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# Effects of Increased Trawl Cod-End Mesh Size on Georges Bank Haddock Yields

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Upon recommendation by the International Commission for the Northwest Atlantic Fisheries, the United States and Canada adopted in 1953 regulations increasing the mesh of trawl cod-ends from 2-7/8 inches (73 mm) to 4-1/2 inches (114 mm) in ICNAF Subarea 5 (including Georges Bank). This was considered an international experiment in conservation and, as with any scientific experiment, measurement of the effects was essential for its evaluation. This measurement is of vital concern to the participating nations, Canada and the United States, and is also of great interest to other nations who see in this experiment a source of information as to the practicality of mesh regulations in their own fisheries. Historical background is given by Graham (1952) and evaluation has already been investigated by Graham (1954, 1956, 1957, 1958), Graham and Premetz (1954), Clark (1955), Taylor (1957, 1958a), Paloheimo (1958), Taylor and Dickie (1958), and Dickie (1958).

The conclusions of the authors cited above are not in complete agreement as to the correct approach to the problem nor as to the interpretation of the data adduced. The objectives of the present paper are to resolve conflicting findings insofar as possible, to add one new method of calculation, and to provide as firm as possible a preliminary estimate of the effects of the mesh increase on yield.

## Immediate Effects

The consequences which occurred as soon as the cod-end mesh was increased are illustrated by a comparison of length compositions of catches taken in the same year with the two mesh sizes (Fig. 1).

Elimination of the discards, indicated by absence of the mode of small fish in the frequency polygon for the larger mesh, saves these small fish, formerly thrown back dead, for growth to larger commercially valuable sizes. The length frequencies also indicate that the fish landed are larger in size, thus more valuable, with the larger mesh. Such large fish permit greater speed in handling, cheaper filleting, and more desirable fillets.

The excess of the large mesh catch over the small mesh catch in the right hand limbs of the frequencies is an automatic consequence of the smaller catch of the smaller fish by the larger mesh, since the frequencies are expressed in percentages. However, further analysis of the catch data revealed that this difference exists on an absolute as well as a percentage basis (Graham and Premetz, 1955).

Finally, the increased mesh size released undesired fish and non-living materials. Items in this category include hake, herring, pieces of shell and coral and the like. Labor formerly devoted to sorting out and discarding these items could be applied to more productive pursuits.

## Ultimate Effects

### Year Classes in the Fishery

The ultimate measure of any change in fishing practices is revealed in the yields obtained from a year class during its passage through the fishery. The standardized landings

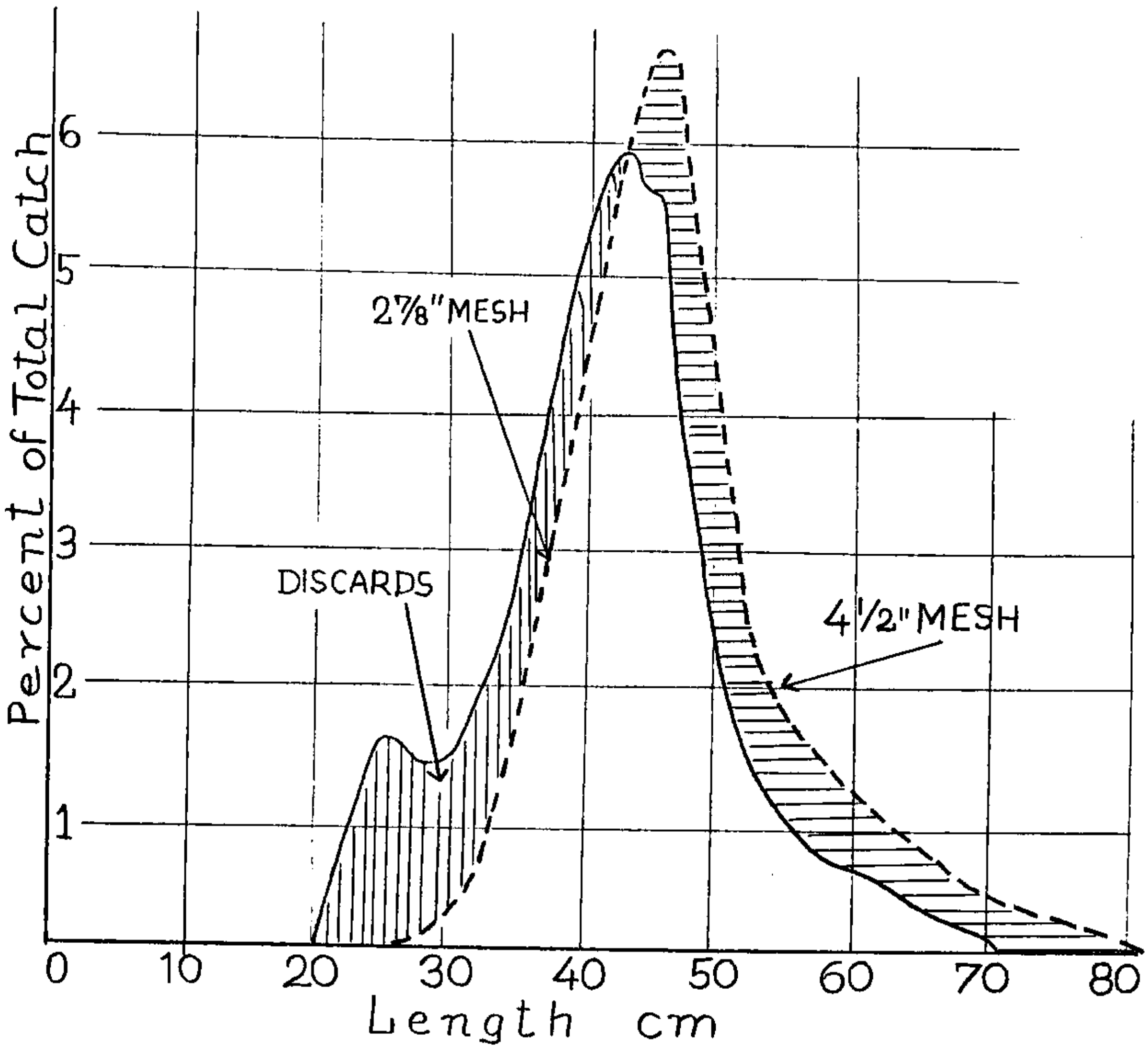


Figure 1. Comparison of sizes of haddock caught with two different cod-end mesh sizes. 14 observed trips, 7-12/53. Catch of each group reduced to 100%. Graham, ICNAF Ann.Proc. Vol.4, 1953-54, p.57, fig.2.

per-boat-day (Fig.2) for the years immediately preceding and succeeding institution of the mesh regulation indicates passage of three important year classes: those of 1948, 1950 and 1952. Of these, year class 1948 completed its significant contributions before mesh regulation in late 1953, year class 1950 straddled the regulation, and year class 1952 was exploited entirely with the new mesh size in effect. Thus comparison of the yields of the 1948 and 1952 classes should provide information on the results of the change in mesh size.

Comparison of 1948 and 1952 Year Classes

Assuming for the moment (this assumption will be treated more fully below) that these two year classes had the same initial strength, analysis of total yields in numbers as numbers at each age.(Fig.3) reveals changes in age composition which are in accord with the theoretical effects of increased mesh size, with one exception. The exception occurs at age 2, where one would expect a lesser relative catch with the larger mesh size, whereas in actuality the proportions taken were almost the same. This anomaly may be due to changes in availability during the four-year interval between years of catch for the two classes.

Again assuming equal initial year class strength, catches at ages 3 to 5 were in accordance with expectations. Thus the age 3 fish were selected against by the larger mesh, resulting in a smaller representation in the catches. Fish at ages 4 and 5 were augmented by recruits which had escaped the larger mesh at young ages in earlier years, and had a

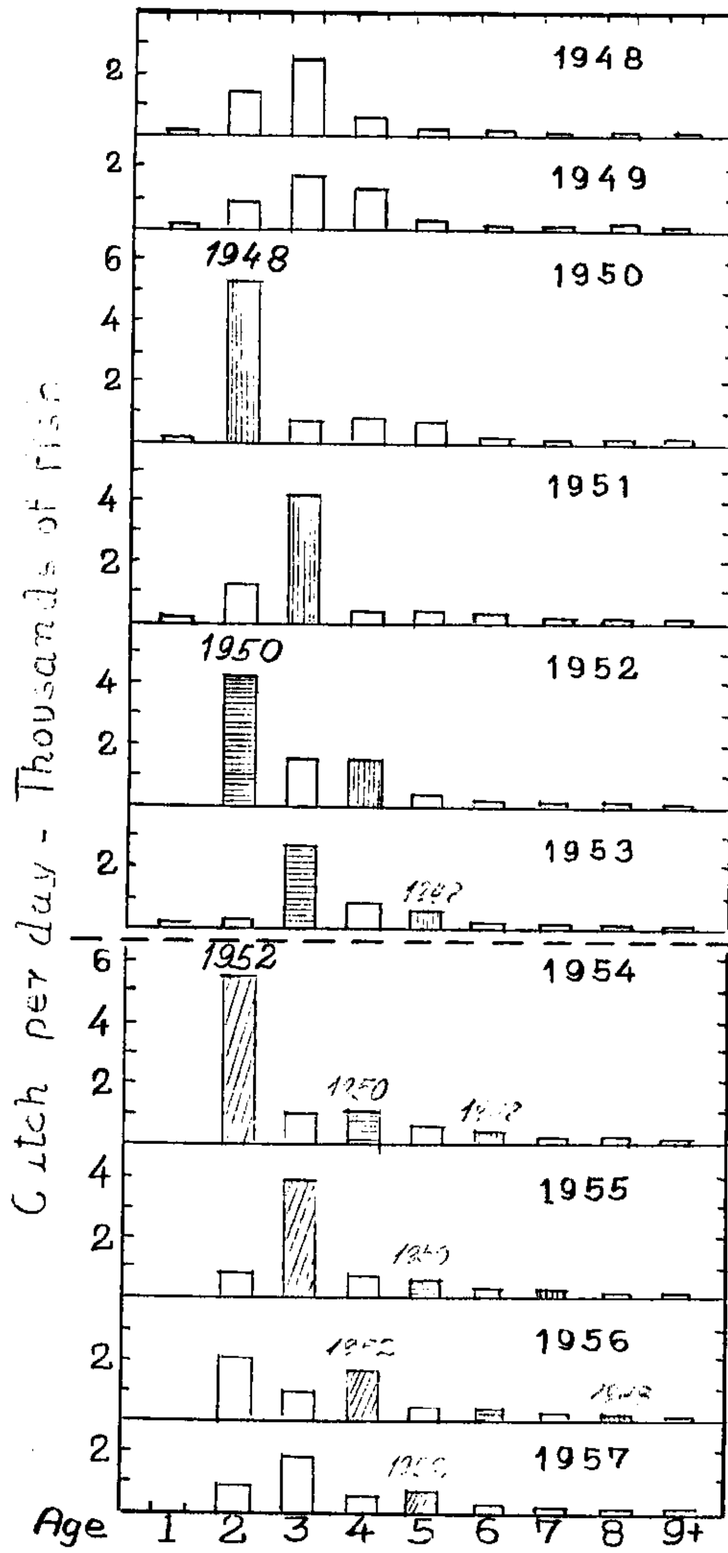


Figure 2. Catch-per-unit-effort (Day) of Georges Bank haddock by age groups, 1948-1957.

correspondingly greater representation in the catches.

If the total yields of year classes 1948 and 1952 are to be used in interpreting the effects of mesh change, their relative initial strengths must be known, and this question has been investigated by Taylor (1957) and Paloheimo (1958). These authors employed formulations that were essentially similar, and in which the effect was to work back from the known catches at certain ages to the unknown recruitment. Taylor found the lifetime yield of a year class to be closely related to the square root of its catch-per-day at age two, concluding that this relation correctly represented the relation between initial abundance of a year class and its catch-per-day at age two. Both Taylor and Paloheimo used identical values of the

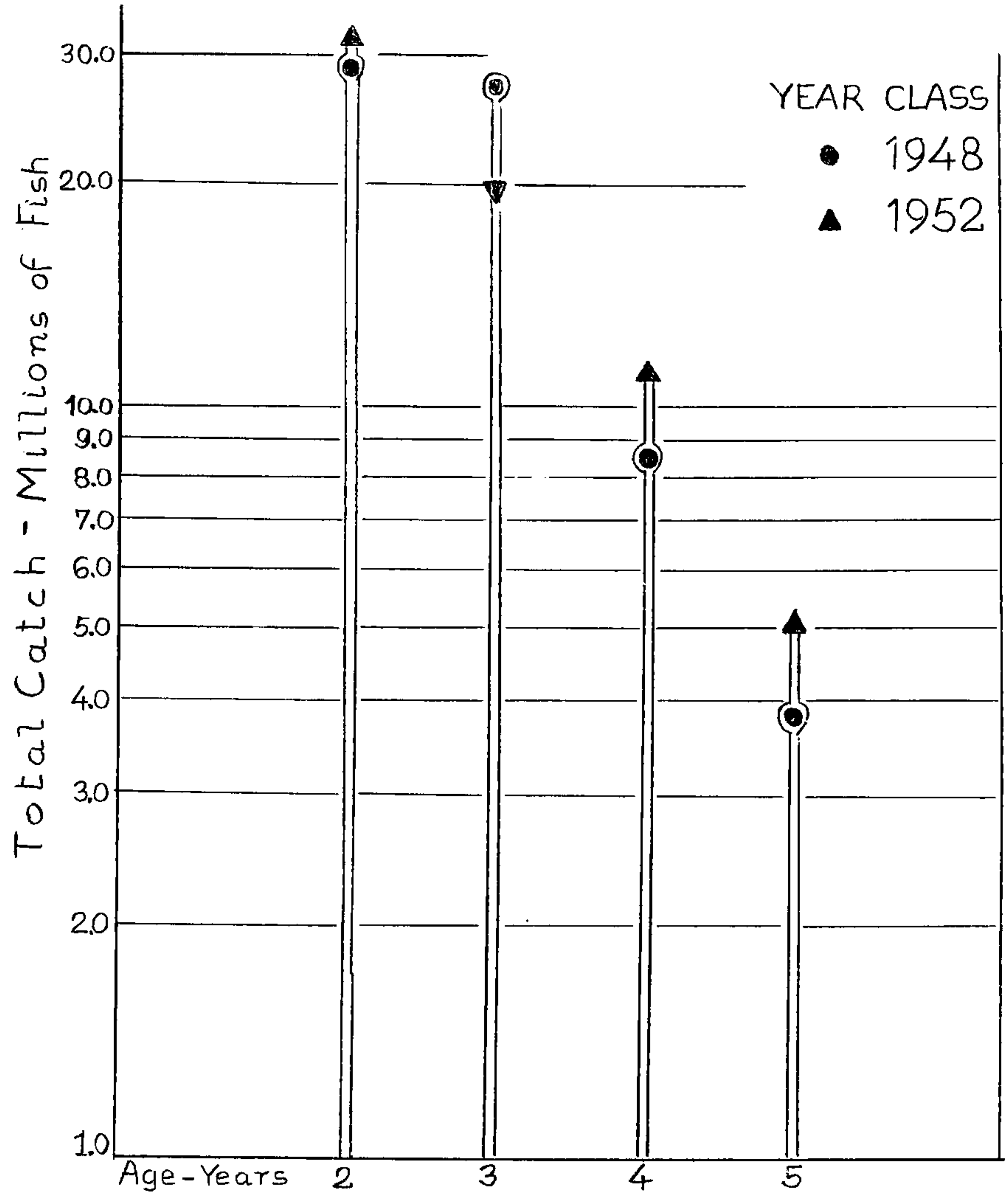


Figure 3. Yields at successive ages of two Georges Bank haddock year classes.

natural mortality coefficient M and the constant c relating fishing mortality to fishing effort; each of these constants was derived from data on several year classes. Taylor's final calculation used data from each year class at a single age (age 2) while Paloheimo's used data from several ages. Also Paloheimo's treatment allowed for the effect of discards under the smaller mesh, while Taylor's did not. Taylor estimated year class 1952 to be about 0.9 the initial strength of year class 1948, while Paloheimo found the two to have approximately the same initial strength. The two determinations might be considered to be in rather close agreement if one considered ordinary sampling errors and the sampling errors inherent in using the catch as a measure of the stock, in addition to such sources of error as imprecision in measuring number of fish landed at age, amounts and distribution of discards, year-to-year variations in availability, and imprecision in estimating effort. These errors arise from changes in selective availability due to varying distribution of both the stocks and the fishing fleet.

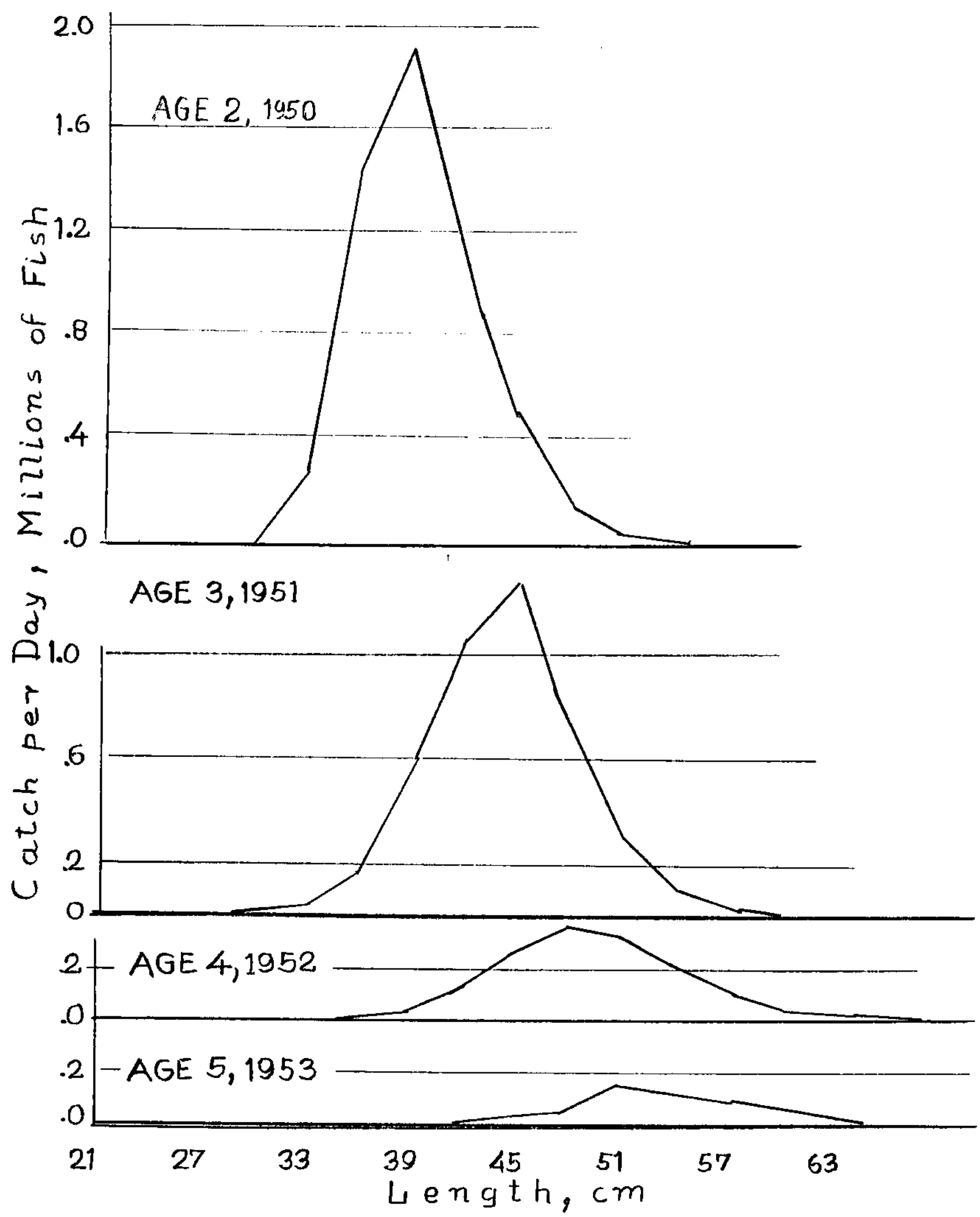


Figure 4. Georges Bank Haddock. Size composition at successive ages, year class 1948.

Because of the importance of information on initial strengths of year classes to the assessment of mesh effects, it was considered worthwhile to apply a third method. This method, as developed by the senior author, makes use of the length distribution of the two year classes at various ages. For the 1948 year class, the distributions (Fig.4) for ages 2 and 3 are skewed, presumably by mesh selection and selective availability, but approach normality for ages 4 and 5. This is brought out more clearly in an arithmetic probability plot of length frequencies for ages 2 and 4 (Fig.5). Similar treatment for year class 1952 (Figs. 6, 7) leads to similar findings.

The comparison described above indicates it to be a reasonable hypothesis that the basic length distribution of the fish within a year class is normal at any age, but that it is modified in the lower limb of the age 2 frequencies. By means of the probability plots (Figs. 5 and 7) it is possible to tell at what point the distributions approach normality. This occurs

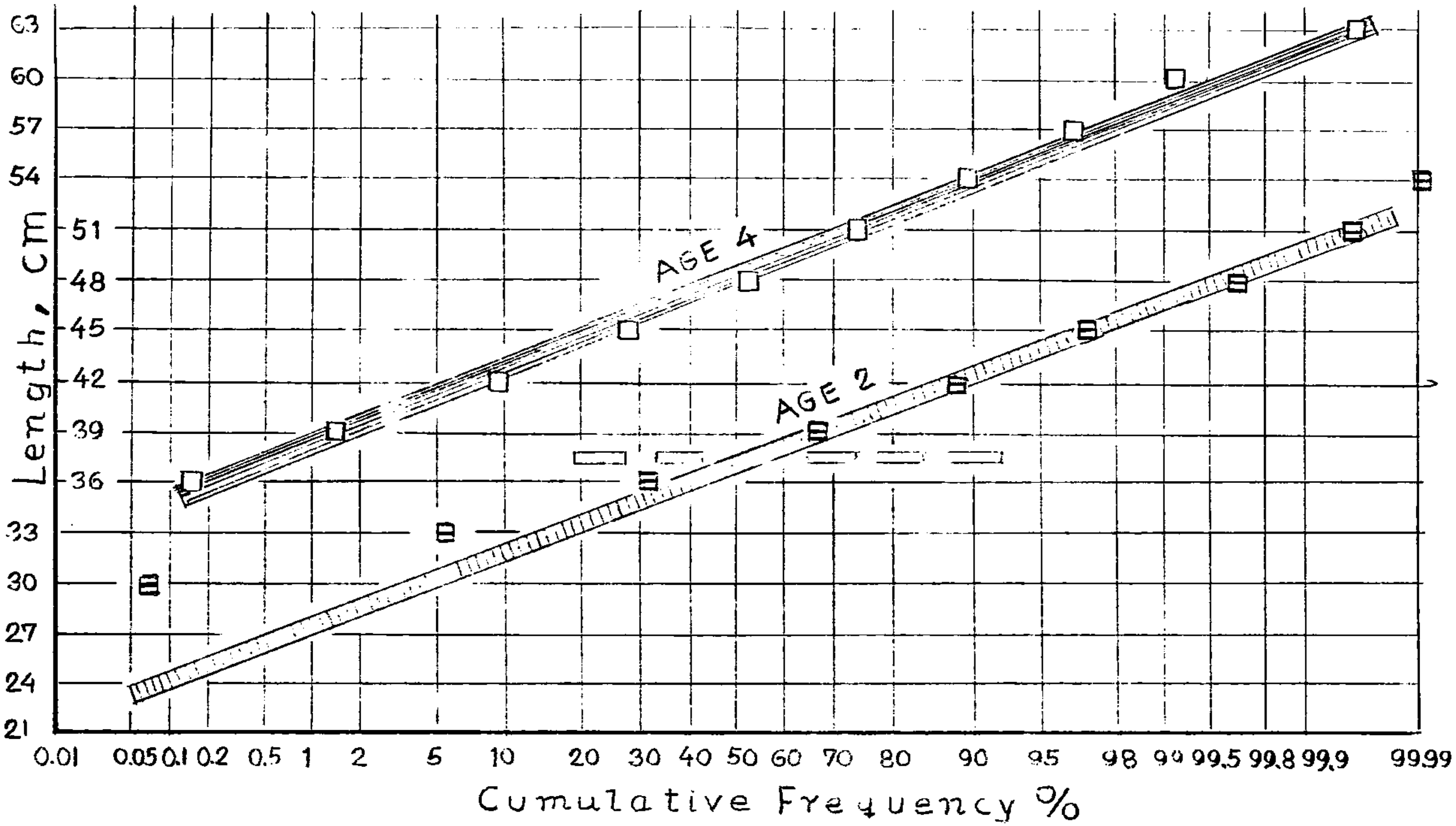


Figure 5. Georges Bank Haddock. Arithmetic probability plot of size composition, year class 1948 at ages 2 and 4.

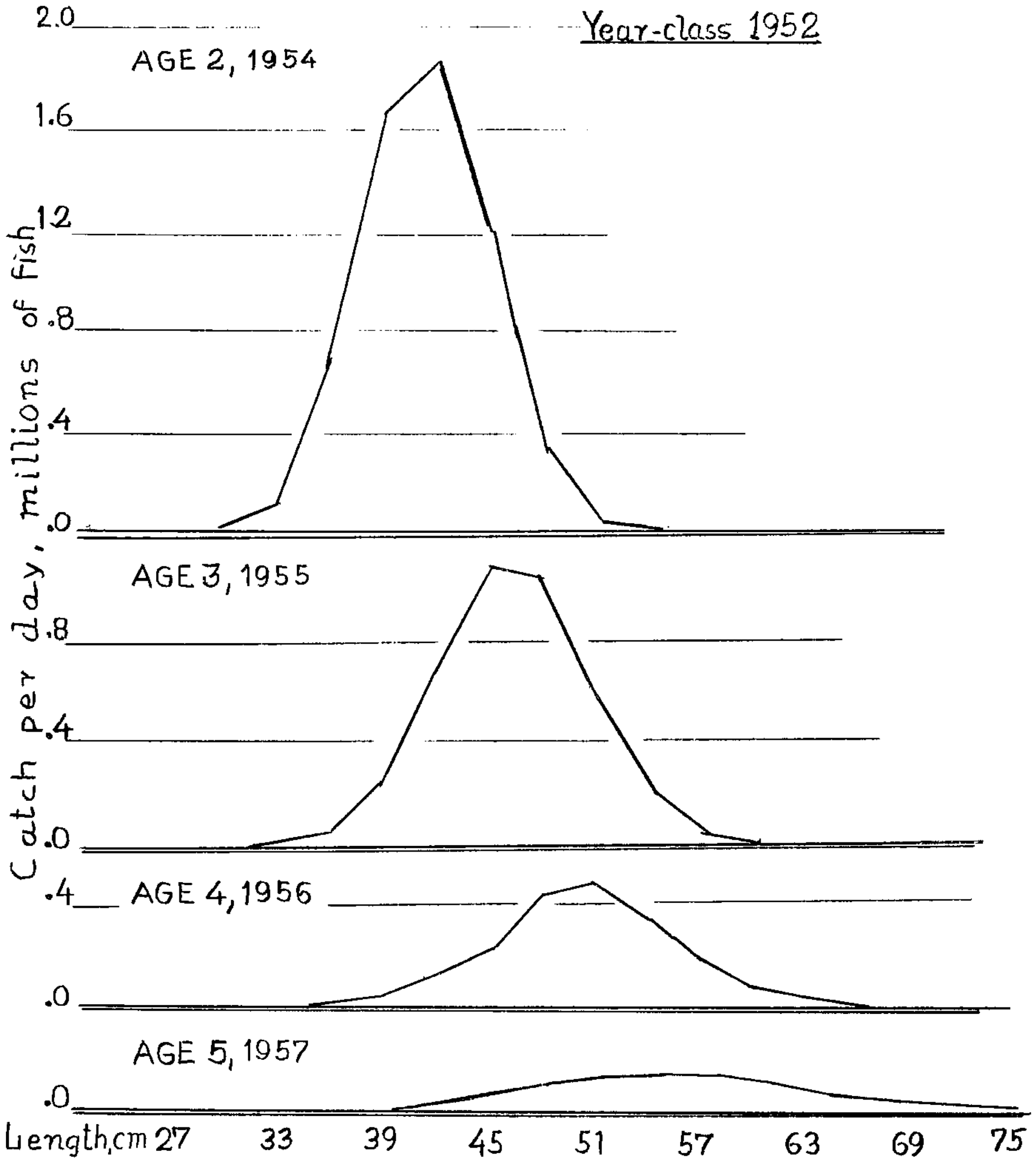


Figure 6. Georges Bank Haddock. Size composition at successive ages, year class 1952.

between 36 and 39 cm for year class 1948 and between 42 and 45 cm for year class 1952. Curves were fitted to the ordinates above these points in each case, disregarding the points for the largest fish, in which small numbers introduce excessive variability. Results of these fittings are brought out clearly in an ordinary length frequency plot (Fig. 8). Initial year class strengths are measured by the areas under the fitted curves, and results indicate year class 1952 to have 1.07 times the initial strength of year class 1948.

Like all graphical methods, the procedure described above is subject to a number of sources of imprecision. It will be of value in assessing the accuracy of the results to consider these sources. Obviously, for instance, the slope of the lines is much affected by the choice of cut-off point as well as rejections at the extreme right hand side of the distribution. Furthermore, for the 1952 year class the selection curve for the 4 1/2 inch mesh in use during its passage through the fishery overlaps the age 2 length distribution. Variation in selection and cull practices may have made the characteristics of the observed distributions

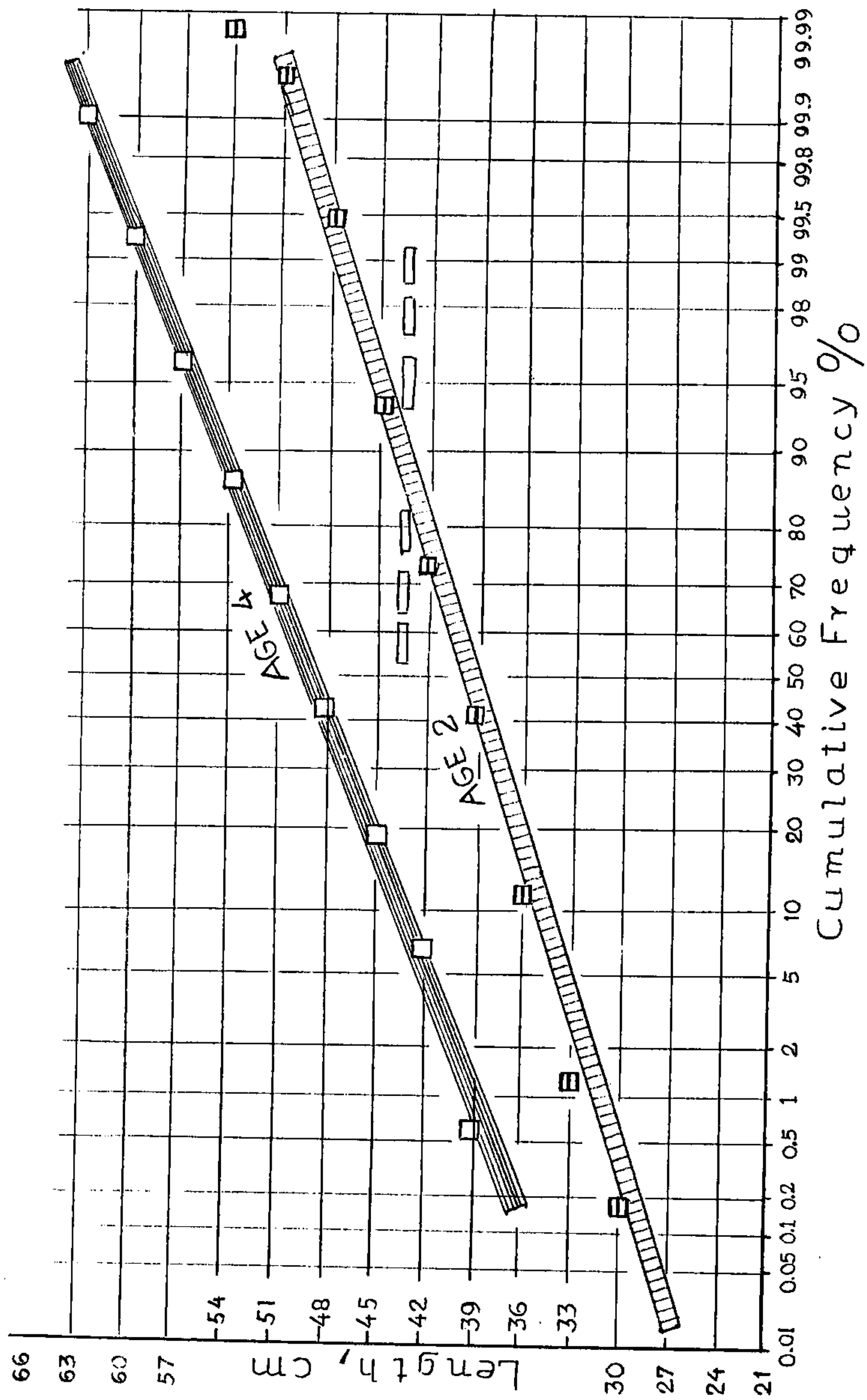


Figure 7. Georges Bank Haddock. Arithmetic probability plot of size composition, year class 1952 at ages 2 and 4.

different from those of the actual populations of haddock on Georges Bank.

Recapitulating, the following expresses three determinations of the relative initial strengths of year classes 1948 and 1952:

| Determination | Ratio, yc 1952/yc 1948 |
|---|---|
| Taylor (1957) | 0.90 |
| Paloheimo (1958) | 1.00 |
| Length frequency method | 1.07 |

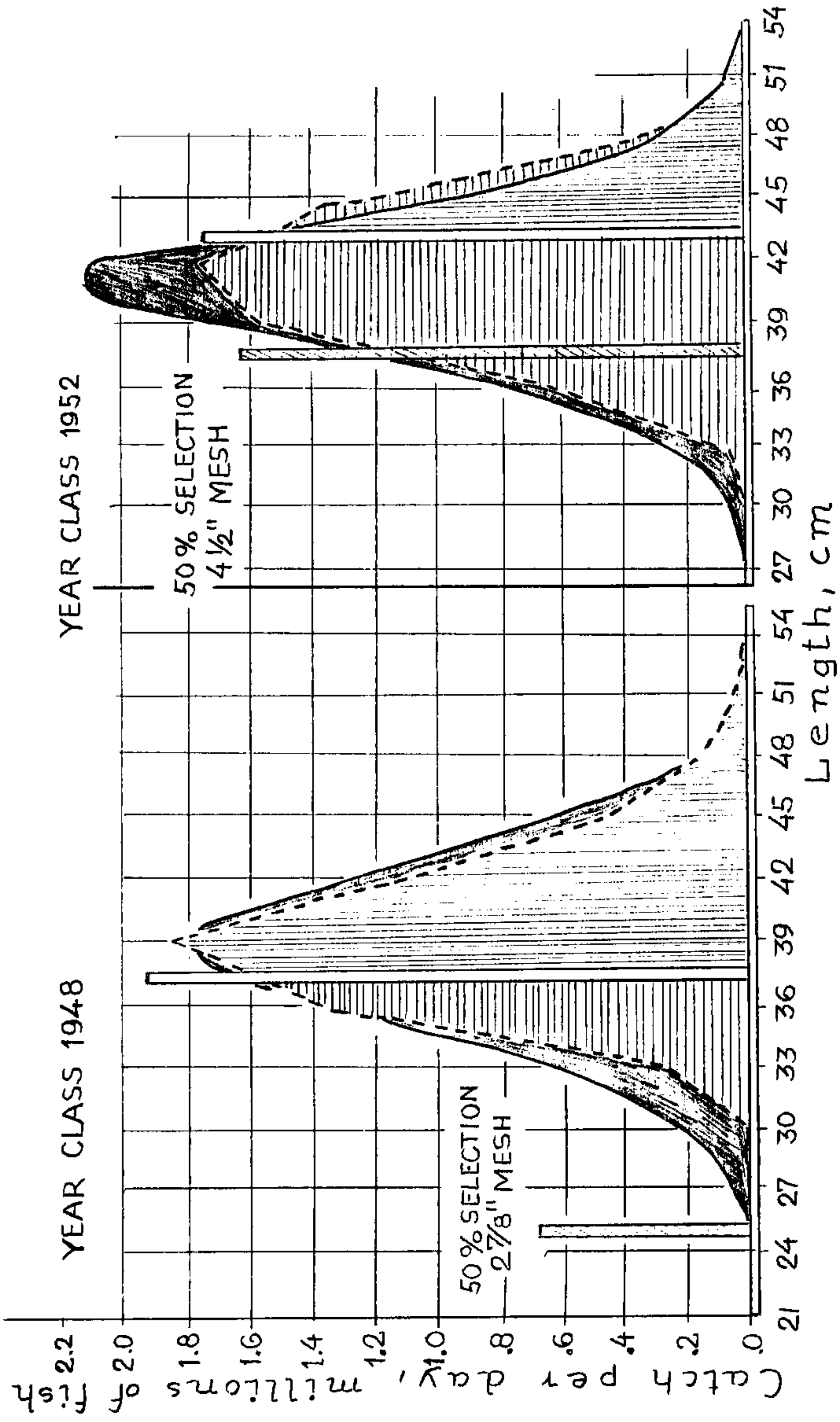


Figure 8. Georges Bank Haddock Age 2. Normal curves fitted to size composition of catch-per-unit-effort, year classes 1948 and 1952.

Again viewing these estimations as rough preliminary measures, we can probably say that they show the two year classes to be of approximately the same size. Provisionally accepting such a conclusion, yields of the two year classes may be used to measure the effect of the change in mesh size.

Comparison of Yields.

The pertinent data on 4 year effort and yield (Table 1) demonstrate that a slightly (but probably not significantly) reduced fishing effort produced 67.4 million haddock from year class 1952 within a 4-1/2" mesh, as compared with 68.0 million from year class 1948 with a 2-7/8" mesh, by the time each of these year classes had reached the age of 5 years. These data lend some support to the view that the gain in the weight of the yield from the 1952 year class resulted from taking it at a later average age.

Table 1. Georges Bank Haddock. Effects of Mesh Change. Comparison of characteristics and yields, year class 1948 and 1952.

Year Class...1948 - Ages 2-5; 1950-1953. 2 7/8" Cod End Mesh
Year Class...1952 - Ages 2-5; 1954-1957. 4 1/2" Cod End Mesh

| Characteristic | Year Class 1948 | Year Class 1952 |
|---|---|---|
| Initial Strength | Approximately Equal | |
| Fishing Effort Index | 408 | 400 |
| Yield, Millions of Fish...Age 2-5 | 68.0 | 67.4 |
| Yield, Millions of Pounds, Age 2-5 | 113.6 | 135.0 |
| Yield by Weight, in Percentage | 100. | 119. |

The above results, taken by themselves, may seem anomalous in that the numerical yield of the fishing intensity applied to year class 1952 was almost as great as that of the slightly greater intensity applied to year class 1948. Now the larger mesh used to fish the 1952 year class was designed to delay capture until the fish had reached greater age and size; it apparently did so except for age 2 (Fig.3). The age 2 anomaly has been attributed above to a change in availability, and no other rational explanation occurs to us at the moment. Leaving age 2 for future investigation, we find that the 1952 year class yield at age 3 was substantially less than that of year class 1948; the reverse was true at ages 4 and 5. This means that capture for some of the fish was delayed by 1 to 2 years. Since natural mortality was taking place we might expect the numerical yield of year class 1952 to be somewhat less than that of year class 1948; the small change that did occur was in this direction. The fact that there was no greater numerical decline in yield may be associated with fluctuating availability, specifically the greater number of fish taken at age 2 from the 1952 year class than the 1948 year class.

## Evaluation of Theoretical Yields

The increase in yield indicated above was considerably less than the 30 percent originally predicted (Graham, 1952). It is of interest to ascertain, if possible, the reasons for this discrepancy, and an examination of the basic data employed in the theoretical calculations is in order. We believe the most likely sources of error lie in the hypotheses made regarding natural mortality and the availability of the youngest fish.

### Natural Mortality

The theoretical calculations employed by Graham (1952) in justifying the proposed mesh increase employed an annual expectation of death from natural causes (v) of 15 percent, which with a total expectation of death (a) of 45 percent, is equivalent to an instantaneous natural mortality rate (M) of 0.20. This is supported by the statement: "It was the considered opinion of the advisers to Panel 5 based on experience in other fisheries that the natural mortality rate does not exceed 15 percent."

In his study of the effects of the 4-1/2" mesh Taylor (1957) used a value of M of 0.10. He based this on a study then in press about which he said "It was concluded that M probably does not exceed 0.2 and that 0.1 is a fair working value."

The most comprehensive study of haddock natural mortality rates to date has been that of Taylor (1958b), based on the catch-per-day of haddock for the 20 year period 1932-1951. For various ages of fish he quotes estimates of M ranging from -0.17 to 0.491. In conclusion he states: "Although a value of 0.2, which is equivalent to an annual mortality of 15 percent from natural causes, is sufficiently conservative for analytical purposes at the present time, other yield models with values of M ranging up to 0.4 must be explored."

Our brief review of the estimates of M published so far indicates that there is still considerable doubt about the true value of this parameter. It follows then, that theoretical calculations of mesh benefits are similarly in doubt. Use of too small a value of M would yield estimates of benefit that were too large, and too large a value would conversely yield estimates too small.

Availability Effects

It is well recognized that in most fisheries the youngest fish are not fully available to the fishermen, and the Georges Bank haddock fishery is no exception. Fish of age 1 are extremely rare in the catches (Fig.2). Research vessel catches have shown these fish to be largely distributed on parts of the Bank other than those frequented by the commercial fishery, and midwater trawl experiments indicate that they are pelagic during at least part of the year, thus escaping the bottom trawls. That age 2 also is not fully available is shown by the average age composition of the catch for the period 1932-1948 (Graham, 1952, Fig.6), in which 2-year fish comprise a smaller proportion than the 3-year.

To simplify the calculations, estimations of mesh effects reported by Graham (1952) were made under the assumption of full availability at age 1. Such an assumption can have considerable effect on estimated benefits, for it gives the larger mesh credit for saving fish that never were available to the fishery. It is worthwhile then, to make some estimates assuming lesser availability of the two entering age groups.

Crude estimations of the availability fraction can be made from length frequency distributions, and we did this using the data from some experimental trawling done on Georges Bank in 1951 (Graham, 1952, Fig.3). The procedure was to make by inspection a rough extrapolation of the length frequency backward from the length considered to be fully available (45 cm). This extrapolated "recruitment curve" provided indices of "abundance" at each length less than 45 cm., and particularly at 28 cm and 40 cm, the midpoints between ages 1 and 2, and 2 and 3, respectively. These midpoints represent the average age at capture for the first two years in the fishery. Dividing the catch index by the selection ogive provided corrected catch indices from which availability fractions could be calculated. Pertinent data are as follows:

| Length | Age | Indices in 1000's of Fish | | | | Fraction |
|---|---|---|---|---|---|---|
| cm | Yrs. | Abund. | Catch | Selection | Corrected Catch | Available |
| 28 | 1.5 | 21.4 | 7.0 | 0.8 | 8.8 | 0.4 |
| 40 | 2.5 | 16.5 | 11.2 | 1.0 | 11.2 | 0.7 |

It will be evident to the critical reader that this graphical method, like the other one described above, is subject to many errors. Chief among these, perhaps, is the visual extrapolation of the length frequency curve backward from 45 cm to 28 cm. Recognizing the validity of such criticisms, we nevertheless believe that the values are not unreasonable from what is known of the general biology of the Georges Bank haddock. The values of 40 percent availability at age 1 and 70 percent at age 2 of course refer only to selective availability caused by differential distribution of the various sizes of fish, and are in addition to selection exercised by the size of the trawl cod-end meshes.

Yield Curves.

Curves of yield at various ages of first capture (Fig.9), employing availabilities as set forth above, differ from those assuming 100 percent availability at all ages. Inspection of the curves calculated on the two bases show that curves (from Graham, 1952) based on 100 percent availability indicate much greater gains from increases in age at first capture (in the younger ages) than those based on 40 percent availability at age 1 and 70 percent at age 2.

As an example, it is pertinent to examine the predicted gains from an increase in age at first capture from 1-1/2 to 2-1/2 years, roughly equivalent to the change achieved by the regulated change in mesh size from 2-7/8 inches to 4-1/2 inches. The 100 percent

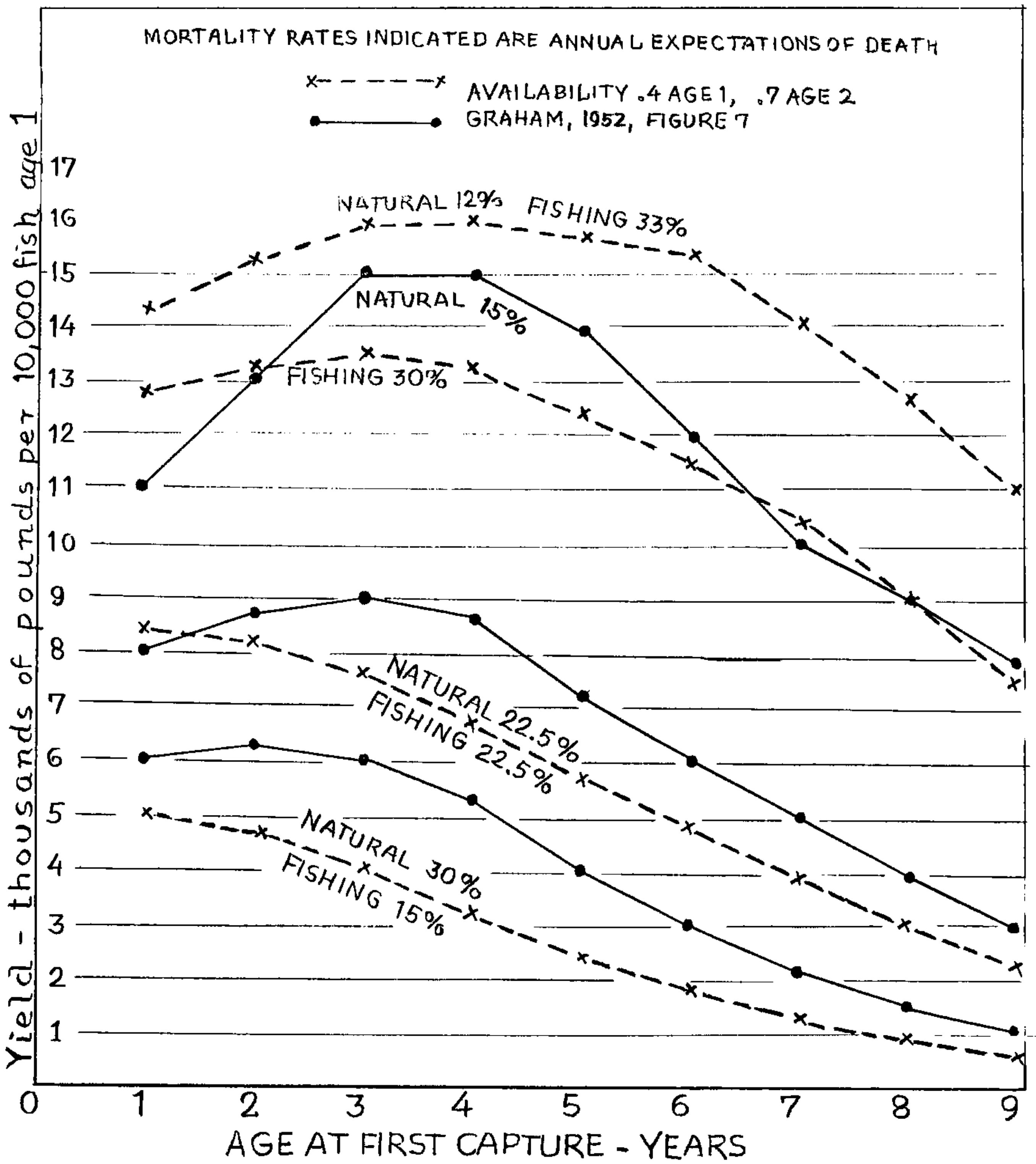


Figure 9. Georges Bank Haddock. Theoretical yield curves, with and without allowance for lesser availability of ages 1 and 2.

availability curve, for the 15-30 percent natural-fishing mortality combination believed to be closest to the truth, indicates a very much greater gain than that assuming lesser availabilities of the entering groups.

## Other Effects

All of the estimations described above, and quoted from other publications, deal with mesh effects in terms of yield per recruit. Obviously, a change in mesh size will affect the age composition of the stock. It is entirely possible that the rate of recruitment might change as the result of this change in stock composition. Also, all calculations have assumed that growth rate will remain the same after mesh change as before it, whereas a change in stock density could affect growth. Finally, a change in stock could affect survival (natural mortality) which again was assumed to remain the same as before mesh change.

These secondary effects point toward a broad field for long-term biological investigation of the stocks, in order to assess the ultimate effects of mesh regulation. Such investigations are now being actively pursued by United States and Canadian biologists interested in the haddock stocks.

## Other Causes of Change in Yield

In reviewing the results of the haddock mesh regulation, fishery scientists have considered possible causes other than change in mesh size for increase in yield. Chief among these are change in weight-at-age (growth rate) and increased efficiency of the fishing vessels.

Data on average weights of fish in the two year classes studied, obtained by dividing commercial catch weights by numbers, are furnished in Taylor et al (1959) and are as follows:

| Age | Av. wt., lb. Yc 1948 | Av. wt., lb. Yc 1952 | Ratio, 1952/1948 |
|---|---|---|---|
| 2 | 1.32 | 1.49 | 1.13 |
| 3 | 1.84 | 2.09 | 1.14 |
| 4 | 2.50 | 2.60 | 1.04 |
| 5 | 3.14 | 3.43 | 1.09 |

It is evident that the average weight of fish at ages 2 and 3 was substantially greater for year-class 1952 than for year-class 1948. This is the effect that would be expected from an increase in mesh size, since the larger meshes select the larger fish of the younger year classes (Taylor and Dickie, 1958). The catch at ages 4 and 5, however, can be considered substantially free of the effect of mesh selection. Here the increase in weight-at-age is much milder than for ages 2 and 3, and the observed change of 4 to 9 percent could not account for the 20 percent increase in yield which has been estimated above.

Adoption of improved methods of fishing, such as the use of electronic instruments, undoubtedly has increased the efficiency of capture to some extent. Increases in efficiency of the larger mesh trawls could contribute to gains resulting from the larger mesh sizes, even though this would probably not relate directly to the selection ogive.

In summary, an appraisal based on information now available indicates that increased growth rate and increased gear efficiency were not sufficient to account for the amount by which the yield of year class 1952 exceeded that of year class 1948. Obviously, however, the question should be investigated further for a more precise assessment of the effects of the two variables.

## Summary

The effects on haddock yields of an increase from 2-7/8" (73 mm) to 4-1/2" (114 mm) in mesh size of trawl codends used by the Georges Bank fleet have been examined. It has been demonstrated that at least the following benefits have been achieved:

1. Elimination of discards of small fish.
2. Increase in average size of fish landed, resulting in easier handling, cheaper filleting, and a product more desirable on the market.
3. Release of unwanted fish (hake, herring) and foreign materials (shell, coral, etc.).
4. A larger yield in weight from year class 1952 than from year class 1948, which could have resulted from the fact that it was entirely subject to the larger mesh, while year class 1948 was subject to the smaller mesh.

It will be evident to any reader of the earlier sections of this report that the estimated increase in yield represents a rather crude approximation based on the data now available. Although the confidence limits have not been calculated, it is obvious that they must be rather broad. If we were to consider only the variability in the estimates of initial year class strengths and take no account of other sources of error, the range of calculated benefits would be from 12 to 33 percent. As data become available from additional year classes, and as analytical techniques are refined, the accuracy and reliability of mesh assessment evaluations will increase. Undoubtedly the findings will require some modification of the estimates of benefits.

An investigation of theoretical yield curves has accounted for the fact that the gain realized was somewhat less than that originally predicted.

Finally, it has been recognized that the possibility of secondary effects on recruitment, growth and survival requires continuing biological investigation of the stocks.

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