International Council for the Exploration of the Sea

C.M. 1963

Symposium on the Measurement of Abundance of Fish Stocks

No. 8

Att. Comparative Fishing Committee

Correlations between Indices of Relative Abundance of Young Fish, Recruitment Size, and Maturity Rate as a Basis for Annual Prediction

by

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The assessment of the relative abundance of fish is mainly used for the evaluation of the annual fluctuations in the fish stock. The relativity of indices may be explained by the assumption that they are promising in the assessment not of the total stock size, but only of the changes which have occurred in the stock composition and size within a year.

If the indices of the relative abundance are extended to the total catch in compliance with time, place, and fishing gear as well as the fishing intensity, a "weighted" stock can be obtained proceeding from the recruitment size calculated and the fishing mortality.

The authenticity of the indices of the relative fish strength depends on the extent of knowledge of the ecological conditions of the habitat and the reproduction of the species as well as on the representation of the material collected. The true criterion can be correlation between the indices of relative strength of the year-class assessed at the stage of one-summer-olds and recruitment size calculated from the fishing mortality. Characteristics of growth are used for the assessment of changes in the biomass size and mortality rate of fish. The natural mortality is determined, if possible and necessary, by indirect indices.

Thus the method of assessment of the relative abundance of fish as well as other methods include recruitment, growth, fishing and natural mortalities, i.e. four initial processes of the dynamics of fish populations. Most publications on the fishing theory and methods of assessment of the fishing stock are devoted to consideration, quantitative determination and analysis of the said processes. The present paper considers some propositions on the assessment of the recruitment size and in this way we would try to make the methods of assessment of the relative abundance of fish more accurate.

At present much attention is devoted to the various methods of assessment of the total stock due to the application of mathematical models. G. Hempel and D. Sahrhage (1961) stated that the main aim of the numerous investigations were to find out such mathematical models which would include the relations between recruitment, growth, natural and fishing mortalities quite visiually, but without needless simplification. So the dynamics of the populations can be studied experimentally on a mathematical model, each time some factor should be alterated, while others remain constant. It should be noted, however, that consideration of a change in some factor in relation to other constant factors does not seem to secure desirable results, since the very basis of changes in the factors roots in the reciprocal action with other processes and they are most unlikely to be disconnected in this way. Besides, hypotheses regarding which condition the extent of changes in the factors concerned, are often based on a number of so far unsolved biological problems, particularly on the relation of the influence of the recruitment size on the composition of the fish stock and on the conditions governing the strength of the year-classes.

When working-out the fishing theory workers often proceed from the point that the recruitment size, though being variable, depends on the stock density. Beverton and Holt (1957) do not deny that in most populations of marine fishes the recruitment does not depend on the stock density, nevertheless they worked out a model reflecting only a relation between the eggs spawned and recruitment. This concept is also supported by W. E. Ricker (1958), G. V. Nikolsky (1963) and other workers.

If the recruitment size fluctuates by years, the mean recruiment size is used instead of the actual one to predict mean catches for a given period or to substantiate the establishment of a regulated fishery. However, the fishing industry needs forecasts not only for a certain average period, but also for every year coming. It is quite necessary to have such a prognosis available since the catch should be scientifically planned.

The annual recruitment size is known to range widely. The determination of this value is the most important stage in the assessment of the stock. With this in mind G. N. Monastyrsky (1952) worked out a method of a complex evaluation of the stock with the recruitment composition in which he used all the experience of workers accumulated for a long period of years by studying the dynamics of fish populations, including F. Baranov (1918), J. Hjort (1914), and he tried to have all the rational dependencies confirmed by fishing practice. This method is based on the proposition that the stock fluctuations depend not only on the effect of the fishery but also on the changes in the recruitment size of the populations, as was stated and confirmed by a vast actual material on many species from different water bodies. It was furthermore stated that the fluctuations in the recruitment size are mainly dependent on reproduction and biological peculiarities of the populations. Thus, the relation between the recruitment size and environment formed the basis for the application of the method since all other methods suggest that the recruitment be considered a constant value or dependent on the population density, i.e. on the number of spawners. But the latter, in its turn, depends on the fishery, thus a relation between changes in the stock and changes in the fishery itself substantiates the method used. In view of this fact the models may include changes in the fishery.

The difference in the backgrounds of the methods stipulates the principal divergencies in understanding the causes governing the changes in the fish stocks. Since the recruitment is mostly dependent on natural processes, which are never constant, the models used are most unlikely to suggest always the ready conclusions on the recruitment size and causes, which bring about the changes in it. Thus, recently the concept necessitating the inclusion of the environmental data into the models of fish populations became more widely spread (J. Gulland, 1962; et al.)

The most representative knowledge of the recruitment size can be obtained from the above-mentioned method of "taking the recruitment size into account". This method aims at determination of this value, as a variable and independent on the stock density and seems to be advantageous as most composite and dynamic. Along with the advantages it requires thorough versatile observations on changes in the biological peculiarities of the population, its composition, fishing methods and fishing intensity, as well as in the regime and productivity of waters.

The main elements of the method are as follows:-

1. Usual determination of age and size composition of the stock by obtaining average samples to be viewed either from the total catch (when the fishing intensity remains the same) or from the catch per fishing effort (when different fishing power is applied).
2. Determination of the correlation between the growth rate and the maturity rate of the recruitment (by spawning marks) and evaluation of the causes affecting the fluctuations in growth and maturity rates.
3. Determination of a proposed strength of the year-classes by counting one-summer-olds and by finding a correlation of these indices with the strength of the year-classes at different stages of life.
4. Determination of the density of the population in the spawning or wintering concentrations.
5. Calculation of brood strengths and fishing mortality rate.
6. Determination of the ratio between the actual catches, the density of population and the strength of the year-classes.
7. Determination of the lowest level of the stock and the value of possible or permissible catch.

The process of calculation of the said indices and of collection of the material needed is well known. It is worth mentioning that samples are most representative for the determination of the fishing stock in the period of gathering for spawning migrations, on the way to spawning places and at the spawning.

Growth and Maturity

In the analyses of the peculiarities of growth and maturity it is desirable to have the following items in mind:-

a) Maturation is bound with the length of the fish, but not with the age;

b) At a lower rate of growth the fish, as an exception, reach maturity being shorter-sized due to some acceleration in the development of the fish;

c) As a rule, the specimens with a higher rate of growth, especially in the early stages, reach maturity sooner. For example, in the North Caspian Sea bream, the maturity is reached by 3o-4o% of 3-year-olds with a higher rate of growth, while at a lower rate of growth only 1o-2o% of specimens of this age reach maturity.

The Baltic cod usually reach maturity at the age of 3, but at the spawning places the catches include 13-17% of the same year-class with a lower rate of growth, while in the years of intensive growth 32% of 3-year-olds occurred in the catches (G. Tokareva, 1963).

The growth of fish depends both on the quantity of food in the water and on the number of consumers. As shown from the studies carried out by K. Zemskaya (1958), changes in the strength of consumers sooner affect the growth of fish than the fluctuations in the food resources. The fluctuations in the fish growth is the result of different rates of metabolism. Any rise in temperature to a certain limit increases the "appetite", i.e. promotes more active movements of fish in search for food and more intensive assimilation of food.

The interrelation of the temperature regime in the water body, metabolic intensity and growth rate in fish is often mentioned by many authors (G. Alm, 1959; G. V. Nikolsky, 1961; V. Hegel, 195o; P. Hansen, 1958; W. Nümann, 1959; G.Karzinkin, 1952, et al.) The difference in the average length of fish at the same age in relation to metabolic intensity may be very high, for example, in the Baltic herring it amounts to more than 3 cm (Dementjeva, 1952).

The data on growth may be reversely calculated with otoliths and scales. The increments obtained are separately compared within each most numerous age-groups, as a result of which a higher degree of accuracy can be obtained, the age peculiarities of growth being of no importance. If the increments are expressed by deviations from the long-range average it is possible to get a sum of deviations for each year of growth for all the year-classes of the stock in a given year. This is being illustrated in the table below.

Table 1. Deviations of annual increments in the length of the North Caspian bream from the long-range average (in cm) (T. Dementjeva & K. Zemskaja)
4-year-olds

Year-class	Year of growth	194o	1941	1942	1943	1944	1945	1946	1947
1939		+1.4	+o.6	-o.1					
194o		+o.1	+o.9	+o.3	-o.1				
1941			-o.2	-o.3	o	-o.2			
1942				-o.1	-o.2	-o.9	-o.1		
1943					-o.4	-o.2	-o.4	-o.5	
1944						-o.4	-o.2	+o.6	+o.7
1945							-o.4	o	+1.6
1946								+o.4	+o.1
1947									+o.1
		Σ (+1.3)	+1.3	-o.2	-o.7	-1.7	-1.1	+o.5	+2.5

The analysis of the increments shown in Table 1 indicates that in the same year the trends of growth may be similar in a number of year-classes, i.e. in different age-groups in compliance with the peculiarities of their growth. Thus, we may assume that some general conditions in a given year caused changes in the growth of both young and adult specimens, though their feeding grounds were different. This paper does not propose to consider the causes of the changes in the growth shown in the example. It is worth mentioning, however, that as shown in Table 1 the growth of the bream was most intensive in 194o, 1946 and 1947, while in 1943-45 the growth was lowest. The growth indices shown horizontally enable us to judge of the character of growth of each year-class within their span of life.

Maturity and Span of Life in Fish

Proceeding from the relation between the maturity rate and the recruitment size we may state that the earlier a fish reaches maturity, the shorter is its span of life, i.e., the sooner a given year-class complete their life cycle and go out of the fishery. It may be assumed that if the acceleration in growth of the population and the earlier maturity are observed within a period of several years, it may lead to rejuvenation of the fishing stock. The rejuvenation is expressed by an increase in the strength of younger ages and a corresponding decrease in the abundance of the aged specimens of the fishing stock. This regularity should be born in mind when analyzing the causes of rejuvenation of the fishing stock in spite of the fact that it is the intensive fishing that plays the leading role in it.

Examples of differentiated mortalities when fastly-growing specimens reach maturity and die sooner than the slowly-growing individuals can be found in any species (R.Hile, 1936; Smith, 1956; et al.). The values calculated for the Baltic cod and the North Caspian Sea bream are shown in Table 2:-

Table 2.

I. Exploited generations of the Baltic cod at the following ages:

	3 - and 4-year-olds	5-and more year-olds	Number of year-classes
with intensive growth, being as 2-year-olds	7o.o-77.2%	22.4-3o.o%	5
with poor growth, being as 2-year-olds	56.4-65.o%	35.o-43.6%	3
G. I. Tokareva, 1963			

II. Percentage of the fishing mortality rate of bream by catches

Year-classes	Growth 1-3 years	Age								Size of year-classes in millions of specimens
		2	3	4	5	6	7	8	%	
1933	poor	o.6	5.2	71.1	14.9	5.2	2.9	o.1	1oo	34.o5
1934	medium	-	44.8	39.4	11.3	3.1	1.4	o.o5	1oo	9o.65

Both generations of bream had a different growth rate in the early life. In the long run the year-class of 1933 proved to occur in the catches for a longer period than the brood of 1934, in spite of the fact that it was not strong. K. Zemskaja's data (1958) indicate the same ratio in the year-classes of 1939 and 1942 and others.

All the material collected suggest the necessity of studying the biological peculiarities of the fish populations, changes which affect the recruitment rate in the period of forming the fishing stock and fishing mortality.

Proposed Strength of a Generation

When the percentage of recruits in relation to the maturity rates is calculated, it is necessary to find a proposed relative abundance of the year-class, of which the calculation of the recruitment size and the remains could be originated. Counts of young fish may serve for this purpose. Indices of counting are mean catches of one-summer-olds per unit of time. They indicate a density of their distribution over a given area. The period of counting one-summer-olds is advantageous to other methods providing counts of other age-groups for the following reasons:-

a) The heaviest mortalities take place at the earliest stages of development;

b) At the stage of one-summer-olds and further the mortality of the individuals occurs in proportion to the generation sizes, if there is no great increase in strength of predators or some other natural circumstances.

c) The one-summer-olds are far less active and try to avoid trawls to a lesser extent, thus their catchability is greater than that of one- or two-year-olds.

If the necessity of counting the latter arises, then the design of a trawl and towing rate should be changed.

Before commencing the counts of young fish it is expedient to study the distribution of young fish by seasons in relation to depths, currents, salinity, distribution of food organisms and predators, and other factors. In a number of species a correlation between indices of quantitative counts of young fish and the sizes of the year-classes which were born in the same years (calculated from the catches) was found. Such correlations are illustrated by data on the North Caspian bream and the Baltic cod (Figures1 and 2). Material is available to allow to develop the similar curves for the Baltic herring, Barents Sea cod and for other species.

The above-mentioned correlation enables us to conclude as follows:-

1. When the fish become older than one-summer-old the natural mortality becomes much less pronounced, and

2. By the method of analogy it is possible to determine a proposed size of a generation by counting the one-summer-olds. Nevertheless, the correlations thus obtained should be permanently checked in view of:
a) changes in the environment and distribution of one-summer-olds;
b) lack of adaptation in one-summer-olds to severe winters;
c) excessive catch of young fish which does not seem to be subject to statistical accounts and some other causes.

The availability of correlations between the abundance of a generation as calculated from the fishing mortality and the data on the density of concentrations of young fish enable us to suggest a relatively insignificant natural mortality in the main fishable age-groups. Thus, in its turn, it enables us to assume that in some cases we may reckon the fishing mortality as a total mortality.

The assessment of the rate of fishing mortality is carried out by using the above-mentioned method in relation to the fishing stock obtained from the catches, and thus, it reflects only a lower level of the stock. This level is known to fluctuate annually as well as in the total stock in relation to the recruitment size and the fishing power. Knowledge of a range of the stock flurtuations in conjunction with the evaluation of biological peculiarities of the population and their changes will contribute to gaining more accurate predictions.

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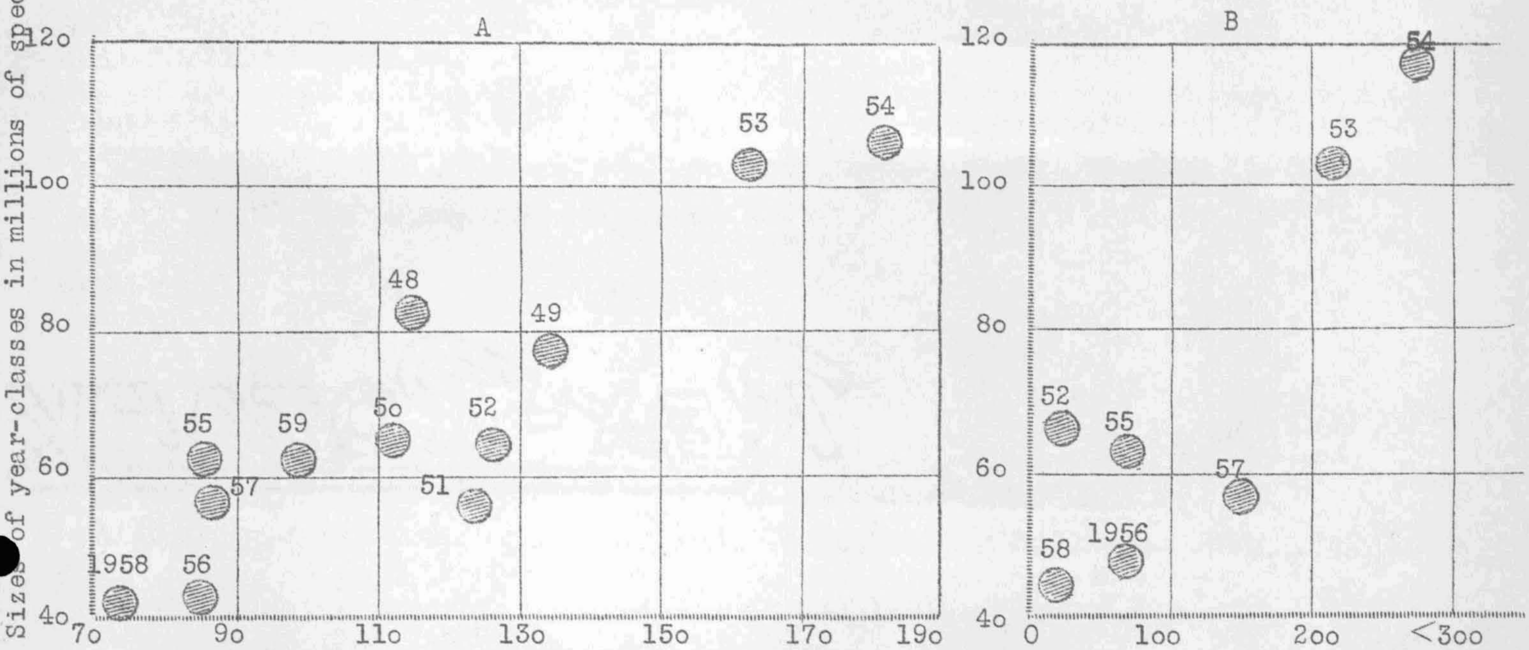
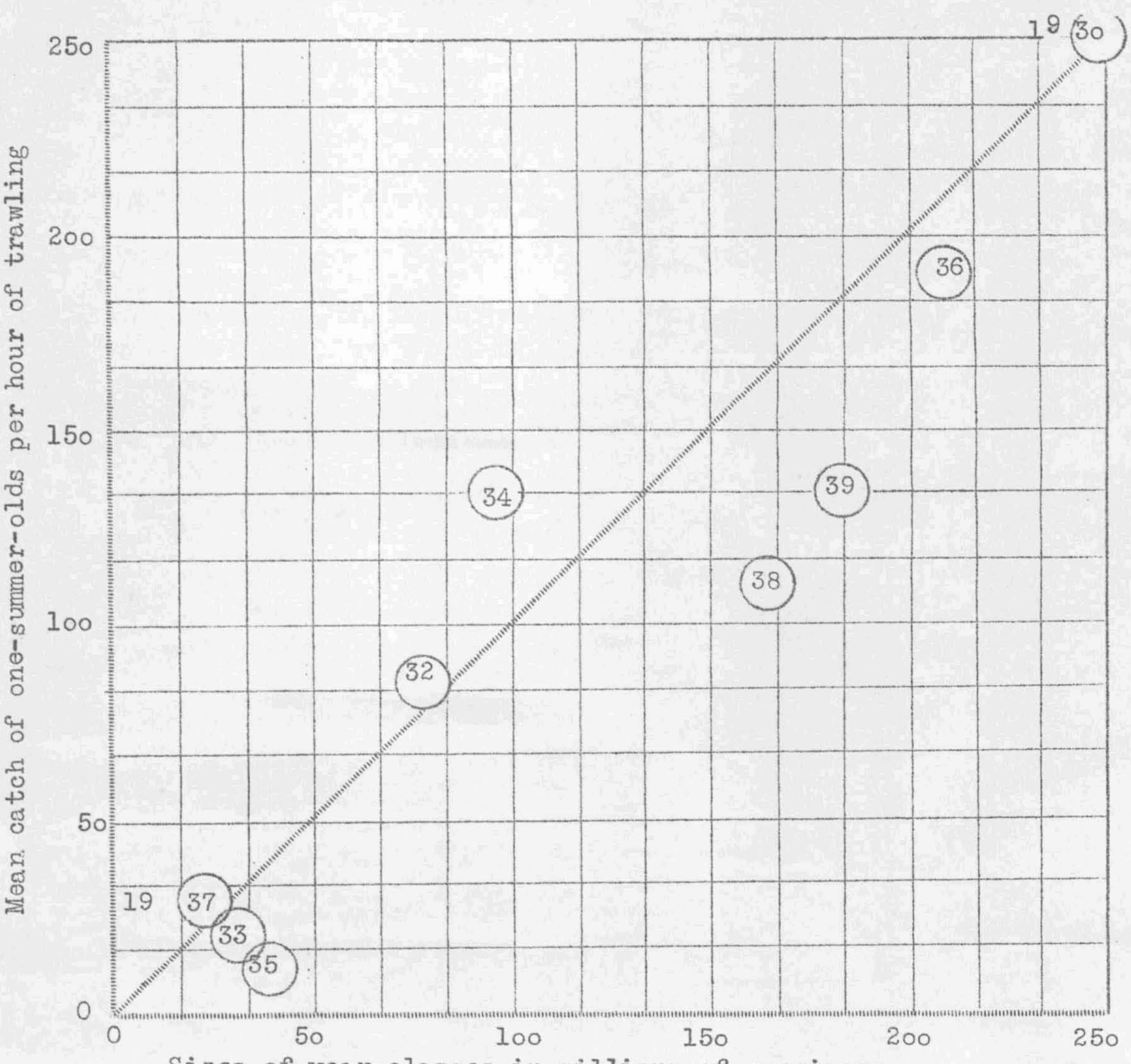
Figure 1. A - relation between the brood strength of the Baltic cod (in millions of specimens) and catches per fishing effort (1 hour of trawling) in kg;
B - relation between the brood strength and mean catch of young fish (in nos.)



A - mean catch per hour of trawling in kg in the year of fishing for 3-4 year-olds.

B - Mean catch of young fish per hour of trawling (in number of fish (by Tokareva).



Sizes of year-classes in millions of specimens.

Figure 2. Relation between the brood strength and the number of young bream in the Caspian Sea.