BIOMASS, ABUNDANCE AND DISTRIBUTION OF FISH IN THE KERGUELEN ISLANDS EEZ (CCAMLR STATISTICAL DIVISION 58.5.1)

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Abstract

'POKER 2006', a bottom trawl fish biomass survey, was conducted from September to October 2006 in the northern part of the Kerguelen Plateau (CCAMLR Statistical Division 58.5.1). The swept-area method was used in the depth range from 100 to 1 000 m with 207 random stratified stations. Estimates of biomass and abundance were produced for eight commercial species. The total biomass was 245 000 tonnes and Patagonian toothfish (*Dissostichus eleginoides*) accounted for half of the value (124 000 tonnes). The fish biomass was distributed between the shelf and the deep sea. However, this evaluation remains incomplete as four of the species (*D. eleginoides*, bigeye grenadier (*Macrourus carinatus*), Eaton's skate (*Bathyraja eatonii*) and Kerguelen sandpaper skate (*B. irrasa*)) extend deeper than 1 000 m, the limit of the POKER 2006 survey. Some shelf and slope species (mackerel icefish (*Champsocephalus gunnari*) and marbled rockcod (*Notothenia rossii*)) exhibit low levels of biomass when compared to the results of previous surveys (SKALP surveys, 1987 and 1988). Other species (unicorn icefish (*Channichthys rhinoceratus*) and grey rockcod (*Lepidonotothen squamifrons*)) seem to have increased, even doubled, their biomass during the period between the two surveys. In addition to the commercial species, *Zanclorhynchus spinifer* was abundant on the shelf and *Alepocephalus* cf. *antipodianus* was abundant in the deep sea; the data on the latter are new. Data on the geographic and bathymetric distribution of the species provide evidence of geographically very stable species-specific concentrations. Distinct cohorts of some species (*D. eleginoides* and *C. gunnari*) were detected in some sectors. The survey has defined the distribution of species, commercial or not, that are important in the ecosystem and are of major interest for the management and conservation of fish populations in the area.

Résumé

Une campagne d'évaluation de la biomasse de poissons « POKER 2006 », a été réalisée par chalutages de fond de septembre à octobre 2006 dans la partie septentrionale du plateau de Kerguelen (division statistique 58.5.1 de la CCAMLR). C'est par la méthode employée, de l'aire balayée, que 207 stations stratifiées au hasard ont été effectuées entre 100 et 1 000 m de profondeur. Des estimations de biomasse et d'abondance sont produites pour huit espèces commerciales. La biomasse totale représente 245 000 tonnes et la légine australe (*Dissostichus eleginoides*) concentre, à elle seule, la moitié de la ressource (124 000 tonnes). La biomasse de poissons est répartie tant sur le plateau qu'en zone profonde. Cette évaluation reste d'ailleurs incomplète puisque quatre des espèces (*D. eleginoides*, grenadier gros yeux (*Macrourus carinatus*), raie d'Eaton (*Bathyraja eatonii*) et raie rugueuse de Kerguelen (*B. irrasa*)) évoluent au delà des 1 000 m que constitue la limite d'investigation de POKER 2006. Certaines espèces du plateau et de ses accores (poisson des glaces (*Champsocephalus gunnari*), colin de Kerguelen (*Notothenia rossii*)) présentent des biomasses très faibles si on compare les valeurs obtenues à celles de résultats antérieurs (campagnes SKALP, 1987 et 1988). D'autres (grande-gueule (*Channichthys rhinoceratus*), colin austral (*Lepidonotothen squamifrons*)) semblent avoir sensiblement augmenté, voire doublé, leur biomasse sur l'intervalle de temps considéré. En dehors des espèces commerciales, deux espèces s'avèrent abondantes : *Zanclorhynchus spinifer* sur le plateau et *Alepocephalus* cf. *antipodianus* en zone profonde, les données sur cette dernière étant nouvelles. Les données sur la distribution tant géographique que bathymétrique des espèces mettent en évidence une très forte stabilité géographique des concentrations selon l'espèce. Pour certaines espèces (*D. eleginoides*, *C. gunnari*), des cohortes sont détectées dans certains secteurs bien définis. Cette campagne a permis de préciser et même découvrir les zones de concentration d'espèces tant commerciales qu'importantes dans l'écosystème ce qui, en terme de gestion et de conservation, présente un intérêt indéniable.

Резюме

С сентября по октябрь 2006 г. в северной части плато Кергелен (Статистический участок 58.5.1 АНТКОМ) была проведена донная траловая съемка биомассы рыбы «POKER 2006». Использовался метод протраленных площадей в диапазоне глубин от 100 до 1 000 м с 207 случайными стратифицированными станциями. Были получены оценки биомассы и численности по восьми промысловым видам. Общая биомасса составила 245 000 т, и половину этого объема (124 000 т) составлял патагонский клыкач (*Dissostichus eleginoides*). Биомасса рыбы распределялась между шельфом и глубоководными районами моря. Однако эта оценка остается незавершенной, поскольку четыре вида (*D. eleginoides*, южноатлантический макрурус (*Macrourus carinatus*), скат Итона (*Bathyraja eatonii*) и скат *B. irrasa*) распространены и на глубинах более 1 000 м, что было пределом съемки POKER 2006. Некоторые обитающие на шельфе и склоне виды (щуковидная белокровка (*Champsocephalus gunnari*) и мраморная нототения (*Notothenia rossii*)) имеют низкие объемы биомассы по сравнению с результатами предыдущих съемок (съемки SKALP, 1987 и 1988 гг.). Биомасса других видов (носорожьей белокровки (*Channichthys rhinoceratus*) и серой нототении (*Lepidonotothen squamifrons*)), как представляется, увеличилась, даже удвоилась в течение периода между этими двумя съемками. Помимо промысловых видов, на шельфе был широко распространен вид *Zanclorhynchus spinifer*, а в глубоководных районах – *Alepocephalus* cf. *antipodianus*; данные по второму виду являются новыми. Данные о географическом и батиметрическом распределении видов свидетельствуют об очень стабильных, в географическом плане, видовых концентрациях. В отдельных секторах были обнаружены четкие когорты некоторых видов (*D. eleginoides* и *C. gunnari*). Съемка позволила установить распределение промысловых и непромысловых видов, которые важны в экосистеме и представляют большой интерес для управления и сохранения популяций рыбы в этом районе.

Resumen

'POKER 2006', una prospección de la biomasa de peces con redes de arrastre de fondo, fue realizada de septiembre a octubre de 2006 en la zona norte de la plataforma de Kerguelén (División estadística 58.5.1 de la CCRVMA). Se utilizó el método de área barrida en el intervalo de 100 a 1 000 m de profundidad, efectuándose 207 estaciones estratificadas aleatoriamente. Se obtuvieron estimaciones de la biomasa y de la abundancia para ocho especies de peces explotadas comercialmente. La biomasa total fue de 245 000 toneladas, correspondiendo la mitad de este valor (124 000 toneladas) a la austromerluza negra (*Dissostichus eleginoides*). La biomasa de peces se encontró distribuida entre la plataforma y las aguas de altura. Sin embargo, esta evaluación está incompleta ya que la distribución de cuatro especies (*D. eleginoides*, granadero ojisapo (*Macrourus carinatus*), raya de Eaton (*Bathyraja eatonii*) y la raya rugosa (*B. irrasa*)) sobrepasa los 1 000 m de profundidad, el límite de la prospección POKER 2006. Algunas especies de la plataforma y pendiente como el draco rayado (*Champsocephalus gunnari*) y la trama jaspeada (*Notothenia rossii*) mostraron bajos niveles de biomasa en comparación con los resultados de prospecciones anteriores (SKALP, 1987 y 1988). La biomasa de otras especies como el draco rinoceronte (*Channichthys rhinoceratus*) y la trama gris (*Lepidonotothen squamifrons*) aparentemente ha aumentado, y hasta se ha duplicado durante el período entre las dos prospecciones. Además de las especies explotadas comercialmente, *Zanclorhynchus spinifer* abundó en la plataforma y *Alepocephalus* cf. *antipodianus* abundó en aguas de altura; los datos de esta última especie son nuevos. Los datos sobre la distribución geográfica y batimétrica de las especies demuestran que las concentraciones específicas de cada especie en un área geográfica se mantienen constantes. Se detectaron cohortes bien definidas de algunas especies (*D. eleginoides* y *C. gunnari*) en algunas zonas. La prospección ha definido la distribución de especies, explotadas o no comercialmente, que juegan un papel importante en el ecosistema y son de gran interés para la ordenación y conservación de las poblaciones de especies del área.

Keywords: fish biomass, Kerguelen EEZ, *Dissostichus eleginoides*, CCAMLR

Introduction

The Kerguelen Islands zone is included in CCAMLR Statistical Division 58.5.1. The zone is located at the northern tip of the Kerguelen Plateau with a shelf occupying a large part of the zone. The shelf of the Heard and McDonald Islands (HIMI), in Division 58.5.2, forms the southern part of this plateau.

The fishery in Division 58.5.1 developed in three distinct phases. Initially, a foreign (mainly USSR and Poland) trawl fishery began operating on the slope of the Kerguelen Islands shelf in the 1970s targeting three main species: the mackerel icefish (*Champsocephalus gunnari*), the marbled rockcod (*Notothenia rossii*) and the grey rockcod (*Lepidonotothen squamifrons*). (Note throughout the text common names are provided for commercial fish species only.) The largest catches in the zone were taken during this period. The creation in 1978 of the French Exclusive Economic Zone (EEZ) corresponds to the second phase in the fishery's development with the setup of a controlled fishery and the beginning of a French interest in the fishery. However, no real changes in the fishery methods appeared and the catches of the target species drastically decreased (Duhamel, 1995), as was also observed in the other main fisheries in the Southern Ocean, such as at South Georgia (Kock, 1992). The discovery of a deep-sea stock of Patagonian toothfish (*Dissostichus eleginoides*) during the 1984/85 fishing season and the appearance of a new and more adapted deep-sea fishing method, longlining, changed the characteristics of the fishery in the early 1990s and constituted the third phase in the development. During the period from 1997 to 2004, an illegal, unreported and unregulated (IUU) fishery for *D. eleginoides* operated in addition to the legal fishery (Duhamel, 2003) but has recently been eradicated. The fishery is currently limited to French longline vessels.

Despite the collection of the fishery statistics and biological data since the creation of the EEZ, the status of the exploited stocks has been difficult to evaluate. The first fishery surveys occurred in 1987 and 1988 (SKALP surveys; see Duhamel, 1993a), nearly 20 years after the beginning of fishery. The first biomass estimates were produced from these surveys (Duhamel, 1988; Duhamel and Agnew, 1990) but, with no recent surveys available, the urgent need to produce new estimates to improve the management of fish stocks was apparent. A fishery-independent biomass survey 'POKER 2006' (from POissons de KERguelen) was conducted from September to October 2006 to address this necessity. The aim was to estimate the abundance, biomass, geographic and bathymetric distribution, and the biology of the main fish species both on the shelf and the deep-sea zones. The results of the cruise are presented here in order to revise the resource potential of the area.

Material and methods

The aims of the POKER 2006 survey were to conduct a random depth-stratified trawl survey using the swept-area method and to analyse all catch in each trawl (including species identification, measurements, biological sampling and tagging). This approach follows the methods currently in use in the Southern Ocean and especially off Heard Island (Williams and de la Mare, 1995; de la Mare et al., 1998). Due to the considerable amount of time since the previous survey (1987/88), no existing data on fish species concentrations was used in the survey stratification. The most recent bathymetric charts (GEBCO 97 Atlas®) and the plots of additional depth contour data from longline fishing cruises were used for the calculation of seabed surface using MAPINFO® software. The fishing capacities of the chartered trawler for the cruise determined the depth limit (1 000 m) of the studied area. The selected trawler was FV *Austral*, a French fishing vessel with a fishing master with a great knowledge of the Kerguelen fishing grounds, having been in command of the vessel fishing in the area from 1993 to 2000. The technical characteristics of the *Austral*, the bridge equipment and the gear design are given in Appendix 1.

The inner limit of the survey was defined by the 100 m depth isobath as this corresponds to the change in ichthyofauna from shelf to coastal species (Duhamel et al., 2005). It also corresponds to the large area of kelp (*Macrocystis pyrifera*) and of dangerous unchartered reefs. The southern boundary of the survey area was defined by the boundary between the French EEZ and the Australian HIMI EEZ. The other limits (northern, eastern and western) of the survey area are fully included in the French EEZ (Figure 1).

The selection of bathymetric strata corresponds first to the shelf zone (100–500 m) and second to the deep sea (500–1 000 m). A separation of areas north and south of 49°S was established to facilitate data processing. The isolation of the Skiff Bank from the Kerguelen Islands shelf in the southwestern part of the zone led to it being considered separately (the shallowest depth here is 200 m, therefore the shallower zone covers the range 200–500 m). Consequently, six strata were considered: shelf north and south, deep-sea north and south, Skiff Bank 200–500 m and deep sea (Figure 1a). The area of each stratum is given in Table 1.

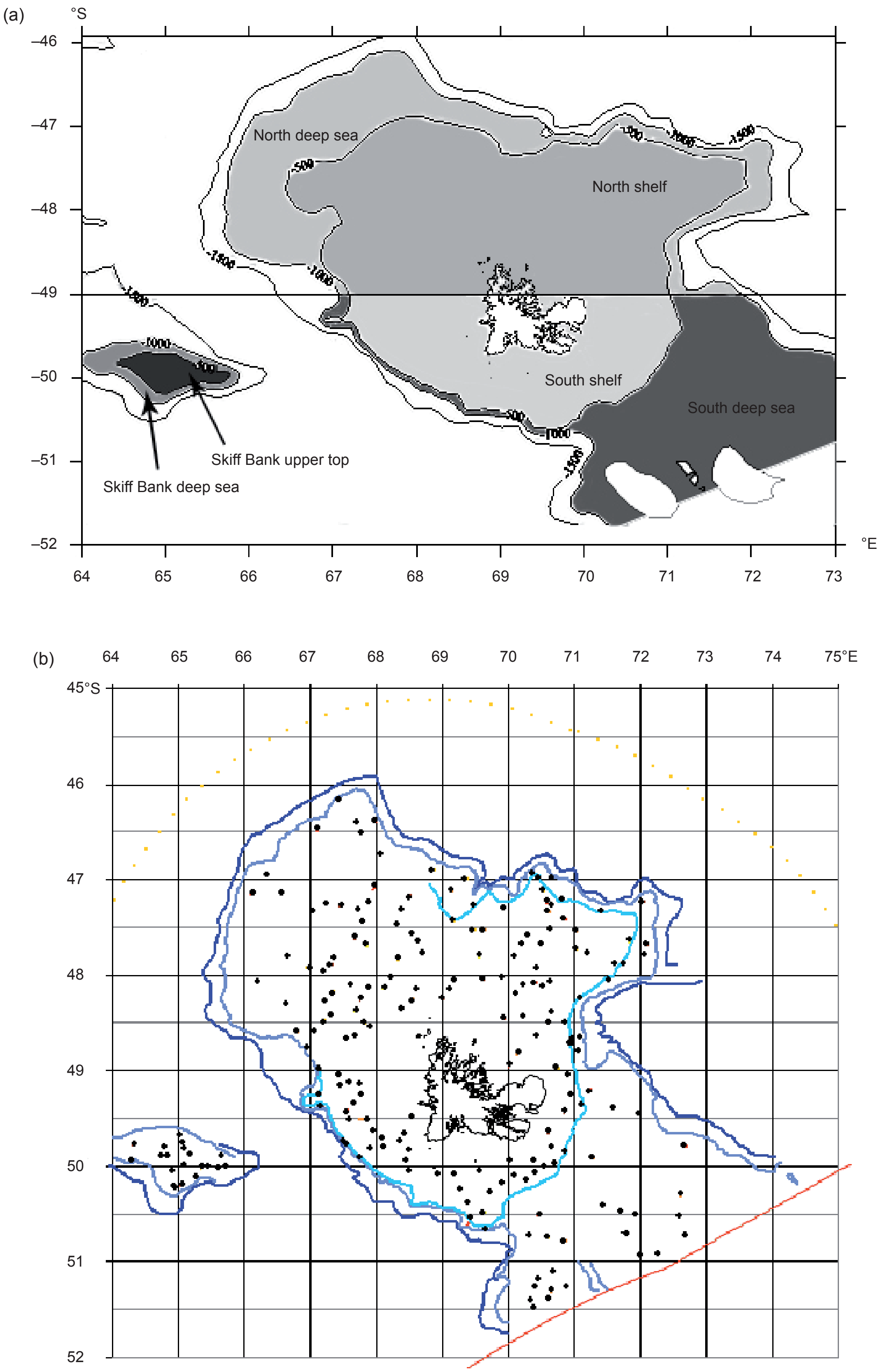

Figure 1: (a) The six strata defined for the POKER 2006 survey off the Kerguelen Islands. (b) Map of the trawl positions during the POKER 2006 survey (bathymetric contour increasing with line intensity: 500, 1 000 and 1 500 m).

Table 1: Area (km^2) of the six strata defined for the POKER 2006 survey off the Kerguelen Islands. * 200–500 m.

Strata: Depth (m)	North	South	Skiff Bank
100–500	63 164	27 032	3 117*
500–1 000	38 540	46 965	3 755

The number and location of stations was based on the expectation of a survey of about 200 trawls. A minimum distance between stations of 5 n miles (3 n miles for the limited area of the Skiff Bank) was introduced before allocating the random station positions. A replacement series of stations was also designed in case of rough bottom conditions or cancellation of some selected positions. In order to control for the diel migration in the water column of the semi-pelagic species *C. gunnari*, all shelf stations, including Skiff Bank, were conducted during daytime. This constraint does not apply for the deep-sea stations because of the limited bathymetric range of the species.

The standard duration of a trawl was 30 min on the ground (bottom trawling) and the selected mesh size in the codend was 40 mm. SCANMAR® trawl sensors were attached to the head rope and on the wings to measure the mouth opening (vertical and horizontal spread). The track of the trawl was computerised on MAXSEA® software.

Catch-per-haul was sorted on board by fish species. Count, weight (g) and measurements (cm) of specimens (total length (TL) for all specimens; standard length (SL) for the biological samples; anal length (AL) in the case of Macrouridae) were collected (with sub-sampling when high catch rates occurred). A sample of 25 fish of the dominant species in each catch was analysed to record the sex, the gonad maturity state (following Everson's scale (1977)), the stomach fullness and diet composition. Scales and otolith samples were taken for ageing. A tagging program of *D. eleginoides* was also conducted for future study of the species' growth and movements.

Catch-per-haul data by species were analysed in the laboratory under TRAWLCI Ver. 2 (available from CCAMLR at www.ccamlr.org) to estimate the mean density per stratum and subsequently to calculate the abundance and biomass. The Skiff Bank survey was considered separately from the other strata (referred to as 'the plateau') for these calculations.

The depth and geographic distribution of fish species abundances were examined using the krigeage method (SURFER 8® software) using abundance values. The krigeage method used was the point kriging, which estimates the values of the points at the grid nodes; further details of this method can be found in Isaaks and Srivastava (1989). The plateau stations were the only ones used in the kriging as the Skiff Bank's isolated data introduced distortion in the analysis because of the lack of transitional stations.

Results

The survey was conducted from 6 September to 9 October 2006 (with two stations on 19 and 20 October 2006) in the whole area of Kerguelen EEZ (Figure 1b) comprising 207 hauls. Three hauls were eliminated due to major damage to the net. Eight other hauls were retrieved before the normal 30 min duration because either rough bottom conditions were expected based on the depth-finder bottom profile, too high a tension on winches (in tonnes) indicated potential trawl damage, or bad weather conditions endangered the deck crew. The adjusted results of these hauls were nevertheless used in the analysis because no major problems occurred (no net damage in the trawl, duration of haul long enough, significant catch indicating normality of trawling condition). The Skiff Bank survey has not been fully completed owing to a very hard bottom in the deep-sea stratum 500–1 000 m, so these specific results were not considered in the evaluations.

The catches comprised 63 fish species (two sharks, three skates, 28 near-bottom and 30 midwater teleosts fish) (Appendix 2) totalling about 70 125 specimens and 19 115 kg. The highest values observed (all the hauls) for all the species are:

(i) in number: *Zanclorhynchus spinifer* with 25 905 specimens (2 492 kg);

(ii) in weight: *D. eleginoides* with 4 721 specimens (7 431 kg).

All midwater species (30 species, 2 514 specimens, and 49.05 kg; see Appendix 2) were excluded in the biomass analysis because they were considered as by-catch of bottom trawling and therefore the estimates would be biased in relation to the selectivity of the gear. Furthermore, five other species (*Mancopsetta maculata*, *M. milfordi*, *Bathyraja murrayi*, *Notothenia cyanobrancha* and *Paranotothenia magellanica* totalling 338 specimens and 80.91 kg) were also excluded from the analysis because epibenthic (flatfish or small skate for the first three) are undersampled with a bottom trawl and because the latter two species are coastal and their range has only a limited overlap with the survey area (see Duhamel et al., 2005).

Among the remaining species, known commercial species of the shelf and slope of the Kerguelen Islands EEZ (Duhamel et al., 2005) include *D. eleginoides*, *C. gunnari*, *L. squamifrons*, *N. rossii*, Eaton's skate (*Bathyraja eatonii*), Kerguelen sandpaper skate (*B. irrasa*), bigeye grenadier (*Macrourus carinatus*) and unicorn icefish (*Channichthys rhinoceratus*). Other abundant species both from the shelf (*Channichthys velifer*, *Gobionotothen acuta*, *Lepidonotothen mizops*, *Muraenolepis marmoratus*, *Z. spinifer*) and the deep sea (*Alepocephalus* cf. *antipodianus*, *Antimora rostrata*, *Paradiplospinus gracilis*, *Etmopterus* cf. *granulosus*) were also recorded. Finally some deep-sea species were also caught (*Bathydraco antarcticus*, *Coryphaenoides armatus*, *Halargyreus johnsonii*, *Guttigadus kongi*, *Lepidion ensiferus*, *Lychenchelys hureaui*, *Lycodapus antarcticus*, *Melanostigma gelatinosum* and *Somniosus antarcticus*).

Of the commercial species, only eight were abundant enough in the trawls to allow density and abundance estimations. In strata where other species occur in one or two stations only (or in few stations with very high density but in a limited area), it is impossible to calculate confidence limits for the density and abundance estimates. This was especially the case for the shelf species *Z. spinifer* in the northwestern shelf and the deep-sea species *A.* cf. *antipodianus*. Consequently, the biomass and abundance estimates were produced only for the commercial species.

Biomass

The biomass estimates for the plateau strata show a range of values between the eight commercial species (Table 2). The confidence intervals (CIs) are very large for some species in relation to values in one stratum (Appendix 3). This is the case for *B. eatonii* in the south deep-sea stratum where the 7 689 tonnes, almost 40% of the total (19 483 tonnes) estimated biomass, had CIs of 1 621–163 495 tonnes. This reduces the reliability of the biomass estimation. The same observation is made for *L. squamifrons* for the two deep-sea strata (north – 396–22 344 tonnes for an estimated abundance of 1 654 tonnes; south – 157–6 962 tonnes for an estimated abundance of 837 tonnes).

For the whole survey area, only two species had a biomass over 40 000 tonnes; these were *D. eleginoides* (124 000 tonnes) and *C. rhinoceratus* (54 000 tonnes). All the other species had a biomass lower than 20 000 tonnes. The lowest biomass recorded for a commercial species was for *C. gunnari* with less than 5 000 tonnes (Table 2). The total biomass of the commercial species was about 241 000 tonnes.

The Skiff Bank upper stratum had a limited biomass (2 810 tonnes) and two commercial species (*B. irrasa* and *M. carinatus*) showed no significant biomass (i.e. a biomass which would not support commercial exploitation) (Table 3).

D. eleginoides showed a widespread biomass distribution, both on the shelf and in the deep sea, in the northern and southern sectors (Figure 2). This was not the case for *C. rhinoceratus* which was distributed mainly on the northern shelf. *Bathyraja eatonii* had a similar pattern to that of *D. eleginoides* but its deep-sea biomass was more important in the southern sector. The biomass of *C. gunnari*, *L. squamifrons*, *N. rossii* and *C. rhinoceratus* was concentrated on the shelf, while that of *M. carinatus* occurs in the deep sea and *D. eleginoides*, *B. eatonii* and *B. irrasa* were distributed in the two depth ranges.

Abundance

The densities in number provide another view for the commercial species. The results of the POKER 2006 survey (Tables 4 and 5 and Appendix IV) underline the high abundance of *C. rhinoceratus* with about 260 million of specimens. The values for *D. eleginoides* are less than those of *L. squamifrons* (76 million of specimens versus 98 million). The number (32 million) of *C. gunnari* seems more significant than expected from the biomass values. Low levels in abundance were recorded for *N. rossii* and the two skates (*B. eatonii* and *B. irrasa*). The total abundance was about 493 million of specimens.

The Skiff Bank shows, only for its top stratum (200–500 m), about 12 million specimens of all species.

The relative distribution of abundance between the depth strata was similar to those reported for the biomass (Figure 3) with only small differences in relative proportions.

Table 2: Biomass of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) in the northern part (Kerguelen Islands French EEZ) of the Kerguelen Plateau.

Species	Biomass (tonnes)	±SD	Confidence interval	
			Lower limit	Upper limit
Dissostichus eleginoides	123 971	20 155	73 494	263 945
Champsocephalus gunnari	4 128	1 287	2 097	10 371
Lepidonotothen squamifrons	15 499	5 720	6 017	77 324
Notothenia rossii	8 090	2 881	3 268	31 657
Bathyraja eatonii	19 463	5 457	7 218	199 253
Bathyraja irrasa	8 968	3 355	4 233	69 875
Macrourus carinatus	6 508	2 181	2 815	24 676
Channichthys rhinoceratus	54 057	9 368	40 586	81 377

Table 3: Biomass of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) on the Skiff Bank (Kerguelen Islands French EEZ) and only for the 200–500 m stratum. ns: not significant (i.e not present in commercially fishable concentrations).

Species	Biomass (tonnes)	±SD	Confidence interval	
			Lower limit	Upper limit
Dissostichus eleginoides	661	136	457	1 120
Champsocephalus gunnari	147	71	59	715
Lepidonotothen squamifrons	586	378	157	6 962
Notothenia rossii	909	498	305	6 266
Bathyraja eatonii	263	135	95	1 465
Bathyraja irrasa	ns	ns	ns	ns
Macrourus carinatus	ns	ns	ns	ns
Channichthys rhinoceratus	241	107	106	994

Table 4: Abundance of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) in the northern part (Kerguelen Islands French EEZ) of the Kerguelen Plateau.

Species	Abundance (millions of specimens)	±SD	Confidence interval	
			Lower limit	Upper limit
Dissostichus eleginoides	75.7	10	60.5	103.5
Champsocephalus gunnari	31.6	8.5	16.9	74.4
Lepidonotothen squamifrons	97.5	27	42.4	351.9
Notothenia rossii	3.3	1.1	2	10
Bathyraja eatonii	4.4	0.6	2.4	10
Bathyraja irrasa	1.1	0.2	0.7	2.4
Macrourus carinatus	15.2	5.2	8	34.9
Channichthys rhinoceratus	264.6	37.6	195.2	358.1

Table 5: Abundance of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) on the Skiff Bank (Kerguelen Islands French EEZ) and only for the 200–500 m stratum. ns: not significant (i.e not present in commercially fishable concentrations).

Species	Abundance (millions of specimens)	±SD	Confidence interval	
			Lower limit	Upper limit
Dissostichus eleginoides	0.87	0.16	0.62	1.37
Champsocephalus gunnari	4.86	2.97	1.42	48.18
Lepidonotothen squamifrons	3.25	0.18	1.1	23.35
Notothenia rossii	0.33	0.18	0,11	2.41
Bathyraja eatonii	0.08	0.02	0.04	0.12
Bathyraja irrasa	ns	ns	ns	ns
Macrourus carinatus	ns	ns	ns	ns
Channichthys rhinoceratus	2.62	1.13	1.19	10.21

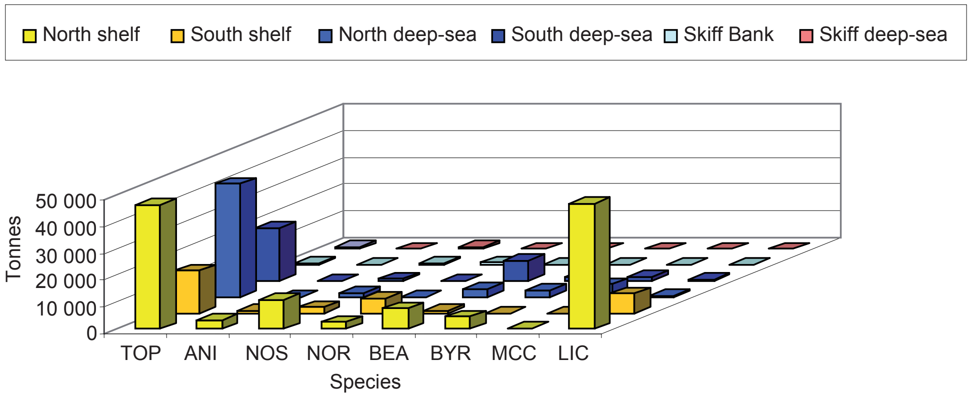

Figure 2: Biomass (tonnes) in the six selected strata for each of the eight commercial fish species obtained during the POKER 2006 survey. (TOP – *Dissostichus eleginoides*; ANI – *Champsocephalus gunnari*; NOS – *Lepidonotothen squamifrons*; NOR – *Notothenia rossii*; BEA – *Bathyraja eatonii*; BYR – *Bathyraja irrasa*; MCC – *Macrourus carinatus*; LIC – *Channichthys rhinoceratus*).

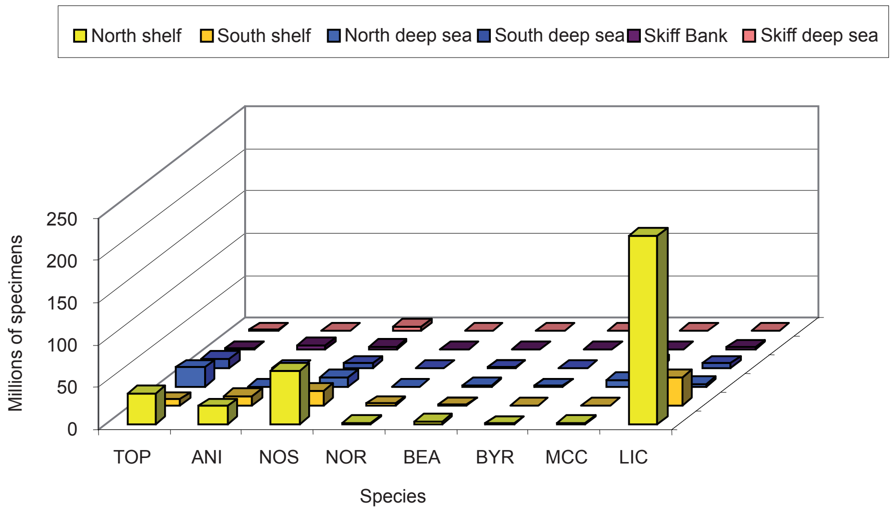

Figure 3: Abundance (million of specimens) in the six selected strata for each of the eight commercial fish species obtained during the POKER 2006 survey. (TOP – *Dissostichus eleginoides*; ANI – *Champsocephalus gunnari*; NOS – *Lepidonotothen squamifrons*; NOR – *Notothenia rossii*; BEA – *Bathyraja eatonii*; BYR – *Bathyraja irrasa*; MCC – *Macrourus carinatus*; LIC – *Channichthys rhinoceratus*).

Geographic and bathymetric range of the commercial species

The analysis of all abundance values of the POKER 2006 survey (Skiff Bank data excluded) were used to produce distribution maps for all commercial species. In addition some by-catch species (*Z. spinifer*, *A.* cf. *antipodianus*, *E.* cf. *granulosus*), for which the biomass estimates were biased with few spots of high concentration, were also mapped (Appendix 5).

The geographic distribution and depth range of each species were highly different:

(i) *D. eleginoides* showed a rather uniform distribution both on the shelf and in the deep sea, with some local deep-sea concentration in the southwest, north and northeast;

(ii) *C. gunnari* was found in shallow waters (<500 m), east of the Kerguelen Islands, with few concentrations in the northern and northeastern limit of the 200 m isobath;

(iii) *L. squamifrons* exhibits some areas of high density close to the 500 m isobath;

(iv) *N. rossii* is mainly found in the southeastern area of the Kerguelen shelf;

(v) *B. eatonii* and *B. irrasa* were concentrated in the northern to northeastern deep sea;

(vi) *C. rhinoceratus* showed a shelf distribution (<200 m), with high-concentration areas on the whole northern shelf;

(vii) *A.* cf. *antipodianus* did not occur on the shelf but was concentrated in the northwestern deep sea;

(viii) *Z. spinifer* was concentrated in the northwest from 200–1 000 m;

(ix) *E.* cf. *granulosus* was not recorded outside the deep sea with only two high-concentration areas in the northwest and northeast.

Length-frequency distributions of commercial species

Length-frequency distributions (LFDs) were obtained for all commercial species (Appendix 6). When significant differences were observed between strata, data from the strata were analysed separately. This was the case for *C. gunnari* (Appendix 7) and *D. eleginoides* (Appendix 8) which exhibit different size structures in geographic areas and bathymetric ranges. *Champsocephalus gunnari* showed three major modes on the northern shelf, two on the southern and only one on Skiff Bank (Appendix 7). *Dissostichus eleginoides* was present in all strata, but exhibited differences in size structures (Appendix 8). The LFDs of the northern and southern shelves were different. Three well-distinguished modes (18, 31 and 41 cm) in a size range from 14 to 69 cm were observed in the northern shelf, but a different pattern was found in the southern shelf LFD (range: 25 to 94 cm). The deep-sea LFDs, both north and south, were identical with fish from 33 to 85 cm. Finally, the observed LFD from the top part of the Skiff Bank comprised fish of about 40 cm.

Discussion

Previous knowledge of the size structure of the commercial species confirms that the POKER 2006 survey sampled the size range of the stocks in the area after the selectivity of the mesh size had been considered (Slosarczyk and Wysokinski, 1980; Duhamel, 1981, 1982, 1987a, 1991a, 1993a). Only one species, *L. squamifrons*, showed an LFD with very few specimens larger than the recognised size-at-maturity and therefore should be considered as undersampled (Duhamel and Ozouf-Costaz, 1985). This could be explained by the local spring-spawning concentration of the adult part of the population (Duhamel, 1987a, 1987b) that this survey was unable to detect. Therefore, only juvenile fish (<30 cm) (Appendix 6) are present in the samples.

The study of the size and related demographic structure and spatial distribution of the commercial fish species also adds useful information with which to interpret the biomass and abundance values. LFDs for two major species, *C. gunnari* and *D. eleginoides*, from the POKER 2006 survey results, are informative. In this respect, peaks in LFD of *C. gunnari*, a species only living in the shallow shelf strata and the top of the Skiff Bank, correspond to specific age classes (cohorts) previously recognised in the stocks and growth studies (Sosinski, 1981; Duhamel, 1987a, 1991a, 1993b, 1995; Herasymchuk, 1993). The geographic distribution of these cohorts is not homogeneous. The most studied stock in the northeastern part of the shelf shows:

(i) a first modal length (11 cm) of juvenile fish present only in the shallow and more inshore waters (age 0+, 6.14 million specimens from the abundance estimates, 28.9% of fish);

(ii) a second modal length (26 cm, 10.32 million specimens, 46.6% of fish) of sub-adult fish (age 2+), focused geographically more offshore;

(iii) a last group of post-spawning adults (stage 5 on Everson's scale with modes at 35 and 38 cm, ages 4 and 5, 4.78 million specimens, 22.5% of fish) concentrated near the slope of the shelf, to the north (see Appendix 5).

Two of these modes are similar in the southern part of the shelf zone for the 2+ and 4/5 age classes but the older fish are less numerous (4.41 million specimens and 42.4% of fish, 0.63 million specimens and 6.2% of fish respectively). Another peak, probably a combination of two age classes, 0+ and 1+, shows a 15 cm modal length (5.34 million specimens and 51.4% fish).

The only well represented mode on the Skiff Bank (17 cm, age 1+, 479 100 specimens, 98.6% of fish) clearly differs in the location (centre and west of the bank) from the rarely observed post-spawners (east of the bank, 5 830 specimens and 1.4% of fish). Similar cohort succession has previously been observed on this bank with only one strong cohort present at once (Sosinski, 1981; Duhamel, 1987a, 1991a, 1993b, 1995).

The northern shelf LFD observations of *D. eleginoides* are very similar to those noted during the SKALP surveys in 1987 and 1988 (Duhamel, 1993b, see Figures 18 and 19) with modes mainly corresponding to the age classes 1, 2 and 3 (Duhamel, 1987a). The deep-sea zone shows LFD of older fish. Owing to the fact that the maximum size of *D. eleginoides* reported by Duhamel et al. (2005) was not recorded in the POKER 2006 survey samples, two explanations can be put forward: a deeper range of these adults or an effect of fishing reducing that part of the stock. Deeper longline catches (Duhamel, 1991b, 1993b) support the first hypothesis but the second seems to be considered as the most important (Lord et al., 2006). The SKALP and POKER 2006 survey results show that the prominent part of the northern Kerguelen shelf is the recruitment zone of *D. eleginoides* on the Kerguelen Plateau, whereas the adults are found in the deep-sea zone.

The estimations from the POKER 2006 survey give the present state of the biomass and the abundance of main commercial fish species in the northern part of the Kerguelen Plateau and the Skiff Bank for the spring of 2006/07. However, to obtain a complete range of values for fish resources in the area, it would be necessary to add the coastal zone (0–100 m) and the resources beyond the 1 000 m depth contour, outside the depth limit investigated during the POKER 2006 survey. The current longline fishery indicates that a significant resource of deep-sea species still occurs both commercially (*D. eleginoides*, *M. carinatus*, *B. irrasa* and *B. eatonii*), and as by-catch (*A. rostrata*), and some additional species (*A.* cf. *antipodianus*) seem not to be selected by that fishing method. The mean values of yields (catch-per-unit-effort, CPUE) for *D. eleginoides* longline catches reported during October/November 2006 (immediately after the POKER 2006 survey) for three increasing depth ranges (500–1 000, 1 000–1 500 and >1 500 m) confirm such an assumption (168, 146, and 227 g hook^{-1} or 38, 30 and 30 fish/thousand hooks respectively). Consequently, the estimations provided for the above commercial species are minimum values and need to be re-evaluated significantly when the whole bathymetric range and spatial distribution of these species in the Kerguelen area is known.

The geographic and bathymetric fish distributions over a 20-year interval are interesting to compare. The 1987/88 SKALP results allowed Duhamel (1993b) to describe the localised fish concentrations of five commercial species, *N. rossii*, *L. squamifrons*, *D. eleginoides*, *C. rhinoceratus* and *C. gunnari*) and *Z. spinifer* in the first bathymetric stratum (100–500 m). Such concentrations were stable for the two successive years of the survey. The long-term stability of these fish concentrations, and for another season, is confirmed by the POKER 2006 survey for the commercial species and for by-catch species when their biomass has not been drastically reduced. The northwestern shelf concentration of *Z. spinifer*, the high importance of the northeastern shelf both for *C. rhinoceratus* and *C. gunnari*, and the southwestern, northern and northeastern deep-sea extension of *D. eleginoides* abundance are now confirmed. Undertaking a deeper survey than had previously been conducted has provided new data on fish distribution. In particular, new aggregations of species have been discovered, including (because of the survey's period) spawning areas for *G. acuta* in the western shelf, *L. mizops* in the southwest and *A.* cf. *antipodianus* in the northwestern deep-sea zone. Other deep-sea species, such as *M. carinatus*, *B. eatonii*, *B. irrasa*, *E.* cf. *granulosus* and *D. eleginoides*, clearly have a stock overlapping the boundaries of the survey which shows that stocks occupy a very large area of the EEZ.

The comparisons between biomass estimates from the SKALP and POKER 2006 surveys are of limited utility because the first survey was not based on random stratified sampling and only the shallow bathymetric strata of the POKER 2006

Table 6: Comparative results of biomass estimates (tonnes) inside the 100–500 m bathymetric range only (Skiff Bank not included) for five commercial fish species during the SKALP (Duhamel, 1988) and POKER 2006 surveys. * Partial result in relation to the incomplete coverage of the stratum.

Survey:	SKALP		POKER
Year	1987	1988	2006
Champsocephalus gunnari	15.024	429.052	4.090
Channichthys rhinoceratus	20.330	23.247	54.000
Notothenia rossii	28.290	17.940	8.090
Lepidonotothen squamifrons	9.189	5.407	12.954
Dissostichus eleginoides	104.934	(42.969)*	61.974

survey were investigated. However, some comparisons can be attempted for five of the commercial species (*D. eleginoides*, *C. gunnari*, *L. squamifrons*, *N. rossii* and *C. rhinoceratus*) (Table 6). The biomass of *C. rhinoceratus* and *L. squamifrons* seems to have had a two-fold increase between the two surveys. Conversely, *C. gunnari* and *N. rossii* biomass seem to have strongly decreased while *D. eleginoides* shows a smaller change in the bathymetric range concerned. Such trends need to be connected with the environmental, species and human (fishery-related) changes between surveys. The following points are to be considered:

(i) Only a trawl fishery occurred in 1987–1988 (the time of the SKALP surveys) targeting three species (*C. gunnari*, *L. squamifrons* and *N. rossii*) with nearly two decades of intense exploitation (beginning of the fishery: 1970/71) at depths not exceeding 300– 400 m. The *D. eleginoides* fishery was in its early development and its status was nearly a virgin stock with only a cumulative catch of 10 910 tonnes in the western sector of the Kerguelen shelf (depths <500 m) after the discovery of the first fish in 1984/85.

(ii) The traditional trawl fishery was not operating in 2006 (fisheries for *N. rossii* and *L. squamifrons* ended in 1990/91 and for *C. gunnari* in 1994/95). Only a deep-water (>500 m) legal longline fishery, targeting *D. eleginoides*, still exists. The cumulative catch for that species reached 149 000 tonnes at the time of the POKER 2006 survey, including estimated catches of an IUU fishery between 1997 and 2005.

The *C. gunnari* cohorts present on the Shelf and the Skiff Bank in 2006 indicate very low biomass compared to those observed both during 1987 and 1988 (Duhamel, 1988; Duhamel and Agnew, 1990). The progressive reduction in the strength of successive cohorts through overfishing is probably the main reason for the decrease in abundance of stocks but other factors could be advanced to explain why no recovery has been observed since the closure of the fishery in 1994. First, the temporal increase in sea-surface temperatures (1992, 1997/98 and 2001/02 El Niño Southern Oscillation (ENSO); see Lea et al., 2006) has probably led to a negative effect on the physiology of this white-blooded species. In addition, a possible increase in predation by Antarctic fur seals (*Arctocephalus gazella*), which have undergone a rapid increase in the Kerguelen area (recolonisation in the 1980s, present population of 40 000 *A. gazella* and with a 10% annual increase, C. Guinet pers. com.), may have impacted stocks. *Arctocephalus gazella* is recognised as a top predator with *C. gunnari* in its diet (Guinet et al., 2001) mostly when its main prey (lanternfish of genera *Gymnoscopelus*, *Electrona*) are difficult to obtain. As the colonies are located near the *C. gunnari* concentrations, the impact could be strong. Finally, the current levels of predation on *C. gunnari* from three main fish species (*C. rhinoceratus*, *D. eleginoides*, *N. rossii*) (Duhamel, 1987a; Melnikov, 1993) may have the effect of delaying any recovery of the reduced stocks.

The apparent increase in biomass of *C. rhinoceratus*, on a stable and large geographic distribution on the shelf (see Duhamel, 1993b for comparison), seems explainable. The species has never been a by-catch of the trawl fishery because its grounds are mainly in shallower waters than the concentrations of the other targeted species by fishery. Then it took advantage of a predator release (with the decrease in the stocks of *D. eleginoides* and *N. rossii*). Also, a weak shelf population of *C. gunnari* could have reduced diet competition, because both species feed mainly on Euphausiids and hyperiid Amphipods in early stages (Duhamel, 1987a), giving this stock an opportunity to increase.

The low biomass of *N. rossii*, already noted from SKALP survey results, is noticeable. The stock has been overexploited in the 1980s and the level of the 1987/88 biomass was already heavily reduced compared to the virgin stock. An oriented trawl fishing towards spawning grounds aggregation had led to a negative trend in the stock (Duhamel and Hureau, 1990). However, after the closure of the fishery, there were indications that the juvenile part of the population had increased in the coastal waters (G. Duhamel, unpublished data) but the adult stock seems to have not undergone a similar recovery. The population collapse of *C. gunnari*, a major prey source for adult *N. rossii* (Chechun, 1984; Duhamel, 1987a), could also have an effect on the stock.

There has been no trawl fishery for *L. squamifrons* since 1990/91 and this duration has probably given the stock time to recover. The abundant gelatinous plankton diet of the species, the quasi-absence of natural predators and one of the highest fecundity among the Nototheniidae (including annual recruitment) (Duhamel, 1987b; Koubbi et al., 2001) are positive factors for the recovery of the stock. The same evolution in biomass to that of *C. rhinoceratus* should be expected. The POKER 2006 survey masks in part such an assumption because the spring-spawning aggregation of the adult stock (Duhamel, 1987b) was not found and the total biomass of the species was impossible to estimate. It is possible that *L. squamifrons* could probably be, again, a commercial species in the future. However, such hypothesis needs to be supported by further studies, undertaken on the adult part of the stock.

Finally, *D. eleginoides* shows a decrease in the biomass of recruits (shelf area) between the SKALP and POKER 2006 surveys (Table 6) but a cumulative catch of nearly 150 000 tonnes has occurred during the period from 1985 to 2007 (legal and IUU fishing for the Kerguelen EEZ), excluding additional catches from the Australian HIMI southern zone of the Kerguelen Plateau (see CCAMLR, 2008). The status of the stock has moved from nearly virgin to fully exploited. The total biomass of *D. eleginoides* nevertheless represents the most important current biomass of commercial fish in the Kerguelen area with an estimation of 123 971 tonnes (51.5% of a total biomass). Additionally, the above estimation covers only the 100–1 000 m range. Therefore, such a value is probably an underestimate and needs to be revised because various fishery methods and catches of the current longline fishery have established that the stock extends deeper (>1 800 m). The balanced breakdown in biomass (and abundance) between the unfished juvenile part (northern shelf dependant) and the adult part (deep sea) of the stock suggests that there should be no major problem in the recruitment if the spawning stock biomass maintains a high enough level. Insertion of the demographic structure into the stock assessment models would be the next step in addressing this question. It should also allow linking of the biomass and abundance estimates of the POKER 2006 survey with the Generalised Linear Model (GLM) results (Lord et al., 2006) from the fishery.

Conclusion

The POKER 2006 survey provides a reference point for the fish populations of the northern part of the Kerguelen Plateau. These can now be compared to those obtained in the southern part, the Australian HIMI zone. Additionally, the knowledge of the geographic and bathymetric distributions of 17 main species of fish in the marine ecosystem of the Kerguelen Plateau, which have proved to be stable over time, could and should be used in the management and the conservation of marine biodiversity of this area.

Similar surveys using the same methods as the POKER 2006 survey have already produced results for the fish species of the HIMI zone (Williams and de la Mare, 1995), in particular for *C. gunnari* (de la Mare et al., 1998) and by-catch species of the trawl fishery (Constable et al., 1998). In addition, there are the results of tag-recapture data for *D. eleginoides* which can be compared with the earlier work of Williams et al. (2002). A joint analysis of data from the French and Australian EEZs would constitute a global view of fish resources of the largest plateau in the Southern Ocean.

Acknowledgements

We are grateful to the crew and ship owner of the FV *Austral* for their help during the POKER 2006 survey. We also thank the Terres Australes et Antarctiques Françaises for logistic support. The work of the scientific team (E. Richard, J.L. Aubert, R. Causse, E. Hoarau, P. Gaspard), on board with the authors, has allowed the presented results to be obtained. Scientific advice of R. Williams (Australian Antarctic Division), technical support of CCAMLR staff (D. Ramm and S. Morgan) for the use of TRAWLCI (Ver. 2) and from N. Gasco for the creation of a modified version of his CD COPEC have been also greatly appreciated. The Ministère de la Recherche (ANR), Ministère de l'Agriculture et de la Pêche and the French ship owners involved in the Southern Ocean fishery (Armas Pêche, Armements Réunionnais, Cap Bourbon, Comata, Pêche et Avenir, Sapmer) provided financial support for the cruise. We warmly thank C. Lord who greatly improved the English translation.

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Appendix 1

Main technical characteristics of the trawler *Austral* during the POKER 2006 survey

Name	*Austral*	
Type	Freezing trawler, stern trawler	
Building	Gdynia (Poland)	
Owner	SAPMER	
Year	1993	
Characteristics		
Dimensions (length, width, draught)	L = 76.6 m w = 14.6 m d = 6.5 m	
Tonnage (BRT)	1 697	
Tonnage (UMS)	2 343	
Engine (HP)	3 400	
Deck equipement		
Trawl winch	BOPP	
Fishing ropes	2 x 2 000m	Diametre 32 mm
Otter boards	1 800 kg each	Morgère polyfoil type OF
Trawl	Bottom 35/39, 35 m headline /39 m footrope (large vertical opening)	Ets Le Drezen, ref.: G2035013
	Footrope equipment	300 mm rockhopper rubber bobbins
	Vertical opening	About 6.5 m
	Horizontal opening (between otter boards)	About 180 m
	Horizontal opening (at wings)	About 20 m
	Codend mesh	40 mm scientific/ 120 mm commercial
Fishing/routing electronics		
Rope tension controller	Marelec SM 2 -D	Electric/hydraulic with adjusted tension Alarm and automatic release
Sensor/trawl position device	Scanmar	Sensors for trawl opening and filling
Sonic depth finder	1 colour Furuno FCV 1200 1 Kaijo	With magnifying glass
GPS Global Positioning System	Furuno GP 31 et 32 / Leica / Magnavox	
Mapping system	MaxSea	GPS dependent, using SHOM* maps

* SHOM – Service Hydrographique et Océanographique de la Marine

Appendix 2

Fish species list collected during the POKER 2006 survey

Domain: Family	Neritic	Deep sea	Pelagic
Dalatidae		*Etmopterus* cf *granulosus*	
	Somniosus antarcticus	*Somniosus antarcticus*	
Rajidae	*Bathyraja eatonii*	*Bathyraja eatonii*	
		Bathyraja irrasa	
	Bathyraja murrayi		
Bathylagidae			*Bathylagus tenuis*
Alepocephalidae		*Alepocephalus cf. antipodianus*	
Stomiidae			*Borostomias antarcticus*
			Idiacanthus atlanticus
			Stomias boa
Scopelarchidae			*Benthalbella elongata*
Paralepididae			*Arctozenus risso*
			Notolepis coatsi
			Magnisudis prionosa
Alepisauridae			*Alepisaurus brevirostris*
Myctophidae			*Electrona antarctica*
			Electrona carlsbergi
			Electrona subaspera
			Gymnoscopelus bolini
			Gymnoscopelus braueri
			Gymnoscopelus nicholsi
			Gymnoscopelus fraseri
			Gymnoscopelus hintonoides
			Krefftichthys anderssoni
			Lampadena speculigera
			Nannobrachium achirus
			Protomyctophum andriashevi
			Protomyctophum bolini
			Protomyctophum gemmatum
			Protomyctophum tenisoni
Muraenolepidae	*Muraenolepis marmoratus*		
Macrouridae		*Coryphaenoides armatus*	
		Macrourus carinatus	
Moridae		*Antimora rostrata*	
		Guttigadus kongi	
		Halargyreus johnsoni	
		Lepidion cf. ensiferus	
Carapidae		*Echiodon cryomargarites*	*Echiodon cryomargarites*
Melamphaidae			*Poromitra crassiceps*
Congiopodidae	*Zanclorhynchus spinifer*		

(continued)

Domain: Family	Neritic	Deep sea	Pelagic
Liparidae		*Paraliparis copei kerguelensis* *Paraliparis neelovi* *Paraliparis operculosus* *Paraliparis thalassobathyalis*	
Zoarcidae		*Lycenchelys hureaui* *Lycodapus antarcticus* *Melanostigma gelatinosum*	*Melanostigma gelatinosum* *Melanostigma vitiazi*
Nototheniidae	*Dissostichus eleginoides* *Gobionotothen acuta* *Lepidonotothen mizops* *Lepidonotothen squamifrons* *Notothenia cyanobrancha* *Notothenia rossii* *Paranotothenia magellanica*	*Dissostichus eleginoides*	
Bathydraconidae		*Bathydraco antarcticus*	
Channichthyidae	*Champsocephalus gunnari* *Channichthys rhinoceratus* *Channichthys velifer*		
Gempylidae			*Paradiplospinus gracilis*
Centrolophidae			*Icichthys australis*
Achiropsettidae	*Mancopsetta maculata* *Mancopsetta milfordi*	*Mancopsetta milfordi*	

Appendix 3

Biomass by strata of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) in the northern part of the Kerguelen Plateau (Kerguelen Islands French EEZ)

ns: not significant (i.e. not present in commercially fishable concentrations)

Patagonian toothfish (*Dissostichus eleginoides*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	46 203	16 372	23 958	111 995
South shelf	17 072	7 731	7 275	61 136
North deep sea	42 056	8 927	28 729	71 166
South deep sea	19 641	4 200	13 383	33 663
Skiff Bank	661	136	457	1 120
Skiff deep sea	860	146	440	1 397

Mackerel icefish (*Champsocephalus gunnari*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	3 378	1 268	1 677	8 921
South shelf	750	211	447	1 520
North deep sea	ns	ns	ns	ns
South deep sea	ns	ns	ns	ns
Skiff Bank	147	71	59	715
Skiff deep sea	ns	ns	ns	ns

Grey rockcod (*Lepidonotothen squamifrons*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	10 762	4 989	4 441	37 539
South shelf	2 513	1 247	970	10 942
North deep sea	1 654	1 118	396	22 344
South deep sea	837	547	204	10 011
Skiff Bank	586	378	157	6 962
Skiff deep sea	630	531	82	202 115

Marbled rockcod (*Notothenia rossii*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	2 526	1 217	998	10 236
South shelf	5 861	2 690	2 404	22 512
North deep sea	ns	ns	ns	ns
South deep sea	ns	ns	ns	ns
Skiff Bank	910	498	305	6 266
Skiff deep sea	ns	ns	ns	ns

Eaton's skate (*Bathyraja eatonii*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	7 649	3 256	3 422	24 266
South shelf	565	289	202	2715
North deep sea	3 145	809	1 853	5.420
South deep sea	7 689	5 457	1 621	163 495
Skiff Bank	263	135	95	1465
Skiff deep sea	ns	ns	ns	ns

Kerguelen sandpaper skate (*Bathyraja irrasa*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	4 588	2 784	1 326	37 217
South shelf	ns	ns	ns	ns
North deep sea	2 618	1 664	684	28 785
South deep sea	1 763	777	649	3 873
Skiff Bank	ns	ns	ns	ns
Skiff deep sea	ns	ns	ns	ns

Bigeye grenadier (*Macrourus carinatus*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	267	157	77	1.739
South shelf	6	4	1	19
North deep sea	4 770	2 070	2 121	16 975
South deep sea	1 465	669	615	5 943
Skiff Bank	ns	ns	ns	ns
Skiff deep sea	ns	ns	ns	ns

Unicorn icefish (*Channichthys rhinoceratus*)				
	Biomass (tonnes)	SD	Confidence interval	
			Lower limit	Upper limit
North shelf	46 755	9 223	32 653	73 706
South shelf	7 245	1 621	4 843	12 476
North deep sea	378	134	190	955
South deep sea	616	319	207	2 757
Skiff Bank	241	107	106	994
Skiff deep sea	9	5	2	22

Appendix 4

Abundance by strata of eight commercial fish species during the POKER 2006 survey (September–October 2006, 100–1 000 m) in the northern part of the Kerguelen Plateau (Kerguelen Islands French EEZ)

ns: not significant (i.e. not present in commercially fishable concentrations)

Patagonian toothfish (*Dissostichus eleginoides*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	35.7	8.5	23.0	62.8
South shelf	6.5	1.8	4.0	12.9
North deep sea	22.8	4.5	16.0	36.8
South deep sea	10.7	2.0	7.7	16.8
Skiff Bank	0.9	0.2	0.6	1.4
Skiff deep sea	1.2	0.2	0.6	1.7

Mackerel icefish (*Champsocephalus gunnari*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	21.2	7.2	11.3	49.9
South shelf	11.0	3.6	6.0	25.8
North deep sea	ns	ns	ns	ns
South deep sea	ns	ns	ns	ns
Skiff Bank	4.9	3.0	1.4	48.2
Skiff deep sea	ns	ns	ns	ns

Grey rockcod (*Lepidonotothen squamifrons*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	62.5	24.6	29.9	173.6
South shelf	18.6	9.2	7.1	81.2
North deep sea	11.2	6.1	3.8	68.8
South deep sea	5.3	3.3	1.4	52.2
Skiff Bank	3.3	1.8	1.1	23.4
Skiff deep sea	5.4	4.2	1.0	598.0

Marbled rockcod (*Notothenia rossii*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	1.0	0.3	0.6	1.8
South shelf	2.4	1.1	1.0	8.6
North deep sea	ns	ns	ns	ns
South deep sea	ns	ns	ns	ns
Skiff Bank	0.3	0.2	0.1	2.4
Skiff deep sea	ns	ns	ns	ns

Eaton's skate (*Bathyraja eatonii*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	2.4	0.6	1.4	4.4
South shelf	0.1	0.0	0.1	0.2
North deep sea	1.0	0.3	0.6	1.8
South deep sea	0.9	0.4	0.3	3.5
Skiff Bank	0.1	0.0	0.0	0.1
Skiff deep sea	ns	ns	ns	ns

Kerguelen sandpaper skate (*Bathyraja irrasa*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	0.4	0.1	0.2	0.8
South shelf	ns	ns	ns	ns
North deep sea	0.0	0.1	0.1	0.7
South deep sea	0.4	0.2	0.1	0.9
Skiff Bank	ns	ns	ns	ns
Skiff deep sea	ns	ns	ns	ns

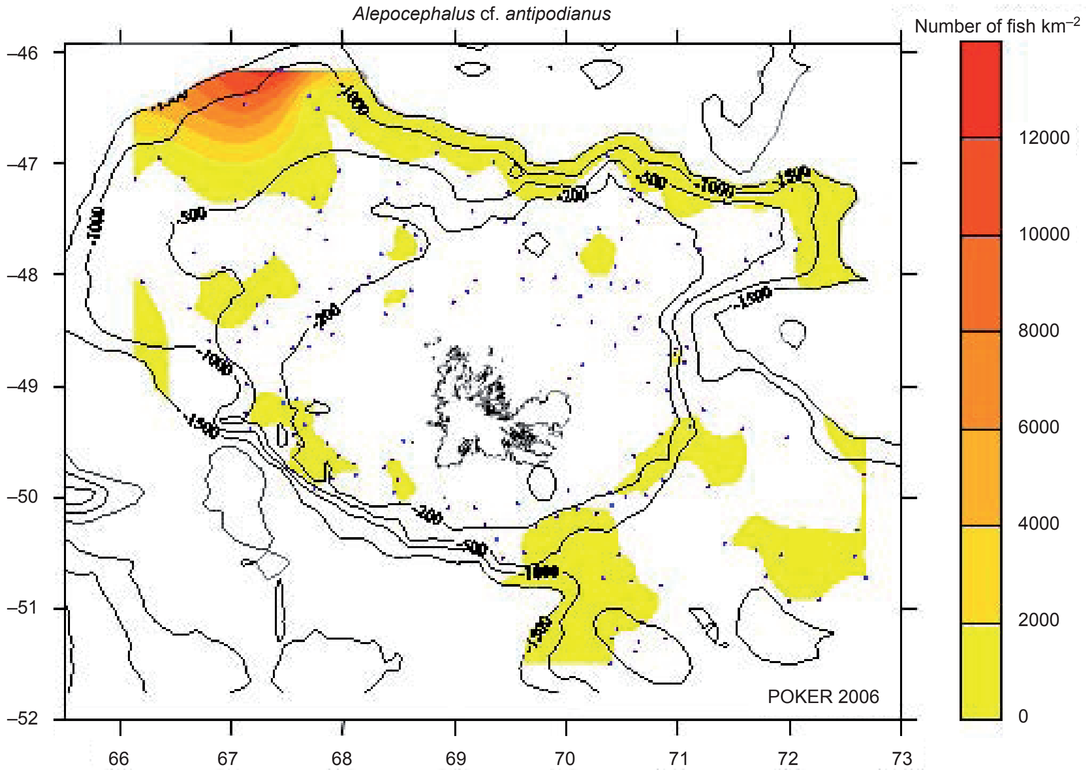
Bigeye grenadier (*Macrourus carinatus*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	0.9	0.6	0.2	9.5
South shelf	0.0	0.0	0.0	0.1
North deep sea	8.1	2.5	4.5	18.5
South deep sea	6.2	2.1	3.2	15.6
Skiff Bank	ns	ns	ns	ns
Skiff deep sea	ns	ns	ns	ns

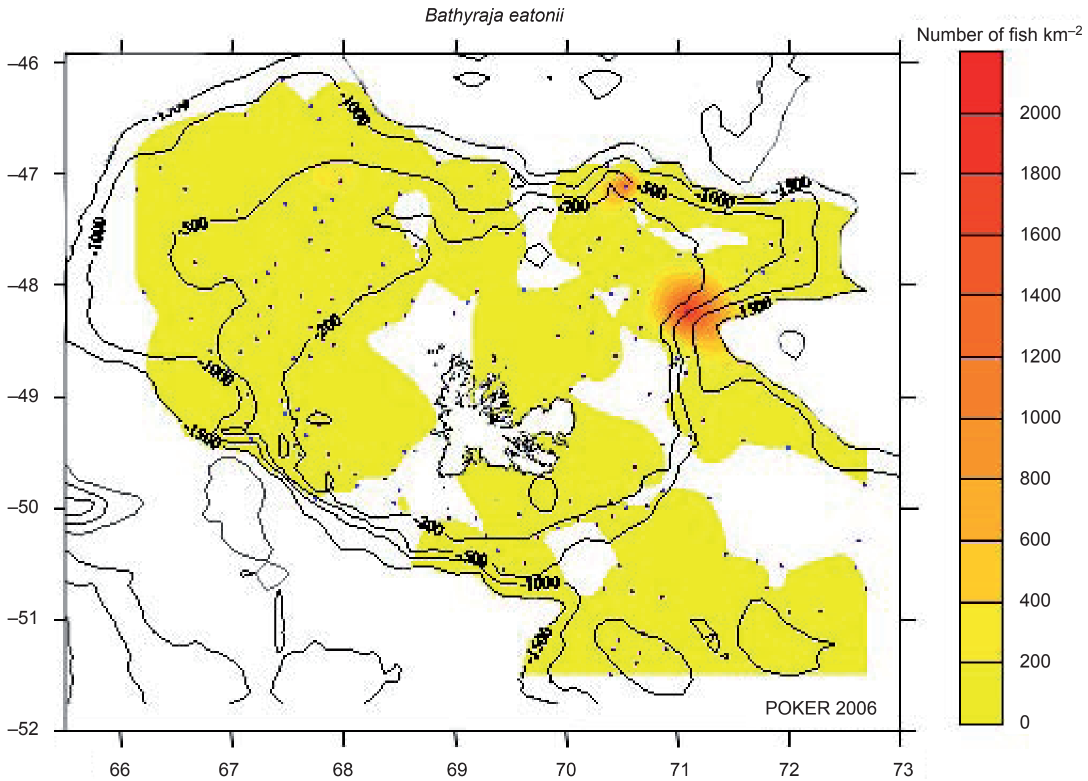
Unicorn icefish (*Channichthys rhinoceratus*)				
	Abundance (millions of fish)	SE	Confidence interval	
			Lower limit	Upper limit
North shelf	222.8	36.9	164.7	324.4
South shelf	32.5	6.3	22.9	51.,6
North deep sea	2.7	0.9	1.4	6.5
South deep sea	5.9	3.6	1.6	54.5
Skiff Bank	2.6	1.1	1.2	10.2
Skiff deep sea	0.1	0.1	0.0	0.2

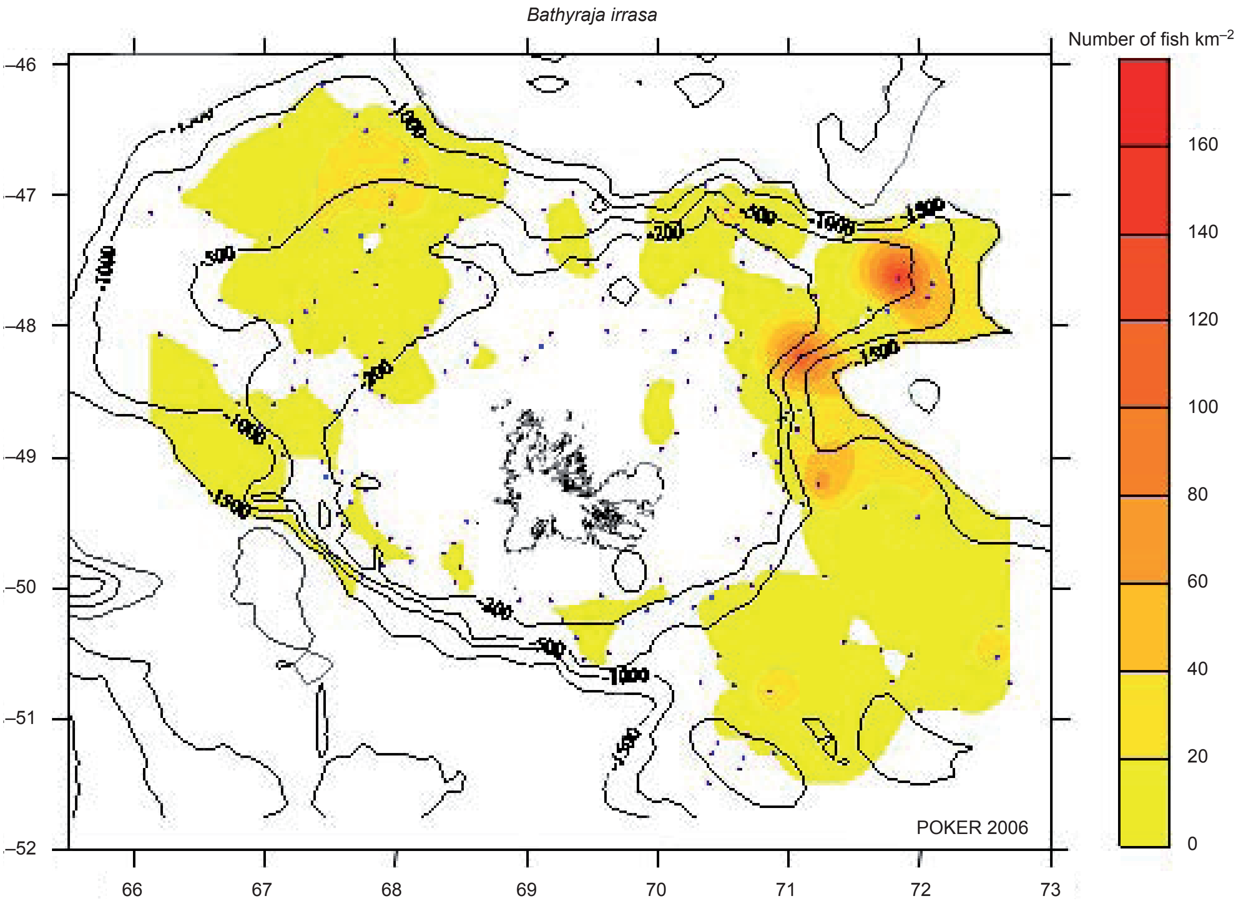
Appendix 5

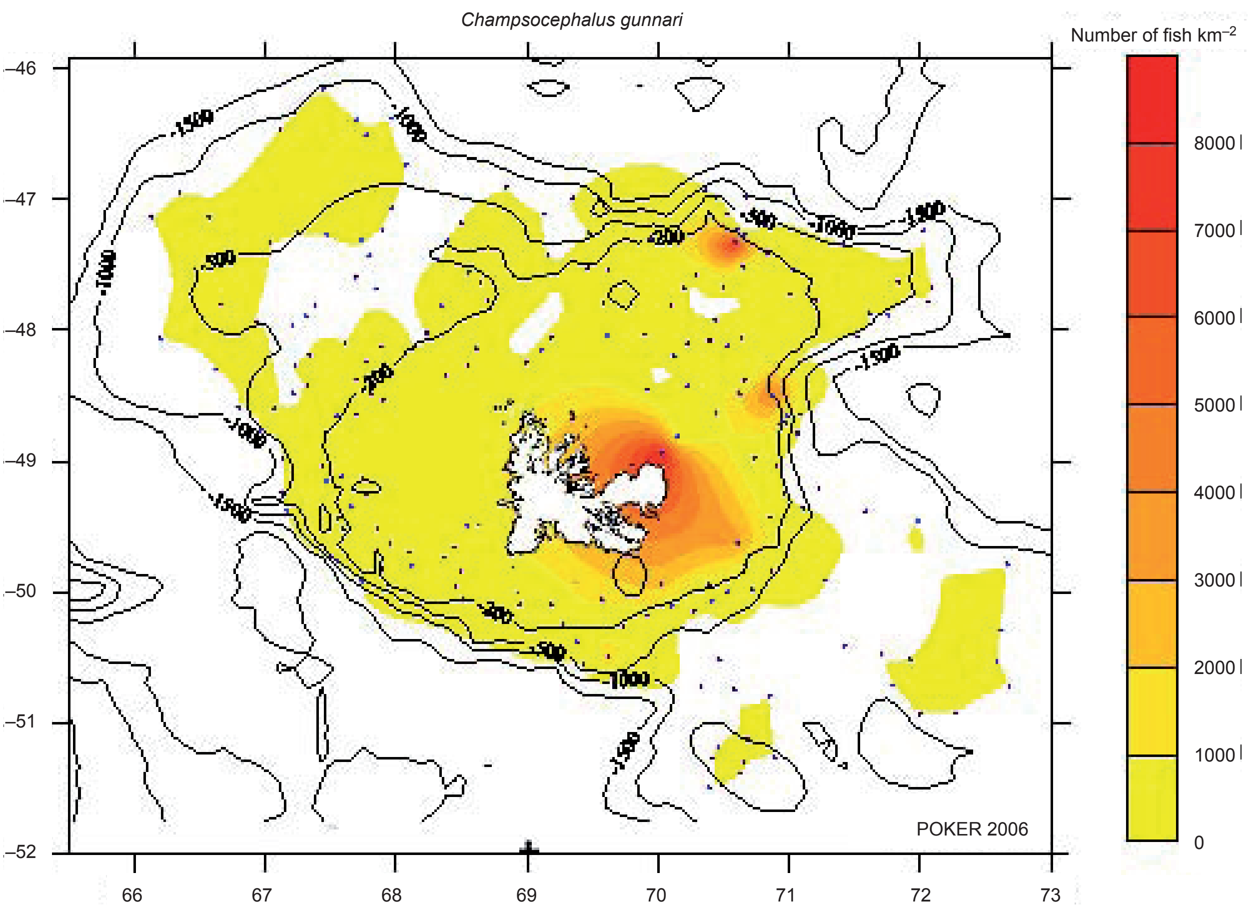
Geographic and bathymetric distribution of abundances (number of fish km^{-2}) of eight commercial fish species and some other by-catch species (*A.* cf. *antipodianus, Z. spinifer* and *E.* cf. *granulosus*) during the POKER 2006 survey

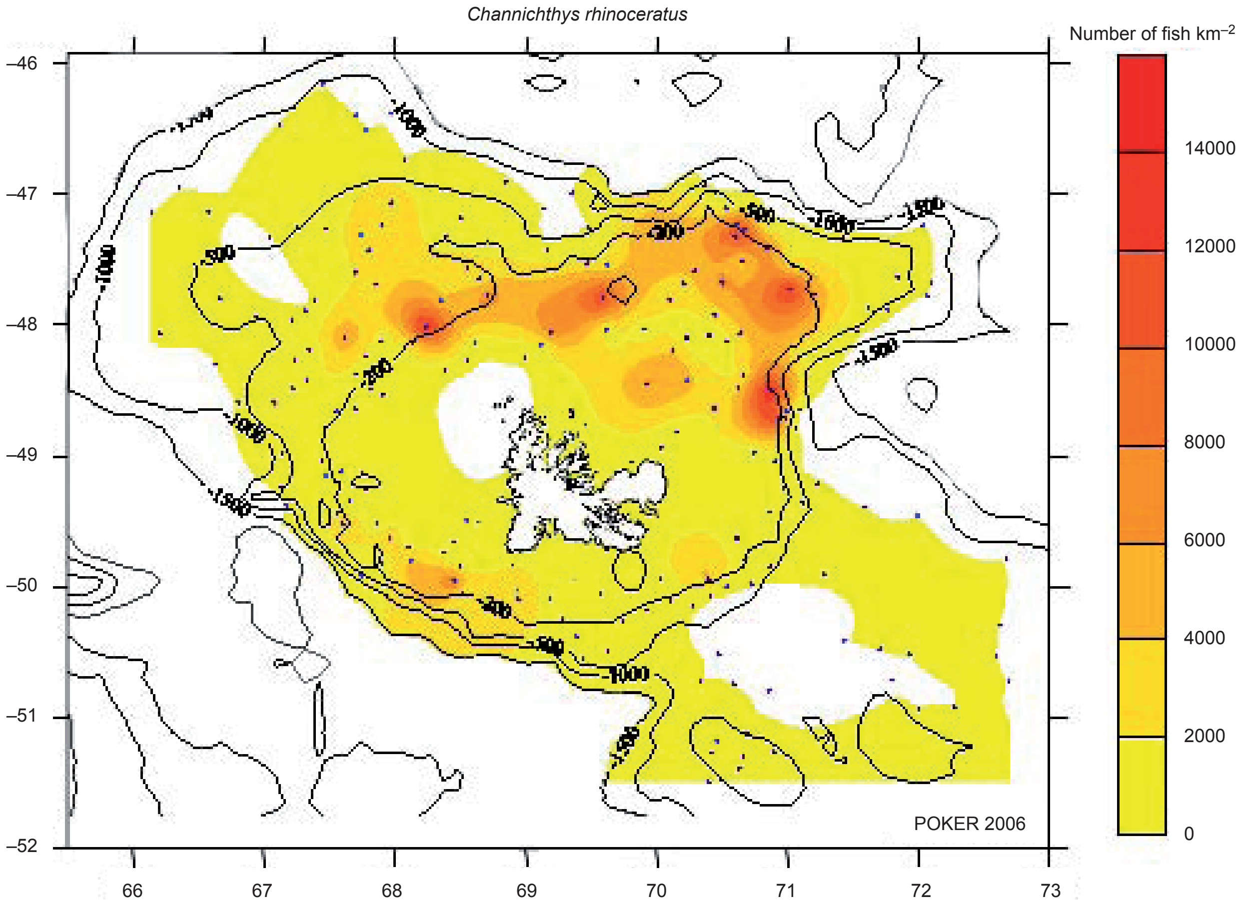
(NB: scales are different between species and do not consider the data over 1 000 m isobath; y-axis : latitude = south, x-axis: longitude = east)

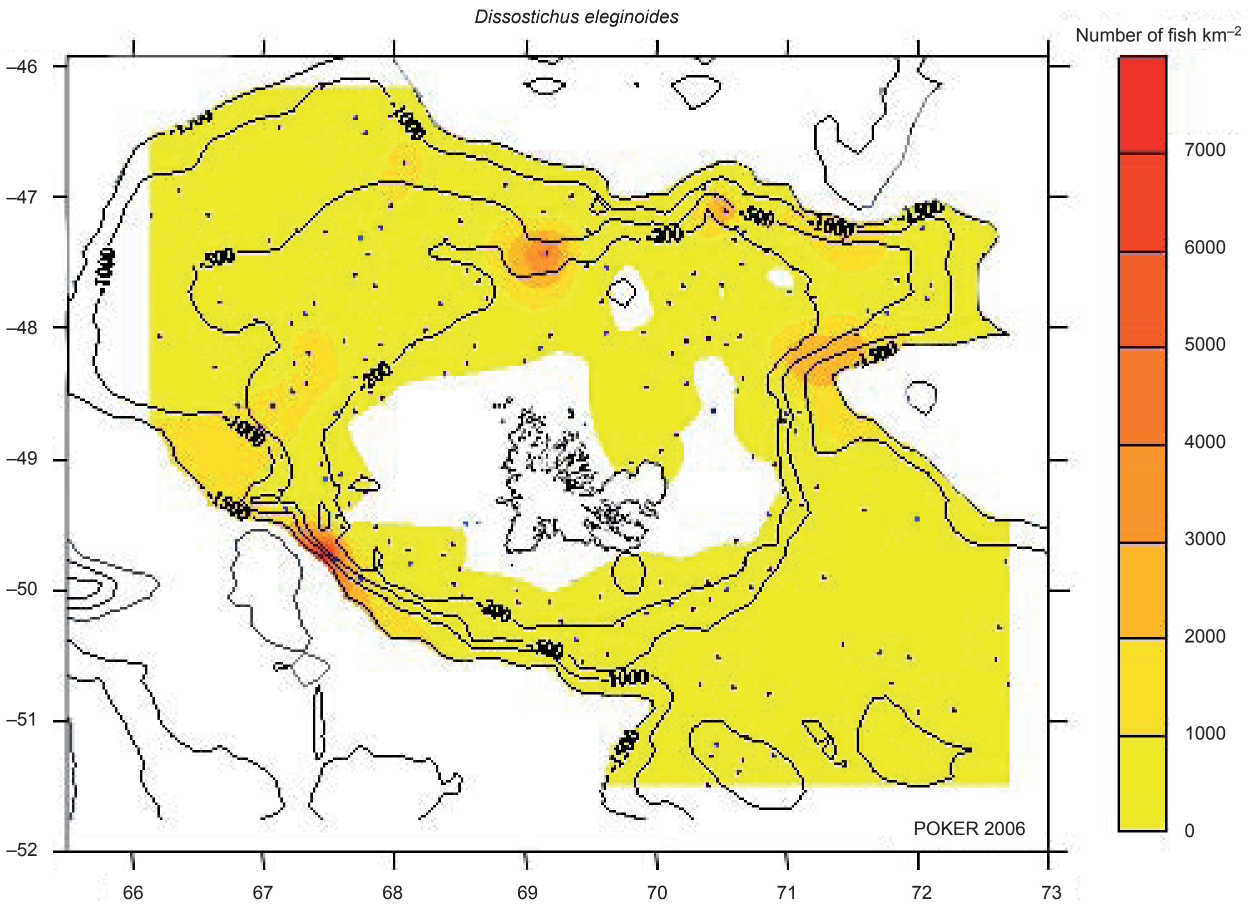


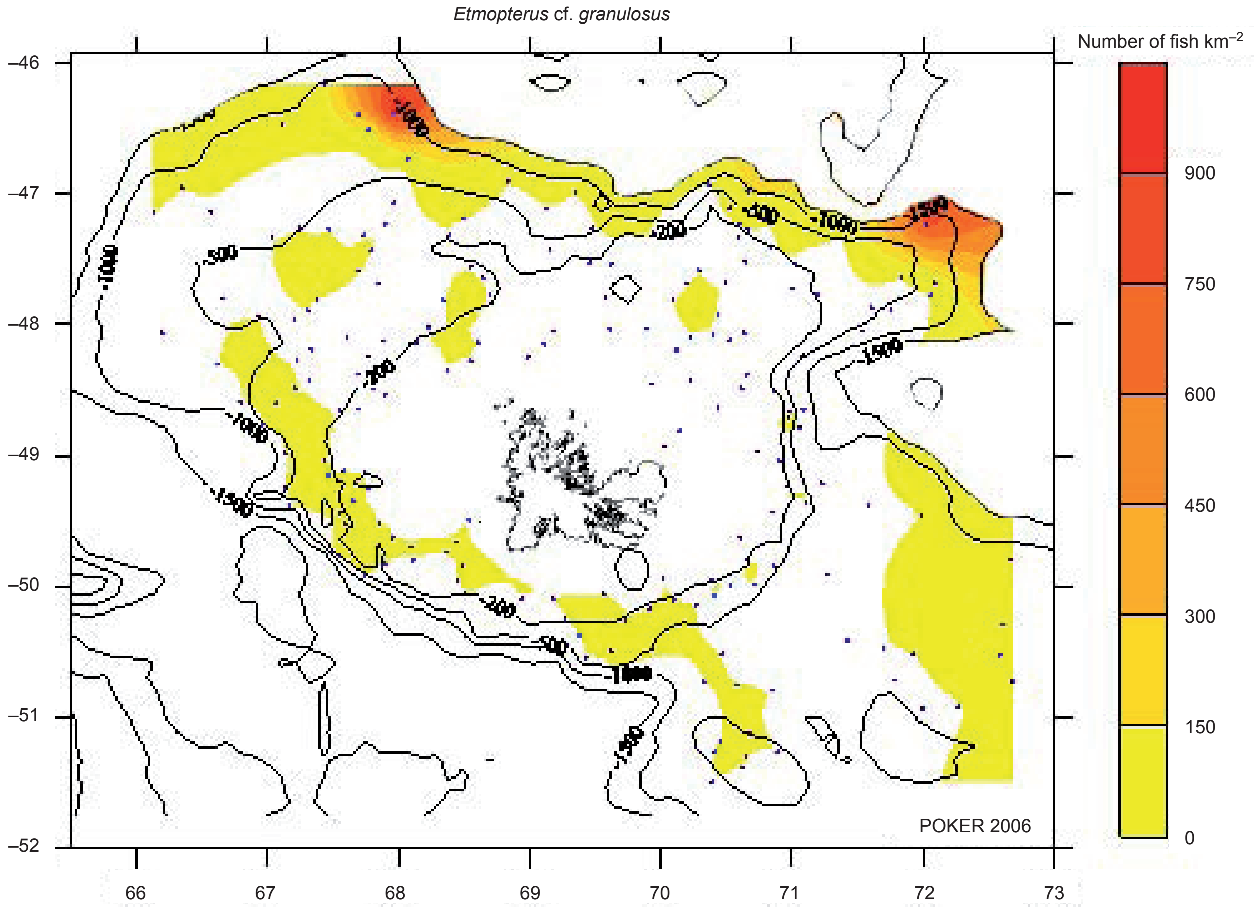



Bathyraja irrasa
Number of fish km⁻²
160
140
120
100
80
60
40
20
0
POKER 2006
-46
-47
-48
-49
-50
-51
-52
66
67
68
69
70
71
72
73

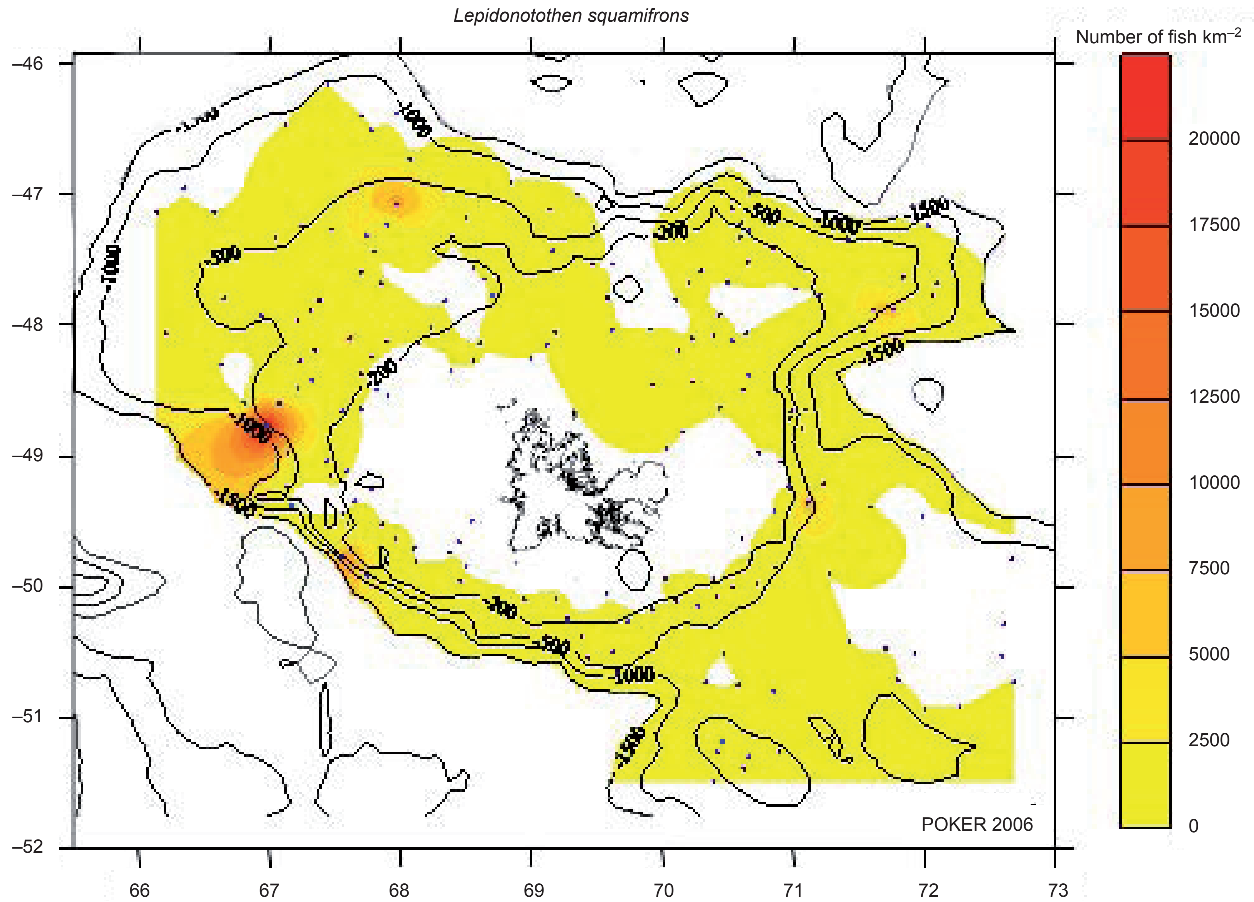

Champsocephalus gunnari
Number of fish km⁻²
8000
7000
6000
5000
4000
3000
2000
1000
0
POKER 2006
-46
-47
-48
-49
-50
-51
-52
66
67
68
69
70
71
72
73


Channichthys rhinoceratus
Number of fish km−2
14000
12000
10000
8000
6000
4000
2000
0
−46
−47
−48
−49
−50
−51
−52
66
67
68
69
70
71
72
73
POKER 2006

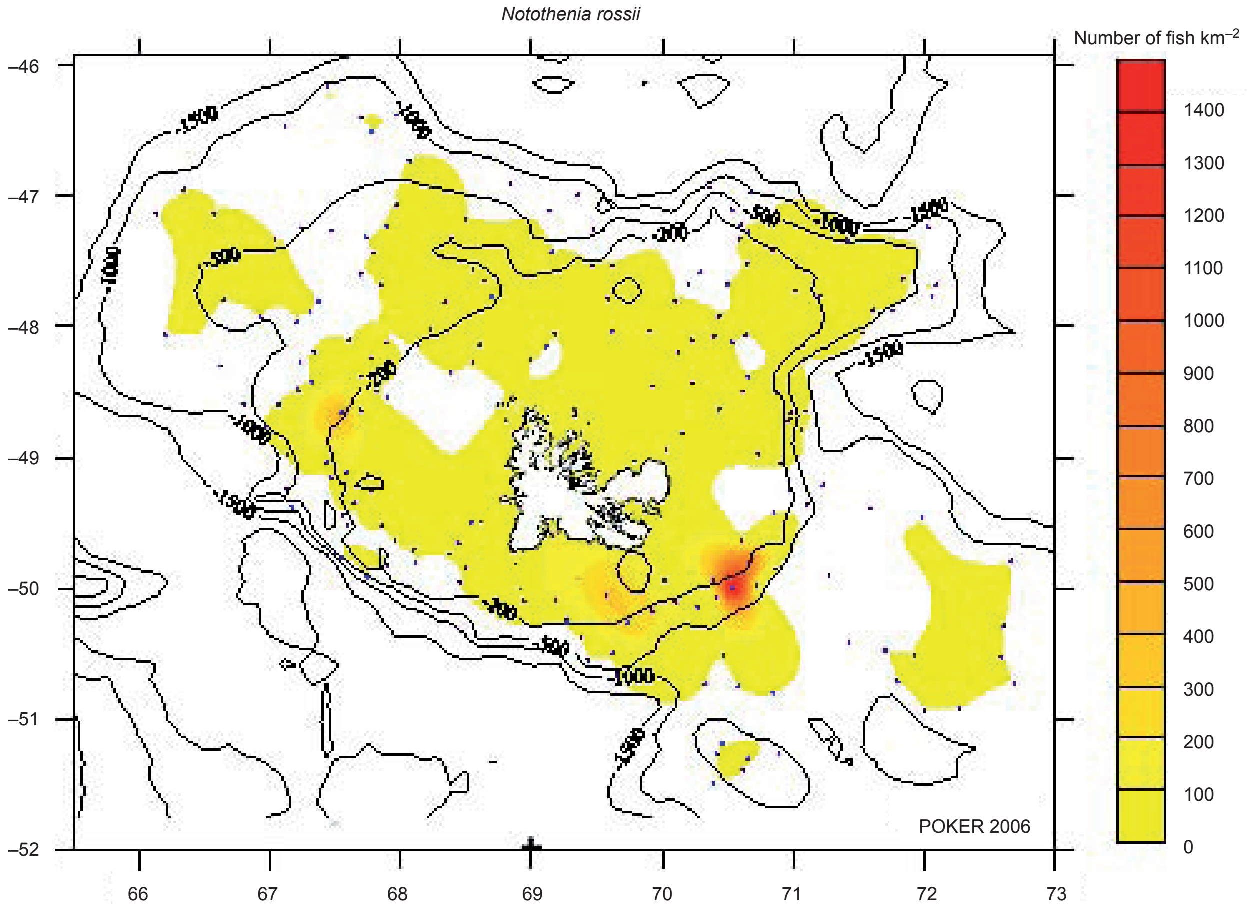

Dissostichus eleginoides
Number of fish km−2
7000
6000
5000
4000
3000
2000
1000
0
−46
−47
−48
−49
−50
−51
−52
66
67
68
69
70
71
72
73
POKER 2006

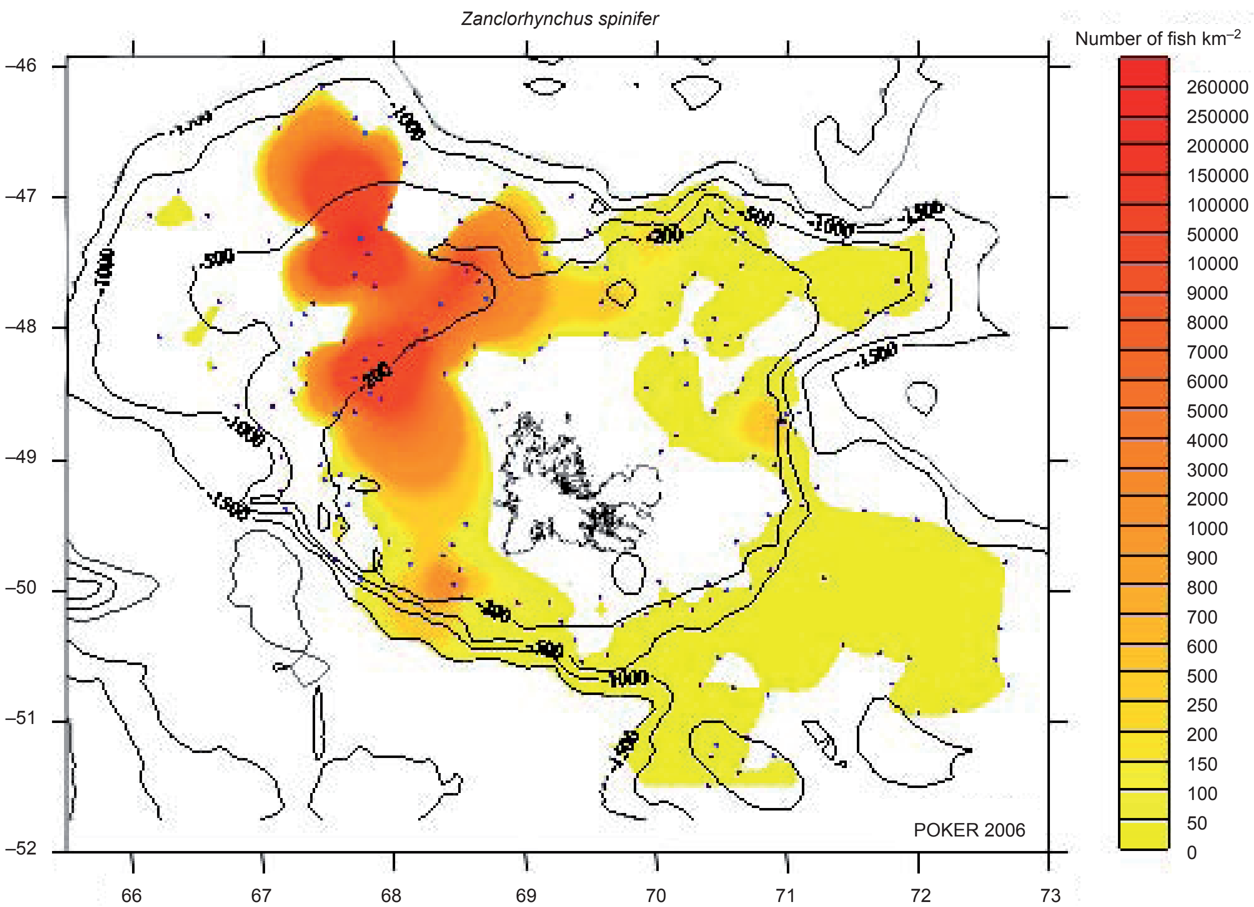


Etmopterus cf. *granulosus*
Number of fish km^{-2}
900
750
600
450
300
150
0
–46
–47
–48
–49
–50
–51
–52
66
67
68
69
70
71
72
73
-200
-500
-1000
-1500
POKER 2006



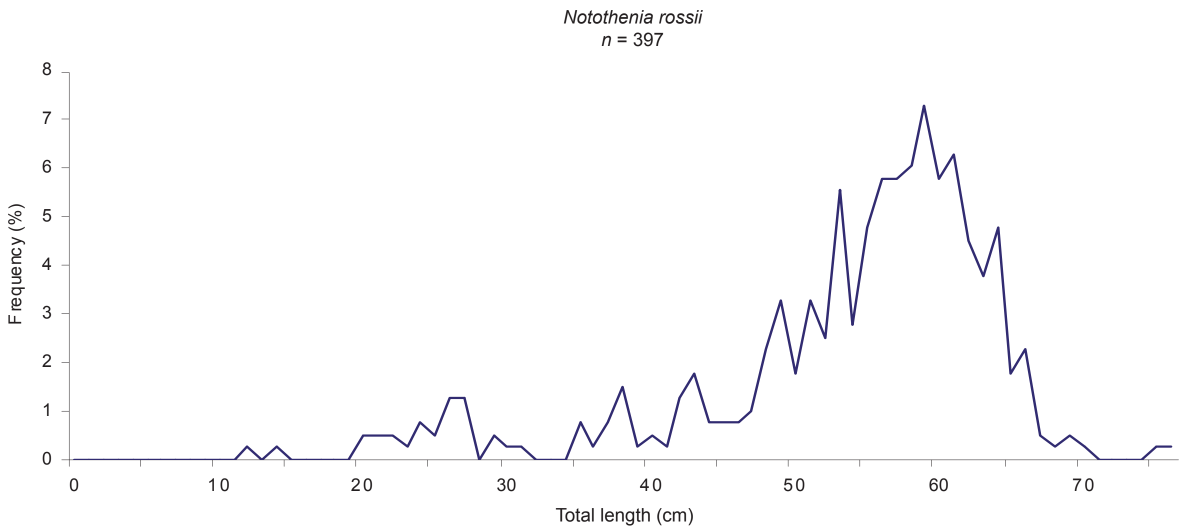
Lepidonotothen squamifrons
Number of fish km^{-2}
20000
17500
15000
12500
10000
7500
5000
2500
0
–46
–47
–48
–49
–50
–51
–52
66
67
68
69
70
71
72
73
-200
-500
-1000
-1500
POKER 2006

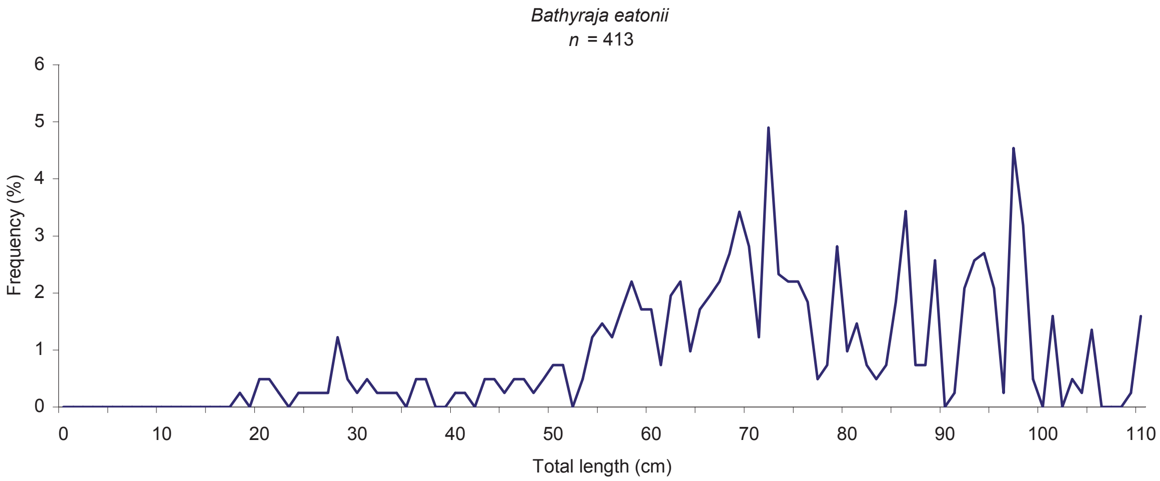

Notothenia rossii
Number of fish km−2
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
−46
−47
−48
−49
−50
−51
−52
66
67
68
69
70
71
72
73
POKER 2006

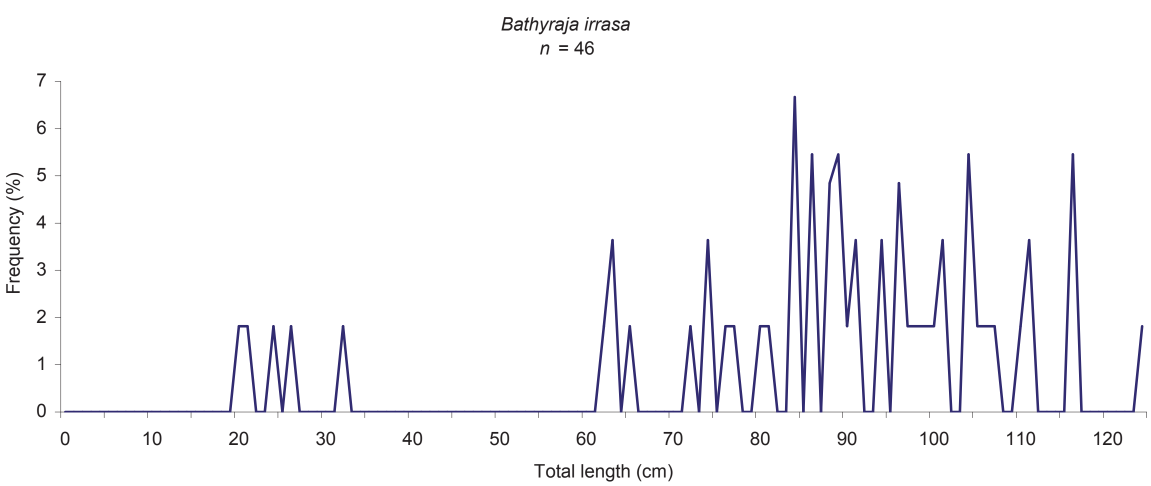

Zanclorhynchus spinifer
Number of fish km−2
260000
250000
200000
150000
100000
50000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
250
200
150
100
50
0
−46
−47
−48
−49
−50
−51
−52
66
67
68
69
70
71
72
73
POKER 2006

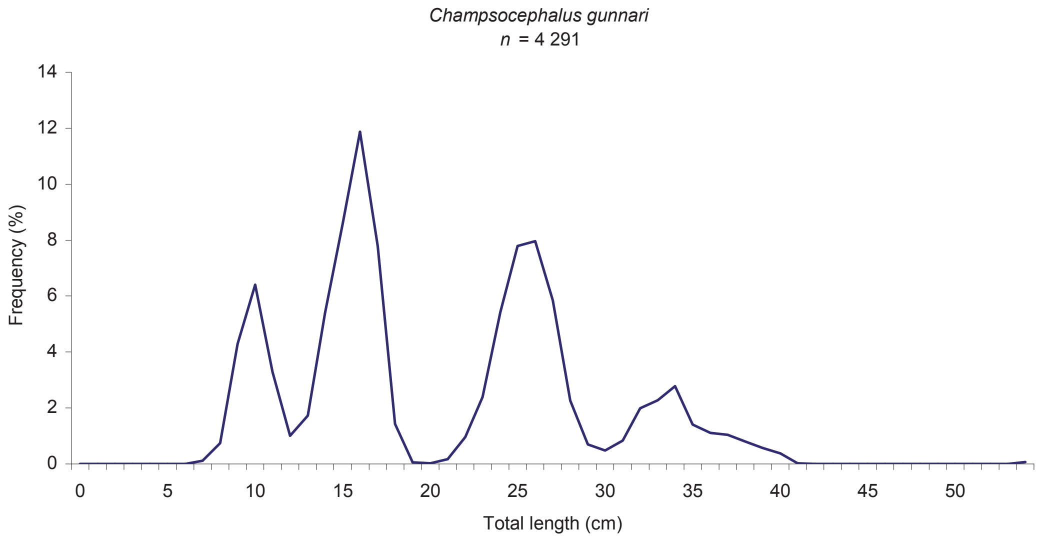
Appendix 6

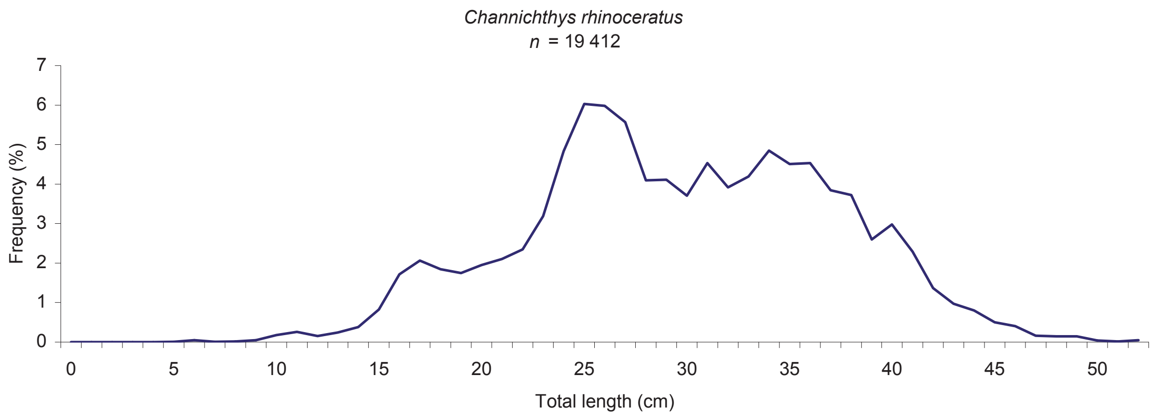
Length-frequency distributions for eight commercial fish species during the POKER 2006 survey (September–October 2006)

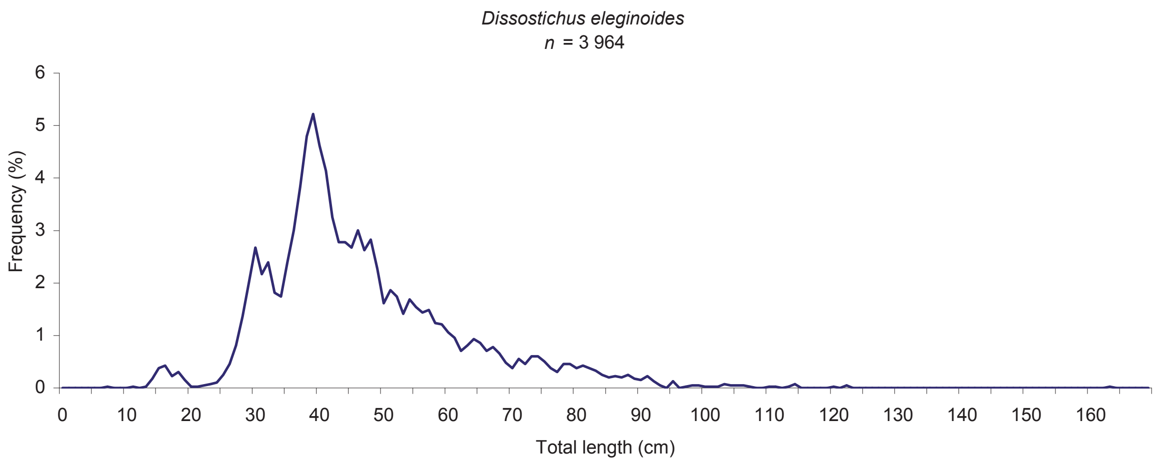


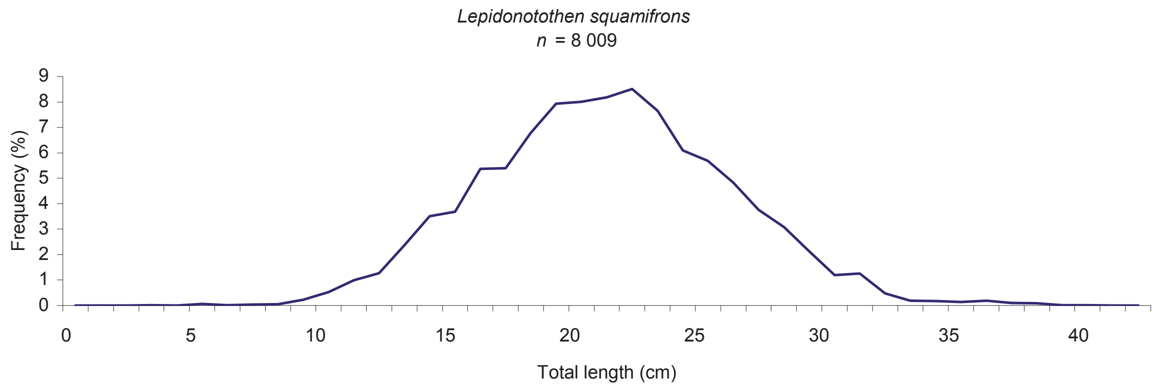


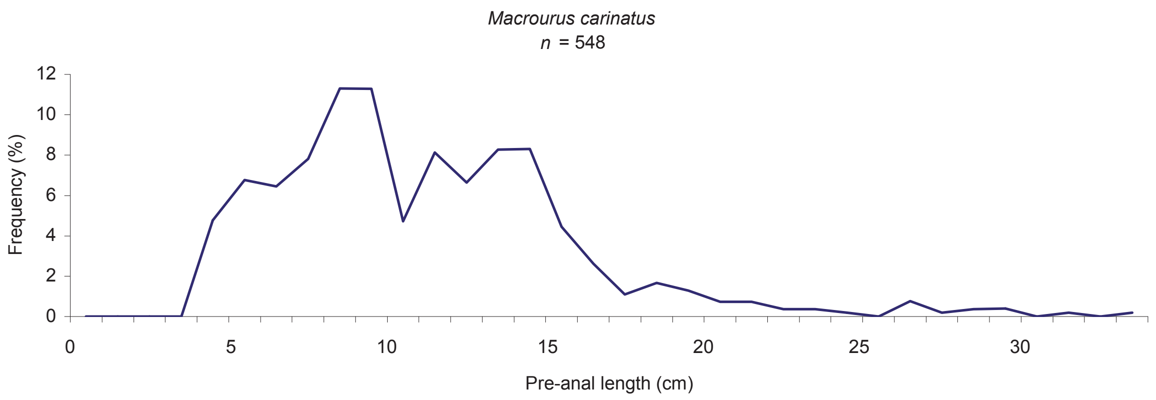



Champsocephalus gunnari
n = 4 291
Frequency (%)
Total length (cm)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40
45
50


Channichthys rhinoceratus
n = 19 412
Frequency (%)
Total length (cm)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40
45
50

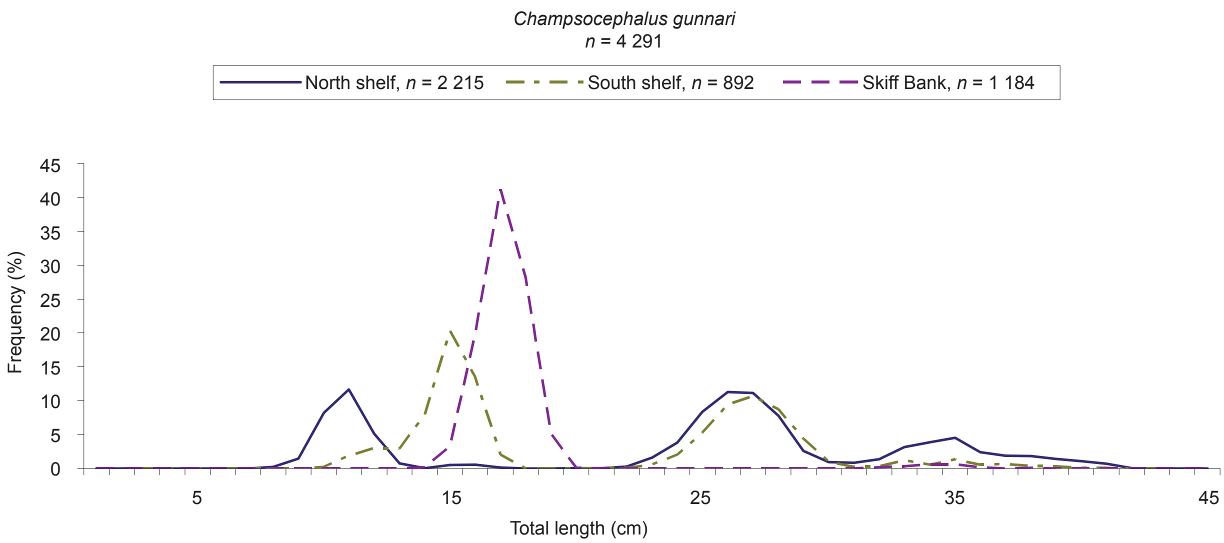

Dissostichus eleginoides
n = 3 964
Frequency (%)
Total length (cm)
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160





APPENDIX 7

Length-frequency distributions obtained in each stratum for *Champsocephalus gunnari* during the POKER 2006 survey (September–October 2006)



Appendix 8

Length-frequency distributions obtained in each stratum for *Dissostichus eleginoides* during the POKER 2006 survey (September–October 2006)