ON THE INTENSITY OF SAMPLING KRILL TRAWL CATCHES

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Abstract

This paper uses actual krill length-frequency data in an attempt to address the problem of the determination of adequate sample size to obtain representative krill length-frequency distributions from commercial catches. The possible effect of two other factors (within-trawl variability and sample decomposition) which may influence length-frequency data quality is also considered. Attention is drawn to the following:

- all measurements of length from commercial krill catches should be made, as far as possible, by a single observer/vessel;
- consideration still has to be given to the minimum length differences which should be detectable between catches. Account must be also taken of the desired biological characteristics which are to be discerned (e.g., length-with-age). At present, and in the interests of both statistical rigour and efficiency of measurement, it is proposed that length measurements made on commercial krill catches should be grouped into 2 mm size classes;
- biological implications associated with the detection of specific differences in length should be considered in conjunction with the need to collect information on maturity stages;
- for most purposes a minimum sample size of at least 100 animals/trawl is necessary to obtain statistically meaningful differences between samples; and
- the problem of how frequently commercial krill catches should be sampled still requires consideration.

Résumé

C'est en utilisant les données actuelles de fréquence de longueurs de krill que ce document tente de résoudre le problème de la détermination de la taille de l'échantillon qui permettrait d'obtenir de manière adéquate les distributions de fréquence de longueurs de krill des captures commerciales. Les conséquences possibles de deux autres facteurs (variabilité dans un même trait et décomposition des échantillons) d'influence potentielle sur la qualité des données de fréquence de longueurs sont également étudiées. Il convient de souligner les points suivants:

- toutes les mesures de longueurs du krill provenant de captures commerciales devraient (si possible) être effectuées par un seul observateur/navire;

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- l'examen des différences minimales de longueurs décelables d'une capture à l'autre reste à faire. Il faut dûment prendre en considération le choix des caractéristiques biologiques à discerner (par ex. longueur-avec-âge). A présent, et dans l'intérêt de la rigueur statistique et de l'efficacité de la prise de mesures, il est suggéré de grouper les mesures de longueurs provenant des captures commerciales de krill en classes de tailles de 2 mm;
- les implications biologiques associées à la détection des différences spécifiques de longueurs devraient être étudiées conjointement à la nécessité de recueillir des informations sur le stade de maturité;
- dans la plupart des cas, une taille d'échantillon d'un minimum de 100 individus par chalut est nécessaire pour obtenir des différences significatives sur le plan statistique entre les échantillons; et
- le problème de la détermination de la fréquence à laquelle il faut échantillonner les captures commerciales de krill reste à examiner.

Резюме

В данном труде делается попытка рассмотреть проблему определения размера проб, необходимого для получения репрезентативных данных по распределению частоты длины криля в коммерческих уловах, с помощью анализа фактических данных по частоте длины криля. Кроме того, рассматривается вероятное воздействие двух других факторов (изменчивость в улове за одно траление и разложение проб) на качество данных по частоте длины. Внимание обращается на следующее:

- все замеры длины особей криля в коммерческих уловах должны (по возможности) проводится одним наблюдателем и/или судном;
- остается открытым вопрос об определении минимального различия в длине криля между уловами, которое должно быть измеримо. Необходимо уделить должное внимание идентификации желательных биологических характеристик, напр. - соотношение длина-возраст. В настоящее время в интересах как статистической точности, так и эффективности измере-ния, предлагается сгруппировать данные по длине, полученные по коммерческим уловам криля, по 2-миллиметровым размерным классам;
- при рассмотрении вопросов биологического характера, связанных с выявлением конкретных размерных различий, следует учитывать необходимость сбора данных по стадиям половозрелости; для определения статистически значимой разницы между пробами, в большинстве случаев минимальная проба должна включать по меньшей мере 100 особей за траление; и
- дальнейшему рассмотрению подлежит вопрос частоты сбора проб из коммерческих уловов криля.

Resumen

Este documento utiliza la información actual sobre frecuencia de tallas del krill, en un esfuerzo por estudiar el problema asociado con la determinación del tamaño de muestra de las capturas comerciales que permitirá obtener distribuciones representativas de las frecuencias de tallas del krill. También se considera el posible efecto de otros dos factores (variabilidad en el arrastre y estado de descomposición de la muestra) que pueden afectar la calidad de los datos de frecuencia de tallas. Se destacan los siguietes aspectos:

- todas las mediciones de talla de krill de las capturas comerciales deberán efectuarse, en lo posible, por un sólo observador/buque;
- se deben tomar en cuenta también las diferencias mínimas detectables en las tallas entre capturas. También se deberán examinar las características biológicas que son de interés (por ejemplo, talla por edad). Actualmente, para lograr una precisión estadística y mejorar la eficacia de la medición, se propone que las mediciones efectuadas en las capturas comerciales de krill sean agrupadas en intervalos de tallas de 2mm;
- se deberán considerar las consecuencias biológicas asociadas con la detección de diferencias específicas en tallas, junto con la necesidad de obtener información de las fases de madurez;
- en general, se necesita un tamaño de muestra mínimo de por lo menos 100 especímenes por arrastre, de modo que las diferencias estadísticas entre muestras sean coherentes;
- queda todavía por considerarse más a fondo la cuestión de ¿cuán frecuentemente se deben muestrear las capturas comerciales de krill?

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1. INTRODUCTION

At its first meeting in June 1989, the CCAMLR Working Group on Krill (WG-Krill) recommended:

- the development of sampling procedures to take account of how many samples and how frequently samples of krill length distributions in commercial catches should be taken; and
- an interim measure whereby sampling of at least 50 krill from one haul per fishing day should be undertaken by all vessels other than those of the Japanese fishing fleet, which already carry out such sampling.

This recommendation was subsequently endorsed by the Scientific Committee (SC-CAMLR-VIII, paragraph 2.44). In the process of receiving the necessary consensus for this endorsement, SC-CAMLR requested that (a) studies should be undertaken to develop standardized sampling procedures for krill catches, (b) due account should be taken of the number and frequency at which krill length-frequency samples in commercial catches should be collected, and (c) procedures should be developed by which within-catch variances in the sampling of length-frequency distributions in addition to between-catch and vessel variability

could be assessed (SC-CAMLR-VIII, paragraph 2.43). The Scientific Committee also urged Members to report any difficulties experienced with the interim sampling procedure outlined above as well as the procedures they are currently using or intend to use to sample krill length distributions (SC-CAMLR-VIII, paragraph 2.44).

Considering the above sampling procedures, it should be noted that Watkins *et al.* (1986) have emphasized that the high level of heterogeneity in many krill populations necessitates implementation of sampling procedures which take account of the extent of such heterogeneity. Not only does this directly influence the extent of sampling, in the case of sampling commercial catches it requires that an appropriate balance between the minimum levels of sampling desired and the cost of sampling be found.

This paper therefore uses actual krill length-frequency data to address the problem of determining adequate sample size as part of the ongoing effort within WG-Krill to obtain representative krill length-frequency distributions from commercial catches. In addition, the possible effect of two other factors which may influence length-frequency data quality are also considered. These are the effect of elapsed time after capture (i.e., decomposition of samples) on measurements of length and within-catch sample variability as related to the position within a trawl from which a particular length sample is taken.

2. MATERIALS AND METHODS

Krill were sampled at 22 localities close to Coronation (South Orkneys) (**n**=13) and Elephant (South Shetlands) (**n**=19) Islands during an acoustic survey by RS *Africana* in March 1990. A Polish commercial krill trawl (16/41) was used for all sampling and reference should be made to Slosarczyk (1986) and Miller (1987) for details of its construction and operation.

Routinely, krill samples were collected from the aft-quarter of the trawl codend and the lengths of 50, 100 and 150 animals were measured. A variable number of animals per sample were also measured until 50 animals in a single 1 mm size class were obtained. The length measurement used was that recommended by SC-CAMLR - namely, from the front of the eye to the tip of the telson, excluding the terminal setae - and to avoid problems of sampling error alluded to by Watkins *et al.* (1985) all measurements were made by a single observer. Analyses of Variance (ANOVA) were undertaken using the Statistical Analysis Software (SAS 1985) package to compute length statistics and to investigate differences in mean length between stations and between areas. Additional statistical procedures described in Zar (1984) were used to estimate projected sample sizes, based on variances in mean length between areas, and minimum detectable length differences independent of, and relative to, projected sample sizes. The formulae for these various procedures are given in Appendix 1.

The length measurement procedure and statistical analyses outlined above were repeated for samples collected from 10 different localities within a single trawl, proportionately increasing in distance from the codend mouth. Similarly, a single sample of 50 animals was measured repeatedly at various times (up to 46 hours) after collection.

3. RESULTS

3.1 Analysis of Length by Station and Area

Length-frequency distributions for animals collected at the South Orkneys and Elephant Island respectively are given in Figure 1. The data in this figure are based on measurements until 50 animals in each single 1 mm length size class were collected. The ANOVA of mean length by area indicated a significant difference between the two areas (F_{ratio}=8476.21,

α=0.05). Mean lengths and standard deviations by station in the two areas are shown in Figures 2 and 3. Again significant differences were found between mean lengths by station at both the South Orkneys (**F**=120.38, α=0.05) and Elephant Island (**F**=86.46, α=0.05).

The procedures outlined in Appendix 1 (A) were then used to compute the required sample size to detect various differences (1, 2 and 5 mm) in mean length at a 0.05 level of significance with a 90% chance of detecting a true difference. As explained in Appendix 1 (A), a simple two-sample *t* test was used and the between-population variance was calculated from the combined error mean squares for length at the two islands derived by the ANOVA procedure. From Figure 3 it can be seen that the maximum benefit in terms of detecting real differences in mean length with area as a function of sample size is to be derived by increasing the length class intervals being used in the sample analyses. In this connection it is apparent that the greatest impact on the required sample size occurs when the length class difference being assessed is increased from 1 to 2 mm. This trend is also apparent in the computed minimum detectable differences in mean length in relation to projected sample size for various functions of the pooled variance obtained from the analyses between areas (Figure 1). In both cases, a sample size of at least 100 animals appeared most suited for the detection of a 2 mm difference in mean length between the two areas.

A similar picture to that obtained from between area analyses is apparent when between-station differences in mean length are analyzed (see Appendix 1 (B) for details of analytical procedures) for the two areas separately. Figure 5 shows the minimum detectable differences in mean length in relation to various functions of the between station variance in length encountered. Table 1, on the other hand, illustrates the projected sample sizes required for the detection of specific differences in mean length between stations. Once again a sample size of approximately 100 animals appears best suited for detecting a 2 mm difference in mean length between stations at both islands. It would be logical to assume, however, that this picture would change with the extent of the underlying variance encountered between stations.

The ANOVA for between station differences in length indicates that for sample sizes of 100 animals or less, no significant differences in between-station lengths were detectable (**F**=1.967 and 1.187 and **F**=2.14 and 1.295 [α=0.05] for measured sample sizes of 50 and 100 animals at the two islands respectively). This would imply that such samples were too small to detect differences in length between stations, a conclusion supported by the results of the projected sample size-detectable length difference analysis reported above.

3.2 Analysis of Samples by Locality Within a Single Catch

Mean lengths for different sample sizes taken from 10 localities within a single trawl are shown in Figure 6. Both a nested ANOVA for all localities as well as a comparison-of-means test between localities indicate that there were no significant differences (**F**=8.75, α=0.10 to 0.05) between mean lengths or the number of animals measured/location (i.e., 50, 150 or 50 in one size class).

3.3 Analysis of Samples With Time

The mean lengths of a sample of 50 animals measured at various times up to 46 hours after collection are shown in Figure 7. Results from the ANOVA (**F**=0.31, α=0.10 to 0.05) indicate no significant changes in mean length with time thereby implying that sample length measurements are not affected by decomposition, at least over the period considered.

4. DISCUSSION

From the current results, the sample size of 50 animals/trawl/vessel/day recommended by SC-CAMLR appears insufficient to detect even quite large differences in mean length between areas and between samples in one area unless a large number of vessels are operating (i.e., a large number of samples are measured) in one locality. In this connection, some consideration needs to be given to precisely how large detected differences in mean length should be in order to provide meaningful insights into the underlying biological characteristics and/or differences of commercial krill catches.

Both the projected sample size and minimum detectable length difference analyses suggest that in the interests of minimizing underlying measurement effort whilst still maintaining the ability to detect meaningful length differences, the most cost effective grouping of length is into 2 mm size classes. Furthermore, from both a statistical and practical point of view, it would appear that measurement of about 100 animals/sample is sufficient to obtain an adequate representation of the length structure. The number of animals to be measured, however, is obviously a function of the underlying variance in length of the population(s) being considered and similarly so is the minimum detectable difference in length. In this paper, therefore, some attempt has also been made to illustrate how both these parameters may change with underlying variance in length of the population concerned (see Figures 4 and 5).

From the above results it is also interesting to note that observed trends in the minimum detectable differences in length as a function of between-station variance are essentially similar to those between areas. This suggests that even length samples from a relatively small area may yield quite high variances thereby necessitating the collection of a larger number of samples in order to quantify such variance more adequately (cf. Watkins *et al.*, 1986). This would in turn imply that once again the standard of only length sample/fishing day recommended by SC-CAMLR is probably insufficient to detect real changes in length, especially in the presence of marked small-scale (say between-swarm) variability in the length composition of the population(s) being sampled and when the number of catches sampled is small (i.e., only a small number of vessels is operating in the area concerned).

From the analyses of samples taken from different localities in the trawl, it would appear that mean length and length-frequency distribution are not affected by spatial differences within-trawl. This conclusion is substantiated by similar results reported by Ichii (1990) from his sampling of Japanese commercial catches. It is also apparent that there are no significant differences between length data obtained via various sample sizes (i.e., 100, 150 and 50 animals in one size class). Given that the trawl catch used in this particular experiment was "aimed" into a single krill swarm, then it would be reasonable to assume that the sample length variance would be low. It is interesting to note, however, that comparison of length between stations in relation to sample size indicates that small samples (i.e., <100 animals) also did not indicate any significant differences in length. This result is in accordance with the estimated minimum sample size ($\geq$100) required to detect specific length differences between stations reported above.

Surprisingly, length did not appear to vary significantly with time post-capture. This was despite the fact that the condition of individual animals being measured noticeably deteriorated. Fluctuations in measured length were observed, however, as can be seen from minor differences in mean length with time as shown in Figure 7. No consistent trend was observable and it can only be assumed that such fluctuations fell within the limits of normal measurement error as highlighted by Watkins *et al.* (1985).

In conclusion, therefore, the following points are offered for consideration:

- All measurements of length from commercial krill catches should be made, as far as possible, by a single observer/vessel. As proposed by Watkins *et al.* (1985)

further studies of between-observer variances in the measurement of length should be encouraged so as to improve quantification of this effect.

- Consideration must be given to the minimum length differences between-catches which are to be detected. As far as possible, account should be taken of the particular biological characteristics which the measurements are aimed at best discerning (e.g. length-with-age). At present, and in the interest of both statistical rigour and the efficiency of measurement, it is proposed that length measurements from commercial catches should be grouped into 2 mm size classes.

- In addition to the biological implications of detecting specific length differences, there seems to be little doubt that if current knowledge of the fishery's operational characteristics is to be improved then attention should be given as to whether, and how, maturity stage information could be collected. The recommendations put forward by Morris *et al.* (1988) therefore need to be noted and critically reviewed.

- From the present analyses, and for most purposes, a minimum sample size of at least 100 animals/trawl appears necessary in order to obtain statistically meaningful differences between samples.

- The problem of the frequency of sampling still has not been satisfactorily resolved other than that a single length sample/trawling day does not appear sufficient to obtain even a representative approximation of the length-frequency distributions in an area(s) where the between-sample variance is quite low (as was the case in this study) and where the number of fishing vessels is likely to be sparse. The issue of sampling frequency thus obviously requires further consideration.

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Table 1: Projected minimum sample sizes for the detection of specific differences in mean length between-stations at the South Orkneys and Elephant Island. Significance level α=0.05 and confidence limit of 90%.

Minimum Detectable Length Difference	Projected Sample Size	
	South Orkneys	Elephant Island
1 mm	750	500
2 mm	200	150
5 mm	30	25

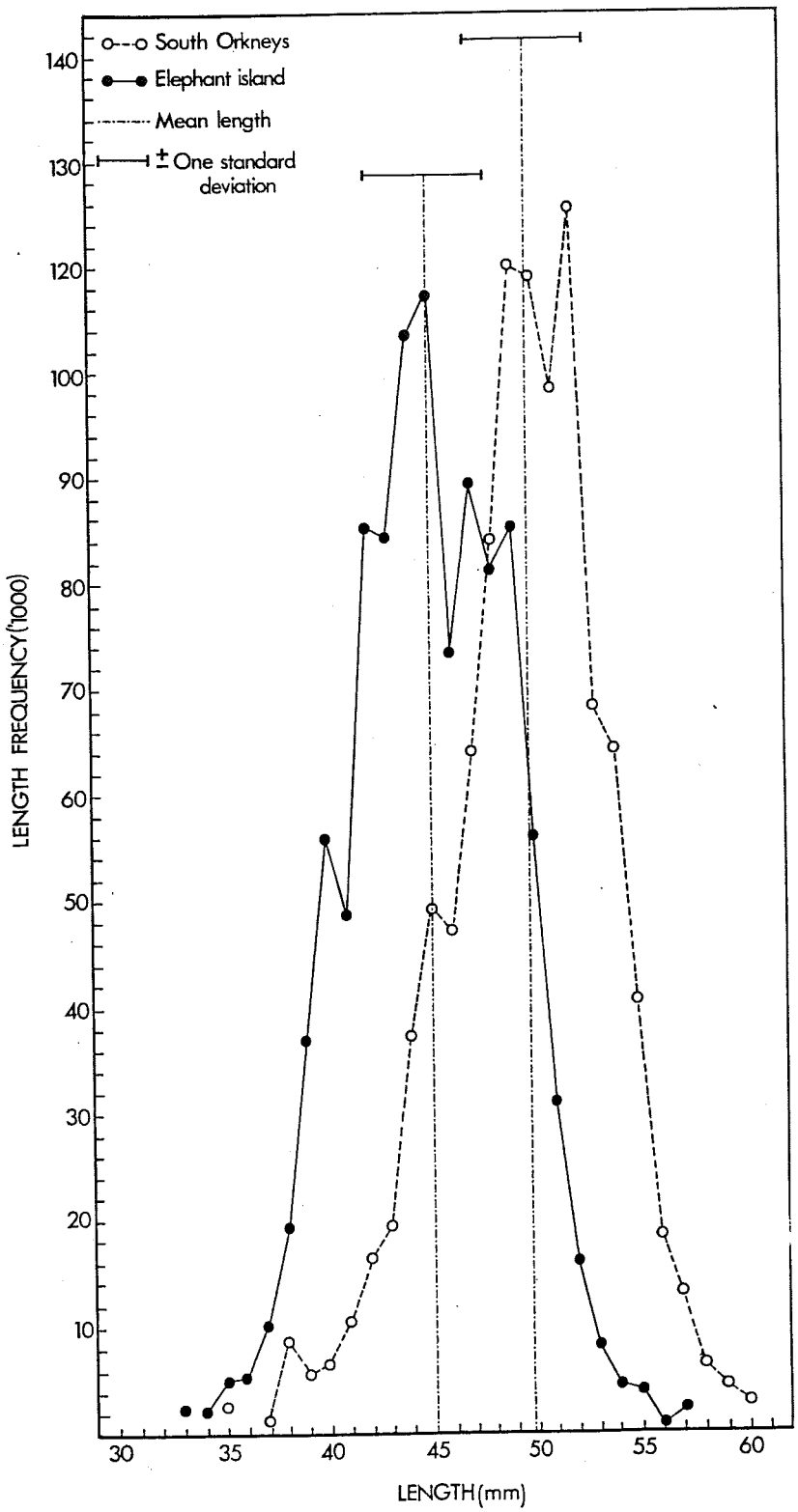

Figure 1: Length-frequency distributions for krill collected with a Polish commercial krill trawl at the South Orkneys and Elephant Island. Mean lengths for each area (±1 S.D.) are also shown.

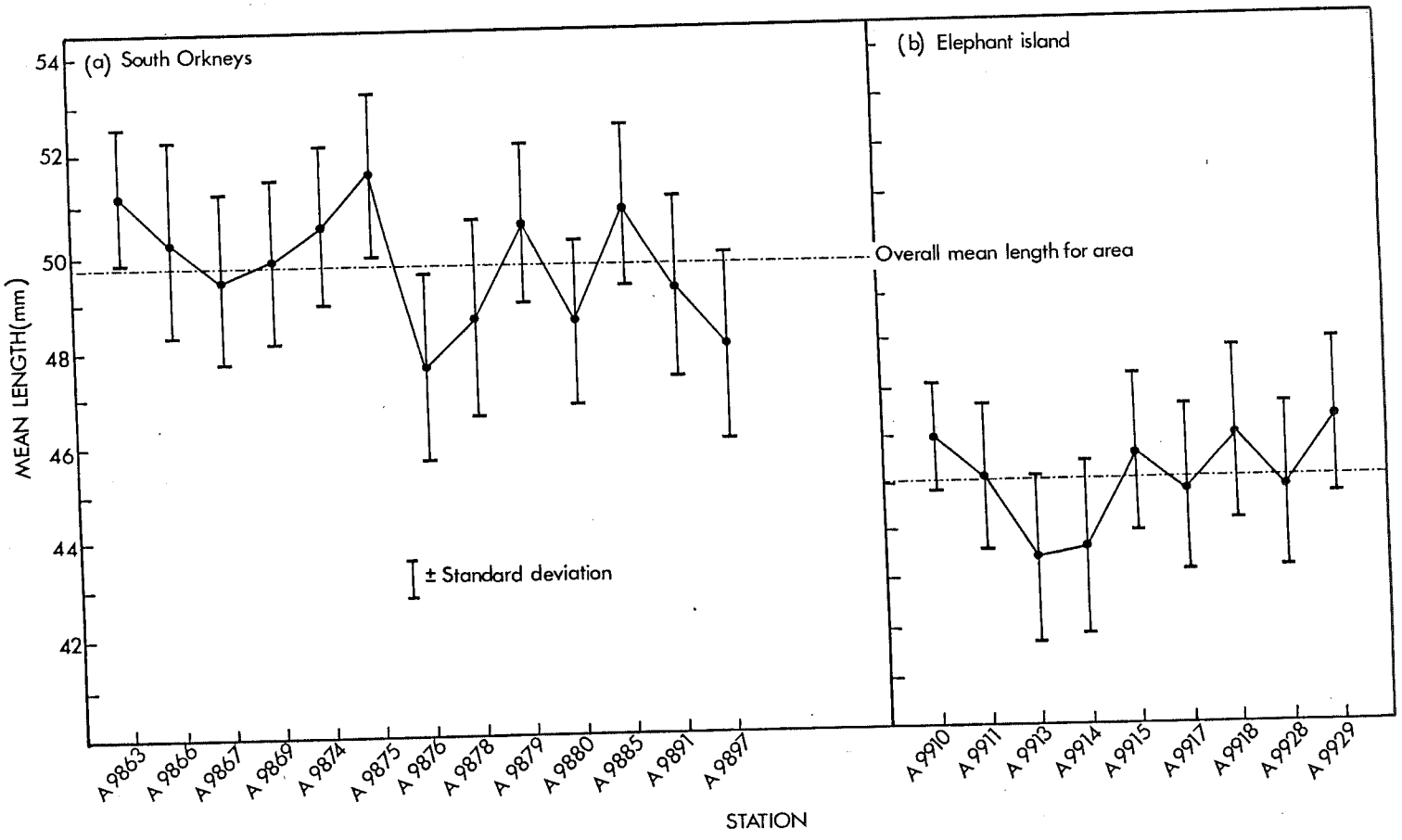

Figure 2: Mean Length (± 1 S.D.) by station for krill collected at (a) the South Orkneys, and (b) Elephant Island.

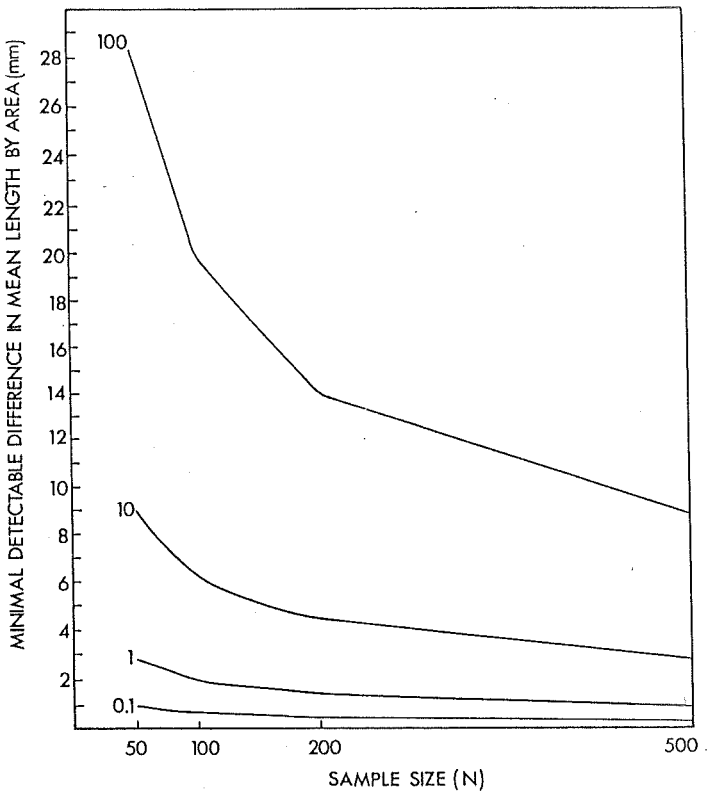

Figure 3: Detectable differences in length as a function of sample size. Data for analyses derived from data for the South Orkneys and Elephant Island together (i.e., between areas - see text for explanation).

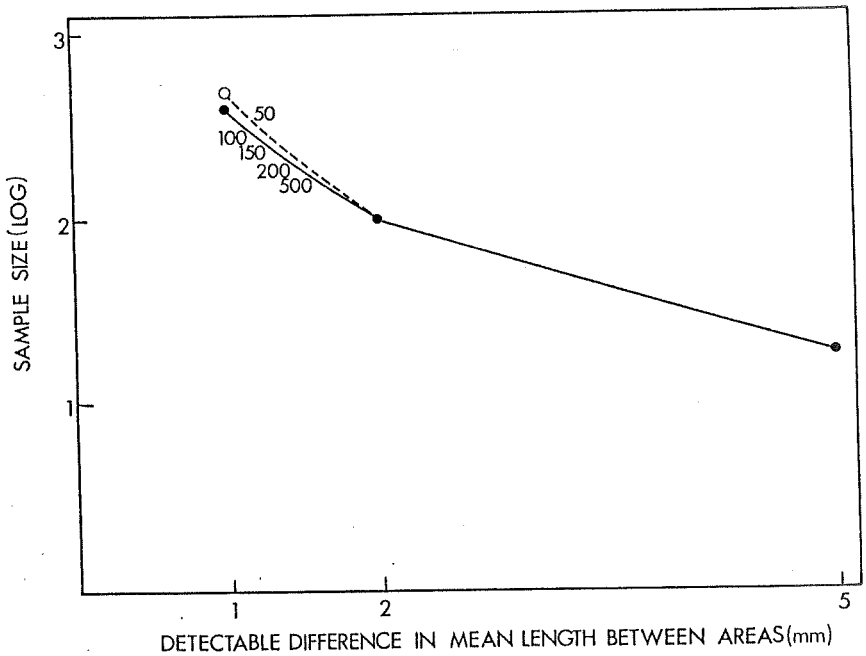

Figure 4: Projected minimum detectable differences in length as a function of sample size (n) and in relation to various functions of the between-area variance (s^2 - see Appendix 1 (A) for explanation) in length obtained during the present study.

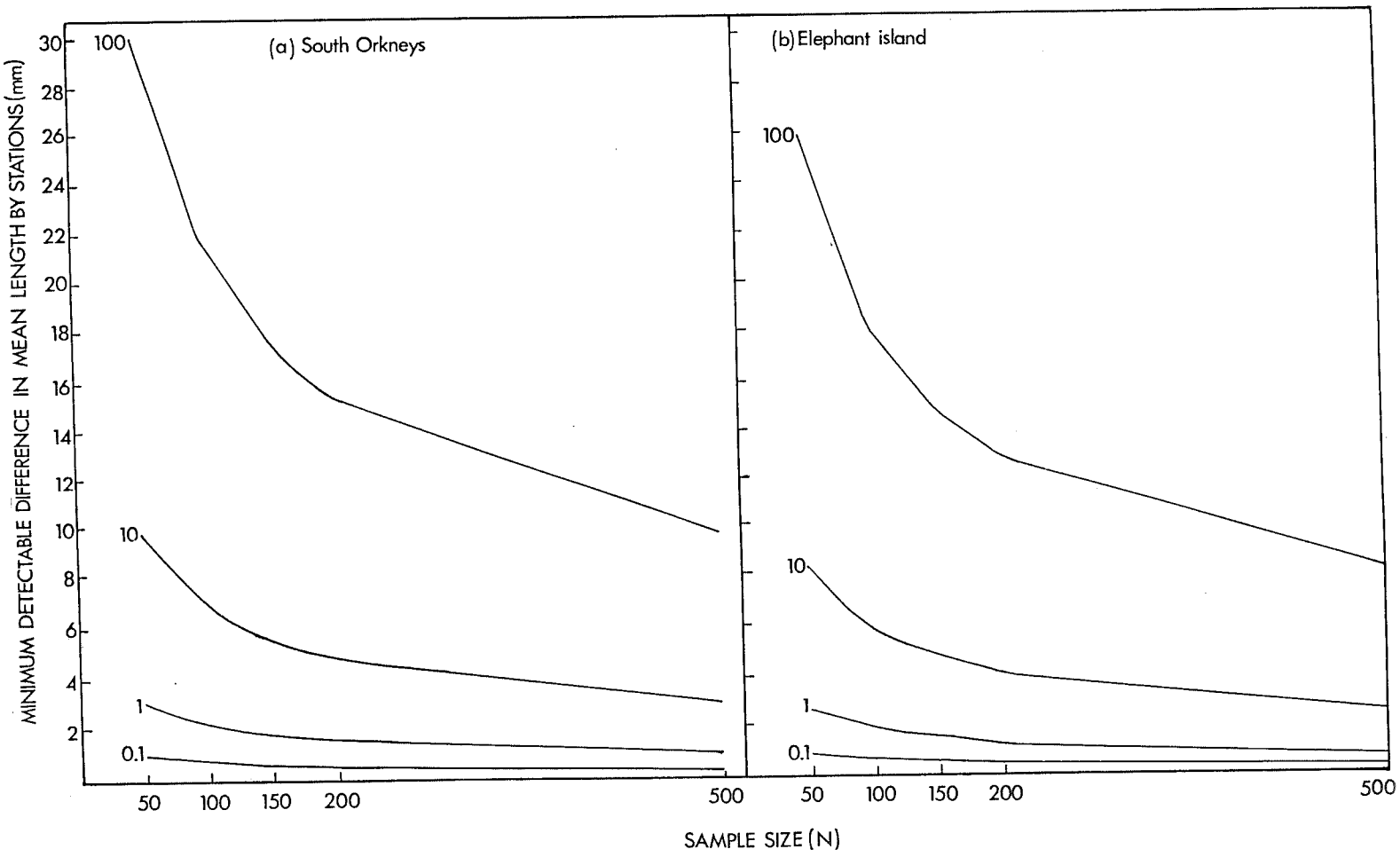

Figure 5: Projected minimum detectable differences in length as a function of sample size (n) and in relation to various functions of the between-station variance (s^2 - see Appendix 1 (B) for explanation) in length obtained during the present study at (a) the South Orkneys and (b) Elephant Island.

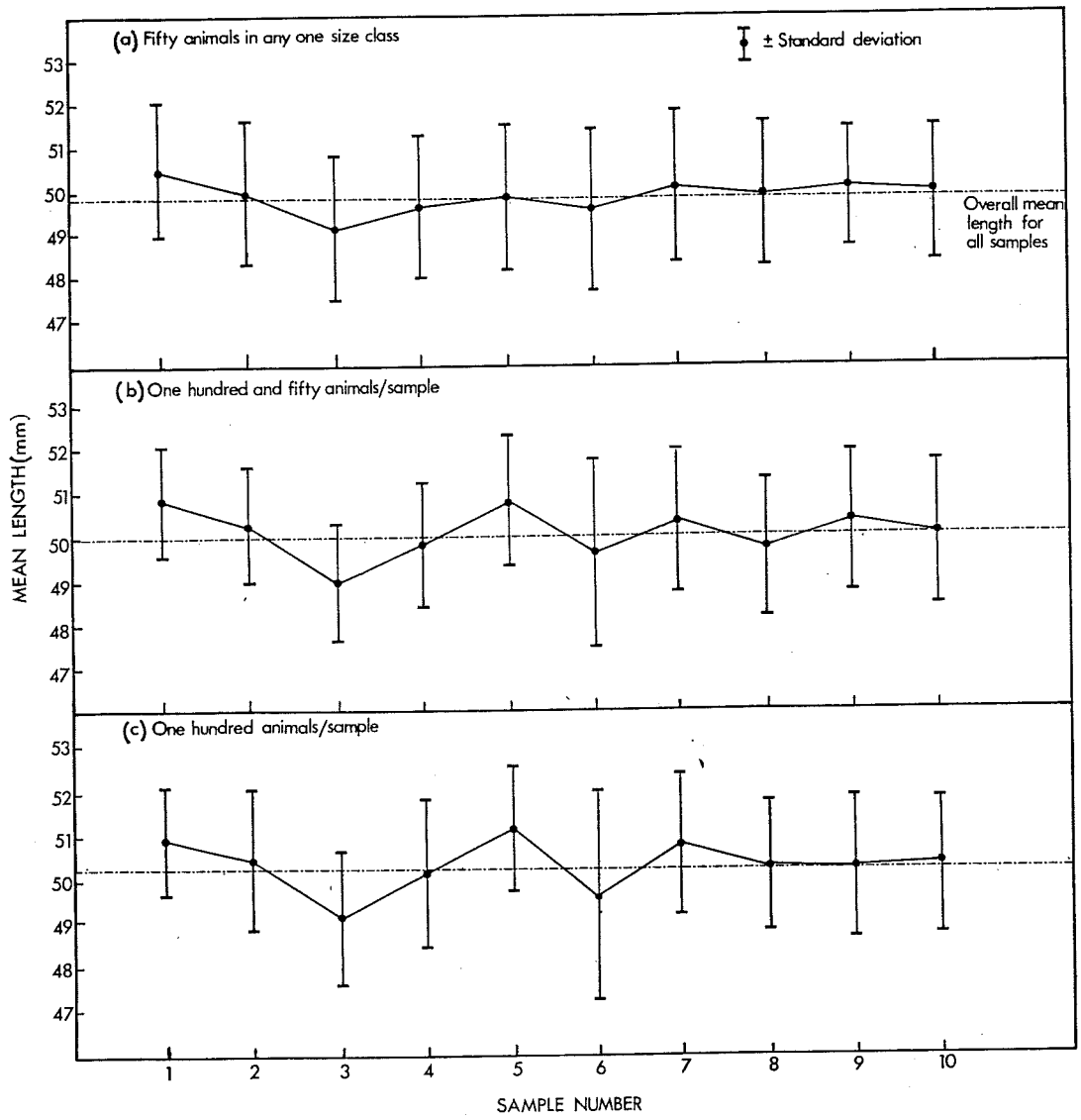

Figure 6: Mean lengths (±1 S.D.) of animals collected from various localities within a single trawl. The number of animals measured was (a) up to 50 in a single 1 mm size class, (b) 150 and (c) 100.

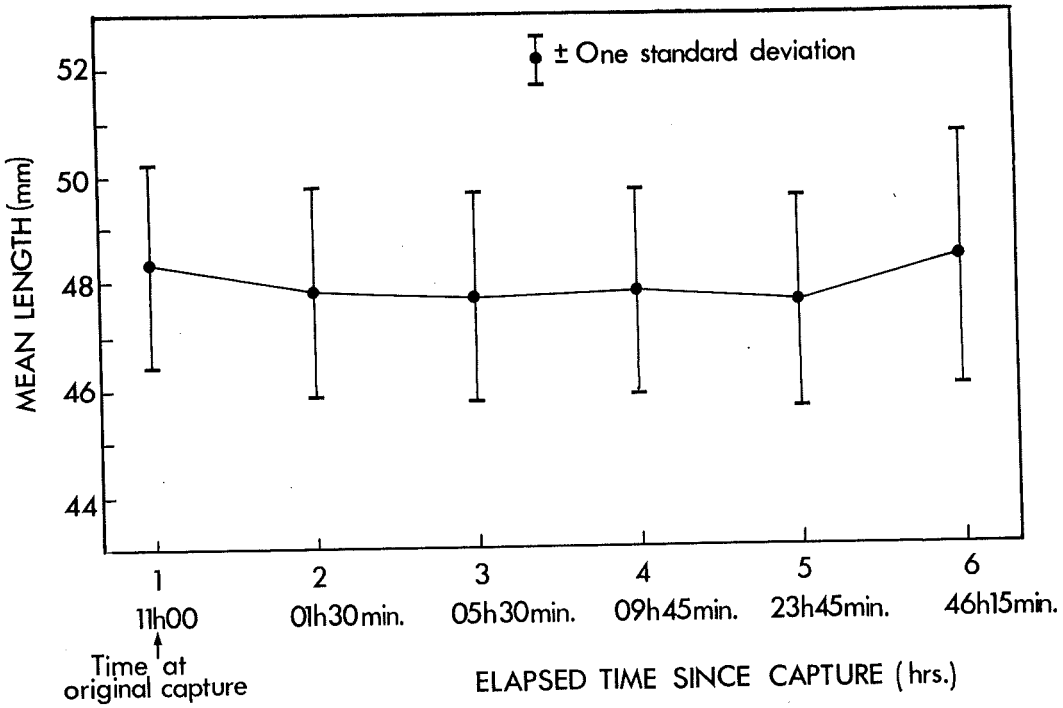

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Figure 7: Tallas medias (±1 S.D.) de 50 individuos medidos en distintos intervalos después de la captura.

FORMULAE AND PROCEDURES FOR SPECIFIC STATISTICAL ANALYSES

(A). Projected Sample Size Required for and Minimum Detectable Difference in Mean Length Between Areas

This procedure may be considered as an estimation of the minimum sample size required to detect differences between two sample means (i.e., a two-sample *t* test is used). The appropriate formula is given below and the estimation procedure followed can be found in Chapter 9.7 of Zar (1984). The formula used was:

$$n \geq \frac{2s^2p}{\delta^2}(t_{\alpha,\nu} + t_{\beta(1),\nu})^2 \qquad (1)$$

where δ = minimum detectable difference between population means,

s^2 = the pooled variance, assuming that the populations sampled have the same variance. (In fact the individual areal sample variances were remarkably similar - 13.45 and 13.73 for Elephant Island and the South Orkneys respectively). The variances used were calculated from the Analysis of Variance (ANOVA) results for between area mean lengths using the sum of squares and necessary degrees of freedom from the relevant variables (see Zar, 1984, p. 134),

α = significance of level where ν equals $\mathbf{2(n-1)}$. The level of significance employed in the performance of the necessary *t*-test was 0.05,

$\mathbf{1-\beta}$ = the power of the test. Since a 90% chance of detecting a true population difference in mean length was chosen, then the value of β equals 0.10.

Equation 1 above can be rearranged to determine how small a population difference (δ, defined above) is detectable for a given sample size:

$$\delta \geq \frac{2s^2p}{\delta^2}(t_{\alpha,\nu} + t_{\beta(1),\nu}) \qquad (2)$$

(B). Projected Sample Size Required for and Minimum Detectable Difference in Mean Length Between Stations

The procedures used to analyze mean length differences in the two areas separately were based on the between-station variances in the two areas and required the computation of the non-centrality parameter ϕ (see Zar, 1984, Chapter 11.3 for procedural details). In order to determine the projected sample size required to detect a specific change in mean length between stations, the following formula was used:

$$\phi = \frac{n\delta^2}{2ks^2} \qquad (3)$$

where ϕ = noncentrality parameter,

n = number of length measurements per station,

δ = minimum detectable difference in mean length;

k = number of stations, and

s^2 = variability (i.e., error MS from ANOVA) within k.

Having estimated ϕ for a desired value of δ, the power and sample size analysis of variance curves developed by Pearson and Hartley (1951) (cf. Zar, 1984) were used to determine the sample size, *n* (by iteration) required to detect δ at the stipulated significance level (α=0.050 and within the chosen confidence limits (90%).

To estimate the minimum detectable difference in length for a given sample size in relation to various functions of the between-station variances obtained during the current study, Equation 3 was rearranged such that:

$$\delta = \frac{2s^2\phi^2}{n} \qquad (4)$$

The Pearson and Hartley tables were then used to estimate ϕ at the desired significance level (α=0.05) and within the stipulated confidence limits (90%).