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An approximate estimate of the stock abundance of red hake (*Urophycis chuss*) in 1965-1972

by

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Abstract

The biomass of the two red hake stocks (Georges Bank and Cape Cod-Hudson Canyon area) for the period of 1965-1970 determined by different methods agrees generally with the commercial catches. The methods used in the present paper seem to give the actual values of the stock size of the species. To obtain a higher degree of accuracy it is advisable to combine both methods. Estimates of the second stock abundance in winter (1970-1972) when the fishery is closed together with the previous estimates indicate the decisive role of recruitment in the formation of the commercial stock of red hake and the inexpediency of measures which regard the stock size and result in a sharp decrease in the catches.

Introduction

The year 1965 can be considered as a beginning of an intensive fishery for red hake. Not so much time has elapsed since then, but the events for the past period compel us to pay some attention to estimating and forecasting the stock abundance of this species. Maximum catches in 1965-1966 were followed by a sharp drop during the next two years. In 1969 the catches again increased abruptly. In 1970 the red hake fishery was closed during January, February and March for 3 years when the fish formed winter concentrations. There is no doubt that the catch fluctuations were caused by the state of the stock. Since the period of restrictions expired in 1972, the estimate of the red hake population both in the year of intensive fishing and in the period of restrictions when the catches dropped to the pre-1965 level is of great importance because we should decide whether it is advisable to re-impose restrictions for the winter period in the fishery for this species.

Material and methods

The material used in the present paper was taken from the fishery statistics for the period of 1965-1970, as well as from the joint surveys in 1967-1970. Mostly, the data on age-composition of the catches obtained by the 36 Yankee trawl during the joint surveys have been used. Age-composition of the commercial catches was an additional source of information. Estimates of absolute stock abundance were made by two methods. One method is the calculation of the mean stratified catches per haul for the group of strata in 13-25, 1-12 and 61-76 similar to the calculations made by Grosslein (1971). Then, using the catchability coefficient equal to 0.07 (Edwards, 1968) the stock for each group of strata was assessed. The following equation was used:

$$P_w = \frac{\overline{Y}st\ A^*}{q\ a}$$

where P_w = absolute stock
$\overline{Y}st$ = mean stratified stock
A = area of the strata groups
a = area fished by the 36 Yankee trawl per haul
q = catchability coefficient

* In this case, the size of the stock in the beginning of each year following the survey was determined including the young fish (age 1+ at the time of survey) which had not yet entered the recruiting category.

The other method of stock evaluation (with the exception of fish of age 1+ in the present case) was based on the equation:

$$C_i = Ni\ \frac{F}{F+M}\ (1-e^{-z})$$

where C_i = catch in a given year i
Ni = stock abundance in the beginning of the year i
z, F and M = coefficients of the total fishing and natural mortality, respectively.

z was everywhere taken as equal to 1.1 (Rikhter, 1972). As the results of the author's investigations show, with M = 0.8-0.9 (Rikhter, *op.cit.*) the catch approximating the optimum level is attained when F = 0.7 (Rikhter, 1970). The latter value of F was accepted for the stock size evaluation in 1965-1969.

The age at which the main recruitment to the commercial stock takes place was determined by the method of Horsted and Garrod (1969), while the evaluation of the stock size in the beginning of 1972 was based on the scheme of calculations developed by Halliday (1970).

Estimates of the stock during 1965-1971

The estimates of the mean size of the stock in the beginning of each commercial fishery year by using the catchability coefficient suggested by Edwards (1968) are based on the mean stratified catches per haul which were obtained during joint surveys in 1967-1970 (Table 1). A doubled standard deviation (± 2 S.D.) served as a measure of precision.

Table 1. Mean stratified catches (lb) per haul and estimates of their precision.

Year of survey	First stock: Mean catch 13-25	First stock: ± 2 SD	Second stock: Mean catch 1-12	Second stock: ± 2 SD	Second stock: Mean catch 61-76
1967	-	-	7.0	3.6	0.2
1968	3.7	1.6	10.3	5.3	1.8
1969	3.0	1.2	13.5	6.1	1.0
1970	1.2	0.6	8.6	2.2	0.4

For the group of strata 13-15 the error in the estimates averaged 43%; for the strata 1-12, 44%, which are significant values. However, the nature of these errors is not quite clear. Thus, according to Grosslein (1971), the error in the mean stratified catches for yellowtail flounder and haddock appeared to be the same or even higher. Nevertheless, the coincidence of the abundance indices with the commercial catches for these species turned out to be rather good.

Since the surveys were carried out in the end of a year, the stocks evaluated by the first method were referred to the beginning of each year following the survey (Table 2).

Table 2. Stock abundance values ('000 tons) estimated by the catchability coefficient.

Year	First stock (13-25): Stock	First stock (13-25): Confidence intervals	Second stock (1-12) 61-76: Stock	Second stock (1-12) 61-76: Confidence intervals	Total
1968	10-15	-	43.8	21.1-66.5	54-58
1969	13.7	7.8-19.6	71.7	35.2-108.2	85.4
1970	17.5	10.5-24.5	87.1	47.8-126.4	104.6
1971	9.6	4.8-14.4	53.8	39.8-67.8	63.4

There was no survey on the Georges Bank made in 1967. However, judging from the catches (slightly over 5,000 tons) the biomass of the first stock in the beginning of 1968 could hardly exceed 15,000 tons. Thus, the total size of both red hake stocks was about 55,000-60,000 tons.

It is necessary to consider the catchability coefficient used in the present paper.

Edwards (1968) gives similar coefficients for many other species. However, the absence of any calculation makes their validty doubtful, although they certainly have some biological foundation. It is also rather difficult to presume the invariability of these coefficients from year to year. The precision of the stock estimates obtained by this method seems to be judged only by comparing them with the commercial catches and the estimates obtained by other methods.

The catches of red hake during 1965-1970 are given in Table 3.

Comparing the catches with the stock estimates (Tables 2 and 3), it can be seen that in 1968 and 1969 the stock size was markedly above the lower limit of the confidence intervals and seemed to be about at the level of the mean values.

Table 3. Total red hake catches during 1965-1970.

Year	First stock	Second stock	Total
1965	54.8	29.6	84.4
1966	39.9	74.5	114.4
1967	27.3	31.0	58.3
1968	5.1	15.2	20.3
1969	4.6	50.4	55.0
1970	1.9	9.7	11.6

Particular attention should be paid to a sharp decrease in the catches in 1968. A decrease in the fishing effort in this case is nothing but the consequence of a significant reduction of the catch-per-unit effort (Rikhter, 1970) which increased again in the following year. One would think that the data on the joint surveys in 1967-1968 would also indicate a sharp decrease of the commercial stock in the beginning of 1968 and an increase in 1969. However, the analysis of the age-composition of the second red hake stock for 1968-1969 makes such an interpretation of events rather doubtful (Table 4).

Table 4. Catch-per-unit effort (number of individuals) of different age-groups from the second red hake stock.

Year	Age						Total
	1	2	3	4	5	6	
1968	-	346	391	792	545	122	2196
1969	527	787	3240	2400	672	15	7641

Table 4 shows that the increase in catch in 1969 occurred due to the abundance of 3- to 5-year-old individuals (1964 to 1966 year-classes). Nevertheless, in 1968, the abundance of these year-classes at age 2-3 years, judging by the catches, was significantly lower, while 4-year fish were only slightly more numerous than fish at age 5 years in 1969, although the mortality rate of red hake at the fifth year of their life was very high (Rikhter, 1972). Such a paradox can only be explained by the behaviour pattern of red hake late in 1967 and in the first half of 1968 which made fishing for this species by bottom trawls rather difficult. It is rather doubtful, however, that during this period a significant proportion of the commercial stock was somewhere beyond the reach of research and commercial gears. Unfortunately, we are unable to find any certain explanation for the unusual behaviour of red hake late in 1967 and in the first half of 1968. However, judging from the above, we can suppose that the stock estimates for the first part of 1968 are underestimated.

For estimation of the commercial stock size by the second method for the period from 1965 to 1969, the F and Z values were assumed to be 0.7 and 1.1, respectively. For 1970, considering that the survey data showed stock abundance at least not lower than in the previous year, while the fishing effort and the catches sharply decreased, we assumed that the F value had decreased in proportion to the fishing intensity in 1970 and for the first and second stocks it was 28 and 0.15, respectively. The results of the calculations are given in Table 5.

Table 5. Stock abundance ('000 tons) estimated by the second method.

Stock	Year					
	1965	1966	1967	1968	1969	1970
1	125.3	91.2	62.1	12.2	10.9	11.3
2	69.1	173.5	72.4	35.6	117.2	104.0
Total	194.4	264.7	134.5	47.8	128.1	115.3

Comparing Tables 2 and 5 we can see that similarity in the stock abundances calculated by the two methods is generally rather close. We can suppose that the estimates given in both Tables are sufficiently real and valid for practical use.

To avoid the danger of over-estimation we suggest that from the stock estimates obtained by different methods the lowest ones should be used. Thus, the size of the lowest stock in the beginning of 1968, 1969 and 1970 should be 47,800, 85,400 and 104,600 tons, respectively.

Estimate of abundance and biomass of the commercial stock at the beginning of 1972

Estimation of the abundance for the stock which will be exploited some years later, that is the forecast, requires a knowledge of the dynamics of the commercial stock.

Certainly, the ratio of individuals which enter every age-group of the commercial stock for the first time does not remain unchanged. The process is affected by such factors as growth rate and maturity rate which can vary within the limits acceptable for a given species. At present, however, we are unable to take into consideration the effect of these factors upon the recruitment dynamics separately for each year, and so we must use the ratios of recruit numbers averaged for several years. Nevertheless, these data reflect rather precisely the most characteristic features in the abundance dynamics of the species under study and can be used for a tentative forecast of the stock size.

Table 6 presents estimates of the so-called partial recruitment (ratio of the individuals fished from each age-group) calculated by the method suggested by Horsted and Garrod (1969).

Table 6. Estimates of recruitment to the commercial part of the stock.

	Age				
	2	3	4	5	6
Partial recruitment	0.084	0.811	0.881	0.990	1.000

The above data show that the 6-year-olds are represented exclusively by the remainder. At ages 5, 4 and 3 years the recruitment accounts for 1%, 12% and 19%, respectively. However, in the 2-year-old fish population the recruits account for 90%. Thus, the process of recruitment to the exploited stock is practically completed by the age of 3 years. Knowing the total abundance of the 3-year fish in the forecast stock and the abundance of the remainder of the previous years stock, we can readily obtain the unknown value.

Data from the joint surveys allow us to estimate the total number of age 1+ red hake. To estimate the abundance of that year-class after two years, it is necessary to have the corresponding survival coefficients which were calculated from the data on age structure for 1967-1970 (joint surveys). The results are given in Table 7.

These data seem to be rather strange. But all this is explained by the lower catchability of the first two age-groups as compared with the following ones (Rikhter, 1971).

Table 7. Survival of 1966-1968 year-classes at ages 1+ to 3+ (%).

Age	Year-classes			Mean value
	1966	1967	1968	
1+ - 2+	138	88	164	130
2+ - 3+	122	124	55	100

With the accumulation of data, the values in Table 7 will undoubtedly change. Yet, as long as the old gear (36 Yankee trawl) is employed, any significant change will hardly occur in the catchability as compared with the period of 1967-1970. Consequently, the mean survival coefficients will remain at about the same level and in the same correlation, and can be used for a tentative evaluation of the 3-year individuals.

According to the 1970 survey the total abundance of red hake in the second stock was about 420,000,000 individuals by the beginning of 1971. Among these, the commercial stock (fish at age 2+ and older) and 2-year-old fish (1+) made up 312,500,000 and 107,500,000 individuals, respectively. The remainder of the commercial stock with Z = 1.1 would be 104,000,000 individuals by the beginning of 1972. This figure is somewhat underestimated, since the fishing mortality in 1971 is likely to have remained at the low level of the preceding two years, and the actual total annual withdrawal from the stock was below that used in the present paper.

The abundance of 3-year-old fish at the beginning of 1972, according to the above survival coefficients, would be 107,600 x 1,300 = 140,000,000 individuals.

Thus, the total abundance of the commercial stock would be 104,000,000 + 140,000,000 = 244,000,000 individuals, or in terms of weight = 59,000 tons.

The abundance of the first stock according to the survey data will remain at a low level, and in 1972 is unlikely to exceed 10,000-11,000 tons. Thus, the total abundance of the commercial stock at the beginning of 1972 will be about 70,000 tons. This figure is entirely tentative and, as stated above, seems to be underestimated.

Discussion

The stock estimates obtained by the three methods were combined in Table 8 for easier analysis.

Table 8. Estimates of the stock biomass ('000 tons) in 1965-1972*.

Stock	Year							
	1965	1966	1967	1968	1969	1970	1971	1972
1	125.3	91.2	62.1	12.2	13.7	17.5	9.6	11.0
2	69.1	173.5	72.4	35.6	71.7	87.1	53.8	59.0
Total	194.4	264.7	134.5	47.8	85.4	104.6	63.4	70.0

* Estimates for 1965/1968 are obtained by the commercial fishing statistics and by the coefficients of the total and fishing mortality. The stocks for 1969-1971 were evaluated by catchability coefficients.

The above data indicate that the biomass dynamics of the two red hake stocks during the period under study differed significantly. The abundance of the first stock

decreased until 1968, and then it stabilized at a new low level (1968-1971) indicating the entry into the fisheries of a number of poor year-classes. The abundance of the second stock was oscillating continuously, not showing any particular trend.

The abundance dynamics of the first stock was to a certain degree affected by intensive fishing in 1965-1967, although no special exploitation of red hake on Georges Bank was conducted since 1968. In contrast, the second stock, in spite of a rather active exploitation in 1965, increased significantly at the beginning of the following year. In 1970 stock abundance exceeded that of 1965 and 1969, although in 1969 the fishing intensity was significantly higher than in the pre-1965 period. In 1971 the stock abundance decreased again, although the fishing activity in the preceding year fell sharply. The above facts suggest that the fluctuations in the abundance of the second stock are caused mainly by natural factors, and not by the fishing activity. It may also be suggested that on Georges Bank, as well, fishing activity does not play a decisive role, especially as its effect here was shorter in time than in the habitat of the second stock.

In 1964-1968 the conditions for survival of the young fish at earlier stages (the year-classes subject to the fishery in 1968-1971) seemed to be unfavourable on Georges Bank, while in the western part of the area under study, though unstable, they were in general satisfactory. The differences in the abundance dynamics of the two red hake stocks during the period under study caused by the natural factors indicate a reproductive isolation of these stocks.

Summary

The data presented suggest that the restrictions placed on the fishery for red hake for the winter seasons, 1970-1972, did not produce the desired end. Despite the sharp decrease in fishing activity during the above period, fluctuations occurred in the abundance which are accounted for by the influence of the environmental factors, the size of the second stock in 1970 being higher than in 1965 when the intensive fishing had just begun. That and the other above-mentioned facts are readily explained if recruitment is assumed to play the decisive role in the formation of the commercial stock of red hake. This means that closed fishing seasons and areas will not yield the results sought for. The proportion of fish removed from the stock by fishing in earlier years would now be removed by a high rate of natural mortality.

A more expedient measure for regulation of the red hake fishery would seem to be the introduction of annual quotas based on data on stock size at the beginning of each year and on optimum removal by the commercial fishery.

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