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Approximate estimates of total and natural mortality rates for red hake (*Urophycis chuss* Walbaum) from the Northwest Atlantic

by

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Abstract

Total mortality rates for red hake of the Georges Bank and Cape Cod-Hudson Canyon stocks have been determined based on the age-composition of the commercial and research catches (joint research surveys).

A rough estimate of the natural mortality rate for red hake of the second stock was attempted characterized by the non-exploited population. The high value obtained agrees generally with the age structure of the population and seems valid for use in calculations of red hake abundance dynamics.

Introduction

The first attempts to determine the mortality rate for red hake were made in 1968 and 1970 (Rikhter, 1968 and 1970). However, insufficient material and a rather short series of observations pointed to the obvious need for more reliable evaluations of the mortality rate. The present paper gives mean values of the total and natural mortality rates for red hake from the Georges Bank stock and the Cape Cod-Hudson Canyon stock.

Material and methods

Mortality rate was determined using the difference between the natural logarithms of abundance for the adjacent age-groups (Beverton and Holt, 1956). The main material was taken from the Soviet-American joint research surveys conducted from 1967 to 1970 inclusive.

Size composition for red hake was recalculated into age-composition by using length-age keys. At first, mortality rate (z) was calculated separately for each year, and then, in order to diminish the effect of the fluctuations in the abundance of the year-classes, a mean value was determined for the whole period (Ricker, 1958) Negative values for some age-groups in particular years, which seem to be accounted for not only by the sharp fluctuations in abundance, but partially by the errors in the age reading as well, have been excluded from the calculations of the mean values.

In contrast to the age samples obtained from the commercial catches, the joint trawl surveys data permitted us to get an idea about the age structure of the whole population, beginning from yearlings. This provided additional opportunities for evaluation of the natural mortality rate. Such a method was used earlier by Halliday (1970) in his studies of dynamics of the Nova Scotia haddock populations.

An attempt was also made to calculate the mortality rate for the adjacent age-groups of one and the same year-class. However, this was successful for only the individuals aged 3 years and older, because the catchability of the gear used in the joint trawl surveys (36 Yankee trawl) appeared to be lower for the younger age-groups (Rikhter, 1971). It turned out that abundance indices (mean catch per haul) for the first two age-groups of red hake are not proportional to the actual abundance of the year-class in that age.

For comparative purposes, the data from commercial catches obtained in the period from 1965 to 1970 were also used. The catch per unit of effort was recalculated into age-composition.

Results

Table 1 shows the age-composition of red hake in the catches made by the research 36 Yankee trawl (joint surveys, 1967-1970).

Table 1. Age-composition (%) from research catches in the Georges Bank (1) and Cape Cod-Hudson Canyon (2) stocks, 1967-1970.

Age	1967	1968		1969		1970	
	2	1	2	1	2	1	2
1	33.5	15.6	35.7	11.2	31.4	3.2	25.6
2	28.3	22.8	29.7	16.3	23.3	15.3	49.9
3	22.5	36.4	22.3	37.1	27.2	25.9	12.4
4	9.8	15.6	7.8	20.7	11.0	33.1	8.4
5	3.7	6.2	3.1	7.8	4.7	16.9	3.1
6	1.1	1.7	0.7	3.4	1.2	3.2	0.3
7	0.7	1.1	0.5	2.6	0.8	1.6	0.3
8	0.4	0.6	0.2	0.9	0.4	0.8	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 1 shows that there is a significant difference in the age structure of the two stocks. First and rather notable is the small number of 2-year-old fish in the first stock and their dominance in the second one. Also notable, though not so significant, is the difference in the relative quantity of 3-year-old fish. Georges Bank seems to be inhabited by the older and mature fish and the age data from this area can be used for mortality estimate of only matured fish, starting from the 3-year-old individuals.

Table 2 shows the age-composition of red hake from the commercial catches.

Table 2. Age-composition (%) from the commercial catches of the Georges Bank (1) and Cape Cod-Hudson Canyon (2) stocks of red hake, 1965-1970.

Age	1965		1966		1967		1968		1969		1970	
	1	2	1	2	1	2	1	2	1	2	1	2
1	-	-	-	4.9	-	-	-	-	7.1	6.9	-	-
2	28.7	-	17.7	35.5	-	18.6	11.0	15.0	3.7	10.3	2.1	1.5
3	35.7	-	41.7	27.8	-	43.6	22.3	16.9	12.9	42.4	70.5	73.7
4	27.6	-	24.5	19.9	-	25.0	29.4	34.3	62.9	31.4	24.0	23.0
5	5.4	-	8.5	9.9	-	8.6	17.9	23.6	13.0	8.8	3.3	1.6
6	2.6	-	6.4	2.0	-	3.1	10.3	5.3	0.4	0.2	0.1	0.2
7	-	-	1.2	-	-	1.1	4.2	-	-	-	-	-
8	-	-	-	-	-	-	1.4	4.9	-	-	-	-
9	-	-	-	-	-	-	3.5	-	-	-	-	-
Total	100.0	-	100.0	100.0	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In comparison to the data from the research catches (Table 1), from Table 2 there is an almost total absence of fish of the first age-group, in a significantly lesser quantity of the 2-year-old individuals and in a notable predominance of the 3- to 4-year-old fish. Also, Table 2 shows that, in 1969-1970, there is a rather high portion of 5-year-old fish on Georges Bank and an almost complete absence of 6-year-olds which results in an extremely high mortality rate (see further in the text) at the sixth year of the life history. This is not confirmed by the trawl survey data (Table 1). This fact supposes that the age samples from the episodical catches do not give a true picture of the age structure of the commercial stock. Recently, there has been no commercial fishing for red hake on Georges Bank.

Table 3 presents mortality rates (Z) for red hake of the Georges Bank stock.

Table 3. Total mortality rates (Z) for red hake of the Georges Bank stock based on commercial (1) and research (2) catches.

Year of study	Age (years) 3		4		5		$\bar{Z}_1$	$\bar{Z}_2$
	1	2	1	2	1	2		
1965	0.26	-	1.62	-	0.73	-	0.87	-
1966	0.53	-	1.05	-	0.29	-	0.89	-
1967	-	-	-	-	-	-	-	-
1968	-0.27	0.84	0.49	0.93	0.55	1.30	0.52	1.02
1969	-1.59	0.58	1.58	0.97	3.48	0.81	2.53	0.79
1970	1.07	-0.25	1.98	0.57	3.50	1.76	2.18	1.16
$\bar{Z}_1$	0.62	-	1.34	-	1.71	-	1.40	-
$\bar{Z}_2$	-	0.71	-	0.82	-	1.29	-	0.99

Rather significant differences observed in the mortality rates seem to be explained by an insufficient representation of the samples from the commercial catches on the Georges Bank in 1968-1970. In the latest case, the obtained mortality rate seems to be above its actual value.

Table 4 gives mortality rates (Z) for red hake of the Cape Cod-Hudson Canyon stock.

Table 4. Mortality rates (Z*) based on the commercial (1) and research (2) catches for red hake of the Cape Cod-Hudson Canyon stock.

Year of study	1		2		3		4		5		$\bar{Z}_1$	$\bar{Z}_2$
	1	2	1	2	1	2	1	2	1	2		
1966	-	-	-	-	0.33	-	0.70	-	1.60	-	0.88	-
1967	-	0.17	-	0.33	0.56	0.82	1.07	0.97	1.02	1.20	0.88	1.00
1968	-	0.19	-	0.29	-0.12	1.05	0.37	0.92	1.50	1.47	0.93	1.14
1969	-	0.30	-	-0.15	0.30	0.90	1.27	0.86	3.80	1.40	1.79	1.05
1970	-	-0.67	-	1.40	1.16	0.38	2.66	1.00	2.08	2.20	1.96	1.19
$\bar{Z}_1$	-	-	-	-	0.59	-	1.21	-	2.00	-	1.27	-
$\bar{Z}_2$	-	0.22	-	0.64	-	0.79	-	0.94	-	1.57	-	1.09

* Z was calculated only for 3- to 5-year-old fish.

Table 4 shows that the similarity of the mean estimates for all years appears to be rather significant in this case, though the data from the commercial catches supposes that the mortality has increased markedly in the last two years (1969-1970). However, this increase is unlikely to be explained by the fishery effect, since in 1970 its intensity was extremely low.

Based on the joint trawl survey data, the mean value of the total mortality for hake can be considered as equal to 1.1.

The estimates of the mortality rates for the adjacent age-groups of the same year-class are given in Table 5.

As can be seen, the estimate for the 1964 year-class is very close to the mean values for all years. A very small number of 6-year-old fish in the commercial catches for 1969 resulted in an over-estimation for the 1963 year-class.

Estimates of the mortality rate for the first two age-groups of red hake of the Cape Cod-Hudson Canyon stock (research catches) can evidently be taken as the value of the natural mortality, since, as can be seen from the data in Table 2, fishery effect upon these age-groups from 1967 was insignificant.

Table 5. Estimates of mortality for red hake of the Cape Cod-Hudson Canyon stock for 1963 (commercial catches) and 1964 (research catches) year-classes.

Year-class	Age-group 3	4	5	Z
1963	0.55	0.69	3.59	1.61
1964	0.66	0.20	2.58	1.14

Thus, the mean estimate of the natural mortality rate (M) for the first age-group is 0.22, while for the second one it is 0.54 (assuming that the fishing mortality for this age averages about 0.1).

Further, the discussion takes the following pattern. It can be assumed with a high degree of probability that the fishing mortality rate is equal for the degree groups on which the fishery is based (3- to 5-year-old fish). It means that the increase of Z (Table 4), as the fish becomes older, is explained exclusively by the increase of the natural mortality rate. This factor was used to obtain an approximation of the natural mortality rate for the unexploited stock of 3- to 5-year-old hake. Actually, it seems that, with intensive fishing, the natural mortality of the age-groups in the catch is overlapped by the fishing mortality and, consequently, is directly associated with the fishing intensity (Beverton and Holt, 1957).

Thus, we assume that the natural maturity rate of 2- and 3-year-olds is about equal. It cannot be lower because, if in the case of the 3-year-old fish the losses due to predation decrease, then its post-spawning mortality increases. Consequently, the 3-year-old fish have also $\bar{M}$ equal to 0.54. The same circumstance is preserved: the fishery is absent or it is insignificant.

Now, the calculations are simple with $\bar{M}_1 = 0.54$, then

$$\bar{M}_2 = (\bar{Z}_2 - \bar{Z}_1) + \bar{M}_1$$

$$\bar{M}_3 = (\bar{Z}_3 - \bar{Z}_2) + \bar{M}_2$$

where $\bar{M}_1$, $\bar{M}_2$ and $\bar{M}_3$ are mean estimates of the natural mortality rate for hake of age 3, 4 and 5 years respectively, $\bar{Z}_1$, $\bar{Z}_2$ and $\bar{Z}_3$ are mean estimates of the total mortality rate of the same groups (Table 4). Mean estimate for the natural mortality rate for 3- to 5-year-old hake will be:

$$\frac{0.54 + 0.69 + 1.32}{3} = 0.85$$

Conclusion

The estimates given in the present paper are, certainly, approximate. Nevertheless, they are, in our opinion, within the range of the real values for the species. The high rate of the natural mortality under conditions of non-exploitation of the stock agrees rather well with the age structure of the population. As the amount of data increases, the quality of the estimates will improve. But even now, the results obtained seem to be valid for use in calculations of the abundance dynamics of the red hake population.

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