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CHANGES IN THE FISH BIOMASS AROUND ELEPHANT ISLAND (SUBAREA 48.1) FROM 1976 TO 1996

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Abstract

Finfish stocks in the Antarctic Peninsula region (Subarea 48.1) were exploited from 1978/79 to 1988/89, with most of the commercial harvesting taking place in the first two years of the fishery. Results of bottom trawl surveys conducted by Germany in the vicinity of Elephant Island in the 1980s showed that stocks of *Champsocephalus gunnari, Notothenia rossii, Gobionotothen gibberifrons* and *Chaenocephalus aceratus* have been considerably affected by fishing. Stocks of *G. gibberifrons* and *C. aceratus* had apparently recovered to a large extent by the second half of the 1980s, while *C. gunnari* stocks remained at a low level. The status of *N. rossii* is still unclear, although some recovery was apparent from length compositions obtained in the 1980s. The Antarctic Peninsula region was closed for finfishing from 1989/90 onwards. Results of the first bottom trawl survey carried out after the closure of the area in November/December 1996 suggested that the biomass of the standing stock of finfish may have further declined. Given the low abundance of *C. gunnari* and other species and the difficulties encountered in managing fisheries which exploit mixed-species assemblages, there appears to be little prospect at present of re-opening the fishery around Elephant Island.

Résumé

Les stocks de poissons de la région de la péninsule antarctique (sous-zone 48.1) ont été exploités de 1978/79 à 1988/89, mais c'est au cours des deux premières années qu'ont eu lieu les principales activités de pêche commerciale. Les résultats des campagnes d'évaluation par chalutages de fond menées par l'Allemagne aux alentours de l'île Éléphant dans les années 80 indiquent que les stocks de *Champsocephalus gunnari, Notothenia rossii, Gobionotothen gibberifrons* et *Chaenocephalus aceratus* ont été considérablement affectés par la pêche. Les stocks de *G. gibberifrons* et de *C. aceratus* semblaient avoir en grande partie récupéré vers 1985, alors que le niveau de ceux de *C. gunnari* est resté faible. L'état de *N. rossii* n'est toujours pas déterminé, bien que les compositions en longueurs obtenues dans les années 80 laissent supposer une certaine récupération. La région de la péninsule antarctique est fermée à la pêche depuis 1989/90. La première campagne d'évaluation par chalutages de fond après la fermeture du secteur fut réalisée en novembre/décembre 1996. Ses résultats semblent indiquer que la biomasse du stock existant pourrait avoir encore baissé. Vu la faible abondance de *C. gunnari* et d'autres espèces, et les difficultés associées à la gestion des pêcheries qui exploitent des assemblages multispécifiques, il semble peu probable à l'heure actuelle qu'une réouverture de la pêcherie autour de l'île Éléphant puisse être envisagée.

Резюме

Промысел плавниковых рыб в районе Антарктического полуострова (Подрайон 48.1) осуществлялся с 1978/79 по 1988/89 г., при этом наиболее интенсивный коммерческий лов проводился в первые два года этого периода. Германские донно-траловые съемки, выполненные в районе о-ва Мордвинова в течение 1980-х годов, выявили, что промысел существенно сказался на запасах *Champsocephalus gunnari*, *Notothenia rossii*, *Gobionotothen gibberifrons* и *Chaenocephalus aceratus*. Ко второй половине 1980-х годов запасы *G. gibberifrons* и *C. aceratus*, по-видимому, в большой степени восстановились, в то время как запасы *C. gunnari* оставались на низком уровне. Состояние вида *N. rossii* все еще неясно, хотя данные по размерному составу, полученные в 1980-е годы, указывают на некоторое увеличение численности. Промысел плавниковых рыб в районе Антарктического полуострова закрыт с 1989/90 г. Результаты первой донно-траловой съемки, проведенной после закрытия данного района в ноябре-декабре 1996 г., говорят о возможности дальнейшего сокращения биомассы запаса плавниковых рыб. Если учесть низкую численность *C. gunnari* и других видов, а также трудности, связанные с управлением промыслом более одного вида, то в настоящее время представляется нецелесообразным вновь открыть промысел у о-ва Мордвинова.

Resumen

Los stocks de peces en la región de la Península Antártica (Subárea 48.1) fueron explotados desde 1978/79 a 1988/89 y la mayor parte de las extracciones comerciales se llevaron a cabo en los dos primeros años de la pesquería. Los resultados de prospecciones de arrastres de fondo efectuadas por Alemania en los alrededores de la isla Elefante en los años 80 demostraron que los stocks de *Champsocephalus gunnari, Notothenia rossii, Gobionotothen gibberifrons* y *Chaenocephalus aceratus* han sido muy afectados por la pesca. Parece ser que a fines de los años 80, los stocks de *G. gibberifrons* y *C. aceratus* ya se habían recuperado en gran parte, pero los niveles del stock de *C. gunnari* permanecieron bajos. Aún no se sabe con exactitud cuál es el estado del stock de *N. rossii*, aunque se observó una cierta recuperación en las composiciones por talla obtenidas en la década del 80. En 1989/90 se declaró una veda indefinida a la pesca de peces en la región de la Península Antártica. Los resultados de la primera prospección de arrastre efectuada desde el cierre del área a la pesca, que se llevó a cabo en noviembre/diciembre de 1996, indican que la biomasa instantánea de los stocks de peces aparentemente ha continuado disminuyendo. La reapertura de las pesquerías alrededor de isla Elefante no parece ser una opción productiva por ahora, en consideración a la escasa abundancia de *C. gunnari* y de otras especies, y a las dificultades experimentadas al intentar la ordenación de pesquerías que explotan conjuntos de especies mixtas.

Keywords: stock biomass, finfish, trawl surveys, Subarea 48.1, CCAMLR

INTRODUCTION

Fish stocks in the vicinity of the South Shetland Islands and the neighbouring Antarctic Peninsula (Statistical Subarea 48.1) were exploited by trawling from 1978/79 to 1988/89, with most of the harvesting occurring in the first two years of the fishery (reviews in Kock, 1991, 1992; Agnew and Nicol, 1996). The main fishing grounds on the South Shetland Island shelf were located on the western and northwestern part of the shelf of Elephant Island and north of King George Island (*inter alia* Sosinski, 1981). The main target species in Subarea 48.1 were mackerel icefish (*Champsocephalus gunnari*) and spiny icefish (*Chaenodraco wilsoni*) in 1978/79, and marbled notothenia (*Notothenia rossii*) in 1979/80 (Agnew and Nicol, 1996; Table 1). Most of the catches of *C. gunnari* and probably all catches of *N. rossii* were taken on the northern and western parts of the Elephant Island shelf, while *C. wilsoni* was only exploited on a localised fishing ground northeast of Joinville Island at the tip of the Antarctic Peninsula. By-catch species reported were bumphead notothenia (*Gobionotothen gibberifrons*), Scotia Sea icefish (*Chaenocephalus aceratus*) and ocellated icefish (*Chionodraco rastrospinosus*) (CCAMLR, 1990). From 1980/81 onwards, catches declined considerably (Agnew and Nicol, 1996; Table 1). The area was closed for finfishing by CCAMLR from 1989/90. In 1997, CCAMLR modified this closure to the extent that trawling in waters shallower than 600 m remained prohibited, while longlining on Antarctic toothfish (*Dissostichus mawsoni*) in waters deeper than 600 m was allowed on an exploratory basis (CCAMLR, 1997).

Since 1975/76, the Institute for Sea Fisheries of the Federal Research Centre for Fisheries in Hamburg, Germany has conducted investigations on the species composition, stock structure, demography, dynamics and ecology of coastal fish species on the shelf (<500 m) of Elephant Island (*inter alia* Kock, 1986, 1989a; Nast et al., 1988; Tiedtke and Kock, 1989; Gröhsler, 1992) (Table 2). The first survey to be carried out after the closure of the fishery was conducted in November/December 1996 (Table 2). Biomass estimates and length compositions for the most abundant species are presented for the 1996/97 season. These are compared with findings from previous surveys and are discussed with a view to a possible re-opening of the fishery in the area.

MATERIAL AND METHODS

The analysis was primarily based on catch compositions (in weight and numbers) of 175 bottom trawl hauls conducted during six surveys of FRV *Walther Herwig* and RV *Polarstern* on the shelf around Elephant Island at depths of 50 to 550 m from 1981 to 1996 (Table 2). The surveys were based on a random stratified survey design. Stratification of the area was by depth, with the following depth intervals being designated as strata: 0–100 m, 101–200 m, 201–300 m, 301–400 m and 401–500 m. Areas of seabed within a stratum were taken from Kock and Harm (1995). All trawl sites were selected randomly but restricted to areas where trawling conditions were known to be moderate or good. The number of hauls allocated to each stratum was proportional to its area, and from 1985 also weighted by the fish abundance in each stratum known from the surveys in 1981 and 1983, i.e. more hauls were allocated to strata in the depth range 100 to 400 m where fish were more abundant than in the remaining two strata.

Trawl sites in 1986, 1987 and 1996 were, in essence, repeats of those sampled in 1985 in order to reduce damage to the trawl gear. There is a danger, when successive surveys use the same sampling sites, of the results being biased if the fish distribution shows a consistent year-to-year pattern (Williams and de la Mare, 1995). However, due to the often rough weather conditions and variation in the time needed to deploy the trawl, repeated sites were often only within 1 or 2 n miles of the original sites which balanced this effect to some extent. Furthermore, five to eight new locations were used during each of these surveys. Trawl sites of the 1996 survey are shown in Figure 1.

The fishing gear used consisted of 140-ft (*Polarstern*) and 200-ft (*Walther Herwig*) bottom trawls. We did not have the benefit of *in situ* trawl monitoring equipment (see Williams and de la Mare, 1995; Pilling and Parkes, 1995). However, it was known from previous experiments (Kroeger and Kock, 1982) that the net geometry of the two trawls showed comparatively little variation (<7%, but mostly less) in the course of a tow at a towing speed of approximately 4 knots. Mean horizontal openings between the wingtips were 22 m and 23.5 m and mean vertical openings were 3 m and 5.5 m for the 140 ft and the 200 ft trawl respectively. The codends were equipped with 20 mm (diamond) mesh liners. The ground gear of both kinds of nets was mounted with 22″ steel bobbins. Polyvalent doors of 4.5 m^2 were used for both kinds of nets. The rigging of trawl and ground gear was kept constant over all surveys. The warp/fishing depth ratio was kept at approximately 3:1.

The duration of each haul was 30 minutes, except when, as happened on several occasions during each survey, the net was hauled earlier due to rough grounds. Hauls during which the trawl spent less than 15 minutes on the sea floor were not considered. Towing speed was approximately 4 knots. GPS positions (in 1981 only SATNAV positions) were recorded when the net was on the bottom and when it left the bottom. From these, the distance travelled by the net over the bottom was calculated. Mean mouth opening of the net multiplied by the towing distance gave the area swept. Net selection should have been negligible due to the use of small-meshed liners. No information was available to estimate the catchability factor c. A catching efficiency of 100% (i.e. c = 1) has therefore been adopted as a conservative approach. More details on each of the surveys carried out prior to 1996, fishing gear used and maps showing the location of fishing stations are provided in Kock (1982, 1986, 1989b).

Length compositions (TL, cm below) of the most abundant species from three bottom trawl surveys of the chartered trawlers *Weser* and *Julius Fock* in 1976 and 1978 and of the *Walther Herwig* in 1978 (Table 2) were taken into account. Information from these surveys was not used to calculate biomass estimates due to the non-random distribution of hauls of the chartered trawlers and the low number of hauls of the *Walther Herwig*.

Standing stock biomass of the most abundant species was estimated from catch-per-haul information using the minimum variance unbiased estimators (Pennington, 1983) of biomass for each stratum and cruise. Confidence intervals were calculated using de la Mare's method (1994). All length measurements, if not otherwise stated, are to the nearest centimetre below. For length measurements (total length to the nearest centimetre below), a representative subsample of at least 200 specimens of each species was selected from each haul or, if less than 200 specimens were present, the entire catch of a species was used.

RESULTS

Eight species were sufficiently abundant to warrant a detailed study: *C. gunnari, N. rossii, G. gibberifrons, C. aceratus* and *C. rastrospinosus* had been either target or by-catch species in the commercial fishery. The small-sized *Lepidonotothen larseni* is a ubiquitous species around Elephant Island. *Lepidonotothen squamifrons* had been exploited on the deeper shelf of the Kerguelen Islands and, to a much lesser extent, also on the deeper shelf of South Georgia (Duhamel and Hureau, 1990; Kock, 1991). *D. mawsoni* has recently become the target of an exploratory fishery in the Peninsula region. Biomass estimates for these species are provided in Tables 3 to 10. Two main features are apparent:

- biomass estimates for most species were lower in 1981 and 1985 when a 200-ft bottom trawl was used; and
- most species showed a notable decline in biomass between the last two surveys in 1987 and 1996.

Mackerel icefish (*C. gunnari*)

Mean densities of *C. gunnari* were similar in the three depth strata between 101 and 400 m. These strata were therefore combined for analysis. Biomass estimates from 1981 to 1996 varied between 683 (1981) and 2 049 tonnes (1987) (Table 3). Length-frequency distributions obtained during the surveys exhibited considerable year-to-year variation (Figure 2). Length compositions for 1976 and 1978, which were obtained during two exploratory fishing cruises carried out by two chartered trawlers (Table 2) in a limited area on the northwestern shelf of the island, showed the predominance of the 1973 year class; fish from this year class were 20 to 25 cm long in January/February 1976 and 30 to 37 cm in January-February 1978 (Figure 2). This year class formed the backbone of the fishery in the subsequent season (Kock, 1991). Fish from this cohort had already been, for the most part, fished out when our survey took place in March 1981.

Individuals of 20 to 28 cm in length accounted for most of the catches during the 1981 survey. They were still present in similar numbers two years later (Figure 2), but had virtually disappeared in 1985. A similar picture was apparent from 1985 to 1987 when fish which were 24 to 28 cm in 1985 were almost non-existent during our survey in 1987 (Figure 2). The length composition for 1987 was considerably skewed by a single large catch of about 37 000 one-year-old fish (11–13 cm long). The length-frequency distribution obtained in 1996 was similar to those observed in 1985 and 1986 (Figure 2).

Marbled notothenia (*N. rossii*)

Mean densities of *N. rossii* were similar in each of the two strata in the 51 to 200 m depth range and in the two strata in the 201 to 400 m depth range. They were therefore combined to one stratum each for the analysis. The greater part of the biomass was found in the 201 to 400 m depth range (Table 4). Biomass estimates from 1981 to 1996 varied between 32 (1996) and 4 500 tonnes (1986) (Table 4). Catches of *N. rossii* during the surveys consisted of only a few fish in most hauls and, on a few occasions, of several hundred kilograms to more than one tonne of fish. This pattern of catches confirms observations from other areas, such as South Georgia, that the species has a very patchy distribution (e.g. Kock, 1986 – Figure 5). As a consequence, biomass estimates were very low during surveys when no concentrations of *N. rossii* were encountered, such as those of 1983 and 1996 (Table 4). Biomass estimates for this species should therefore be viewed with considerable caution.

The stock was unfished in 1976 when dense aggregations of the species were found during exploratory fishing in a very localised area on the northwestern shelf of the island. Such aggregations were still present in the same location during a second exploratory cruise in 1978, when the biomass of the stock was estimated to be 15 600 tonnes (Kock, 1991). The majority of fish were 40 to 70 cm long (Figure 3) and up to 15 age classes were present in the stock (Kock, 1991 – Figure 30). These aggregations were apparently exploited by Soviet fishing vessels in 1979/80 when a catch of 18 760 tonnes was reported (Table 1). No concentrations of fish were found during the West German survey in 1981, and fish larger than 45 cm had almost disappeared from the stock (Figure 3). Age classes 5 and 6 were the predominant age classes in the stock (Kock, 1991 – Figure 30). After this, the proportion of larger (older) fish increased slowly from 1985 to 1987 when the majority of the stock was made up of fish of 40 to 60 cm in length, (Figure 3) which were 5 to 8 years old (Kock, 1991 – Figure 30). No representative length composition was available for 1996 when only individual fish were caught (Figure 3).

Bumphead notothenia (*G. gibberifrons*)

Mean densities of *G. gibberifrons* were similar in the three depth strata from 101 to 400 m. These strata were therefore combined for the analysis. *G. gibberifrons* was by far the most abundant species in terms of biomass from 1981 to 1996 (Table 5), with biomass estimates varying from 5 000 tonnes in 1996 to 50 785 tonnes in 1986. The 1986 estimate is likely to be biased upwards for several reasons. The species had a more patchy distribution at the time of the survey (May/June) than in other years. The main cause of this patchy distribution was probably the formation of prespawning aggregations. Eight of these aggregations of fish in prespawning condition was encountered during the survey in 1986 yielding catches of 0.6 to 4.7 tonnes. The 1986 survey was the only survey during which a substantial proportion of the biomass of *G. gibberifrons* was found in the 401 to 500 m depth range (Table 5).

Length-frequency distributions showed a considerable decline in the abundance of larger fish from 1976 to 1981 (Figure 4). The proportion of larger fish increased considerably again from 1983 onwards. There appeared to be little change in the length composition of the stock from 1985 to 1996 (Figure 4).

Scotia Sea icefish (*C. aceratus*)

Mean densities of *C. aceratus* were similar in the three depth strata from 101 to 400 m. These strata were therefore combined for analysis. Most of the biomass of *C. aceratus* was present in the 101 to 400 m depth range (Table 6). Biomass estimates varied from 768 (1985) to 7 619 tonnes (1986).

No representative length compositions were available for 1976 and 1978. In 1981, one-year-old fish (15–20 cm long) made up a considerable proportion of the fish caught during the survey (Figure 5). The number of large fish in the stock increased considerably from 1983 onwards. The composition of the stock seems to have changed little from 1983 to 1996 with the exception of 1986 when a larger proportion of adult fish (>45 cm) appeared to have been present (Figure 5). Some catches of several hundred kilograms each, consisting of fish in prespawning condition, may have biased the length composition from this survey towards larger (adult) fish.

Ocellated icefish (*C. rastrospinosus*)

C. rastrospinosus was only very rarely found in waters of less than 200 m in depth (Table 7). Its vertical range exceeds 500 m depth (Iwami and Kock, 1990) and is thus only partly covered by our surveys. Mean densities in each of the three strata between 201 and 500 m were very similar and all three strata were therefore combined for the analysis. Biomass estimates were low, exceeding 200 tonnes only in 1987 (Table 7). With the exception of 1987, variation in biomass estimates was low between surveys (Table 7).

Length compositions were available from 1978 to 1996. For four surveys (1981–1986), sample sizes were small and are unlikely to be representative (Figure 6).

Painted notothenia (*L. larseni*)

L. larseni was mostly found at depths greater than 100 m (Table 8). As mean densities were similar in all strata deeper than 100 m, strata were combined for the analysis. Although abundant in terms of numbers, biomass estimates of this small species only exceeded 180 tonnes in 1987 (Table 8).

Length-frequency distributions were available from 1981 onwards. With the exception of 1983, when a considerable proportion (24%) of the fish caught during the survey were 10 cm and less, length compositions were very similar for each of the surveys from 1981 to 1996 (Figure 7).

Grey notothenia (*L. squamifrons*)

This species was only found at depths greater than 200 m. Its vertical range reaches well beyond 500 m in depth (Kock, unpubl.), and was thus only partly covered by our surveys. Mean densities were similar in all strata. Strata were, therefore, combined for the analysis. Biomass estimates ranged from 61 (1983) to 572 tonnes (1985) (Table 9). Length distributions were similar in most years (Figure 8).

Antarctic toothfish (*D. mawsoni*)

This species was more common at depths of over 200 m, although catches were always small and varied in distribution, with more than one or two individuals being only rarely present in a haul. Consequently, biomass estimates resulted in low standing stock estimates, sometimes having wide confidence intervals, underlining the irregular pattern of occurrence (Table 10). All individuals caught, except one of 120 cm in 1986, were juvenile fish (Figure 9).

DISCUSSION AND CONCLUSIONS

Previous biomass estimates of fish stocks around Elephant Island (Kock, 1981, 1986, 1991; Balguerías, 1989; Balguerías et al., 1987) were different from those obtained in this analysis. The differences are mainly due to:

- the refinement of estimates of areas of seabed used in previous analyses by Kock and Balguerías et al. This has led to a substantial reduction of those estimates, particularly for the strata 301–400 m and 401–500 m (Kock and Harm, 1995). Applied to biomass estimates provided in Kock (1986 – Tables 9 and 10), for example, the refinement of the estimates of areas of seabed accounted for a reduction of 29 to 45 % in the biomass estimates dependent on the species;

- the method previously used to calculate mean abundance per stratum (Saville, 1977) and associated *t*-statistics as a basis for confidence interval estimation. This method assumes that catches obtained during the surveys and mean densities per stratum fit a normal distribution, which they do not in almost all cases investigated here. Confidence intervals estimated by de la Mare's method (1994) have a coverage probability much closer to the nominal; and

- the use of a semipelagic trawl during the survey conducted by Balguerías et al. (1987) in the 1986/87 season. When towed on the bottom, a semipelagic trawl has a catching efficiency which is considerably different from that of a bottom trawl. The vertical mouth opening of a semipelagic trawl is higher than in a bottom trawl; however, due to its lighter ground tackle the net is unlikely to stick as closely to the ground as a bottom trawl. As a consequence, the catching efficiency of a semipelagic trawl compared to a bottom trawl tends to be lower for benthic species such as *G. gibberifrons* and *C. aceratus*, but higher for bentho-pelagic species such as *C. gunnari*. This is obvious from Table 46 in Balguerías (1989) which provides biomass estimates for the 1986/87 season of only 2 057 tonnes for *G. gibberifrons* and 274 tonnes for *C. aceratus*, but of 1 962 tonnes for *C. gunnari*.

As a result, biomass estimates provided in this paper are not directly comparable to previous estimates.

For all species, 95% confidence intervals of the biomass estimates overlap for most surveys in the 1980s which suggests that, in addition to actual changes in abundance, sampling variability was a major cause for differences in biomass estimates between surveys. However, biomass estimates obtained during the two *Walther Herwig* surveys in 1981 and 1985 using a 200-ft bottom trawl were outside the lower bound of the biomass estimates derived from *Polarstern* surveys in 1983, 1986 and 1987 which used a 140-ft bottom trawl. This was most obvious for *C. gunnari*, *G. gibberifrons* and *C. aceratus* (Tables 3, 5 and 6). However, with the exception of *C. aceratus*, there is no statistically significant difference between the 1985 survey and the 1983, 1986 and 1987 surveys, since all confidence intervals overlap.

Both trawls use the same type of ground gear with steel bobbins of equal size and have a similar horizontal opening. However, as indicated by the higher vertical opening, the 200-ft trawl is designed to also catch fish some metres above the bottom. It is possible that the 200-ft trawl had a lesser degree of contact with the seabed than had the 140-ft trawl with its much lower vertical opening. As a consequence, the 200-ft trawl may have been less effective in catching fish which sit on the bottom, such as *G. gibberifrons* and *C. aceratus*. It is therefore likely that biomass estimates derived from the two surveys in 1981 and 1985, in which a 200-ft trawl was used, are underestimates of the true standing stock biomass, but the extent of this underestimation is unknown.

Results from our surveys were consistent with the history of exploitation in the area. Large-scale harvesting in the vicinity of Elephant Island was confined to two seasons, 1978/79 and 1979/80, only. Although fishing was continued until the second half of the 1980s, annual catches rarely exceeded 2 000 to 3 000 tonnes (Table 1). Information from the second half of the 1970s collected during two exploratory fishing cruises in 1976 and 1978 combined with survey results from the 1980s provided sufficient evidence to demonstrate the extent to which large-scale exploitation in only two seasons had adversely affected stocks of *C. gunnari*, *N. rossii* and probably also *G. gibberifrons* and *C. aceratus*. A catch of 35 930 tonnes of *C. gunnari* in two seasons, largely based on the 1973 cohort, was sufficient to exhaust this year class almost completely, as only very small numbers of this cohort were still present during our survey in March 1981. Although considered as belonging to a separate stock of *C. gunnari*, the 1973 cohort had also formed the back-bone of the fishery in the South Orkney Islands in 1977/78. A year class as abundant as the 1973 cohort has never been observed again in either area (Kock, 1991).

The reported catch of *N. rossii* of 18 760 tonnes in 1979/80, which exceeded even the biomass estimate for the aggregations of adult fish of this species in a localised area on the northern shelf of Elephant Island in 1978, may have led to a considerable decline in the abundance of the species after the 1979/80 season. During the survey in March 1981, aggregations of *N. rossii* were no longer found in the localised area where they had been observed in 1976 and 1978. The length composition of the stock had changed considerably in that few fish larger than 45 cm were present in the stock one year after intensive fishing. Our survey results from 1985 to 1987 provided evidence that the proportion of fish larger than 45 cm in the stock had increased again in the mid-1980s. Biomass estimates, which should be regarded with caution, however, were still much lower.

There is some evidence that large-scale fishing led to a decline in the occurrence of large fish in the stocks of *G. gibberifrons* and *C. aceratus*. Biomass estimates and length-frequency distributions indicated that both species appear to have recovered by the mid-1980s. The other four species *C. rastrospinosus*, *L. larseni*, *L. squamifrons* and *D. mawsoni* appear to have been affected little by fishing, if at all.

Despite very little fishing and a closure of the area for commercial fishing since 1989/90, the biomass estimates in 1996 for the most abundant species *C. gunnari*, *G. gibberifrons* and *C. aceratus* were considerably lower than for the previous survey in 1987. However, with the exception of *N. rossii* and *L. larseni*, confidence intervals of biomass estimates for 1987 and 1996 overlap. No information was available on *N. rossii*, as only few individual fish had been caught during the 1996 survey. 95% confidence intervals of the abundance estimates from the two surveys still overlap to some extent, which suggests that sampling variability has added to this difference. In order to exclude effects on the catching efficiency of the trawl by possible undetected changes to the trawl, the trawl rigging or the ground gear from 1987 to 1996, the geometry of the trawl was re-examined by *in situ* monitoring with a net surveillance sonar in a separate experiment in the northern North Sea in 1997. This experiment confirmed the measurements on the trawl geometry obtained earlier in the 1980s. However, we cannot exclude that with the arrival of a new fishing officer in the early 1990s changes in fishing operations took place which have not been readily detectable by us and need further investigation.

Illegal fishing, which might have taken place after the closure of the area for fishing in 1989, could be a possible explanation for the decline in the biomass of the standing stock of fish. However, length compositions of the most abundant species have changed little, which makes it seem unlikely that there has been substantial illegal fishing between 1987 and 1996.

The staple food of *C. gunnari* and juvenile *C. aceratus* is krill (*Euphausia superba*), whereas *G. gibberifrons* is primarily a benthos-feeder, although it does feed on krill whenever the latter is available (Kock, 1981; Gröhsler, 1992). The biomass of krill in the Elephant Island region and other areas of the Peninsula region declined substantially in the first half of the 1990s due to a number of poor year classes recruiting to the stock (Siegel et al., 1997). A decline in krill biomass could have affected recruitment in some of the fish stocks and thus could have led to a decline in fish stock biomass. However, any speculation on such a relationship seems premature given the current poor knowledge on the effects of a decline in krill biomass on any of the higher-level predators.

A precautionary catch limit for each species could be calculated using the generalised yield model (Constable and de la Mare, 1996). However, there appears to be little prospect of a substantial fishery given the biomass estimates for the 1996/97 season and some of the uncertainties associated with these estimates. Furthermore, with the possible exception of *C. gunnari*, the species could only be caught in a mixed-species fishery which may bear a considerable risk for less abundant by-catch species if total allowable catches (TACs) are only set for the target species. If CCAMLR continues to manage the fisheries as it has in the last few years, by tying the TAC to all species, a TAC set for all species would soon be exhausted due to the low catch set for most species.

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Table 1: Reported catches of finfish in the Antarctic Peninsula region (Subarea 48.1) (CCAMLR, 1990).

Species/ Season	*C. gunnari*	*N. rossii*	*C. wilsoni*	*G. gibberifrons*	*C. aceratus*	*C. rastrospinosis*	Others
1975/76	4*	125*		3*			
1977/78	44*	237*		3*			
1978/79	35 930	470	10 130	3 280	1 393	370	626
1979/80	1 087	18 763	4 320	765	153	390	673
1980/81	1 700			50			4 266
1981/82				4			
1982/83	2 604						16
1983/84							
1984/85	17			86			20
1985/86		5					
1986/87	75			54			7
1987/88	1	1		11			
1988/89	141			667	1		17

* Catches of exploratory fisheries of the Federal Republic of Germany around Elephant Island

Table 2: Bottom trawl surveys of the Federal Republic of Germany conducted on the shelf of Elephant Island from 1976 to 1996.

Name of Vessel	Time of Survey	Numbers of Hauls	Survey Design
Weser	Jan–Feb 1976	18	Non-random
Julius Fock	Jan–Mar 1978	20	Non-random
Walther Herwig	Nov 1977, Jan 1978	7	Random
Walther Herwig	Mar 1981	13	Random
Polarstern	Nov 1983	12	Random
Walther Herwig	Feb 1985	37	Random
Polarstern	May–Jun 1986	36	Random
Polarstern	Oct/Dec 1987	40	Random
Polarstern	Nov–Dec 1996	37	Random

Table 3: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Champsocephalus gunnari* around Elephant Island from 1981 to 1996.

Year		Stratum			
		51–100 m	101–400 m	401–500 m	Total
1981	Mean		683		683
	CI		195–8 017		195–8 017
1983	Mean	4.9	1 192		1 196
	CI	1.7–17.5	549–4 910		505–3 756
1985	Mean	28	474	0	502
	CI	13–129	221–1 533		248–1 561
1986	Mean	84	916	39	1 040
	CI	45–232	574–1 784	14–98	694–1 909
1987	Mean	261	1 652	146	2 059
	CI	70–6 558	610–8 054	30–1 384	929–8 406
1996	Mean	79	526	0	606
	CI	35–334	302–1 186		374–1 268

Table 4: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Notothenia rossii* around Elephant Island from 1981 to 1996.

Year		Stratum			
		51–200 m	201–400 m	401–500 m	Total
1981	Mean	24	1 810		1 834
	CI	11–106	352–73 505		376–73 529
1983	Mean	11	230		241
	CI	2–25	98–927		106–938
1985	Mean	84	592	0	677
	CI	30–469	93–27 051		161–27135
1986	Mean	78	3 091	1 353	4 524
	CI	23–796	1 093–18 003	415–21 767	2 149–19 457
1987	Mean	0	630	0	630
	CI		223–3 414		223–3 414
1996	Mean	18	14	0	32
	CI	5–171	7–26		16–48

Table 5: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Gobionotothen gibberifrons* around Elephant Island from 1981 to 1996.

Year		Stratum			
		51–100 m	101–400 m	401–500 m	Total
1981	Mean		10 948		10 948
	CI		6 713–23 754		6 713–23 754
1983	Mean	3.6	35 810		35 810
	CI	0.7–353	9 386–539 028		9 386–539 028
1985	Mean	1 433	10 635	0	12 069
	CI	178–259 817	6 723–20 459		7 517–29 458
1986	Mean	466	40 896	9 423	50 785
	CI	155–6 216	24 229–87 626	2 209–608 262	31 112–605 274
1987	Mean	32	20 913	364	21 309
	CI	6–1 460	10 598–58 112	127–4 722	10 982–45 679
1996	Mean	7	4 786	363	5 157
	CI	1–137	2 437–13 263	38–225 371	2 679–212 193

Table 6: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Chaenocephalus aceratus* around Elephant Island from 1981 to 1996.

Year		Stratum			
		51–100 m	101–400 m	401–500 m	Total
1981	Mean		2 879		2 879
	CI		1 181–15 122		1 181–15 122
1983	Mean		6 499		6 499
	CI		2 952–30 939		2 952–30 939
1985	Mean	14	754	0	768
	CI	4–190	518–1 261		532–1 184
1986	Mean	182	6 956	480	7 619
	CI	46–2 760	3 766–17 405	44–717 864	4 262–672 201
1987	Mean	99	5 369	61	5 530
	CI	56–204	3 074–12 090	14–118	3 234–12 251
1996	Mean	41	1 939	142	2 124
	CI	16–347	1 016–5 117	22–11 025	1 169–13 015

Table 7: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Chionodraco rastrospinosus* around Elephant Island from 1981 to 1996.

Year		Stratum		
		101–200 m	201–500 m	Total
1981	Mean	4.6	78*	83
	CI	0.6–56.7	23–1 088	26–1 092
1983	Mean	0	205*	205
	CI		69–1 739	69–1 739
1985	Mean	0	243	243
	CI		133–581	133–581
1986	Mean	0	284	284
	CI		172–582	172–582
1987	Mean	0	475	475
	CI		285–985	285–985
1996	Mean	2	282	282
	CI	0.4–12	135–856	135–856

* 201–400 m only

Table 8: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Lepidonotothen larseni* around Elephant Island from 1981 to 1996.

Year		Stratum		
		51–200 m	101–500 m	Total
1981	Mean		170*	170
	CI		75–754	75–754
1983	Mean		138*	138
	CI		67–391	67–391
1985	Mean	0.17	94	94
	CI	0.03–0.48	43–309	43–222
1986	Mean	0	170	170
	CI		127–284	127–284
1987	Mean	0.6	533	533
	CI	0.2–1.03	317–1 115	317–944
1996	Mean	0.9	181	182
	CI	0.3–17	131–280	131–269

* 101–400 m only

Table 9: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Lepidonotothen squamifrons* around Elephant Island from 1981 to 1996.

Year		Stratum		
		51–200 m	101–500 m	Total
1981	Mean		542*	542
	CI		99–2 415	99–2 415
1983	Mean		61*	61
	CI		6–15 034	6–15 034
1985	Mean	0	572	572
	CI		168–5 115	168–5 115
1986	Mean	0	313	313
	CI		120–1 489	120–1 489
1987	Mean	0	139	139
	CI		48–809	48–809
1996	Mean	0	312	312
	CI		65–5 564	65–5 564

* 201–400 m only

Table 10: Biomass estimates (in tonnes) and their lower and upper 95% confidence limits for *Dissostichus mawsoni* around Elephant Island from 1981 to 1996.

Year		Stratum		
		51–200 m	201–500 m	Total
1981	Mean	32	37*	69
	CI	6.2–70	6.8–128	23–162
1983	Mean	5.6	15*	21
	CI	0.6–140	1.8–208	6.5–209
1985	Mean	0.01	3.8	3.8
	CI	no CI	no CI	no CI
1986	Mean	1.1	139	140
	CI	0.2–2.9	50–357	68–254
1987	Mean	2.3	118	120
	CI	0.7–8.2	59–257	61–259
1996	Mean	7.1	38	45
	CI	1.1–515	19–77	24–336

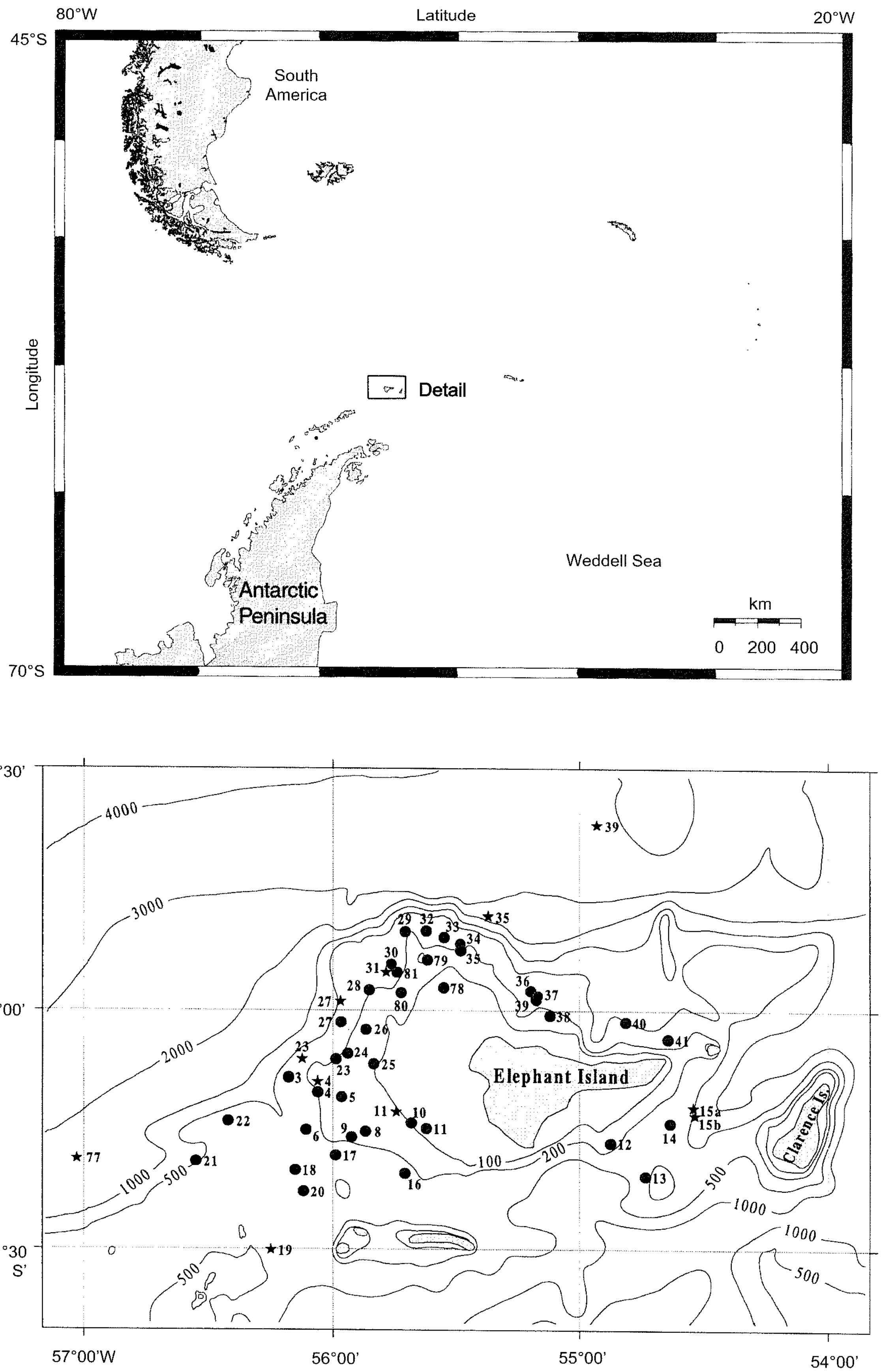

Figure 1: Area of investigation. Location of fishing stations in the vicinity of Elephant Island in November/December 1996.

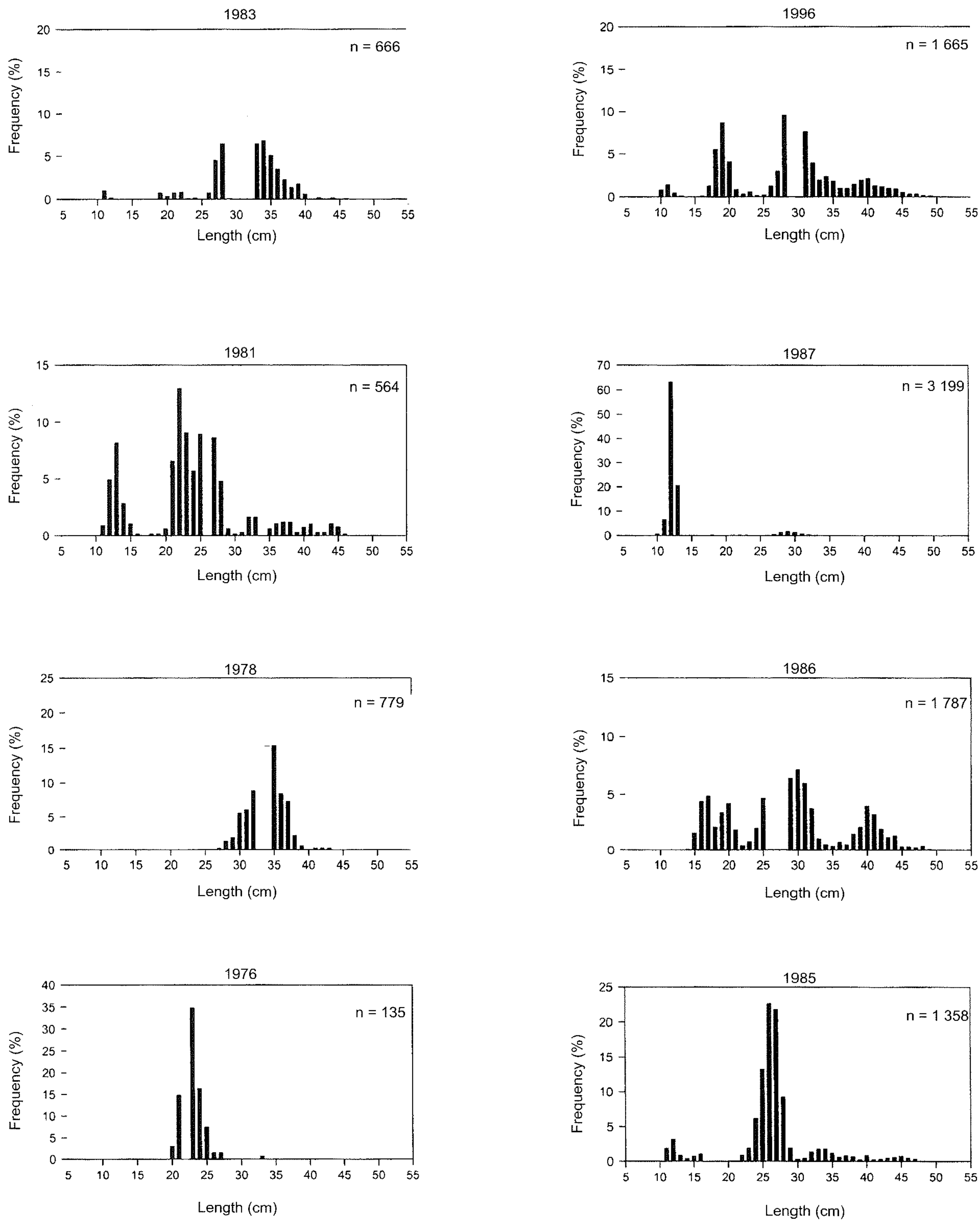

Figure 2: Length-frequency distributions of *Champsocephalus gunnari* calculated using data obtained during surveys around Elephant Island from 1976 to 1996.

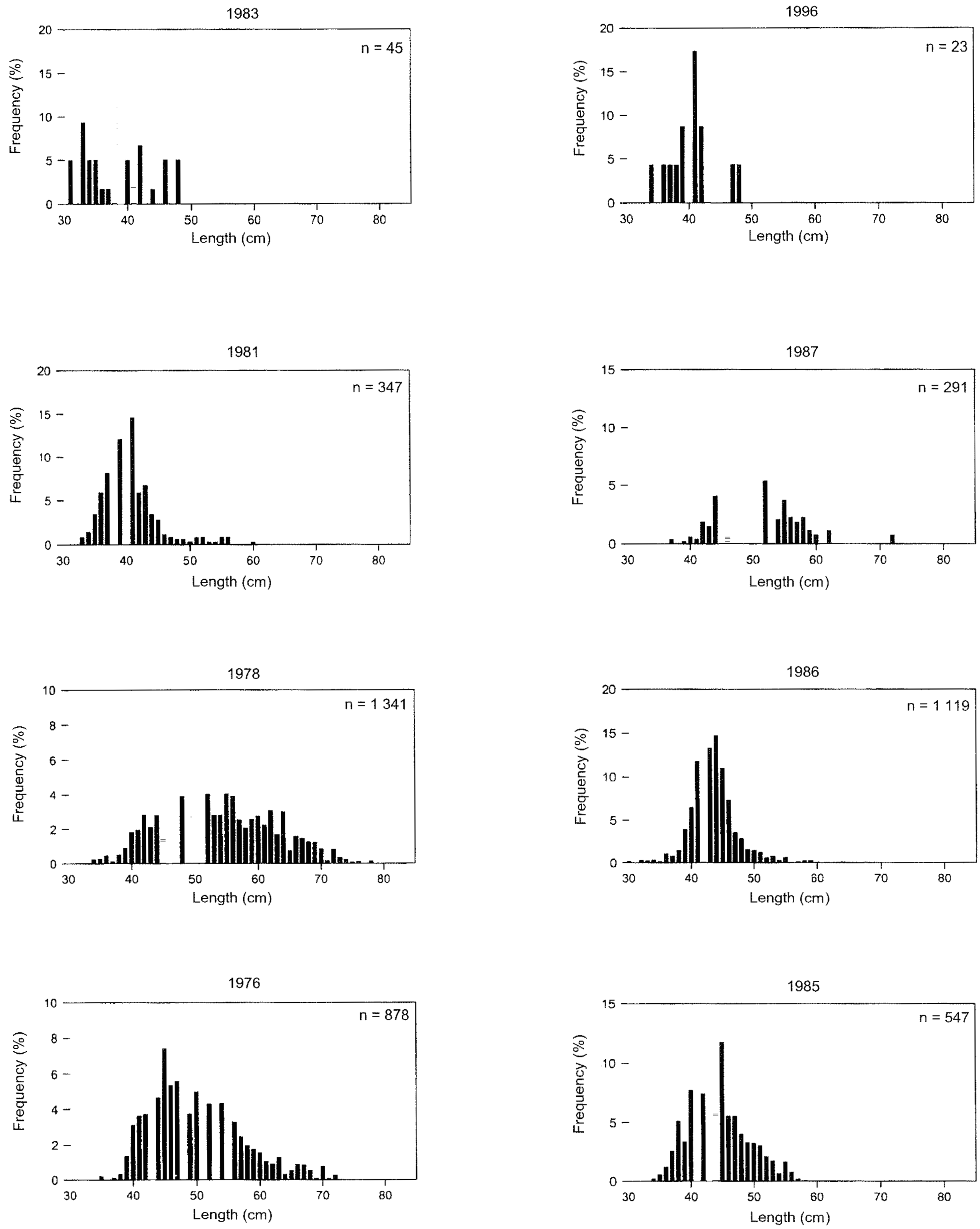

Figure 3: Length-frequency distributions of *Notothenia rossii* calculated using data obtained during surveys around Elephant Island from 1976 to 1996.

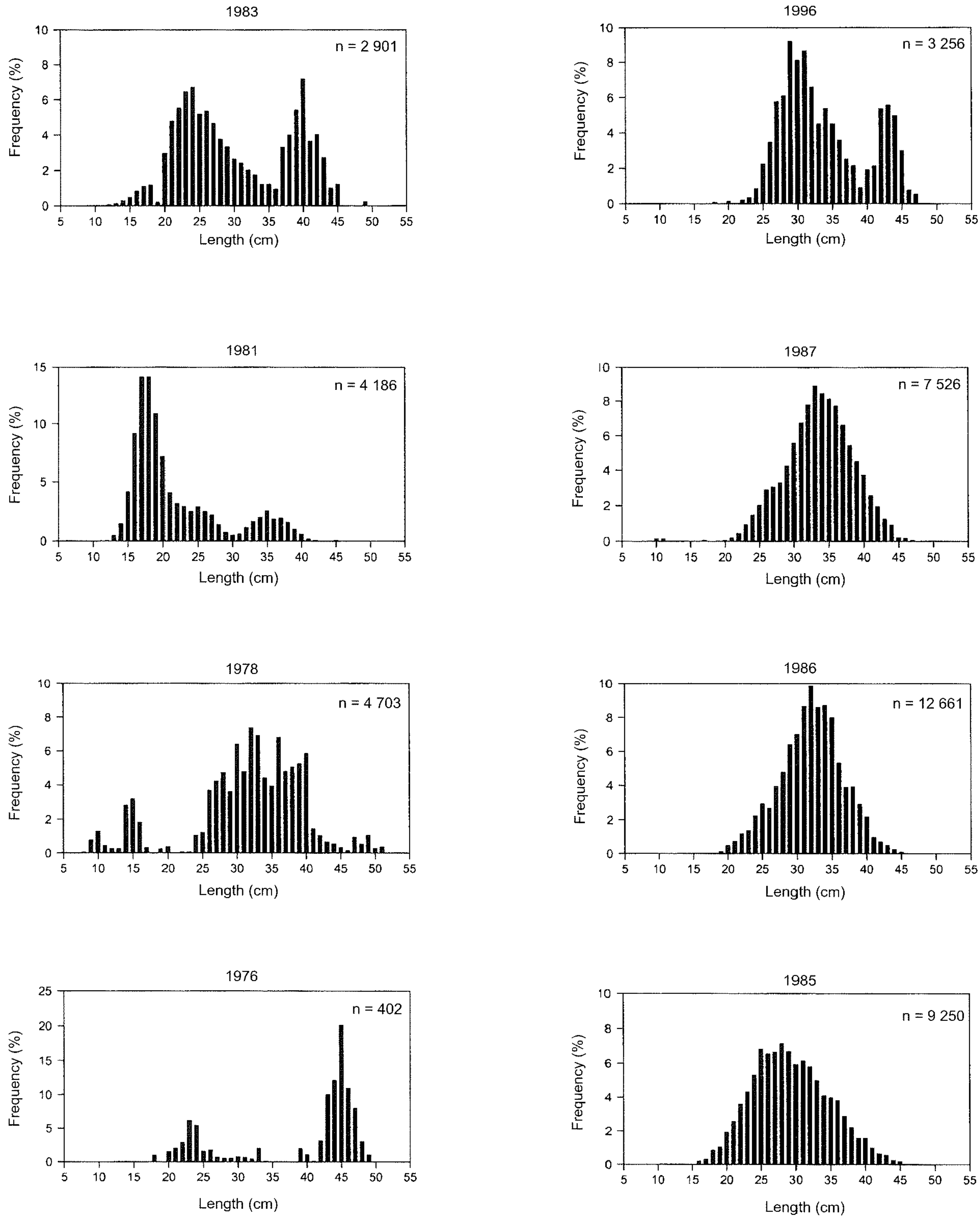

Figure 4: Length-frequency distributions of *Gobionotothen gibberifrons* calculated using data obtained during surveys around Elephant Island from 1976 to 1996.

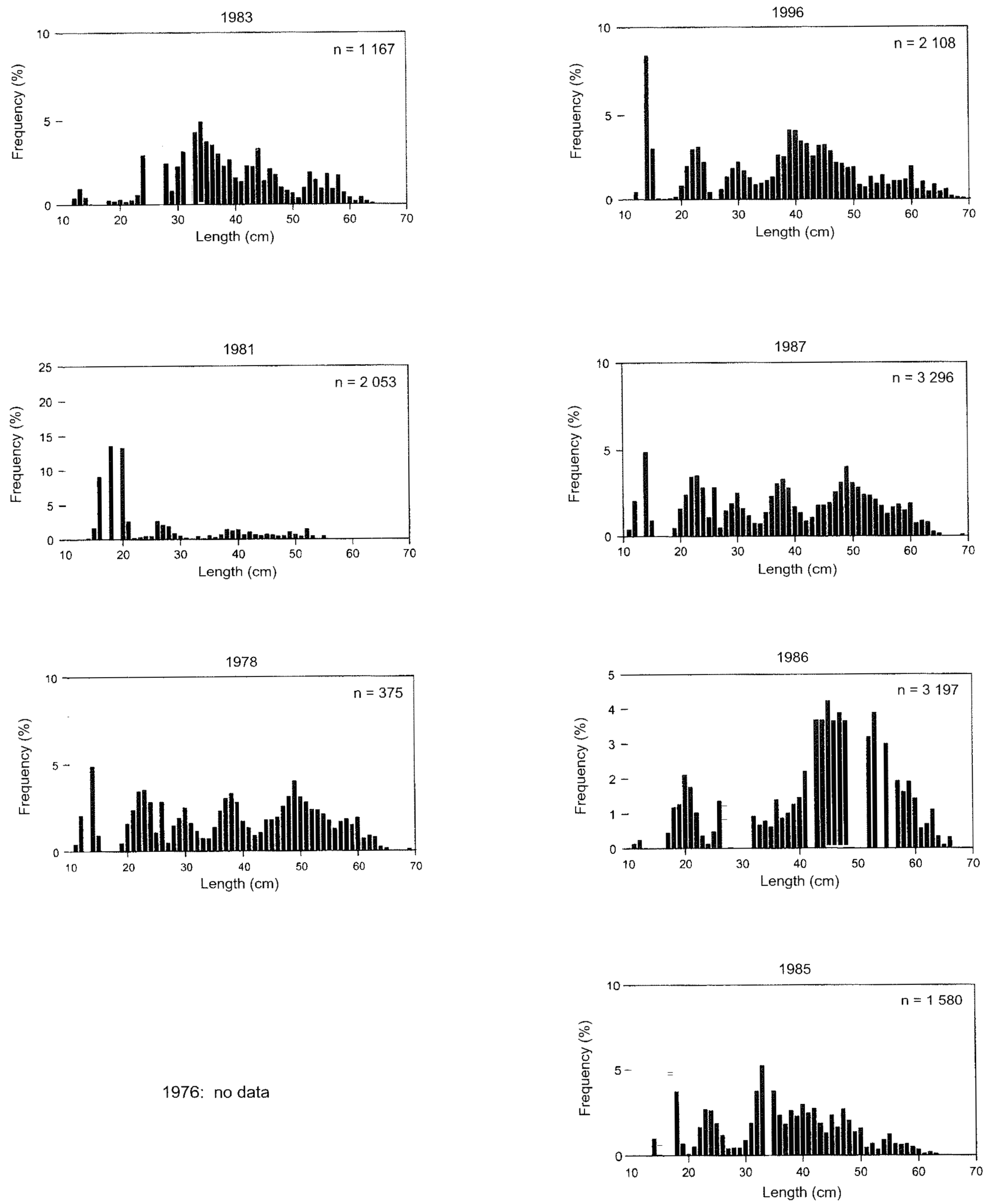

Figure 5: Length-frequency distributions of *Chaenocephalus aceratus* calculated using data obtained during surveys around Elephant Island from 1981 to 1996.

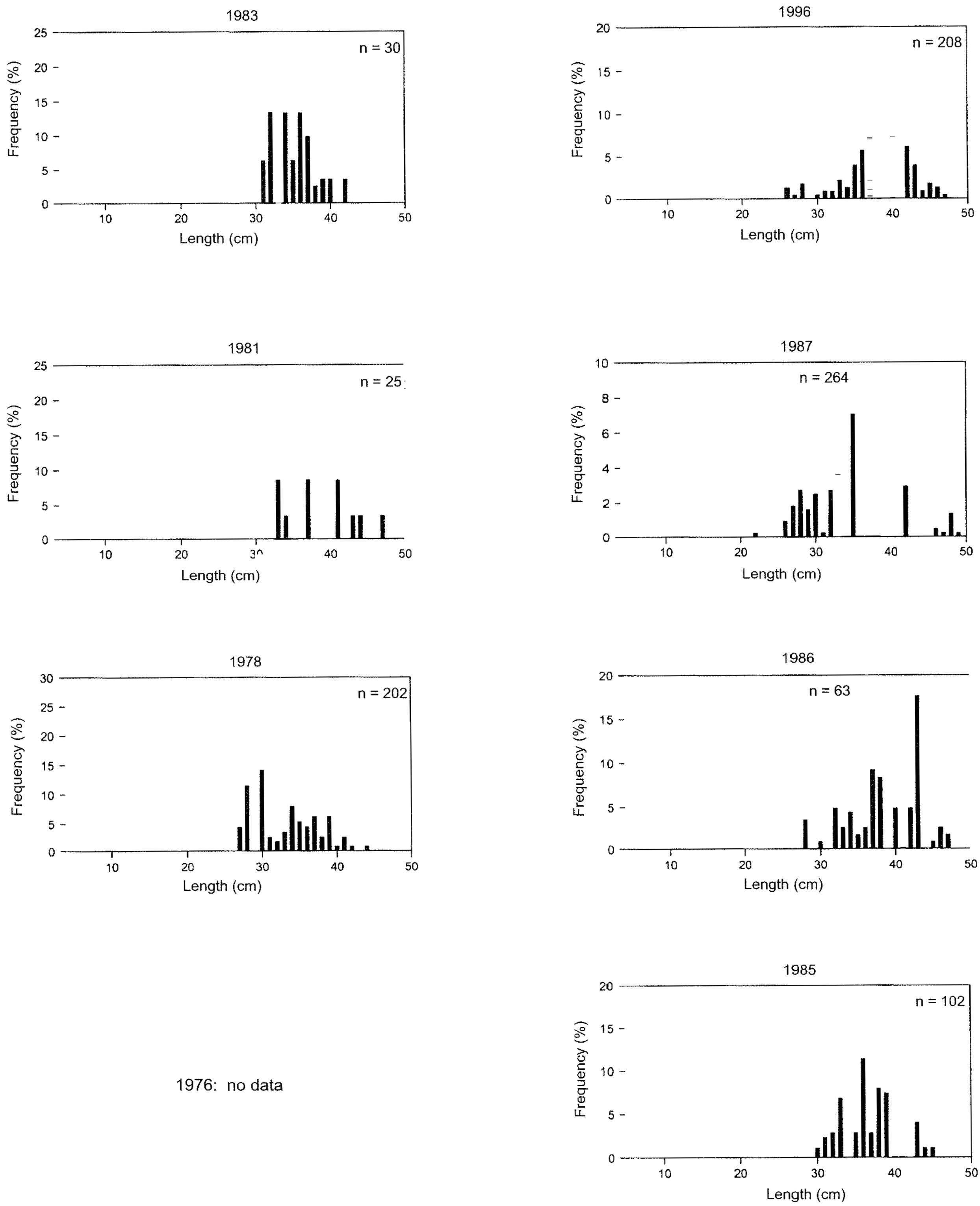

Figure 6: Length-frequency distributions of *Chionodraco rastrospinosus* calculated using data obtained during surveys around Elephant Island from 1978 to 1996.

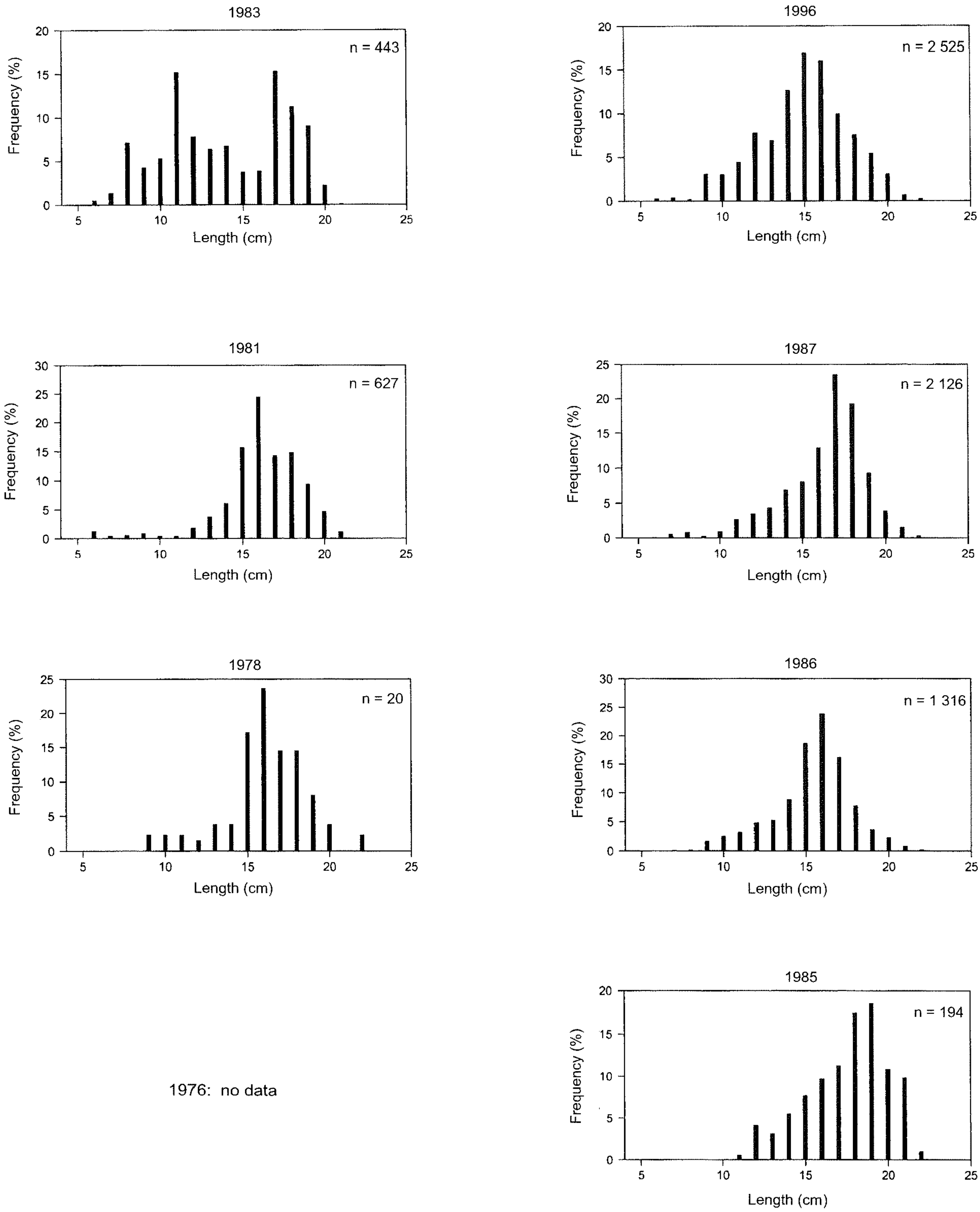

Figure 7: Length-frequency distributions of *Lepidonotothen larseni* calculated using data obtained during surveys around Elephant Island from 1981 to 1996.

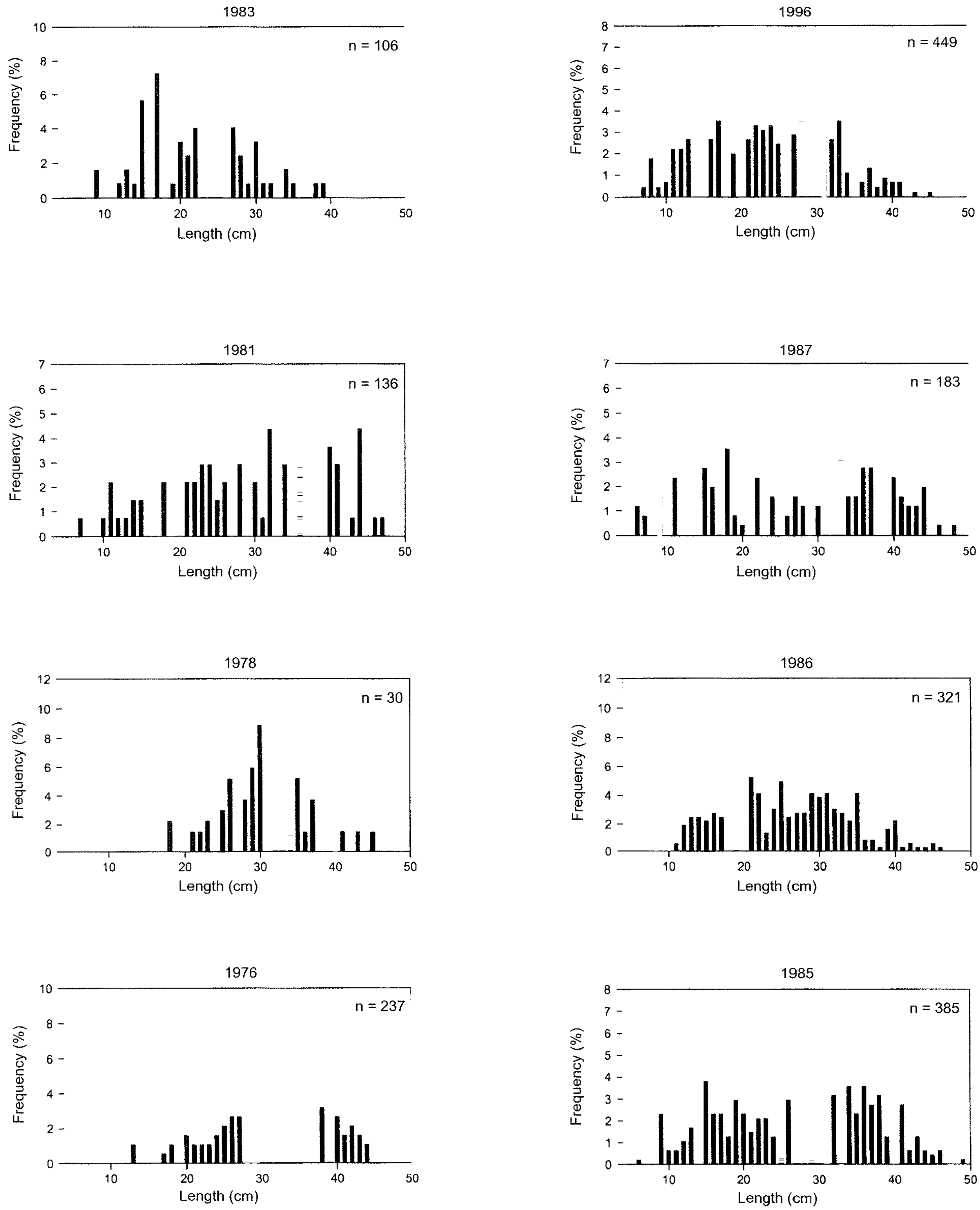

Figure 8: Length-frequency distributions of *Lepidonotothen squamifrons* during surveys around Elephant Island from 1976 to 1996.

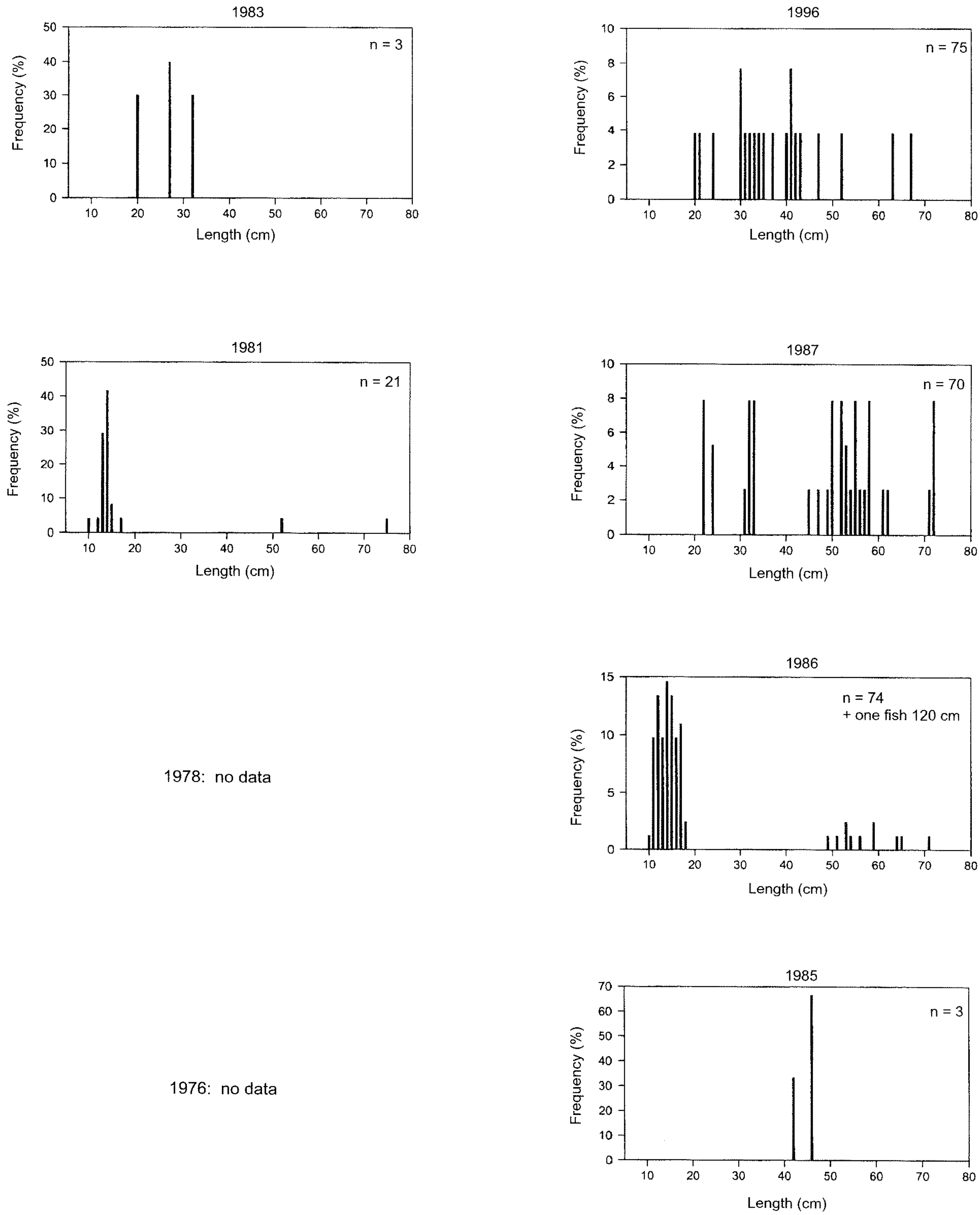

Figure 9: Length-frequency distributions of *Dissostichus mawsoni* calculated using data obtained during surveys around Elephant Island from 1981 to 1996.

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