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SELECTIVITY OF COMMERCIAL AND RESEARCH TRAWLS IN RELATION TO KRILL

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Abstract

This paper describes the results of fishing a single krill aggregation with a commercial trawl RT 72/308 and an Isaacs-Kidd midwater research trawl (IKMT). The commercial trawl catches contained more large krill (35–58 mm) than catches of the research trawl (30–54 mm). The maximum difference in mean length in catches made by both trawls was $\Delta\bar{L}$ = 6.2 mm. Statistically significant variability in krill length composition was observed between catches made by the research trawl, while in commercial trawl catches krill length composition hardly varied at all. Statistical analysis of catches showed that when it comes to obtaining representative trawl samples, estimates of length composition in krill catches made using the commercial RT 72/308 trawl are more accurate than those obtained using the IKMT research trawl. The two types of trawl have different catchability characteristics: the research trawl is better at retaining small krill, while the opposite is true for the commercial trawl. Consequently, estimates of krill length based on data obtained using either commercial or research trawls will be biased and contain systematic errors, mainly due to the selectivity properties of the trawls. The various selectivity properties of the trawl used in acoustic surveys have different effects on the accuracy of krill abundance and biomass estimates. Estimates of krill mass density (g/m^2) and biomass are less dependent upon the selectivity properties of trawls used in acoustic surveys than are estimates of krill numerical density (numbers/m^2) and abundance.

Résumé

L'auteur donne les résultats de l'exploitation d'une concentration de krill par un chalut commercial de type RT 72/308 et un chalut pélagique de recherche Isaacs-Kidd (IKMT). Les captures du chalut commercial contiennent davantage de krill de grande taille (35–58 mm) que celles du chalut de recherche (30–54 mm). La différence maximale de longueur moyenne dans les captures effectuées par les deux chaluts est $\Delta\bar{L}$ = 6.2 mm. Une variabilité importante sur le plan statistique de la composition en longueurs du krill est observée dans les captures du chalut de recherche, alors que dans les captures du chalut commercial, la composition en longueurs varie à peine. L'analyse statistique des captures montre que lorsqu'il s'agit d'obtenir des échantillons représentatifs des chaluts, les estimations de la composition en longueurs des captures de krill provenant du chalut commercial de type RT 72/308 sont plus précises que celles provenant du chalut de recherche de type IKMT. Les deux types de chalut ont des caractéristiques de capturabilité différentes : le chalut de recherche retient davantage le krill de petite taille alors que c'est le contraire pour le chalut commercial. En conséquence, les estimations de longueurs de krill fondées sur des données provenant de ces deux chaluts seront biaisées et contiendront des erreurs systématiques dues principalement au caractéristiques de sélectivité de ces deux engins. Les diverses caractéristiques de sélectivité des chaluts utilisés dans les campagnes d'évaluation acoustique influent différemment sur la précision des estimations de l'abondance et de la biomasse de krill. Les estimations de la densité de la masse de krill (g/m^2) et de la biomasse de celui-ci sont moins dépendantes des caractéristiques de sélectivité des chaluts utilisés dans les campagnes d'évaluation acoustiques que ne le sont les estimations de la densité numérique (nombre/m^2) et de l'abondance de krill.

Резюме

В настоящей работе описаны результаты облова одной и той же агрегации криля двумя типами пелагических крилевых тралов: современным промысловым тралом 72/308 и исследовательским тралом Айзекса- идда (IKMT). В уловах промыслового трала присутствовал более крупный криль (35–58 мм), чем в уловах исследовательского трала (30–54 мм). Максимальное расхождение средних длин криля в уловах двух тралов составило $\Delta\bar{L}$ = 6,2 мм. При этом размерный состав криля в уловах исследовательского трала изменялся от траления к тралению, в то время как размерный состав криля в уловах промыслового трала практически не менялся. Статистический анализ показал, что с точки зрения однородности траловых выборок, оценка размерного состава криля по уловам промыслового трала 72/308 будет более точной, чем по уловам исследовательского трала IKMT. Рассматриваемые типы тралов обладают различными улавливающими свойствами. Исследовательским тралом IKMT более успешно будут удерживаться мелкие рачки, чем крупные особи. В уловах промыслового трала картина будет обратная. Поэтому, оценки длины криля, получаемые по данным уловов как промыслового, так и исследовательского тралов, являются смещенными и содержат систематические ошибки, обусловленные, прежде всего, селектирующими свойствами тралов. Селектирующие свойства трала, используемого на эхосъемках, по-разному оказывают влияние на точность получаемых оценок численности и биомассы криля. Оценки весовой плотности (г/м^2) криля и биомассы меньше зависят от селектирующих свойств используемого на эхосъемках трала, чем оценки численной плотности (шт/м^2) и численности криля.

Resumen

Este documento describe los resultados de la pesca de arrastre de una agregación de kril realizada mediante una red comercial RT 72/308 y una red de investigación Isaacs-Kidd de arrastre pelágico (IKMT). Las capturas de la red de arrastre comercial contenían mayor cantidad de kril de tallas grandes (35–58 mm) que las capturas de la red de arrastre de investigación (30–54 mm). La diferencia máxima entre los promedios de las tallas de las capturas de ambas redes fue de $\Delta\bar{L}$ = 6.2 mm. Se observó una variabilidad estadísticamente significativa de la composición por tallas de kril de las capturas efectuadas por la red de arrastre de investigación, mientras que en las capturas de la red de arrastre comercial la composición por tallas apenas varió. El análisis estadístico de las capturas demostró que en la obtención de muestras representativas del arrastre, las estimaciones de la composición por tallas de las capturas de kril efectuadas a partir de muestras de la red de arrastre comercial RT 72/308 eran más exactas que las estimaciones obtenidas de muestras de la red de arrastre de investigación IKMT. Los dos tipos de redes de arrastre tienen distintas características con respecto a la capturabilidad: la retención de kril de tamaño pequeño es mejor en la red de arrastre de investigación, en tanto que con la red de arrastre comercial ocurre lo contrario. Consecuentemente, las estimaciones de la talla de kril basadas en datos obtenidos de arrastres comerciales o de investigación estarán sesgadas e incluirán errores sistemáticos, debido, sobre todo, a las características de selectividad de los arrastres. Las distintas características de selectividad del arrastre utilizado en las prospecciones acústicas tienen efectos distintos en la exactitud de las estimaciones de abundancia y biomasa de kril. Las estimaciones de la densidad de la biomasa de kril (g/m^2) y de la biomasa dependen en menor grado de las características de selectividad de los arrastres utilizados en las prospecciones acústicas que las estimaciones de la densidad numérica de kril (número/m^2) y de la abundancia.

Keywords: biomass surveys, krill, sampling, selectivity, trawl, CCAMLR

INTRODUCTION

Currently the main source of information on the length-weight composition of krill aggregations present during census surveys of one type or another is trawl haul data. In practice both commercial and pelagic research trawls are widely used. Each pelagic trawl, however, has its own catchability and selectivity properties, therefore the question of length-weight estimates obtained using trawl data is one which needs to be investigated.

During recent years one of the main methods of estimating krill biomass and distribution has been acoustic surveys, in which krill target strength (TS) has been calculated according to length (L) using the regression equation TS = $f(L)$

Table 1: Details of trawl sampling stations.

RT 72/308				IKMT			
Station	Location	Time	Catch (tonnes)	Station	Location	Time	Catch (kg)
1	60°44′2″S 55°21′8″W	16:45 – 17:15	7.0	1	60°44′0″S 55°21′3″W	15:40 – 16:10	22.0
2	60°44′5″S 55°19′5″W	21:25 – 21:55	7.0	2	60°44′0″S 55°20′8″W	20:30 – 21:00	65.0
3	60°46′3″S 55°23′8″W	02:25 – 02:55	5.0	3	60°46′2″S 55°21′6″W	00:53 – 01:23	45.0

(SC-CAMLR, 1991). The primary acoustic parameter, MSBS (mean surface backscattering strength), is determined during surveys using modern calibrated equipment (e.g. EK-500/BI-500), while this value (MSBS) is converted into absolute density (number/m^2) using krill length composition in swarms as derived from samples taken by pelagic krill trawls, which is not an effective means of taking measurements. Therefore, when analysing the many factors which affect the accuracy of krill density estimates during acoustic surveys, it is necessary to take into account such factors as the use of pelagic trawls to determine krill length-weight composition.

MATERIAL AND METHODS

The survey was carried out in the Elephant Island area in January, 1985. The same krill aggregation was fished by two types of trawl: an Isaacs-Kidd midwater research trawl (IKMT) modified by Samyshev and Aseev (RV *Evrika*), and an RT 72/308 commercial trawl (RV *Argus*). Trawling duration was 30 minutes and trawling speed was 3.5 knots.

The IKMT is a midwater trawl with a length of 26.8 m along the belly line. The trawl bag has no rope or large-mesh sections. Therefore, the effective catching zone of the IKMT begins immediately at the trawl mouth. The trawl opening (7 m^2) is maintained during fishing operations by means of a special device (a depressor). The trawl is made of 5-millimetre mesh size netting and is covered by a double-meshed chafer (mesh size – 20 mm) which protects the codend against mechanical wear and tear. The trawl is towed with a single wire.

Unlike the IKMT research trawl, the commercial trawl RT 72/308 is equipped with trawl boards and bridles and has rope and large-mesh sections in the trawl bag. The length of the trawl belly line is 182 m, the height of the trawl mouth is 35 m, while its area (approximately 1 109 m^2) is significantly greater than that of the IKMT trawl.

A total of 10 hauls were made with the IKMT trawl and five hauls with the commercial trawl. Only results obtained for hauls made on the same krill aggregation were used for comparative analysis. Three hauls for each type of trawl, made as the vessels followed one another and trawled along the same course with only a small time difference between hauls, were selected for comparative analysis (Table 1).

All krill measurements were carried out by the same scientific observer and all samples were sorted by 2 mm length classes.

RESULTS

In general, krill aggregations fished during the day were recorded by hydroacoustic equipment as a field of swarms. At night krill were concentrated in the upper depth layer of 0 to 40 m and were observed as either individual swarms or as a near-surface dispersed layer (Table 2).

Table 2: Parameters of krill swarm.

Parameter	Mean (m)	CV %
Depth layer of distribution	39	
Depth of upper edge	30	53
Vertical length	7	43
Horizontal length	29	54

All krill specimens were found to be prespawners. Analysis of stomach content showed that krill were feeding actively over 24-hour periods.

According to Miller (1990), in most cases a minimum of 100 individuals should be sampled to determine statistically significant differences in krill length between hauls. Clearly, the trawl samples obtained for this analysis are sufficiently representative of krill length distribution in catches (see Table 3).

Krill Length Distribution

Histograms of krill length distribution in each catch and summary length data are shown in Figures 1 and 2 and statistics of samples are given in Table 3.

There was a manifest difference in krill length composition between the two types of trawl – the commercial trawl caught larger individuals (35–58 mm) than the IKMT trawl (30–54 mm) (see Figures 1 to 3). The maximum difference between mean krill length in catches made by the two trawls was 6.2 mm, i.e. more than three length classes (Table 3). A comparison of length frequency distributions (%) of krill in catches clearly shows the differences in the selectivity properties of the two types of trawl (see Figures 1 and 2).

The differences between krill length distributions in catches made by the two types of trawl were verified using a Kolmogorov-Smirnov test (λ). The significance of differences in krill length frequency distributions in catches made by the two types of trawl was estimated at a probability $P(\lambda) = 0.95$. Calculations demonstrated statistically significant differences in the size composition of krill in samples taken from the commercial and research trawls. From this, one may conclude that samples were taken from two separate statistical populations which would be the case when fishing different krill aggregations. In actual fact, one aggregation was fished. The term 'statistical population' in this instance refers to the targeted aggregation of krill in front of the trawl.

As can be seen from Table 3 and Figures 1 and 2, krill size composition in catches made by the research trawl varied more greatly between hauls than was the case with the commercial trawl. Homogeneity of trawl samples was determined by estimating the probability of difference between sample means. A probability of $P = 0.05$ was taken as the significance level.

Calculations showed that the difference between mean values of krill length in commercial trawl samples was not statistically significant ($P < 0.05$). The coefficient of variation (CV) of sample means was CV($\bar{L}$) = 0.7%.

The difference between mean values of krill length in the research trawl samples, on the other hand, was statistically significant ($P > 0.05$). The coefficient of variation of sample means for this type of trawl was CV($\bar{L}$) = 5.7%.

Krill Density and Target
Strength Evaluation

Table 4 contains estimates of krill target strength obtained using the following parameters of the regression TS = $f(L)$ recommended by CCAMLR's Working Group on Krill (WG-Krill) for an operating frequency of 120 kHz (SC-CAMLR, 1991):

$$TS = 34.85 \log L - 127.45$$

where L is krill length in millimetres.

TS values were estimated on the basis of mean krill length in trawl samples. Krill density estimates (individuals/m^2) were calculated for a single value of mean surface backscattering strength (MSBS = -55 dB).

Table 4 shows that the maximum difference in mean krill lengths ($\Delta\bar{L}$ = 6.2 mm) in samples from catches made by both types of trawl affects the difference in krill target strength estimates (ΔTS = 2.2 dB).

Therefore, differences in krill length composition in catches made by the two types of trawl affect acoustic estimates of krill density (individuals/m^2) in the following manner (Tables 3 and 4):

- Firstly, assuming the same MSBS value (-55 dB), krill density estimated on the basis of commercial trawl data will be lower than that obtained with the IKMT research trawl data. For the maximum observed difference in krill mean lengths ($\Delta\bar{L}$ = 6.2 mm) in commercial and research trawl catches, krill density estimates differed by a factor of 1.63.

- Since krill length composition varies from haul to haul in the research trawl catches taken from the same krill aggregation, the density values calculated on the basis of those hauls and

Table 3: Statistics of trawl samples.

Characteristic	IKMT				RT 72/308			
	1	2	3	Total	1	2	3	Total
Krill sample size	200.0	200.0	200.0	600.0	339.0	316.0	327.0	982.0
Mean length (mm)	40.3	44.9	42.6	42.9	45.9	45.9	46.5	46.1
Standard deviation (mm)	3.9	4.0	3.9	3.9	3.8	3.6	3.6	3.7
Mode (mm)	40.0	45.0	40.0	43.0	45.0	46.0	46.0	46.0
Maximum length (mm)	54.0	54.0	52.0	54.0	57.0	55.0	58.0	58.0
Minimum length (mm)	30.0	39.0	34.0	30.0	36.0	35.0	37.0	35.0
Median length (mm)	40.0	45.0	42.0	43.0	46.0	46.0	46.0	46.0

Table 4: Krill target strength (TS) and krill mean density based on krill length/TS relationship (SC-CAMLR, 1991) and MSBS = -55 dB.

Parameter	MSBS = -55 dB					
	IKMT			RT 72/308		
	1	2	3	1	2	3
Mean length of krill in the sample (mm)	40.3	44.9	42.6	45.9	45.9	46.5
Target strength (dB)	-71.5	-69.9	-70.7	-69.5	-69.5	-69.3
Mean density (ind/m^2)	44.7	30.9	36.3	28.2	28.2	27.5
CV (%)		18.8			1.4	
Mean density (g/m^2)	19.9	19.7	19.5	19.4	19.4	19.7
CV (%)		1.0			0.9	

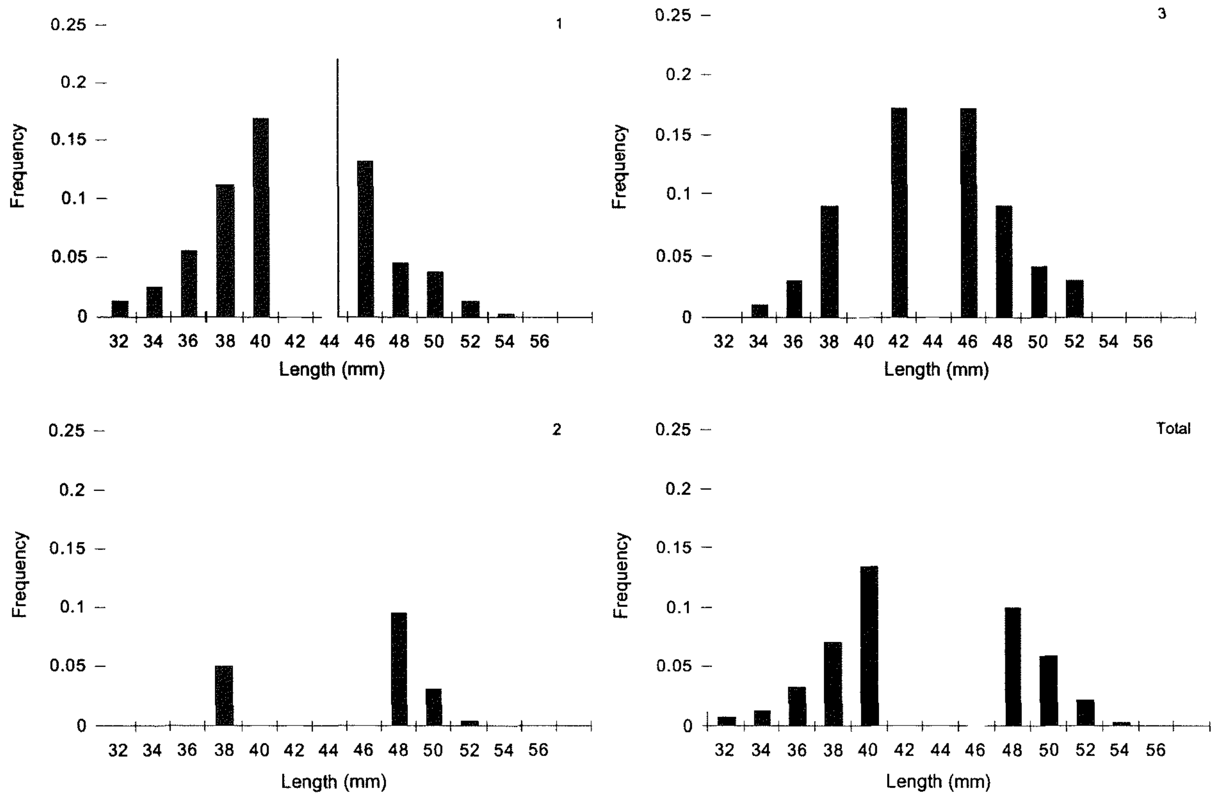

Figure 1: Krill length frequency distribution in catches made by the IKMT research trawl.

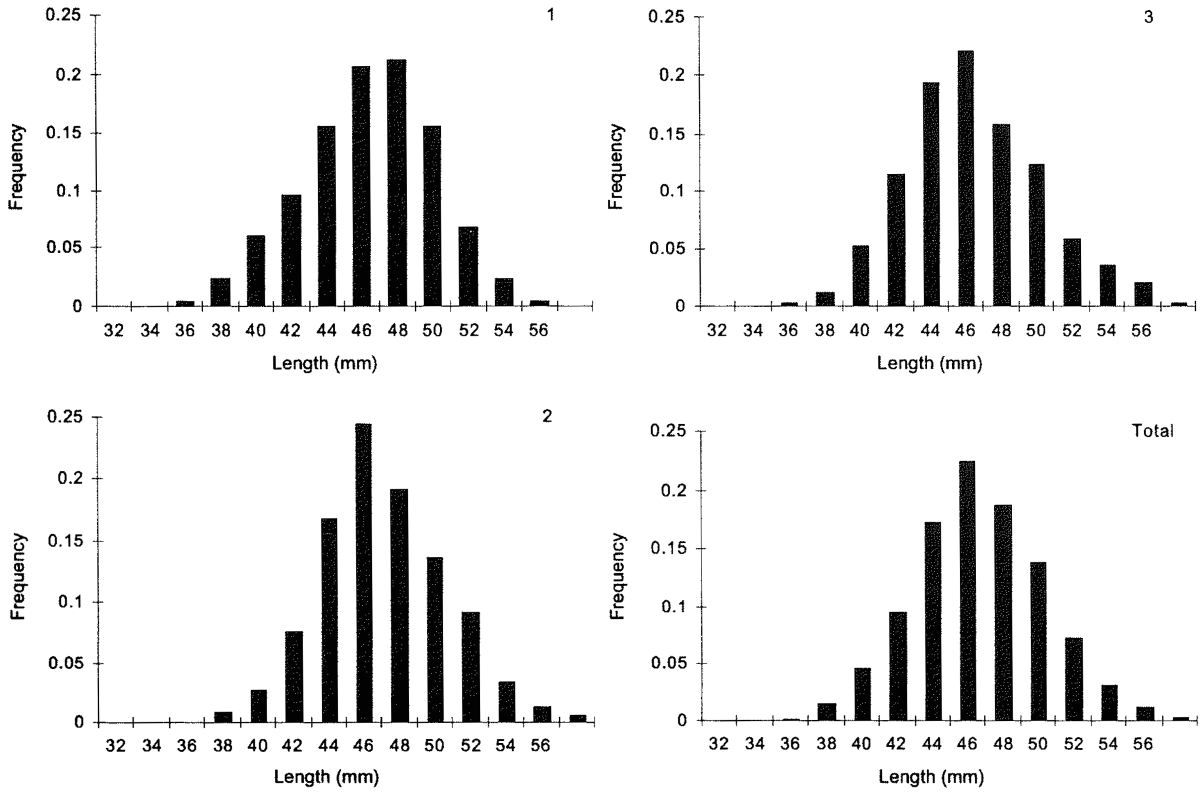

Figure 2: Krill length frequency distribution in catches made by the commercial trawl RT 72/308.

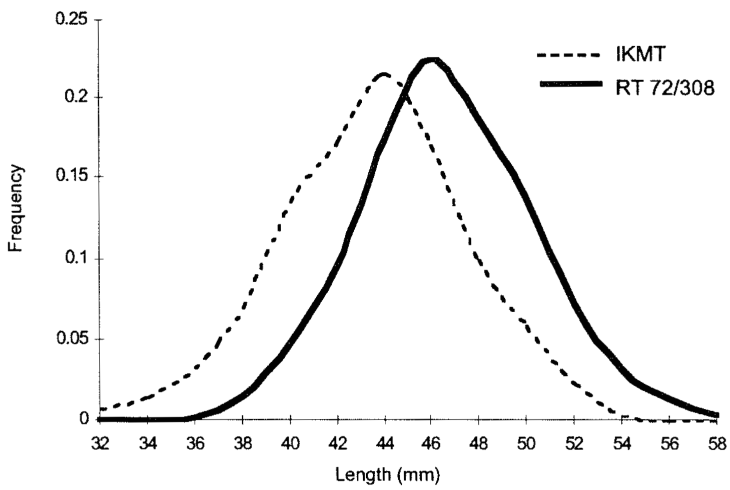

Figure 3: Krill length frequency distribution in catches made by the IKMT research and RT 72/308 commercial trawls (data from Tables 1 and 3, all catches combined).

assuming constant MSBS = -55 dB also vary. The krill density calculated on the basis of three IKMT catches has CV($\bar{\rho}$) = 18.8%. Moreover, the maximum difference in mean krill lengths in IKMT catches was $\Delta \bar{L}$ = 4.6 mm, while the corresponding difference between density estimates equated to a factor of 1.45.

- The krill density estimated on the basis of commercial trawl data was CV($\bar{\rho}$) = 1.4%, and the maximum difference in mean krill lengths in commercial trawl catches was $\Delta \bar{L}$ = 0.6 mm.

As can be seen from Table 4, the use of trawl sample data in calculating weight density (g/m^2) has virtually no effect on estimates obtained. Coefficients of variation of krill weight density were similar for both types of trawl and did not exceed CV($\bar{\rho}$) < 1%.

DISCUSSION

A single aggregation of krill was fished by two trawls of different construction:

- The commercial trawl has trawl boards with cables and a trawl bag with rope and large-meshed sections, which enlarges the effective fishing area, i.e. although krill can swim freely through the rope and large-meshed sections, these sections herd the krill into the fine-meshed area (Kadilnikov, 1993).
- The research trawl, by contrast, has only a trawl bag with a fine-meshed section. The trawl-mouth opening is much smaller in the research trawl than the commercial trawl.
- The effective fishing zone of the commercial trawl is many times greater than that of the research trawl (effective fishing zone – that area in which the possibility of the fishing target being caught is greater than zero (Kadilnikov, 1993).

The commercial trawl fishes a large volume of water and has a large vertical trawl-mouth opening, therefore samples taken from it provide representative length composition of krill in the target aggregation. Therefore, when targeting a single aggregation commercial trawl samples of length composition are homogeneous, which is shown up by the statistically insignificant difference between mean krill lengths in catches that one could consider to be random.

The research trawl fishes a small volume of water and covers only a small part of the aggregation, mainly due to its low catchability resulting from its reduced trawl-mouth height (Kasatkina, 1991). It should be recalled that catches made by the IKMT trawl amounted to between 22 and 65 kg, while catches by the commercial trawl were in the order of 7 tonnes. Therefore, when targetting a single aggregation the size composition will vary from one haul to another and will not be truly representative of the whole aggregation, but rather reflect just a small portion of it. The variation between mean krill lengths in research trawl samples is statistically quite significant.

Based on the above one may conclude that, in the context of representativeness, estimates of krill length composition in catches made by the RT 72/308 commercial trawl will be more accurate than those based on data from the IKMT trawl.

On the other hand, compared to data from the research trawl, the krill length distribution curve for commercial trawl catches is skewed to the right in favour of larger individuals (Figure 3 and Table 3). This skewness is typical of all research trawl samples. The variations in krill length distribution in catches made by the two types of trawl are not random, they are statistically significant.

Therefore, despite the small number of hauls carried out, it is clear that the two types of trawl under investigation have different catchability characteristics for krill. The IKMT research trawl is better at retaining smaller specimens than the commercial trawl. In catches made by the latter, the opposite holds true. Therefore, estimates of krill length based on data obtained from hauls made by both types of trawl will be biased and contain systematic errors caused mainly by the catchability properties of the respective trawl. The nature of these biases, however, will be different.

The selectivity properties of the trawl used during acoustic surveys will have different effects on the precision of krill abundance and biomass estimates. Numerical density (individuals/m^2) is determined using the value of krill target strength calculated according to the regression equation TS = $f(L)$, i.e. this parameter is directly dependent upon the krill length estimate obtained from trawl samples. Weight density (g/m^2) is determined by the value TS_{1kg} – the target strength of 1 kg of krill. This parameter is not dependent upon length and is virtually a constant value since the target strength and mass of a single specimen krill have the same degree of dependency on the krill's length, i.e. a function of L^3 (Greene et al., 1991; Siegel, 1992). Therefore, krill weight density (g/m^2) and estimates of biomass are less dependent on the selectivity properties of the trawl used during echosurveys than are estimates of krill numerical density and abundance (Table 4).

It must be pointed out that the selectivity properties of a trawl will affect the accuracy of biomass estimates for specific age groups of krill because the biomass of any length class will be calculated from the total estimated biomass according to the percentage composition of that particular group in all catches.

CONCLUSIONS

- Pelagic trawls used during krill biomass and abundance surveys have different selectivity properties affecting the precision and level of bias in krill length estimates based on data obtained from various types of trawls.
- The selectivity properties of krill trawls affect acoustic estimates of krill abundance more than they do biomass estimates.
- Comparative analysis of the results of different surveys require that the selectivity properties of the trawls used be taken into account. This is especially relevant when conducting surveys with a group of vessels using different trawls.

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