SC-CAMLR-VII/BG/22

STATISTICAL PROBLEMS IN KRILL STOCK HYDROACOUSTIC ASSESSMENTS

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Abstract

Two primary issues are at question for hydroacoustic assessments of krill. The first is the methods applied to establish biomass in a survey area and the second is the improvement in accuracy of target-strength measurements. In the case of statistical methods, there are no clear guidelines for deciding what method is most appropriate, this is made even more difficult by the fact that most survey methods assume the population is fixed in space, relative to the sampling interval. There remain several unsatisfied needs for improvements in sampling design and tests for systematic trends in survey data collected from non-stationary populations, which have not been well addressed by present techniques. However, this does not invalidate the use of available methods to conduct surveys and analyze results. In the case of target-strength accuracy, even if the present values were very accurate, the issue of interest would seem to be not the absolute amount of biomass present in an area, but rather how it is distributed. The issue of patchy years vs more even distribution would seem to have more impact on ecosystem management than absolute accuracy of biomass estimates.

Résumé

Deux questions fondamentales se posent à l'égard des évaluations hydroacoustiques du krill. La première concerne celle des méthodes utilisées pour établir la biomasse d'une zone d'étude et la seconde est celle de l'amélioration de la précision des mesures de la réponse acoustique. Dans le cas des méthodes statistiques, il n'existe aucune directive qui permettrait de choisir sans hésitation le procédé le mieux adapté, et le problème est d'autant plus difficile à résoudre que la plupart des méthodes de recherche présument que la population est fixe sur le plan spatial, en rapport avec l'intervalle d'échantillonnage. Il reste encore beaucoup à faire pour répondre aux besoins d'amélioration des types d'échantillonnage et des tests portant sur les tendances systématiques dans les données d'étude recueillies à partir de populations non-stationnaires, questions auxquelles les techniques actuelles ne sont pas suffisamment intéressées. Cependant, ceci n'exclut pas l'utilisation des méthodes disponibles de recherche et d'analyse des résultats. Pour ce qui est de la précision concernant la réponse acoustique, l'intérêt semble se trouver non pas dans la quantité absolue de biomasse présente dans une région, mais plutôt dans la manière dont elle est répartie, et cela même si les valeurs actuelles étaient très précises. La question des années de répartition irrégulière contre répartition plus régulière semblerait avoir un effet plus important sur la gestion de l'écosystème que la précision absolue des évaluations de la biomasse.

Резюме

Рассматриваются два основных аспекта проведения оценки запасов криля гидроакустическими методами: первый - методы, применяемые для оценки биомассы в районе съемки, и второй - повышение точности при измерении силы цели. В случае статистических методов не имеется четких правил для выбора наиболее подходящего метода, и дело осложняется еще и тем, что при применении большинства методов съемки популяция принимается неподвижной в течение всего времени взятия проб. Все еще требуют усовершенствования некоторые аспекты взятия проб и выявления систематических отклонений от данных, полученных по нестационарным популяциям, чего современными способами на достаточно хорошем уровне сделать нельзя. Но это никак не обесценивает применения имеющихся методов при проведении съемок и анализировании результатов. В вопросе о точности величины силы цели, даже если имеющиеся значения были очень точны, интерес, как кажется, представляла бы не абсолютная величина имеющейся в каком-либо районе биомассы, а скорее то, как она распределена. Представляется, что результаты сравнения данных за годы с очень неравномерным распределением с картиной более равномерного распределения могли бы в вопросе управления экосистемой представить большую ценность, чем абсолютно точные оценки величины биомассы.

Resumen

Se cuestionan dos problemas fundamentales de las evaluaciones hidroacústicas del krill. El primero son los métodos que se aplican para establecer la biomasa de una zona de prospección, y el segundo es el perfeccionamiento de la precisión de medición de la fuerza de blanco. En lo que se refiere a los métodos estadísticos, no existen pautas claras para decidir qué método es el más apropiado, lo cual es otro problema, ya que la mayoría de métodos de prospección suponen que la población se encuentra fija en el espacio con relación al intervalo del muestreo. Quedan todavía varios requisitos no satisfechos en cuanto a mejoras en el diseño de muestreo y en los análisis de tendencias sistemáticas de datos de prospección recolectados sobre poblaciones no estacionarias, todo lo cual no ha sido tratado satisfactoriamente por las técnicas actuales. Sin embargo, esto no invalida el uso de los métodos existentes en la realización de prospecciones y análisis de resultados. En el caso de la precisión de la fuerza de blanco, aún cuando los valores actuales fueran muy precisos, el punto de interés no sería la biomasa absoluta presente en una zona, sino más bien su distribución. El tema de los años de distribución más regular, parece tener más incidencia en la administración del ecosistema que la precisión absoluta de las estimaciones de biomasa.

1. INTRODUCTION

Distribution and abundance estimates for midwater zooplankton and nekton are often obtained using quantitative hydroacoustic methods. The usual method employed is echo integration, producing estimates of abundance by depth and distance along a survey track. These relative estimates of abundance are then converted to absolute estimates of abundance using the target strength of the identified target organisms. Target strength is a measure of how much sound an organism reflects, expressed in terms of the amount of sound reflected per individual or per unit weight of organism. All other electronic and acoustic variables are taken into account in the relative estimate of abundance so that if the target strength employed is later refined or revised, these acoustic estimates may be corrected by adjusting the estimate by the ratio of the old and new target strengths.

Surveys are conducted along pre-determined tracklines of parallel or zigzag pattern which cover the area of interest in a systematic manner. For repeated surveys, the pattern of transects may be refined to better fit the expected distribution of populations, but in all cases, the limiting factor is shiptime to conduct the survey. This constraint usually imposes some compromises on the nature and spacing of the trackline pattern and this may be in conflict with optimum distribution of effort for statistical sampling methods.

Zooplankton and nekton populations are seldom, if ever, random in their distribution with respect to the sampling effort. Thus the use of the random sample mean and random sample variance will often provide a biased estimate of the mean and variance of the population. Because of the high sampling frequency of a hydroacoustic survey (one sample per second), there sometimes is a lack of independence between samples due to overlapping of sampling volume and consequently an expectation of serial correlation or some degree of covariance contributing to the bias. Williamson (1982) addresses the process of accounting for this serial correlation by treating individual clusters of observations (usually an entire transect) as independent and the variance is therefore a function of the number of clusters and the total number of observations. Other authors have used the ratio estimation methods of Cochran (1977) to partition the variance by transect but this method assumes there is no serial correlation or other covariance.

At present, there are no clear guidelines for deciding what method is most appropriate, this is made even more difficult by the fact that most survey methods assume the population is fixed in space, relative to the sampling interval. In fact, this is seldom the case in an aquatic environment. True planktonic organisms may be carried through the sampled area, either in a systematic way due to abiotic factors (e.g. currents and eddies) or biotic ones due to migratory behaviour. Micronekton and nekton (especially large zooplankton and fish) may swim fast enough in a single day to traverse from one transect to another and hence be sampled multiple times. Given the fact that large surveys often take two weeks or more, this migratory behaviour needs to be considered.

In some senses, the collective actions of individuals of a species may produce a combined distribution for a population or subpopulation which makes the aggregation behave as one large patch with variable discontinuities within some definable boundary. These large aggregations may require separate treatment, i.e. separate stratification of sampling, to minimize the variance estimate. Large aggregations of this kind have been observed in the Antarctic (Macaulay, 1984) for krill (*Euphausia superba*) and may be true for segments of fish populations as well. A krill aggregation observed in 1981 covered an area 3 km by 5-6 km and extended from the surface to 250 m (Figure 1a).

2. GENERAL STATUS AND NEEDS

The first issue is that of large statistical variances. Hydroacoustic surveys are often characterized by large to very large confidence intervals. These large variances result from the highly discontinuous distribution of many marine stocks (the patchiness problem) often caused by the contagious distribution of the negative binomial or Poisson type models where mean and variance are proportional or equal. Some degree of post-survey stratification can be used to minimise this effect but more objective methods for such stratification would help to make the confidence in the results of such stratification greater. The tendency to consider many zooplankton as weak swimmers needs to be more carefully analyzed and verified. The problem of a mobile population moving within the survey area still remains and may not be addressable or even known without special surveys designed to examine an area multiple times from different starting points and possibly even different sampling strategies. However, awareness of the problem can at least prompt consideration of prevailing currents (abiotic factors) or known migratory behaviour (biotic factors) in the development of a sampling plan. There remain several unsatisfied needs for improvements in sampling design and tests for systematic trends in survey data collected from non-stationary populations, which have not been well addressed by present techniques. However, this does not invalidate the use of available methods to conduct surveys and analyze results.

The second issue is the improvement of estimates of target-strength for krill. Given that present values are probably within a factor of 2 of being correct, it seems reasonable to consider the following. Even if the present values were very accurate, the issue of interest would seem to be not the absolute amount of biomass present in an area, but rather how it is distributed. Consider as a test case that we have two surveys in two consecutive years giving identical biomass for a surveyed area, in one, the biomass is nearly uniform with only a few small patches and in the other, the biomass is concentrated in some areas and low to absent in others. If a predator (e.g. a penguin) must obtain not only its own daily ration but also sufficient extra to return to feed its offspring, the time spent searching becomes critical. If such an individual encounters a patch (a patch dominated year) it can quickly obtain sufficient food for its needs. If, however, it must spend a great deal of time picking up isolated individuals, it may have to spend too much time just satisfying its own requirements to have sufficient for its offspring too. Figure 1 shows an example of this with abundant patches near Seal Island in 1981 and much lower abundance of patches in 1984. The shaded area is approximately 20 n miles from Seal Island (the estimated foraging range of a penguin, personal communication John Bengtson). The point is that if we can begin to isolate the causes of patchiness and/or areas more typically possessing patches of krill, the implications for ecosystem management of the resource will be more important than just improving our accuracy.

3. CONCLUSIONS

Improvement of the accuracy of target-strength estimates and measurements can and will continue to increase the accuracy of our biomass estimates by the consequences of not surveying and especially not maintaining a temporarily coherent data set will be a longer delay in our understanding of the ecosystem. I would, therefore, recommend that surveys be conducted by those currently involved in such efforts and where possible, other interested parties contribute to this effort. Further delays in obtaining the needed data due to deficiencies in current methods would be counterproductive to the goals of CCAMLR. The time-series information cannot be obtained by any other means and, so long as data are collected and archived in detail, it may be possible to correct for inadequacies in methods at a later date including correcting for errors in target-strength.

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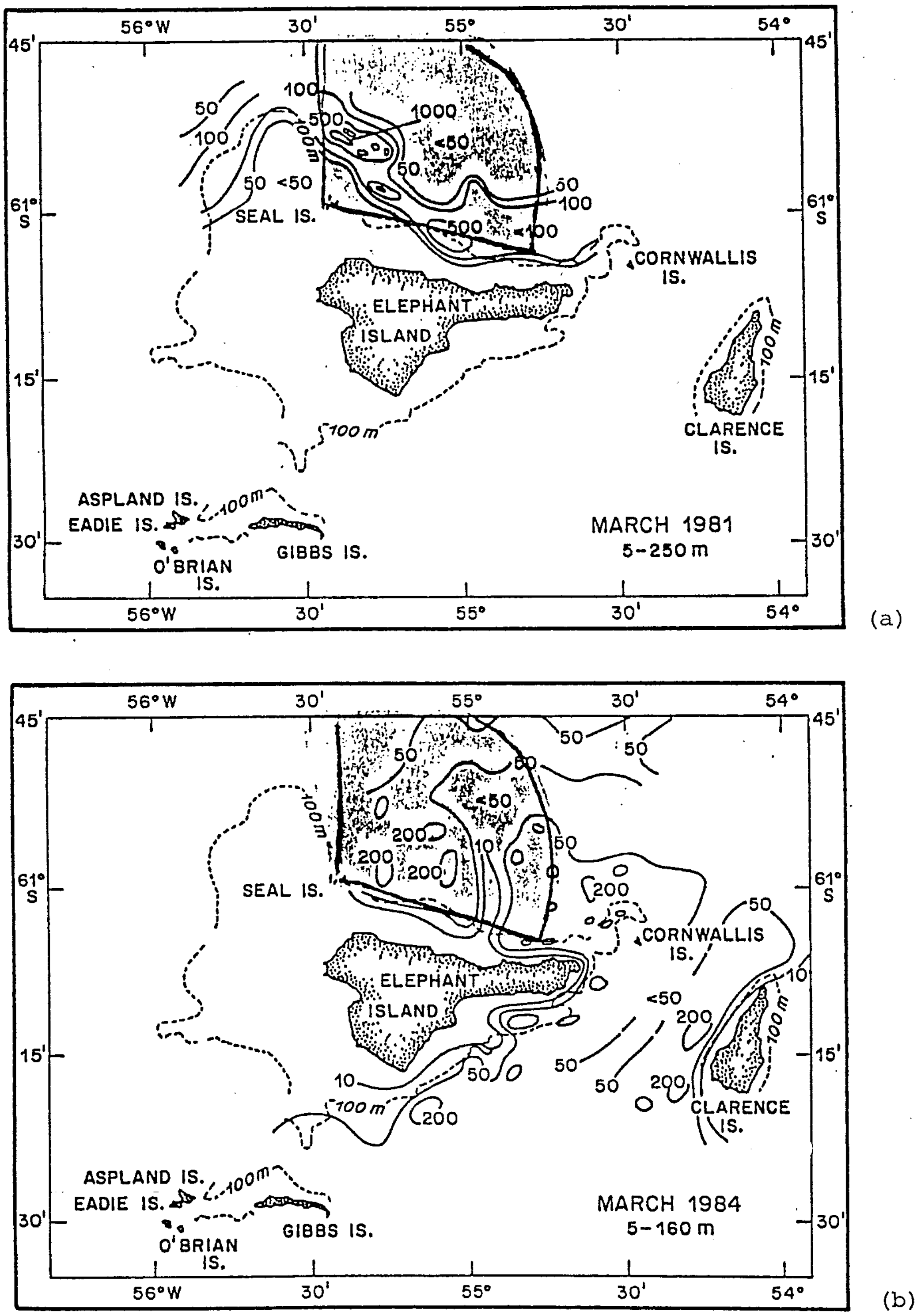

Figure 1: Distribution of krill in the vicinity of Elephant Island in March 1981 (a) and March 1984 (b). The shaded area is approximately 20 n miles from Seal Island, a known penguin rookery. The large swarm observed in 1981 contained over 1 million tonnes of krill. The contour intervals are in kg/m^2.

Légende de la figure

Figure 1 Distribution du krill aux abords de l'île de l'Eléphant en mars 1981 (a) et mars 1984 (b). La zone hachurée est située à environ 20 milles n de l'île des Phoques, une colonie de manchots reconnue. L'essaim étendu observé en 1981 contenait plus d'un million de tonnes de krill. L'équidistance des courbes est en kg/m^2.

Подписи к рисункам

Рисунок 1 Распределение криля в районе о. Элефант в марте 1981 г. (a) и марте 1984 г. (b). Затушеванный участок на карте находится примерно на растоянии 20 морских миль от о. Сил, известной залежки пингвинов. Большое скопление, наблюдавшееся в 1981 г., насчитывало свыше 1 миллиона тонн криля. Растояние между контурами выражено в кг/м^2.

Leyenda de la Figura

Figura 1 Distribución del krill en los alrededores de la isla Elefante en marzo 1981 (a) y marzo 1984 (b). Las zonas oscuras están aproximadamente a 20 millas náuticas de la isla Seal, una conocida colonia de pingüinos. El extenso cardumen observado en 1981 contenía más de 1 millón de toneladas de krill. Los intervalos contorneados de densidad de krill se expresan en kg/m^2.