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GEORGES BANK (ICNAF DIVISION 5Z AND SUBAREA 6)

HERRING ASSESSMENT

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Catch and Effort Trends

The Georges Bank herring fishery was initiated in 1960 by the USSR (Table 1). From 1961 to 1966 the USSR was the only nation harvesting the herring stock to any degree although in 1965 and 1966 they diverted much of their fishing effort to silver hake and haddock. From 1964 to 1965 two very good year classes of herring (1960 and 1961) were recruited to the fishery as 3 and 4 year olds and in 1967 the USSR directed their effort back on herring with significant increases in catch. Figure 1 shows the significant year classes that have contributed to the herring catch on Georges Bank since the fishery began. There is some evidence that the 1956 year class was a fairly good year class but actually disappeared from the catches with the appearance in 1963 of the very strong 1960 year class. The 1960 year class remained dominant in the catches through 1967. The 1961 year class was also excellent in size and together with the 1960 year class produced a large stock size of herring during the mid-sixties on Georges Bank. Poland and West Germany began catching large amounts of herring for the first time in 1967 with the majority of catch coming from the 1960 and 1961 year classes (71.8% by number). Fishing effort increased greatly in 1968, more than triple that of 1967, and has continued to increase through 1971. This increase in effort resulted in a total catch of 219,000 metric tons in 1967 and 373 and 305 thousand metric tons in 1968 and 1969 before falling to 246 and 261 thousand metric tons in 1970 and 1971. The catch in 1971 was much higher than expected; actually slightly greater than that of 1970. The very strong 1960 year class was finally out of the fishery and the strong 1961 year class contributed only 22 million fish to the catch in 1971. There was a dramatic increase in the catch of younger fish as these two year classes left the fishery.

Other than perhaps the 1968 year class which is now entering the fishery, there has been no evidence of strong year classes since the 1961 year class was recruited in 1964 and 1965 so it appears that the herring stock began to decline rapidly after 592 thousand metric tons were removed in 1967 and 1968. The magnitude of the decline in abundance of herring on Georges Bank, however, has been difficult to define from catch and effort data. The catch per day fished for the USSR, Poland, West Germany and Non-members of ICNAF are compared in Table 2. The effort is simply the total number of days fished in which herring were caught (not adjusted for fishing power of vessel size). The catch per effort for West Germany fell greatly in 1968 from that of 1967 but increased again in 1969 and 1970. The catch per day for the Non-members increased in 1967 over that of 1966 but fell in 1968. Catch data for Non-members are available since 1968 but effort information is not. The catch per day declined steadily from 1967 through 1970 for the USSR and from 1967 through 1969 for Poland. Poland's catch per effort increased slightly in 1970, perhaps, due to improvements in fishing methods.

SURPLUS-YIELD MODELS

Surplus-yield models are useful in determing levels of maximum sustainable yield (MSY) and associated fishing effort (f_{opt}) from developing fisheries when population parameters have not yet been defined. The Georges Bank herring fishery is a new fishery and although some parameters such as fishing mortality and growth have been estimated the problem is one of steadily increasing effort on a stock of unknown potential. Fishing effort has increased rapidly since 1966 (Table 3) with a subsequent decline in catch per effort. Surplus-yield models depend only on proper catch and effort statistics so the technique is a simple one which can be applied to most fisheries by generalizing the method according to methods given by Pella and Tomlinson (1969) and Fox (1971). The problem with the method is the misinterpretation possible when the assumptions of immediate response of the population to changes in density and of stable age distribution are not met. Thus there are difficulties in the estimation of equilibrium conditions from a rapidly developing fishery which may lead to overestimation of maximum sustained yield. A further problem in utilizing yield models with the Georges Bank herring fishery is the pronounced effect of 2 good year classes entering and passing through the fishery at the time of its most rapid development. Nevertheless, a surplus yield model can show, at least in a very rough way, the MSY and optimum level of effort expected from the Georges Bank fishery if one assumes that the catch and effort data from 1961 to 1970 on Georges Bank provide an example of equilibrium conditions and that future recruitment will include two strong year classes similar to the 1960 and 1961 year classes at least once in 10 years.

Gulland (1961) suggested a method of approximating equilibrium conditions from a transient fishery by relating the catch per unit effort in a given year to the fishing effort averaged over the mean number of years that a year-class contributes significantly to the catch. For example, if total mortality is approximately 0.5 then a year class contributes significantly to the catch over a 2-year period (Holt, 1965). Assuming that fishing mortality has been quite high in recent years, effort was averaged over this 2-year period in application of the model to this fishery.

In ICNAF area 5Z, the USSR in 1961 caught herring almost exclusively. In the years following through 1970 their catch was no less than 40 percent herring except for 1965 and 1966 when the herring catch fell to 7.9 and 24.1% of the catch of all species. In those years the USSR directed their effort toward haddock and hake. Large Soviet vessels ($\geq$ 1800 MT) normally are used for catching haddock and hake while the small vessels (150-500 MT) are used for taking herring. From 1964-1969, exclusive of 1965 and 1966, Soviet large vessels took 88% of the catch of haddock and hake and only 28% of the herring. In 1965 and 1966, 74% of the haddock and hake and 91% of the herring were caught by the larger vessels. Only 9% of the herring caught in 1965 and 1966 were taken by the smaller vessels whereas 63% were caught by the smaller vessels in other years. The herring catch in 1965 and 1966 may have been only a by-catch to the haddock and hake fishery. The 1960 and 1961 year classes were recruited in 1963-1965 so it is known that the herring stock was very large (in terms of numbers) in 1965 and 1966. Figure 2 compares indices of abundance for the Georges Bank stock of herring and shows the low international catch per effort in 1965 and 1966. Realizing that these values must be wrong years 1964 to 1966 were connected by a straight line and the data points on the line were used as adjusted values for 1965 and 1966.

The effort data were also adjusted by a "learning curve." Since the Georges Bank herring fishery is new to the international fleet, I felt that an effort unit must increase in efficiency (an increase in q, the catchability coefficient) through learning. To my knowledge, no data exist to determine this increase in efficiency. I therefore arbitrarily assumed an increase in efficiency of 29% during the first year that a nation caught significant quantities of herring and 50% thereafter. This adjustment is actually achieved by a reduction in effort units by 50% in the first year and by 29% in the second year so that in a time series of effort data, the actual effort units are used in all years other than the first two.

Finally, the basic effort data were obtained by estimating fishing power factors among the international fleet that reported effort data by month, area (5Ze, 5Zw, 6A, 6B and 6C) and vessel size. Robson (1966) suggested an efficient method of estimating power factors by a linear, additive two-factor model with missing cells which yields maximum likelihood estimates if the within-class errors are normally distributed with zero mean and constant variance. The standard cell value was catch per day of USSR 150-500 MT side trawlers. My analysis followed that of Robson through a computer program developed by Berude (1971). For those nations reporting herring catches but no effort data (Canada, Iceland, and E. Germany), estimates of effort were obtained by dividing their catches by the international catch per effort obtained from those nations reporting effort. The additional effort data were then added to obtain the effort given in Table 3. An additional set of effort data is also shown in Table 3 which is based on the percent of herring caught of the total catch. Since several species of fish have been taken by the same effort units in certain years, the amount of effort was determined in proportion to the catch of herring of the total catch. These estimates of catch per unit of effort can be viewed as a minimum estimate of decline in abundance.

Figure 3 shows the decline in catch per effort with increasing effort. The curves were obtained with effort averaged over a 2-year period ($k = 2$) in an effort to approximate equilibrium conditions from a transient fishery and with annual effort. The curves are somewhat different depending on whether $k = 1$ or 2. The estimates of maximum sustainable yield and optimum effort are not greatly different, however (Table 4).

The program used for this analysis was GSPFIT (Fox, 1971). The relationship investigated was

$$\frac{dP}{dT} = \pm HP^m \pm KP - qfP$$

where P is the population size, q is the catchability coefficient, f is the fishing effort and H, K, and m are parameters. The upper signs in equation (1) apply where $m<1$ and the lower signs apply where $m>1$ (as m approaches 1 the Gompertz model applies). At equilibrium, $dP/dt = 0$, and

$$\pm HP^m = \mp KP + qfP$$

or

$$U^{m-1} + (Kq^{m-1})/H + q^m/\ (\pm H) \cdot f$$

where $U = q \cdot P$, the catch per unit effort. A linear regression is run for varying values of m until a minimum ratio of residual variance to Y variance is selected giving the best value of m. Table 4 gives the values of m which best describe the model for the various sets of data along with the predicted MSY and optimum effort.

Figure 4 shows yield curves for values of equilibrium effort with the data points from 1963 to 1971. The catch declined only 30,000 tons in 1969 but dropped by an additional 90,000 tons in 1970. The fishing effort in 1968 more than tripled that of 1967 and greatly exceeded the optimum level of effort for the Georges Bank herring population. The effort continued to increase in 1970 and 1971 in order to maintain the catch at about 250 thousand metric tons. It is obvious that with continued high effort, the catch will decline and according to the model a new equilibrium population size and age structure will be established providing a much reduced sustained yield.

The estimates of maximum sustainable catch are very high, undoubtedly due to the presence of the very strong 1960 and 1961 year classes that dominated the catches from 1963 to 1969. All year classes since have been much smaller and this surplus production analysis is only valid under similar conditions of recruitment, i.e. two year classes of the size of the 1960 and 1961 year classes at least once every ten years. This analysis perhaps should be viewed as the optimum situation when very good year classes are occasionally recruited to the fishery.

Estimates of Fishing Mortality

A first approach to the estimation of fishing mortality for the Georges Bank herring is the decline in catch per unit effort from one age to the next for each year class. Catch per effort for each year class and resulting estimates of fishing mortality assuming a constant natural mortality rate of 0.2 are given in Tables 5 and 6. The effort data are total international effort weighted by fishing power for various vessel sizes and adjusted for 1965 and 1966 when effort was directed toward haddock and hake. The effort data were also adjusted for learning for the first two years of fishing by a given nation. There are many minus values within the table due to year classes not being fully recruited and probably faulty age composition information as well. The average $\hat{F}$ for age 5 and older was weighted over year classes for each year by the relative abundance of each year class. The average fishing mortality rates increase from 1966 to 1970 and then decline. The apparent decline in 1971 is due to the estimate of F for the 1961 year class of about 0.5. The low value of average $\hat{F}$ in 1968 of 0.29 was due to an estimate of F for the 1959 year class of -0.32. The estimates at the older ages are not reliable due to problems in age reading after about 33 cm in total length (age 4-5). Realizing that these low estimates of fishing mortality are probably too low means that the average estimates of F increased after 1966 to very high levels of mortality. These increases in fishing mortality are supported by a similar increase in total fishing effort. These estimates are approximate, however, due to the dominating influence of the 1960 and 1961 year classes. These year classes were so much stronger than the other year classes, that they may have reduced the availability (catchability) of the other year classes. The effort data are themselves questionable. Better estimates of mortality are required than those given in Table 6, for purposes of assessment.

Additional fishing mortality rates (F) were estimated for the Georges Bank herring fishery by using the virtual population method for natural mortality rates (M) of 0.2, 0.3 and an increase in M with age of 0.15, 0.15, 0.25, 0.36, 0.47, 0.58, 0.69, 0.81, and 0.92 for ages 3 through 11. Starting values of F used in the virtual population analysis were 1.5 for ages 6 and older, 1.0 for age 5 and 0.6 for age 4 since F increases with age. The numbers of herring caught from the Georges Bank fishery were determined according to a method described by Schumacher and Dornheim (1971). The total catch is given in Table 7. Simulation of the virtual population procedure indicates that starting estimates of F should be large rather than too small in order that correct estimates of F be obtained quickly in the age series if F is increasing with age.

The estimates of fishing mortality were made for ages 2 through 10 (Tables 8, 9 and 10). The estimates are unreliable for ages 2-3 due to their incomplete recruitment and ages 9-10 due to problems in aging. For ages 4-8 the estimates of F have increased with time and age (except for 1969 when effort declined slightly) and should be reliable. All estimates of mortality increased markedly from 1965 to 1971.

Estimates of Natural Mortality

An estimation of natural mortality (M) is a necessary provision for the assessments of the status of the fish stocks and for estimation of catch quotas. This estimate of M can be obtained by regarding the total mortality in the first year of exploitation of a stock as a maximum estimate of M. This method has been applied to several fish stocks in the North Atlantic with reasonable agreement with values obtained by the mortality-effort regression. For the Georges Bank herring (ICNAF Div. 5Z and 6), total mortality (Z) has been estimated on the basis of the catch per effort data of USSR trawlers greater than 1800 metric tons in 1961 and 1962. It has been thought that this type of vessel has only little changes in efficiency from one year to another (Anthony, 1972). The basic data and the results of the calculations are given in Table 11. The values obtained indicate that M varies between 0.19 and 0.23 for ages 4-7.

Incidental catches of adult herring along the Maine coast may provide rough estimates of natural mortality. Until recently there has been no fishery for adult herring along the coast of Maine except as incidental catches to trawling for shrimp, groundfish, etc. Since 1963, however, enough adult herring have been sampled from these incidental catches to provide an estimate of decline in abundance which is due to natural mortality. A catch curve analysis was applied to numbers of fish sampled by age from 1963-1970 from western Maine based on an equal sample size in each year. Years 1963-1970 were combined to remove the effect of the strong 1960 year class. The estimates of M increased rapidly with age being 0.15, 0.30 and 0.47 for ages 5, 6 and 7.

Tester (1955) described the catch curves of a herring population from British Columbia fished for the first time. The curves were noticeably convex even though variation in year class strength was not considered. Jensen (1939) found convex catch curves for Atlantic herring of the southern part of the North Sea and suggested that the cause of the convex catch curves was natural mortality, emigration of old fish, or net selectivity toward young fish. Ricker (1958) indicated that net selectivity could not explain the curvature in the catch curves so the cause of the convexity is probably increasing natural mortality or emigration. Hodgson (1932) found the same convex catch curves in the East Anglian herring of the North Sea and Lea (1929) found convex catch curves from twenty years of averaged catch data for the Atlanto-Scandian herring. The estimates of M as determined by Tester and Hodgson are given in Table 12.

A third method of estimating M is the relation of total mortality to fishing effort. The estimates of total mortality as determined from the virtual population analysis were plotted against effort for each age and regression lines were fitted to the data. The intercept on the Y-axis is an estimate of M while the slope provides an estimate of q, the catchability coefficient. The estimates of M were 0.21 (0.00 - 0.43 confidence limits) for age 5, 0.43 (0.13-0.72) for age 6, 0.48 (0.31-0.65) for age 7, and 0.56 (0.30-0.82) for age 8. The correlation coefficients ranged from 0.74 to 0.91. These estimates of natural mortality also increased with age. The various estimates of M are presented in Table 12. The range of estimates are 0.15-0.32 for age 5, 0.30-0.43 for age 6, 0.47-0.55 for age 7, and 0.54-0.82 for age 8 including estimates from the North Sea and Pacific Ocean. An average of all estimates indicates a gradual consistent increase in natural mortality with age.(Figure 6).

Considering that in recent years the catches consist mainly of herring of age 5 and younger with increasing tendency towards ages 4 and 3, a value of M = 0.2 is regarded as a reasonable value for assessment purposes.

STOCK ABUNDANCE

Indices of herring stock size in Division 5Z and Subarea 6 have been obtained from several sources. First, using catch, estimates of weight of fish at age, and fishing mortality, and assumed natural mortality of 0.2, 0.3 and an increase in M with age (given above), simple estimates of stock size at the beginning of the year were made (Tables 13 through 15).

The significance of the strong 1960 and 1961 year classes is seen in the tables of stock size. As the 1960 year class began to be recruited in 1963 the stock size increased by 150% in weight and rose by nearly an additional 75% in 1964, assuming an M of 0.2. The stock size in number was at its greatest in 1964 and declined by 50% by 1970 depending on the assumption of natural mortality. In terms of weight, the stock peaked in 1966 and also declined by 50% by 1970. Projections of stock size for 1972 were 15% and 23% of maximum depending on the assumption of natural mortality. The estimated stock size in 1972 of fully recruited age groups is only 44% - 48% of 1971 (varying by the assumption of natural mortality). The 1972 stock size was estimated from survival rates calculated for 1971. The 1960 - 1962 year classes will be out of the fishery in 1972 and the large mortality rates in 1971 on the 1967 and 1968 year classes should reduce the stock size of these two year classes by an average of 75% (unless the 1968 year class was not fully recruited in 1971).

Herring of age 3 and 4 are assumed to be recruiting to the fishery with age 5 and older assumed to be fully recruited. From 1966 to 1968, age 3 and 4 herring provided 8.1%, 7.7%, and 8.3% of the catch by number (and less in terms of weight). In 1969, 1970 and 1971, however, the contribution of this segment of the herring stock provided 19%, 49% and 48% of the total herring catch for Subarea 5Z and 6 in numbers (Table 7). This development is confirmed by an analysis of age and maturity from the samples taken from the West German fishery on Georges Bank herring (Table 16). The increasing trend in the proportion of herring of age 3 and 4 in the West German catch and a corresponding decrease in fish older than 4 years of age is shown clearly, particularly since 1969. In 1971, herring of age 3 became dominant in the catches of West German vessels and even mature fish of age 2 appear. This change in the age structure of the catch indicates that in 1967-71 the fishery changed from the exploitation of an accumulated stock to a stock highly dependent on incoming recruitment. The same observations have been made in the North Sea herring stock for the mid-fifties. It has to be concluded, therefore, that a higher proportion of recruits in the catches does not necessarily mean that a good year class is entering the fishery.

The residual stock size (age 5 and older) of Georges Bank herring declined steadily and rapidly from 1966 to 1971 (Figure 5 and Tables 17 and 18). Recruitment (age 3 and 4 year old herring) declined from 1964 through 1968 with a slight increase in 1969 due chiefly to the 1966 year class.

Independent estimates of herring stock size are made annually in the form of research cruise surveys (Figure 2 and Table 19). Indices were developed from the spring survey for the middle Atlantic (Cape Hatteras to Long Island) and southern New England (Long Island to Nantucket Shoals) areas and from the fall survey for Georges Bank. All three show extensive declines from 1966 through 1971, except the middle Atlantic survey between 1970 and 1971. From 1966 to 1970 the average decline in abundance was approximately 60% per year.

Finally, USSR research on stock abundance also indicates a strong decline in herring spawning population on Georges Bank (Figure 2 and Table 20). The USSR estimate of spawning stock decline, as estimated from egg surveys, is the most drastic decline that has been estimated for this stock. The USSR catch per unit effort in September on the spawning grounds shows a decline in abundance more in agreement with other sets of data. The decline in spawning population from 1964 to 1969 is 95% while the decline in catch per effort from 1964 to 1969 is 76%.

YIELD PER RECRUIT

The shape of the Georges Bank herring yield per recruit curve against fishing mortality has been given by Anthony (1971-Figure 12) and Schumacher and Dornheim (1971-Figure 1). This relation of yield to mortality is typical of herring yield per recruit curves with the right hand side of the curve becoming flat as fishing mortality increases.

The curve shows a rapid increase in yield per recruit as F increases to 0.4-0.6 After 0.5 the yield per recruit increases only slightly for even a very great increase in mortality. An F of 0.6 on a long term basis will provide 95% of the yield per recruit realized from a F of 1.6. The increase in yield per recruit for an F greater than 0.4 or 0.5 is so small as to make such an increase in fishing effort unwise in terms of long term management of the stock.

Estimates of F used in yield per recruit considerations are for fully recruited age groups only. Before 1970 herring were not fully recruited prior to age 5 for the Georges Bank stock of herring so that an F indicated from yield per recruit considerations applied only to herring of age 5 and older. Weighted average fishing mortality of ages 5-9 has been greater than that of ages 3-5 so that an upper limit of F which should be applied to the Georges Bank stock from yield per recruit considerations is too large for the entire stock. To determine an average F that should be applied to the Georges Bank stock which produces catches from age 3 and age 4 herring, a regression of values of F for ages 3-9 was constructed against values of F for ages 5 and older. If age 3 and 4 herring are not fully recruited, an F of 0.5 for fully recruited age groups is equal to an average F of 0.3 for all age groups. Since an F of 0.5 is the maximum that should be allowed on the Georges Bank herring stock from yield per recruit considerations, an F of 0.3 is the maximum that should be allowed over all age groups.

In order to compare the effects of different levels of natural mortality ($M = 0.2$ and $M = 0.4$) on a stock with equal recruitment stable at an average level of 10^9, Figure 7 has been drawn from simulated data. This figure shows clearly that the size of the stock assuming a high level of natural mortality is considerably smaller compared with that for lower levels of M. This is quite logical, if a greater proportion is disappearing from the stock by causes other than fishing the remaining proportion will be small. Consequently, the yield taken from this reduced population will also be smaller compared with the yield obtained with the same fishing mortality but at lower levels of M.

Another striking feature is the shape of the yield curves; 80% of the maximum yield can be reached with a level of $F = 0.3$ assuming $M = 0.2$ compared with an F of 0.6 assuming $M = 0.4$.

It should be mentioned that for practical purposes i.e. computer programming, values of fishing mortality for fish older than age 6 are used in Figure 7 and Figure 11. For the younger age groups, those values are reduced by a certain percentage derived from an average of the estimates of fishing mortality in 1970 and 1971 (Table 8). Therefore, the values of F in Figure 7 and Figure 11 are not directly comparable with those given in other tables, but from the regression line given in Figure 8 comparable values can be derived which are applicable to the stock as an overall weighted average.

Catch Level in 1972

On the conditions of good recruitment (200,000 metric tons annually at ages 3 and 4) and an established residual stock (200,000 metric tons) of ages 5 and older, an F of 0.5 and natural mortality of 0.2 would allow an annual catch of 140,000 metric tons to keep the stock fairly stable at 400,000 metric tons. Under conditions of exceptional recruitment (400,000 metric tons annually) in addition to a large residual stock of 400,000 metric tons, an F of 0.5 would produce an annual catch of 280,000 metric tons with no change in standing stock size. An MSY of over 300,000 metric tons can only be achieved under conditions of recruitment similar to that in the early 1960's, i.e. approximately 3 years of recruitment averaging at least 500,000 metric tons annually to build the stock up and annual recruitment of 414,000 metric tons (with F = 0.5, M = 0.2) after that to balance the loss from fishing and natural mortality. This MSY should be viewed, therefore, as a maximum achieved under only ideal recruitment levels, something that is not now present in the Georges Bank herring stock and is not indicated for the immediate future.

The projected stock size by weight at the beginning of 1972 as calculated at the Rome assessment meeting (1972) was 305,000 MT. This assumed an M of 0.2 recruitment in 1971 of 760 million herring and an F for 1971 as estimated according to proportional increases in F from 1969 to 1970. Assuming similar recruitment in 1972 as in 1971, catch quotas of 50 - 95,000 metric tons were recommended depending on assumptions of recruitment levels and desired stock sizes for 1973. To prevent a further decline in stock size (over that of 1972) assuming recruitment of 760 million herring, 95,000 metric tons was the upper limit of suggested catch. As the total stock is reduced the catch in any year depends more and more on the annual recruitment. The catch quota for 1972 assumes recruitment levels to be the same as that calculated for 1971. If recruitment declines still further the catch quota will have to be revised downward.

The assumption of M for the Georges Bank herring stock also influences the catch quota. Assuming an M of 0.3 and a recruitment level of 760 million fish produces a maximum catch quota of 84,000 metric tons which is comparable to 95,000 metric tons for M = 0.2. If M increases with age as given above, the catch quota is reduced even further. A catch quota of 58,000 metric tons with an increase in M is comparable to 95,000 metric tons under the assumption of M = 0.2. For estimated values of F the stock sizes are greater for larger values of M than 0.2 but a greater amount of fish die from natural causes, thus producing a lower catch quota. Figure 9 compares the effect of catches in 1972 on the stock size in 1973 for natural mortality rates of 0.2, 0.3 and increasing with age. These data were calculated in a slightly different manner than mentioned previously. The estimates of F from the virtual population analysis were determined with the same starting fishing mortality rates as given above but the catches ($\ln C_i$) were extrapolated for 3 ages beyond that available for 1971. This provided an estimate of F and recruitment directly for 1971. The recruitment for 1971 (age 3 stock size) was 567, 605 and 687 million fish for M = 0.2, 0.3 and increasing with age. These levels of recruitment were used in Figure 9.

Catch Level in 1973

At the special meeting on herring in Rome 1972 panel 5 recommended that the Commission shall establish the level of catch which will neither "further reduce spawning stocks already at a low level nor reduce productivity by lowering the yield per recruit during 1973 based on the recommendations of its Standing Committee on Research and Statistics." Considering that the catch in 1973 is essentially dependent on the recruitment in 1972 and 1973, an attempt has been made(by using the V.P. technique) to estimate the catch in 1973 which ensures that the size of the spawning stock will not fall below the desired level.

The catches in 1973 are given in Figure 10 for the level of stock size (174,000 MT) at the end of 1971 (Figure 10A) and for various levels of stock size at the end of 1972 (Figure 10B), which are dependent on the recruitment in 1972. The entire stock at the end of the year may be regarded as representing the spawning stock for this purpose even if the limited number of young herring in the stock may not spawn in the following year.

If, for example, recruitment is assumed to be 2,000 X 10^6 in 1972 and in 1973, the catch in 1973 which would sustain the size of the spawning stock at the level of 1971 (174,000 t) can be estimated as follows:

> Starting from the 2000 recruitment level for 1972 (bottom line of Figure 10A) and moving up the figure to the 2000 recruitment line for 1973 produces a point which defines the allowable catch for 1973 as indicated on the left hand scale, in our example, 398,000 metric tons. This recruitment produces a stock size at the end of 1972 of 283,000 metric tons.

If the level of the spawning stock at the end of 1972 must be at least maintained at that level, the catch for 1973 can be obtained by the same procedure in Figure 10B. In our example, the catch would be 270,000 t to maintain the spawning stock at 283,000 t in 1972.

Assuming recruitment of 500 X 10^6 in 1972 and 1000 X 10^6 in 1973 the catch figure for 1973 would be 48,000 metric tons (Figure 10A) to maintain the 1971 stock size of 174,000 metric tons and 138,000 metric tons (Figure 10B) to maintain the 1972 stock size of 94,000 metric tons.

Even if Figure 10 is subject to further refinement particularly in relation to the estimated stock sizes, this figure may give some guidance for the 1973 catch level.

A defined level of stock size can be achieved for the Georges Bank herring stock by introducing a certain level of fishing mortality. To reach a stable stock size higher than the present level, a period of at least 6 years of fishing at a lower level than at present is required. On the other hand, a lower level of stock size can be reached by a higher level of stagle fishing mortality in a shorter time period of 3-4 years. For example, still providing stable recruitment at an average level,of 1000 X 10^6 fish, to stabilize the level of stock size a little higher than that at the end of 1971, a stable F of 0.8 for the ages older than 6 (equal to an F of 0.5 over all ages) is required (Figure 11). This corresponds to an allowable catch of:

121,000 metric tons in 1973
125,000 metric tons in 1974
128,000 metric tons in 1975
130,000 metric tons in 1976
131,000 metric tons in 1977
132,000 metric tons in 1978

Good recruitment would speed up the increase in stock size or allow an increase of the catch quota. Poor year classes would enlarge the period of adaptation on the desired level or require an adjustment of the catch quota to a lower level. Preliminary estimates of recruitment from using the virtual population method with extrapolated catches indicates that recruitment may be less than 1000 X 10^6 herring, perhaps, in the area of 500-600 X 10^6 herring.

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Table 1. Catch of herring from Georges Bank.
(metric tons)
Division 5Z and Subarea 6.

Years	Canada	Poland	Germany	Japan	USSR	USA	Romania	Iceland	Non-members	Total
1961					67,550	105				67,655
1962		277			151,864	101				152,242
1963					97,102	205				97,307
1964		35			130,723	268				131,026
1965		1,447			36,349	861			1,982	40,639
1966		14,473			120,113	4,308			3,810	142,704
1967	1,306	37,677	28,171		126,663	1,211	1,420		22,159	218,607
1968	13,674	75,080	71,086		143,097	758	1,656	292	67,784	373,427
1969	945	45,021	61,990		138,673	3,678	337	12,786	42,000	305,430
1970		70,691	82,498	1,000	61,579	1,791	230	----	28,000	245,789
1971 1/	12,000	86,000	55,000	2,000	84,000	5,000	1,000	----	16,000	261,000
Total	27,925	330,701	298,745	3,000	1,157,713	18,286	4,643	13,078	181,078	2,035,826

1/ Preliminary data.

Table 2. Catch per day (metric tons) of herring caught in ICNAF Division 5Z and Subarea 6 by nations.

Year	USSR			Poland			West Germany			Non-Members		
	Catch MT	days fished	Catch per day	Catch MT	days fished	Catch per day	Catch MT	days fished	Catch per day	Catch MT	days fished	Catch per day
1961	67,550	5,926	11.40									
1962	151,864	-----	-----	277	50	5.54						
1963	97,102	17,223	5.64									
1964	130,723	18,477	7.07	35	34	1.03						
1965	36,349	17,133	2.12	1,447	142	10.19						
1966	120,117	20,640	5.82	14,473	467	30.99				1,133	66	17.17
1967	126,663	20,806	6.09	37,677	2,888	13.05	28,266	578	48.90	22,159	657	33.73
1968	143,097	26,523	5.40	75,080	6,529	11.50	71,086	2,579	27.56	67,824	3,085	21.99
1969	138,673	34,442	4.03	45,021	6,880	6.54	61,990	1,590	38.99			
1970	61,579	23,830	2.58	70,691	9,308	7.59	82,498	1,829	45.11			

Table 3. Total international effort and catch per unit of effort for Georges Bank herring.

Year	No learning curve applied					
	Years 1965 and 1966 not adjusted		Years 1965 and 1966 adjusted		All years adjusted by percent of herring caught	
	Effort (Days)	Catch per effort	Effort (Days)	Catch per effort	Effort (Days)	Catch per effort
1961	18,563	3.65	18,563	3.65	7,144	9.47
1962	136,420	1.12	136,420	1.12	31,572	4.82
1963	24,371	3.99	24,371	3.99	14,459	6.73
1964	13,708	9.56	13,708	9.56	16,356	8.01
1965	34,893	1.16	4,660	8.72	7,273	5.59
1966	143,911	0.99	18,160	7.86	13,265	10.76
1967	31,324	6.98	31,324	6.98	24,516	8.92
1968	103,262	3.62	103,262	3.62	46,556	8.02
1969	95,777	3.20	95,777	3.20	52,007	5.89
1970	122,765	2.01	122,765	2.01	45,525	5.42

Year	Learning curve applied					
	Years 1965 and 1966 not adjusted		Years 1965 and 1966 adjusted		All years adjusted by percent of herring caught	
	Effort (Days)	Catch per effort	Effort (Days)	Catch per effort	Effort (Days)	Catch per effort
1961	12,363	5.47	12,363	5.47	4,759	14.22
1962	117,682	1.29	117,682	1.29	27,227	5.59
1963	24,371	3.99	24,371	3.99	14,458	6.73
1964	13,707	9.56	13,707	9.56	16,355	8.01
1965	33,755	1.20	4,508	9.02	7,094	5.73
1966	142,030	1.01	17,635	8.09	13,115	10.88
1967	29,929	7.30	29,929	7.30	23,316	9.38
1968	99,256	3.76	99,256	3.76	44,889	8.32
1969	95,125	3.22	95,125	3.22	51,653	5.93
1970	122,599	2.01	122,599	2.01	45,401	5.44

Table 4. Stock production results of Georges Bank herring from GSPFIT with K = 1 and 2 years.

No learning curve	K	MSY (1000 MT)	F_{opt} (1000 days)	m
Years 1965 and 1966	1	228	94	1.29
not adjusted	2	---	--	≥3.0
Years 1965 and 1966	1	253	87	0.91
adjusted	2	314	65	2.36
Effort adjusted by	1	326	58	4.02
percent herring catch	2	271	44	4.95
Learning curve applied				
Years 1965 and 1966	1	250	85	1.59
not adjusted	2	---	--	≥3.0
Years 1965 and 1966	1	269	80	1.14
adjusted	2	310	63	2.46
Effort adjusted by	1	283	37	5.17
percent herring catch	2	---	--	≥5.4

Table 5. Catch per unit of effort for each year class for the Georges Bank herring fishery. Effort is total international effort directed in part toward herring adjusted for learning and for years 1965 and 1966.

Year	YEAR CLASS 1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Effort (thousand days)
1961	0.566	1.117	5.186	13.900	3.657	1.117												12.36
1962	0.082	0.156	1.193	2.542	0.846	0.369												117.68
1963			0.242	0.603	2.774	5.975	2.712	7.809										24.37
1964					2.546	7.112	9.365	16.813	10.999	1.204								13.71
1965			0.288	0.643	2.062	2.816	5.654	22.838	7.738	2.284	0.089							4.51
1966				0.034	0.113	0.771	3.690	15.879	10.091	1.961	0.726	0.017						17.64
1967					0.341	0.371	1.651	12.670	8.376	3.608	2.025	0.231	0.060					29.93
1968						0.066	0.220	3.391	4.361	2.351	3.385	0.725	0.525	0.025				99.26
1969							0.248	1.153	2.003	1.981	2.923	2.913	2.216	0.478				95.13
1970								0.144	0.241	0.421	0.758	0.998	2.205	3.675	1.023	0.103		122.60
1971									0.119	0.076	0.275	0.567	0.959	1.552	1.503	1.813	0.071	184.64 1/

Table 6. Estimates of F from decline in catch per effort for the Georges Bank herring fishery. Effort is total international effort directed at least in part toward herring adjusted for learning and for years 1965 and 1966.

Year	YEAR CLASS 1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Weighted average age 5 and older
1961	1.731	1.766	1.270	1.498	1.265	0.909												1.505
1962			1.395	1.240	-1.388	-2.985												0.245
1963			0.006	0.026	-0.114	-0.374	-1.439	-0.967										-0.269
1964					0.011	0.726	0.304	-0.506	0.151	-0.840								0.372
1965				2.737	2.700	1.095	0.226	0.164	-0.465	-0.048	-2.302							0.244
1966					-1.305	0.532	0.605	0.026	-0.014	-0.810	-1.226	-2.809						0.042
1967						1.526	1.817	1.117	0.452	0.228	0.714	-1.344	-2.369					0.675
1968							-0.320	0.879	0.579	-0.029	-0.054	-1.591	-1.640	-3.151				0.288
1969								1.879	1.920	1.346	1.151	0.870	-0.195	-2.240				1.264
1970									0.505	1.509	0.813	0.366	0.632	0.663	-0.585	-3.068		0.642

1/ $f_{71} = \dfrac{C_{71}\, f_{70} \bar{N}_{70}}{C_{70}\, \bar{N}_{71}}$

Table 7. Total international catch of herring from the Georges Bank fishery (ICNAF Division 5Z and Subarea 6).

	YEAR CLASS																		
Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Total catch in number (millions)	Total catch in weight (1000 MT)
1961	7.0	13.8	64.1	171.8	45.2	13.8												315.7	67,655
1962	9.7	18.3	140.4	299.1	99.5	43.4												610.4	152,141
1963			5.9	14.7	67.6	145.6	66.1	190.3										490.2	97,307
1964					34.9	97.5	128.4	230.5	150.8	16.5								658.6	131,026
1965			1.3	2.9	9.3	12.7	25.5	103.0	34.9	10.3	0.4							200.3	40,639
1966				0.6	2.0	13.6	65.1	280.1	178.0	34.6	12.8	0.3						587.1	142,704
1967					10.2	11.1	49.4	379.2	250.7	108.0	60.6	6.9	1.8					877.9	218,607
1968						6.6	21.8	336.6	432.9	233.4	336.0	72.0	52.1	2.5				1493.9	373,427
1969							23.6	109.7	190.5	188.5	278.1	277.1	210.8	45.5				1323.8	306,000
1970								17.7	29.6	51.6	92.9	122.3	270.3	450.5	125.4	12.6		1172.9	247,000
1971									21.7	13.8	50.2	103.5	175.2	283.5	274.5	331.2	12.9	1266.5	261,656

Table 8. Estimates of fishing mortality for the Georges Bank herring fishery using the virtual population method with M = 0.2

	YEAR CLASS																		
Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Weighted[2] average age 3 and older	Weighted[2] average age 5 and older
1961	0.50	0.50	0.30	0.36	0.12	0.02												0.20	0.35
1962	0.50	0.50	2.36	2.24	0.42	0.10												0.98	1.48
1963			0.71	0.73	0.57	0.53	0.11	0.06										0.13	0.56
1964					0.66	0.84	0.31	0.09	0.06	0.01								0.10	0.47
1965			0.80[1]	1.41	0.38	0.24	0.09	0.05	0.02	0.01	0.00							0.04	0.07
1966				0.80[1]	0.11	0.43	0.37	0.21	0.12	0.03	0.01	0.00						0.13	0.18
1967					0.80[1]	0.74	0.53	0.48	0.24	0.14	0.05	0.01	0.00					0.19	0.31
1968						0.80[1]	0.46	1.10	0.85	0.53	0.45	0.09	0.05	0.00				0.44	0.69
1969							0.80[1]	1.61	1.25	1.14	0.85	0.59	0.28	0.04				0.52	0.92
1970								0.80[1]	0.63	1.24	0.79	0.57	0.70	0.71	0.16	0.01		0.55	0.71
1971[3]									0.80[1]	0.25	1.20	0.54	0.38	0.81	1.31	0.66		0.72	0.60

1/ Fishing mortality for age 10 arbitrarily assumed to be 0.8.
2/ The average $\hat{F}$ is weighted over year-classes by the stock size in number.
3/ Fishing mortality for 1971 was estimated by assuming the same proportional change in 1971 over 1970 as occured in 1970 over that of 1969.

Table 9. Estimate of fishing mortality for the Georges Bank herring fishery using the virtual population method with M = .3.

	YEAR CLASS																	Weighted average age 3 and older[2]	Weighted average age 5 and older[2]
ear	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969		
961	0.50	0.50	0.31	0.33	0.09	0.02												0.16	0.33
962	0.50	0.50	2.69	2.08	0.35	0.08												0.86	1.38
963			0.85	0.65	0.47	0.44	0.08	0.04										0.09	0.47
964					0.55	0.69	0.24	0.07	0.04	0.01								0.07	0.37
965			0.80[1]	1.33	0.31	0.20	0.08	0.04	0.01	0.01	0.00							0.03	0.05
966				0.80[1]	0.11	0.37	0.31	0.18	0.09	0.03	0.01	0.00						0.09	0.15
967					0.80[1]	0.69	0.46	0.43	0.21	0.12	0.04	0.01	0.00					0.16	0.27
968						0.80[1]	0.44	1.03	0.77	0.47	0.39	0.08	0.04	0.00				0.37	0.62
969							0.80[1]	1.52	1.13	1.05	0.77	0.52	0.24	0.03				0.43	0.83
970								0.80[1]	0.59	1.15	0.73	0.53	0.64	0.56	0.14	0.01		0.36	0.66
971[3]									0.80[1]	0.23	1.18	0.51	0.36	0.79	1.29	0.64	0.01	0.50	0.57

/ Fishing mortality for age 10 arbitrarily assumed to be 0.8.
/ The average $\hat{F}$ is weighted over year-class by the stock size in numbers.
/ Fishing mortality for 1971 was estimated by assuming the same proportional change in 1971 over 1970 as occurred in 1970 over that of 1969.

Table 10. Estimate of fishing mortality for the Georges Bank herring fishery using the virtual population method with M increasing with age.

	YEAR CLASS																	Weighted average age 3 and older 2/	Weighted average age 5 and older 2/
Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969		
1961	0.50	0.50	0.24	0.31	0.08	0.02												0.15	0.30
1962	0.50	0.50	1.75	1.77	0.24	0.07												0.66	1.02
1963			0.43	0.47	0.28	0.33	0.05	0.04										0.08	0.32
1964					0.29	0.42	0.14	0.06	0.04	0.01								0.08	0.21
1965			0.60 1/	1.05	0.17	0.11	0.04	0.03	0.01	0.01	0.00							0.02	0.04
1966				0.60 1/	0.08	0.24	0.18	0.13	0.07	0.03	0.01	0.00						0.08	0.11
1967					0.60 1/	0.51	0.28	0.32	0.15	0.11	0.04	0.01	0.00					0.15	0.21
1968						0.60 1/	0.31	0.78	0.56	0.39	0.36	0.08	0.05	0.00				0.35	0.50
1969							0.60 1/	1.21	0.78	0.86	0.66	0.50	0.27	0.04				0.44	0.70
1970								0.60 1/	0.43	0.96	0.64	0.49	0.65	0.61	0.16	0.01		0.50	0.61
1971 3/									0.60 1/	0.15	1.17	0.47	0.36	0.84	1.37	0.69	0.01	0.70	0.56

1/ Fishing mortality for age 10 arbitrarily assumed to be 0.6.
2/ The average $\hat{F}$ is weighted over year-classes by the stock size in number.
3/ Fishing mortality for 1971 was estimated by assuming the same proportional change in 1971 over 1970 as occurred in 1970 over that of 1969.

Table 11. Estimation of Z for years 1961-1962 for the Georges Bank herring.

Year		AGE 3	4	5	6	7	8	9	Total	Mean weight (kg)	Catch per effort (kg)
1961	%	4.4	14.3	54.4	20.3	4.4	2.2	---	100.0	0.214	2410
	Numbers[1]	496	1610	6126	2286	496	248	---	11262		
1962	%	---	7.1	16.3	49.0	23.0	3.0	1.6	100.0	0.249	2410
	Numbers[1]	---	687	1578	4743	2226	270	155	9679		
	Z[2]	-.326	.020	.256	.027	.537	.470		.180		

Mean Z (age 4-9) = .190

(weighted by size of age gropps)(age 5-9) = .220

1 The numbers per unit effort are calculated by multiplying the percentages of the age distribution by the average weight per age group. The sum of the results divided by 100 gives the mean weight per herring in that year. The catch per effort in weight divided by the mean weight gives the total number caught per unit effort. This total has been allocated to the different age groups according to the percentage distribution.

2 $Z = \log_e \frac{N_{i(1961)}}{N_{i+1(1962)}}$

Table 12. Comparison of estimates of natural mortality of herring.

Age	Catch Curve Western Maine	regression of Z on effort	Tester (N. Pacific)	Hodgson (N. Sea)	Average
2					(0.20)
3					(0.15)
4					(0.15)
5	0.15	0.21		0.32	0.23
6	0.30	0.43	0.32	0.39	0.36
7	0.47	0.48	0.48	0.55	0.50
8		0.56	0.54	0.82	0.64
9			0.64	1.02	0.83
10			0.88	1.18	1.03
11			1.26		1.26
Average	0.29	0.42	0.69	0.71	

Extrapolated estimates in brackets (Figure 6).

Table 13 . Stock size (millions of fish) of Georges Bank herring (M = 0.2).

ear	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Total stock size (millions of fish)	Total stock size (thousands metric tons)
								YEAR CLASS											
961	19	38	272	624	441	660												2054	400.5
962	27	51	165	357	320	528												1448	320.4
963			13	31	172	393	716	3703										5028	743.0
964			5	12	80	190	526	2860	2879	1713								8265	1298.8
965			3	4	34	67	315	2133	2221	1388	1990							8155	1363.5
966				1	19	43	235	1653	1787	1127	1629	1379						7873	1449.1
967					20	23	133	1100	1302	891	1322	1128	1505					7424	1408.4
968						13	64	557	839	632	1027	918	1231	1523				6804	1288.6
969							47	152	295	306	537	686	960	1245				4228	892.7
970								35	69	80	188	311	596	978	951	993		4201	724.5
971									43	69	78	271	608	557	406	745	1017	3794	679.3

Table 14. Stock size (millions of fish) of Georges Bank herring (M = .3).

	YEAR CLASS																		
Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Total stock size (millions of fish)	Total stock size (thousands metric tons)
1961	20	40	277	710	587	986												2620	498.2
1962	28	53	164	377	392	689												1703	370.7
1963			12	35	205	467	1033	5767										7519	1244.9
1964			5	13	95	222	702	4116	4362	2777								12292	1897.9
1965			3	4	41	82	411	2861	3103	2027	2326							10858	1840.3
1966				1	22	50	281	2001	2270	1497	2252	1744						10118	1852.6
1967					21	25	152	1235	1530	1081	1665	1540	2086					9335	1725.2
1968						14	71	593	920	709	1181	1131	1567	2228				8414	1528.7
1969							49	157	317	327	590	776	1117	1671				5004	1024.3
1970								36	76	85	203	341	648	1198	1081	1146		4814	825.1
1971									45	78	82	294	659	587	426	794	1174	4139	735.0

Table 15. Stock size (millions of fish) of Georges Bank herring (M increases with age).

	YEAR CLASS																		
Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Total stock size (millions of fish)	Total stock size (1,000 metric tons)
1961	20	37	355	717	661	867												2,600	435.8
1962	29	52	200	408	527	731												1,947	375.8
1963			22	48	323	589	1351	1351	5537									7,870	1322.4
1964			8	19	170	331	1101	4587	4080	1983								12,279	2005.0
1965			4	6	79	151	745	3729	3374	1686	2162							11,936	2124.4
1966				2	38	85	499	2815	2872	1444	1752	1622						11,129	2155.5
1967					32	37	261	1732	2079	1206	1502	1165	1386					9,400	1913.2
1968						21	110	789	1244	844	1237	990	1173	1498				7,906	1586.1
1969							73	202	445	398	670	785	960	1280				4,813	1037.1
1970								55	114	106	241	370	632	1059	891	924		4,392	790.1
1971									67	132	91	337	677	556	390	306	946	3,502	669.7

Table 16. Percentage distribution of mature fish in the West German catch (maturity stage 4-8) per age group from 1967-1971.

			YEAR		
Age	1967	1968	1969	1970	1971
2	0	0	0	0	0.1
3	1.5	3.1	3.4	7.5	42.2
4	10.2	10.6	32.9	56.4	30.2
>4	88.3	86.3	63.7	36.1	27.5

Table 17. Stock size (1000's of metric tons) of recruits and fully recruited Georges Bank herring.

Year	M = 0.2 Ages 3 and 4	M = 0.2 Ages 5 and older	M = 0.2 Total	M = 0.3 Ages 3 and 4	M = 0.3 Ages 5 and older	M = 0.3 Total	M increases with age Ages 3 and 4	M increases with age Ages 5 and older	M increases with age Total
1961	181.7	218.8	400.5	258.5	239.7	498.2	253.4	166.2	419.6
1962	95.0	225.4	320.4	124.0	246.7	370.7	131.6	219.3	350.9
1963	702.8	140.2	843.0	1079.8	165.1	1244.9	1101.4	221.0	1322.4
1964	961.0	188.5	1149.5	1417.0	239.3	1656.3	1458.1	374.4	1832.5
1965	614.9	575.5	1190.4	872.7	765.2	1637.9	868.6	1067.7	1936.3
1966	455.4	873.7	1329.1	618.6	1082.3	1700.9	531.5	1482.9	2014.4
1967	412.8	864.7	1277.5	538.4	1005.3	1543.7	451.0	1341.6	1792.6
1968	356.0	800.1	1156.1	446.5	888.4	1334.9	360.0	1095.8	1455.8
1969	365.7	517.0	882.7	460.1	564.2	1024.3	371.2	665.9	1037.1
1970	323.4	314.7	638.1	383.2	342.2	725.4	328.7	381.1	709.8

Table 18. Stock size (millions of fish) of recruits and fully recruited Georges Bank herring.

Year	M = 0.2 Ages 3 and 4	M = 0.2 Ages 5 and older	M = 0.2 Total	M = 0.3 Ages 3 and 4	M = 0.3 Ages 5 and older	M = 0.3 Total	M increases with age Ages 3 and 4	M increases with age Ages 5 and older	M increases with age Total
1961	1101	953	2054	1573	1047	2620	1528	1129	2657
1962	528	920	1448	689	1014	1703	731	1216	1947
1963	4419	609	5028	6800	719	7519	6888	982	7870
1964	4592	796	5388	8478	1037	9515	8667	1602	10269
1965	3609	2556	6165	5130	3402	8532	5060	4714	9774
1966	2756	3738	5494	3749	4625	8374	3196	6309	9505
1967	2450	3469	5919	3205	4044	7249	2667	5347	8014
1968	2149	3132	5281	2698	3488	6186	2163	4245	6409
1969	2205	2023	4228	2788	2216	5004	2240	2573	4813
1970	1929	1279	3208	2279	1389	3668	1950	1518	3468

Table 19 U.S. research cruise indices of herring abundance.

Year	Fall cruises Georges Bank	Spring cruises So. New England	Spring cruises Mid-Atlantic
1963	7.02		
1964	1.13		
1965	6.45		
1966	10.41		
1967	3.26		
1968	1.36	120.6	17.4
1969	1.14	45.8	6.4
1970	0.66	34.7	1.2
1971	0.55	4.1	3.7

Table 20. Soviet indices of herring abundance for Georges Bank herring.

Year	Kilograms/100 hrs. of fishing in Sept.	Spawning population estimated from egg surveys 10^{-6} kg.
1963	62.7	No data
1964	78.3	1,180
1965	No fishing	530
1966	No fishing	150
1967	50.0	No data
1968	32.5	130
1969	18.6	60
1970	No data	12
1971	----	11

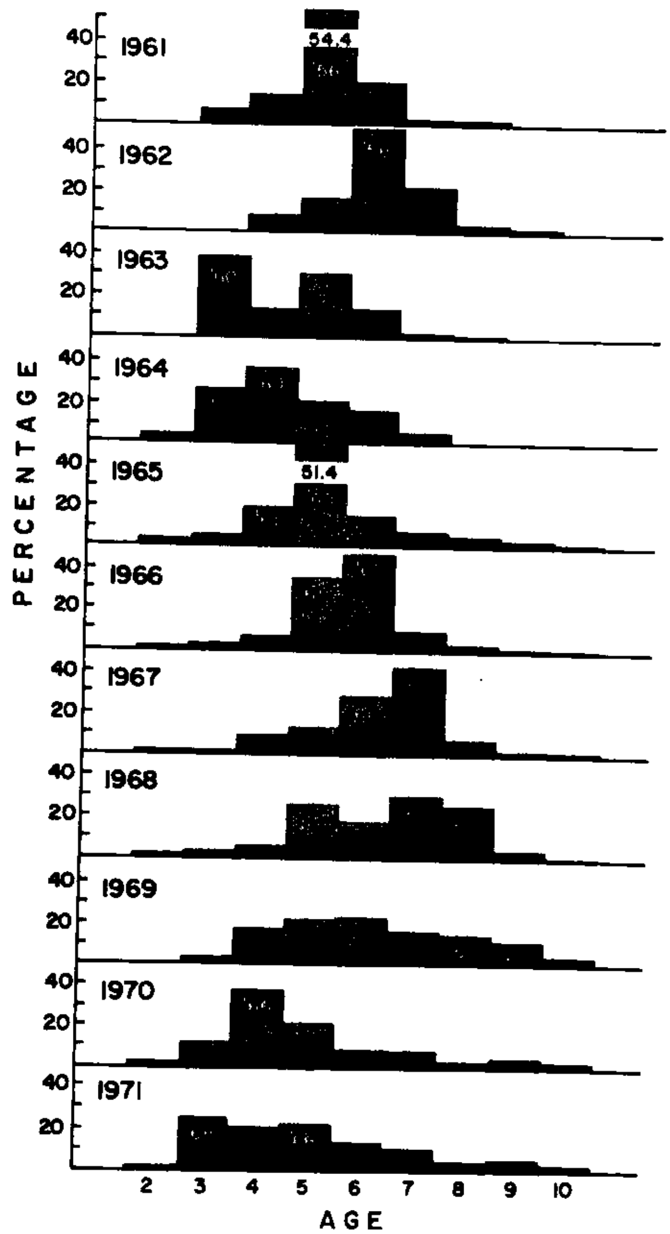
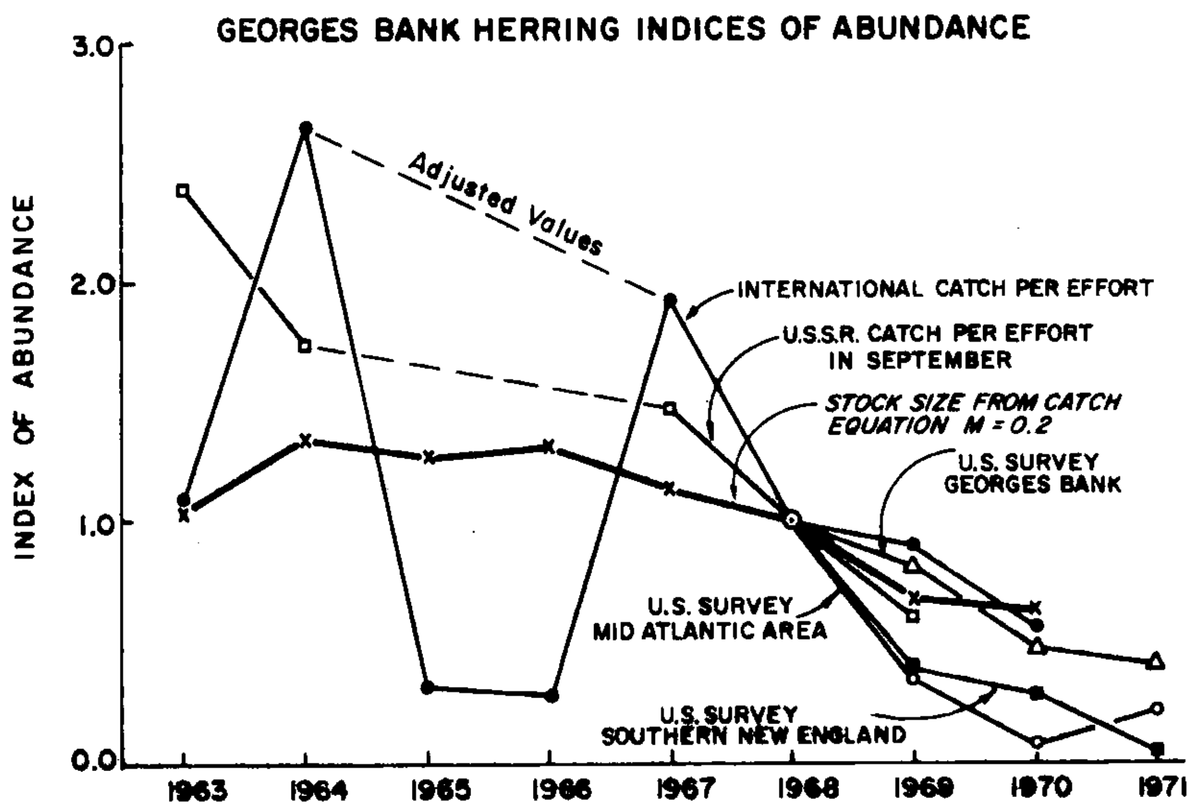


Figure 1. Percentage age composition of the Georges Bank herring catch showing the strong year classes that have supported the fishery.

Figure 2


GEORGES BANK HERRING INDICES OF ABUNDANCE
3.0
2.0
1.0
0.0
INDEX OF ABUNDANCE
Adjusted Values
INTERNATIONAL CATCH PER EFFORT
U.S.S.R. CATCH PER EFFORT IN SEPTEMBER
STOCK SIZE FROM CATCH EQUATION M = 0.2
U.S. SURVEY GEORGES BANK
U.S. SURVEY MID ATLANTIC AREA
U.S. SURVEY SOUTHERN NEW ENGLAND
1963
1964
1965
1966
1967
1968
1969
1970
1971

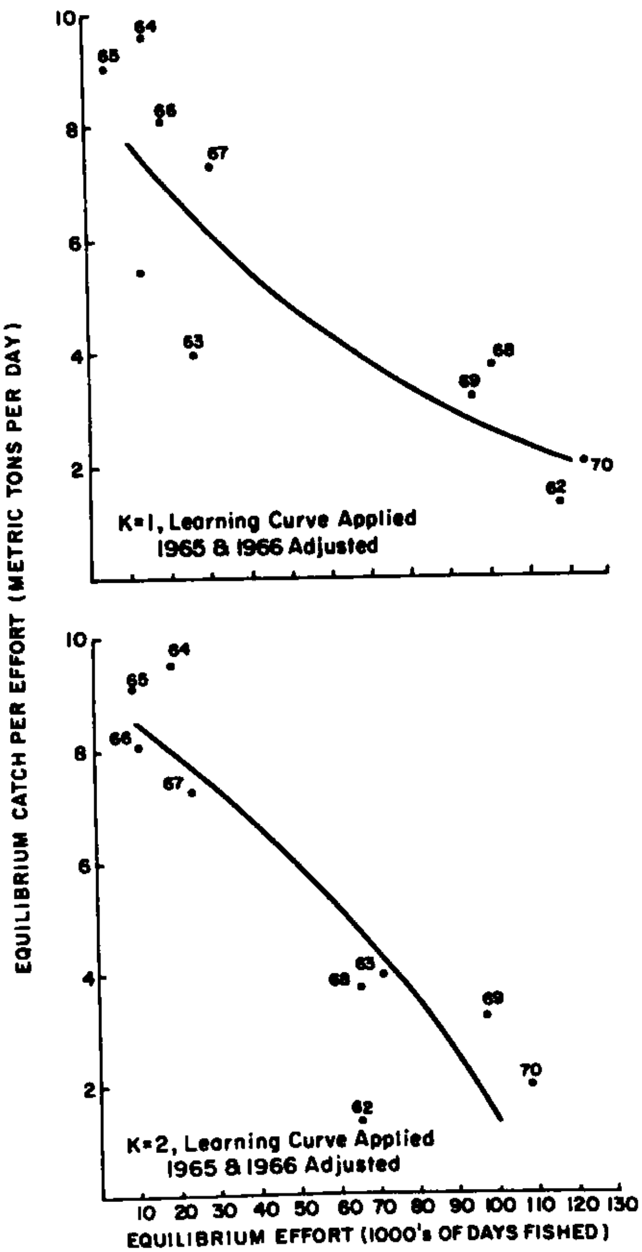


Figure 3. Equilibrium catch per unit of effort as related to effort for K = 1 and 2 with a learning curve applied and years 1965 and 1966 adjusted.

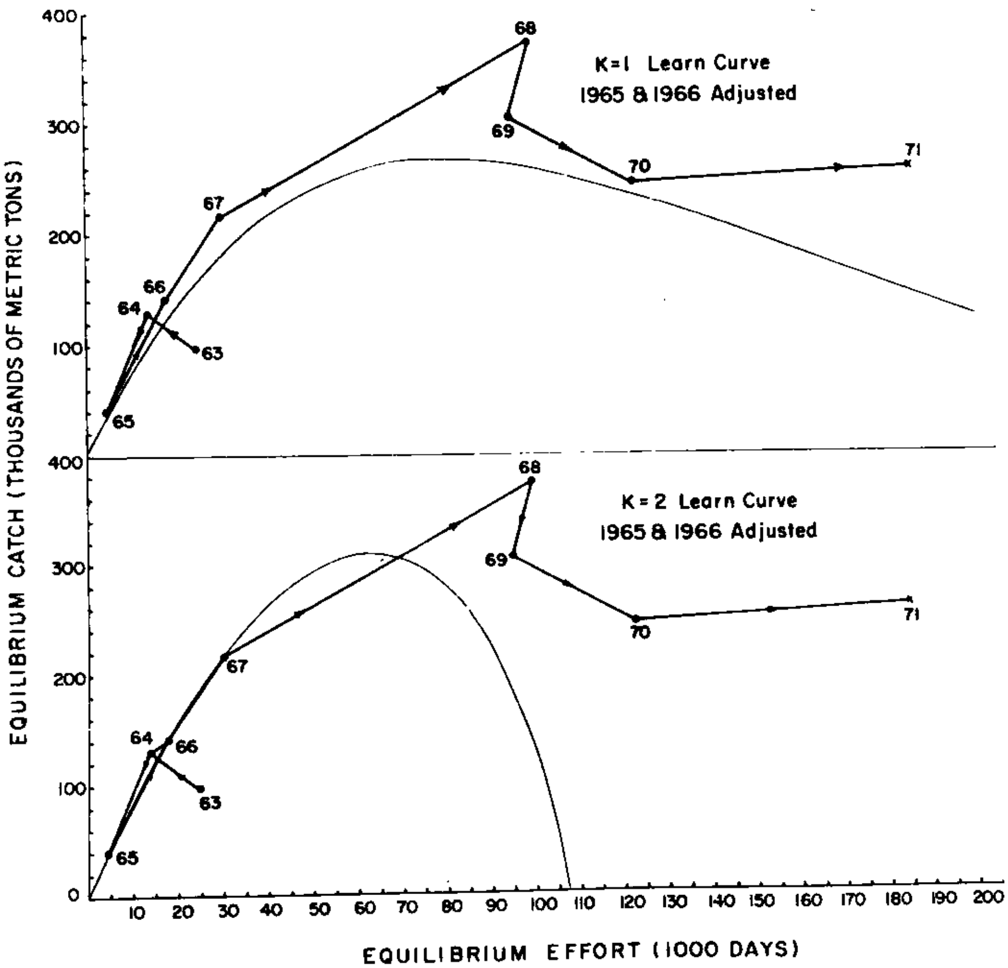


Figure 4. Equilibrium yield curves against effort for K = 1 and 2 with a learning curve applied and years 1965 and 1966 adjusted.

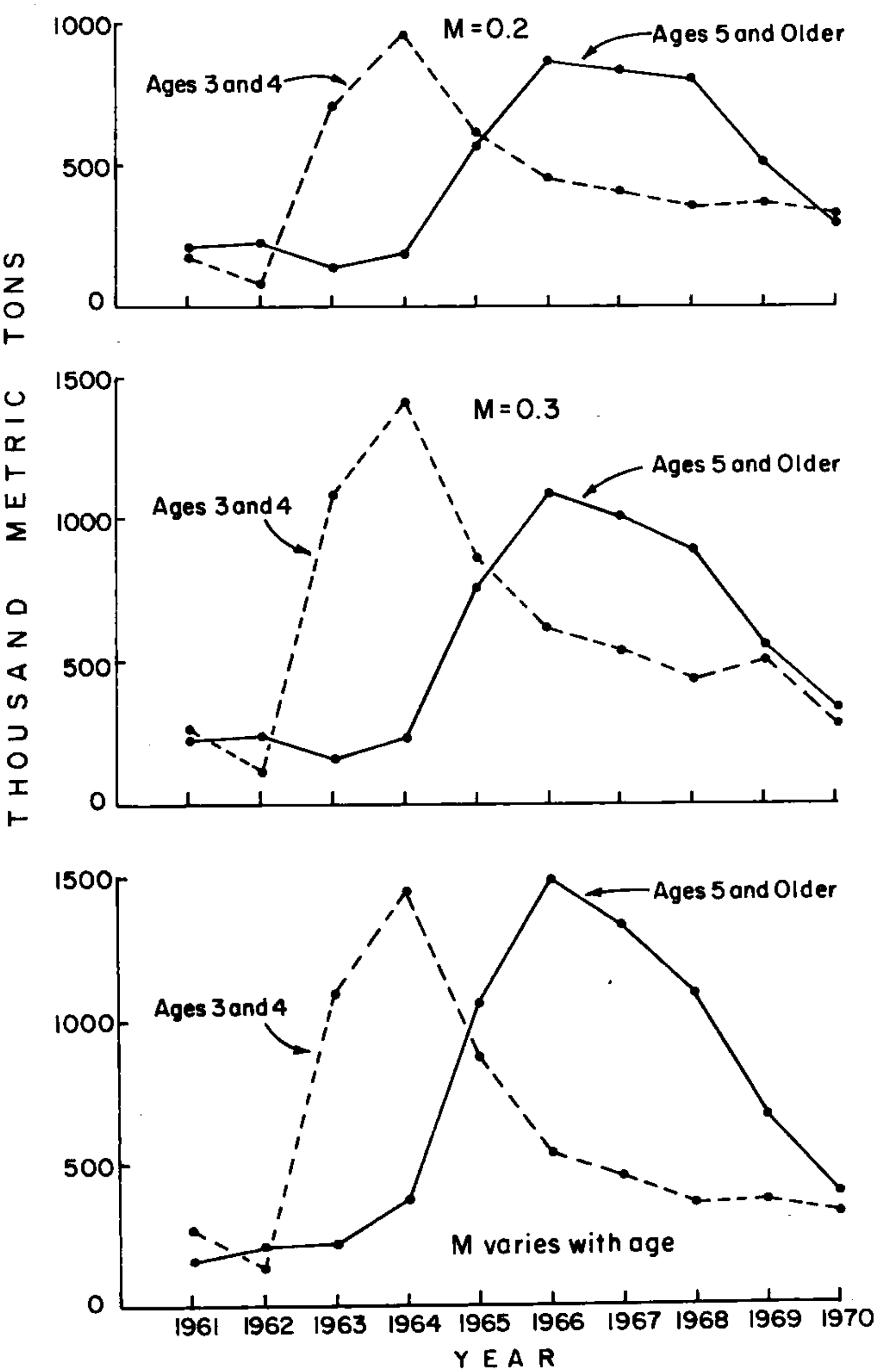


Figure 5. Stock sizes of recruits and fully recruited Georges Bank Herring under three assumptions of natural mortality.

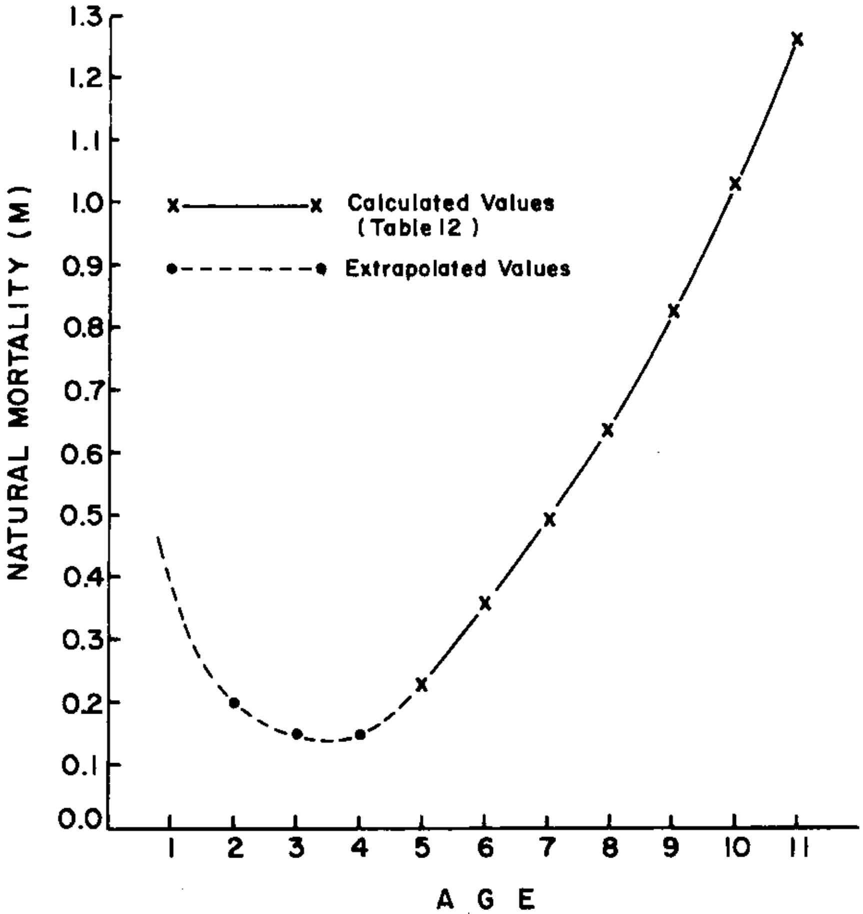


Figure 6. CHANGE OF NATURAL MORTALITY WITH AGE

Figure 7. STOCK SIZE AND YIELD OF GEORGES BANK HERRING FOR DIFFERENT LEVELS OF F ASSUMING A STABLE RECRUITMENT OF 10^9 HERRING

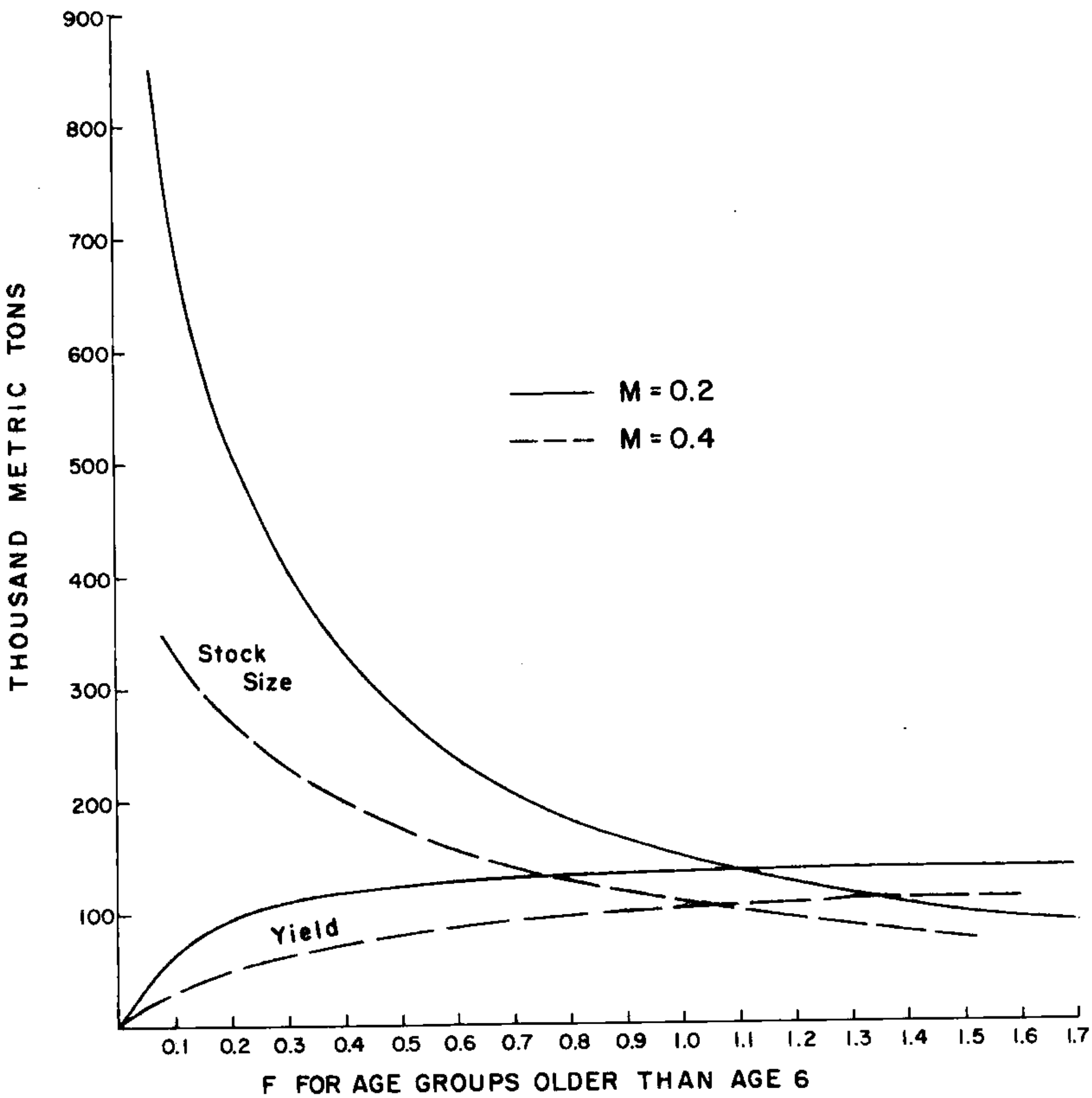


Figure 8. Relationship between F for ages older than 6 and the corresponding average F weighted by stock size.

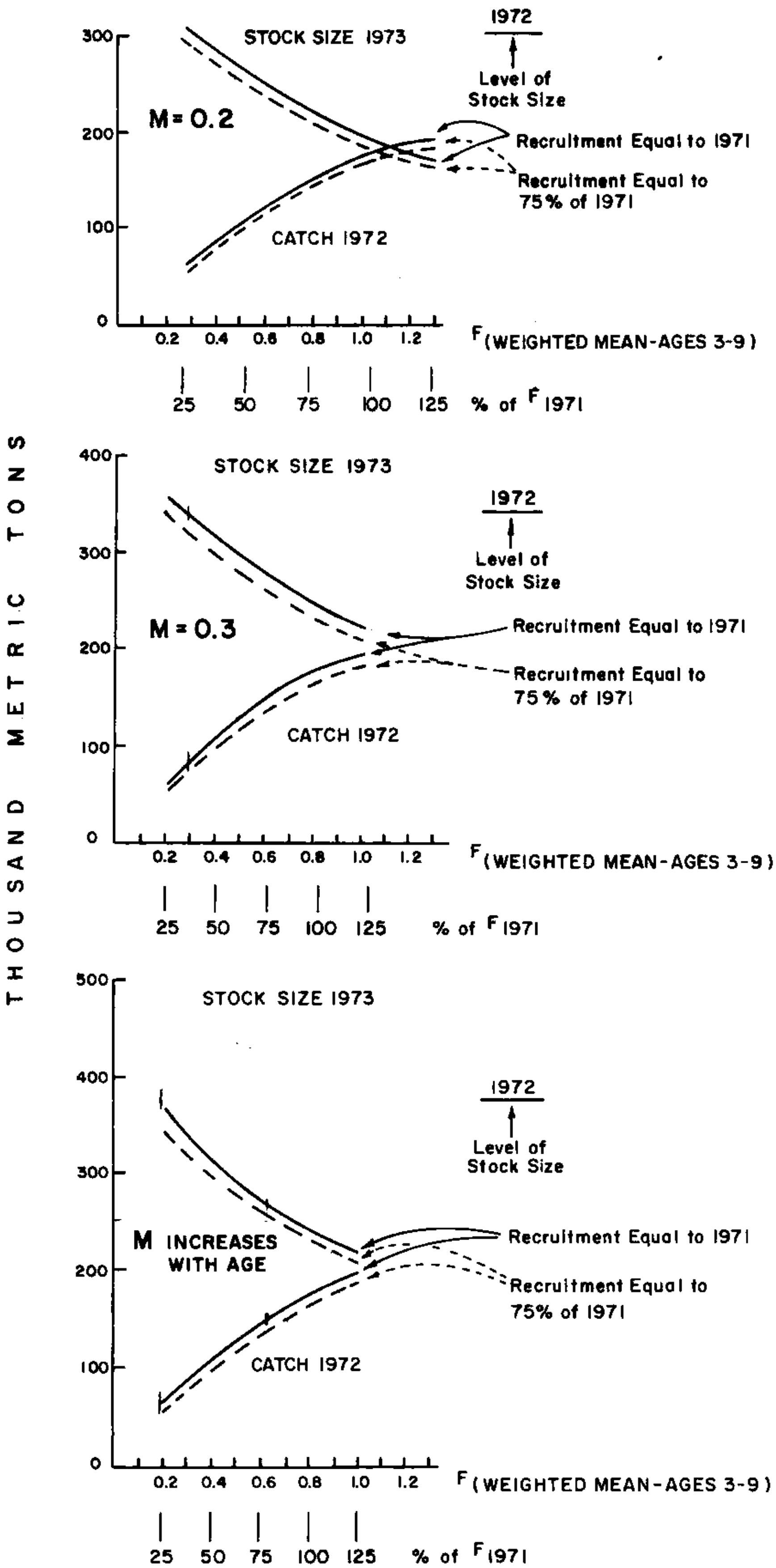


Figure 9. GEORGES BANK HERRING STOCK SIZES IN 1973 BY LEVELS OF CATCH AND FISHING MORTALITY IN 1972 FOR 3 ASSUMPTIONS OF NATURAL MORTALITY.

Figure 10. CATCH IN 1973 TO MAINTAIN STOCK SIZE OF GEORGES BANK HERRING AT THE END OF 1973 AT THE LEVEL OF 1971 (A) AND 1972 (B)
(CATCH 1972 = 150 000 t)

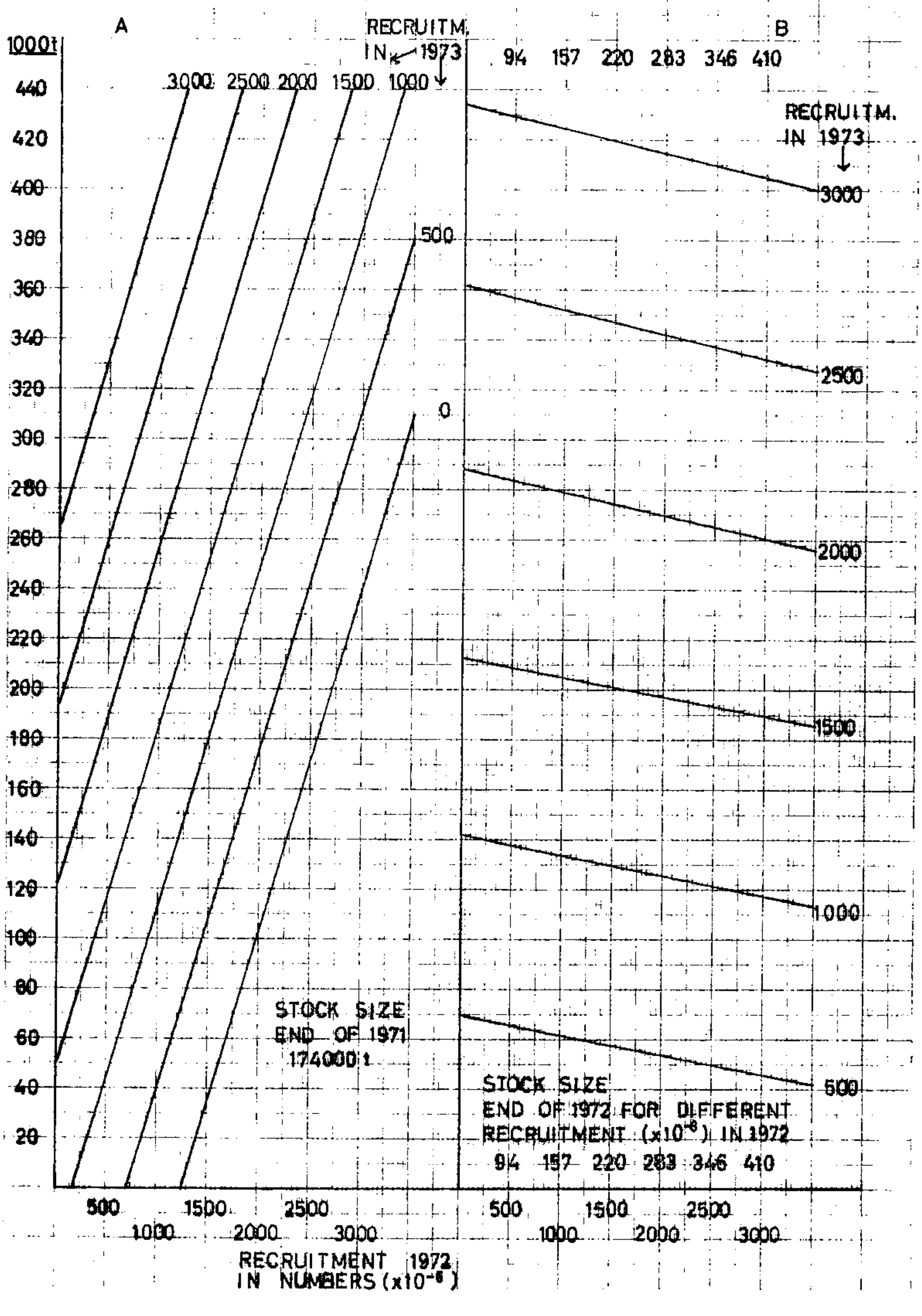


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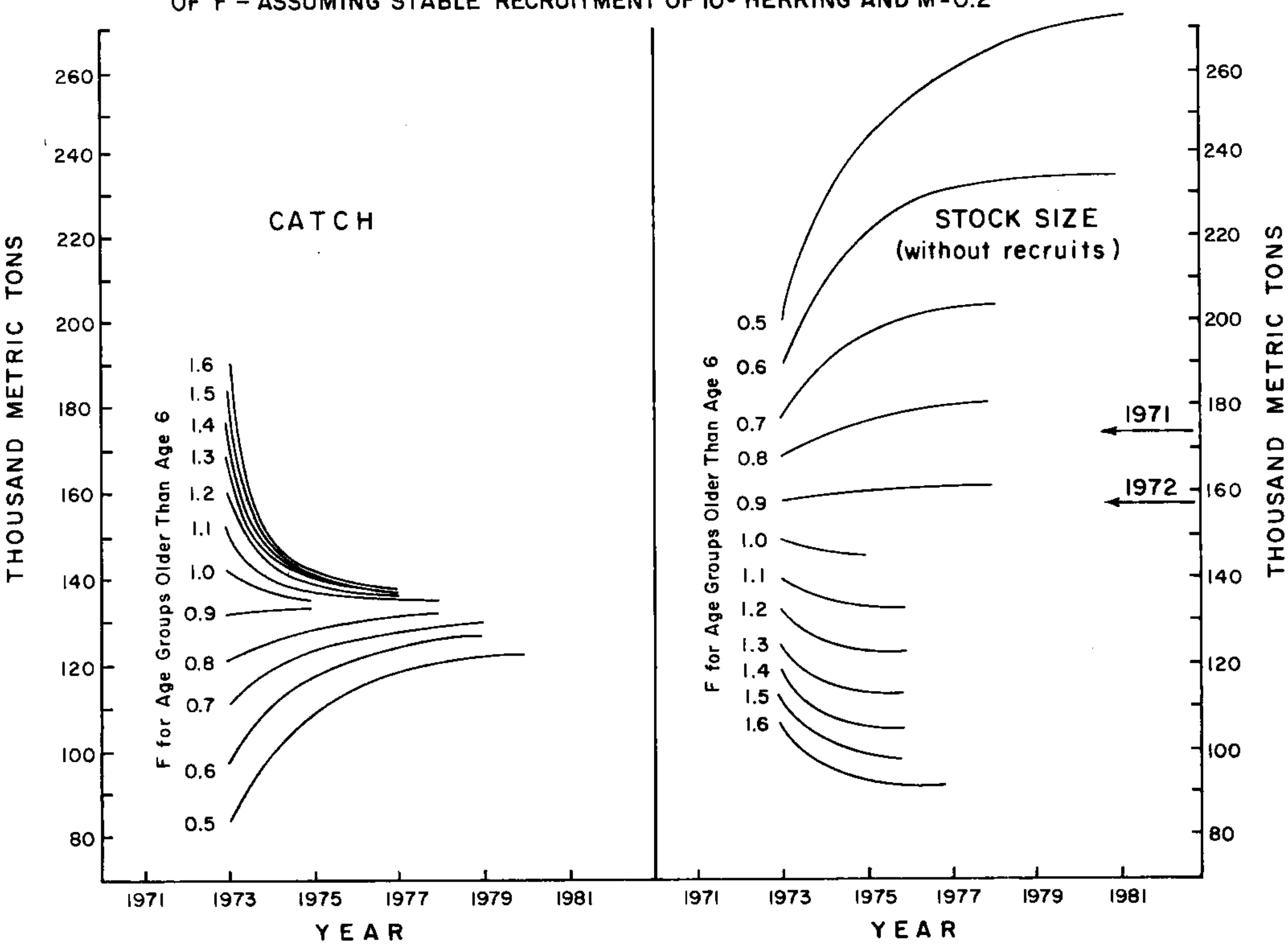
Figure 11. NUMBER OF YEARS REQUIRED TO REACH A STABLE STOCK SIZE OF GEORGES BANK HERRING WITH RESULTING CATCHES FOR DIFFERENT CONSTANT LEVELS OF F – ASSUMING STABLE RECRUITMENT OF 10^9 HERRING AND M=0.2



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