RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3777
(D.c.3)

ICNAF Res.Doc. 76/VI/8

ANNUAL MEETING - JUNE 1976

On one of the approaches to estimation of natural mortality of fish populations

by

V.A. Rikhter and V.N. Efanov
AtlantNIRO
Kaliningrad, USSR

ABSTRACT

In the paper the analysis of a dependence between natural mortality rate (M) and the age at first and massive maturation has been made. A hyperbolic character of a relation between M and the latter index has been revealed. Basing on this dependence a method of approximate estimation of M is suggested which allows to obtain a sought for result by the end of the first year of studies.

INTRODUCTION

At present a number of analytical methods of natural mortality rate estimation is available. The application of these methods is preceeded by long-term observations and collection of information for determination of necessary parameters. Modern rapid development of fisheries does not allow, as a rule, timely achievement of the result sought for one or another specific population. Hence, both the calculation and practical utilization of the optimum fishing parameters are retarded. However, the data on natural mortality rate for many fish populations accumulated by now, combined with other indices of abundance dynamics obtained during short-term investigations offer a possibility for development of the method of accelerated estimation of natural mortality rate.

Material and methods

From the equations of Kutty and Qasim (Kutty and Qasim, 1968) it follows, that natural instantaneous mortality rate (M) is in inverse dependence on the optimum age at exploitation (T_{opt}). Given the estimate of the latter, it is easy to find that of M. In certain cases T_{opt} can be described as mean age at first maturation (Beverton, 1963). However, a determination of the above parameters in itself presents rather a complicated matter. Therefore, it was decided to study a relation between M, T_{opt} and those indices of abundance dynamics which can be obtained during short-term investigations. In our opinion, the age at first maturation and the age at which the share of mature specimens exceeds 50 % are most suitable.

It is known that there exists a rather close inverse dependence between natural mortality rate, on one hand, and sexual maturation age and life span, on the other hand (Nickolsky, 1974).

Basing on this statement we ignored the values of M which contradicted the above dependence.

The data on natural mortality rate, age composition, growth rate, age at first and massive maturation were selected so as to provide a possibility of acquiring of most complete representation on the ratio of parameters of interest. As a result, we succeeded in fitting a row including the representatives of fishes having short, average and long life spans. These are : (1) Mallotus villosus (Mull), Pungitius pungitius (L.), Phoxinus phoxinus (L.); (2) Limanda ferruginea (Storer), Lucioperca lucioperca (L.),Theragra halcogramma (Pall.), Scomber scombrus (L.), Urophycis chuss (Walbaum); (3) Acipenser gudenstadti Brandt, Sebastes mentella Travin, Argentina silus Ascanius, Gadus morhua (L.), Salvelinus alpinus (L.), Salmo trutta (L.).

The information was adopted from the papers by A.I. Ambroz (1964), Beverton R.J. and Holt S.J. (1959), E.G.Boiko (1964), O.D.Borodulina (1964), V.N.Efanov (1973), V.I.Isakov (1973, 1974), S.M.Kaganskaya (1950), Yu.A.Kolesnik (1970), Pitt (1958), V.P.Ponomarenko (1964), Rikhter (1972, 1974), L.I.Shevchuk (1974 a, b).

The parameters of Bertalanfy's equation and natural instantaneous mortality rate for one of the redfish populations have been calculated by the author of the given paper (unpublished). A description to the atlas " Commercial fishes of the USSR " (1949) and " Particular ichthyology " (Nickolsky, 1954) have been also widely used. Preference was given to natural mortality rates obtained by means of analytical methods.

For the species, for which the data on growth rate (age, length) were available the parameters of Bertalanfy's growth equation (K - a factor of growth rate deceleration; t_o - the age at which fish length is zero; L_∞ - mean theoretical maximum length) have been calculated according to K.Hohendorf (Hohendorf, 1966). In some cases it was needed to determine an exponent for the " length-weight " dependence. In calculating of T_{opt} the equations of Kutty and Qasim (1968) were applied :

$$T_{opt} = \frac{\ln(3K+M)-\ln M}{K} + t_o \quad \text{- isometrical growth}$$

$$T_{opt} = \frac{\ln(nK+M)-\ln M}{K} + t_o \quad \text{- allometrical growth,}$$

where

T_{opt} is the optimum age at the commencement of fish exploitation ;

K is a factor of decelerated growth rate ;

M is natural instantaneous mortality ;

t_0 is the age at which fish length is zero.

Then the analysis of relations between M and T_{opt} and the age at first and massive maturation was made.

Results

The values of T_{opt} for various species calculated from above equations are given in Table 1.

Table 1

The parameters of abundance dynamics for some fish populations

Species	Parameters of abundance dynamics					
	t_0	K	M	Topt	1-st matur.	massive maturation
1	2	3	4	5	6	7
Mallotus villosus, N.W.Atlantic	0,17	0,92	1,3	1.38	2+	2+
Pungitius pungitius (England)	-	1.60	1.1	-	1	1
Phoxinus phoxinus (England)	-	0.64	0.9	-	1+	2+
Limanda ferruginea, N.W.Atlantic (New England)	-0.26	0.34	0.6	2.68	2+	3+
Lucioperca lucioperca (the Asov Sea)	-0.11	0.23	0.39	4.08	2+	4+
Theragra halcogramma the Bay of Peter-the-Great	0.44	0.08	0.5	4.54	4+	4+
Scomber scombrus N.W.Atlantic	-	0.22	0.35	2.68	2+	4+
Urophycis chuss N.W.Atlantic	-1.00	0.37	0.8	1.60	1+	2+
Acipensep guldenstadti (Denube)	0.15	0.09	0.1	14.75	7+	14+
Sebastes mentella N.W.Atlantic	-6.57	0.07	0.1	9.91	8+	11+
Argentina silus N.W.Atlantic	-3.84	0.09	0.23	4.64	4+	7+
Gadus morhua	-	-	0.15	-	5+	8+
Salvelinus alpinus (England)	-	-	0.24	-	-	7+
Salmo trutta (Enagland ,)	-	-	0.24	-	-	7+

Basing on the data summarised in Table 1 the figures 1 - 3 were drawn, the analysis of which is given below.

A comparison made between T_{opt} and the age at first and massive maturation despite lacking data demonstrated that in fish having a prolonged life span a marked lag in age at first maturation could be observed (fig. 1). Simultaneously, the age at massive maturation showed rather a good agreement with T_{opt} all over the row and could, perhaps, replace the latter. Then, basing both on the parameters of Bertalanfy's growth equation, and on an exponent in " length-weight " dependence it is easy to estimate the value of M using the above equations of Kutty and Qasim.

The age at which sexual maturity is achieved and the rate of natural loss are reckoned among the most important characteristics of the population abundance dynamics. A dependence between the value of M and the age at first and massive maturation is shown in fig.2. One can see that relation patterns are approximately similar in both cases. Neither a considerable difference in point scattering is observed which allows to succeed in analytical description of both curves. Since the data on the age at massive maturation appeared to be more numerous, preference was given to the analysis of the latter dependence which is of a kind of hyperbolic function judging from the curve shape, and can be expressed by a general type equation :

$$Y = \frac{a}{x^n} + B$$

A resultant empirical equation is :

$$Y = \frac{1.521}{x^{0.720}} - 0.155 ,$$

where

Y is natural instantaneous mortality rate ;

x is the age at massive maturation .

In fig.3 the curves built according to observations and estimated values of M are shown. It is evident that a coincidence seems to be rather satisfactory, as a whole. Some divergence at the beginning and at the end of the curves can rather be attributed to highly rough values of M selected for the fishes having the shortest and longest life spans. Nevertheless, a hyperbolic character of a dependence between M and the age at massive maturation has been confirmed. Variability of the value of M with an increase of age of sexual maturity achievement is presented in table 2.

Table 2

Decrease of M with an increase of age at massive maturation

Age at massive maturation, years	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Decrease of M (%)	-	44	17	9	7	4	3	3	1	2	1	2	1	1

As it is evident from the data, a difference amounting te one year in the age of sexual maturity achievement for the fishes having a shorter life span, suggests a considerable variation of the natural loss value. Subsequently, a gradual attenuation in the decrease of M occurs. And, at last, this process becomes very slow for the fishes with a longer life span. Thus, within the range of 9 to 15 years a decrease constitutes about 8 %.

Discussion

At present, the reliability of the values of M can be corroborated, as a rule, indirectly by means of comparing, for instance, of the assessments or results of estimating of stock size and possible catches using a given value of M with the results obtained by means of other methods. Such factors as life span, age of sexual maturity achievement, availability or absence of strong fluctuations in year-class abundance, reaction to the fishing effect prove to be important reference-points in qualitative evaluation of reliability of the values of M. At any rate, all these allow to avoid rough errors and offer a possibility for subsequent correction as the data are entering which indicate a discrepancy degree between calculated and actual values of M.

Preciseness of the values obtained from the empirical equation deduced by the authors, is confirmed by a reliability degree of the initial data (a row of M values given in table 1), which could be examined only by means of the above mentioned method.

A method of M estimation suggested in this paper can be applied provided that (1) the availability of a local population is ascertained, and (2) the data are obtained on the age at which over 50 % of specimens in investigated population are mature.

The suggested method does not seem to give a precise estimate of natural mortality rate, however, it allows to obtain approximate values of M with the shortest possible delay and avoiding rough errors.

We have a feeling, that parallel with the express-method by P.V.Tyurin (1962, 1972) an approach to estimation of natural mortality rate stated in our paper and based on actual dependence can be applied and developed in fishery investigations.

Now we may consider practical utilization of the suggested method. The estimates of natural instantaneous mortality rate for the North Sea haddock, Melanogrammus aeglefinus, (Beverton and Holt, 1957), yellowtail flounder from the eastern coast of the USA (Brown, 1970), and herring from Georges Bank region seem to be too understated when compared with the age at massive maturation. According to our data, M is 0.2 for the species given, the ages we are interested in being 2,3 and 4 years. From our equation the values of M for the same species will be 0.8, 0.5 and 0.4, accordingly.

Baltic herring, Clupea harengus membras L., achieving sexual maturity by the end of the second year of life (massive maturation) is a good example of fishes having a short life span and strongly pronounced fluctuations in abundance. It is doubtless that replacement rate in this stock is very high and the value of M estimated from hyperbolic dependence and amounting to 0.8 is in rather a good agreement with this notion.

Conclusion

1. There exists a certain agreement between M and the age at massive maturation which allows to use the latter in the equations by Kutty and Quasim instead of T_{opt} in some cases.
2. A dependence between M and the age at massive maturation is a kind of hyperbolic function which can be analytically described.
3. The equation deduced makes it possible to estimate the approximate value of M which may be used for development of preliminary recommendations for rational fishing.

References:

1. Ambroz A.I., 1964. The sturgeons of the north-west region of the Black Sea. Trudy VNIRO, vol. 52.
2. Boiko E.G., 1964. On estimation of natural mortality of the Asov pike perch. Col. of papers on the methods of stock assessment and forecasting of commercial fish yields. M.
3. Borodulina O.D., 1964. Some data on the biology of argentina, Argentina silus (Ascanius). Voprosy ichthiol., vol.4, vyp.I (30).
4. Efanov V.N., 1973. On the question of natural mortality of yellowtail fleunder from the New England area. Transactions. Fishery investigations in the Atlantic ocean, vyp. III, Kaliningrad.
5. Koganskaya S.M., 1950. The material on the Alaska pollock investigations. Transactions of TINRO, vol.32, Vladivostok.
6. Kolesnik Yu.A. A method of estimation of natural instantaneous mortality rate of the Alaska pollock from the Bay of Peter-the-Great. Voprosy ichthiologii, vol.10, vyp.6.(65)
7. Nickolsky G.V. Particular ichthyology. M.
8. Nickolsky G.V., 1974. A theory of stock dynamics as a biological basis of rational exploitation and fish resources reproduction. M. Pishcheprom.
9. Ponomarenko V.P., 1964. Natural, fishing and total mortality of cod from the Barentz Sea stock in 1946-1963. The material of fishery investigations in the Northern basin. Vyp. 4. Trans.of PINRO. Murmansk.
10. Commercial fishes of the USSR, 1949. VNIRO.
11. Rikhter V.A., 1974. The study of dynamics of red hake, Urophycis chuss (Walbaum), catches from the North - West Atlantic by means of simulation. Voprosy ichthyologii, vol.14, vyp. 4 (87).
12. Tyurin P.V., 1962. A factor of natural mortality in fishes and its importance in regulated fishery. Voprosy ichthyologii, vol.2, vyp. 3 (24).

13. Tyurin P.V., 1972. " Normal " curves of survial and natural mortality rate of fishes as a theoretical basis of fishery regulations. Trans. of the state Research Institute of Lake and River fisheries. vol. 71. L.

14. Beverton R.J. and Holt S.J. 1957. On the dynamics of exploited fish population. London.

15. Beverton R.J. and Holt S.J. 1959. A review of the life-spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. Giba foundation colloquia on ageing., Vol. 5. London.

16. Beverton R.J.H., 1963. Maturation, growth and mortality of Clupeid and Engrauling stocks in relations to fishing. Rapport R.V. Reun. Couns.perm. int. Explor. Mer. Vol. 154 Copenhague.

17. Brown B.E., 1970. Assessment of the yellowtail flounder fishery in subarea 5. - Int. Comm. North - West Atl. Fish., Rrs. Doc. 70/87. Canada.

18. Hohendorf K. 1966. Eine Diskussion der Bertalanfysfunktionen und ihre Anwendung. Charakterisierung des Wachstums von Fischen. Kieler Meerforschungen, Heft 1. Kiel.

19. Isacov V.I. 1973. Growth and total mortality of mackerel from the New England area. Int. Comm. North-West Atl. Fish. Res. Doc. 73/23.

20. Isacov V.I. 1974. The estimation of natural mortality and optimum fishing intensity of mackerel from the New England area. Int. Comm. North- West Atl. Fish. Res. Doc. 74/108.

21. Kutty M.K. and Qasim S.Z. 1968. The estimation of optimum age of exploitation and potential yield in fish populations. J.du Cons., vol. 32, No. 2. Copenhague.

22. Pitt T.K. 1958. Age and growth of the capelin, Mallotus villosus (Muller), from Newfoundland and Grand Bank areas. I.Fish. Res. Bd. Canada, Vol. 15, No. 3, Canada.

23. Rikhter V.A. 1972. Estimates of total and natural mortality rates for red hake (Urophycis chuss Walbaum)

from the Northwest Atlantic. Int. Comm. North-West Atl. Fish. Redbook 1972, Part III.

24. Shevchuk L.I. 1974. Assessment of total and natural mortality of argentine (Argentina silus Ascanium) in the Brown's Bank area. Int Comm. North-West Atl. Fish., Res. Doc. 74/22.

25. Scevchuk L.I. 1974 b. The optimum level of exploitation and an approximate assessment of argentine (Argentina silus Ascanius) in the Brown's area. Int. Comm. North-West Atl. Fish., Res. Doc. 74/27. Canada.

26. Schumacher A. and Antony V.C. 1972. Georges Bank (ICNAF Division 5 Z and subarea 6) herring assessment. Int. Comm. North-West Atl. Fish., Res. Doc. 74/24. Canada.

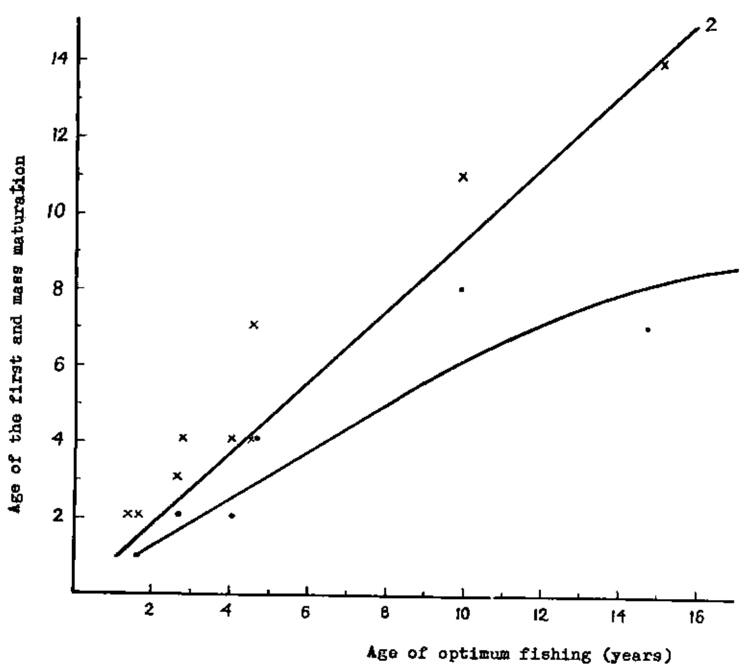

Fig. 1. A relation between optimum age of exploitation and the age at first (1) and massive (2) maturation.

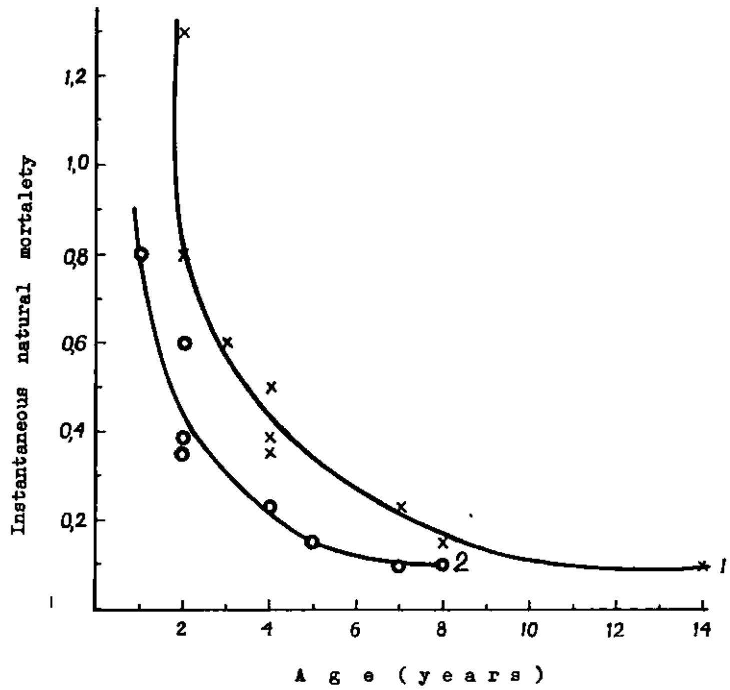

Fig. 2. A dependence between natural instantaneous mortality rate and the age at first (2) and massive (2) maturation.

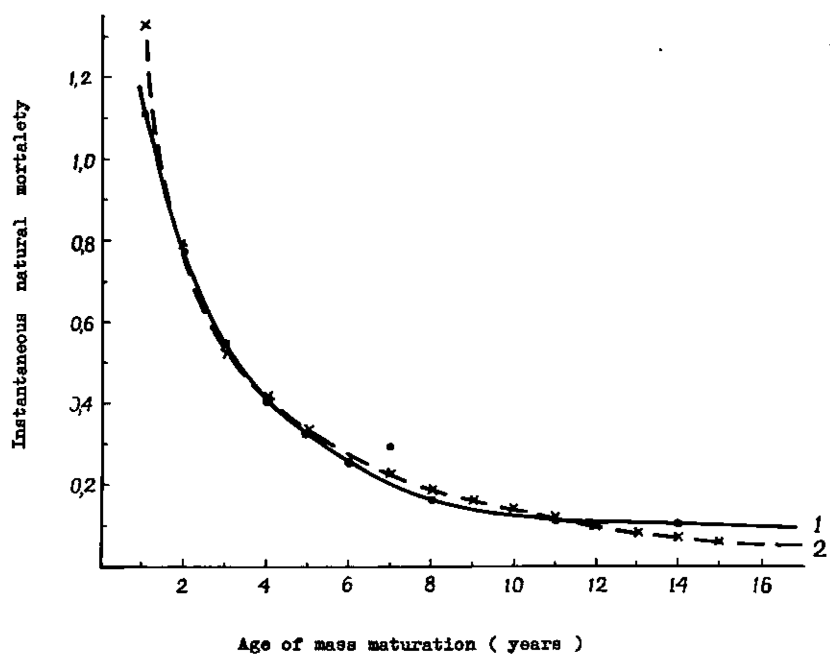

Fig. 3. A relation between natural instantaneous mortality rate and the age at massive maturation resulting from observed (1) and calculated (2) values of M.