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INDICES OF PREY AVAILABILITY NEAR THE SEAL ISLAND CEMP SITE: 1990 TO 1996

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Abstract

Four indices of prey availability are calculated from surveys conducted in the vicinity of the Seal Island CEMP site during the austral summers of 1990 to 1996. The indices are measures of average prey density, depth, distance from Seal Island, and persistence over time. Acoustic data from two AMLR surveys each year were subsampled to include the foraging range of predators breeding at Seal Island. Indices derived from these data indicate that although average prey density varied by a factor of almost five between 1990 and 1996, prey were consistently distributed along the edge of the shelf break north of Elephant Island, and between 25 and 100 m depth. Indices of average prey density agree with demographic indices of krill abundance derived from net samples. Indices of persistence over time reflect the relative biomass of juvenile krill near Seal Island during the first survey of each year as compared to the biomass of post-spawning adults near Seal Island during the second survey of each year. It is hoped that these indices may be useful in modelling krill predator breeding success as a function of prey availability.

Résumé

Calcul de quatre indices de disponibilité des proies d'après les campagnes d'évaluation menées aux alentours du site CEMP de l'île Seal pendant les étés austraux de 1990 à 1996. Ces indices sont des mesures moyennes, relatives aux proies, de la densité , de la profondeur, de la distance de l'île Seal et de la persistance au fil du temps. Sur les données acoustiques des deux campagnes d'évaluation AMLR réalisées chaque année, ne sont utilisées que celles portant sur le secteur d'alimentation des prédateurs se reproduisant à l'île Seal. Les indices dérivés de ces données indiquent que bien que la densité moyenne des proies ait varié d'un facteur de presque cinq de 1990 à 1996, leur répartition demeure le long de la bordure du plateau au nord de l'île Éléphant, entre 25 et 100 m de profondeur. Les indices de densité moyenne des proies concordent avec les indices démographiques d'abondance de krill dérivés des échantillons prélevés des filets. Les indices de persistance au fil du temps reflètent la biomasse relative des juvéniles de krill près de l'île Seal pendant la première des campagnes annuelles, mais la biomasse des adultes après la reproduction dans le même secteur durant la deuxième de ces campagnes annuelles. On espère que ces indices faciliteront la modélisation de la réussite de la reproduction des prédateurs de krill en fonction de la disponibilité des proies.

Резюме

Были вычислены четыре индекса наличия потребляемых хищниками видов по результатам съемок, выполненных в районе участка CEMP 'остров Сил' в течение южных летних сезонов за период с 1990 по 1996 г. Эти индексы отражают среднюю плотность потребляемых видов, глубину, расстояние от острова Сил и постоянство во времени. Акустические данные двух съемок, проведенных в рамках Программы AMLR, были подразделены так, чтобы охватить нагульный ареал размножающихся на острове Сил хищников. Выведенные по этим данным индексы говорят, что, хотя средняя плотность распределения потребляемых видов за период с 1990 по 1996 г. отличалась почти в пять раз, эти виды постоянно находились вдоль границы шельфа к северу от острова Элефант на глубинах 25-100 м. Индексы средней плотности потребляемых видов согласуются с демографическими индексами численности криля, полученными с помощью сетевых проб. Индексы постоянства во времени отражают относительную биомассу молоди криля в ходе первой съемки каждого года по сравнению с биомассой отнерестившихся половозрелых рачков

в районе острова Сил в ходе второй съемки каждого года. Надеемся, что эти индексы окажутся полезными в моделировании репродуктивного успеха питающихся крилем хищников как функция наличия потребляемых видов.

Resumen

En base a prospecciones efectuadas en los alrededores de la localidad CEMP de Isla Foca durante los veranos australes de 1990 a 1996, se calcularon cuatro índices de la disponibilidad de presas. Los índices miden el promedio de la densidad de la presa, la profundidad, la distancia de la Isla Foca y la persistencia a través del tiempo. Se extrajeron submuestras de datos acústicos provenientes de dos prospecciones anuales AMLR a fin de incluir el radio de alimentación de los depredadores que se reproducen en la Isla Foca. Los índices derivados de estos datos indican que a pesar de que la densidad promedio de la presa entre 1990 y 1996 varía en un factor de aproximadamente cinco, ésta se encontraba distribuida uniformemente a lo largo del borde de la plataforma hacia el norte de la Isla Elefante, y entre 25 a 100 m de profundidad. Los índices de la densidad promedio de presa concuerdan con los índices demográficos de la abundancia de kril deducidos de muestras de la red. Los índices de persistencia a través del tiempo reflejan la biomasa relativa de kril juvenil cerca de la Isla Foca durante la primera prospección de cada año, comparada con la biomasa de los adultos después del desove cerca de la Isla Foca durante la segunda prospección de cada año. Es de esperar que estos índices sean de utilidad en la elaboración de modelos del éxito reproductor de los depredadores de kril en función de la disponibilidad de la presa.

Keywords: prey availability, Seal Island, time series, CCAMLR

INTRODUCTION

One of the long-range goals of the CCAMLR Ecosystem Monitoring Program (CEMP) is to link the performance of predators of krill (*Euphausia superba*) with the availability of their prey. Indices of the performance of land-breeding predators have been adopted (SC-CAMLR, 1992), but standard indices for prey availability have yet to be established. At a recent meeting, CCAMLR scientists identified a number of indices of prey availability that could be calculated from existing datasets, and recommended that the feasibility of calculating such indices be investigated (SC-CAMLR, 1996).

Indices of availability of prey to land-breeding predators should include measures of prey abundance, distance from breeding colonies, depth distribution, persistence over time, intensity and scale of spatial dispersion pattern and energy value.

In this paper, indices are proposed for the first four of these aspects of prey availability. Acoustic volume backscattering data, from surveys conducted by the US Antarctic Marine Living Resources (AMLR) program during the austral summers of 1990 to 1996, were used as data sources.

MATERIALS AND METHODS

Approximately 50 000 km^2 of sea surface area in the northern portion of the South Shetland archipelago was surveyed every year from 1990 to 1996 (Amos et al., 1990; Holt et al., 1991; Rosenberg et al., 1992, 1993, 1994, in press; Martin et al., in press). Surveys were designed to describe the oceanographic conditions, phytoplankton biomass and productivity, and zooplankton biomass and species composition at a spatial scale of tens of kilometres. Survey designs, including station positions and acoustic transects, varied between 1990 and 1991 (Figures 1 and 2), but became standardised from 1992 (Figures 3 and 4).

Two surveys were selected for each year, details of which are listed in Table 1. For 1990, surveys 1 and 2 were combined and surveys 3 and 4 were combined. Acoustic data were filtered to include only those data collected within the boxes indicated in Figures 1 to 4, at depths shallower than 100 m. This was assumed to be the foraging space of krill predators that breed at Seal Island.

Acoustic data collection from 1992 to 1996 was described by Hewitt and Demer (1992, 1993a, 1993b, 1994a, in press (a,b)). Echoes from a 120-kHz transducer, towed 5 m below the surface of the water (1992 and 1993) or hull-mounted at 5 m depth (1994 to 1996), were passed to a

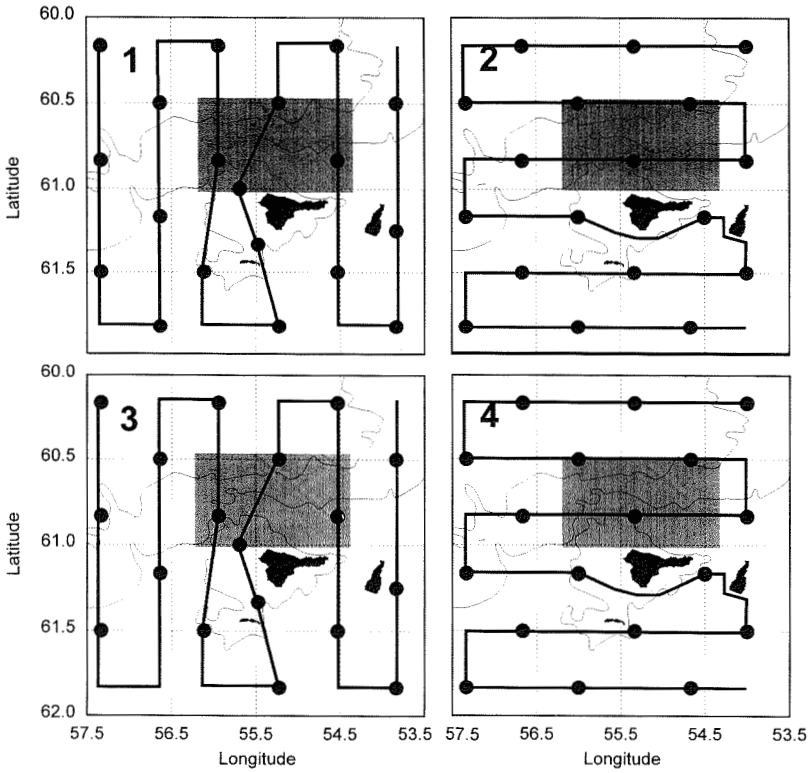

Figure 1: 1990 AMLR survey design. Surveys 1 and 2 were combined and referred to as 1990A. Surveys 3 and 4 were combined and referred to as 1990D. Shaded box indicates area subsampled for calculation of indices of prey availability near to Seal Island.

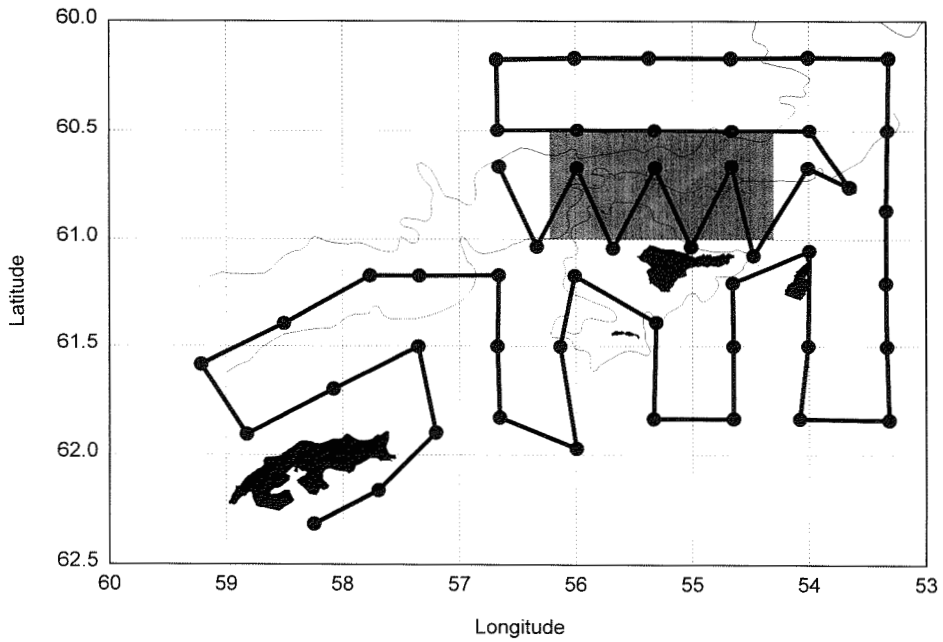

Figure 2: 1991 AMLR survey design. Shaded box indicates area subsampled for calculation of indices of prey availability near to Seal Island.

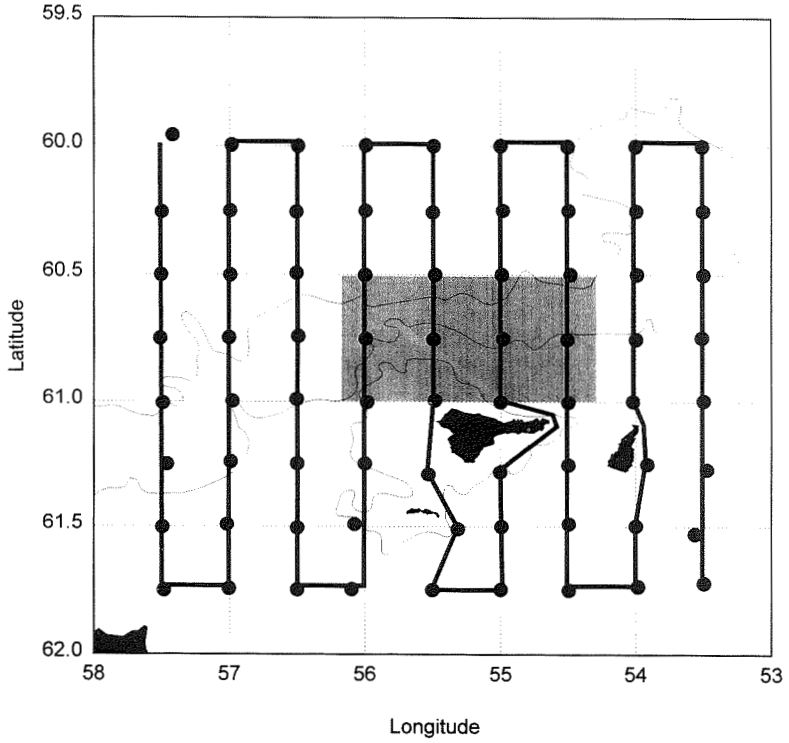

Figure 3: 1992 AMLR survey design. Shaded box indicates area subsampled for calculation of indices of prey availability near to Seal Island.

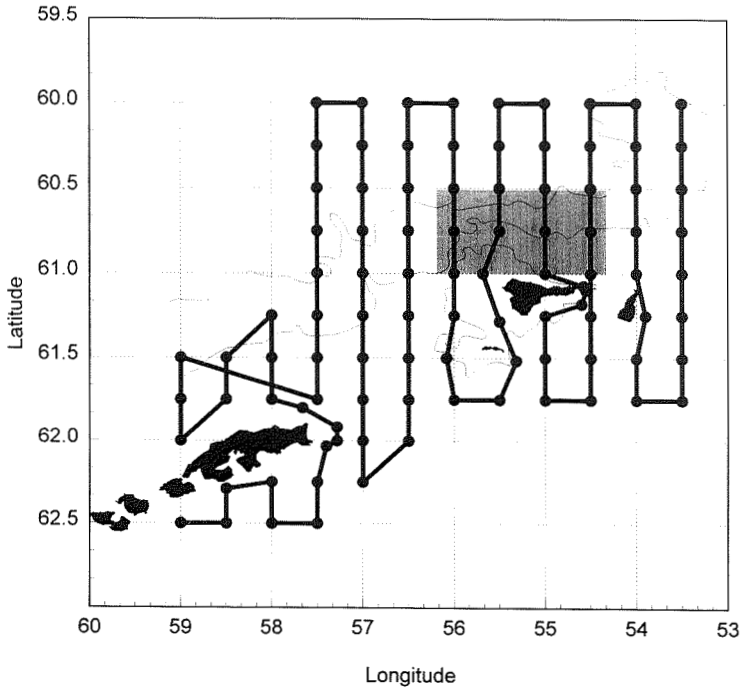

Figure 4: 1993 to 1996 AMLR survey design. Shaded box indicates area subsampled for calculation of indices of prey availability near to Seal Island.

Table 1: Acoustic surveys used for data sources in the calculation of indices of prey availability relative to krill predators breeding on Seal Island.

Year	First Survey		Second Survey	
	Designation	Dates	Designation	Dates
1990	1 and 2	6 – 11 Jan, 21 – 26 Jan	3 and 4	7 – 13 Feb, 21 – 27 Feb
1991	A	21 – 31 Jan	D	26 Feb – 7 Mar
1992	A	19 Jan – 2 Feb	D	29 Feb – 11 Mar
1993	A	15 – 31 Jan	D	22 Feb – 6 Mar
1994	A	17 – 28 Jan	D	25 Feb – 9 Mar
1995	A	16 – 29 Jan	D	15 – 27 Feb
1996	A	23 Jan – 4 Feb	D	24 Feb – 8 Mar

shipboard computer for digitising and processing. Volume backscattering strength was sampled vertically every 0.5 m and averaged every 5 m of depth and 185 m of distance along the trackline.

Acoustic data collection during 1990 and 1991 was described by Amos et al. (1990) and Macaulay and Mathisen (1991). Echoes from a 200-kHz transducer, towed 6 to 10 m below the surface of the water, were passed to a shipboard computer for digitising and processing. Non-krill targets were removed from the data. Acoustic biomass per cubic metre, in 1-m depth bins, was estimated using a target strength of -35.93 dB per kilogram of krill. These values were vertically integrated to 250 m depth and averaged over each 100 m of distance along the trackline. For the purposes of this paper, mean volume backscattering strength at each 100 m along the trackline was estimated by reconverting krill density estimates back to backscattering cross-sectional area and dividing by 100 m. Equivalent backscattering strength at 120 kHz was estimated by subtracting 2.22 dB from the backscattering strength at 200 kHz (10log(120/200)). Vertically structured acoustic data were not available for 1990 and 1991.

Four indices of prey were derived:

(i) Overall average volume backscattering strength,

$$\bar{\bar{S}}_V = \frac{\sum_{i,j,k}^{I,J,K} (S_V)_{i,j,k}}{I * J * K}$$

where $(S_V)_{i,j,k}$ is the average volume backscattering strength of the ith depth bin at the jth location during the kth survey, and I is the number of depth bins, J is the number of locations and K is the number of surveys for each year.

(ii) Mean distance of prey from Seal Island,

$$\bar{d} = \frac{\sum_{j,k} d_{j,k} * (\bar{S}_V)_{j,k}}{\sum_{j,k} (\bar{S}_V)_{j,k}}$$

where $(\bar{S}_V)_{j,k}$ is the volume backscattering strength averaged over 100 m depth at the jth location during the kth survey, and $d_{j,k}$ is the distance from the jth location to Seal Island.

(iii) Mean depth of prey,

$$\bar{D} = \frac{\sum_{i,j,k} D_{i,j,k} * (S_V)_{i,j,k}}{\sum_{i,j,k} (S_V)_{i,j,k}}$$

where $D_{i,j,k}$ is the mid-depth of the ith depth bin.

(iv) Persistence over time,

$$\Delta S_V = \frac{(\bar{S}_V)_2}{(\bar{S}_V)_1}$$

where $(\bar{S}_V)_1$ and $(\bar{S}_V)_2$ are the overall average volume backscattering strengths during the first and second survey of each year.

Linear measures of volume backscattering strength were used in all calculations. Results, however, are expressed in decibels.

Table 2: Annual indices of prey availability near the Seal Island CEMP site. Blank cells indicate that no data are available.

Year	Prey Field			
	$\bar{\bar{S}}_V$ (dB)	$\bar{d}$ (km)	$\bar{D}$ (m)	ΔS_V (dB)
1990	-63.21	22.47		3.13
1991	-65.11	13.73		1.65
1992	-65.92	19.01	52.83	-5.90
1993	-69.84	18.13	50.81	-9.23
1994	-69.50	19.91	58.20	6.30
1995	-69.94	21.13	54.95	2.17
1996	-65.49	24.27	58.56	0.38

RESULTS AND DISCUSSION

Values of the four indices are listed in Table 2. Between the years 1992 and 1996 there appears to be relatively low variability in the average depth of the prey field (51 m in 1993 to 59 m in 1996) and the average distance from Seal Island (18.1 km in 1993 and 24.3 km in 1996). This reflects our observation that krill are consistently distributed along the edge of the shelf break north of Elephant Island, and between 25 and 100 m depth during the day (Hewitt and Demer, 1992; 1993a; 1993b; 1994a, in press (a,b)).

The relative values of average volume backscattering agree well with estimates of krill density over the entire survey area, with the exception of 1993. Hewitt and Demer (1994b) reported relatively high values of krill density for surveys conducted during 1993, but cautioned that misinterpretation of backscatter from salps (*Salpa thompsoni*) may have caused a positive bias. When the offshore areas, where salps dominated the plankton catches (Loeb and Siegel, 1994), are excluded, average volume backscattering is relatively low for 1993, confirming this suspicion. The results in Table 2 are consistent with those of Loeb and Siegel (1994).

Average volume backscattering strength increased from the first to the second survey in each year except 1992 and 1993. Krill caught near Seal Island during the first surveys are usually dominated by 1-year-old juveniles, whereas krill caught in this area during the second surveys tend to be post-spawning adults (Amos et al., 1990; Loeb, 1991, in press; Loeb and Siegel, 1992, 1993, 1994, in press). High numbers of juvenile krill were caught during the first survey of 1992, indicating good recruitment of animals spawned in 1991. By the second survey, however, few post-spawning adults were caught. Poor spawning in 1992 and poor subsequent recruitment were evident during the first survey of 1993. Few post-spawning adults were caught during the second survey of 1993 and the poor recruitment from this year was evident during the first survey of 1994. Although average volume backscattering increased during the second survey of 1994, catches did not contain high numbers of post-spawning adults and recruitment remained at a low level. It was not until the second survey of 1995 that high numbers of post-spawning adults were caught, and the first survey of 1996 confirmed good recruitment from 1995.

These indices are our first attempt at quantifying prey availability to land-breeding predators around Seal Island. Our intention is to model breeding success of predators of krill as a function of prey availability and environmental conditions (e.g. extent of sea-ice). The residuals of such a model might then provide deeper understanding of how a krill fishery affects predator breeding success.

CONCLUSION

Indices of prey availability to krill predators breeding on Seal Island indicate that although average prey density varied significantly between years, prey were consistently distributed along the edge of the shelf break to the north of the island. In the South Shetland Islands juvenile krill appear in the late spring and early summer and are later displaced by spawning adults. Variation of prey density between surveys within a year thus reflects the relative importance of survival

from spawning during the previous year and reproduction during the current year. Additional indices should include measures of prey dispersion patterns and caloric value of individual prey items. Collectively, these indices may be useful in understanding how the reproductive success of land-breeding krill predators is affected by the availability of their prey.

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Liste des tableaux

Tableau 1: Campagnes d'évaluation acoustiques servant de sources de données dans le calcul des indices de disponibilité des proies pour les prédateurs de krill se reproduisant à l'île Seal.

Tableau 2: Indices annuels de disponibilité des proies aux environs du site CEMP de l'île Seal. Les cases blanches indiquent qu'aucune donnée n'est disponible.

Liste des figures

Figure 1: Modèle de la campagne d'évaluation AMLR de 1990. Les campagnes d'évaluation 1 et 2 sont combinées sous la référence 1990A. Les campagnes d'évaluation 3 et 4 sont combinées sous la référence 1990D. La case foncée indique le secteur sous-échantillonné en vue du calcul des indices de disponibilité des proies à proximité de l'île Seal.

Figure 2: Modèle de la campagne d'évaluation AMLR de 1991. La case foncée indique le secteur sous-échantillonné en vue du calcul des indices de disponibilité des proies à proximité de l'île Seal.

Figure 3: Modèle de la campagne d'évaluation AMLR de 1992. La case foncée indique le secteur sous-échantillonné en vue du calcul des indices de disponibilité des proies à proximité de l'île Seal.

Figure 4: Modèle des campagnes d'évaluation AMLR de 1993 à 1996. La case foncée indique le secteur sous-échantillonné en vue du calcul des indices de disponibilité des proies à proximité de l'île Seal.

Список таблиц

Таблица 1: Акустические съемки, предоставившие данные для вычисления индексов наличия потребляемых видов по отношению к питающимся крилем хищникам, размножающимся на острове Сил.

Таблица 2: Ежегодные индексы наличия потребляемых хищниками видов в районе участка CEMP 'остров Сил'. Пустые клетки обозначают отсутствие данных.

Список рисунков

Рисунок 1: Схема съемки в рамках Программы AMLR 1990 г. Съемки 1 и 2 были объединены и обозначены 1990A. Съемки 2 и 3 были объединены и обозначены 1990D. Затененный участок соответствует району, данные по которому были подразделены с целью расчета индексов наличия потребляемых видов вблизи острова Сил.

Рисунок 2: Схема съемки в рамках Программы AMLR 1991 г. Затененный участок соответствует району, данные по которому были подразделены с целью расчета индексов наличия потребляемых видов вблизи острова Сил.

Рисунок 3: Схема съемки в рамках Программы AMLR 1992 г. Затененный участок соответствует району, данные по которому были подразделены с целью расчета индексов наличия потребляемых видов вблизи острова Сил.

Рисунок 4: Схема съемки в рамках Программы AMLR 1993-1996 гг. Затененный участок соответствует району, данные по которому были подразделены с целью расчета индексов наличия потребляемых видов вблизи острова Сил.

Lista de las tablas

Lista de las figuras