Northwest Atlantic Fisheries Organization

Serial No. N1089 NAFO SCR Doc. 85/112

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1985

Calculated Estimate of Differential Catchability for Two Fry Trawls (International IYGPT and the Soviet 13.6 m Trawls)

by

N. M. Ivanova and A. I. Sherstjukov
AtlantNIRO, Kaliningrad, USSR

Abstract

Comparative analysis of differential catchability of two fry trawls (international IYGPT and Soviet 13.6 m trawls) was made for correct interpretation of the results of trawling.

Introduction

The present investigation was necessitated by the results of comparative trawlings conducted with two fry trawls: the international IYGPT and the Soviet 13.6 m trawls. These trawls were used in the area of massive aggregation of the young silver hake, on the Scotian Shelf, during the cruise of the SRTM-8086 "1500 LET KIEVU" in October 1983. The mean length of the young fish taken with the IYGPT trawl was 6 mm below that taken with the 13.6 m trawl.

In the present paper an attempt is made to disclose the influence of constructural differences in the two trawls on the distribution of length frequences of the youngs in the catches.

Materials and methods

Various methods were used to catch the young silver hake. The 13.6 m trawl was used only for near-bottom hauling, and the IYGPT trawl for three-step hauling: off bottom, in the pelagial and at the surface. 30-min hauls were made at the ship's speed of 3.5 knots. Echo depth meter (IGEK) was attached to the headline to set the trawl to the required depth. The trawls and their rigging somewhat differed in parameters (table 1). The method of statistical theory of fishing systems (Kadilnikov, 1973; Kadilnikov, 1983, a, b) was applied to determine whether constructural differences in the trawls had affected the distribution of length frequences of the young fish in the catches. According to this theory, the differential catchability should be estimated first (Karpenko et al., 1984), followed by the determination of the fish length distribution in the catches for the two trawls.

The statistical theory implies that the probability of obtaining a catch other than zero is a measure of catchability (Kadilnikov, 1983 a). It is regarded as the probability of a complex event:

$$P = P_1 P_2 P_3 P_4 P_5 P_6 P_7 P_8 P_9 P_{10}$$

where P_1 is the probability of fish entering between headline and footrope;

P_2 is the probability of fish entering between trawl boards;

P_3 is the probability of catching fish along the trawl track;

P_4 is the probability of fish entering between trawl wings;

P_5 is the probability of fish entering in the trawl opening;

P_6 is the probability of fish entering in a zone fished with small mesh section of the trawl;

P_7 is the probability of retention of fish in the trawl while hauling;

P_8 is the probability of retention of fish in netting cover of the trawl bag;

P_9 is the probability of retention of the fish in the trawl while haulback;

P_{10} is the probability of retention of fish in the trawl during a time interval T_k, after fish entered it.

The differential catchability is the catchability of a trawl relative to the fish of the same species, but differing in length, that is, the differential catchability is considered to be a function of the fish length.

The probabilities P_3, P_7, P_9 and P_{10} are approximately equal to a unity, because the young silver hake do not form large shoals, these shoals move at small speeds, and the trawl parameters are large enough.

The probabilities P_1, P_2 and P_5 are similar for all length frequences of the young fish. Therefore, only those probabilities should be calculated, which are functions of the fish length and their exterior, i.e. the probabilities P_4, P_6 and P_8. Product of these probabilities would be called a sensitive fraction of the differential catchibility, and expressed as $\bar{P}$. On assumption, that the range of the young silver hake's response to the elements of the moving trawl is small, the probabilities P_4 and P_6 can be derived from the following formulas:

$$P_4 = \begin{cases} \frac{\ell}{\ell_t} + \frac{\ell_t - \ell}{\ell_t}\left(1 - \frac{V_t \cdot \sin \alpha_c}{V_{max}}\right) \cdot P_{11} & V_t \cdot \sin \alpha_c \leq V_{max} \\ \frac{\ell}{\ell_t} & V_t \cdot \sin \alpha_c > V_{max} \end{cases} \qquad (2)$$

where ℓ_t is the distance between trawl boards, m;
ℓ is the distance between trawl wings, m;
V_{max} is the maximum horizontal speed of moving fish (differing by length), m/sec;
V_t is the hauling speed, m/sec;
α_c is the angle of attack of cable, degrees;
P_{11} is the probability of fish entering the surfaces occupied with hydrotrains left by trawl boards and cable sling of the trawl.

$$P_{11} = \frac{b + h_t}{2 h_t} \qquad (3)$$

where b is the height of a fore rib of a trawl board, m;
h_t is the vertical opening of the trawl, m.

$$P_6 = \left[\frac{\ell_o h_o}{\ell h_t} + \frac{\ell h_t - \ell_o h_o}{\ell h_t}\left(P_{13}\right)\right] \qquad (4)$$

$$P_{13} = \begin{cases} 1 - \frac{V_t \cdot \sin \alpha}{V_{max}} & V_t \cdot \sin \alpha \leq V_{max} \\ 0 & V_t \cdot \sin \alpha > V_{max} \end{cases} \qquad (5)$$

where ℓ_o is the horizontal opening of the small mesh section, m;

h_o is the vertical opening of the small mesh section, m;

α is the angle of attack of the netting twine;

P_{13} is the probability of fish entering the guaranteed zone of fishing from the active zone.

The probability of retention of the fish in the netting cover of the trawl bag can be derived from the formula recently deduced by Kadilnikov, and kindly offered by the author for using in the present paper.

$$P_8 = 1 - \varphi\left(\frac{m}{\sigma}\right), \qquad (6)$$

where $m = m_{fish} - m_{mesh}$

$$\sigma = \sqrt{\sigma_{fish}^2 + \sigma_{mesh}^2}$$

m is the mathematical expectation of the difference between the mesh perimeter and circumference of the fish body, mm;

$\varphi(m, \sigma)$ is the normal distribution function;

σ is the mean square deviation of the difference between the mesh perimeter and circumference, mm;

m_f is the mathematical expectation of the perimeter of the maximum circumference of fish of the preset length, mm;

m_m is the mathematical expectation of the inside mesh perimeter, mm;

σ_f is the mean square deviation of the perimeter of the maximum circumference of the fish body, mm;

σ_m is the mean square deviation of the inside mesh perimeter, mm.

To estimate the above-mentioned fraction of the differential catchability, limited information on the fish behaviour in the trawl, and their biometrical data are required. The maximum speed for the fish below 7 cm in length can be calculated from the formula by Kadilnikov:

$$V_{max} \approx 0{,}04\, l_f^{1{,}18} \qquad (7)$$

where l_f is the total length of the fish body, cm.

The estimated values of the maximum speed of movement and processed results of biometrical measurements of the young hake are presented in table 2.

The results of estimating the elements of the differential catchability are given in table 3. As is apparent from the table, there is a marked difference between the values of the probability $\bar{P}$ for the two trawls (2-2.5 times) for the entire examined range of fish lengths, so, in order to determine the influence of differences in trawl parameters on the shift of the mean length of the fish in the catch, it is necessary to estimate the distribution of the fish length in the catch, which can be expressed by the ratio:

$$\eta = \frac{m_{Q_i}}{\sum_{j=1}^{N} m_{Q_j}}, \qquad (8)$$

where m_{Q_i} is the mathematical expectation of the catch of the i-th length class in number;

N is the number of length classes.

The mathematical expectation of the catch (Kadilnikov, 1983c) can be derived from the formula:

$$m_Q = (\lambda \cdot m_6)\, m_\rho (\ell_t h_t V_t \tau_t)\, P_o \bar{P}, \qquad (9)$$

where λ is the density of a field of the young hake shoals;
m_6 is the mean volume of a shoal, m^3;
m_ρ is the density of fish in shoals, sp./m^3;
P_o is a fraction of the complete catchability constant for all fish;
τ_t is the hauling duration, sec.

Let's observe that

$$(\lambda \cdot m_6 \cdot m_\rho)_i \cdot B_o = n_i \qquad (10)$$

where n_i is the number of fish of the i-th length class;
B_o is the habitat volume.

From the formulas (9) and (10) the expression (8) is modified as follows:

$$\eta = \frac{(\lambda \cdot m_{\delta} \cdot m_{\rho})_i \cdot \bar{P}_i}{\sum_{j=1}^{N} (\lambda \cdot m_{\delta} \cdot m_{\rho})_j \cdot \bar{P}_j} \qquad (11)$$

where N is the number of length classes.

To apply the formula (11) the length frequency of the fish in the exploited aggregation should be known. The authors examined four types of length distribution in the aggregation: according to trunkated exponential, equiprobable, normal and Weibull laws. The observed distribution of the fish length in the catch is the closest to the calculated distribution (table 4), when the fish length in the aggregation is distributed according to the Weibull law (Gost 11.007-75):

$$f(x, a, b, c) = \begin{cases} \frac{b}{a}\left(\frac{x-c}{a}\right)^{b-1} \cdot e^{-\left(\frac{x-c}{a}\right)^{b}} & x > c \\ 0 & x \leq c \end{cases} \qquad (12)$$

with parameters a = 1.0 m; b = 0.5 mm; c = 20.0 mm.

The investigation into the laws of distribution of the fish length in the aggregation has resulted in different theoretical distributions, which are practically identical for both ships. The calculations were made with regard for similar operational conditions for both ships.

Summary

According to calculations, the distribution of length frequences of the youmg hake in the catches of the IYGPT and the Soviet 13.6 trawls is practically the same for both trawls. and differs insignificantly from the observed data. The shift of the mean length of the youngs (by 6 mm) in the catches taken with the IYGPT trawl can be related to the fact that it was predominately (2/3 of the haul) towed in the pelagial and at the surface, where, evidently, the smaller size young fish had concentrated.

References

1. Gost 11.007-74. Applied statistics. Point and interval estimators for parameters of Weibull distribution.

2. Kadilnikov Yu.V., 1973. Main directions of probable approach to estimating the fishing gear efficiency and determining the zones of their action with the use of the theory of searching. M., OI TsNIITEIRCH, 67 p.

3. Kadilnikov Yu.V., 1983 a. Theoretical Premices of Influence of Angle of Attack of Cable, Netting and of other Parameters on Size-specifics Selectivity of Fishing Trawls. ICES, Doc. C.M., 1983/B:8.

4. Kadilnikov Yu.V., 1983 b. Behaviour of Fishing Targets and Catchability of Fishing Trawls. ICES, Doc. C.M., 1983/B:9.

5. Karpenko E.A., Dudov V.I., Efanov S.F. and Baturin V.L., 1984. Methodical directions for estimating the differential catchability of trawls. M., VNIRO, 27 p.

Table 1 Parameters of IYGPT and 13.6 m trawls

Parameters	Meas. units	IYGPT trawl	13.6 m trawl
Vertical opening, h_t	m	7.00	6.00
Door spread, l_t	"	48.30	15.80
Horizontal trawl opening, l	"	11.00	8.00
Vertical opening of small mesh section (zone of guaranteed fishing), h_o	"	4.20	3.40
Horizontal opening of small mesh section, l_o	"	4.20	3.40
Angle of netting attack, α	degree	8.90	8.60
Height of fore rib of a trawl board, b	m	1.44	1.44
Hauling duration, τ_t	sec	1 800	1 800
Hauling speed, V_t	knots	3.5	3.5
Assessment of mathematical expectation of mesh perimeter in trawl bag, m_m	mm	20	20
Assessment of mean square deviation of inside mesh perimeter in trawl bag, σ_m	"	1	1
Angle of cable attack α_c	degree	19.80	17.40

Table 2 Estimated maximum speeds of movement of young hake and results of biometrical measurements

Total length of fish body, l_f, mm	Maximum speed of movement of the fish, V_{max}, m/sec	Perimeter of maximum circumference of fish body, mm	
		Estimate of mathematical expectation, m_f, mm	Estimate of mean square, σ_f, mm
20	0.1	12.0	1.0
30	0.1	14.5	1.5
40	0.2	17.6	2.0
50	0.3	21.6	2.2
60	0.3	25.1	2.3
70	0.4	29.1	2.8
80	0.4	33.0	3.0
90	0.5	36.7	2.9
100	0.6	41.7	3.5
110	0.7	47.6	4.6
120	0.7	52.5	4.4
130	0.8	59.0	4.0
140	0.9	60.8	6.5

Table 3 Sensitive part of differential catchability ($\bar{P}$) and its elements

Fish length, mm	IYGPT trawl	13.6 m trawl
20	0.00000	0.00000
30	0.00005	0.00012
40	0.00750	0.01723
50	0.04998	0.11962
60	0.06524	0.15615
70	0.10706	0.24475
80	0.10717	0.24500
90	0.13145	0.29600
100	0.14770	0.35112
110	0.20114	0.40500

Table 4 Calculated distribution of length of young fish in the catches

Total length of young fish, ℓ_f, mm	Ratio of young fish of different length in the catch, %	
	IYGPT trawl (mean length, $\bar{\ell}$ = 58mm)*	13.6 m trawl (mean length, $\bar{\ell}$ = 58mm)*
20	0.0	0.0
30	0.7	0.7
40	20.6	20.2
50	30.6	31.3
60	20.0	20.3
70	13.8	13.5
80	6.4	6.3
90	3.9	3.8
100	2.3	2.4
110	1.7	1.5

* Calculated mean length of young fish

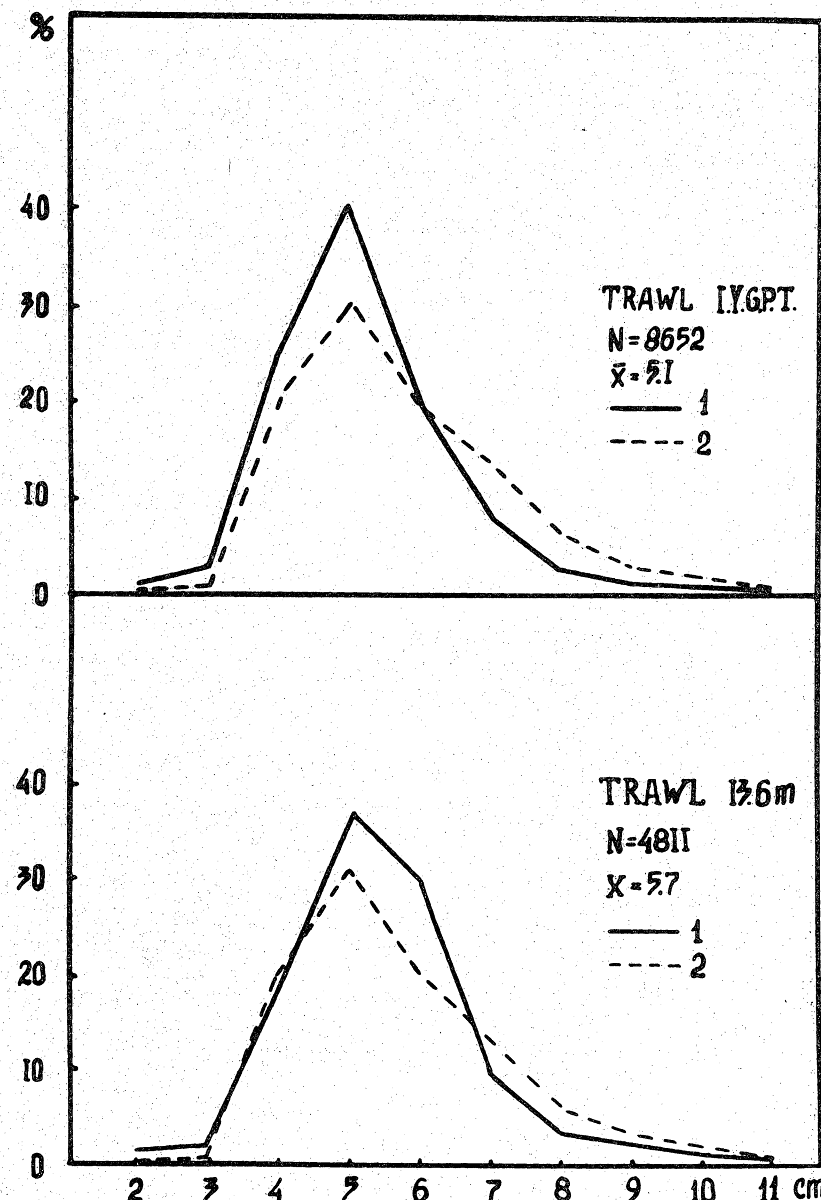

Fig. 1. Young hake distribution in the catches by IYGPT and 13.6 m trawls: 1 - observed and 2 - calculated.