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ACOUSTIC STUDIES OF CATCHABILITY BY MID-WATER TRAWL OF SLOW AND FAST-MOVING COMMERCIAL SPECIES

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INTRODUCTION

Knowing the performance of fishing gear used for catching diverse target species is essential for their improvement. By probabilistic-statistical theory of trawls, the complete catchability of the trawl, P, is the probability of taking a catch, other than zero, which can be represented as a multiplicative scheme. This scheme is equivalent to a production of its elements that are probabilities of events promoting the catching process. Numerical characteristics of catch per haul depend on trawl parameters, characteristics of behaviour and distribution of commercial target species in space, namely, two-dimensional λ_2 and three-dimensional λ_1 of the school field-density, relative density of occurrence, β, and mean biomass density ρ [1]. In her studies, the author considered the application of fisheries acoustics for assessment of catching characteristics of mid-water trawls used for fishing both slow and fast-moving target species and also investigated aspects of their spatial distribution. The widespread techniques of instrumental assessment of the fishing trawl catchability, ie. the small mesh chafer method [2] and the use of undersea photo- and TV cameras [7] do not yield the required information block.

METHOD

Based on the analysis of algorithms of catchability P and expectation of catch per hauling, a scheme for assessment of catching characteristics (complete catchability and a number of its elements) of a midwater trawl has been developed according to which:

1. complete catchability can be estimated from samples of two random values: (a) the aggregation biomass in the zone of trawl action determined by means of echo-integration below the ship bottom within the depth range fished and, (b) the corresponding catch;
2. the estimate of separate catchability elements is based on catch sampling and biomass sampling of the fished aggregation crossing the particular trawl sections of interest; this information is provided by means of echo-integration with the use of removable acoustic transducers attached to the upper trawl panel in appropriate sections [4].

The process of fishing the pelagic krill and horse-mackerel aggregations with midwater trawls was studied during the cruises in the South Atlantic and south-eastern part of the Pacific. The results of the study show that the value of β (the sum of school volumes to their habitat volume ratio) fluctuates insignificantly in different aggregation types of the given biological target species. The analysis of mean statistical parameters of the distribution of krill in various parts of the Sea of Scotia over the 1980 to 1986 period confirms the hypotheses of ecological pattern of "β", whose range of values is determined

by the position of a species in the trophic chain of the region [3]. The catching characteristics of the trawl estimated during the experimental work are as follows:
- complete catchability of trawl, P;
- catchability i trawl tug , P_{tug}, corresponding to probability of entering the target species from the zone of action of trawl to its mouth;
- catchability of rope-net part, P_{r-n}, corresponding to the probability of entering the target species from the trawl net to its bag;
- coefficient of escape, K_e, of the target species throughout active parts of trawl

$$K_e = \frac{G}{G+Q}$$

where G is biomass of target species that escape the trawl;
Q is the catch;
In accordance with the multiplicative trawl catchability scheme it can be written

$$P = P_{tug} \cdot K_{r-n}$$

Note that the traditional method of studying K_e, when the biomass G of target species that escape the trawl throughout its netting is estimated by means of small mesh chafers (ie. net traps), gives only relative indices as the catchability of traps is unknown and is taken to be unity.

The ships's acoustic complex consisted of two echo-integration systems: one based on the shipboard echo-sounder, and the other on the basis of the trawl probe with the cable to the transducer which was fixed in the tug of the trawl headline. The measurement of instrumental constants, C_I of the echo-integration systems was made with the use of standard spheres of known target strength. This enabled the sound attenuation in the cable-wire of the trawl probe to be included in calibrating the echo-integration system.

RESULTS

Target strength of krill was determined by ensonification of concentrations in a calibration cage [3]. The target strength of horse-mackerel was estimated from the results of earlier studies [5]. Experimental estimates of the catching characteristics of trawls were compared with the theoretically ones obtained from the methods of statistical theory of fisheries systems. Krill was not chosen by chance for investigation. Due to its relatively low swimming ability (mean movement velocity: V=0.2 m/s Xamner, 1984) [6] the observation could be made under conditions of minimum influencing factors. The krill aggregations were fished with a krill midwater trawl with the headline 72 m in length.
Horse-mackerel aggregations were fished with three types of large-size midwater trawls using the trawling tactics of exceeding the speed of school diving (fast moving species: for medium-size specimens, l = 33 cm, in an aggregation their maximum velocity is V_{max} = 3.6 m/s) [1]. The characteristics of aggregations, ie. of fields consisting of separate schools of the fish species caught, are

given in table 1. The results of estimating the catching characteristics of the trawls tested are presented in tables 2 and 3, where the expectation values ($\tilde{m}$) and unbiased estimate of standard deviation ($\tilde{\sigma}$) of empirical and theoretical distributions of catchability are given.

TABLE 1.
Mean statistical characteristics of distribution of fished krill and horse mackerel aggregations

Characteristic	target species	
	krill	horse mackerel
Mean depth of schools, m	3	18
Mean diameter of schools, m	9	68
Three-dimensional school density field, λ_1, m^{-3}	$0.6348.10^{-3}$	$0.685.10^{-7}$
Two-dimensional school density field, λ_2, m^{-2}	0.2857	$0.3430.10^{-5}$
Relative density of occurrence, β	0.1211	0.00735
School shape (adopted hypothesis)	cylindrical	

TABLE 2
Results of assessment of catching characteristics of the trawl in fishing for krill aggregations

Catchability	Experimental value		Theoretical value	
	$\tilde{m}$	$\tilde{\sigma}$	$\tilde{m}$	$\tilde{\sigma}$
P	0.0580	0.0231	0.0541	0.0167
P_{tug}	0.3052	0.0831	0.2062	0.0800
P_{r-n}	0.1907	0.0519	0.2624	0.0904
K_e	0.8093	0.2000	0.7376	0.3050

TABLE 3
Results of assessment of catching characteristics of midwater trawls in fishing for horse-mackerel aggregations

Catchability	Type I trawl		Type II trawl		Type III trawl	
	$\tilde{m}$	$\tilde{\sigma}$	$\tilde{m}$	$\tilde{\sigma}$	$\tilde{m}$	$\tilde{\sigma}$
Experimental value						
P	0.1172	0.0782	0.1459	0.0585	0.2006	0.1759
P_{tug}	0.3744	0.0715	0.4174	0.1002	0.4601	0.0850
P_{r-n}	0.3130	0.0715	0.3495	0.1002	0.4360	0.0685
K_e	0.6870	0.0733	0.0650	0.1100	0.5640	0.0715
Theoretical value						
P	0.1642	0.0782	0.1477	0.0577	0.2020	0.1195
P_{tug}	0.2816	0.0682	0.3154	0.0750	0.3620	0.0920
P_{r-n}	0.5776	0.0683	0.4688	0.0730	0.5580	0.0920
K_e	0.4224	0.0730	0.5312	0.0810	0.3420	0.0897

Data are missing on the value of deepening, H, of pelagic schools of horse-mackerel after they stay below the passing ship. As a result, the hypothesis that the value of school deepening is distributed according to the equiprobable law within the 0 to H_{max} range has been adopted. Theoretical calculations of the catchability were made for a number of estimates of the maximum value of school deepening, H_{max} = 20 m, 50 m, 75 m, 100 m. The consistency of the experimental data on the catchability was the best with the theoretical values at H_{max} = 100 m. Table 3 presents theoretical values of catchability at H_{max} = 100 m. As is evident from table 2, there is a good agreement between the experimental and theoretical values of complete catchability and its elements in the krill fishery. However, while fishing for horse-mackerel the bias of the experimental values of P_{tug} to the left, and those of P_{r-n} catchability to the right, relative to the calculated data, can be seen. The pattern of these differences, which appeared to be similar for the three types of trawl tested, suggests that the biomass of the horse-mackerel schools that had passed through the trawl mouth was overestimated. This can be explained by the fact that the horse-mackerel schools are characterized by a high swimming velocity, which has resulted in their lingering in the trawl mouth and in multiple records of their presence there by the trawl probe. It has also been indicated by a good agreement between the experimental and calculated values of the complete catchability P, the value of which is not related to echo-integration in the trawl mouth. It should be noted that the range of the fish response to danger was ignored in theoretical calculations which, according to the results of the statistical modelling, is fraught with errors in estimating the calculated catchability.

CONCLUSIONS

A good agreement between the experimental and calculated values of the catching characteristics of midwater trawls used in fishing for slow-moving target fishes can be noted. In fishing for fast-moving target species the experimental catchability data are not at variance with the theory. But the overestimation of the fished aggregation biomass value in the trawl mouth has been observed which led to erroneous assessment of the catchability P_{tug} and P_{r-n}, and K_e. In this context, it seems necessary to leave out of account multiple records of schools of fast-moving target species made by the trawl probe in the trawl mouth. At present, this problem requires a technical decision. The results of the studies are indicative of possible application of the acoustic method for assessment of catching characteristics of midwater trawls. This also leaves a possibility to carry out comparative tests of trawls of different design in the catchability studies.

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