DETERMINATION OF ANTARCTIC KRILL ACOUSTIC BACK-SCATTERING CROSS-SECTION

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Abstract

When determining the density krill of concentrations it is necessary to know the acoustic cross-section of back-scattering of krill. The target strength can be determined in situ by measuring the echo signal from one specimen resolved by the hydroacoustic instrument. By calculating the mean level of the directivity diagramme of the antenna and the mean level of the standardized echo signal, it is possible to determine the acoustic cross-section of the back-scattering of krill. By experiments, the authors have obtained the dependence of the acoustic section of back-scattering of krill on its length at a frequency of 120 kHz.

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DETERMINATION DE LA SECTION ACOUSTIQUE DIFFUSANTE INVERSE DU KRILL ANTARCTIQUE

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Résumé

Lorsque l'ont veut déterminer la densité des concentrations du krill, il est nécessaire d'en connaître la section acoustique diffusante inverse. Avec l'enregistrement résolvant du krill, la force de la cible peut être déterminée in situ par la mesure de l'échosignal d'un spécimen isolé. Ayant calculé le niveau moyen de diagramme de directivité du transducteur et d'échosignal normalisé on peut définir la section acoustique diffusante inverse du krill. Le rapport entre cette dernière et la taille du krill est établi expérimentalement sur la fréquence de 120 kHz.

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DETERMINACION DEL CORTE TRANSVERSAL ACUSTICO DE RETRODISPERSION DEL KRILL ANTARTICO

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Resumen

Al determinar la densidad de krill en las concentraciones es necesario conocer el corte transversal acústico de retrodispersión de krill. La fuerza objetivo se puede determinar en el lugar midiendo la señal de eco de un especimen señalada por el instrumento hidroacústico. Es posible determinar el corte transversal acústico de retrodispersión de krill calculando el nivel medio del diagrama de directividad de la antena y el nivel medio de la señal uniforme de eco. Por medio de experimentos, los autores han obtenido la dependencia del corte transversal acústico de retrodispersión de krill con respecto a su tamaño a una frecuencia de 120 kHz.

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ОПРЕДЕЛЕНИЕ СЕЧЕНИЯ ОБРАТНОГО РАССЕЯНИЯ АКУСТИЧЕСКОГО СИГНАЛА, ОТРАЖЕННОГО АНТАРКТИЧЕСКИМ КРИЛЕМ

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Резюме

При определении плотности концентраций криля необходимо знать сечение обратного рассеяния акустического сигнала, отраженного крилем. Сила цели может быть определена in situ путем измерения интенсивности сигнала, отраженного одной особью и разрешенного гидроакустическим прибором. Высчитав средний уровень диаграммы направленности антенны и средний уровень стандартизированной интенсивности сигнала, можно определить сечение обратного рассеяния акустического сигнала, отраженного крилем. С помощью экспериментов авторами была определена зависимость сечения обратного рассеяния акустического сигнала, отраженного крилем, от его длины при частоте в 120 кГц.

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DETERMINATION OF ANTARCTIC KRILL ACOUSTIC BACK-SCATTERING CROSS-SECTION

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When estimating biomass of marine organisms by the hydroacoustic method, it is necessary to know the mean acoustical cross-section of back-scattering from an individual object (σ_0). It is possible to determine σ_0 in situ by measuring the echo signal from an individual specimen resolved by a hydroacoustic instrument.

The echo signal from an individual object is equal to

$$U^2 = \frac{p^2 x^2 \cdot \mu^2 \cdot G^4(\theta . \rho) \cdot \sigma_0}{r^4 \cdot 10^{0 \cdot 2\beta . r}} \quad (V^2) \qquad (1)$$

where p = acoustic pressure on antenna axis reduced to 1 m distance, Pa
- x = antenna sensitivity in reception, V/Pa
- μ = amplification of the receiver
- $G(\theta,\rho)$ = directivity function
- r = distance to the object, m
- β = space attenuation of sound, dB/m
- σ_0 = acoustic cross section of back-scattering from individual object on axis, m^2.

By excluding the dependence of the echo signal on the acoustic and electric parameters of the echo sounder and on the distance to the target its standardized value is determined

$$b = \frac{U^2 \cdot r^4 \cdot 10^{0 \cdot 2\beta . r}}{p^2 \cdot x^2 \cdot \mu^2} = G^4(\theta . \rho) \cdot \sigma_0 \quad (m^2) \qquad (2)$$

The directivity effect is a random value which is dependent on the location of the individual specimen about the acoustic axis. Value σ_0 is also a random value and is dependent on many factors : the size of the biological object, its physiological state, aspect of insonfication, etc. Consequently, the standardized echo signal is the product of two random values. Due to the statistical independence of random values,

$$\bar{b} = \bar{G}^4 \cdot \bar{\sigma}_0 \quad (3)$$

where $\bar{\sigma}_0$ = mean acoustic back-scattering section for the given concentration

$\bar{G}^4(\theta,\rho)$ = mean level of directivity diagram corresponding to the range of operation of the echo sounder for σ_o

$\bar{b}$ = mean value of the standardized echo signal.

Knowing $\bar{G}^4$ and $\bar{b}$, it is possible to determine the mean value of the acoustic back-scattering of an individual object of the given concentration :

$$\bar{\sigma}_0 = \bar{b}/\bar{G}^4(\theta.\rho) \qquad (4)$$

Using the methods suggested by Lozow (1979), the mean level of directivity for a narrow-directional antenna is determined by expression

$$\bar{G}^4 = \frac{1-\ell^{-\frac{1}{2}(\frac{\pi d}{\lambda})^2 \cdot \theta^2 m}}{\frac{1}{2}(\frac{\pi d}{\lambda})^2 \cdot \theta^2 m} \qquad (5)$$

where θm = maximum detection angle, rad

d = diameter of transducer, m

λ = wave length, m.

With $\frac{\pi d}{\lambda} \sin\theta m \leqslant 2.5$ the maximum detection angle

$$\theta m = \frac{\ell n\ G^4 \min}{\frac{1}{2}(\frac{\pi d}{\lambda})^2} \qquad (6)$$

by substituting (6) into (5) we obtain

$$\bar{G}^4 = \frac{G^4 \min^{-1}}{\ell n\ G^4{}_{\min}} \qquad (7)$$

This method was used in determining the acoustic section of Antarctic krill back-scattering.

Assuming that the greatest value of the standardized echo signal corresponds to the largest krill specimen on the antenna axis and the least value to the mean-size krill on the minimal level of the directivity diagram we obtain

$$G^4_{min} = \frac{\sigma max}{\bar{\sigma}_o} \Big/ \frac{b_{max}}{b_{min}} \tag{8}$$

Measurements for a number of shrimp species (Sofoulis, 1978 and Samovolkin, 1981) established the dependence of acoustic back-scattering on the length :

$$\sigma_o = aL_k^2 \qquad \text{with } L_k \geq \lambda \tag{9}$$

where L_k = object length
λ = wave length

Assuming in our investigations a similar dependence, the minimal level of the directivity diagram can be determined as

$$G^4_{min} = \frac{L^2_{k\ max}}{\bar{L}^2_k} \cdot \frac{b_{max}}{b_{min}} \tag{10}$$

By substituting (7) in (10) and (4) in (7) we obtain the expression for determining the mean value of acoustic back-scattering for an individual krill for the given concentration :

$$\bar{\sigma}_o = \bar{\ell} \cdot \frac{\ell n \left(\frac{L^2_{k\ max}}{\bar{L}^2_k} \Big/ \frac{\ell_{max}}{\ell_{min}} \right)}{\left(\frac{L^2_{k\ max}}{\bar{L}^2_k} \Big/ \frac{\ell_{max}}{\ell_{min}} \right) - 1} \tag{11}$$

The value of the standardized echo signal and its mean value are determined on the basis of measuring amplitudes of echo signals from individual specimens and the distance. The mean and maximum length of krill are determined from data collected in sample trawls.

Measurements were made during the Antarctic expedition under the FIBEX programme on board the fisheries research vessel Odessey in January-March 1981. Simrad echo sounder SK-120 (Norway) was used in the following mode of operation :

> transducer diameter 20 cm, power - 1/1, bandwidth : wide band, impulse length 0.1 msec., amplification 0dB.

To increase the sensitivity and to reduce errors in measuring, the TVG of the echo sounder was switched off. As a result of acoustic and electric measurements, the following parameters of the echo sounder were determined : $p = 49 \ 10^3$ Pa/m, $= 3.1 \ 10^{-3}$ v/Pa/m, $= 20 \ 10^3$. The echo signal level was determined with the help of an osciiograph which was engaged by an impulse from the output interval of Simrad echo integrator QM (Norway). The ratio signal/noise was not less than 3. To exclude the dependence of the maximum detection angle on the depth, standardized echo signals $\geq \frac{b_{max}}{10}$ were used in calculations.

The attenuation coefficient was determined for conditions characteristic of the Antarctic during the period of operation (temperature 1^{o}C, salinity 34^{o}/oo) according to the methods described in the paper by Clay and Nedvin (1980), at a frequency of 120 khz and β=0.035 dB/m.

In order to determine the size composition of krill, sample tows were made using an Isaacs Kidd and RT/TM, 36.6 trawls.

Amplitudes of echo signals with the vessel adrift were measured for dispersed krill at dusk and night time. In all, five series of measurements were made. The results are given in Table 1.

Figure 1 shows the curve of dependence of acoustic back-scattering of an individual krill on its length.

The regression equation takes the following expression :

$$\sigma_o = 0.36 \cdot L_k^{1.93} \quad (m^2) \qquad (12)$$

The closeness of the indices to 2 testifies to the validity of our assumption that σ_o is related quadratically to the length. For the target strength of an individual krill, the following equation holds :

$$TS = 2.1\ L_k - 72.3 \quad (dB) \tag{13}$$

with correlation coefficient K = 0.96

The Polish investigators measured the target strength of krill under laboratory conditions (Kalinovski et al 1979). At 159 kHz the target strength of formalinized krill was :

$$TS = 2.3\ L_k - 72 \quad (dB) \tag{14}$$

So we and the Polish investigators have obtained target strength functions related to the length of krill with similar parameter values.

It is planned to continue measuring the acoustic back-scattering of krill at other frequencies.

REFERENCES

Clay C., and Medvin H. Acoustic oceanography principles and application. Mir, Moscow, 1980 (Russian).

Kalinovski J., Kilian L. and Dyka A. Sile celu kryla.Promiary parametrow tawic kryli i ryb. Studia i materialy Seria C.N. 43 MIR, Gdynia, 1979.

Lozow J.B. Transducer directivity : a simple calculation of its spatial averages. Contribution to Soviet-American symposium in Boston (USA), 1979. N20.

Samovolkin V.G. Back-scattering of ultrasound from fish and shrimp. VNIRO Transactions. Voprosy promyslovoj gidroakustiki, in Legkaja i pischevaja promyshlennost, Moscow, 1981 (Russian).

Sofoulis N.G. A study of acoustic strengths of small targets relevant to the farming industry. M. App. Sc. thesis. Western Australian Institute of Technology, 1978.

Table 1 : Results of measuring acoustic back-scattering from an individual krill according to echo signal value

No	Area	Standardized echo signal value			Krill Length					
		$\bar{b}$ $\times 10^{-6}$ (m^2)	b_{max} $\times 10^{-6}$ (m^2)	b_{min} $\times 10^{-6}$ (m^2)	$\bar{L}_k$ (cm)	Standard deviation (cm)	L_{kmin} (cm)	L_{kmax} (cm)	$\bar{\sigma}_o$ $\times 10^{-6}$ (cm)	TS (dB)
1	Scotia Sea	2.87	8.5	0.8	4.57	0.77	3.40	5.80	6.4	-63.0
2	Scotia Sea	2.76	7.1	0.7	4.30	0.64	3.20	5.80	5.8	-63.4
3	Scotia Sea	3.45	11.5	1.1	4.61	0.75	3.60	6.00	7.5	-62.2
4	South Georgia	1.97	5.6	0.5	3.57	0.17	3.00	5.00	4.2	-64.7
5	Mordvinov's Island	3.38	11.7	1.1	4.88	0.44	3.20	5.80	7.9	-62.0

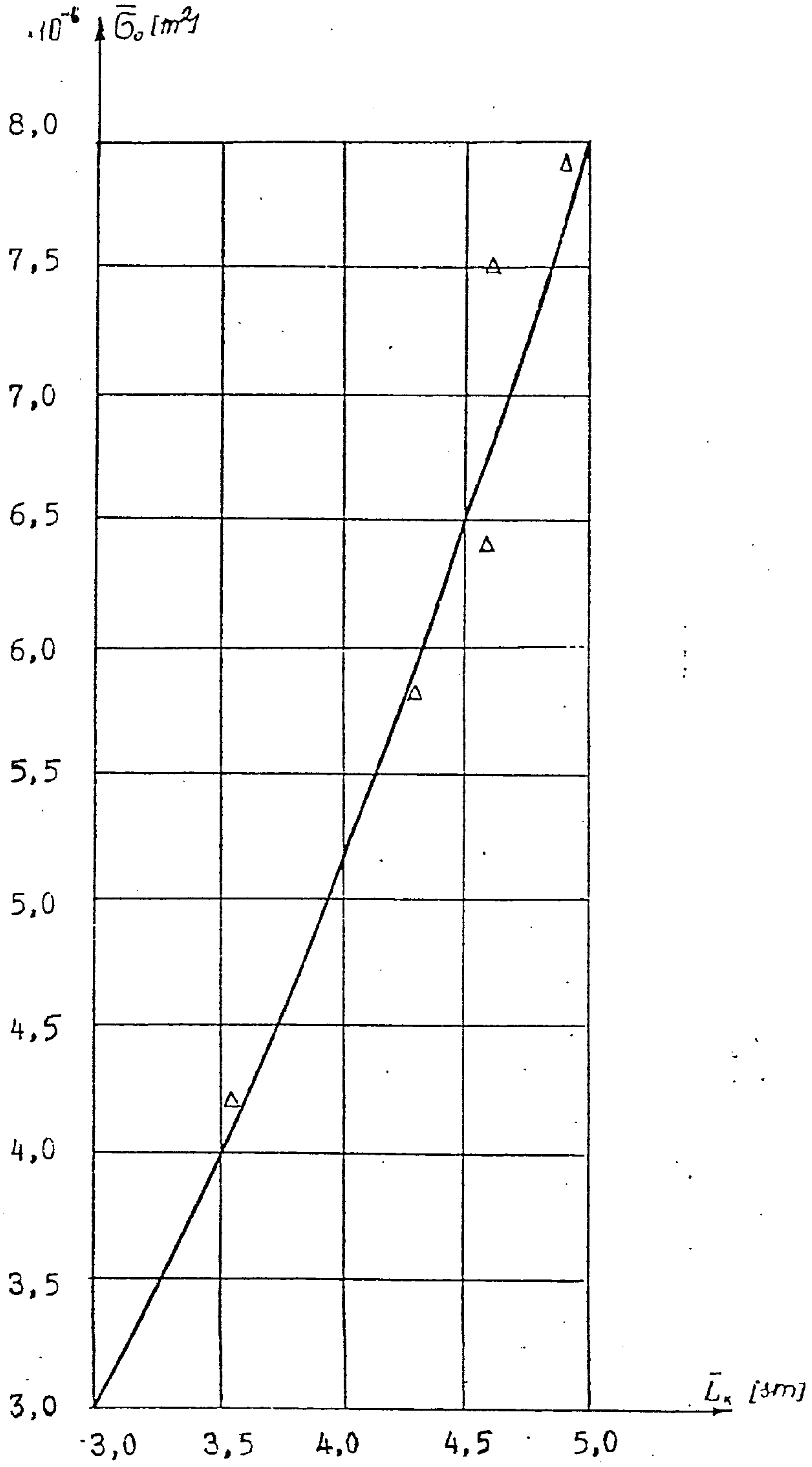

Figure 1 Dependence of acoustic back-scattering of krill on its length at 120 kHz.

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