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Report of Scientific Advisers to Panel 5

By Lionel A. Walford

(Meeting at St. Andrews, N.B., Dec. 9 and 10, 1953, and at Woods Hole, Mass., March 3 - 5, 1954.)

Participants: Scientists from Canada and U.S.A., with Dr. Lionel A. Walford in the chair.

HADDOCK

Effect of the Mesh Regulation

United States biologists reported on experience to date with the regulation of the mesh size of nets fishing for haddock in Subarea 5. The fishing industry did not immediately adopt the legal mesh unanimously. Some fishermen continued to use the small mesh nets; others who adopted the large mesh net used small mesh liners in their cod ends. However, enough vessels did adopt the new nets promptly so that it has been possible to follow the results of their fishing in comparison with those of a group of 8 vessels licensed to fish with the small mesh nets. See Appendix I.

An analysis of catches at sea shows that the small haddock are being saved precisely as had been expected. The small mesh vessels discarded fish at sea in the same proportions as in previous years, while the large mesh boats discarded a negligible quantity.

However, there has been a relative increase in landings of larger haddock and of other species of fish. This effect was evident from the time the first group of boats converted shortly after June 1.

During June, July and August, the landings of the vessels using large mesh nets were 6.1 percent less than in the same period of the previous year; while those of the licensed small-mesh vessels were down 17.2 percent. By October 1 all vessels (except the licensed group) had converted to large mesh.

During the period October 1 to December 31, 1953 landings of haddock caught with the large-mesh trawls were down 10 percent below those of the same period in 1952, while the landings of haddock by licensed vessels were down 22 percent. The landings of all species of fishes by the vessels with large mesh were about equal to those of the same period in 1952; while the landings of all species by the licensed boats were down 10 percent.

Studies have shown that the difference does not result from a change in habits of fishermen but evidently from the fact that the large meshed nets are more efficient than the small meshed ones in catching the heavier large sized fish.

The value of the Study Group Program in demonstrating the effect of the mesh regulation is already apparent, and the Scientific Advisers affirmed the necessity of continuing with the Study Group Program for a number of years to permit the precise assessment of the long term effect of the regulation.

United States biologists described the proposed revision of the United States regulation for 1954. The Commission's recommendation for the amended regulations provides that fishermen may elect either to limit their mesh size to 4-½ inches inside measurement when-wet-after-use, or to use a mesh that has been certified by Government inspection. United States scientists conducted a special study to determine the sizes of dry mesh with various weights of Manila twine corresponding to the 4-½ inch inside measurement when-wet-after-use. Results of this study showed that during the average life of a cod end, i.e., 1-½ trips, a mesh initially between 5-⅝ and 5-¾ inches between knot centers dry new shrinks to 4-½ inches inside measurement when-wet-after-use. On the basis of these experiments it was decided to certify nets which measured 5-⅝ inches between knot centers dry new, constructed of a weight of twine commonly in use.

The group recommends that further experiments be conducted to extend the 50 percent escapement point beyond that indicated by present data. This will be needed as a basis for arriving at any future regulations in the Convention Area.

United States biologists have prepared a series of diagrams which illustrate theoretical relations between fishing rates, age at first capture, and yield. These are given in Appendix II.

Problem of Exemption from the Mesh Regulation

United States biologists reported that an amendment to the Subarea 5 regulation in 1955 may be proposed, providing for exemption of small boats of some specified tonnage which normally fish for species other than haddock. They showed that vessels of 50 tons or less now take 3.2 percent of the total catch of haddock in Subarea 5, and posed this question: What can be the basis of an objective criterion of a size limit for the proposed exemption?

The scientific advisers pointed out that any exemption of the regulation would establish a precedent that may have far-reaching consequences. In Subarea 4 many small vessels are engaged in groundfishing; and were a mesh regulation to be adopted elsewhere, as in Subarea 4, for example, any problem of exemption might there be difficult to settle. It would therefore be desirable to try to evolve a principle by which exemptions could be objectively determined.

It was agreed that the only sound reason for exemptions is to prevent the regulation from interfering seriously with lucrative fisheries which are primarily for other species and in which haddock are caught incidentally. At the same time vessels fishing primarily for haddock should not be exempted, regardless of their size.

United States biologists made an analysis of the effects on the benefits to be expected from the regulations, of exempting various proportions of the haddock catch. The attached summary (Appendix II) of this analysis shows that the loss of benefits is almost proportional to the part of the catch exempted. For example, if 20 percent of the catch were exempted, about 22 percent of the benfits would be lost; if 50 percent of the catch were exempted, about 54 percent of the benefits would be lost.

The scientific advisers recommend that the Commission be asked to approve of the exemption of a specified maximum percentage of the catch of haddock by each country in Subarea 5, provided that the general principles stated above are satisfied. Each country would then be permitted to formulate regulations, within that specified limit, which would provide for exemptions which would meet its particular economic needs, and would be required to report to the Commission what regulations are enforced and what catches are made by the exempted fishing operations.

Before the Fourth Annual Meeting of the Commission, the scientific advisers will examine additional information which is being assembled, and on the basis thereof will recommend the percentage to be exempted.

Status of the haddock fishery in Subarea 5

Since 1949 there has been a steady decline in the landings of large haddock from the subarea. This decline has been partly compensated by increased landings of scrod. In 1950 the landings of scrod exceeded the landings of large haddock for the first time in history, and this situation has continued to the present. The fishery has been supported by a few dominant year classes entering the fishery in alternate years. The year classes of 1948 and 1950 have been the mainstays during this period.

The year class 1952 appears to be a strong one so that there probably will be a repetition of the events which occurred in 1950 and 1952, with a new class of two-year-olds coming into the fishery in great numbers as the previous strong classes move into the group of large haddock and decrease in abundance. Thus, 1954 promises to be a year in which the large mesh nets will save great quantities of fish among the incoming dominant year class. If licensed boats using small mesh were to concentrate their fishing effort on these small fish they might for a time land more fish than the vessels using large mesh.

Quantitative surveys for haddock eggs, larvae and young fish

United States biologists reported results of three egg and larval fish surveys of two weeks duration during March, April and May 1953 in which approximately 15,000 miles of continuous records were obtained on the Hardy plankton recorder. Principal spawning centers were located, the resultant drift of eggs and larvae was traced and integrated in relation to the circulation pattern as determined from drift bottles. The majority of larval fish resulting from eggs spawned on Georges Bank were evidently swept off the southern edge of the bank and presumably lost. Eggs and larvae from Browns Bank moved northwest into the Gulf of Maine where conditions are presumably suitable for survival. It appears that the 1953 year class on both Georges and Browns Banks will depend upon the success of spawning and survival of haddock from the latter area. Sampling of zero age haddock during September revealed that the majority of the fish of that age were located in the western side of the Gulf of Maine and in the South Channel area, and substantiated conclusions drawn from the distribution and drift of eggs and larvae. Subsequent samplings over a period of years are necessary to validate these conclusions.

The scientific advisers consider this work to be important to our understanding of the causes of fluctuations and hence to our ability to regulate to best advantage. It should also make possible predictions of catch, which would be of great value to the fishing industry.

REDFISH

The growth and geographic expansion of the fishery for redfish raises questions as to the effect of fishing on productivity of the stocks, and as to the possible need of regulations to obtain maximum sustained harvests. To provide a basis of answering these questions, biologists of the member countries have begun research on growth rates and other aspects of the biology of the species.

United States biologists studying the formation of rings in otoliths of young redfish have found that the opaque zone at the edge of otoliths increases progressively during the year and is followed by a clear zone laid down between November and February. The principal growth of the fish corresponds to the growth of the opaque zone. Thus, one ring is formed annually. However, the age at which the first clear zone is formed has yet to be determined. Zone counts by several people are highly consistent. These results are encouraging enough to justify intensifing age analysis of samples of the commercial catch, even though results of further research may show that assigned ages must be adjusted by one year.

Studies of meristic counts of fish from various localities throughout the range of redfish have been inconclusive, owing to the small ranges of variation in all items examined. Growth rates and age at first maturity, seen from such otolith studies as have been made, vary from bank to bank, but much more work is needed in order to establish definitively the nature of these differences. It was suggested that biochemical methods (serological studies, paper chromatography) might be more sensitive than morphometric methods in bringing out differences. United States biologists will explore the possibilities of these methods as far as facilities permit.

The group examined the questions as to whether the fishery is taking the fringe of a vast population, and reached an opinion that it probably is not. No evidence has been found to indicate that there are seaward extending bathypelagic stocks inhabiting relatively deep strata, which are available to fishermen only in the areas where those strata touch the slopes of banks.

The group concluded that programs now in progress should be continued, that age analysis should be intensified in order to provide a dependable estimate of total mortality rate, that systematic work on the identity of the stocks should be intensified, that more effort should be given to trying to devise means of tagging redfish, and that attention should be given to the possible advantages of concentrating research effort on a particular small stock of redfish rather than extending the effort to stocks in widely different areas.

The group recommends that the subcommittee on redfish and halibut be asked to discuss methods of estimating natural mortality rate of redfish. Two techniques are suggested:

1. By tagging. To overcome the difficulties of tagging redfish, which do not survive when brought to the surface, divers might be able to tag fish captured in a specially constructed trawl dragged from deeper into relatively shallow water.

2. By statistical analysis of the age composition of a stock in an area that has been subjected to two contrasting conditions of fishing pressure. There is the further possibility of closing an exploited area for a long enough interval to effect a significant change in population composition.

STATISTICS

The Scientific Advisers draw attention to the fact that in some of the statistics by the Commission data on fishing effort are not separated by species, and in these cases it is not feasible to compute indices of abundance. It is therefore recommended that the Committee on Research and Statistics be requested to include on the agenda of the 1954 Annual Meeting the subject of abundance indices, particularly in relation to the collection for ICNAF of statistics relative to landings by species and effort. Some suggested topics for discussion under that subject are as follows:

How can catch per unit of effort be measured by sampling?
What is an adequate sample?
How can individual trip cards be standardized, even though collected by different countries?

THE END

CONSERVING NEW ENGLAND HADDOCK [1/]

Herbert W. Graham

The international mesh regulation for haddock fishing on Georges Bank went into effect June 1, 1953. The purpose of this paper is to report on the effects of this regulation during the first seven months of its operation. Conversion from small to large mesh gear took place gradually. A few boats converted soon after June 1, but conversion was not complete until October 1. From June 1 eight large trawlers were licensed to fish with small mesh in order to provide information necessary for testing the effect of the regulation. Observers were sent to sea on both large mesh and small mesh boats to sample the catches and to sample the fish discarded as well as those landed.

Until this regulation became effective trawlers caught and discarded at sea millions of pounds of small haddock with nets having cod end meshes averaging 2-$\frac{3}{8}$ inches (Herrington, 1935; Graham, 1952a, 1952b; Premetz, 1953). The regulation requires a minimum mesh size of 4-$\frac{1}{2}$ inches inside dimension.

The purpose of this minimum mesh regulation is to increase the age of first capture of haddock, that is, to save the undersize fish for later capture at a larger size. An advantage is gained by saving young fish only if they grow sufficiently fast and if enough of them survive to be caught at a later date. Growth rates and total mortality rates are well known for Georges Bank haddock (Graham, 1952b). We calculated, using Beverton's (1952) formula, that with known growth and mortality rates and with present fishing effort, the optimum sustained yield would be obtained if the effort were applied to ages down to but not below three. Since there is a market for fish somewhat smaller than three-year-olds, fish of ages down to two and one-half years or slightly younger were regularly landed.

Accordingly the size of mesh in the cod end of nets was adjusted to allow escapement of fish two and one-half years of age and younger (Graham, 1952b). The lowest age of capture with the small mesh cod ends had been one and one-half years. Again using Beverton's formula we calculated that increasing the lowest age of capture from one and one-half years to two and one-half years would increase the annual landings of haddock about 30 per cent after a new equilibrium had been attained if fishing effort remained the same. With this lowest age of capture the effort could be considerably increased without reducing the total yield. In fact, greater total yields would be expected with fishing intensity increased up to 25 per cent.

The immediate effect of the regulation was expected to be a slight decrease in landings due to a loss of a few small marketable fish. This decrease was expected to be less than 10 per cent the first year and to be compensated by benefits the second year. Thereafter there were to be increasing benefits until maximum was attained several years later.

1/ This paper was read at the North American Wildlife Conference in Chicago, March 9, 1954 and will appear in the transactions of that conference.

The results of the first few months of regulation have been more gratifying than expected. The small fish have been saved but the expected initial decrease in landings has not occurred. Instead there has been a definite benefit enjoyed by the large mesh boats beginning from the time of conversion.

Figures 1 and 2 present a comparison of size distribution of fish caught by licensed small mesh vessels with that of fish caught by the large mesh vessels. It will be noted first that the quantity of discarded fish was reduced to a negligible amount by the use of the large mesh. Over two million haddock were saved by the use of these nets during the first half year of the regulation and its use was not general for more than three months of that period. Another point demonstrated by these data is the lower landings of marketable fish under 40 cm. in length (2.5 pounds) by large mesh vessels. This loss, however, was more than compensated for by greater numbers of large fish caught and landed. Since these larger fish weigh more per individual, the net result was a benefit to the large mesh boats.

The magnitude of this benefit is shown in Table 1. It will be noted that the average landings of haddock by the large mesh boats during the last three months of 1953 were about 2,000 pounds per trip greater than that of the small mesh boats. Other species of fish such as cod and pollock were also taken in greater quantity by the large mesh boats. The total of all species landed by large mesh boats was about 8,000 pounds greater per trip.

This direct comparison of landings of small mesh boats and large mesh boats for the same period is not a fair one because no account is taken of different sizes and efficiencies of the vessels represented. A more valid test is a comparison of each group's landings in the three months of 1953 with their respective landings in the same period in 1952. This comparison is also shown in Table 1. It will be noted that in the 1952 period the average catch per trip of haddock by the main part of the fleet, those boats which were subjected to regulation in 1953 (Group B), was less than the average catch per trip of the eight boats which in the 1953 period were licensed to continue fishing with the small mesh (Group A). Their total catch of all species, however, was slightly greater than that of the selected eight boats. Apparently the particular eight boats later selected for licensing normally tended to fish in areas in which haddock are proportionately more available than other groundfish.

In 1953, during the period of complete conversion of all regulated vessels, the catch of haddock from Georges Bank was down for all boats but to a greater degree for the licensed study boats. The total catch of all species held steady for the large mesh vessels but went down 10 per cent for the licensed boats.

The landings of groundfish at Boston alone during the three month period amounted to about 33 million pounds, worth about three million dollars as landed. Had the regulation not been in effect, this amount would have been about ten per cent less, or down by about $300,000. There is every indication that the advantage enjoyed by the large mesh vessels will continue throughout the year, when the benefit will be at the rate of $1,000,000 annually. 1/

1/ This is assuming that the net has the same beneficial effect on Nova Scotian banks as has been calculated for Georges Bank. A large proportion of the effort of the Boston fleet is now spent on Nova Scotian banks.

What is the reason for these better landings? It was suggested when the regulation was proposed (Graham, 1952b, p.30) that the new nets might prove more efficient and thus reduce any deleterious initial effect caused by the loss of some small marketable fish. Experiments by Davis (1934) in England had indicated greater catches of the larger sizes of haddock with a three inch mesh than with a two and one-half inch mesh.

When the advantage of the larger mesh in the Boston fleet was first noted, it was suggested that perhaps the fishermen had changed their fishing practices. Colton (unpublished manuscript) has found that there is to some extent a separation of sizes of haddock with depth. At certain seasons of the year, at least, larger haddock are found in depths greater than 90 fathoms, and the actual pounds of haddock available per tow are greater there than in depths less than 60 fathoms.

If fishermen should tend to fish deeper in order to avoid concentration of small fish because of a loss of some of the smaller sizes, they would obtain larger catches by dragging in the areas of larger fish. However, our present analysis of the distribution of fishing effort with depth does not reveal any difference in the habits of the large and small mesh boats. The study boats during the last three months of 1953 spent as much of their time proportionately in depths over 90 fathoms as did the large mesh boats. We are forced to conclude for the present, at least, that the comparatively greater landings of the large mesh boats is due to greater efficiency of the large mesh nets.

The effect of the conservation of the young fish will, of course, not be evident for a year or two. This advantage will be added to that resulting from the more efficient net. The increased catch of the larger fish will not negate the value of conserving the small fish. Increasing the efficiency of the net constitutes an increase in the fishing effort and, as stated above, increasing the effort up to 25 percent will result in increased total sustained yield.

Thus the large mesh net seems to be operating with a double advantage: small fish are being saved to add to the catch later at the same time that catches of larger fish are being immediately increased.

THE END

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TABLE 1. Comparison of Landings of Small Mesh and Large Mesh Vessels from Georges Bank

A. Average catch per trip* for period October, November, December, 1953

Group	Haddock Pounds	All Fish Pounds
Group A (8 Small Mesh Boats)	47,700	67,300
Group B (32 Large Mesh Boats)	49,600	75,500

B. Comparison of landings during October, November, December, 1952 with same period in 1953.

Group	Landings of Haddock Pounds per trip			Landings of All Fish Pounds per trip		
	1952	1953	% change	1952	1953	% change
Group A (8 boats)	60,900	47,700	-21.7	75,200	67,300	-10.5
Group B (32 boats)	54,800	49,600	- 9.5	75,400	75,500	+ 0.1

*The number of days fished per trip is fairly standard as the length of trip is subject to union regulation.

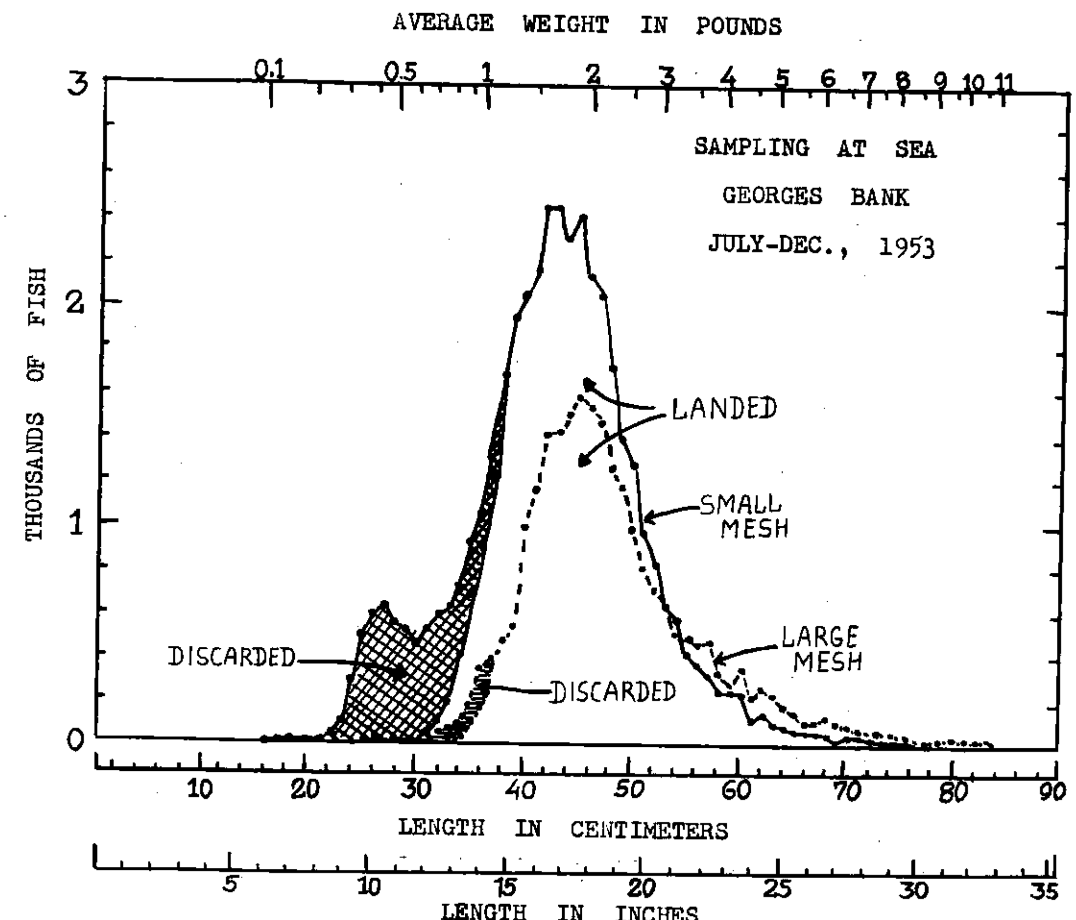

Figure 1. Size composition of catch of 14 observed trips, July to December, 1953. Vertical scale represents numbers of fish taken by each group of boats.

Figure 2.

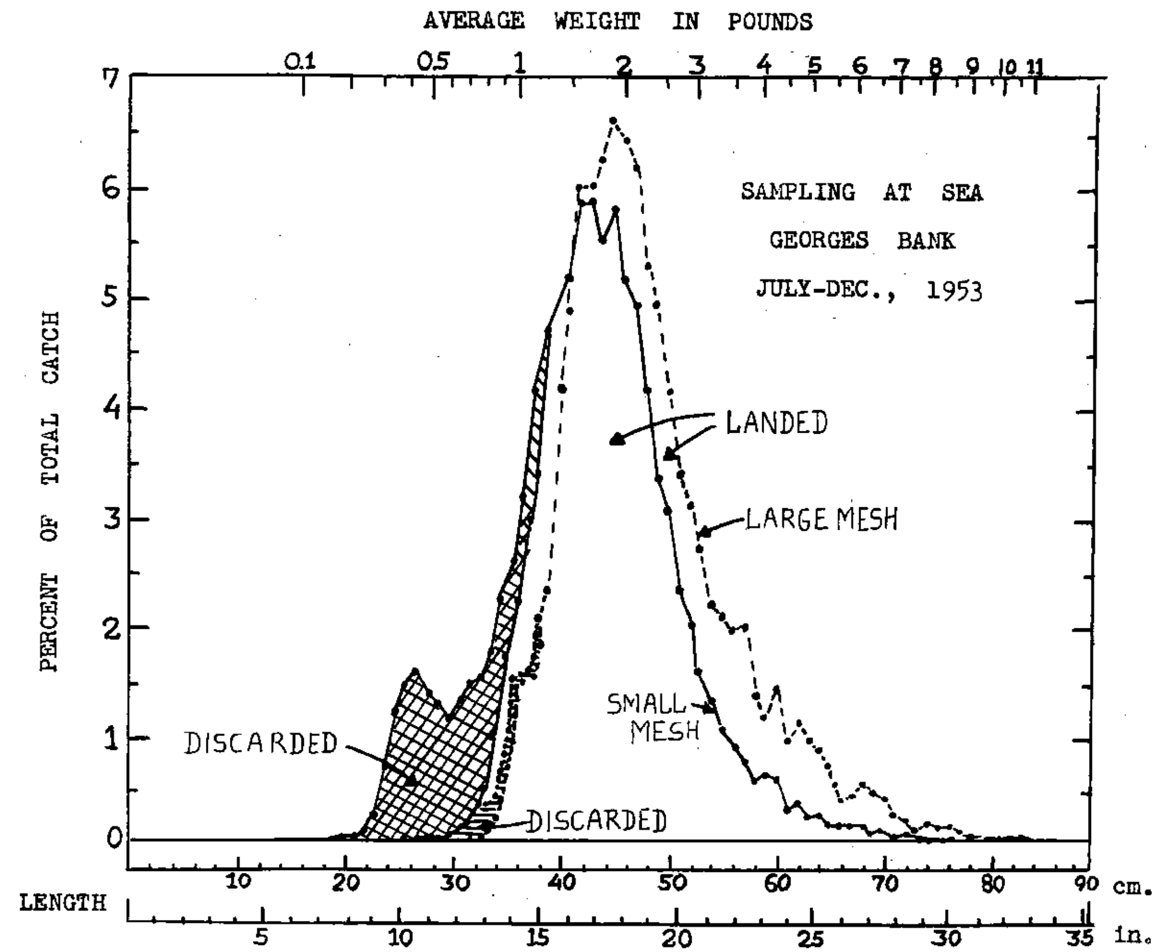

Figure 2. Size composition of catch of 14 observed trips, July to December, 1953. Vertical scale in percent of total catch of each group of boats.

SOME DYNAMIC CONSIDERATIONS IN REGULATING THE GEORGES BANK HADDOCK FISHERY

by CLYDE C. TAYLOR 1/

INTRODUCTION

The haddock fishery of Subarea 5 of the Convention Area, which includes Georges Bank and the Gulf of Maine, is now subject to a mesh regulation which has changed the age of first capture of haddock from about $1\frac{1}{2}$ years to $2\frac{1}{2}$ years. The considerations which led to the enactment of this regulation have been given by Graham (1952).

The enactment of a regulation of mesh size in Subarea 5 is in accord with the purpose of the International Convention for the Northwest Atlantic Fisheries, the Preamble of which states that the participating governments have resolved to conclude a convention "in order to make possible the maximum sustained yield from those fisheries." It is necessary in evaluating regulations or other measures proposed to achieve this purpose to consider the dynamic factors which influence the characteristics of fish populations, especially insofar as these factors may be controlled by man. It is our purpose to examine the probable effects on yield of changes in the amount of fishing and changes in the age of first capture of haddock with particular reference to the Georges Bank fishery.

<u>The theoretical model</u>: The primary factors in an exploited fish population were first elucidated by Russell (1931) and are expressed in the equation:

$$S_2 = S_1 + (A+G) - (M+C) \qquad (1)$$

where S_2 is the stock at the end of the period, S_1 is the stock at the beginning of the period, $\underline{A}$ is recruitment, $\underline{G}$ is growth, $\underline{M}$ is natural mortality and $\underline{C}$ is the catch. In a steady state, $S_1 = S_2$, which is equivalent to saying that removals by natural mortality and fishing are balanced by increments through growth and recruitment.

Equation (1) is axiomatic. Since its elements are interrelated and dependent, it is quite impossible to apply it directly to an analysis of the theoretical effects of changes in its factors on a population.

In the following analysis of the effects of altering the age of first capture of haddock through mesh regulation or of changing the amounts of fishing concentrated on the Georges Bank haddock stock, the theoretical model developed by Beverton and Holt (Beverton, 1953; Beverton and Holt, in press) is followed. The general assumptions implicit in the form of the model we have used, and the particular assumptions applicable to the Georges Bank haddock fishery are as follows:

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For any level of fishing intensity and age of first capture, it is assumed that the fishery is in a steady state with growth, recruitment and mortality rates constant. It is assumed that the rate of decline of the population at any time is proportional to the population present at that time. From the age of first recruitment to the fishing area (t_ρ) to the age of first capture by the fishing gear ($t_{\rho'}$), all deaths are assumed to be due to natural mortality, so that we have:

$$N_{t_{\rho'}} = Re^{-M(t_{\rho'}-t_\rho)} \qquad (2)$$

where R is the number of fish recruited to the fishing area at age t_ρ, $N_{t_{\rho'}}$ is the number of fish surviving to enter the exploited phase of the fishery, and M is the instantaneous natural mortality rate.

Beginning at age $t_{\rho'}$, the fish are subject to both fishing and natural mortality. It is assumed that during their first year in the exploited phase, one-half of the fish are retained by the nets, the other half escaping through the meshes. It is further assumed that all haddock die at the end of their twelfth year of life (t_λ).

Letting F indicate the instantaneous fishing mortality rate, we have, then, beginning at age $t_{\rho'}$:

$$N_t = + N_{t_{\rho'}} e^{-(F + M)(t - t_{\rho'})} \qquad (3)$$

In order to make the model apply as realistically as possible to the particular conditions existing in the Georges Bank Fishery, the habits of the fishermen in discarding fish of unmarketable size have been taken into consideration. The extent of this destruction has been described (Premetz, 1953). Through knowledge of the selection properties of the gear (Clark, 1952a, 1952b) and the cull curves (Premetz, 1953), a correction factor has been applied to the yields of fish between the ages of one and three. It is assumed, for example, that haddock are recruited to the fishing area at age one. If the gear in use captures fish of this age, it is assumed that none are saved for the market. The yield in weight of these fish is, then, always zero, although they are a loss to the population because they are destroyed in the process of capture.

The introduction of these practical considerations into the model makes it necessary to compute yields in numbers and in weights on a year to year basis during the lifetime of a year-class in the fishery. We have found it inconvenient, therefore, to use Beverton's (1953) yield-in-weight equation even though the advantages of its use are quite obvious. The computations and summations we have used do not, however, differ in principle.

Growth rate of Georges Bank haddock: The fundamental biological characteristic which distinquishes the yield curves on one species of fish from those of another is the growth rate. If the gear of a fishery is stabilized so that its selectivity among the smaller and younger fish is constant, the growth function may be effectively represented by the actual sizes at each age of fish in the commercial catch. Once the gear is altered, however, we must know the actual size composition of each age and the actual growth rate to properly assess the effect of the new gear.

Scales for growth studies have been collected routinely during Season A (February, March and April) since 1931. These data have been analyzed for ages three through six and back-calculations of sizes at each age have been made. Since the gear in use prior to June, 1953, retained all fish three years and older, we have used the average sizes at ages three through six in our growth curve.

For ages one and two, we have used a mean size based on back-calculations and weighted by the relative numbers of ages three through six in the average annual catch.

The parameters of Beverton's modification of the Bertalanffy growth equation were determined by fitting a regression line to a Walford plot of the growth data (Walford, 1946; Beverton and Holt, in press). The resulting equation, giving length at age t is:

$$L_t = 66.86 \ (1 - e^{-0.3436t}) \qquad (4)$$

Equation (1) provides a means of extrapolating to sizes at ages older than six where scale reading analysis data are not available. The unweighted growth in length data (Graham, 1952) are shown in Figure 1, together with the Bertalanffy curve fitted to the weighted data.

Since Beverton's (1953) yield-in-weight equation is not used in our computations, we have preferred to use the actual length-weight relationship for Georges Bank haddock in Season A, rather than a cubic relationship. The equation is:

$$\log W = 2.7793 \ \log L - 4.2322. \qquad (5)$$

Yield Curves: Yield-isopleth diagrams (Beverton, 1953) have been constructed for the Georges Bank haddock fishery for two levels of natural mortality. Figure 2 shows the yield-isopleth diagram constructed with an assumed natural mortality of 0.2 and Figure 3 with an assumed natural mortality of 0.1.

Interpretation of the yield-isopleth diagrams may be facilitated by examining Figures 4 and 5. Figure 4 is a yield curve for a constant fishing mortality rate of 0.4 and a natural mortality rate of 0.2 while the age of first capture is varied from ages one to 12. It is a vertical cross-section of Figure 2 at the point $F = 0.4$. Figure 5 is the yield curve in which the age of first capture is held constant at $t_{\rho'} = 2.5$ while the fishing mortality rate is varied. It is a horizontal cross-section of Figure 2 at the point $t_{\rho'} = 2.5$.

It will be noted that there are two lines of maxima crossing the surface of the yield-isopleth diagrams, indicated by the lines AA' and BB'. AA' indicates the fishing intensity which will produce the maximum sustained yield for any given age of first capture. BB' indicates the age of first capture which will produce the maximum sustained yield for any given level of fishing intensity.

Eumetric yields: For any given value of the instantaneous fishing mortality rate, F, we see from Figures 2 and 3 that there corresponds an age of first capture which produces a maximum yield. These maxima are joined by the lines BB' in the two figures. Beverton (1953) calls the line BB' the eumetric fishing curve and suggests that the adjustment of fishing intensity and age of first capture to the criterion of eumetric fishing is the principle which should underlie regulation of any commercial fishery in which $t_{\rho'}$ can be varied. This is, of course, the principle underlying the regulation of mesh size in Subarea 5 of the Convention Area.

In Figure 6, the eumetric fishing curves of Figures 2 and 3 are shown two-dimensionally. The value of $t_{\rho'}$ corresponding to each level of F is understood to be that which produces the maximum sustained yield as defined by the lines BB' in the yield-isopleth diagrams.

The probable effects of mesh regulation: With the population model for the Georges Bank haddock fishery of the preceding sections, it is possible to assess the direction and magnitude of changes in yield to be expected for any age of first capture or level of fishing. The effects must apply only to average conditions over a period of years, since in the simple model used, all the assumptions in its construction are not fulfilled. Recruitment and fishing intensity are not, for example, constant from year to year. They have tended, however, to fluctuate about constant mean values so that over a period of years the general implications of the model are not invalidated. Natural mortality and growth rates may be functions of population density. Beverton (1953) has shown that the introduction of density-dependent growth and natural mortality into the population model does not alter the general character of the eumetric yield curve.

Prior to June, 1953, the mesh in use by the New England haddock fleet had a fifty-percent selection point at about $1\frac{1}{2}$ years (Graham, 1952). The average annual yield from Georges Bank was 94.2 million pounds and the average days fished was 7,278 standard trawler days. The total annual mortality rate averaged 45 percent, of which 30 percent ($F = 0.4$) was considered fishing mortality and 15 percent ($M = 0.2$) was considered natural mortality. Entering Figure 2 at $F = 0.4$ and $t_{\rho} = 1.5$, we see that the yield per 10,000 recruits is somewhat less than 10,500 pounds. We also note that the maximum yield (line BB') for an age of first capture of 1.5 would be obtained with a fishing mortality rate of slightly less than 0.3. It is apparent, therefore, that a decrease in effort of about 25 percent would have increased the maximum yield slightly for the gear then in use. This increase would have amounted to about 2.6 percent, or in terms of annual landings, would have increased the catch from an average of 94.2 to 96.6 million pounds. While this increase is small, in fact almost negligible, the important fact is that the same or slightly greater landings could have been effected with only about three quarters of the effort expended, a fact suggested by Nesbit (1952). The stock of haddock was also being overfished in the sense suggested by Burkenroad (1952).

Again examining Figure 2 at $F = 0.4$ we note that an age of first capture of 2.5 indicates a yield of about 13,500 pounds per 10,000 recruits, an increase of about 30 percent over that obtained with an age of first capture of 1.5 years. This is the theoretical increase in catch expected to result from the increase in mesh size effected by the haddock regulation in Subarea 5.

Two other facts of importance are to be learned from Figure 2. First we note that in advancing the age of first capture from 1.5 to 2.5 we have crossed over the line AA' and that the maximum sustained yield would now be obtained with an increase in the fishing mortality rate to about 0.65, so that the stock is being underfished in the sense that the average effort is less than that necessary to produce the maximum sustained yield. We also note that for $F = 0.4$, the optimum age of first capture should be about 3.5 years.

Since the natural mortality rate for Georges Bank haddock is not known, it is instructive to consider the effect of rates other than 0.2 on the equilibrium yields. As stated by Graham (1952), it was the considered opinion of the advisers to Panel 5 that the natural mortality rate does not exceed this value, and he pointed out that benefits from increase in the age of first capture could be expected at considerably higher natural mortality rates.

Figure [illegible] indicates the general level of results to be expected if the natural mortality rate is only half as great ($M = 0.1$). We note at once that yields are considerably greater at all values for ages of first capture and rates of fishing mortality. The percent increase in yields in advancing the age of first capture from 1.5 to 2.5 years is approximately the same. It is to be noted, however, that the optimum age of first capture for $F = 0.4$ is now about 5 years, and that in advancing the age of first capture from 1.5 to 5.0 the increase in yield would be about 55 percent.

<u>The effect on yields of exempting certain vessels from regulation</u>: Many of the smaller vessels in the New England fleet fish only part-time or during certain seasons for haddock, or may catch varying quantities of haddock incidental to the pursuit of other species. Since the greater part of their effort is expended on species other than haddock, the requirements that these boats conform to the mesh regulation may be undesirable or may create expensive enforcement procedures. If these boats, or any portion of them, are to be exempted from regulation, it is necessary to know what effect such exemption will have on landings and on the total benefits to be expected from regulation.

The effort of any group of exempted vessels, in standard boat-days, is measured by the ratio of the catch of haddock of the exempted group to the total catch by all vessels. Only one-half of this effort will be applied between the ages of 1.5 and 2.5, since the small mesh used by unregulated boats is assumed to retain only half the fish between these ages. After age 2.5, the nets used by exempted boats will retain all older fish, while the effort of regulated boats is assumed to be only fifty percent effective between ages 2.5 and 3.5, after which all fish are retained.

To estimate the effects of exemption, two curves (Figure 7) have been calculated on the basis of the above divisions of effort. The first (solid line) shows the percentage decrease in landings to be expected by exempting various percentages of the total effort. The second (dotted line) shows the percentage decrease in benefits of the regulation to be expected by exempting various percentages of the total effort.

The catch of haddock by each tonnage category of vessels from 5 to 150 gross tons was tabulated for the principal New England ports for 1952 and expressed as amounts of effort in terms of standard boat-days. In Figure 8 the data of Figure 1 are translated to these amounts of effort expended by all vessels under various gross tonnage from 20 to 150 tons.

- THE END -

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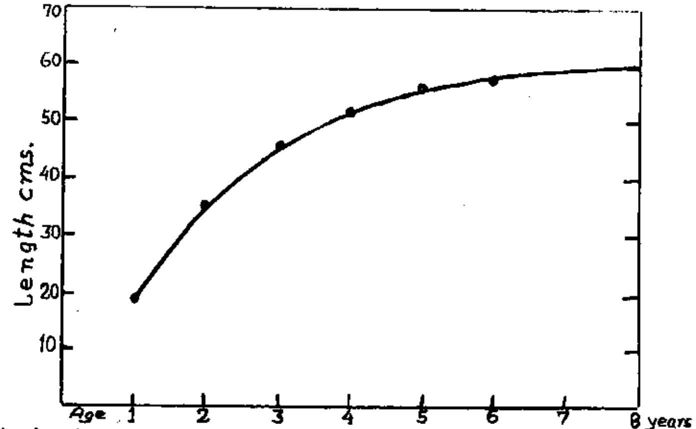

Figure 1. Growth in length of Georges Bank haddock. The solid line is the Bertalanffy curve fitted to weighted data (see text).

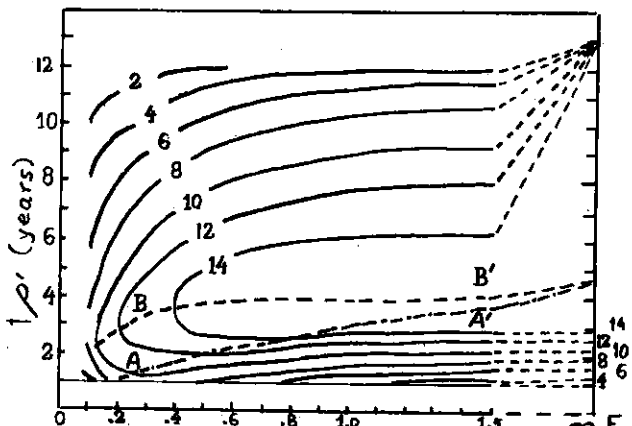

Figure 2. Yield-isopleth diagram for the Georges Bank haddock fishery when the instantaneous natural mortality rate is assumed to be 0.2. Abscissa-instantaneous fishing mortality rate. Ordinate-age of first capture. Yields in thousands of pounds per 10,000 fish recruited at age one.

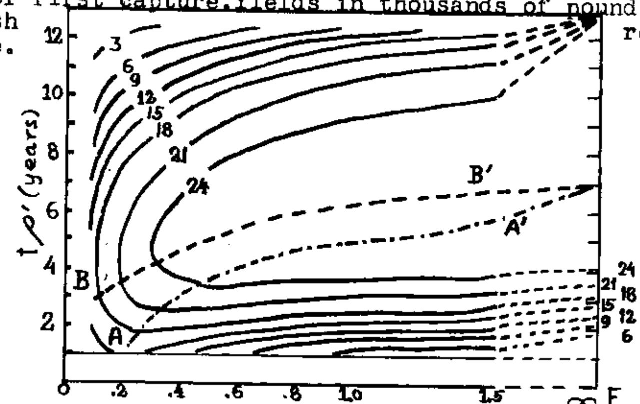

Figure 3. Yield-isopleth diagram for the Georges Bank haddock fishery when the instantaneous natural mortality rate is assumed to be 0.1. Abscissa-instantaneous fishing mortality rate. Ordinate-age of first capture. Yields are in thousands of pounds per 10,000 fish recruited at age one.

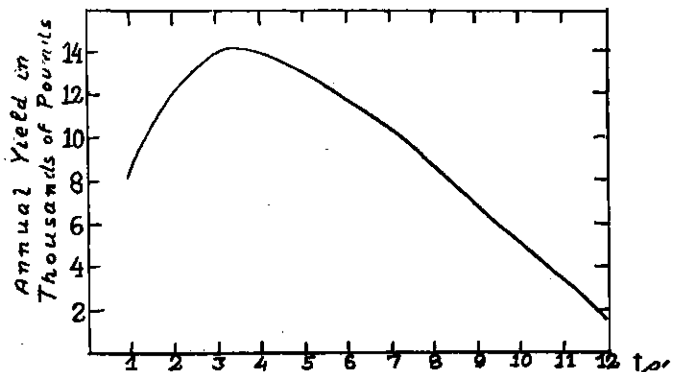

Figure 4. Cross-section of figure 2 at F = 0.4. The annual yield is in thousands of pounds per 10,000 fish recruited at age one.

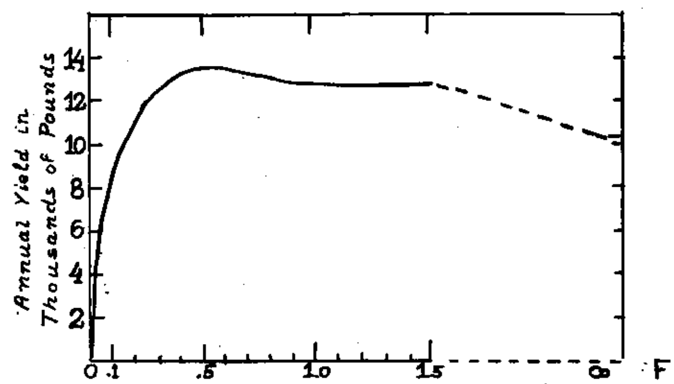

Figure 5. Cross-section of figure 2 at $t_{\rho'}$ = 2.5. The annual yield is in thousands of pounds per 10,000 fish recruited to the fishery at age one.

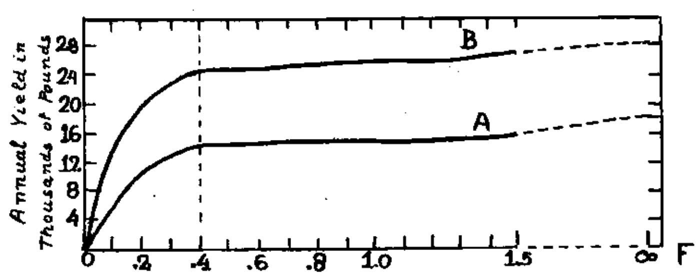

Figure 6. Eumetric yield curves for the Georges Bank haddock fishery. Curve A is with an assumed natural mortality rate of 0.2. Curve B is with an assumed natural mortality rate of 0.1. Yields are in thousands of pounds per 10,000 fish recruited at age one.

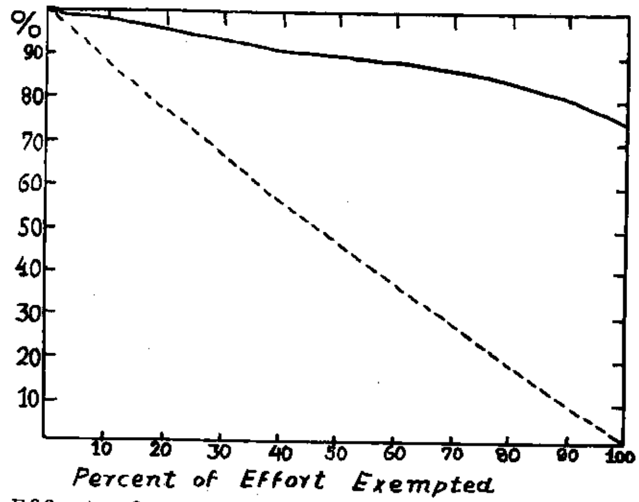

Figure 7. Effect of exempting various percentages of the total effort from mesh regulation. The solid line shows the percentage decrease from the maximum sustained yield. The broken line shows the percentage decrease in benefits to be derived from mesh regulation.

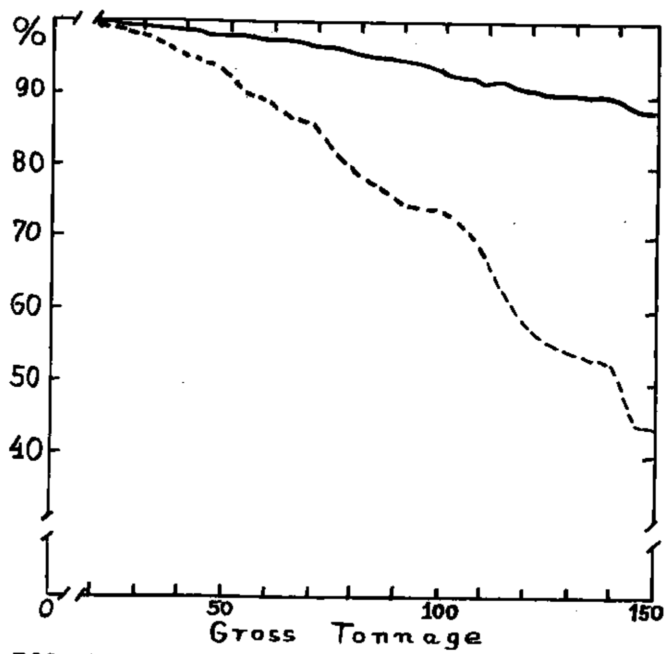

Figure 8. Effect of exempting all boats under various gross tonnages in the New England fleet from mesh regulation. The solid line is the percentage decrease in catch. The broken line is the percentage decrease in benefits to be derived from mesh regulation.