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MORTALITY AND OPTIMAL INTENSITY IN FISHING FOR SPRAT IN THE NORTH SEA

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MORTALITY AND OPTIMAL INTENSITY IN FISHING FOR SPRAT IN THE NORTH SEA

(Theses)

1. The investigation fulfilled is an attempt to estimate some characteristics of sprat population in the central area (IVb) of the North Sea, according to the material of 1970-1974 with regard for variations in fishing intensity.
2. The calculations were made according to Beverton and Holt (1958, 1966), Bertalanffy (1938), Kutty and Qasim (1968), Rikhter (1970), Hohendorf (1966).
3. The natural instantaneous mortality rate of sprat is 0.8 which corresponds to 55% annual loss. The fishing instantaneous mortality rate of sprat is 0.4 which corresponds to 33% annual loss.
4. The abundance of 0-group sprat was assessed by the results of trawling surveys on abundance.
   In 1973 it was 32 milliard 640 mill. specimens, and in 1974 - 15 milliard 853 mill. specimens.
   At optimal fishing intensity of sprat of 0.9 (59.3% annual loss) the yields from the 1973 and 1974 year-classes may be 132 thous. tons and 63 thous. tons accordingly during their lifetime.

In 1970 the sprat of the North Sea has become the object of intensive fishery. The fishery for sprat after a prolonged interval maintained at a steady level, the sprat stocks being underexploited, especially, in the open sea. In the central (IV b) area the bulk of the catches was taken from the inshore Great Britain water. At present the situation has sharply changed - the fishery for sprat in the open sea, including purse-seine fishery, is successfully developed. Beginning from 1971 the sprat fishery in subarea IV b is carried out by the USSR fleet. Simultaneously, the studies of sprat stocks were undertaken. In 1973 the catches of sprat in the North Sea reached the maximum level- 229 thousand tons, which is five times the mean annual yield during the period of 1965-1972, 150 thousand tons being taken in IV b (Bulletin statistique 1966-1974).

In such conditions the investigation of the influence of the fishery on its dynamics is of a great importance. To solve a number of questions concerning the rational fishery of sprat in the North Sea, we have made an attempt to estimate its mortality, the optimal and existing fishing intensity and the catches of 1973 and 1974 year-classes during their lifetime.

MATERIAL AND METHODS

Natural mortality (M) was assessed by an integral method of Beverton and Holt (1958) for the cases, when either there was no fishery for the species at all, or it was insignificant

$$Z = M = \frac{K(L_{\infty} - \bar{l})}{\bar{l} - l'}$$

The estimates for mean ($\bar{l}$) and the least (l') fish length fully represented in the catches were taken for August 1970, January 1973, and February 1974. Since 1973, an intensive fishing for sprat has been carried out in the open North Sea (table 1). The total and fishing mortality values of sprat were determined for January-February 1974.

Besides, according to Beverton (Beverton 1963) the natural mortality was determined; he showed that it is propotional to a constant growth K, and the larger the growth rate of the fish, the higher the value of natural mortality. For the North Sea sprat this dependence can be expressed by

$$M = 1.6\ K.$$

The parameters of Bertalanfy's equation, K, L_{∞}, t°, were determined by a mathematical method of Hohendorf (Hohendorf, 1968). For determination of parameters of Bertalanfy's equation, the mean sizes of sprat by age groups for 1971-1972 were used (table 2). The correlation between the weight and length of the fish was obtained by the least square method.

TABLE 1

The fishing for sprat in the North Sea by areas, 1964 - 1973 (t)

(Bulletin statistique, 1966- 1973)

YEARS / Area	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
IV b	25273	27880	18353	33101	34877	33274	30111	68806	44303	150282
IV a	21151	35684	79627	32555	22881	25666	14938	25116	47524	76928
IV c	24388	12616	8597	3840	7679	6354	5953	1329	544	1010
TOTAL	70812	76180	106577	69496	65437	65294	51002	95251	92371	228220

TABLE 2

The observed and calculated mean lengths of sprat in the Central (IV b) area of the North Sea, 1971-1972

AGE (years)	Observed	Calculated	D %
1	9.9	10.06	1.6
2	12.5	12.56	0.43
3	13.8	14.03	1.7
4	15.0	14.90	- 0.67
5	15.4	15.42	0.13
		SD = ± 1.77	

The age at optimal exploitation of sprat (t'p) was determined by a transform.. formula of Kutty and Qasim (Kutty and Qasim 1968):

$$t'_p = \frac{\ln (3K + M) - \ln M}{K} + t_o$$

The length at optimal exploitation (L_c) of sprat derived from Bertalanfy's equation (Bertalanfy 1938) corresponds to its age at optimal exploitation:

$$L_c = L_\infty \left[1-e^{-k (t'_p - t_o)}\right]$$

The optimal fishing intensity was calculated by the tables of Beverton and Holt (Beverton and Holt 1966) with regard for a relation between the magnitude of optimum exploitation (L_c) and theoretically possible maximum length of the fish (L_∞): $L_c / L_\infty = C$, and the value of M/K correlation.

The analysis of correlation between the growth rate of yield per recruitment (Y/R) and fishing intensity (A) was made according to Rikhter (1970).

The value of sprat catches for the whole lifetime of 1973 and 1974 year-classes was found by

$$Y_w = FR'W_\infty \sum_{n=0}^{3} \frac{\Omega_n e^{-kn(t'_p - t^\circ)}}{F + M + nk} \left[1-e^{-(F+M+nk)\lambda}\right]$$

(Beverton and Holt 1957),

where the values of F, M, W_∞, K, t'p and t° are known, while R' is the recruitment abundance at the moment of its entering the fishery,

$\lambda = t_\lambda - t'_p$ is the last term of fishery,

t_λ is the maximum age,

Ω_n is $_0 = +1$; $_1 = -3$; $_2 = +3$; $_3 = -1$.

e is the base of natural logarithms.

The abundance of sprat recruitment before entering the fishery was estimated by the results of trawling surveys on abundance of 0-group fish of 1973-1974 year-classes. The survey covered the Central area, IV b of the North Sea and was carried out in the light hours of the day by the layers of 0-10m, 10-20 m and 20-30 m. Preliminary 12-hour stations for trawlings at all the horizons from the surface to the bottom were occupied. The fishing area is known.

The abundance of the young fish in water column in a square was estimated by the formula

$$N = \frac{S \cdot n}{Sf},$$

where

S is the square size,

S is the area of fishing,

n is the yield per 45 min hauling,

f is the catchability coefficient.

A theory on catchability as adopted at present indicates that the catchability coefficients of herring trawls approximate 0.2-0.4. In our calculations the catchability coefficient of 0.4 was taken. To estimate the abundance of young fish over the whole area of the controlled zone, its abundance in each square should be summed up.

$$R = N_1 + N_2 + N_3 + \ldots + N_{105} = 32 \text{ milliard } 640 \text{ mill.spp.} \quad (1973)$$

$$R = N_1 + N_2 + N_3 + \ldots + N_{105} = 15 \text{ milliard } 853 \text{ mill sp.} \quad (1974)$$

where

R is the recruitment size before entering the fishery. The recruitment abundance at the moment of entering the fishery was determined by the formula:

$$R' = Re^{-M_p} ,$$

where

M_p is the natural mortality during pre-exploitment phase.

RESULTS

The calculations made it possible to give a numerical estimate of sprat population parameters (table 3).

In estimation of the parameters of Bertalanfy's growth equation, the SD obtained was $\pm$ 1.77 %, which indicated the reliability of the data. A correlation between the weight and length of fish was as follows: $W = 0.0074\ l^{3.08}$.

Thus, the growth of sprat is described by a formula of isometrical growth with good approximation.

The yield per recruitment against fishing efficiency ratio is shown in Fig. 1.

A correlation between the yield and fishing efficiency is close to theoretical one. It indicates that the yield rapidly increases with an increase in fishing intensity for sprat to 0.5-0.6. Subsequenthy, at F=0.9, the fishing intensity decreases below the growth rate of

the yield (table 4).

The abundance of recruitment at the moment of entering the fishery (R') constituted 18 milliard 640 mill and 8 milliard 640 mill. specimens of 1973 1974 year-classes, accordingly.

A possible yield from 1973 year-class during its lifetime may reach 132 thous. tons at optimal fishing intensity of 0.9, while that from 1974 year-class 63 thous. tons.

It should be noted that the yields obtained from 1973 and 1974 year-classes during their lifetime are underestimated, since we have not taken into consideration the young sprat from feeding areas within the fishing zone.

Table 3

The estimation of sprat population parameters in the North Sea

$K = 0.52$

$L_\infty = 16.1$

$W_\infty = 29.1$

$\bar{l} = \begin{matrix} 13.6\ (1970) \\ 13.4\ (1973) \\ 10.8\ (1974) \end{matrix}$

$l' = \begin{matrix} 12.0\ (1970) \\ 11.6\ (1973) \\ 8.5\ (1974) \end{matrix}$

$t^\circ = -0.83$

$t'_p = 1.4$

$L_c = 10.7$

$C = 0.66$

$M/K = 1.5\ (1970)$

$Z = 1.2\ (1974)$

$F = 0.4\ (1974)$

$M = \begin{matrix} 0.81\ (1970) \\ 0.79\ (1973) \end{matrix}$

$t_\lambda = 6.0$

$\lambda = 4.6$

$\rho = 0.7$

$t_p = 0.7$

TABLE 4

The values and growth rate of yield and the entensity of sprat fishing in the North Sea

F	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
F, %	9.5	18.1	25.9	33.0	39.4	45,1	50.3	55.1	59.3	63.2	66.7	69.6
Growth rate	-	47.5	30.0	21.0	16.0	12.4	10.3	8.6	7.0	6.2	5.2	4.6
F % Y/R	0100	0193	0253	0302	0341	0371	0398	0419	0440	0457	0471	0484
Growth rate	-	47.0	23.7	16.2	11.4	8.1	6.8	5.0	4.8	3.7	2.0	2.7
Y/R,%												

CONCLUSIONS

1. Natural instantaneous mortality of sprat in the North Sea is expressed by a coefficient of 0.8, which corresponds to 55% of annual loss.
2. Fishing mortality of sprat for January-February 1974 constitutes 0.4, which corresponds to 33% of annual loss.
3. The yield from a sprat year-class during its lifetime can be forecasted a year in advance.
4. It may be 132 thous. tons for the 1973 year-class at the optimal fishing intensity of 0.9, and 63 thous. tons for the 1974 year-class.
4. Rational sprat fishery can be achieved provided:
   a) the fishing intensity does not exceed 0.9, which corresponds to 59.3 % of annual loss;
   b) The sprat fishery in IV b is started at the age of optimal exploitation, which is 1.4 years, and at corresponding length of optimal exploitation, which is 10.7 cm.

REFERENCES

BEVERTON R.I. and HOLT S.J., 1958. A review of methods for estimation of mortality in exploited fish populations. VNIRO., M., pp 33-37.

RIKHTER V; A., 1970. Optimal intensity of red hake (Urophycis chuss W.) fishery in the West Atlantic. Voprosy ikhtyologii, vol. 10, iss. 10, p 986. M.

Beverton R.I. and HOLT S.J.,1966. Mannual of methods for fish assessment. Partiltables of yield functions, pp 64-112. FAO. ROME.

BERTALANFFY L. Von., A Quantitative Theory of Organic Growth. Ruman Biology. 10./2/ p. 271. 1938.

BULLETIN STATISTIQUE DES PÊCHES MARITIMES, 1966 - 1974. Vol. 49 - 58.

HOHENDORF K. 1966. Eine Diskussion der Bertalanffy-Funktionen und ihre Anvendung zur Characterisierung des Wachstums von Fischen, Kieler Meerforschungen, Heft 1., S. 70 - 113.

KUTTY K.M. and QASIM S.Z., 1968. The estimation of optimum age of exploitation and potential yield in fish populations. Journ du Cons. Vol. 32, No 2. pp 55-58.

BEVERTON R.I., 1963. Maturation, growth and mortality of clupeid and Engraulid stocks in relation

to fishing. Rapp. Proc-Verb. Reun. Cons. perm. later. Explor. Mer. p.p. 21 - 25.

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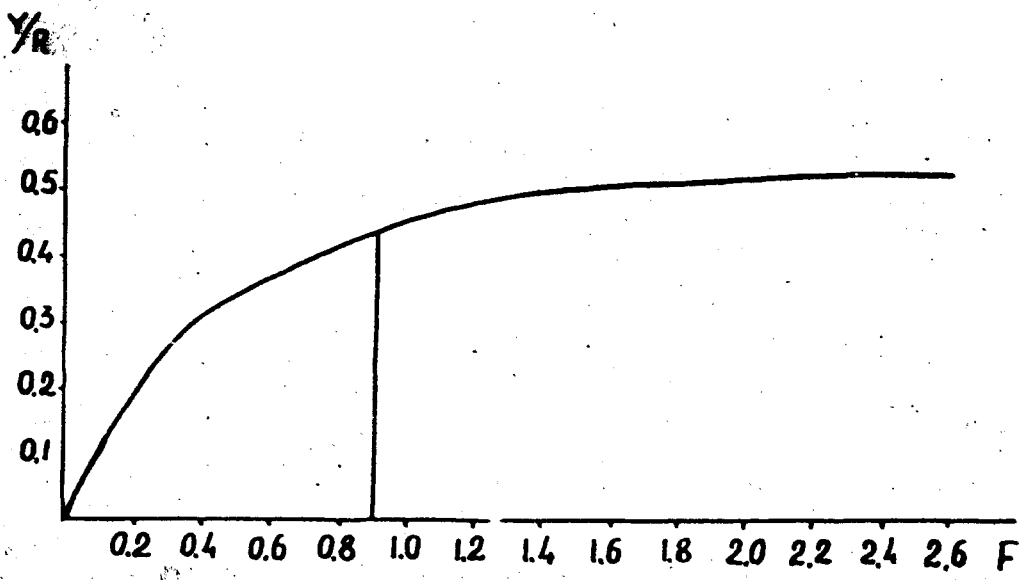
Fig. A correlation between the yield per recruitment and fishing intensity of sprat in the North Sea.



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