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MIDWATER TRAWL CATCHABILITY AS AN ASPECT OF A QUANTITATIVE ASSESSMENT OF KRILL BIOMASS CONDUCTED USING A TRAWL CENSUS SURVEY

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Abstract

Midwater trawl catchability is a variable which depends on both the behavioural and distributional characteristics of the target species and trawl parameters. Reliability of biomass assessments will improve with better knowledge of trawl catchability and krill distribution patterns. A comparative analysis of trawl catchability for commercial midwater trawls and small research trawls, in this case using an Isaacs-Kidd trawl, demonstrated the futility of using the latter for trawl census survey biomass assessments due to their highly variable catchability over the survey area and also because the biomass estimates thus obtained were characterised by high relative error. A standard method for conducting krill trawl census surveys needs to be developed. Mathematical modelling fishing trawls as well as hydroacoustic research on catchability properties of trawls can facilitate selecting the optimal construction of commercial midwater trawls. Assessments of the total amount of krill entering the trawl should be carried out when selecting trawl construction.

Résumé

La capturabilité des chaluts pélagiques est une variable qui dépend des caractéristiques de comportement et de répartition de l'espèce visée ainsi que des paramètres des chaluts. Une connaissance plus approfondie de la capturabilité des chaluts et de la manière dont se répartit le krill entraînera une plus grande fiabilité des évaluations de la biomasse. Une analyse comparative de la capturabilité des chaluts pour les chaluts pélagiques industriels et les petits chaluts de recherche - un chalut Isaacs-Kid étant dans ce cas utilisé -, a démontré combien l'utilisation de ce dernier était futile en ce qui concerne les évaluations de la biomasse provenant des campagnes de recensement par chalutage, du fait de leur capturabilité extrêmement variable sur la zone prospectée et également parce que les estimations ainsi obtenues étaient caractérisées par une erreur relative importante. Il est nécessaire d'élaborer une méthode standard de conduite des campagnes de recensement du krill par chalutage. Une modélisation mathématique liée à des études hydroacoustiques des propriétés de capturabilité des chaluts peut faciliter la sélection du modèle de chalut pélagique industriel le plus favorable. La quantité totale de krill pénétrant dans le chalut devrait être évaluée lors de la sélection du modèle de chalut.

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Резюме

Уловистость разноглубинного трала является переменной величиной, зависящей как от характеристик поведения и распределения облавливаемого объекта так и параметров трала. Улучшенное знание об уловистости трала и характеристик распределения криля в районе съемки позволят повысить надежность получаемых оценок биомассы. Сравнительный анализ уловистостей промысловых разноглубинных тралов и малых исследовательских тралов на примере трала Айзекса-Кидда показал, что последние нецелесообразно использовать для оценок биомассы методом учетных съемок, поскольку они обладают высокими вариациями уловистости на полигоне съемки, а получаемые оценки биомассы характеризуются высокими относительными погрешностями. Необходима разработка стандартной методики учетной траловой съемки криля. Выбор оптимальной конструкции разноглубинного промыслового трала может быть выполнен на основе математического моделирования по моделям статистической теории рыболовных тралов и путем гидроакустических исследований его улавливающих качеств. Выбор конструкции трала должен включать исследования по оценке брутто-изъятия криля.

Resumen

La capturabilidad de las redes de arrastre pelágicas es una variable que depende de las características de distribución y comportamiento de las especies buscadas y de los parámetros del arrastre. La fiabilidad de las evaluaciones de biomasa mejorará al contar con un mejor conocimiento de la capacidad de captura de la red y de la forma de distribución del krill. Un análisis comparativo de la capturabilidad de los arrastres comerciales y la de los pequeños arrastres de investigación, en este caso una red de arrastre Isaacs-Kidd, demostraron que éstos últimos no sirven para hacer censos de evaluación de biomasa debido a la gran variabilidad de la capturabilidad en la zona prospeccionada, y al importante error relativo de las estimaciones de biomasa obtenidas. Es preciso elaborar un método estándar para realizar prospecciones de censo. El modelado matemático de las redes de arrastres, junto con estudios hidroacústicos de las características de capturabilidad, facilitarán la selección óptima del modelo de red de arrastre comercial pelágica. En su selección debería tenerse en cuenta el volumen de krill retenido en el interior de la red.

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1. INTRODUCTION

Direct census surveys using midwater trawls as well as scientific research fishing remain part of an integrated approach to krill studies. Various types of midwater research (e.g. RTM-1, RTM-8, MOCNESS, Isaacs-Kidd) and commercial trawls have been used for this purpose.

However fundamental questions such as trawl catchability, the choice of trawl type and the procedure of its exploitation, factors determining the reliability of krill density and biomass estimates, have yet to be fully resolved.

The author has attempted to address the abovementioned problems using hydroacoustics and simulation studies of fishing trawls.

2. METHODOLOGY

It is well known that for trawl census surveys, specific biomass (density) of krill in the catch is expressed in g/m^2 or g/m^3 at the point of trawling (converted to unit of swept volume or unit of total area). Specific krill biomasses are plotted on the survey chart and depth contours are drawn corresponding to the areas fished. Then krill biomass over all depth strata is determined according to mean specific biomass for each stratum. Finally, total krill biomass for the entire survey area is calculated by adding the values for each layer.

Yu.V. Kadilnikov (1988) demonstrated that the following formula is the basis for estimating biomass from trawl surveys:

$$w = \frac{S_o}{S} \cdot \frac{\overline{m}q}{P} \qquad (1)$$

or $$w = \frac{B_o}{B} \cdot \frac{\overline{m}q}{P} \qquad (2)$$

where S_o, B_o - area and volume of the study area;

S, B - area and volume fished by the trawl over a standard hauling period;

$\overline{m}q$ - mean catch per standard hauling period **T**;

P - trawl catchability.

Assuming that information on values S_o S, B, B_o contains no errors, the relative error in the biomass estimate from formulas 1 and 2 will be calculated as:

$$\xi(w) = \pm[\xi(\overline{m}q) + \xi(P)] \qquad (3)$$

$$\xi(w) = \pm[\xi(\overline{m}\rho) + \xi(P)] \qquad (4)$$

where ρ - specific biomass

$\xi(\overline{m}q)$ - relative error in estimate of mean catch per standard hauling period T;

$\xi(P)$ - relative error in estimate of trawl catchability;

$\xi(\overline{m}\rho)$ - relative error in specific krill biomass estimate in the swept volume:

$$\xi(\overline{m}q) = \pm \frac{t_\varepsilon}{\sqrt{N}} \cdot \frac{\sigma q}{\overline{m}q} \qquad (5)$$

$$\xi(\overline{m}\rho) = \pm \frac{t_\varepsilon}{\sqrt{N}} \cdot \frac{\sigma\rho}{\overline{m}\rho} \qquad (6)$$

$$\xi(P) = \pm \frac{t_\varepsilon}{\sqrt{N}} \cdot \frac{\sigma p}{P} \qquad (7)$$

where t_ε - confidence coefficient corresponding to the accepted confidence probability ε

N - number of hauls

$\sigma q, \sigma p, \sigma \rho$ - mean standard deviations in the catch per haul, catchability and specific biomass.

As can be seen from formulas 3 to 7, the error in biomass assessment from trawl survey data is determined by statistical variation coefficients of catchability ($K_p = \sigma_p/P$) and specific biomass density ($K_\rho = \sigma_\rho / \overline{m}\rho$) or by the coefficient of variation of the catch per haul ($K_q = \sigma_q / \overline{m}q$).

Difficulties in estimating the trawl catchability coefficient led to the following assumption: the biomass value obtained using formulas 1 and 2 will be minimal if the catchability coefficient is equal to 1.0.

Moreover, the catchability of research trawls such as the Isaacs-Kidd is generally known to be equal to 1.0, while in the case of a commercial trawl catchability $P = 1.0$ is applied to the fine-meshed attachment in the trawl mouth. Specific krill biomass over the study area are calculated on the basis of this section of the trawl.

In practice, there was a large dispersion of catches per haul during trawl surveys. This necessitated dividing the large amount of catch (or specific biomass) data into several strata over which the coefficients of variation K_q (or $K\rho$) were not high. This made it possible to lower the relative error $\xi(w)$.

The above approach to krill biomass estimation using trawl census surveys is essentially based on the suppositon that the catchability of this type of trawl is a constant value independent of both the distributional patterns of the target object and trawling procedure. The following assumptions can be made in this regard:

- specific biomass densities are determined practically with the same degree of accuracy over the entire survey area;
- biomass estimates obtained in different seasons in a particular area or various areas may be subjected to comparative analysis.

Therefore, the accuracy of krill biomass estimates using trawl census surveys above all depends on the soundness of the assumption regarding consistent catchability of the particular trawl being used.

This paper will not examine matters such as selecting the optimal set of trawl stations or how to process trawl survey data, both of which significantly affect the accuracy of biomass estimates.

An assessment of midwater trawl catchability depending on the main parameters of the trawl and target species distribution, as well as a comparative analysis of the retaining qualities of various midwater trawl designs from the point of view of improving the reliability of krill biomass estimates, were carried out on the basis of experimental and theoretical research.

The main models of the statistical probability theory of fishing trawls were used in theoretical research. This theory allows one to calculate fairly accurately trawl catchability and catch per ship/day of fishing using information on distributional patterns of target objects and the technichal parameters of the trawl unit (trawl and vessel) (Anon.,1985a). Experiments have proven the applicability of this theory to assessing the retaining qualities of krill trawls (Kasatkina, 1989).

Distributional patterns were assessed in accordance with a set of standard methods (Anon., 1985b).

The hydroacoustic method of determining the retaining qualities of a trawl is based on a comparison of the actual catch with krill biomass estimates obtained using echo integrators located in the effective trawling area and other sections of the trawl (Kasatkina, 1985).

Experiments were conducted using a hydroacoustic unit comprised of two echo integrators, allowing the estimation krill swarm biomass in the effective trawling area as well as in the trawl mouth. This arrangement also enabled an assessment of total catchability ***P*** as a multiple factor event expressed as the following equation (Kadilnikov, 1985):

$$P = P_1 . P_2$$

where P - total catchability
P_1 - the likelihood of krill entering the trawl mouth from the effective trawling area.
P_2 - the likelihood of krill entering the codend from the trawl mouth.

3. RESULTS

Studies of the retaining qualities of midwater trawls were carried out using data from multidisciplinary research by AtlantNIRO in the Scotia Sea from 1983 to 1990.

4. CATCHABILITY OF COMMERCIAL MIDWATER TRAWLS

The catching qualities are discussed following an analysis of the process of krill fishing by several types of trawls. Trawl parameters are given in Table 1.

Experiments were carried out in the fishing areas of the South Sandwhich, South Orkney, South Shetland and South Georgia islands. The dependency of trawl catchability on its working parameters (trawling speed, angle of attack of the net) and distributional patterns of the targetted krill swarms were studied.

Tables 2 to 4 give mean statistical data for estimates of midwater trawl catchability on a number of fishing grounds in the Scotia Sea (Kasatkina, 1990; Kastakina and Latogursky, 1990). Midwater trawl catchability varies considerably within these fishing grounds as the spatial distribution of targetted krill swarms changes.

Analysis of the hydroacoustic assessment of commercial midwater trawl catchability over a wide range of distributional characteristics of targetted krill showed a correlation between catchability and distributional patterns. For example, the correlation coefficient between density of krill swarms and total catchability P for the 72/308 trawl was 0.65.

Moreover, if catchability P_1 (the likelihood of the target entering the trawl mouth from the effective trawling area) greatly depends on such krill distribution characteristics as the depth of the top edge of the krill swarm in relation to trawling depth, then trawling speed and the angle of attack of the net (i.e., the correlation between the trawl mouth and the codend opening) will have a telling effect on catchability P_2 (the likelihood of the target entering the codend from the trawl mouth area) and the escape coefficient (K_B) for the target passing through trawl netting.

By increasing trawling speed and the angle of attack, krill escapement increases significantly and, consequently, catchability P_2 decreases (Kasatkina, 1988).

Simulation studies were used to analyse the retaining qualities of various types of trawls employed in krill fishing. Calculations were made for several types of krill distributional characteristics and demonstrated that the most effective trawl in terms of krill behaviour is the 74/416 trawl (Zimarev *et al.*, 1990).

5. CATCHABILITY OF RESEARCH TRAWLS USING THE ISAACS-KIDD TRAWL AS AN EXAMPLE

The Isaacs-Kidd research trawl as modified by Samyshev and Aseev, is a midwater weighted trawl operating with one towing rope. The length of the trawl along the topenant is 26.8 metres. Total trawl mouth area is about 7 m^2 and remains constant throught all stages of operation. The trawl is made from 5 mm netting, which is in turn covered by a trawl bag of 20 mm twine. This protects the trawl bag from mechanical damage.

Features of this particular trawl include fast submersion and ease of lowering and raising, which saves time during trawl stations. In addition, trawl catchability is generally accepted as being a constant value equal to 1.0.

We will compare the choice of the Issacs-Kidd trawl for carrying out trawl surveys with a commercial trawl in terms of obtaining reliable krill biomass estimates.

From the description of the Isaacs-Kidd trawl it is clear that this type of trawl does not have a rope section and the guaranteed catch zone begins at the trawl mouth. In accordance with the multiplicitive catchability equation:

$$P = P_1 \times 1 \qquad (13)$$

In other words, catchability of the Isaacs-Kidd trawl will be determined by the likelihood of krill entering the trawl mouth from the catching area.

A comparative analysis of the catching qualities of a commercial trawl and the Isaacs-Kidd trawl was of necessity carried out using mathematical modelling since census surveys were not carried out simultaneously by these trawls in the same study area (Kasatkina, 1990).

Calculations were based on data from a census survey using an Isaacs-Kidd trawl over a small area of 3 270 km^2 near the South Orkney Islands. A 72/308 trawl was used for the sake of comparison. The krill distribution pattern in this area is shown in Figure 1. After the survey this area was stratified by specific biomass.

An assessment of catchability for the Isaacs-Kidd trawl operating between 0 and 100 metres at five depth levels (100, 75, 50, 25, 0 metres) showed that catchability differed significantly from a value of 1.0. There was also substantial variation when trawling depth was changed during each haul. At some trawl stations the coefficient of variation of catchability (Kp) reached 3.50. Mean catchability per haul also varied considerably depending on krill distribution patterns in the study area (Kp = 3.64, Table 5).

At some stations trawl catchability reached $P = 0.2$ at various depths. On the whole, however, the mean statistical value of catchability for the Isaacs-Kidd trawl is lower than the commercial trawl both in relation to individual depth strata and the entire study area (Tables 6 and 7). Also the coefficients of variation of catchability (Kp) for the Isaacs-Kidd trawl were much higher than in the case of the commercial trawl (Tables 6 and 7).

High Kp coefficients for the Issacs-Kidd trawl caused high relative errors $\xi(w)$ in the biomass estimate. Table 5 shows the errors $\xi(w)$ are different over the depth layers. It would therefore be incorrect to summarise the biomass estimates made with different relative errors.

6. DISCUSSION

It has been demonstrated that midwater trawl catchability depends on the trawl's parameters and the behaviour and spatial distribution of the target species. Moreover, the heterogeneous nature of krill swarm distribution over the study area and the variability of this distribution in time substantially contribute to changes in the trawl's catchability. As a consequence of this, each trawl census survey will have its own distribution of catchability, characterised by mean statistical parameters, for the particular trawl used.

The assumption that midwater trawl catchability is a constant value during trawl surveys does not correspond to reality.

Therefore, census surveys used to obtain a quantitative estimate of krill biomass must be accompanied by an assessment of mean statistical parameters of the trawl used.

Since midwater trawls are used to conduct census surveys, the choice of which one to use must be made with a view to obtaining reliable assessments of krill biomass.

A comparative analysis of the catchability of midwater trawl and the Isaacs-Kidd trawl demonstrated that the latter should not be used to assess krill biomass since its catchability CVs are high over the survey area and the biomass estimates obtained are characterised by a high degree of relative error.

Calculations showed that in order to guarantee a relative error of catchability no less than ξ x(P) = 0.1, it would be necessary to carry out over the study area 20 hauls with a commercial trawl and by almost an order of two more than that with an Isaacs-Kidd trawl.

The catch per haul coefficient of variation (Kq) of the Isaacs-Kidd trawl used in krill fishing is significant (see Table 5), which is caused by a small effective trawling area (30 minutes trawling with the Isaacs-Kidd, $B = 2\text{x}10^4\text{m}^3$; the same time trawling with the 72/308, $B = 11.34\text{x}106\text{m}^3$) and a high coefficient of variation Kp. It could be proven that with two trawls operating in the same area, one could expect the coefficient Kq for the Isaacs-Kidd to be greater by almost an order of magnitude than the commercial 72/308 trawl, thanks only to their different trawl operational areas (Kadilnikov, 1988).

The Isaacs-Kidd trawl has an advantage over the commercial trawl in that it allows one to save time during trawl stations. On the other hand, it gives less accurate biomass estimates.

Small research trawls (e.g. Isaacs-Kidd, RMT-8 etc.) have one more disadvantage. Krill is able to avoid these trawls. Moreover, krill's reaction to them manifests itself in various ways during the day and at night (Everson, 1986). We recall that the vertical opening of the Isaacs-Kidd trawl is only 2.3 metres, while krill can attain a "burst" speed of 60 cm per second (Kils, 1981). In particular, when fishing krill with the RMT-8 trawl, the latter travelled a distance of 10 metres away from the trawl in 8 seconds (Everson, 1986). Since krill speed depends on its length, size composition of catches landed by commercial and research trawls will be different. A histogram has shown that, compared with a commercial trawl, krill length distribution of catches made by a small research trawl tends significantly towards smaller sized individuals (Siegel, 1982).

In our opinion, therefore, the Isaacs-Kidd trawl cannot replace commercial trawls for krill census surveys both in terms of accuracy of biomass estimates and qualitative assessment of krill swarms.

It would seem appropriate to conduct fishing with two types of trawl (commercial and small research) simultaneously to obtain a qualitative assessment of krill swarms.

For estimating krill biomass density during trawl census surveys commercial trawls are recommended. Coefficients of variation for catch per haul and trawl catchability may be substantially decreased if a rational trawl design is chosen.

Choosing the best trawl design may be facilitated by simulation studies and hydroacoustic research into its catching capabilities. Also, assessments of the total amount of krill entering the trawl should be carried out when selecting trawl design (Zimarev, Kasatkina and Frolov, 1990).

As mentioned above, census surveys should be conducted together with catchability assessments of the midwater trawl used. This may be done using hydroacoustic methods or by calculations based on information about krill distribution patterns in the survey area. In this regard, it would be a good idea to use during census surveys automatic data recording and processing systems for data on spatial distribution of the target species.

It should be noted that planning the network of trawl stations and processing trawl survey data should be based on knowledge of krill distributional patterns in the study area.

7. CONCLUSIONS

Midwater trawl catchability is a variable depending on the behavioural and distributional patterns of the target species, as well as on trawl parameters.

Reliability of biomass estimates can be improved by knowledge of trawl catchability and krill distribution in the survey area.

In terms of accuracy of biomass estimates, commercial trawls are preferable to the Isaacs-Kidd and similar small research trawls.

A standard method for conducting krill trawl census surveys needs to be developed, including the selection of an optimal midwater trawl construction and operating procedure.

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Table 1: Principal parameters of midwater krill trawls.

Parameter	Trawl type			
	72/308	74/416	76/400	67.5/336
Vertical opening from the headline to the footrope (metres)	35	40	43	43
Horizontal and vertical mouth opening in the fine-mesh section (metres)	9.8	11.0	17	13
Horizontal opening between trawl boards (metres)	100	60	70	110
Horizontal opening between wings (metres)	40	35	37	35
Trawl length along the topenant - from wingtips to the fine-mesh section (metres)	115	141	138	115
Length of cables (metres)	150	100	100	150
Angle of attack - cables (degrees)	11.5	7.2	9.5	16.1
Angle of attack - trawl netting in horizontal aspect (degrees)	7.5	4.9	4.2	6
Angle of attack - trawl netting in vertical aspect (degrees)	6.3	5.9	5.4	8.3
Trawling speed (knots)	3.5	3.5	3.5	3.5
Length of trawl board rib (metres)	4	4	4	4
Mesh size in trawl bag (mm)	6.5	10	12	12

Table 2: Mean statistical data on krill swarm distribution patterns and midwater trawl catchability in various fishing areas (Kasatkina, 1990).

Parameter	Sandwich Is.	South Orkney Islands				Elephant Island		
	March 1983	April 1983	May 1983	Dec 1984	Jan 1985	Nov 1984	Dec 1985	Jan 1985
	Trawl 67.5/336	Trawl 67.5/336		Trawl 72/308		Trawl 72/308		
Mean thickness of layer over which swarms are distributed (metres)	62	35	50	33	44	52	57	39
Mean swarm depth (metres)	42	29	41	24	29	25	30	21
σ, swarm depth	13	20	13	8	10	14	16	8
Mean swarm thickness	9	8	15.6	6	9	6	7	3
σ, swarm thickness (metres)	2	4	6	2	6	2	4	1
Mean swarm length (metres)	37	47	59	30	23	20	29	17
σ, mean swarm length (metres)	15	16	19	7	10	7	20	4
Swarm density field in 2-dimensions, λ_s m^{-2}	1.65×10^4	4.95×10^5	1.96×10^5	1.94×10^3	8.3×10^4	1.94×10^3	1.95×10^3	6.19×10^3
β	0.0393	0.067	0.188	0.1266	0.1165	0.0667	0.2670	0.1211
Estimate of mathematical expectation of total catchability, P	0.0353	0.0457	0.063	0.0453	0.0439	0.0353	0.0530	0.0582
σ, total catchability	0.0081	0.0053	0.017	0.0109	0.0304	0.0106	0.0201	0.0231

Table 3: Mean krill distribution characteristics and catchability of trawl 74/416 in the Coronation Island area (Kasatkina, Latogursky, 1990).

Parameter	Period				
	4.12-18.12.1989	19.12.89-7.1.90	8.1-28.1.1990	29.1-18.2.1990	19.2-27.2.1990
Mean thickness of layer over which swarms are distributed (metres)	100	99	100	86	105
Mean swarm thickness (metres)	15	18	5	17	19
σ, swarm thickness (metres)	4	7	2	6	8
Mean swarm length (metres)	72	89	28	89	65
σ, swarm length (metres)	21	25	12	23	18
Mean swarm diameter (assuming that swarms are cylindrical) (metres)	92	120	36	120	84
Mean swarm volume (m^3)	$9.97x10^4$	$2.03x10^5$	$5.09x10^3$	$1.92x10^5$	$1.05x10^5$
Mean swarm density in 3-dimensions	0.0298	0.0982	0.2796	0.188	0.168
Swarm density field in 2-dimensions, λ_s m^{-2}	$2.98x10^5$	$4.78x10^5$	$5.4x10^3$	$7.52x10^5$	$1.11x10^4$
Mean krill concentration density (g/m^3) - calculated estimate	4.49	4.07	2.20	5.88	9.46
Calculated estimate of total catchability *P* for a 74/416 trawl	0.0605	0.068	0.1253	0.0807	0.101

Table 4: Total catchability estimates for the 72/308 trawl in various areas of the Scotia Sea (Kasatkina, 1990).

Area	Estimate of mathematical expectation of total catchability P	Total catchability σ_p
Elephant Island, Jan 1985		
Fishing grounds	0.0582	0.0231
Remaining waters	0.0341	0.0078
South Orkney Islands		
Fishing grounds	0.0439	0.304
Remaining waters	0.0291	0.019

Table 5: Summary data on the Isaacs-Kidd trawl catchability and relative error in biomass estimate over the survey period (Kasatkina, 1990).

Strata	Total catchability			Relative error in estimate		
	Estimate of mathematical expectation P	σ_p	Coefficient of variation K_p	Specific biomass ξ (m_p)	Catchability ξ (P)	Biomass ξ (w)
1	0.0191	0.0601	3.15	0.935	1.3	2.235
3, 2	0.0177	0.0611	3.45	0.26	1.04	1.30
5	0.0035	0.0088	2.5	1.032	0.927	1.959

Table 6: Summary catchability estimates for the 72/308 trawl used in krill census surveys (Kasatkina, 1990).

Strata	Total catchability			Relative error in catchability estimate ξ (P)
	Mathematical expectation, P	σ_p	Coefficient of variation - K_p	
1	0.054	0.0044	0.081	0.10
3 and 2	0.048	0.00456	0.095	0.08
5	0.0288	0.00428	0.15	0.158

Table 7: Statistical estimates of midwater trawl catchability over the survey area (Kasatkina, 1990).

Type of trawl	Total catchability		
	Mathematical expectation, P	σ_p	Coefficient of variation - K_p
Commercial trawl	0.0435	0.00989	0.207
Isaacs-Kidd	0.0127	0.0462	3.64

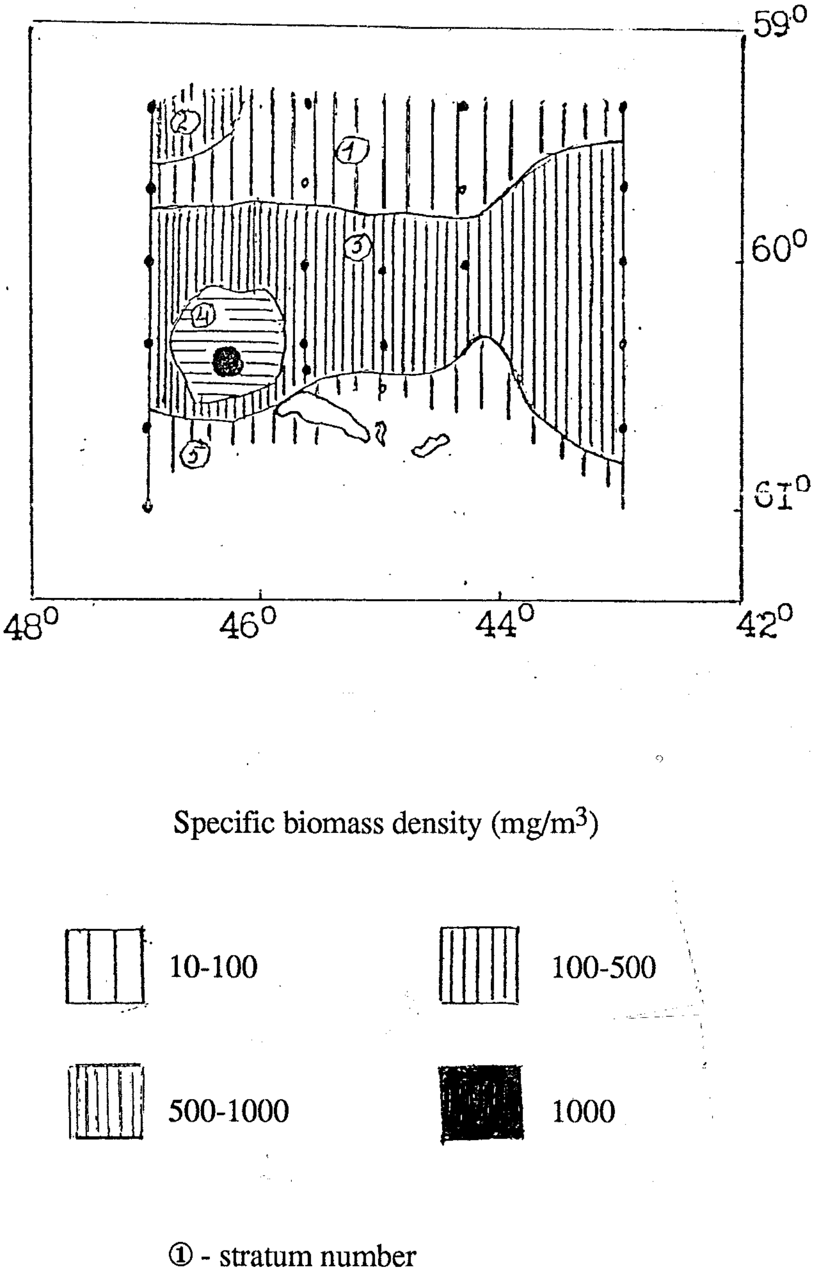

Figure 1: Krill biomass distribution in the South Orkney Islands area from trawl survey data obtained using an Isaacs-Kidd trawl, January 1985 (Anon., 1985c).

Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Lista de las tablas

Lista de las figuras