STATUS OF THE KRILL STOCK AROUND ELEPHANT ISLAND IN 1991/92 AND 1992/93

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Abstract

Krill stock composition and distribution patterns in the vicinity of Elephant Island during the austral summers of 1991/92 and 1992/93 are described and compared with information from previous years. The general distribution of krill length and maturity classes conformed to previous descriptions and appears to be a recurring and predictable aspect of the krill stocks in the Antarctic Peninsula region. The length frequency distributions and maturity stage composition reflected relatively good year class success from the 1990/91 spawning season but poor success from 1991/92. Year class success from these and other years appears to be associated with female maturity development and spawning during the early summer months. The overall abundance, maturity stage composition and reproductive activity of krill appeared to be affected by dense salp concentrations during 1992/93 and 1989/90.

Résumé

Description des tendances de la composition et de la distribution du stock de krill proche de l'île Eléphant pendant les étés australs 1991/92 et 1992/93 et comparaison avec les informations d'années antérieures. La distribution générale des longueurs et des classes de maturité du krill confortait les descriptions précédentes, et il semblerait qu'il s'agisse là d'un aspect répétitif et prévisible des stocks de krill dans la région de la péninsule antarctique. Les distributions de fréquences de longueurs et la composition en stades de maturité reflétaient un succès relativement élevé de la classe d'âge de la saison de ponte 1990/91 mais un succès moindre en 1991/92. Le succès de la classe d'âges de ces années, entre autres, semble être lié au développement de la maturité des femelles et à la ponte pendant les premiers mois de l'été. L'abondance générale, la composition en stades de maturité et l'activité propre à la reproduction du krill semblaient avoir été affectées par de denses concentrations de salpes en 1992/93 et 1989/90.

Резюме

Состав запаса и закономерности распределения криля в районе о-ва Элефант во время южного лета 1991/92 и 1992/93 г. описаны и сравнены с данными предыдущих лет. В общем распределение размерных классов и стадий половозрелости криля согласуется с предыдущими описаниями и представляется повторяющимся и предсказуемым аспектом запаса криля в районе Антарктического полуострова. Частотное распределение длины и состав стадий половозрелости показали относительно высокий уровень выживания годового класса, нерестовавшегося в сезон 1990/91 г., но неудачу годового класса в 1991/92 г. Выживание годовых классов, нерестовавшихся в этом и других годах, похоже связано с развитием половозрелости самок и нерестом в начале летних месяцев. На общую численность, состав стадий половозрелости и репродуктивную активность криля повлияли плотные концентрации сальп в 1992/93 и 1989/90 гг.

Resumen

Se presenta y compara la composición del stock de kril y sus patrones de distribución alrededor de la isla Elefante durante el verano austral de 1991/92 y de 1992/93, con

respecto a la información obtenida de años anteriores. La distribución general de tallas y estados de madurez del kril se ajusta a las descripciones anteriores y parece ser un aspecto recurrente y previsible de los stocks de kril en la región de la península Antártica. Las distribuciones de frecuencia de tallas y la composición de los estados de madurez mostraron una alto índice de supervivenvia de la clase de edad desovada en la temporada 1990/91 y un bajo índice de supervivencia para 1991/92. El éxito de la supervivencia de las clases de edad de éstos y otros años parece estar relacionada con el grado de desarrollo de los estados de madurez y desove de las hembras durante los primeros meses estivales. La abundacia, composición de los estados de madurez y actividad reproductora del kril en general parecen haber sido afectadas por densas concentraciones de salpas durante 1992/93 y 1989/90.

Keywords: *Euphausia superba, Salpa thompsoni,* stock composition, interannual variability, recruitment, CCAMLR

INTRODUCTION

Krill regularly occur in large concentrations in the area around Elephant Island (Nast, 1986) and support one of the major commercial fisheries in the Atlantic sector of the Southern Ocean. Routine meso-scale surveys have been conducted in this area in recent years to assess krill abundance and stock composition and to monitor seasonal and interannual fluctuations (Nast *et al.*, 1988; Loeb and Siegel, 1992; Loeb *et al.*, 1993). Since its establishment in 1982 the CCAMLR Scientific Committee has underlined the need for such studies as prerequisites for sound management of Antarctic krill resources and as a source of background data for predator-prey investigations conducted by the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP).

This paper contains results of krill research conducted in the vicinity of Elephant Island under the US AMLR Program. It includes descriptions of krill distribution, abundance and stock composition during the 1992/93 season. The 1991/92 survey data were considered in part in last year's CCAMLR Working Group on Krill (WG-Krill) contribution by Loeb and Siegel (1992). That data set is now complete and is compared here with the 1992/93 data.

MATERIAL AND METHODS

Net sampling in the Elephant Island area was conducted on board RV *Surveyor* during January and February/March 1992 and 1993. The standard 72-station grid consisted of nine north-south transects between 60° and 62°S and 53° and 57°30'W ('Elephant Island box'). In 1993 additional stations were sampled to the north and south of King George Island (Figure 1). These stations are included in a description of the spatial distribution of krill length frequency clusters across the survey area (Figure 2). Between-cruise comparisons of stock composition and abundance are based on the Elephant Island box station data.

Sampling was done using a 1.8 m Isaacs-Kidd Midwater Trawl (IKMT) fitted with 505 µm mesh net, a flow metre and a time-depth recorder. Tows were open and oblique and generally fished the upper 200 m of the water column. Due to severe weather conditions it was not possible to sample all stations during each survey. The number of tows from each sampling period is presented in Table 1.

Sample analysis was done at sea. Krill demographic studies utilised fresh or freshly frozen specimens. All krill were analysed from samples with approximately 150 or fewer individuals. A minimum subsample of

Table 1: Krill and salp abundance in the Elephant Island box during the summer of 1992 and 1993. Abundance is expressed as stratified mean numbers per 1 000 m^3.

Survey Period	No. of Stations	Krill Mean No./1 000 m^3	Krill SD	Salps Mean No./1 000 m^3	Salps SD
January 1992	63	20.8	11.5	67.4	26.0
February/March 1992	82	29.7	10.2	na	na
January 1993	70	23.6	11.1	896.3	489.5
February/March 1993	67	29.6	10.9	1226.8	780.5

100 specimens was analysed for larger catches, and total counts were made of the entire catch. Total length of krill was measured to the nearest millimetre and their sex and maturity stage were determined according to Makarov and Denys' classification scheme (1981).

Relative abundance, expressed as the stratified mean abundance standardised to numbers per 1 000 m^3, was estimated following Saville's method (1977). Determination of spatially separated length frequency clusters of krill (i.e., groups of stations with similar krill length frequency distributions) using the CSS statistical package was described in detail by Loeb and Siegel (1992). The pooled overall length frequency for the survey area was weighted according to the stratified mean abundance and the proportion of the area covered by each cluster.

RESULTS

Spatial Distribution Patterns

Cluster analysis applied to the January 1992 krill length frequency data showed three distinct clusters. Cluster 1 occurred primarily to the south in a narrow band around Elephant and Clarence Islands (Figure 3) and was associated with extremely low krill abundance. It was dominated by small krill with a modal length of 25 mm (Figure 4); juveniles (the 1+ age class) comprised 69% of individuals (Figure 5). Cluster 3 occurred in the western survey area and was for the most part made up of large krill around 50 mm in length. More than 87% of the individuals were adult, and juveniles made up only approximately 3% of the total. Cluster 2 occupied the intermediate area and represented a mixture of the length classes present in clusters 1 and 3; large mature krill (54% adult stages) were most abundant. The overall length frequency distribution was clearly bimodal with length classes around 35 mm being under-represented (Figure 4).

During February/March 1992, krill were collected at a greater proportion of the stations and cluster 1 covered a much wider area than during January (Figure 6). The modal size of cluster 1 krill was 27 mm (Figure 7) and >72% were juveniles (Figure 8). The length frequency distribution of cluster 2 shifted to even larger values than during January. Cluster 3 krill again showed a clear unimodal pattern around 47 mm, represented predominantly by adult stages (70%). As was the case during January, the overall length frequency was bimodal, but the smaller classes were relatively less abundant (Figure 7).

Three size clusters were identified in the extended area surveyed during January 1993. As in 1992, these clusters demonstrated a southwest-northeast orientation (Figure 9). However, southernmost cluster 1 differed greatly from its 1992 counterpart in that it was represented by medium sized krill having a modal length of 35 mm (Figure 10). Only 24% of these were juveniles: subadults dominated and comprised >57% of the total (Figure 11). These subadults (2+ age class) represent last year's successful juvenile age class. The intermediate cluster 2 also differed from that of 1992: it showed a unimodal length distribution of around 41 mm and comprised mostly small adult krill (55%). The northern cluster 3 occurred in offshore waters beyond the continental shelf. The characteristics of this cluster, a modal length of 47 mm and primarily adult composition (>86%), were very similar to those of cluster 3 in 1992. The overall length frequency distribution in January 1993 (Figure 10) differed greatly from that of January 1992 due to the absence of the small juvenile (1+) age class and the unimodal distribution.

Only two clusters were identified during February/March 1993 (Figure 12). Cluster 1 was distributed across much of the survey area. As in January, this cluster was characterised by medium sized krill; the modal length was 38 mm (Figure 13). Juveniles were relatively less abundant than they were in January (<5%), while subadults made up 65% of the individuals (Figure 14). It is quite likely that this cluster represents a mixture of January clusters 1 and 2. The composition of cluster 2 (48 mm modal length, 94% adults) was almost identical to that of January cluster 3.

Female Maturity Stages

During the January 1992 survey, 97% of the females collected were in adult stages; most (95%) of these exhibited early to late stages of ovarian development (3b and 3c), few were gravid (2%), and none appeared to have recently spawned (Figure 15). Most of the females collected during the February/March survey were also mature, but the majority of these (79%) were in earlier stages of development (3a and 3b) than those observed the previous month, and fewer than 5% were gravid or had recently spawned.

During the January 1993 survey, 89% of the females were mature. Most of these (78%) were in earlier stages of development (3a and 3b) than in the previous year and few demonstrated advanced ovarian development (3c, 17%). Again, few were gravid (5%) and none appeared to have spawned (Figure 15). In contrast to the three other surveys, a relatively small proportion (50%) of the females collected during February/March 1993 were mature. Among these, most (86%) were still in relatively early stages of development (3a to 3c), 9% were gravid and 5% had recently spawned.

Abundance Estimates

The mean abundance estimates for krill during January and February/March 1993 were similar to the corresponding values in 1992 (Table 1 and Figure 16). During both years the mean abundance increased as the season progressed, although this increase was substantially greater in 1992 than in 1993 (43% versus 26%). During 1992 the median abundance values also increased as the season progressed, but in 1993 the February/March median abundance value was a third of the January value (Figure 16), reflecting greater proportions of small catches later in the season. Another major difference between the two years was the abundance of salps (*Salpa thompsoni* - Table 1). Relatively large concentrations of salps were encountered across the survey area during January 1993 (Figure 17). Even greater concentrations (of up to >16 000 per 1 000 m^3) occurred during February/March and the mean salp abundance then was two orders of magnitude greater than during January 1992.

DISCUSSION AND CONCLUSIONS

Distribution of Krill Length and Maturity Classes

The distributions of krill length and maturity classes during January to March 1992 and 1993 are consistent with the seasonal pattern of krill distribution in the Antarctic Peninsula region described by Siegel (1988 and 1989). The presence of small sizes and juvenile and subadult stages in the southern study area results from their eastward transport through Bransfield Strait during spring and summer months; the presence of large krill at sexually mature stages in northern waters reflects their offshore seasonal spawning migration. This summertime distribution pattern has been regularly documented since 1977/78 and appears to be a recurrent and predictable aspect of the krill stocks in the Antarctic Peninsula region. Because of the stability of this pattern it is possible to use data from the Elephant Island area to assess the magnitude of interannual variability in krill abundance and recruitment success (Siegel, 1989 and 1992).

Year Class Success and Recruitment

Alternation of good and bad krill year classes is indicated by changes in length composition resulting from the presence or absence of juvenile stages (1+ age class). The overall length frequency distributions from the 1992 and 1993 AMLR surveys represent large differences in the year class success and recruitment of the previous year's spawn. Substantial proportions of juveniles and krill lengths <30 mm in 1992 (Figures 4 and 7) resulted from successful spawning and larval survival in 1991 and a relatively good 1990/91 year class. The paucity of juveniles and small-sized krill in 1993 (Figures 10 and 13) indicates the poor success of the 1991/92 year class.

Loeb and Siegel (1992) suggested the potential importance of the time of spawning in year class success. Years of good year class success, such as 1987/88 and 1990/91 (Table 2), were associated with relatively advanced female maturity stages (3c to 3e) predominating during January/February. Years of poor year class success, 1988/89 and 1990/91, were associated with the least developed female stages (3a and 3b) predominating during January and February. Relatively undeveloped female maturity stages predominated during January/February 1992. Loeb and Siegel (1992) hypothesised that if the status of female maturity development during early summer is an important factor influencing year class success, due to the timing of larval production relative to seasonal conditions, the result would be poor recruitment for the 1991/92 year class. The apparent failure of the 1991/92 year class supports this hypothesis. Predominance of undeveloped female maturity stages during January and February/March 1993 permits another test of this hypothesis. However, a longterm standard data set is required to identify other possible parameters and to distinguish which of these are most important for the survival of krill during the first year.

Table 2: Indications of good (+), poor (-) and intermediate (+/-) year class strength of krill in the Elephant Island area, 1975 to present. Blanks indicate that no information is available. Table is continued from Siegel (1989) and Loeb and Siegel (1992).

Year Class	Year Class Strength	Reference
1975/76	+	Siegel, 1989
1976/77	-	Siegel, 1989
1977/78		
1978/79	-	Witek *et al.*, 1980
1979/80	-	Siegel, 1986a
1980/81	+	Hempel, 1985; Siegel, 1986a
1981/82	+	Siegel, 1989
1982/83	+	Siegel, 1989
1983/84	-	Hempel, 1985; Siegel, 1986b
1984/85	+/-	Siegel, 1989
1985/86	+	Siegel, 1989
1986/87	-	Siegel, 1989
1987/88	+	Loeb and Siegel, 1992
1988/89	-	Loeb and Siegel, 1992
1989/90	-	Loeb and Siegel, 1992
1990/91	+	Loeb and Siegel, 1992
1991/92	-	Present study

Possible Effects of Salp Concentrations on Krill Stocks

Despite variations in year class success, overall krill abundance in the Elephant Island area has been relatively stable over the past six summer seasons (Figure 16). Over this period the mean abundance estimates varied within an order of magnitude. Lowest krill abundance occurred in 1990 and was associated with extremely large salp concentrations averaging three times greater than during February/March 1993. Various similarities in the krill stocks during 1990 and 1993 suggest that the presence of large salp concentrations (e.g., 100 to 500 per 1 000 m^3 average) may affect their overall abundance, composition and reproductive activity. During both years krill abundance decreased as the season progressed, few krill larger than 50 mm were collected and the females were in relatively undeveloped maturity stages. It is conceivable that the decrease in the median krill abundance as the season progressed in 1993 was related to the increasing seasonal abundance of and competition from salps. The coincidental change in krill maturity stage composition to predominance of subadult stages and the shift in the location of large-sized mature krill suggest that the more nektonic individuals may actively avoid the area. Avoidance could in part explain the extremely low numbers of krill across the study area during the much denser salp concentrations in 1990. If this is true, then the behavioural response to salp concentrations would be another important factor influencing the interannual variation of krill abundance.

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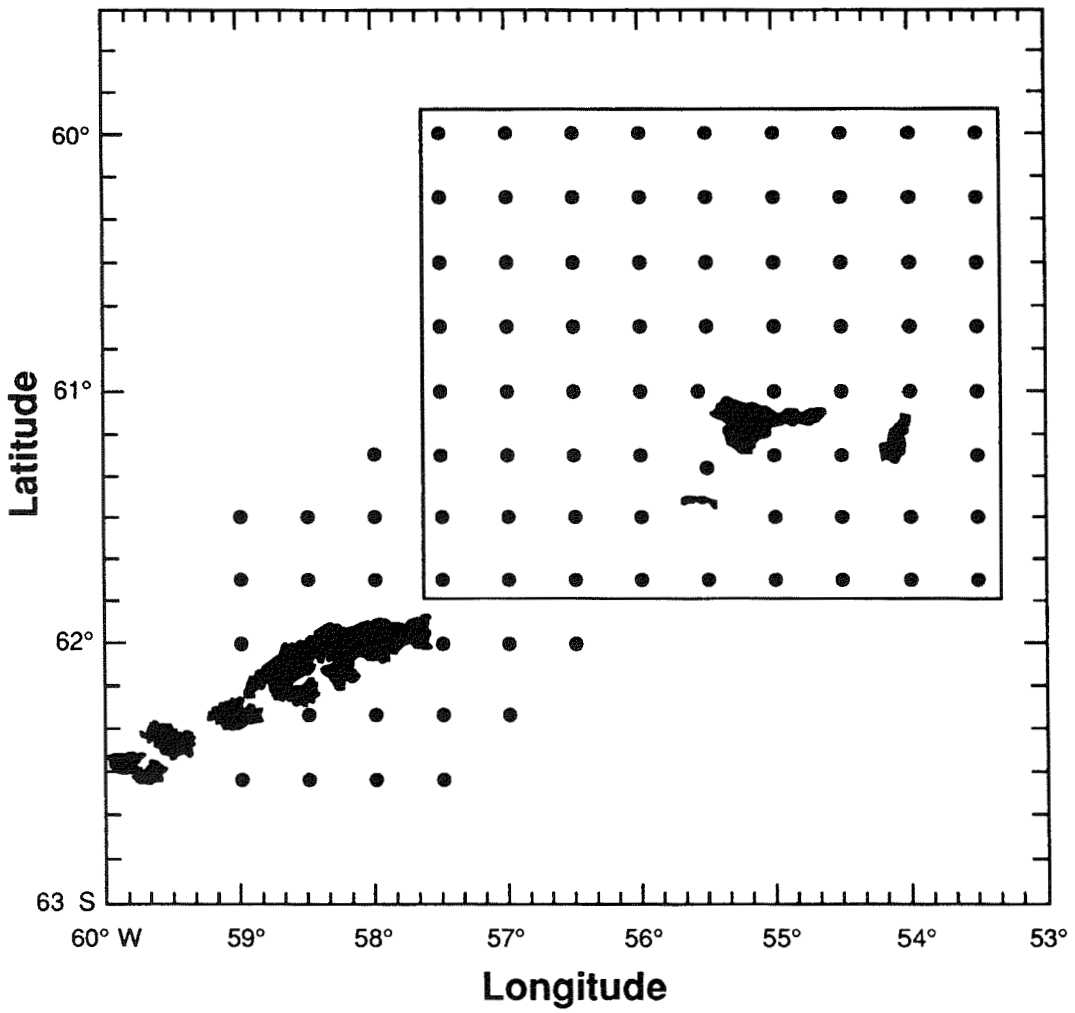


Figure 1: AMLR survey stations sampled during the austral summer of 1993 and the more restricted 'Elephant Island box' which was routinely sampled during 1992 and previous years.

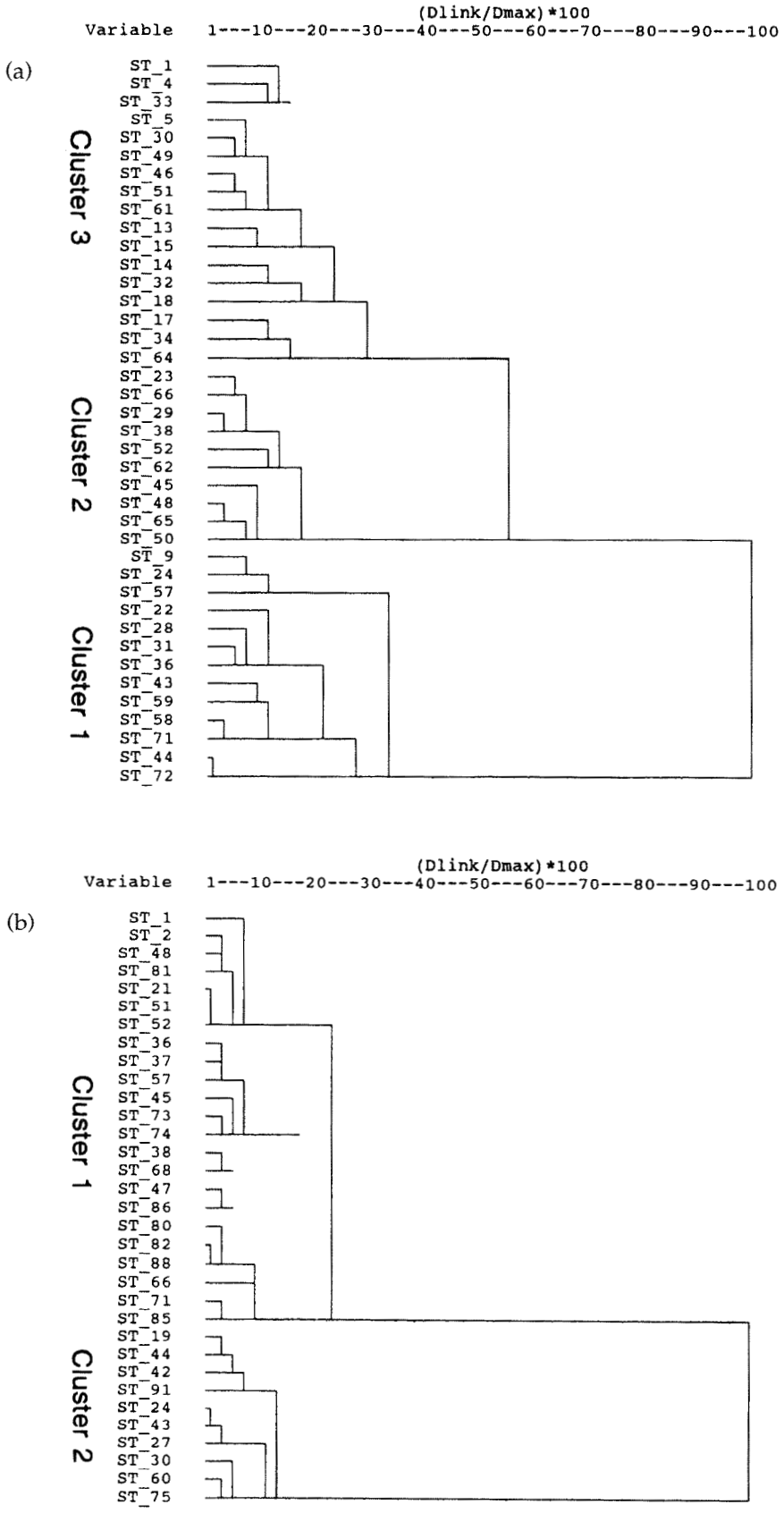


Figure 2: Examples of dendrograms from cluster analyses using standardised abundances of krill length classes as station parameters. Examples shown here represent surveys of (a) February 1992 and (b) February/March 1993 in the Elephant Island area.

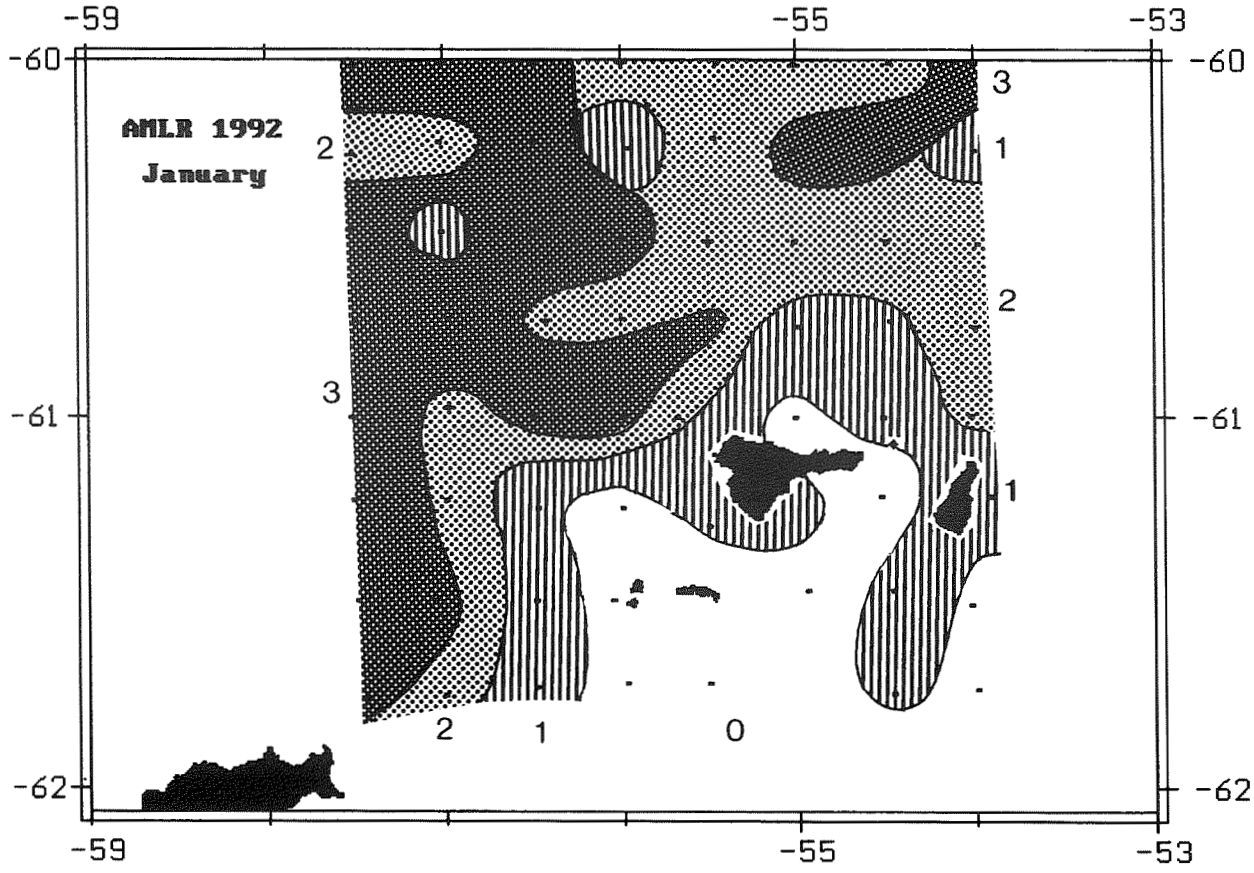


Figure 3: Geographical distribution of krill belonging to different length frequency categories (clusters 1 to 3) during January 1992.

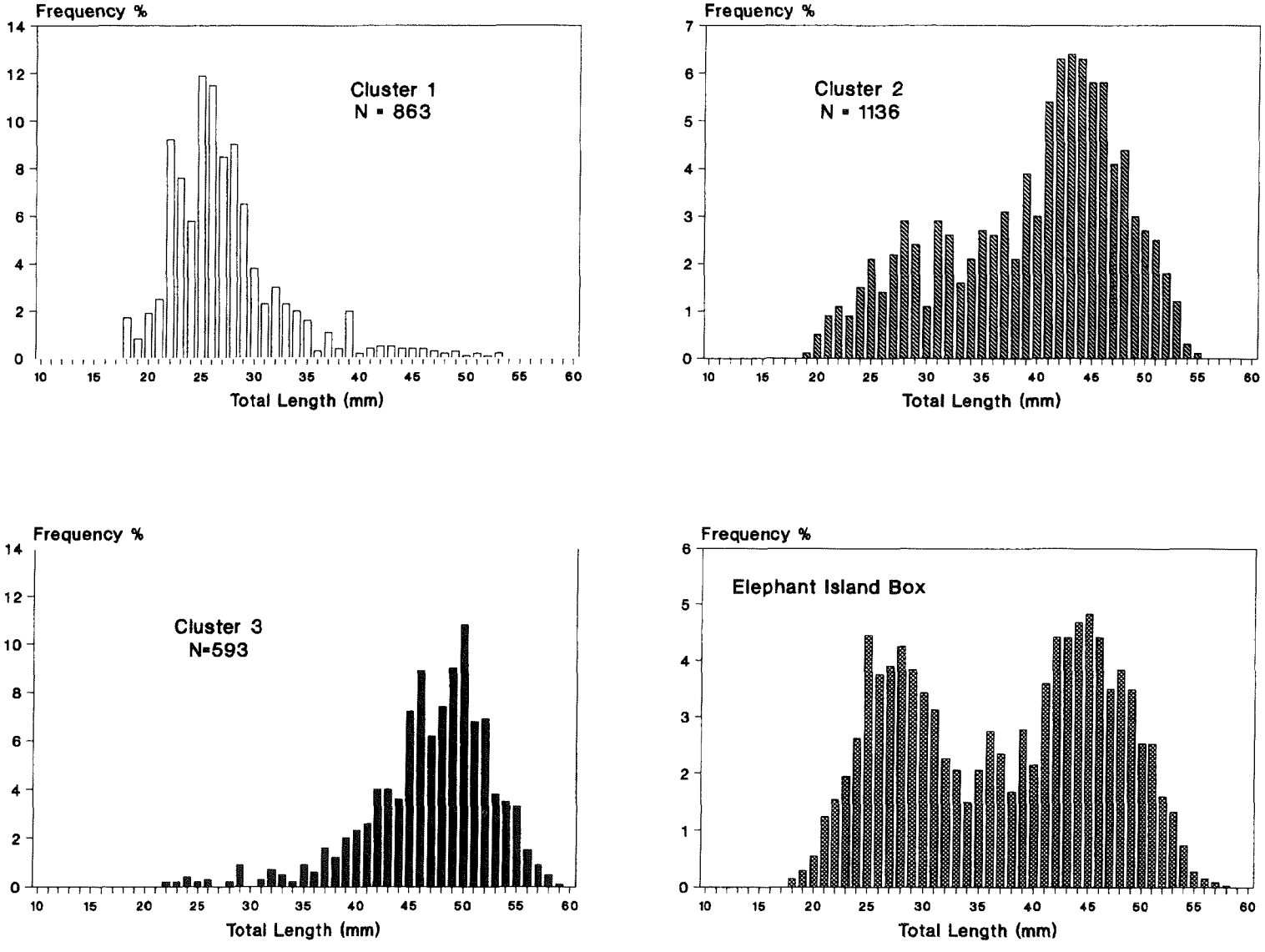
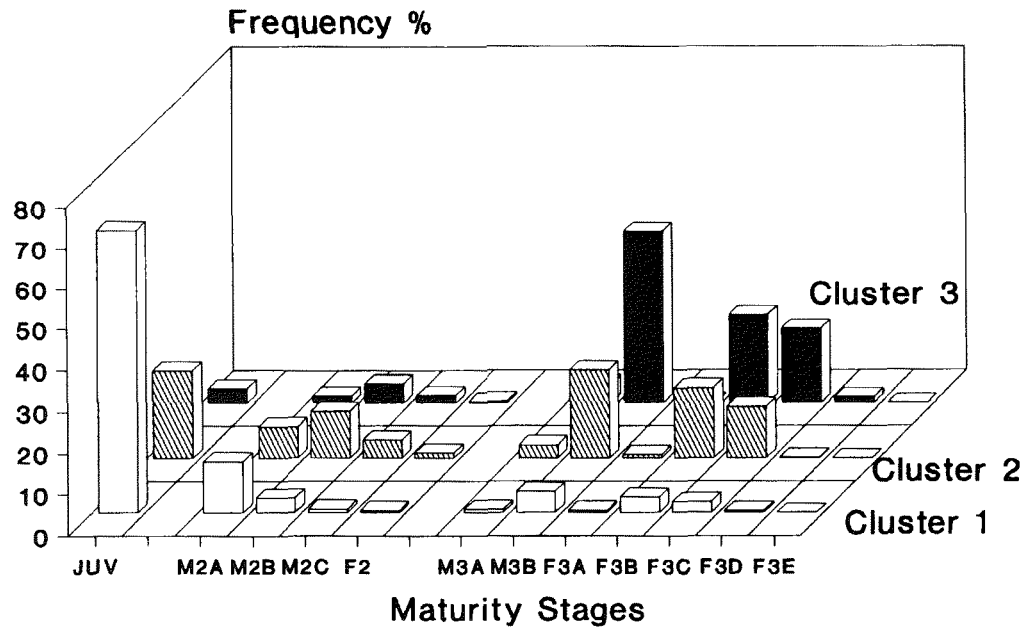


Figure 4: Length frequency distributions of krill belonging to three clusters and the overall weighted length frequency distribution in the Elephant Island area during January 1992.



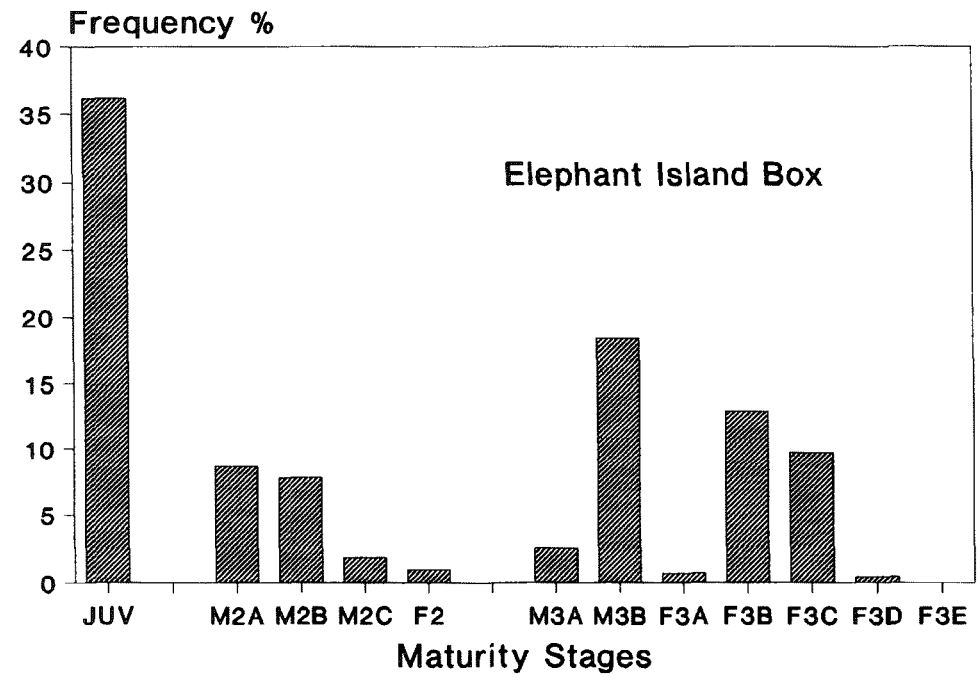


Figure 5: Krill maturity stage composition in three clusters and the overall weighted maturity stage composition in the Elephant Island area during January 1992.

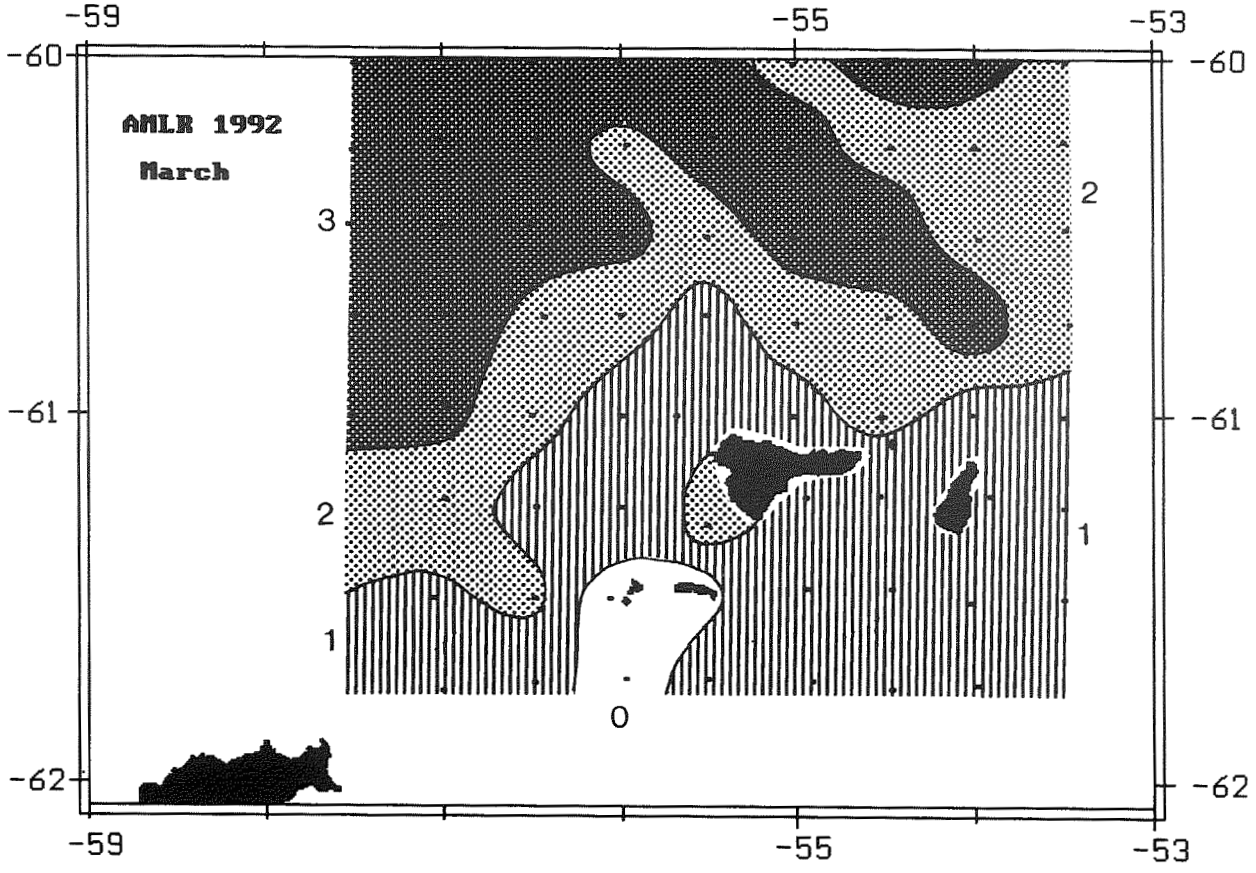


Figure 6: Geographical distribution of krill belonging to different length frequency categories (clusters 1 to 3) during February/March 1992.

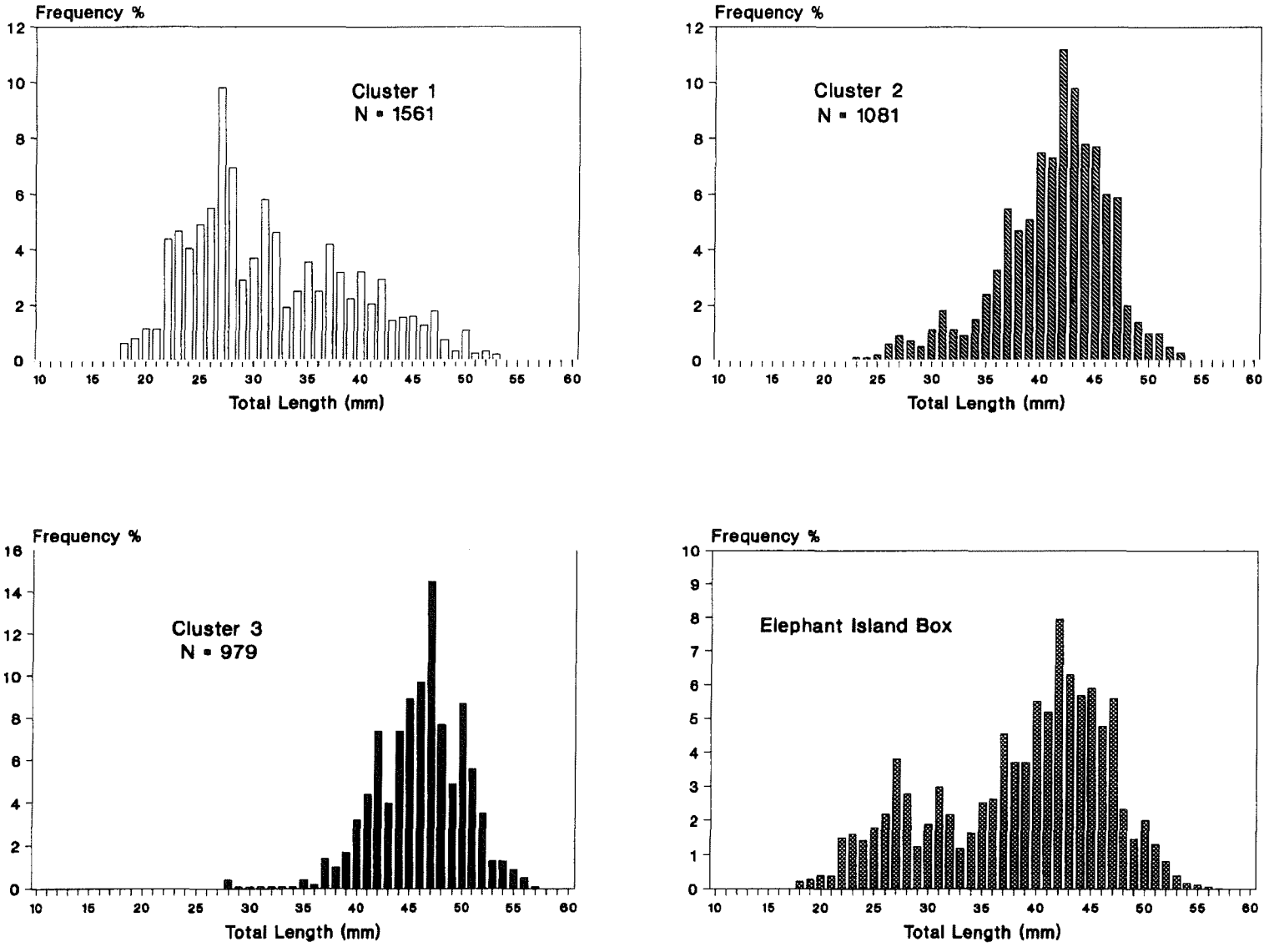


Figure 7: Length frequency distributions of krill belonging to three clusters of the overall weighted length frequency distribution in the Elephant Island area during February/March 1992.

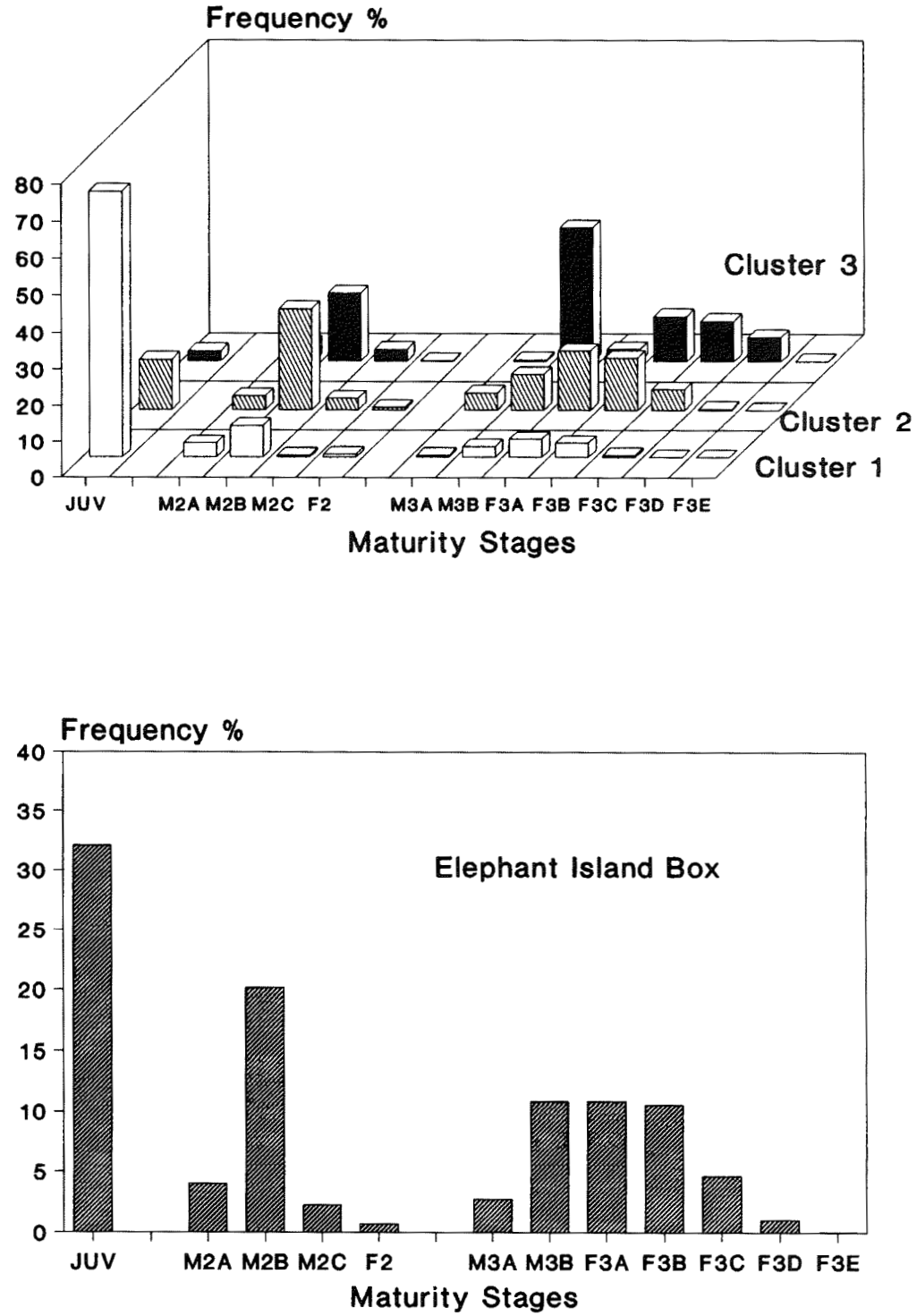


Figure 8: Krill maturity stage composition in three clusters and the overall weighted maturity stage composition in the Elephant Island area during February/March 1992.

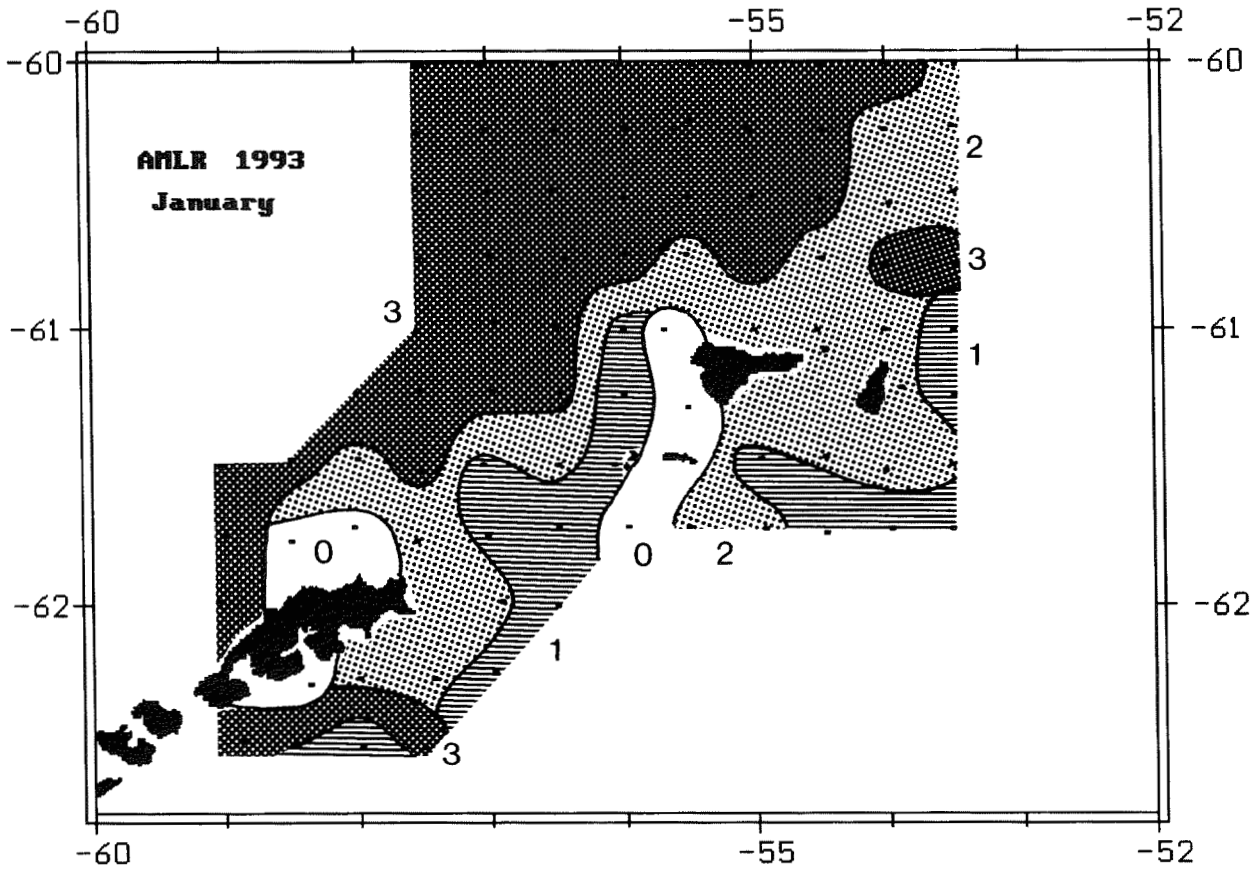


Figure 9: Geographical distribution of krill belonging to different length frequency categories (clusters 1 to 3) during January 1993.

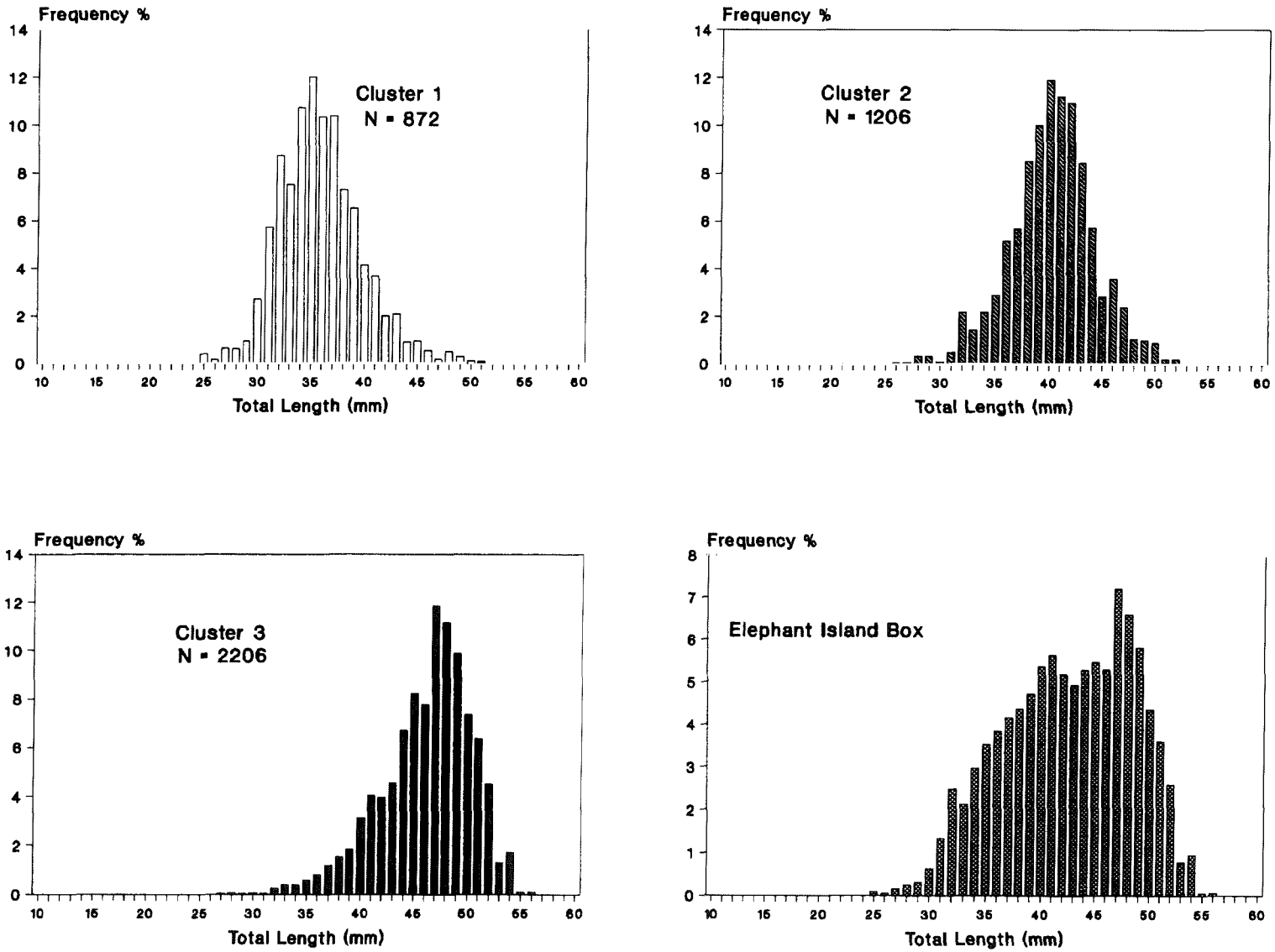
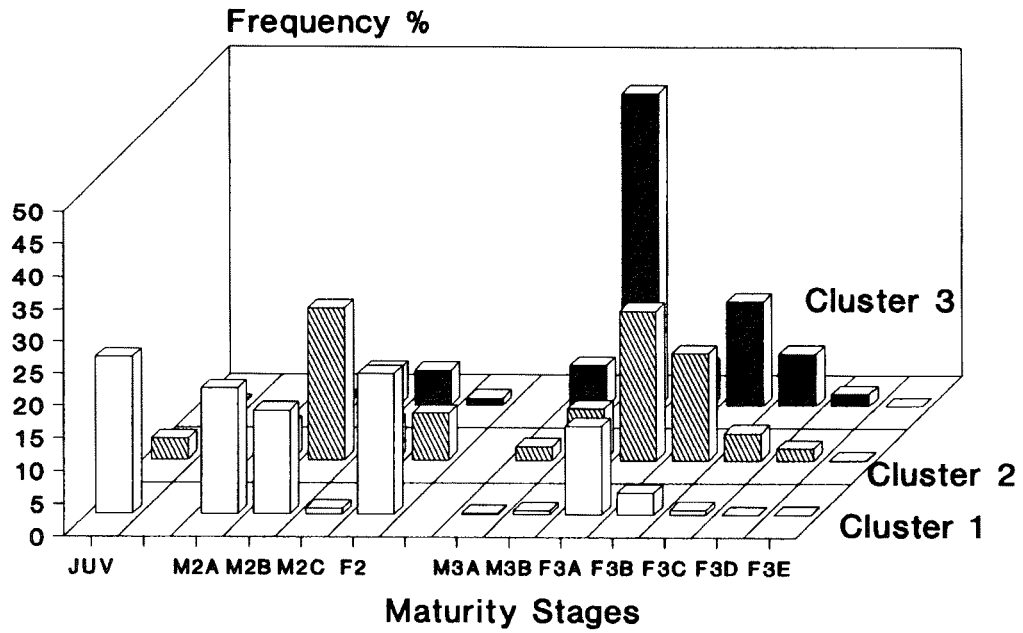


Figure 10: Length frequency distributions of krill belonging to three clusters and the overall weighted length frequency distribution in the Elephant Island area during January 1993.



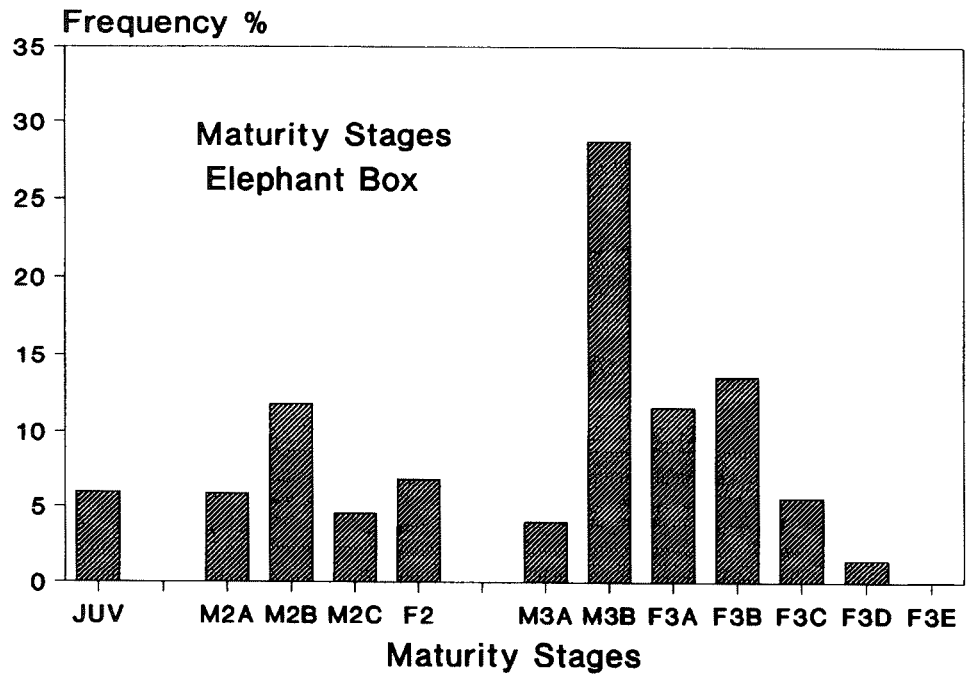


Figure 11: Krill maturity stage composition in three clusters and the overall weighted maturity stage composition in the Elephant Island area during January 1993.

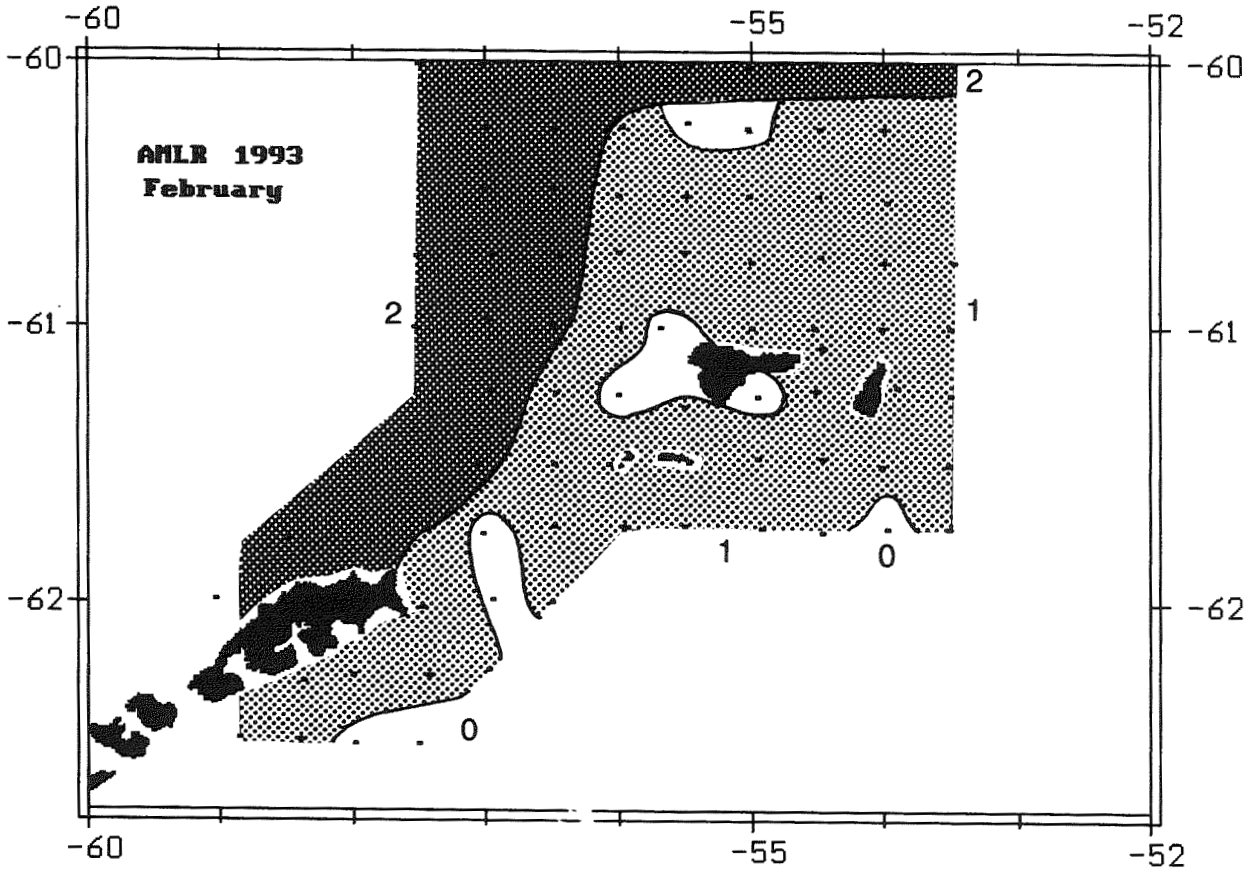
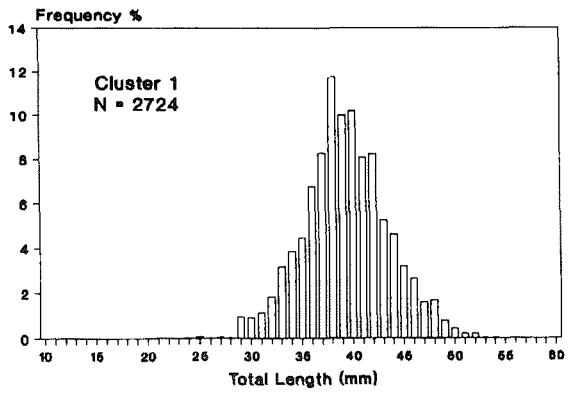
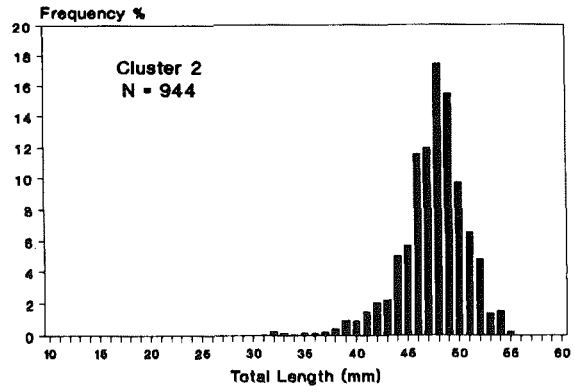


Figure 12: Geographical distribution of krill belonging to different length frequency categories (clusters 1 and 2) during February/March 1993.





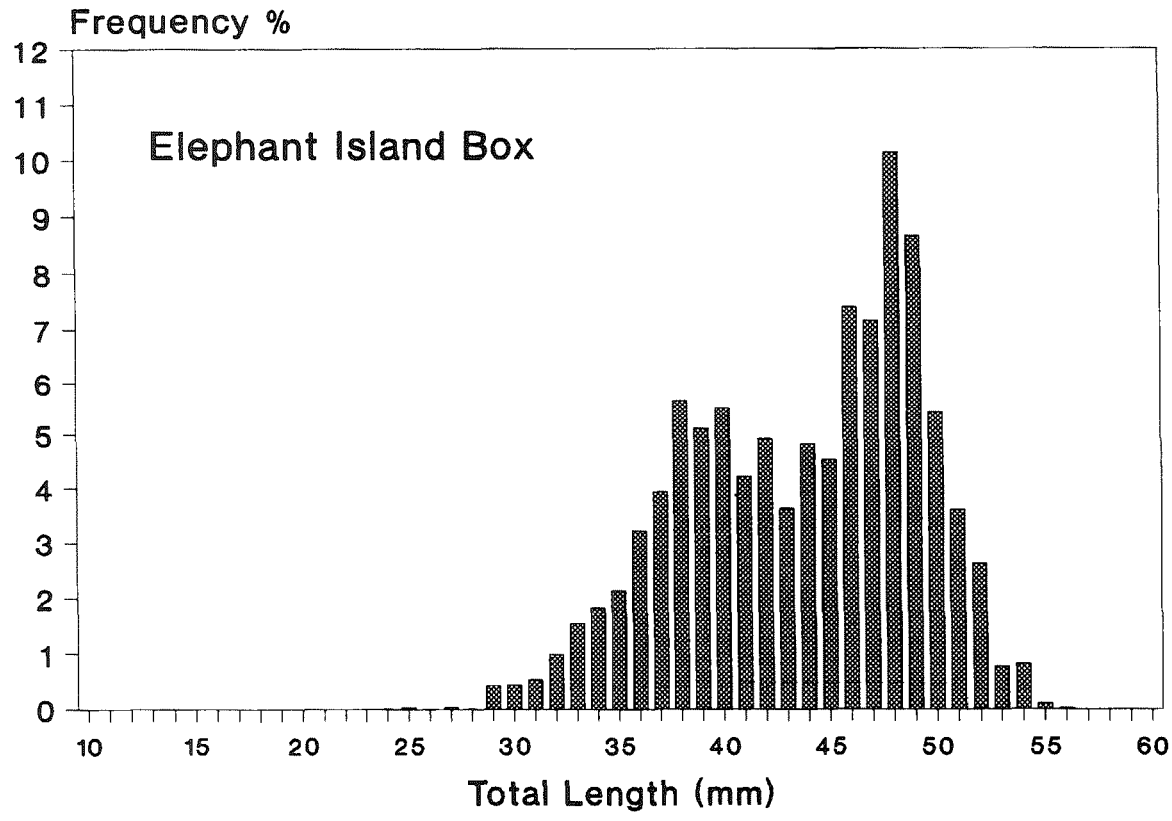
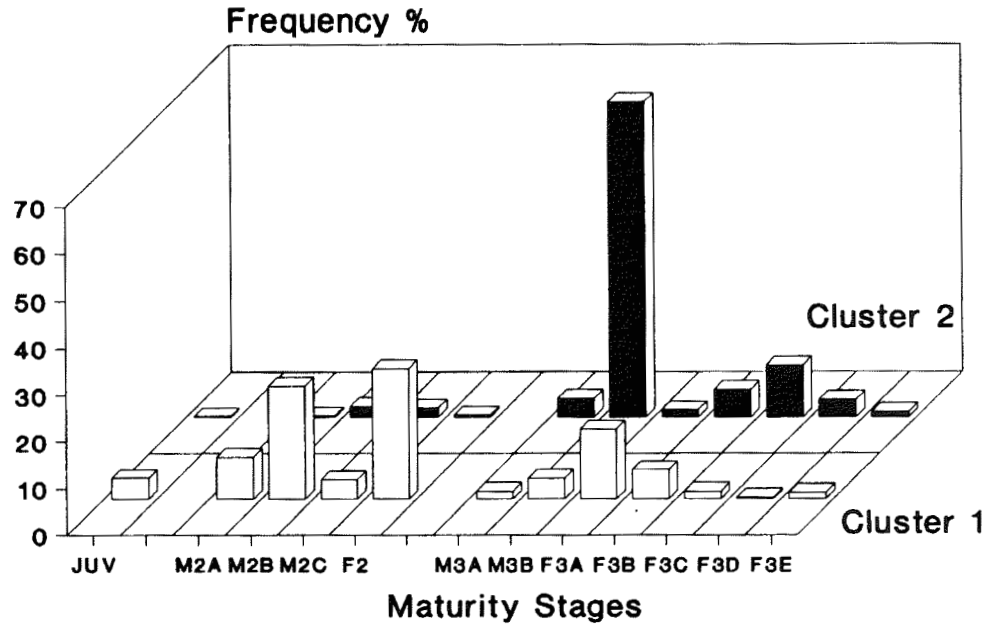


Figure 13: Length frequency distributions of krill belonging to two clusters and the overall weighted length frequency distribution in the Elephant Island area during February/March 1993.



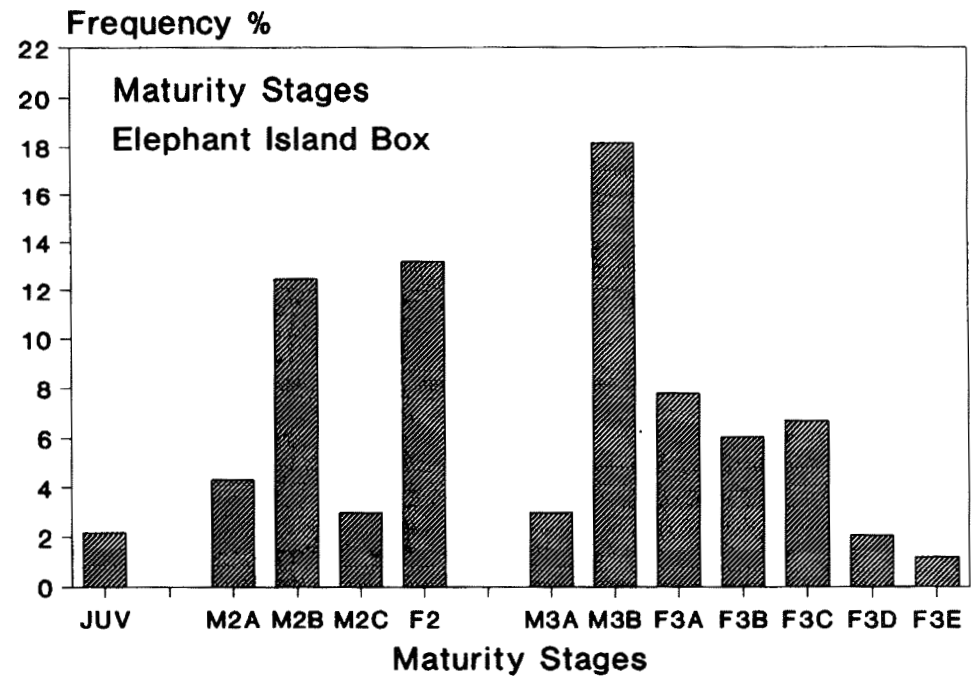


Figure 14: Krill maturity stage composition in two clusters and the overall weighted maturity stage composition in the Elephant Island area during February/March 1993.

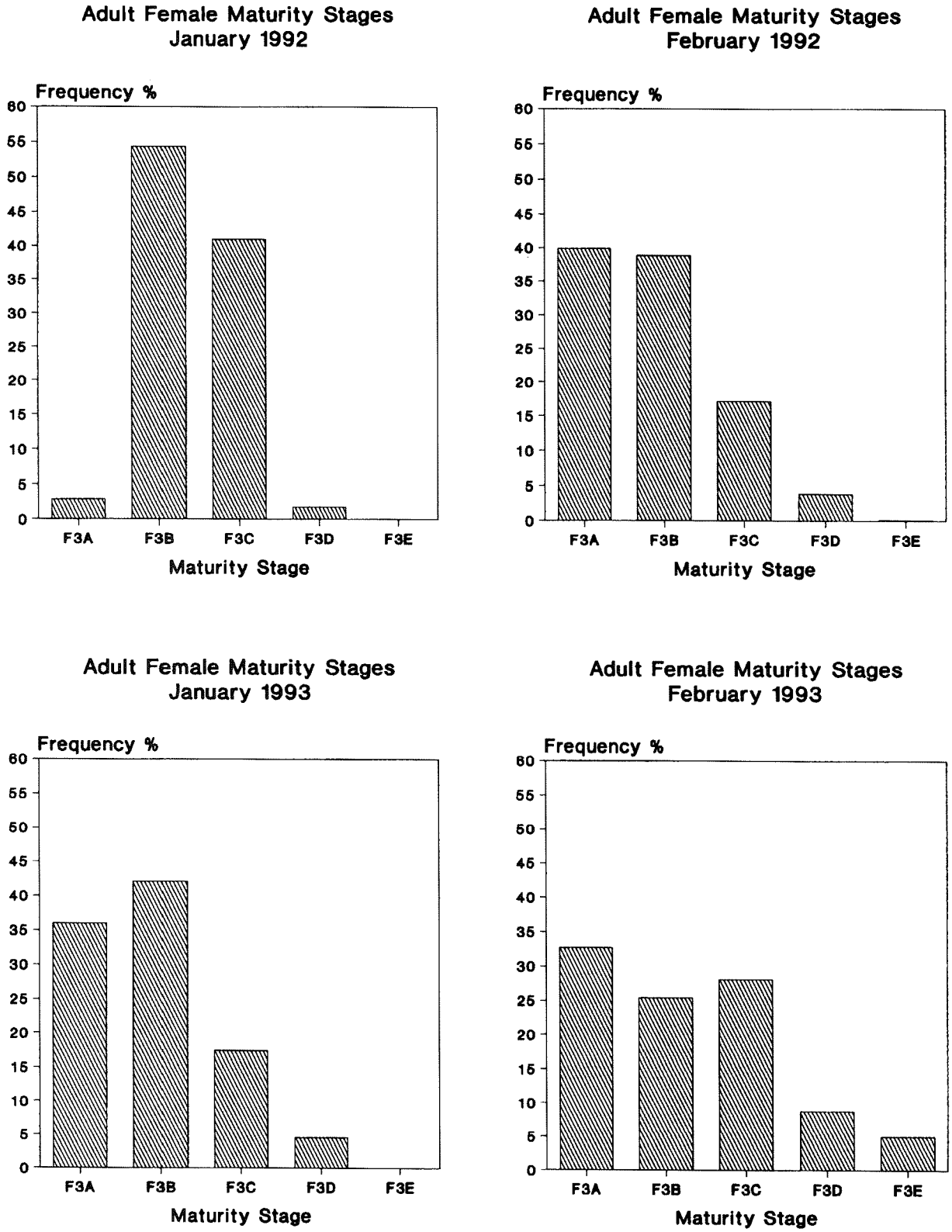


Figure 15: Percentage composition of adult female maturity stages in the Elephant Island area during 1992 and 1993.

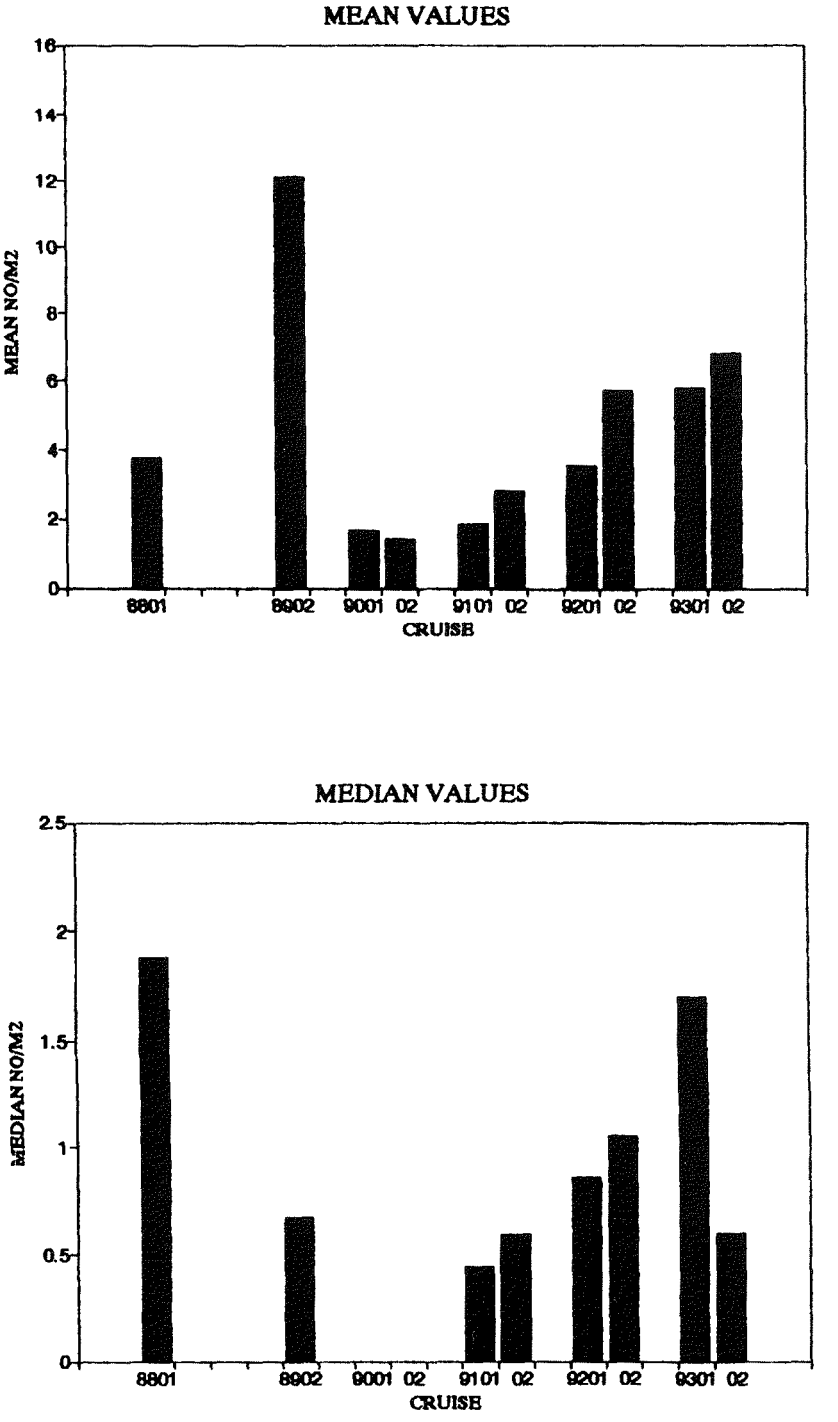


Figure 16: Krill abundance estimates based on net sampling operations in the Elephant Island area from 1988 to 1993. Mean and median values as numbers per m^2 are based on unweighted abundances.

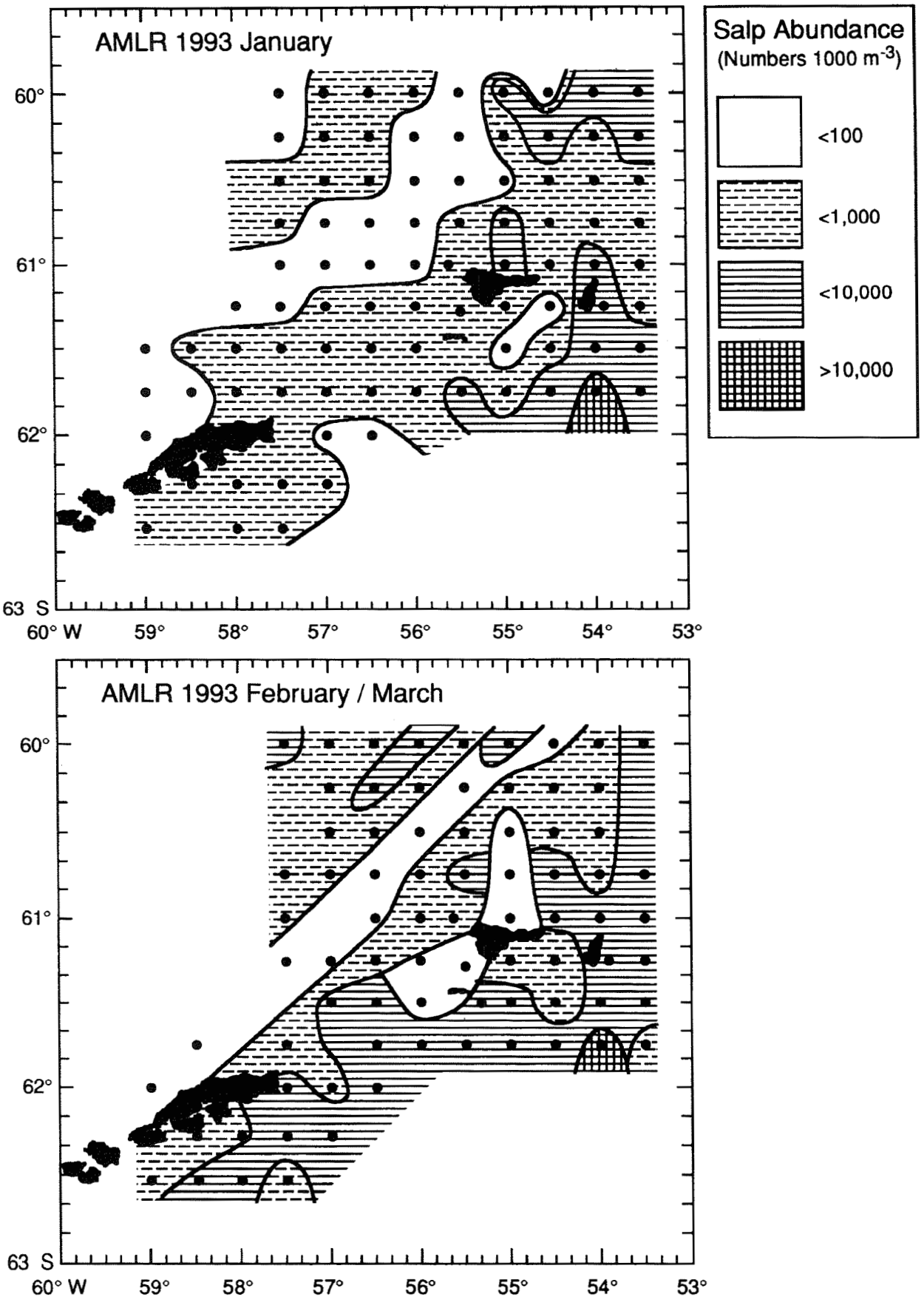


Figure 17: Distribution and abundance of salps (*Salpa thompsoni*) in the Elephant Island area during 1993.

Légendes des tableaux

Tableau 1: Abondance du krill et des salpes dans l'encadré de l'île Eléphant pendant les étés 1992 et 1993. L'abondance est exprimée en nombre moyen stratifié par millier de m^3.

Tableau 2: Indications de l'abondance des classes d'âge du krill à l'île Eléphant de 1975 à nos jours : bonne (+), mauvaise (-) ou moyenne (+/-). Les cases blanches indiquent que les informations font défaut. Cette version complète les tableaux de Siegel (1989) et Loeb et Siegel (1992).

Légendes des figures

Figure 1: Stations de la campagne d'évaluation AMLR qui ont été échantillonnées pendant l'été austral 1993, et "encadré de l'île Eléphant", de surface plus restreinte, qui a fait l'objet d'échantillonnages réguliers en 1992 et pendant les années précédentes.

Figure 2: Exemples de dendrogrammes dérivés d'analyses en grappes utilisant l'abondance standardisée des classes de longueurs de krill en tant que paramètres des stations. Les exemples donnés ici représentent les campagnes d'évaluation de (a) février 1992 et (b) février/mars 1993 dans le secteur de l'île Eléphant.

Figure 3: Répartition géographique du krill appartenant à diverses catégories de fréquences de longueurs (grappes 1 à 3) en janvier 1992.

Figure 4: Distributions de fréquences de longueurs de krill appartenant à trois grappes et distribution générale pondérée des fréquences de longueurs dans le secteur de l'île Eléphant en janvier 1992.

Figure 5: Composition en trois grappes par stade de maturité du krill et composition générale pondérée en stades de maturité dans le secteur de l'île Eléphant en janvier 1992.

Figure 6: Distribution géographique du krill appartenant à trois catégories de fréquences de longueurs (grappes 1 à 3) en février/mars 1992.

Figure 7: Distributions de fréquences de longueurs de krill appartenant à trois grappes et distribution générale pondérée des fréquences de longueurs dans le secteur de l'île Eléphant en février/mars 1992.

Figure 8: Composition en trois grappes par stade de maturité du krill et composition générale pondérée en stades de maturité dans le secteur de l'île Eléphant en février/mars 1992.

Figure 9: Répartition géographique du krill appartenant à des catégories de fréquences de longueurs différentes (grappes 1 à 3) en janvier 1993.

Figure 10: Distributions de fréquences de longueurs de krill appartenant à trois grappes et distribution générale pondérée des fréquences de longueurs dans le secteur de l'île Eléphant en janvier 1993.

Figure 11: Composition en trois grappes par stade de maturité du krill et composition générale pondérée en stades de maturité dans le secteur de l'île Eléphant en janvier 1993.

Figure 12: Répartition géographique du krill appartenant à des catégories de fréquences de longueurs différentes (grappes 1 et 2) en février/mars 1993.

Figure 13: Distributions de fréquences de longueurs de krill appartenant à deux grappes et distribution générale pondérée des fréquences de longueurs dans le secteur de l'île Eléphant en février/mars 1993.

Figure 14: Composition en deux grappes par stade de maturité du krill et composition générale pondérée en stades de maturité dans le secteur de l'île Eléphant en février/mars 1993.

Figure 15: Composition des stades de maturité des femelles adultes, en pourcentage, dans le secteur de l'île Eléphant en 1992 et 1993.

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