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Dynamics of some biological indices, abundance and fishing of red hake *(Urophycis chuss* W.) in the Northwest Atlantic, 1965-1968

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ABSTRACT

In the period from 1965 to 1968, substantial changes took place in the structure and abundance of red hake stocks such as an increase in the number of older fish, a decrease in growth rate and a decline in abundance. This paper analyses these changes and assesses the stock and fishing intensity in different years. A conclusion is reached about the main role of recruitment in the formation of red hake abundance and about the absence of overfishing. The optimum size of the annual catch can be determined depending on the stock size, which may be assessed by trawl surveys.

MATERIAL AND METHODS

A systematic study of red hake, Urophycis chuss W., was started by AtlantNIRO in 1965. The first stage of the work consisted of a study of the distribution and identification of local stocks. Differences between red hake from the various areas were established by the biometric method and by the comparative analysis of length, length in relation to width, and weight of otoliths from specimens with equal body length. The technique of analysis and the results are described in a previous report submitted to the 1968 Annual Meeting of ICNAF (Richter, 1968). These investigations showed that there are at least two stocks in the Northwest Atlantic; the first stock inhabits the southern and southwestern parts of Georges Bank, the second stock extends southwesterly from Cape Cod (Fig. 1).

Since 1966, the analysis of data has been made with regard to this stock division whenever possible. Both stocks appeared to be most similar in the type of dynamics of population abundance and were fished by similar vessels and gear which allows the biomass of the stocks to be considered a "unit stock" (Gulland, 1965).

Basic work consisted of collecting samples for age length from 1965 to 1968 (Table 1).

Table 1. Numbers of age estimations and length measurements from red hake, 1965-1968.

Years	Stock I		Stock II	
	Age estimations (no)	Length measurements (no)	Age estimations (no)	Length measurements (no)
1965	501	1733	85	1743
1966	289	1623	298	1325
1967	-	-	978	3000
1968	868	2894	771	3210
Total	1658	6250	2132	9278

Ages were determined from otoliths. Annual zones were most apparent on a section which was first polished and burned. The surface of a section was cleaned by a drop of enlightening liquid. The results of the age determinations were used to produce length-age keys for the conversion of length composition into age composition.

This procedure was carried out each year and thus provided more reliable data on the age structure of red hake stocks.

The rate of loss (instantaneous mortality coefficient) was estimated by "integral" methods as well as by difference of natural logarithms of abundance (Beverton and Holt, 1956). The estimates obtained for March and October-December 1965 were used to trace changes of total mortality ($\bar{Z}$) at the beginning and at the end of the first year of intensive fishing, and, thus, to obtain separate coefficients of fishing (F) and natural (M) mortality. Later, when the calculation of approximate fishing effort (f) for each year of fishing was made, the method of direct relationship between $\bar{Z}$ and f to estimate M (Beverton and Holt, 1954) was used.

Separate estimates of F and M and the commercial statistics for 1965 gave an estimate of the absolute size of the commercial stock of red hake at the beginning of the year. Early in 1968 and 1969, stock size was calculated on the basis of the data collected during joint USSR-USA groundfish trawl surveys. Methods of conducting these surveys are described in detail by Grosslein (1968).

Absolute stock size was calculated with the aid of catchability factors suggested by Edwards (1968).

ICNAF Statistical Bulletins were the main source of information on red hake catches by years, seasons and vessel types. The collection of data on fishing effort and catch per effort was difficult because a considerable portion of the catches consisted of species other than red hake. Data on the percentage of catches by species overcame this difficulty. Moreover, the distribution of commercial concentrations of red hake in the winter-spring period, particularly in the years characterised by high abundance (1965-1966), was in good agreement with the habitat of the two stocks. This fact permitted the estimation of catch per 1 hour haul and the fishing effort for each stock separately. The calculations were made on the basis of commercial catches taken by BMRT- and RTM-type vessels from January to April inclusive. From 1965 to 1968, the bulk of red hake catches was taken by large trawlers in the months mentioned.

AGE-LENGTH COMPOSITION AND GROWTH RATE

Table 2 shows the most important characteristics of length distribution in the two stocks of red hake.

Table 2. Some characteristics of length distribution in the two stocks of red hake.

Stocks	Sampling Date	Mean length (cm)	Mode (cm)	Maximum length in catches (cm)	Fish <27 cm (%)	Specimens measured (no)
1	March 1965	33.0	30-33	47	4.6	1521
	" 1966	33.0	32-35	47	2.0	623
	" 1968	34.4	32-35	48	2.5	1524
	May 1965	32.3	30-33	51	10.5	1727
	" 1968	33.3	32-35	45	1.4	300
	October-November 1965	35.2	32-35	49	0.7	400
	" 1966	33.8	34-37	49	9.8	618
	" 1968	32.8	28-31	47	3.5	200
2	March February 1966	33.8	32-37	51	8.7	402
	" 1967	30.6	30-33	46	18.0	1944
	" 1968	33.3	32-35	50	12.3	2460
	November-December 1966	33.8	32-35	41	0.0	100
	1967	33.1	32-35	50	4.8	2100
	1968	32.7	32-35	49	2.7	307

From the above data, it is difficult to find any trend in the changes of length composition. This is due partly to the different number of specimens measured. Length composition in the first stock indicates some increase in mean length in 1968 as compared to previous years. The differences between average lengths of fish in the second stock can be explained by the varying number of young fish (length < 27 cm) in catches. The maximum length of red hake did not change significantly from 1965 to 1968. According to data collected in March-February 1968, the mean length of red hake in the first stock appeared to be larger than that in the second one. However, this can be explained by the different quantity of young fish in these stocks (2.5 and 12.3% respectively). The results of the joint USSR-USA groundfish trawl surveys (Table 3) offer the most reliable information on possible changes in the length composition of red hake in 1968 as compared to 1967.

Table 3. Size composition (%) of red hake from the second stock (Data from joint USSR-USA groundfish trawl surveys conducted in autumn 1967-1968).

Length (cm)/ Years	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	Mean lengt (cm)
1967	-	0.3	1.0	5.8	6.7	8.6	5.8	10.8	17.8	15.4	12.8	8.1	2.8	1.4	1.7	0.3	0.2	0.2	0.3	30.3
1968	0.2	0.9	2.5	6.0	5.7	7.5	7.6	12.0	19.5	16.0	8.4	5.9	2.8	2.1	0.8	0.7	0.4	0.1	-	29.7

These data show a slight decrease in mean length in autumn 1968 compared to the same season of the previous year.

The catches from the experimental trawls with small meshes in contrast to the samples from the commercial catches are characterized by a larger number of young fish. Groundfish trawl surveys give a true idea of linear frequency distribution of red hake in the area under survey.

Comparative analysis of age composition of red hake from commercial catches shows that both stocks increased in average age from 1965 to 1968 (Fig.2). The proportion of 2-year-old specimens decreased. The modal group appeared to be shifted by a year to the right. It is difficult to believe that age structure is influenced by the fishery in such a way. The increase of older fish during this period along with the decrease of catches in 1967-1968 can only be explained on the basis of weak year-classes entering the commercial fishery.

Considerable change occurred in age composition from 1965 to 1968. There was an increase of older fish along with the lack of a noticeable size increment due to a slower rate of growth in both stocks (Fig. 3).

It is known that in most cases the reverse relationship is observed between stock size and growth rate. In this case, however, the relationship appeared to be direct with a constant size composition in spite of an increase in the proportion of older fish. Similar cases are described by G.V.Nikolsky (1965) who has noted that "simultaneous reduction of population abundance and delay of growth rate can take place in climatic conditions becoming unfavourable for the population". The Northwest Atlantic is characterized by cooling over almost the complete habitat for red hake. The lowest water temperature was observed in 1964-1966 (Sigaev, 1969). Thus, the climatic conditions caused the slower growth rate and appeared to be the reason for weak year-classes.

STATE OF FISHERY

From 1965 to 1968, the bulk of catches was taken by Soviet fishermen in the winter-spring months (January-April), with the distribution of commercial concentrations overlapping the habitats of the two stocks. This made it possible to calculate the approximate catch from each of the two stocks of red hake by proportional dividing total annual catches by the catches taken by vessels of BMRT- and RTM-type in winter-spring period (Table 4).

Table 4. Approximate estimate of total catches for each of the two stocks of red hake (in thousand tons) from 1965 to 1968.

Years	Stock I	Stock II	Total
1965	54.8	29.6	84.4
1966	39.9	74.5	114.4
1967	27.3	31.0	58.3
1968	2.8	17.9	20.7
Total	124.8	153.0	277.8

The larger total catch from the second stock suggests that this stock is somewhat larger than the first stock.

The data on fishing effort and catch per unit effort are presented in Table 5.

Table 5. Fishing effort and catch per unit effort according to fishery statistics collected annually by large trawlers from January to April inclusive.

Years	Stock I: Number of fishing days	Stock I: Number of hauling hours	Stock I: Catch per haul hour (tons)	Stock II: Number of fishing days	Stock II: Number of hauling hours	Stock II: Catch per haul hour (tons)	Total catch per haul hour
1965	1630	21817	1.32	468	6480	2.44	1.60
1966	794	12172	2.39	2124	32133	1.69	1.89
1967	612	9480	0.96	706	11040	0.96	0.96
1968	95	1371	0.62	686	9690	0.56	0.56
Total	3131	44840		3984	59343		

Table 5 shows that fishing effort varied annually as the catches. If in 1965 when taking catches from the first stock, more considerable fishing effort was used later on, the centre of fishing appeared to be shifted on the second stock, that is in the direction of west. The most remarkable difference in fishing effort was noted in 1968. In the first stock, the catch per unit effort reached its maximum in 1966, probably due to the reduction of fishing effort. In the second stock, the maximum catch per unit effort was reached in 1965, while the decrease of catch in 1966 was due to the sharp rise in fishing effort. On the whole, despite the total increase of fishing effort in 1966, summary catch per unit effort was somewhat larger as a result of an increase in abundance of red hake as compared with 1965. In 1967-1968, however, the reduction of effort on both stocks was followed by an abrupt drop in catch per unit effort which can be attributed only to a decrease in the size of the commercial stock.

ESTIMATES OF ABUNDANCE OF THE 1963-1967 YEAR-CLASSES

Considering age composition of red hake in various years we could not but touch this problem. However, we succeeded in obtaining more reliable information on the relative abundance of year-classes from data relating to catch per unit effort in pieces, and conversion of these catches into age composition (Table 6).

Table 6. Relative abundance of 2-year-old red hake in the two stocks in the years from 1965 to 1968.

Stocks	I			II			
Years of sampling	1965	1966	1968	1965	1966	1967	1968
Year-classes	1963	1964	1966	1963	1964	1965	1966
Catch per unit effort (pcs)	1525	1710	282	7330	2420	768	346

It is obvious from the data that the abundance of 2-year-old specimens was highest in 1965 and 1966. In the following two years the abundance of 2-year-olds decreased sharply. This demonstrates the high abundance of the 1963 and 1964 year-classes and the low abundance of the 1965 year-class and, in particular, the 1966 year-class. This year-class variation agrees with the results of investigations of water temperatures in the area under survey (Sigaev, 1958).

Evidence of the abundance of the 1966 and 1967 year-classes is also provided by the results of joint surveys. Table 7 gives the data on the catches of 2-year-old fish in the autumn of 1967 and 1968.

Table 7. Average catch (in numbers) of 2-year-old fish per 30 min. haul. (Data from Albatross IV surveys during 1967 and 1968).

Stocks	1967	1968
I	-	0.5
II	3.3	5.1

MORTALITY RATE

The estimates of total mortality rate were made by calculating the difference of the natural logarithms of the abundance of adjacent age-groups, and are also shown as relative percent reductions in Table 8.

Table 8. Estimates of total mortality rate of red hake from two stocks during the period from 1965 to 1968.

Years	Stock I		Stock II	
	$\bar{Z}$	reduction in %	$\bar{Z}$	reduction in %
1965	1.18	70.0	1.13	66.7
1966	0.89	58.9	0.88	58.5
1967	-	-	0.89	58.9
1968	0.65	47.3	0.93	60.5

Total mortality rate was maximum in 1965. In the first stock the rate decreased to a minimum in 1968. The value of the fishing effort given in Table 5 shows that fishing intensity on the first stock was very low that year, and $\bar{Z}$ = 0.65 was, in fact, the natural mortality rate. The estimate of M obtained graphically (Fig. 4) gave a similar figure (0.62). Total mortality rate in the second stock was relatively stable from 1965.

An attempt was made to obtain separate values of F and M from data on length composition of the stock early and late in 1965. At the beginning and at the end of the year $\bar{Z}$ was 0.9 and 1.3, respectively. The value of 0.9 for M was adopted because in previous years red hake fishing was conducted by US fishermen exclusively and at a low intensity, as is now evident. Then the difference between the initial and final values of $\bar{Z}$ gave an F value of 0.4.

One of the reasons for the differences in estimates of natural mortality rate (0.9 and 0.62), according to the 1965 and 1968 data, is probably later maturing which can result from slower growth. If this is true, the appearance of numerous and early maturing year-class is to increase natural mortality rate. Change of natural mortality rate must result in variation of optimum level of fishing intensity.

ESTIMATE OF ABSOLUTE STOCK AND FISHING INTENSITY

The total amount of red hake of the two stocks combined was calculated for early 1965 from data on total catch in this year and from the corresponding value of the fishing mortality factor in percent (approximately 33%)* as approximately 250 thousand tons. The assessment of stock size (mean value for 1963-1965) obtained using catchability factors (Edwards, 1968) gave the same amount. Results obtained using the two different methods agree closely and suggest that estimated assessment of stock size approximates the actual stock size.

The results of the joint USSR-USA groundfish trawl surveys and catchability factors given in the above-mentioned paper (Edwards, 1968) were used to assess the stock of red hake late in 1967-68, that is the stock which was exploited in 1968-1969 and, therefore, can be attributed to the beginning of these years. The second survey in contrast to the first covered the whole habitat of red hake and this allowed to obtain stock assessment for each stock separately early in 1969 (Table 9).

Table 9. Assessment of red hake stocks (in thousand tons) from the results of joint USSR-USA surveys, 1967-1968.

Years	1967/1968		1968/1969	
Stock	I	II	I	II
Stock size	-	35.6	16.9	56.5

The increase in stock size late in 1968 compared to the same period in the previous year probably occurred as a result of the appearance of the relatively strong 1967 year-class. Although the amount of the first stock was unknown late

*Although M and F calculated by data for 1965 concern only the first stock, it was decided to spread them over the whole stock of red hake in the area of investigation (see "Materials and Methods") in 1967, it can be suggested by analogy with the second stock that the former was approximately 8-9 thousand tons. Thus, the total amount of both stocks late in 1967 and 1968 was about 44 and 73 thousand tons, respectively. As for abundance in 1966-1967, the increase of total catch per unit effort in 1966 as well as the intensification of fishing effort (see Table 5) indicate higher abundance than in 1965. In 1966 the stock was assessed on the basis of assumed proportionality of total catch per unit effort and of stock size in 1965-1966.

The decline in catch per unit effort in 1967 was followed by a decrease in fishing effort. Had the level of fishing effort remained the same, there would have been, without doubt, a much sharper decrease in catch per effort. The final estimate of 1967 stock size was obtained on the basis of assumed proportionality of stock and catch per effort in 1965 and 1967 and subsequent reduction of the estimate received parallel with fishing effort decrease.

The results of stock assessment compared with actual catches give a picture of fishing intensity in the period from 1965 to 1968 (Table 10).

Table 10. Stocks size and catches (in thousand tons) and fishing intensity from 1965 to 1968.

Years	1965	1966	1967	1968	1969
Stock size	250	295	105	44	73
Catches	84.4	114.4	58.3	20.7	-
Fishing intensity (%)	33	39	56	46	-

Stock assessments and estimates of fishing intensity are rather approximate, of course, but they reflect the general trend in the changes in abundance and the influence of the fishery. The intensity of exploitation of each of the two stocks was defined by the 1968 data (Table 11).

Table 11. Fishing intensity determined for each of the two stocks of red hake in 1968.

Stock	I	II
Stock size (000's tons)	8-9	35.6
Catches (000's tons)	2.8	17.9
Fishing intensity (%)	31-35	50

Naturally, a great difference in the fishing effort resulted in considerable variation in the intensity of exploitation of the two stocks in 1968.

The question is to what extent the given values of fishing intensity are close to optimum ones. Because of lack of data we can cite Baranov (1918) who considered fishing intensity to be in agreement with natural mortality rate, according to our data the latter fluctuating within the range from 0.9 to 0.62 (59-46%).

The approximate value of optimum fishing intensity obtained by modelling stocks and catches at various fishing intensity was 50% with a high level of stock, 45% with an intermediate level and 40% with a low level. As we can see, in 1965-1966 fishing intensity was below the optimum level, in 1967 it probably exceeded the optimum level and in subsequent years it was at about the optimum level. Table 11 shows that the intensity of exploitation of the first stock is well below the optimum. Graham (1967) estimated that the maximum sustainable yield had to be 100 thousand tons. This figure seemed to be in accordance with the truth for the period of high abundance, for example in 1965-1966.

SUMMARY

The fishery for red hake is now restricted in ICNAF Statistical Subarea 6. In 1969, the Annual Meeting of ICNAF adopted a recommendation to restrict fishing in Subarea 5 from January to March inclusive as in this period dense winter concentrations of red hake were observed to be formed. The restriction was introduced as a result of material evidence of the pernicious influence of the fishery upon the state of stocks. Meanwhile, the results of investigations cited in this paper permit conclusions (1) on the main role of recruitment in the formation of red hake abundance and (2) on the lack of overfishing resulting in excessive fishing intensity.

If stock abundance is low for any reason, the destiny of brood from a poor parent stock becomes troublesome, and in this case the restriction of fishing intensity is useful. No information is available, however, confirming direct dependence of recruitment on stock. Moreover, the brood from a rich parent stock (stock of 1965-1966) appeared to be weak (recruitment of 1967-1968) and the less abundant 1967 stock contributed a more abundant year-class than the maximum 1966 stock did.

From the above, it can be concluded that a recommendation for full restriction of the red hake fishery in the period from January to March is not well-grounded. The appearance of strong or weak year-classes depends primarily

on environmental conditions, and the restriction of fishing is not sufficient to increase the commercial stock. The increase in stock size from a strong year-class during the restriction period of 3 years in Subarea 5 cannot be completely utilized because high natural mortality in the following 2 years will result in a sharp decrease in abundance of this year-class.

Since joint USSR-USA groundfish trawl surveys conducted since 1967 make it possible to assess the absolute stock size of red hake in the beginning of a year, this makes it possible to determine the optimum size of the annual catch.

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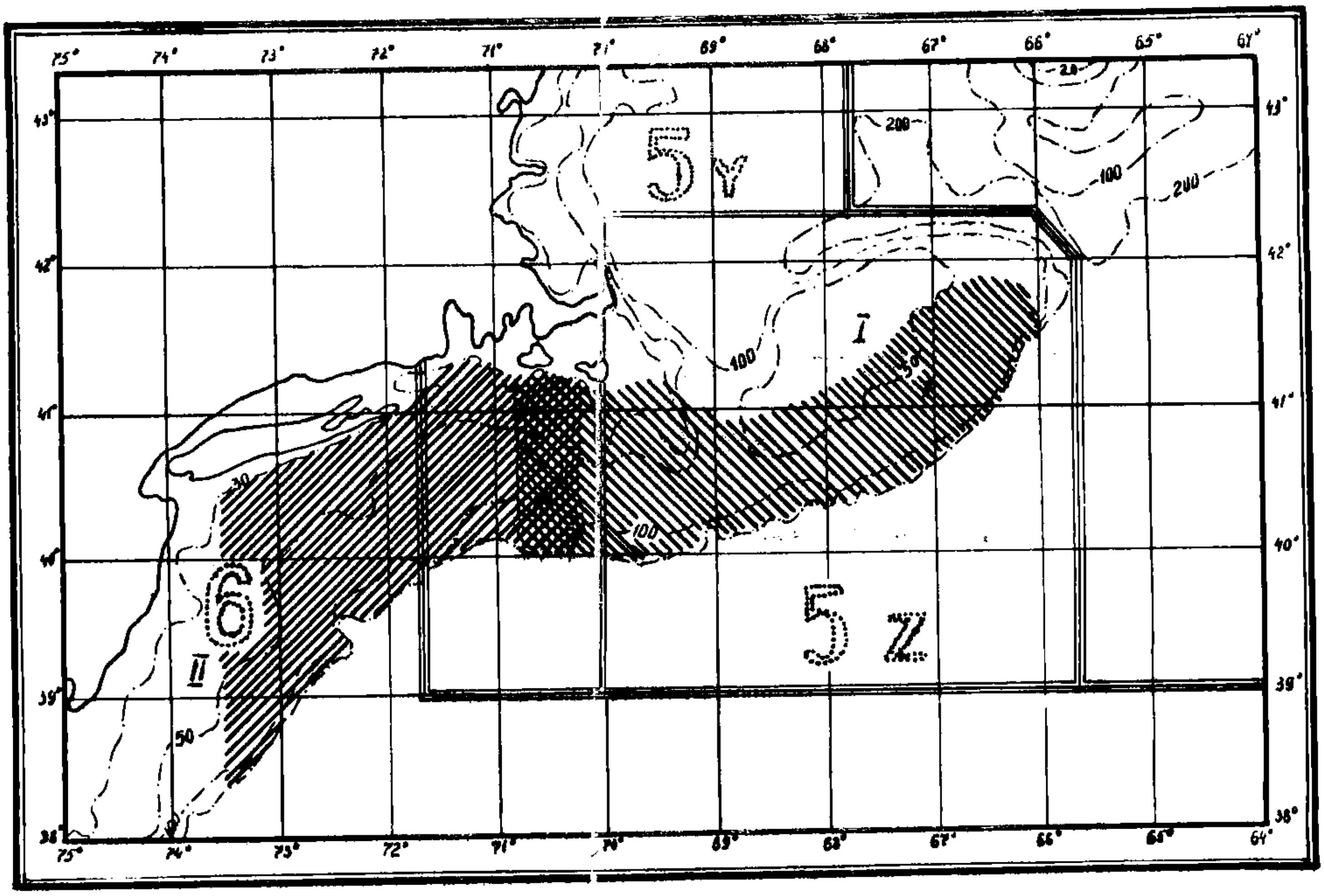

Fig. 1. Chart showing habitat of two stocks of red hake.
\\\ Stock I; /// Stock II; XXX Approximate overlapping zone

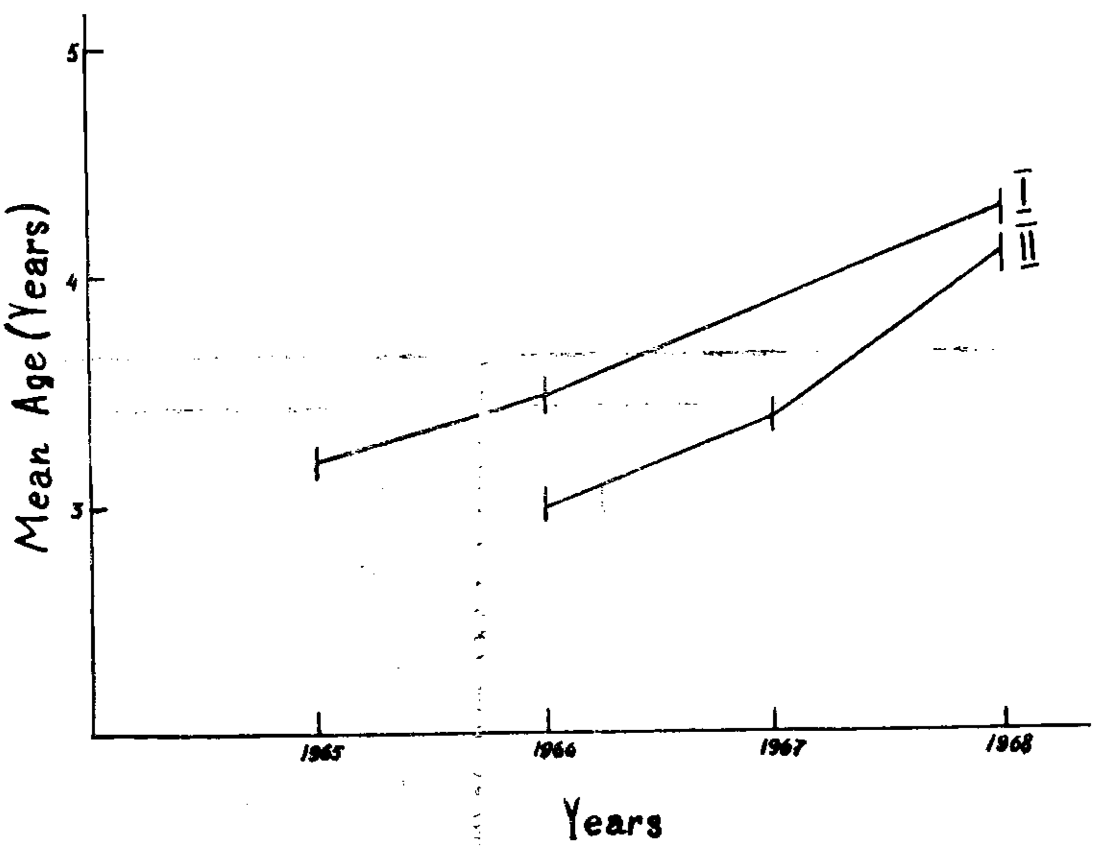

Fig. 2. Mean age of commercial part of two stocks of red hake in various years.

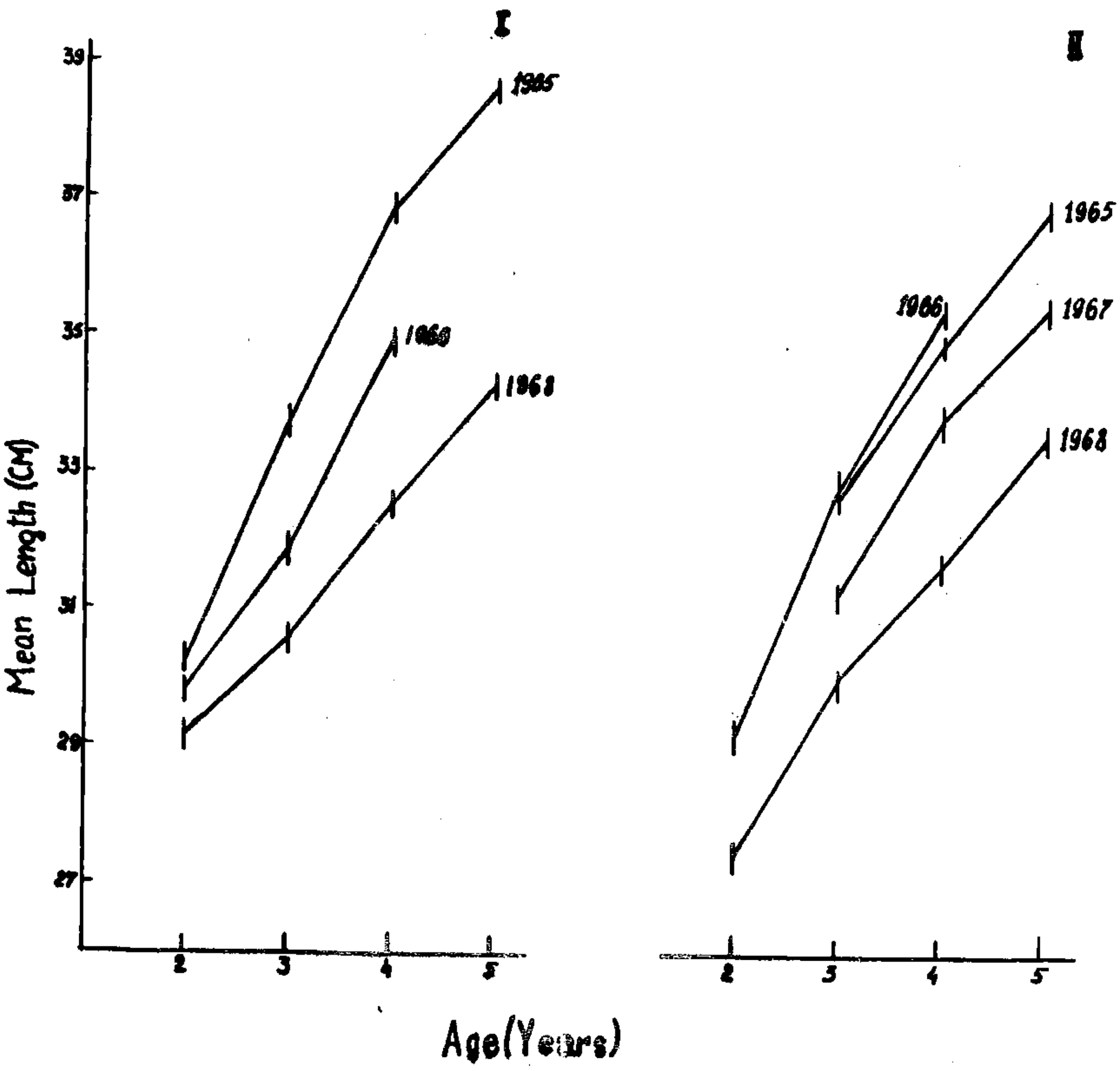

Fig. 3. Mean length of age-groups of two stocks of red hake in various years.

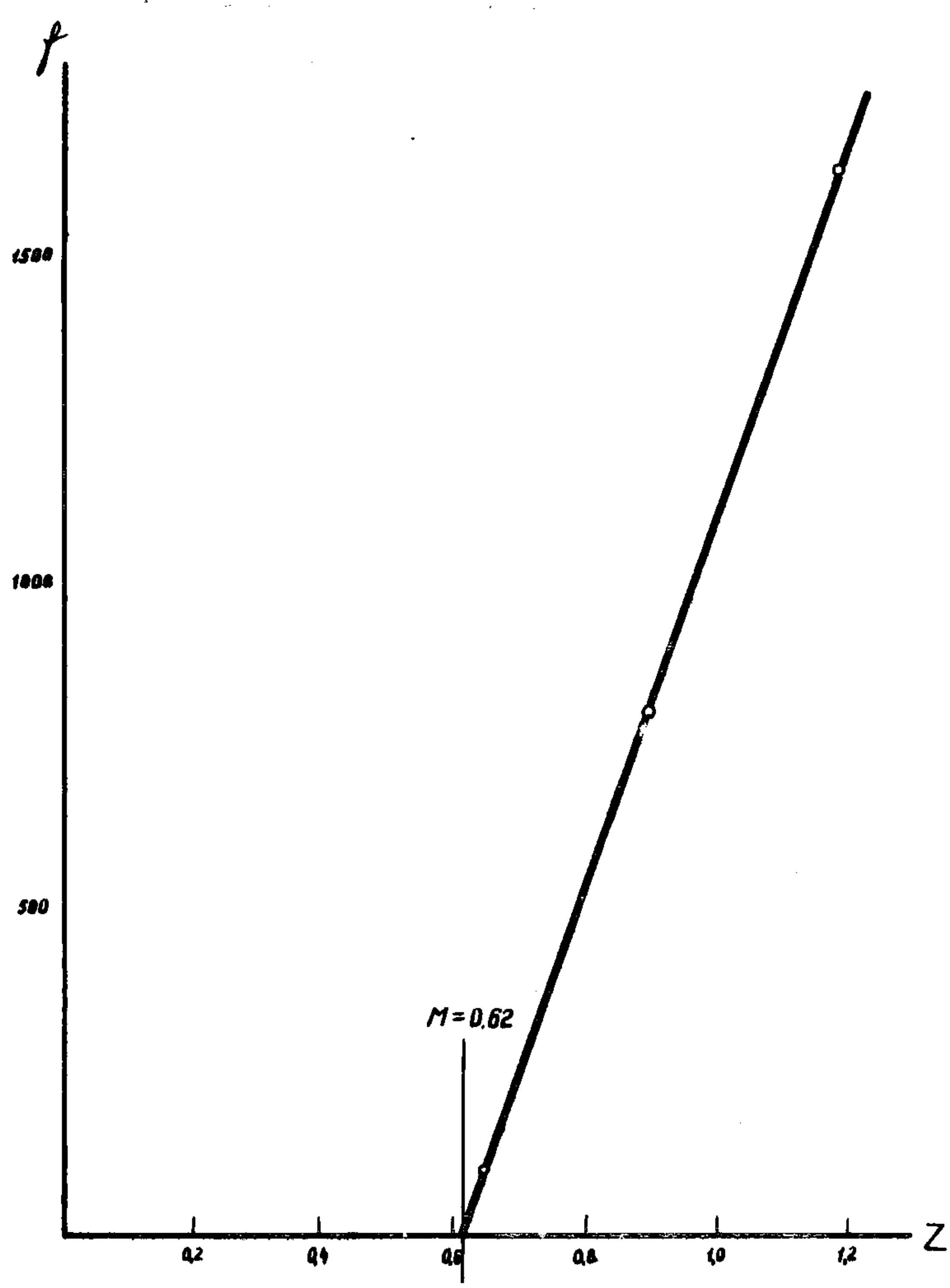

Fig. 4. Assessment of natural mortality rate of red hake from the first stock by the graphic method (f - number of fishing days; Z - total mortality rate).