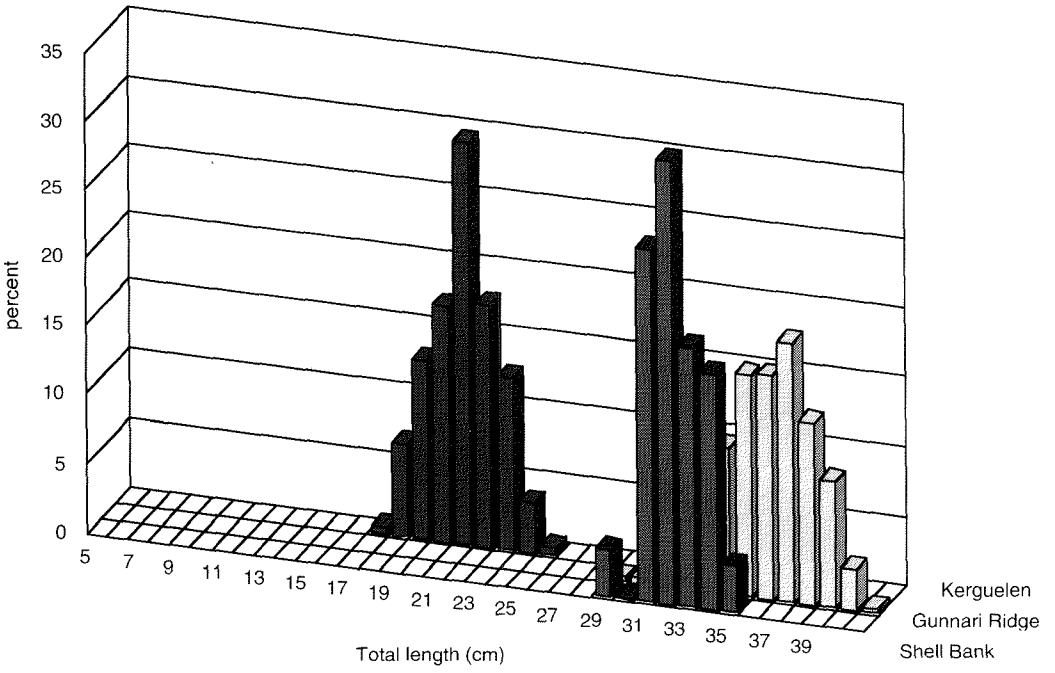


Figure 3a: *C. gunnari* length frequency distributions for three sites in June/July 1990. Data on Kerguelen fish are from the fishing ground to the northeast of Kerguelen (G. Duhamel, pers. comm., 1994).

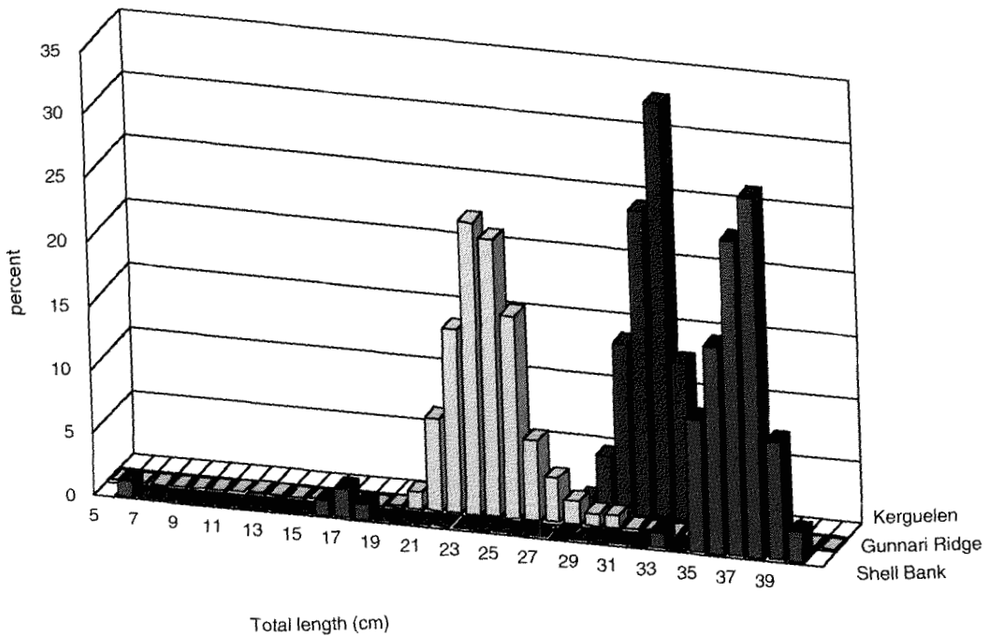


Figure 3b: *C. gunnari* length frequency distributions for three sites in December 1991/February 1992. Data on Kerguelen fish are from the fishing ground to the northeast of Kerguelen (G. Duhamel, pers. comm., 1994).

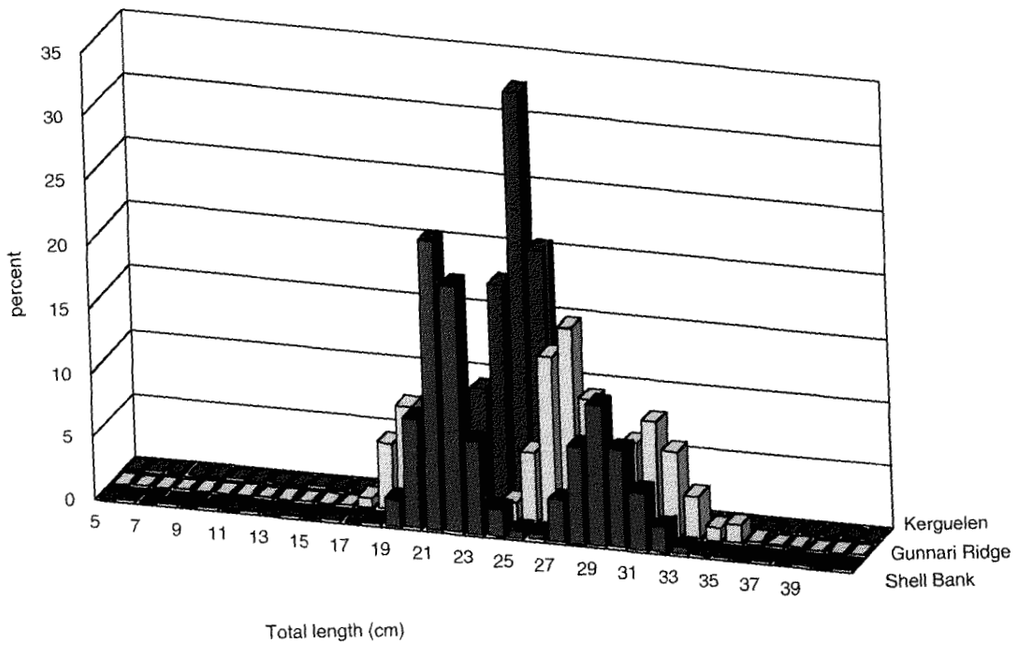


Figure 3c: *C. gunnari* length frequency distributions for three sites in September/October 1993. Data on Kerguelen fish are from the fishing ground to the northeast of Kerguelen (G. Duhamel, pers. comm., 1994).

C. rhinoceratus is more widespread and evenly distributed than *C. gunnari*, occurring in most strata sampled. Its highest densities are found in the shallower strata, often in conjunction with *C. gunnari* on Gunnari Ridge and Shell Bank. Variations in its density on Gunnari Ridge are not coupled with those of *C. gunnari*, although high catch rates of both species often occur at the same place. The density is more evenly spread over the strata and less variable than that of *C. gunnari*, and dense aggregations of this fish were not encountered. During each survey the highest densities were found in stratum GR300, and these ranged from 142 to 1 211 kg km^{-2}. Other strata which had significant densities were 200, Shell, Aurora, 300 and Pike in approximate descending order, but none of these strata had a density exceeding 200 kg km^{-2}. Total abundance was very consistent through the three cruises, but quite low at 2 019 to 2 766 tonnes, most of which is contained in 200, 300, GR300 and Shell strata.

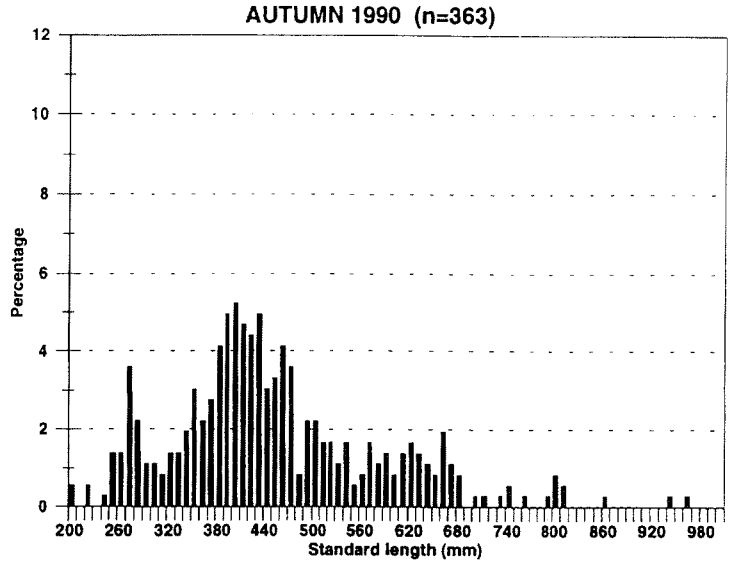
D. eleginoides is quite evenly distributed over the strata, but densities are generally quite low, in the range 50 to 300 kg km^{-2}, with only the small Pike and Aurora strata during autumn 1990 exceeding this (491 and 1 604 kg km^{-2} respectively). The majority of the biomass is contained in the large strata 500 and 750 despite the modest density of this species there. The 750 stratum accounted for 4 975 and 10 224 tonnes of *D. eleginoides* during the two cruises on which it was sampled.

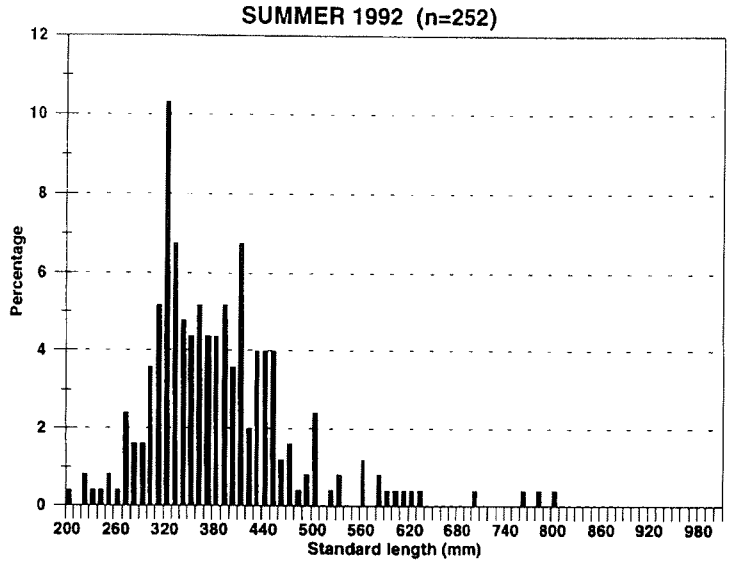
Length frequencies for the three cruises (Figure 4) are very similar. Because the very deepest parts of the plateau and slope were not sampled, few fish larger than 800 mm long were taken. In all cruises the major length mode was at about 400 mm. There was a secondary mode at about 600 mm in autumn 1990 and spring 1993, when the 750 stratum was sampled, but not in summer 1992, when this relatively deep stratum was omitted. These fish are smaller than those caught in equivalent depths near Kerguelen. There, the fish reach a total length of 970 mm in waters shallower than 350 m, and up to 1 200 mm in deeper water (Duhamel, 1991b). This may mean that the larger fish are in deeper water at Heard than at Kerguelen, and were not sampled during the present surveys. Whatever the reason for the virtual lack of fish greater than 800 mm TL in these surveys, the result is that the biomass estimates only apply to the younger part of the population.

L. squamifrons has the most distinctive distribution pattern of the major species. While it occurs at low density in nearly all strata, high densities were recorded only in two restricted localities. One was on Aurora Bank, where densities up to 250 kg km^{-2} were recorded, and the other was on the southern part of Shell Bank. Otherwise there were moderate densities on the other western banks (Discovery, Pike and Coral). These high density aggregations are not consistent from year to year, however. On Aurora Bank, a high-density aggregation was only encountered during autumn 1990. On Shell Bank, mean density was 718 kg km^{-2} during autumn 1990, but 27 times greater during summer 1992 at 19 620 km kg^{-2}. Despite sampling the same sites in this area during all three cruises, the aggregation had disappeared by spring 1993, and the density had dropped to 15 kg km^{-2}.

As this species has a longevity of up to 19 years at Kerguelen (Duhamel and Ozouf-Costaz, 1985), it is unlikely that large annual variations in abundance occur, as in *C. gunnari*, because of the greater number of year-classes available. As the spawning season is not until the end of October at Kerguelen (Duhamel and Ozouf-Costaz, 1985) it is unlikely that migration away from the normal areas of aggregation would have taken place in early September when the low abundance was observed. However, if the Heard fish spawn slightly earlier than those at Kerguelen, this could be the reason. The length frequencies for the three cruises (Figure 5) show a large number of length modes, and according to the data of Duhamel and Ozouf-Costaz (1985), the largest size class should be about 15 years old. The length frequencies for both autumn 1990 and summer 1992 show a high proportion of old fish (ages about 10 to 15 years), but also a good spread of strong younger size classes. By spring 1993, 18 months after summer 1992, the large size classes had all but disappeared and the majority (of a very small number of fish) were aged about 3 to 5 years. This supports the notion of the older spawning fish having left the area.

Except for the banks on the western side of the plateau, rays generally had their greatest density in the strata shallower than 500 m. They did not occur at all in the 750 stratum and were absent from Pike, Coral and Aurora Banks. There was a marked seasonal difference, with relatively high densities during summer 1992, less than half these values from autumn 1990 and lower values still





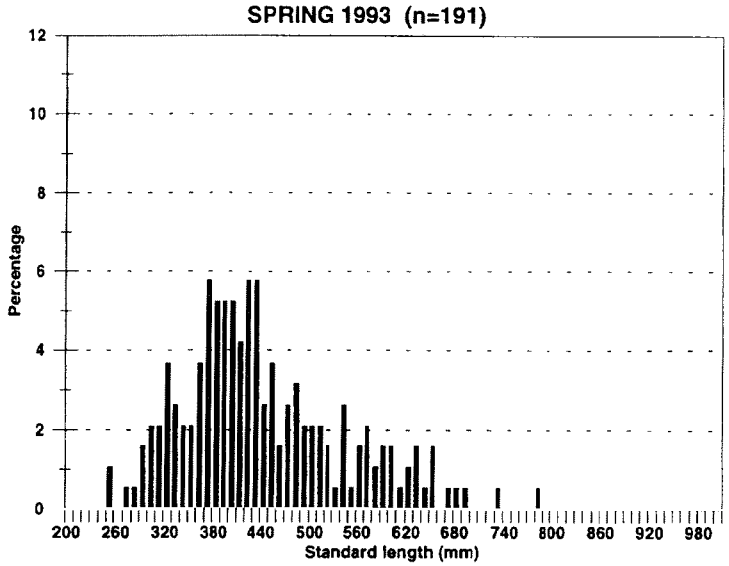


Figure 4: *D. eleginoides* length frequency distribution during the three surveys.

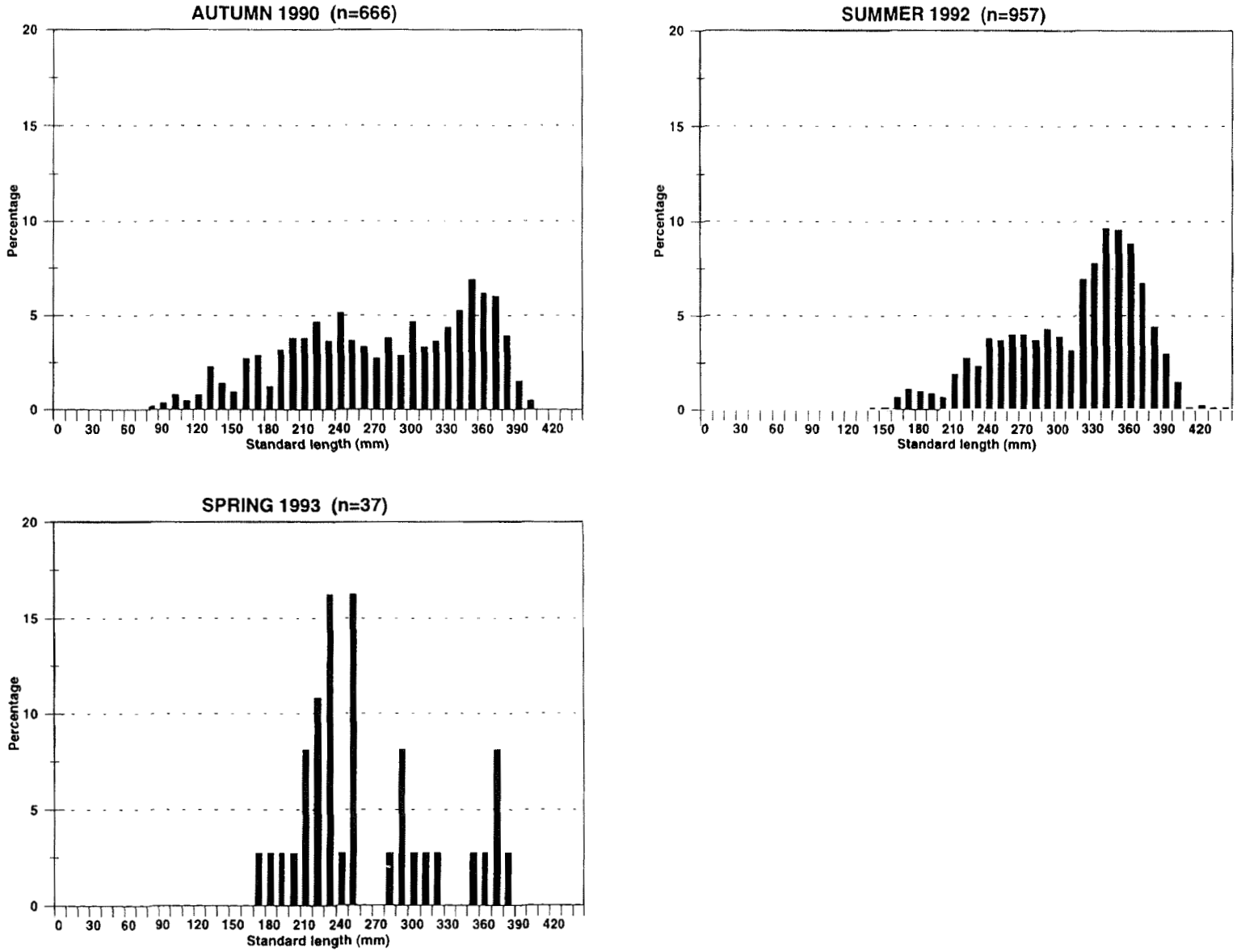


Figure 5: *L. squamifrons* length frequency distribution during the three surveys.

Table 4: Summary of estimates and 95% confidence intervals of total abundance by species and cruise in tonnes.

Cruise	Lower CI	Estimate	Upper CI	CV (%)
C. gunnari				
Autumn 1990	2606	4584	113019	25.7
Summer 1992	945	3112	427728	53.5
Spring 1993	4113	31701	14712200	80.1
C. rhinoceratus				
Autumn 1990	1250	2019	4925	25.6
Summer 1992	1485	2766	24650	30.8
Spring 1993	1397	2220	6629	24.8
D. eleginoides				
Autumn 1990	11210	17716	45004	25.2
Summer 1992	2220	3181	8488	19.2
Spring 1993	8376	11881	19284	18.6
L. squamifrons				
Autumn 1990	1311	2846	58658	41.8
Summer 1992	4250	41378	9586070	87.0
Spring 1993	152	335	4457	39.2
Rays				
Autumn 1990	2736	5372	26771	35.6
Summer 1992	7060	10507	46280	21.2
Spring 1993	851	2370	25453	52.9

from spring 1993. Total abundance was accordingly variable, ranging from 10 507 tonnes (summer 1992) to 2 370 tonnes (spring 1993), more than half of this coming from stratum 300 in each survey.

Fishery Potential

The estimates, 95% confidence limits and coefficients of variation of the abundance of the five major species for each cruise are summarised in Table 4. For all species the confidence intervals derived from the three cruises overlap, so that there is no reason to suppose that differences in the estimates reflect anything other than sampling variability. This is especially true as these are estimates of an unexploited biomass. A precautionary catch limit for each species could be calculated using a method similar to that used for the krill fishery (Butterworth *et al.*, 1994), which is based on the general approach of Beddington and Cooke (1983). However, there is little prospect of a substantial fishery in this region given the above biomass estimates. These are much lower than the biomass estimates from South Georgia (Everson *et al.*, 1992) and Kerguelen (Duhamel, 1988), where commercial fisheries have existed for many years. For example, the estimated biomass of *C. gunnari* between 1984/85 and 1991/92 around South Georgia has ranged between 15 000 tonnes and 333 000 tonnes with a mean of 73 400 tonnes, whereas at Kerguelen the estimated biomass was 15 000 tonnes in 1987 and 429 000 tonnes in 1988. Equivalent figures for *D. eleginoides* are 335 to 8 159 tonnes with a mean of 1 937 tonnes at South Georgia and 105 000 and 45 000 tonnes in 1987 and 1988 at Kerguelen. However, small fisheries for *D. eleginoides* and *C. gunnari* may be possible. The biomass of *D. eleginoides* is consistently one of the highest in the area, and part of the population in deep water (>800 m) was not sampled by these surveys. A small fishery for *C. gunnari* may also be possible on the aggregation associated with Gunnari Ridge, and possibly with the smaller aggregation on Shell Bank. This species, however, requires more research on the degree of separation of the stocks between these two banks and the Kerguelen shelf for the effective management of such a fishery.

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Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Рисунок 3c: Данные по частотному распределению длин *C. gunnari* на трех участках за период сентябрь-октябрь 1993 г. 1992 г. Данные по кергеленским рыбам были взяты с промыслового участка к северо-востоку от Кергелена (Г. Дюамель, лич. сообщ. 1994 г.).

Рисунок 4: Данные по частотному распределению длин *D. eleginoides* в ходе трех съемок.

Рисунок 5: Данные по частотному распределению длин *L. squamifrons* в ходе трех съемок.

Lista de las tablas

Lista de las figuras

APPENDIX

FISH SPECIES CAUGHT PER CRUISE

Species	Autumn 1990	Summer 1992	Spring 1993
Family Squalidae			
Etmopterus cf. granulosus	X		X
Family Rajidae			
Bathyraja eatonii	X	X	X
B. irrasa	X	X	X
B. murrayi	X	X	X
Family Bathylagidae			
Bathylagus antarcticus	X	X	
Family Gonostomatidae			
Cyclothone sp.	X		
Family Stomiidae			
Stomias spp.	X	X	X
Family Paralepididae			
Notolepis coatsi	X	X	X
Family Myctophidae			
Electrona antarctica	X		X
E. carlsbergi	X	X	X
Gymnoscopelus bolini		X	
G. braueri	X	X	X
G. nicholsi	X	X	X
G. opisthopterus	X		
G. (Nasolychnus) fraseri	X		
Gymnoscopelus sp.	X		X
Krefftichthys anderssoni	X	X	X
Lampanyctus sp.			X
Protomyctophum bolini	X		
P. tenisoni	X		
Protomyctophum sp.	X		X
Family Muraenolepididae			
Muraenolepis sp.	X	X	
Family Moridae			
Antimora rostrata	X		X
Family Macrouridae			
Macrourus carinatus	X	X	X
Family Carapidae			
Echiodon cryomargarites			X
Family Oneirodidae			
Oneirodes notius			X
Family Congiopodidae			
Zanclorhychus spinifer	X	X	X
Family Liparididae			
Paraliparis spp.	X	X	X
Family Zoarcidae			
Lycodapus sp.	X	X	X
Melanostigma gelatinosum	X	X	X
Family Nototheniiddae			
Dissostichus eleginoides	X	X	X
Gobionotothen acuta	X	X	X
Lepidonotothen squamifrons	X	X	X
L. mizops	X	X	X
Notothenia rossii	X	X	
Family Bathydraconidae			
Bathydraco sp.	X		X
Family Channichthyidae			
Champsocephalus gunnari	X	X	X
Channichthys rhinoceratus	X	X	X

Species	Autumn 1990	Summer 1992	Spring 1993
Family Gempylidae *Paradiplospinus gracilis*	X	X	X
Family Centrolophidae *Icichthys australis*	X	X	
Family Achiropsettidae *Mancopsetta maculata*	X		