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Studies on performance capacity and selectivity of trawls used for Antarctic krill fisheries *)

ABSTRACT: Studies on performance capacity and selectivity of trawls used for industrial fisheries of krill (*Euphausia superba*) were carried out on the research vessel r/v „Profesor Siedlecki".

It has been ascertained that performance capacity of the proposed trawl is about 0.86 and that chiefly small, 22—26 mm-long, krill specimens are passing through the trawl segments made of 12 mm-meshed fabric. This has an essential effect on the age-size structure of caught specimes of krill.

It has been stated that the insets of less than 10 mm-mesh fabric in the bags and less than 12 mm-mesh fabric in the bellies of the trawl are practically inexpedient.

Key words: Antarctic, krill

1. Introduction

There is a lack of data in the literature hitherto, on performance capacity of fishing gear and the degree of krill (*Euphausia superba* Dana) escape through the meshed fabric of the trawl.

In the existing constructional designs of for trawl bags the size of meshes in the fabrics used for inserts in the bags and the segments of the bellies varies considerably (ranging from 5 mm to 12 mm). The problem of performance capacity — i.e. the relation of the amount of krill caught to the amount of krill trawled — may be considered in the aspect of achieving the maximum of economic effect (large catches at relatively small expenditures) whereas the question of selectivity of the trawls is of a great biological consequence — protection of standing crop against overcatching and insuring satisfactorily effective catches for industrial fisheries.

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Taking into account the fact of great interest of many countries in Antarctic krill and entering upon industrial fisheries by some of them it seems indispensable to start, at once, extensive studies in this direction, so as adequate regulations and conventions, having in view the conservation of standing crop, could be issued before the mass industrial fisheries are undertaken on a large scale. For determination of the degree of selectivity of fishing gear, requisite for preservation of standing crop, the size of the protected specimens should be defined beforehand, as it is agreed upon at present in respect of fish catches.

These studies were carried out within the scape of the First Polish Antarctic Expedition in 1975/1976. The aim of the investigations was to determine the selectivity of trawls in krill fisheries.

2. Material and methods

Deliberations on performance capacity of fishing gear have concerned hitherto fish catches and have mainly theoretical meaning. Baranov (1960), as well as Świniarski and Krępa (1975) considering this subject assume that absolute performance capacity of fishing gear is the relation of the quantity of caught fish to the total quantity of fish existing in the depths of water penetrated by fishing gear. Krępa and Pietkiewicz (1968) describe performance capacity as relation of the amount of caught fish to the total amount of fish in a shoal. However, the methods of determining accurately the quantity of fish in a shoal or in the penetrated depths of water have not been found yet, nor the apparatuses or devices that could help in that matter, have been contrived hitherto.

The simplest formula for the absolute performance capacity of fishing gear is proposed by Baranov (1960):

$$F = \frac{n}{m} \tag{1}$$

where: n — the amount of caught fish
N — the amount of fish existing in the area of the penetration of trawl

The studies were carried out with the view to determine the degree of performance capacity of the trawl, dependent on the size of meshwork used in various segments of the belly and the bag (disregarding the positive or negative effect of the parts of the outfit, such as: wings, legs and water boards, on the results of trawling). Performance capacity of krill trawl was defined as relation of the amount of krill caught (n) to the amount of krill drawn into the belly of the trawl through the inlet of the bag. It was assumed that at fixed speeds of trawling krill taken in by the foremost segments of the belly would not be able to get out by the same way (swimming out through the inlet); the only possible way of escape is through the meshed fabric of the belly and bag.

To determine the quantity of the krill getting out to the outer side of trawl through the meshwork of the fabric the method of catchers sewn on the outside of the belly was used. This method is well-known in fishery and was used for determination of performance capacity of trawls in fish catching, however, due to a rather great swimming speed of some species of fish did not always stand the test satisfactorily. Taking into account the size of the caught specimens of krill (20—60 mm), low speed of krill movement and fixed speed of trawling (about 3.0 knots) the method of catchers used for determination of performance capacity of krill trawls should not raise objections.

Catchers made of knotless, 6 mm meshed fabric were used in the investigations. Schematic diagram of the distribution of catchers and the size of the meshwork on the trawl segments on which catchers were sewn on is shown in Fig. 1. The surface area of the inlet of the catchers sewn on the belly and bag of the trawl are variable and depend on the gape of the meshes, which in turn is dependent on the horizontal and vertical gape of the trawl.

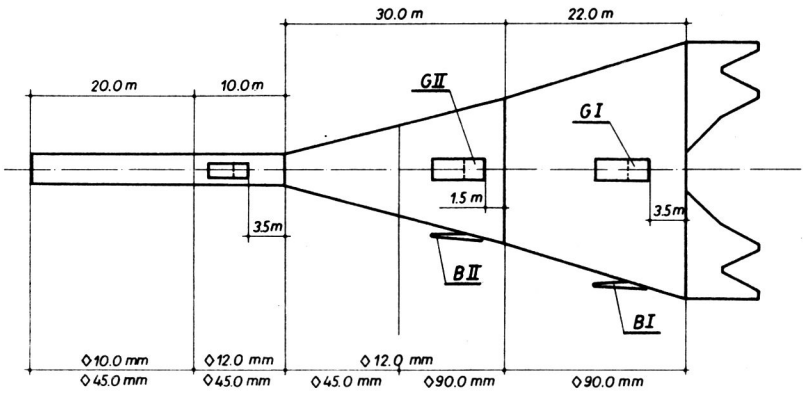


Fig. 1. Scheme diagram of the distribution of catchers on the krill trawl Type 23/56×4 (1100 meshes). *B* and *G* — catchers.

Simplifying this question and assuming that the coefficients of the mesh gapes are identical on the whole surface of a given segment, the quantity of krill getting out beyond the range of the given segment and the bag (u) may be calculated using equation of proportionality:

$$u = \frac{g}{m} \cdot M \text{ (kg)} \tag{2}$$

where: g — quantity of krill in catchers sewn on the segment (kg)
m — number of meshes on the surface of the inlet of the catchers sewn on the segment
M — number of meshes on the whole surface of the given segment

Total quantity of krill getting out beyond the limits of the network part

of the trawl was accepted as the sum of the quantities of krill escaping through all the segments:

$$U = u_1 + u_2 + u_3 \tag{3}$$

Knowing the quantity of krill caught (n) and the quantity of krill that got out to the outside of the trawl (U) the performance capacity of the trawl may be expressed:

$$F = \frac{n}{n+U} \tag{4}$$

Apart from the performance capacity of fishing gear also selectivity of meshed fabrics of the trawl was investigated with attention concentrated on determination of the lenght of the specimes with held or let out through the meshwork. The measurements were carried out for seven, selected at random hauls, taking from every group of catchers and the bag 100 specimens, each (at random) and measuring their body lenght.

Knowing the amount of caught krill (kg), the amount of krill (kg) getting out to the outside of the trawl, the proportional distribution of the body lenght of krill in these two groups and correlation between the lenght and weight of krill specimens, the percentage of individuals escaping to the outside of the trawl was calculated. Data are given in Fig. 2.

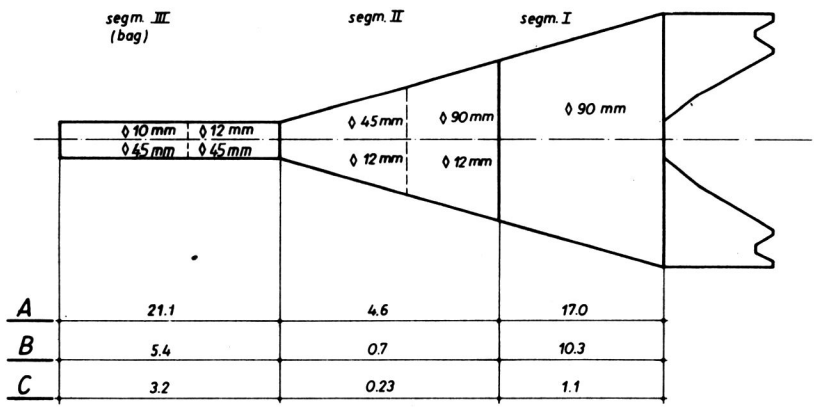


Fig. 2. Krill escape from different segments of the trawl
A — Degree of escape (percentage of individuals, %), B — Degree of escape (percentage of biomass, %), C — Intensity of escape (escaping krill kg · m $^{-2}$ per every 10 ton of catches).

Investigations were carried out using a prototype krill-trawl (23/56 × 4), devised by the Department of Fishing Vessels, Sea Fisheries Institute (MIR), attaining vertical gape of about 15 m and horizontal gape of about 16 m at the inlet into the belly.

The measurements of performance capacity of the trawl were carried out for 16 hauls selected at random, collecting and analysing, by weight, 80 samples taken from the catchers (5 catchers on the trawl).

Table I

Results from the measurements of the degree of krill escape from the belly of the 23/56 × 4 trawl on the research vessel r/v "Profesor Siedlecki"

Haul No.	Catches (kg)	Biomass of krill in catchers (kg)				Mean biomass of krill per catcher (kg)		Biomass of krill passing through the meshed fabric of the belly (kg)			Percentage of krill passing through the meshed fabric of the belly (%)		
		Segment I		Segment II									
		G I	*B* I	*G* II	*B* II	Segm. I	Segm. II	Segm. I	Segm. II	Total	Segm. I	Segm. II	Total
50/39	1800	0.085	0.200	0.095	0.050	0.142	0.072	135.0	21.0	174.0	7.5	1.1	8.6
51/40	5000	0.830	0.160	0.070	0.050	0.495	0.060	468.0	18.0	486.0	9.4	0.3	9.7
53/41	6000	0.400	0.630	0.055	0.065	0.515	0.060	487.0	18.0	505.0	8.1	0.3	8.4
96/73	7000	0.000	0.880	0.100	0.210	0.440	0.155	416.0	46.6	462.6	5.9	0.7	6.6
97/74	3500	0.180	0.230	0.010	0.050	0.205	0.030	194.0	9.0	203.0	5.5	0.3	5.8
113/77	1500	0.290	0.190	0.050	0.120	0.240	0.085	227.0	25.6	252.6	15.1	1.7	16.8
117/81	10000	0.350	0.480	0.100	0.250	0.415	0.175	393.0	52.6	445.6	3.9	0.5	4.4
118/82	4000	2.710	0.800	0.400	0.190	1.755	0.295	1662.0	88.8	1750.8	41.5	2.2	43.7
119/83	4000	0.300	0.140	0.090	0.240	0.220	0.115	208.0	34.6	242.6	5.2	0.9	6.1
138/96	20000	2.280	0.740	0.640	0.160	1.510	0.400	1430.0	120.0	1550.0	7.1	0.6	7.7
142/97	7000	0.860	0.000	0.110	0.050	0.430	0.080	407.0	24.0	431.0	5.8	0.3	6.1
144/98	6000	2.900	0.150	0.750	0.070	1.525	0.410	1444.0	123.0	1567.0	24.5	2.0	26.5
151/104	3000	2.150	0.590	0.160	0.300	1.370	0.230	1297.0	69.0	1366.0	43.2	2.3	45.6
163/112	12000	2.720	0.280	0.370	0.080	1.500	0.225	1420.0	67.7	1487.0	11.8	0.6	12.4
169/117	2500	0.150	0.120	0.050	0.180	0.135	0.115	128.0	35.0	163.0	5.1	1.4	6.5
181/126	25000	3.500	0.390	0.120	0.260	1.945	0.190	1842.0	57.0	1899.0	7.4	0.2	7.6
Average	7380	1.231	0.374	0.198	0.145	0.802	0.168	759.8	50.6	810.4	10.3	0.7	11.0

3. Results and discussion

As results from the measurements, using the experimental type of krill trawl (size of meshes as in Fig. 2), on the average 11% of krill escape beyond the range of the meshed-fabric segment of the belly, calculated in relation to the weight of the caught quantities of krill. In a series of hauls that percentage ranged from 4.4 to 45.6 (Table I). Determining performance capacity after equation (4) the mean value amounted to $F = 0.86$, ranging from 0.69 to 0.96. The causes of such a wide fluctuation of performance capacity and consequently, also, of the quantities of krill escaping beyond the limits of the meshed-fabric segments of the trawl are difficult to explain explicitly. The carried out observations allow to state that in a great measure this is connected with the time of the day (daytime or nighttime) and variable reaction of krill to the type of the meshed fabric used for the trawl-body.

It has been observed that the greatest quantities of krill escape beyond the range of the first segment of the belly, through 90 mm meshes, in the nighttime (Nos. 118/82 and 151/104 hauls) (Table I). At that time krill occurred in very sparse shoals visible on the fishing echosounding recordings in the form of dainty haze. Also, the mean results of the catches from night-trawling were decidedly lower as compared with daytime catches. On the average, per one hour of trawling by night, the catches were threefold lower than in daytime. Taking into account the degree of krill escape beyond the limits of the meshed fabric (higher by night — lower by day) and the results obtained from fishery (lower by night — higher by day it may be assumed that during the day krill reacts strongly to the scaring effect of the meshed fabric and passes through the meshwork less intensly, consequently, at that time (by day) krill can be caught effectively with trawls, having the first segments of the belly made of fabrics with meshes several times larger than the size of krill. This is of a great practical implication, seeing that trawls with larger size of meshwork require less operative energy in haulage. By night krill reaction to the scaring effect of the meshed fabrics is much lower and consequently a higher percentage of specimens is filtered through beyond the range of the segment made

Table II

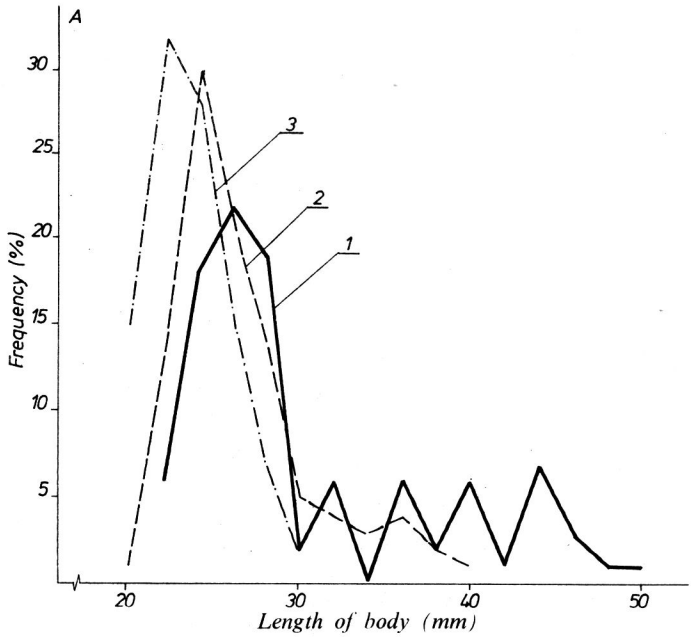
Results from the measurements of the degree of krill escape from trawl-bag through 12 mm-mesh insets

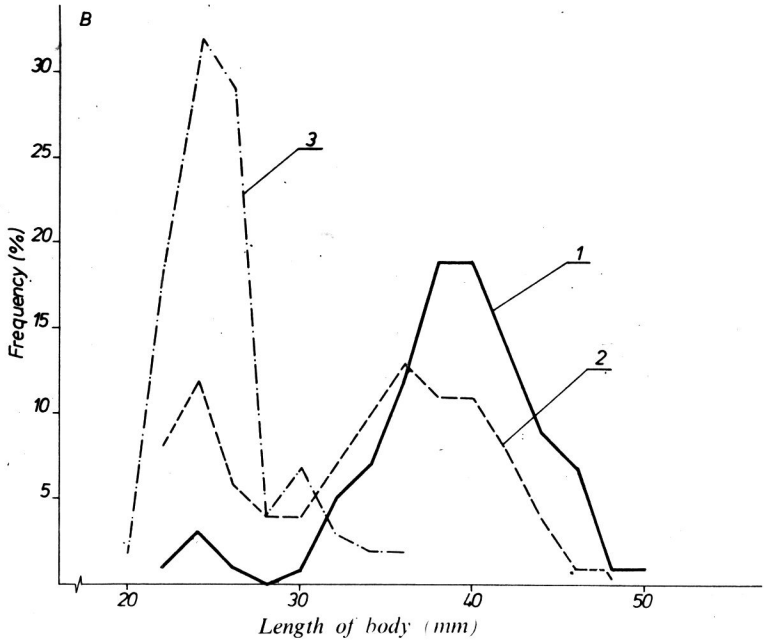
Haul No.	Catches (kg)	Biomass of krill in catchers (kg)	Total biomass of krill filtered from the bag (kg)	Percentage of krill filtered from the bag (kg)
151/104	3000	0.180	80	2.6
159/110	4000	0.750	353	8.8
163/112	12000	1.410	630	5.25
169/117	2500	0.350	156	6.25
181/126	25000	2.910	1300	5.2
Average	9300	1.120	504	5.4

of fabrics with larger meshes. Therefore, to get positive results from night-catches trawls with insets of finemesh fabrics over the whole length of the belly should be used. Small fluctuations of the quantities of krill escaping from this part of the trawl are noticeable (Table II). This leads the conclusion that it is a mechanical filtration of small specimens out of the trawl-bag through the meshes of the fabric.

The behaviour and reaction of krill to the meshed fabric in this part of the trawl have by now no effect, any longer, upon its possibilities to get out beyond the range of the fabric. The greatest quantity of krill, calculated per unit of the surface area, is filtered from the bag — segment III (through 12 mm-meshwork), averaging about 3.2 $kg \cdot m^{-2}$ per each 10 ton of catches (Fig. 2). Since the surface area of the bag (Segment III) is rather small, as compared with the surface area of the whole belly (Segments I and II), it has not an important effect upon the total amount of krill escaping beyond the limits of the trawl.

Considering the scape of krill through various segments of the trawl (Fig. 2) it was found that the greatest quantities of krill (by weigth) over 10% pass through the segment I — without a fine-mesh inset-whereas the total quantity of krill escaping from the trawl amounts to over 16%. The greatest quantity of krill specimens passing through the meshed fabric of the segment III (trawl-bag) amounts to 21% (Fig. 2). The total quantity of krill escaping beyond the limits of the whole trawl (mean value from seven measurements hauls), determined by the number of individuals, amounted to 42%. This high percentage of escaping krill may have a considerable effect on the age-size structure of the caught specimens, so much more that mostly small individuals get away from the trawl (Figs. 3 and 4).





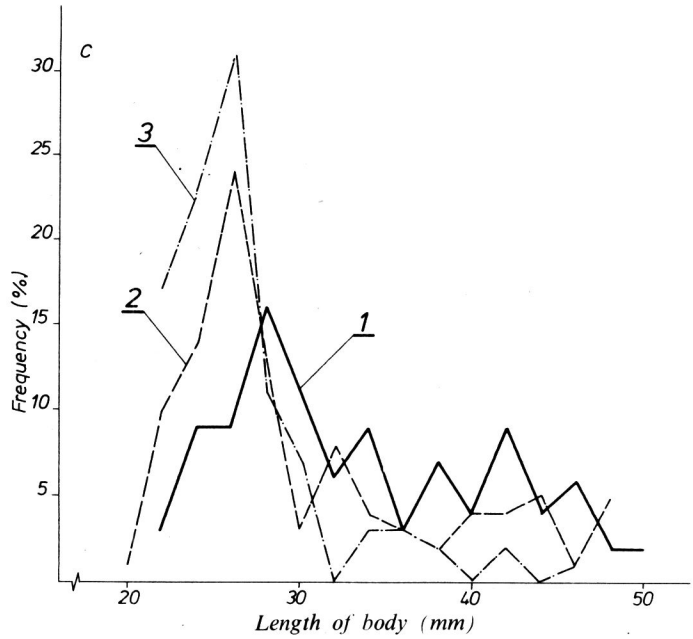


Fig. 3. Percentage of specimens of different size, caught and escaping through the meshed fabric

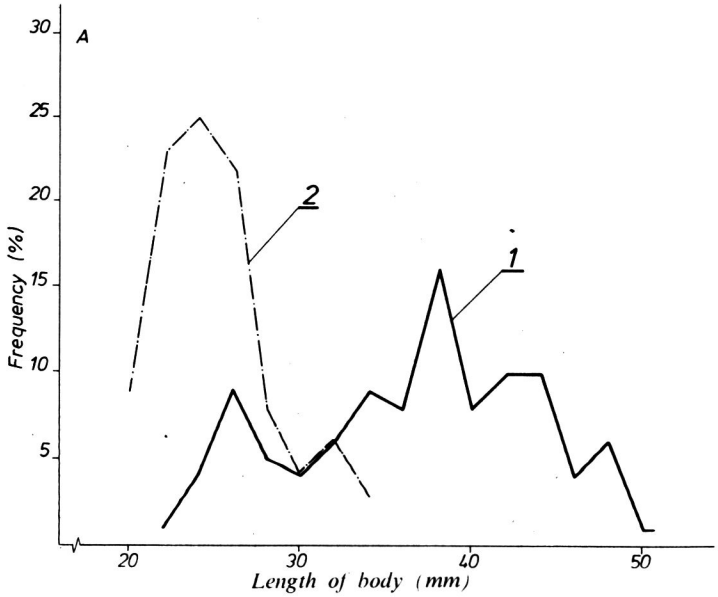
1 — caught specimens (in trawl-bag), 2 — specimens in catchers (Segment I), 3 — specimens in catchers (Segment II), *A* — Haul 142/97, *B* — Haul 163/112, *C* — Haul 169/117

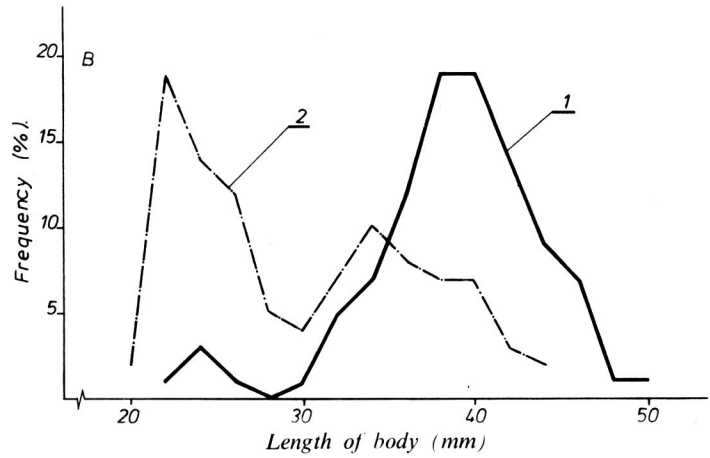
The measurements showed that mainly small specimens (20—34 mm) are getting out beyond the limits of the bag and the parts of the belly (12 mm-meshed fabric), whereas the basic biomass escaping beyond the trawl-net consisted of 22—26 mm long individuals. In the area of the segment I (90 mm meshwork), also, the specimens getting out beyond the limits of the net markedly smaller than the caught ones.

Knowing the proportional distribution of the length of individuals caught and escaping to the outside of the trawl through the different segments (Figs. 3 and 4) and the body weight of these specimens it is easy to determine the factual structure of the trawled standing crop.

A comparatively small quantity of krill escaping through the meshed fabric in the area of the segment II arouses some doubts. It seems that it may result from inaccurate measurements. Namely, the catchers II *B* and *G* (Fig. 1) were mounted on the foremost part of the segment, where the density of krill was still low and consequently small quantities were filtered to the outside. At the end part of the belly (without catchers) the density of krill was many times higher and therefore it must have been filtered more intensively. Taking this into account and the fact that some quantities of very small krill could have been filtered from catchers, as well, it may be suggested that the total quantity of krill escaping beyond the range of the trawl was slightly higher than it results from the measurements and calculations.

The preliminary investigations showed that trawl used for krill fishery operates selectively to a considerable degree and with appropriate choice of the size of the meshwork in various trawlsegments it will be possible to catch the main requisite biomass consisting of specimens of a determined size. This makes possible the preservation of young individuals and





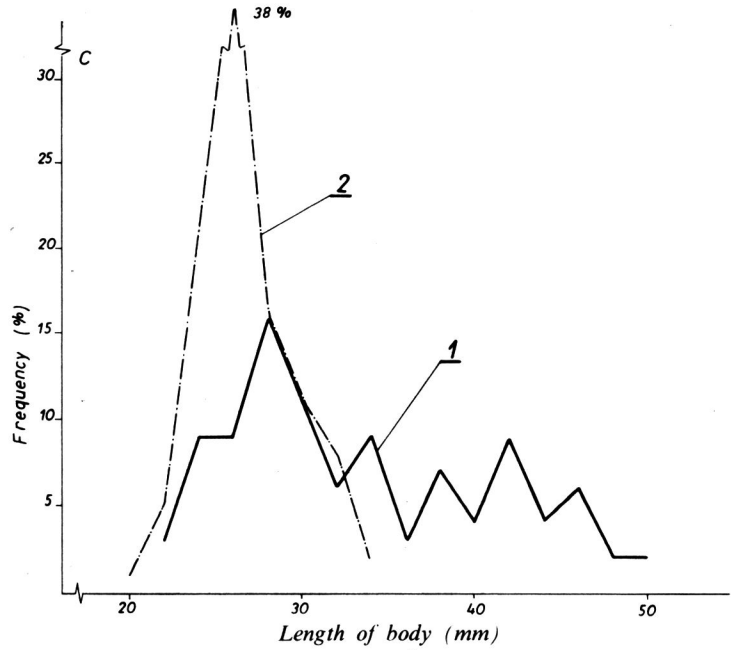


Fig. 4. Percentage of specimens of different size — caught and escaping beyond the range of the trawl-bag.

1 — caught specimens, 2 — specimens escaping from the bag, *A* — Haul 159/110, *B* — Haul 163/112, *C* — Haul 169/117.

consequently in some measure the protection of the standing crop against overcatching.

The investigations of performance capacity and selectivity of fishing gear are also of great importance for technical and technological objectives.

Selective catches of larger individuals supply raw material of better quality that may be utilized more profitably in the procesing of foodstuffs.

It has been ascertained on the basis of the carried out investigations and measurements that from the technical and technological viewpoint the use of the insets with smaller than 10 mm meshwork at the end parts of the trawl belly and bag is inexpedient since it will give only a small increase of the caught biomass with a considerable increase of the number of small specimens. At the same time, size of meshwork causes a decrease in the intensity of filtration and may have an unfavourable effect on the general performance of the trawl.

4. Summary

Investigations of the degree of krill escape from the trawl were carried out during the First Polish Antarctic Expedition on the research vessel "Profesor Siedlecki". Studies were conducted using the method of catchers sewn on the outer side of the belly and on the bag (Fig. 1). Measurements were performed in 16 hauls selected at random, weighing every time the amount of krill in all the catchers and in the bag, additionally the length of the specimens was measured in 7 hauls and their proportional distribution was determined.

The determined by weight mean performance capacity was $F = 0.86$, ranging in extreme cases from 0.96 to 0.69. Mostly small, 22—26 mm-long individuals are getting out through the trawl-segments made of 12 mm-meshed fabric (Fig. 3).

It has been determined that quantitatively (calculated by individuals) over 42% of krill escape beyond the limits of the belly and the bag, the greatest quantity was filtered out from the bag — over 21% (Fig. 2). It was found that in daytime krill reacts rather strongly to the scaring effect of the meshed fabric, due to that fact it may be caught effectively during the day even with a trawl, in which the foremost part of the belly is made of 90 mm-mesh fabric. For effective catches by nighttime the trawl should have on the whole length of the belly fine-mesh insets. It was ascertained, moreover, that the use of less than 10 mm-mesh insets at the end parts of krill trawls is inexpedient, since this brings only a small increase in catches and may have an unfavourable effect on the performance of the trawl.

5. Резюме

Во время I Польской Антарктической Экспедиции на судне „Профессор Седлецки" проведено исследования степени бегства крыля из волокуши. Исследования проведено методом перехвытников нашитых нм наружной части горловины и на мешке (рис. 1). Измерения проведено на 16-ти случайно выбранных неводах, каждый раз взвешивая количество крыля в отдельных перехвытниках и в мешке, а для 7-ми неводов проведено добавочно измерения длины тела особей, определяя их процентное разложение.

Определённая с помощью весов средняя ловность $F = 0{,}86$, а в крайних случаях колеблется с 0,96 до 0,69. Через элементы волокуши сделанные с сетевого полотна с боком ячейки 12 мм выбираются в основном небольшые особи величиной с 22 до 26 мм.

Определено, что количество (перечисляя на штуки) вне горловины и мешка выбирается 42% особей при чём самое большое количество было выфильтровано из мешка — свыше 21% (рис. 2). Констатировано, что днём крыль довольно сильно реагирует на пугающую деятельность сетевого полотна и поэтому днём можно его эффективно ловить волокушей; которая в передней части горловины сделана из ткани с боком ячейки 90 мм. Для проведения эффективной ловли ночью волокуша должна иметь по всей длине горловины микроячеечные вкладки. Обнарумено также, что применение в конечных частях крылевых вкладок с боком ячейки меньшим, чем 10 мм является бесполезным так как это будет способствовать невеликому росту ловли а может повлиять на отрщательную работу волокуши.

6. Streszczenie

W trakcie I polskiej ekspedycji antarktycznej, na statku r/v „Profesor Siedlecki" przeprowadzono badania stopnia ucieczki kryla z włoka. Badania przeprowadzono metodą przechwytników, naszywanych na zewnętrznej części gardzieli i na worku (rys. 1). Pomiary wykonano na 16-tu losowo wybranych zaciągach, ważąc każdorazowo ilość kryla w poszczególnych przechwytnikach i w worku, a dla 7-miu zaciągów wykonano dodatkowo pomiary długości ciała osobników, określając procentowy ich rozkład.

Określona wagowo łowność średnia $F = 0{,}86$, a w skrajnych przypadkach waha się od 0,96 do 0,69. Poprzez segmenty włoka wykonane z płótna sieciowego o boku oczka 12 mm wydostają się głównie osobniki małe, o wielkości od 22 do 26 mm.

Określono, że ilościowo (w przeliczeniu na sztuki) poza obręb gardzieli i worka wydostaje się ponad 42% osobników, przy czym największa ilość była wyfiltrowywana z worka — ponad 21% (rys. 2). Stwierdzono, że podczas dnia kryl dość mocno reaguje na płoszące działanie płótna sieciowego, dzięki czemu w dzień można go skutecznie odławiać włokiem, który w przedniej części gardzieli wykonany jest z tkaniny o boku oczka 90 mm. Dla przeprowadzenia skutecznych połowów nocą włok powinien posiadać na całej długości gardzieli wkładki drobnooczkowe. Stwierdzono również, że stosowanie w końcowych częściach włoków krylowych wkładek o boku oczka mniejszym niż 10 mm jest niecelowe, gdyż spowoduje jedynie niewielki wzrost połowów, a może wpłynąć niekorzystnie na pracę włoka.

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