June 1977 Assessments of Herring From the Gulf of Maine and Georges Bank Areas

by

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77-16

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Herring Assessments - June, 1977

1. Herring Catch in 1976

Herring catches for 1976 by country are given in Table 1. The catch of herring from the Georges Bank area was only 42,000 metric tons in 1976 due to the total allowable catch restriction of 60,000 metric tons as opposed to 150,000 tons set for 1972 through 1975. The 1976 catch from the Gulf of Maine area (other than catches made in the juvenile fishery) totaled 20,200 metric tons, compared with 21,500 metric tons in 1975. Catches from the New Brunswick and Maine juvenile fisheries were 27,000 and 30,200, respectively, compared with 33,000 metric tons in New Brunswick in 1975 and 15,200 metric tons in Maine in 1975.

Catches from the Nova Scotia fisheries under management totaled 114,400 metric tons in 1976 compared with 143,000 metric tons in 1975. This decline was due to management at a lower fishing mortality rate level, reduced abundance and Canada's new system of monthly catch limitations.

In all areas under quota regulation, the 1970 year-class continued, as in previous years, to make up the major proportion of the catches.

Table 1. Catch Statistics for 1976 (metric tons) used in the June, 1977 herring assessments. (For location of fisheries, see Figure 1).

Country	New Brunswick juvenile fishery	Nova Scotia adult fishery	Chedabucto Bay fishery	Maine juvenile fishery	Gulf of Maine adult fishery	Georges Bank adult fishery
Bulgaria	-	9	-	-	-	105
Canada	27,000	75,962	37,196	-	921	-
Cuba	-	30	-	-	-	298
France	-	25	-	-		1,166
FRG	-	280	-	-	-	8,805
GDR	-	-	-	-	-	7,891
Japan	-	-	-	-	-	860
Poland	-	-	-	-	-	10,517
Romania	-	-	-	-	-	115
USSR	-	3,789	-	-	-	12,996
USA	-	-	-	30,195	19,204	735
Total	27,000	80,095	37,196	30,195	20,125	43,488

2. Maine juvenile fishery

The juvenile fisheries for herring occur from Portland, Maine to St. John, New Brunswick inside of 3 miles. They are caught by stop seines, weirs and purse seines.

Both juvenile fisheries (Maine and New Brunswick) take quantities of adult herring which are not included in the assessment when determining the total allowable catch from the adult fisheries off Nova Scotia and in the Gulf of Maine. The catches of ages 1, 2, and 3 herring in the juvenile fisheries, particularly the Maine juvenile fishery, have been used as a relative index to determining good and poor year classes which begin to recruit to the adult fisheries at age 3. The 1976 catch of 30,200 tons was the largest catch since 1968. Except for catches of the very good 1970 year class, the catches in 1976 of the 1973 (age 3) and 1974 (age 2) year classes were the largest since the age 2 and age 3 catches of the 1966 year class.

3. The Gulf of Maine adult fishery

a) Catch statistics. This fishery is prosecuted mainly in the Cape Ann-Jeffreys Ledge area, both inside and outside 3 miles. All catches of herring taken in the Gulf of Maine area (equivalent to the ICNAF 5Y Division) except off Nova Scotia and within 3 miles of the Maine Coast are included in the assessment of this fishery. Previous participants in this fishery, in addition to the US, were the two Germanies, FRG and GDR, Canada and to a small extent the USSR, Poland, Japan, France and Bulgaria. Beginning in 1975 the catch has been mainly taken by the US with 4,500 and 990 metric tons taken by Canada in 1975 and 1976, respectively. The fishery began in 1967-68, reached a peak in catches of 38-43,000 tons in 1970-1972 and has been fairly constant since with catches of 16, 18, 22 and 20,000 tons in 1973-1976.

b) Fishing mortality and year class size in 1976.

i) 1968 and older year classes

The cohort analysis was applied to those year classes assuming starting fishing mortality rates in 1976 of 1.1 and a constant natural mortality rate of 0.2 (.2 was also assumed for all other year classes). The estimate of 1.1 is an average value previously found to apply to older age groups in general.

ii) 1969 year class

The catches for the 1969 year class were extrapolated for years 1977 and 1978 by comparing the percent declines in catch for the 1966-68 year class for ages 5 through 9. An average of catch declines from age 6 to age 7 for the 1967 and 1968 year classes was 51% greater than the catch decline for the 1969 year class. The average catch decline from age 5 to 6 for the 1967 and 1968 year classes was also 51% greater than the decline in catch over the same age for the 1969 year class. The decline in catch from age 7 to age 8 for the 1969 year class was, therefore, assumed to be only 49% of the average of the 1967 and 1968 year classes. This was a 32% decline from 3,943 million at age 7 to 2,697 for age 8 in 1977. The average decline in catch from age 8 to age 9 for year classes 1966 and 1967 was then applied to the catch in 1977 of 2,697 million fish to produce an estimated catch in 1978 of 1,268 million fish. A starting F of 1.1 was arbitrarily applied to this catch in the cohort analysis to provide estimates of F and abundance for all years prior to 1978.

iii) 1970 year class

This year class has been assumed to be twice the size of the 1966 year class at age 3 (267 million) as calculated from an earlier assessment (1974 ICNAF Redbook, p. 42). Under this assumption and with the catches of this year class through 1976 in the Gulf of Maine area (excluding catches from the Maine juvenile fishery) an F of 0.40 is required in 1976 to produce an abundance at age 3 of 534 million fish. This compares well with the F of 0.5 for the 1969 year class in 1976. To examine this assumption further, the percentage declines in catches from age 6 to 7, age 7 to 8 and age 8 to 9 were calculated for all year classes from 1968 to 1976. The average declines in numbers caught were 26%, 53% and 52%, respectively. The maximum declines for any year class from age to age were 73%, 78% and 91% for age 6 to 7, age 7 to 8 and age 8 to 9, respectively. Applying these percentage declines to the catch in 1976 of 54.1 million herring of the 1970 year class gave catches in 1977, 1978 and 1979 that might be expected from this year class. The cohort analysis was applied to these data with a starting F in 1979 of 1.1. The estimates of abundance at age 3 were calculated as 519 million herring (average catch declines) and 363 million (maximum catch declines). These abundance values are 1.95 and 1.40, respectively, greater than the 1966 year class at age 3. Using the catches produced from the average catch declines gave an estimate of F in 1976 of 0.43 and with the catches produced from using the maximum catch declines observed gave an F in 1976 of 1.2. The estimate of F of 1.2 is greater than any F calculated for age 6 to age 7 to date in this fishery. The recruitment size (abundance at age 3) is apparently at least 1.4 greater than the 1966 year class at age and the assumption of twice the size of the 1966 year class still appears to hold. Therefore, the abundance of the 1970 year class is assumed to be 535 million fish (64,000 tons) at age 3 which requires F to be 0.40 at age 6.

iv) 1971 year class

The abundance of the 1971 year class at age 3 has been assumed to be equal to the 1969 year class at age 3 since 1974 (1974 ICNAF Redbook, p. 42). The early estimate of the size of the 1969 year class at age 3 was 64 million fish. The present estimate is 74.3 million herring which requires an F of 0.97 in 1976. While the age 2 catch of the 1971 year class was the second lowest ever observed in the Maine juvenile fishery (from 1960-1976) the catch was still 2.5 larger than the catch of the 1969 year class at age 2. The assumption that the 1971 and 1969 year classes were equal in size was designed to be conservative and it apparently was so. Using a range of starting fishing mortality rates in the cohort analysis in 1976 from 0.4 to 0.9 produces age 3 abundance estimates of 9,100-12,200 tons which range from roughly equal to the size of the 1969 year class to 1.4 times as great. These starting Fs imply an abundance in 1976 of only 4,600-8,700 tons.

The 1971 year class abundance at age 3 is, therefore, probably greater than the 1969 year class although still poor.

The fishing mortality on the 1970 year class as assumed above increased by 48% from 1975 to 1976 and for the 1969 year class increased by 42% from 1975 to 1976. Assuming a similar increase for the 1971 year class implies a starting F in 1976 of about 0.8. This produces an abundance of this year class in 1976 of 5,200 tons and in 1974 (age 3) of 9,400 tons or 5% larger than the 1969 year class.

v) 1972 year class

This year class is and has been assumed to be equal to the 1971 year class since 1975 (1975 ICNAF Redbook, p. 46) from the catches in the Maine juvenile fishery and the poor catches in the Gulf of Maine fishery. The decline in catch from 20.3 to 13.6 million fish from 1975 to 1976 supports this assumption.

vi) 1973 year class

This year class produced catches in the Maine juvenile fishery at age 2 that agreed with the catches from the poor 1971 and 1972 year classes. In the New Brunswick juvenile fishery the catch from the 1973 year class was greater than catches from the 1971 and 1972 year classes. In 1976, 111.4 million herring were taken in the Maine juvenile fishery, the largest age 3 catch since 1969. This year class has, therefore, been assumed to vary in size at age 3 from 64 million (equal to the 1969 year class) to 150 million fish (the conventional level of abundance set in 1974 as one-half of the 1966 year class at age 3) (1974 ICNAF Redbook, p. 10) in 1975 (1975 ICNAF Redbook, p. 46) and from 64 million to 91 million fish in 1976 (1976 ICNAF Redbook, p. 103). For 1977 and 1978 it is assumed that this year class is equal to 134 million fish at age 3, or one-half the size of the 1966 year class as calculated in this assessment.

c) Recruitment levels of the 1974 and 1975 year classes. Noting the large catch of the 1974 year class in 1976 in the Maine juvenile fishery of 310 million fish suggests that this may be a good year class. The last good year class to occur in the Gulf of Maine, except for the very good 1970 year class, was the 1966 year class. Therefore, it was assumed that the 1974 year class was equal to the 1966 year class at age 3 or 269 million fish. In previous assessments due to lack of data, the 1974 year class was assumed to be equal to conventional poor level of 64 million.

Information on the size of the 1975 year class is only available from larval surveys and age 1 catches in the 1976 juvenile catches. This year class is assumed to be poor and equal to the 1969 year class at age 3(73 million).

d) Catch in 1978 and resulting stock in 1970. The last assessment of this fishery (1976 ICNAF Redbook, p. 103-104) assumed a 1976 catch of 7,000 tons (the agreed total allowable catch), and abundance of the 1973 year class of 91 million fish. These conditions forecast a stock size (age 4 and older) in the beginning of 1977 of 60,000 tons. The present assessment assumes a 1976 catch of 20,200 metric tons, and abundance of the 1973 year class at 134 million fish. These conditions predicted a stock size at the beginning of 1977 of 52,800 tons; the second lowest stock size observed for this fishery. Assuming a 1977 catch

of 20,000 tons and the estimate of a good 1974 year class, the stock size would increase to 67,600 tons at the beginning of 1978. A range of fishing mortalities was applied to this stock in 1978 to determine catches (age 3 and older) in 1978 and resultant stock sizes (age 4 and older) in 1979 (Figure 2). Recruitment selection factors applied to the fishing mortality of fully recruited fish were .171, .475, .708, .871 and 1.0 for ages 3-7. Mean weights used were .06, .12, .18, .22, .24, .275, .30, .32, .34 and .36 kilograms for ages 2-11.

To maintain a stock size at 60,000 tons in 1979 an F of 0.38 is required in 1978 which means a catch (age 3 and older) of 14,000 tons in 1978. This level of stock size has been the minimum level sought in past management with the optimum level (to maximize long-term recruitment) set at 110,000 tons. A 10% increase in stock size during 1978 to 74,000 tons can only be obtained with a 1,000 ton catch in 1978. A catch of 20,000 tons (equal to the 1976 level and also assumed for 1977) would cause a fishing mortality rate on fully recruited herring of 0.58 and a stock size at the beginning of 1979 of 54,000 metric tons (a 20% decrease in stock size). To maintain the 1978 stock size of 67,600 tons to the beginning of 1979 requires a catch of 7,000 tons in 1978.

If this stock were managed at the $F_{0.1}$ level of approximately 0.38 and recruitment were equal to the average over the 1967-1976 period, but excluding the good 1970 year class, a long-term annual yield of 15,000 tons would be realized from this stock. This catch level has been exceeded every year since 1967.

4. The Georges Bank herring fishery

a) Catch statistics. The catches from this stock decreased from 374,000 tons in 1968 to 148 and 146,000 tons in 1974 and 1975 under catch quota limitations of 150,000 tons. In 1976 and 1977 allowable catches were severely limited to 60 and 33,000 tons, respectively. The actual catch in 1976 was only 42,000 tons and it is assumed that the 1977 catch will only be 28,000 tons.

b) Fishing mortality and year class size in 1976. Since the total allowable catch in 1976 was so restrictive compared with earlier years, the fishing mortality must have declined in 1976 which decreased the precision of the cohort analysis in calculating fishing mortalities. The cohort (or virtual population) analysis provides the best estimates of mortality when the fishing mortality rate is steadily increasing. Catch data in 1976, therefore, provided less accurate determination of the size of the 1971, 1972, and 1973 year classes than in previous years. The cohort analysis was applied in 1975, therefore, to estimate year class size and mortality for 1975 and earlier. Survival rates were then applied to the 1975 data to obtain the abundance in 1976. With this estimate of abundance and the catches in 1976 the exploitation rates were determined by year class and the survival rates were used, as with the 1975 data, to project the abundance by year class to 1977.

Juvenile herring surveys and Albatross IV bottom trawl surveys continue to provide conflicting estimates of year class strength for recruiting year classes. The juvenile catches along the Maine coast still remain as the best estimates of year class size for both the Gulf of Maine and Georges Bank fisheries. The same assumptions, therefore, as used in the Gulf of Maine were applied to the Georges Bank herring in 1977. This procedure has been followed since 1972.

The year classes 1971 through 1974 make up 98% of the 1978 stock size by weight and the 1973 and 1974 year classes make up 73% of the 1978 stock size by weight. If the assumption of the 1974 year class is wrong and is equal to the conventional poor year class size (85,000 tons) instead of 219,000 tons, then the stock size in 1978 will not be 456,000 tons but 318,000 tons. This is only an 18% increase in stock size instead of a 69% increase in stock size from 1977. The 1974 year class has not yet appeared in the adult fishery and a better index of year class size can be obtained after the 1977 fishery has taken place.

c) Stock size in 1977 and 1978. With the low catches in 1976 and 1977 and the larger estimates of year classes 1973 and 1974, the estimated stock size (age 4 and older) increased to 270,000 tons at the beginning of 1977. The assumed catch in 1977 of 28,000 tons would mean an increase during 1977 of the stock size (age 4 and older) to 456,000 tons at the beginning of 1978.

d) Catch in 1978 and resulting stock in 1979. To maintain the stock at 456,000 tons in 1978 requires an F of 0.20 and a catch of 67,000 tons in 1978. To increase the stock by 10% during 1978 requires a catch of 22,000 tons. Catches of 75,000 and 100,000 tons in 1978 requires Fs of .22 and .31 and would reduce the stock size by 2% and 8%, respectively, to 446,000 and 420,000 tons.

5. Pooled area assessment

To deal with the problem of herring movements and seasonal intermixture of spawning stocks, the catches of herring from all areas from Chedabucto Bay south were combined into one assessment. This assessment includes all herring caught in juvenile as well as adult fisheries. The changes in stock size during 1978 were calculated with a variety of assumptions as to catches in 1978 from the various fisheries. The total catch in this area increased during the 1960's to reach 692,000 tons in 1968, after which the catches steadily declined to reach 248,000 tons by 1976. The total catches during 1973-1975 were 384, 360, and 354,000 tons, respectively. The catch decline from 1975 to 1976 was mostly due to the decrease in total allowable catch on Georges Bank from 150,000 tons to 60,000 tons.

a) Estimates of fishing mortality and year class strength. The cohort analysis was applied to the catches by age beginning in 1976 for year classes 1968 and earlier with a starting F of 1.1. The starting F for the 1969 year class cohort analysis was determined in the same manner as described for the Gulf of Maine adult assessment. The 1970 year class was assumed to be twice the size of the 1966 year class at age 3 or 7,301 million fish. The 1971 and 1972 year classes were assumed to be as poor as the 1969 year class at age 3 (1584 million) and the 1973 year class was assumed equal to one half of the 1966 year class at age 3 (1825 million). The 1974 year class may be a good year class and was assumed (as in other assessments) to be equal in abundance to the 1966 year class at age 3 (3656 million fish).

b) Catches in 1977 and resultant 1978 stock sizes. The stock size at the beginning of 1977 was determined by applying the survival rates in 1976 to the 1976 stock size. It was assumed that the Canadian catch in 1977 would be 77,000 tons in Nova Scotia, 20,000 tons in Chedabucto Bay and 20,000 tons in the New Brunswick juvenile fishery.

In the Gulf of Maine, 20,000 tons was assumed as the catch in each of the juvenile and adult fisheries. On Georges Bank, although a total allowable catch of 33,000 tons has been allocated with the US having 12,000 tons as its quota, it is doubtful that the full 33,000 tons will be caught. The US has never taken as much as 5,000 tons from this area and in 1976 only 735 tons were caught. It was assumed that the US catch from the Georges Bank area would not exceed 7,000 tons and that the total Georges Bank catch would, therefore, be 28,000 tons.

The fishing mortality rates by age were averaged over years 1965-1975 which gave recruitment selection factors for ages 1-5 of .10, .75, .50, .75 and 1.0. These were applied to age groups in the stock for 1977 assuming a total catch of 185,000 tons to derive the stock size in 1978. Mean weights of .015, .05, .12, .18, .22, .24, .275, .30, .32, .34, and .36 kilograms for ages 1-11 were used which were estimated from the Gulf of Maine adult and juvenile fisheries.

c) Catches in 1978 and resultant 1979 stock sizes. A variety of assumed catches of fisheries was examined in 1978 to determine the effect on stock size in 1979 (Table 2). There are six fisheries involved, all with different recruitment rates and mean weights at age. For each set of assumed catches the catch composition was determined separately for each fishery by applying average recruitment selection factors by age for that fishery to the total stock at the beginning of 1978. These catches were then added to form the total catches by age for 1978. The mean weights for each age were determined for each set of catch assumptions by weighting the mean weights of each fishery by the catch of that fishery. Exploitation rate was determined from the total catches and abundance of each age which produced survival rates which were then applied to the abundance in 1978 to provide the estimate of stock abundance in 1979. The results in Table 2 indicate that if the catch of herring in Canada is held at 117,000 tons in 1978, 30,000 tons of herring could be taken in the Maine juvenile fishery and 90,000 tons could be taken in the Georges Bank-Gulf of Maine area adult fisheries with no decrease in stock size. The catches in each fishery are assumed to follow the pattern of catch by age for that fishery given the abundance levels at age over the total areas in 1978. This means for the Maine juvenile fishery, for example, that some adult herring will be caught according to the average proportion since 1967.

To achieve an increase in abundance of 10%, catches of 20,000 tons in each of the juvenile and adult fisheries in the Gulf of Maine-Georges Bank area can be taken (providing that 117,000 tons is not exceeded in Canada).

Table 2 also indicates that changes in abundance from 1978 to 1979 are related to the proportion of the total Gulf of Maine-Georges Bank catch taken as adults and as juveniles. For example, a 70,000 ton catch in this area broken down as 20,000 tons juvenile fishery - 50,000 tons adult fishery gives a 20% greater increase in stock in 1979 than a 30,000 ton juvenile fishery catch and a 40,000 ton adult fishery catch.

Allocations of Catch Between Georges Bank and Gulf of Maine Adult Fisheries

It is necessary to consider the effects of fishing in the Gulf of Maine and the Georges Bank area on the spawning stocks in those areas. While a combined assessment may provide guidelines of the total mortality that can be placed on the overall abundance it says nothing about the effects of the distribution of this mortality on the spawning stocks which are of different sizes. For example, if the fishing were concentrated during the spawning season on the spawning grounds of Jeffreys Ledge and Georges Bank equally, the mortality could be very great on Jeffreys Ledge and quite low on Georges Bank if the Jeffreys Ledge spawning stock is smaller than that on Georges Bank. To prevent severe reductions in individual spawning stocks, the total mortality allowed for the combined assessment should be proportioned on the spawning stocks according to the size of the spawning population. Because of the possibility of extensive intermixture of stocks the calculation of each spawning stock size is difficult. However, some approximations of spawning stock sizes can be obtained from the past catches in the spawning areas at the time of spawning and from estimates of larval production from each spawning area. The catches from August, September and October for both Georges Bank and the Jeffreys Ledge area were used to calculate an estimate of spawning stock for each year. The weighted F for ages 3 and older (1976 ICNAF Redbook, pp. 42, 45) were applied to the catches to obtain estimates of spawning stock abundance. The ratio of the Georges Bank spawning stock to the Jeffreys Ledge spawning stock by year varied from 4.5 to 13.5 with a mean of 8.1 and a standard error of 0.79.

The production of herring larvae from the Georges Bank area was compared with larval production from the coastal Gulf of Maine area for 1971 (1972 ICNAF Redbook, Part I, p. 45) which suggests that the production from the Georges Bank area was 10 times as great as that from the Gulf of Maine area. These estimates suggest that the spawning component of the herring found in the Jeffreys Ledge area is 1/8 to 1/10 as large as that found on Georges Bank.

Equilibrium Catches and Stock Size from all Areas

With the present juvenile fisheries combined with the adult fisheries, the $F_{0.1}$ is 0.20 and F_{max} is at 0.38. If management is at the $F_{0.1}$ level, the average selection coefficients indicate that the mortality on age groups 1 to 4 would be .02, .15, .10, .15 and .2 for ages 5 and older. An equilibrium total annual catch of $F_{0.1}$ of 240,000 tons could be taken from a stock size of 1.7 million metric tons if recruitment is poor (average size of 1967, 1968, 1969, 1971, 1972, and 1973 year classes at age 3). If recruitment is fair (equal to the size of the 1964, 1965 and 1974 year classes) and $F_{0.1}$ is employed, the annual catch could be 377,000 metric tons.

6. Simulation of Stock Rebuilding for a Possible Management Strategy

Maintaining the stock sizes at a moderate level is considered necessary in order to reduce the likelihood of recruitment failures which have resulted in collapses in most of the herring fisheries. Rebuilding the stocks can only be accomplished by harvesting at levels less than the yearly increases due to growth and recruitment. At present stock sizes the annual surplus depends almost entirely on the size of the recruiting year classes, but precise estimates of annual recruitment in advance of fishing are not possible at present. It is important

to recognize that recruiting 3-year-old herring are not all mature and that the maximum yield-per-recruit lies between ages 4 and 5. Thus, estimates of recruitment to the fishery of 3-year-olds which prove to be too low do not result in overall losses in yield the next year, and serve to assure the achievement of maintaining the spawning stock size at the desired level.

In order to examine the long-term consequences of specific management options, several projections were made, based on an earlier assessment (ICNAF Summ. Doc. 75/19). These projections are shown in Figures 3 to 5 for the Gulf of Maine and in Figures 6 and 7 for Georges Bank.

The Gulf of Maine adult fishery was examined by applying over the period 1976-82 a constant catch of 9,000 tons (which gives a stock size of 60,000 tons in 1977) and constant annual recruitment of 64 million fish (about the level of the 1971 to 1973 year-classes at age 3 calculated in an earlier assessment) (Figure 3). This strategy resulted in continued decline in stock size with no opportunity for rebuilding toward the desired level of 110,000 tons. Projections were also made, using constant recruitment of 64 million fish as before and three levels of fishing mortality (Figure 4). Even at the low F-value of 0.1, the stock size showed a continuous decline after 1977. Since good year-classes occasionally occur in herring fisheries, a further simulation was done using a fixed mortality rate of $F_{0.1} = 0.38$ with a good year-class being recruited every fourth year (equal to the 1970 year-class) and low recruitment of 64 million fish for the other three years (Figure 5). The result indicated that the catch would nearly stabilize at about 20,000 tons with an average stock size of about 90,000 tons.

The stock size for Georges Bank was examined by applying for the period 1976-82 a constant catch of 60,000 tons (giving a stock size of 225,000 tons in 1977) and constant annual recruitment of 550 million fish (the low level for recent year-classes) (Figure 6). This strategy resulted in a continuous increase in stock size, but by 1982 the stock size would still be less than the 1975 level and be only 58% of the desired level of 500,000 tons. In order to provide for a faster rate of recovery, projections were made using constant annual recruitment, as before, of 550 million fish and a range of fishing mortalities; the resulting stock size and catch trends are shown in Figure 7.

Under the strategy of maintaining a 60,000 ton catch for the Georges Bank stock, moderate recruitment of about 1,000 million fish (about one-third the size of the 1970 year-class) would increase the stock size to 300,000 tons or more in a single year or to 500,000 tons in about 3-4 years. When the management objective of 500,000 is reached then the catch could be increased to 120,000 tons, corresponding to fishing at $F_{0.1}$ which would maintain the stock size provided that annual recruitment is about 1,000 million fish (the average of the levels observed in the fishery during the past 11 years).

6/27/77

Table 2. Projected stock sizes of herring in 1979 as a function of catches in 1978.

1978 stock size (age 2 and older) (000 tons)	1978 catch (000 tons)					1979 stock size (age 2 and older) (000 tons)	1978 to 1979 percent increase in stock size age 2+
	Chedabucto Bay, Nova Scotia and New Brunswick fisheries (000 tons)	Maine juvenile fishery (000 tons)	Gulf of Maine and Georges Bank fishery (000 tons)	Total New England fishery (000 tons)	Total (000 tons)		
1241	117	20	20	40	157	1354	9.1
1241	117	20	30	50	167	1343	8.2
1241	117	30	20	50	167	1336	7.7
1241	117	20	40	60	177	1331	7.3
1241	117	20	50	70	187	1320	6.4
1241	117	30	40	70	187	1314	5.9
1241	117	30	50	80	197	1303	5.0
1241	117	30	90	120	237	1258	1.4

1978 stock size (age 4 and older) (000 ton)	1979 stock size (age 4 and older) (000 tons)	1978 to 1979 percent increase in stock size age 4+
862	990	14.9
862	979	13.6
862	983	14.0
862	967	12.2
862	956	10.9
862	961	11.5
862	951	10.3
862	907	5.2

Table 3. A summary of assessment parameters used in the June, 1977 Herring Assessment.

Assessment parameters	Gulf of Maine		Georges Bank		Pooled assessment	
	Number $X10^{-6}$	Weight (000 t)	Number $X10^{-6}$	Weight (000 t)	Number $X10^{-6}$	Weight (000 t)
Recruitment at age 3						
1966 year-class	269.0	32.3	1561	219	3657	417
1969 "	73.4	8.8	610	85	1584	181
1970 "	535.0	64.2	3122	437	7301	832
1971 "	78.3	9.4	610	85	1599	182
1972 "	77.7	9.3	610	85	1584	181
1973 "	133.7	16.0	781	109	1825	208
1974 "	269.0	32.3	1561	219	3656	416
1975 "	73.4	8.8	610	85	1584	181
Catch in 1977	-	20.0	-	28	-	185
Stock size (age 4+)						
1975	370.1	80.7	1338	279	8411 1/	1058 1/
1976	263.0	60.6	1016	209	9573 1/	983 1/
1977	228.2	52.8	1308	270	9515 1/	1098 1/
1978	323.0	67.6	2222	456	9686 1/	1241 1/
Surplus Production in 1978	-	7 3/	-	67 3/	-	237 2/
Catch giving 10% increase in 1978	-	1 3/	-	22 3/	-	157 2/

1/ Age 2 and older.

2/ Age 1 and older.

3/ Age 3 and older.

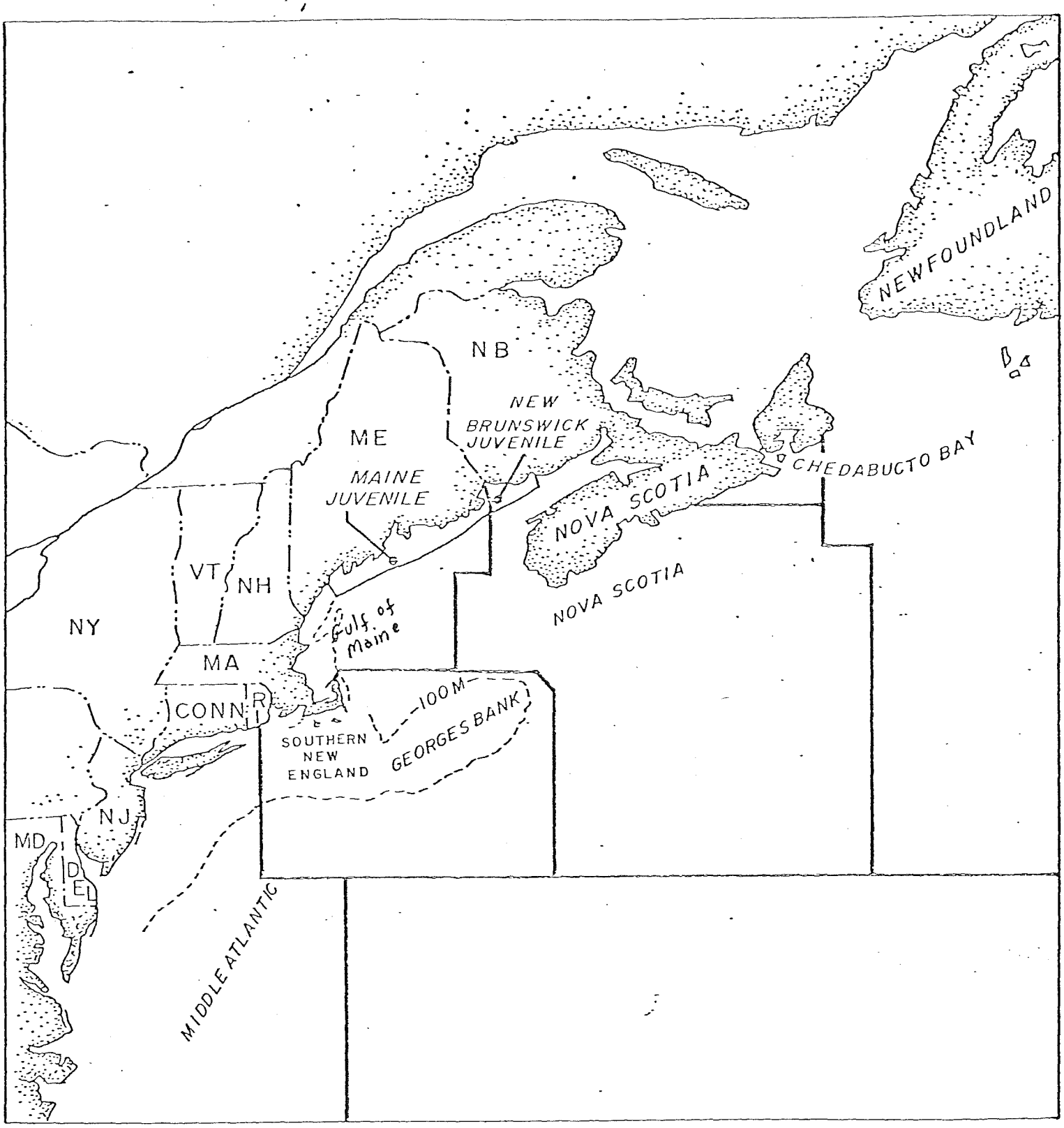

Figure 1. Location of herring fisheries used in the pooled assessment.

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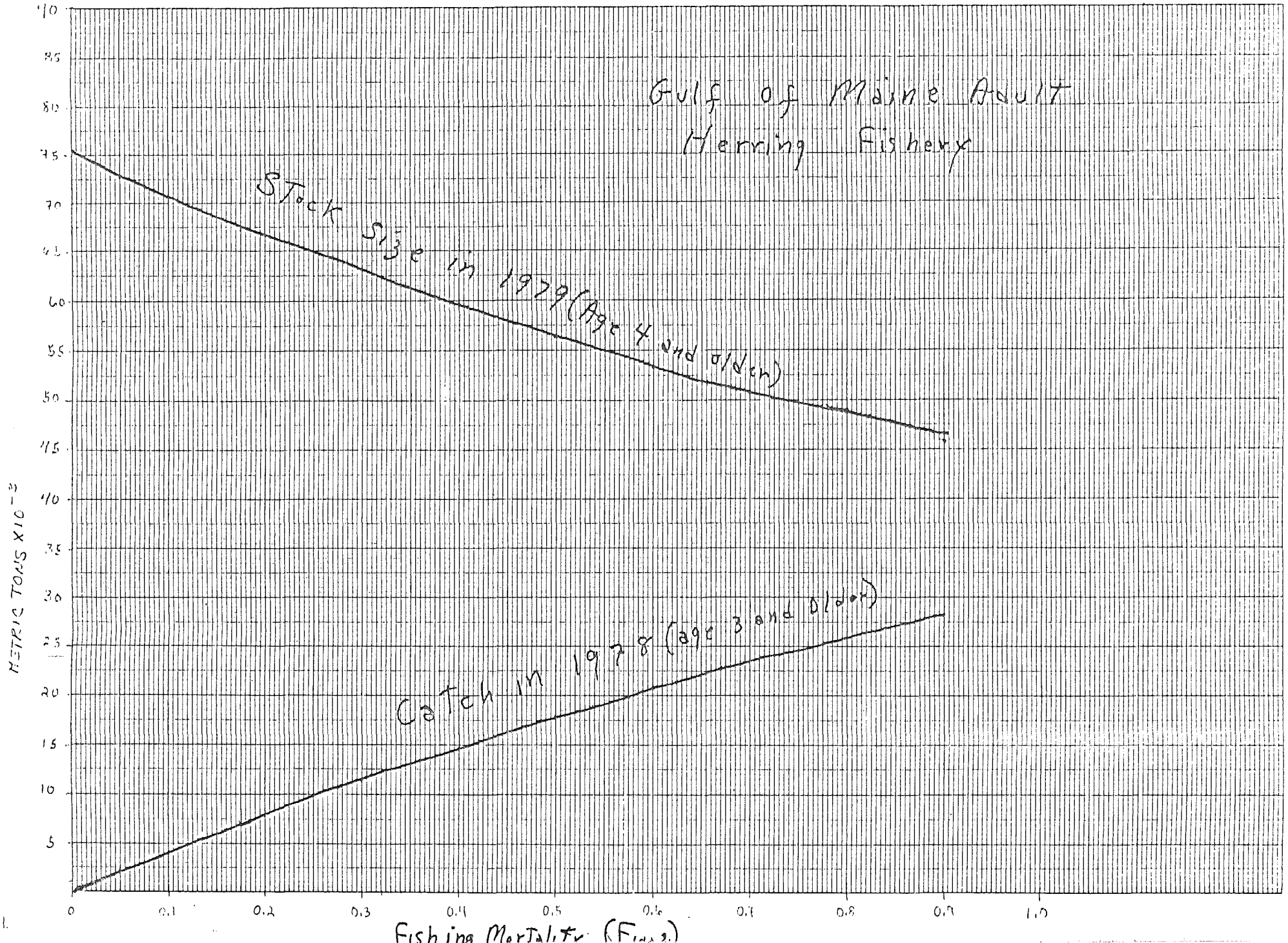

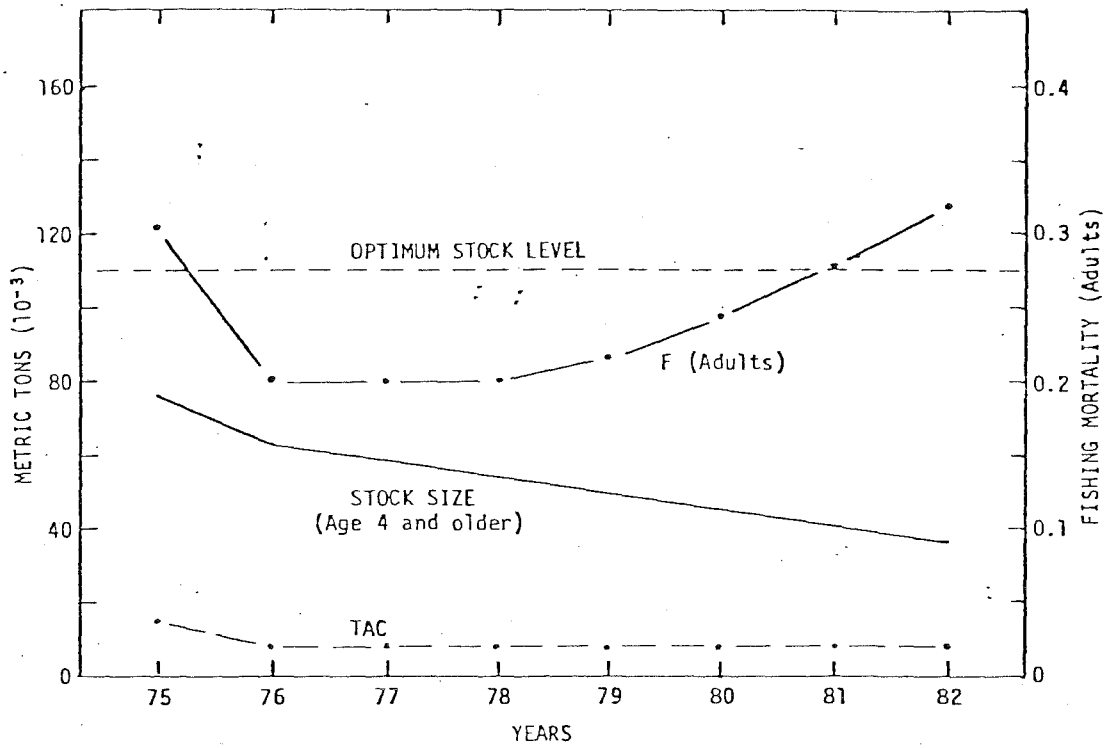

Fig. 3 Herring in Gulf of Me. simulated projection with recruitment of 64 million fish and TAC of 9,000 tons.

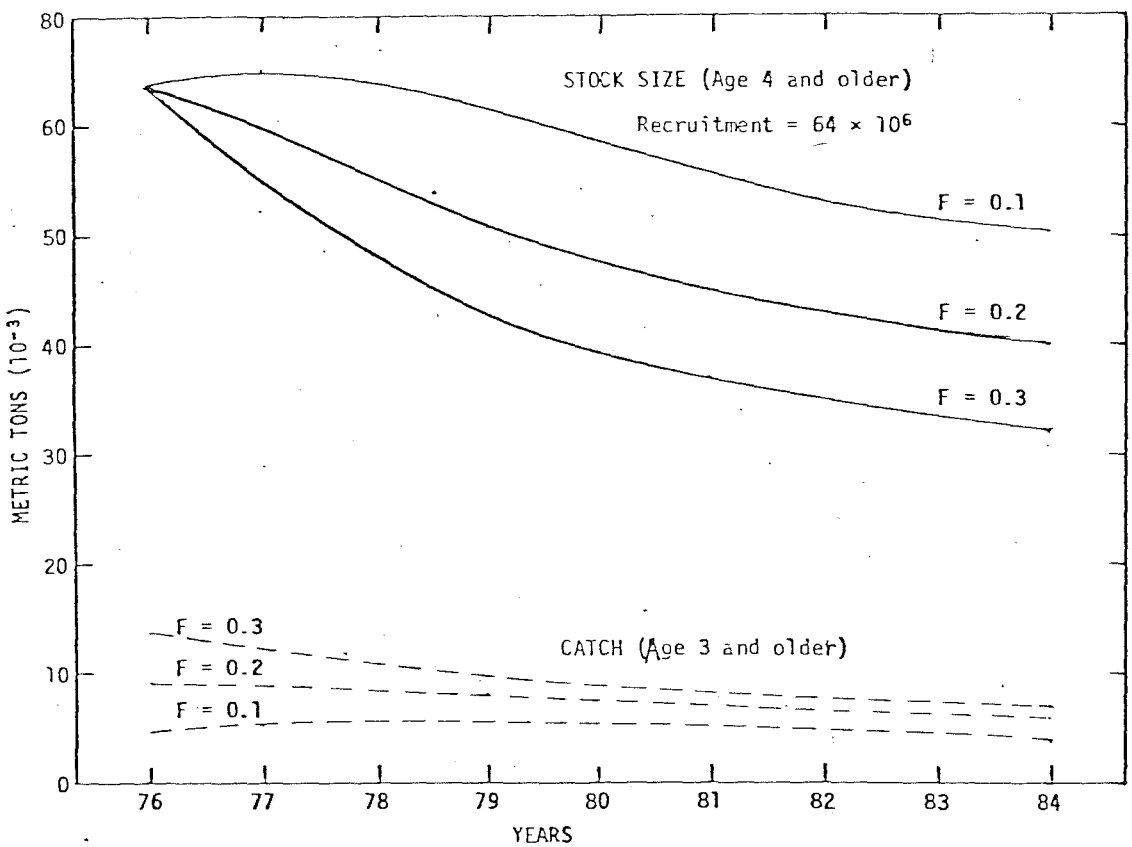

Fig. 4 Herring in Gulf of Me. simulation projections with constant recruitment and three levels of fishing mortality.

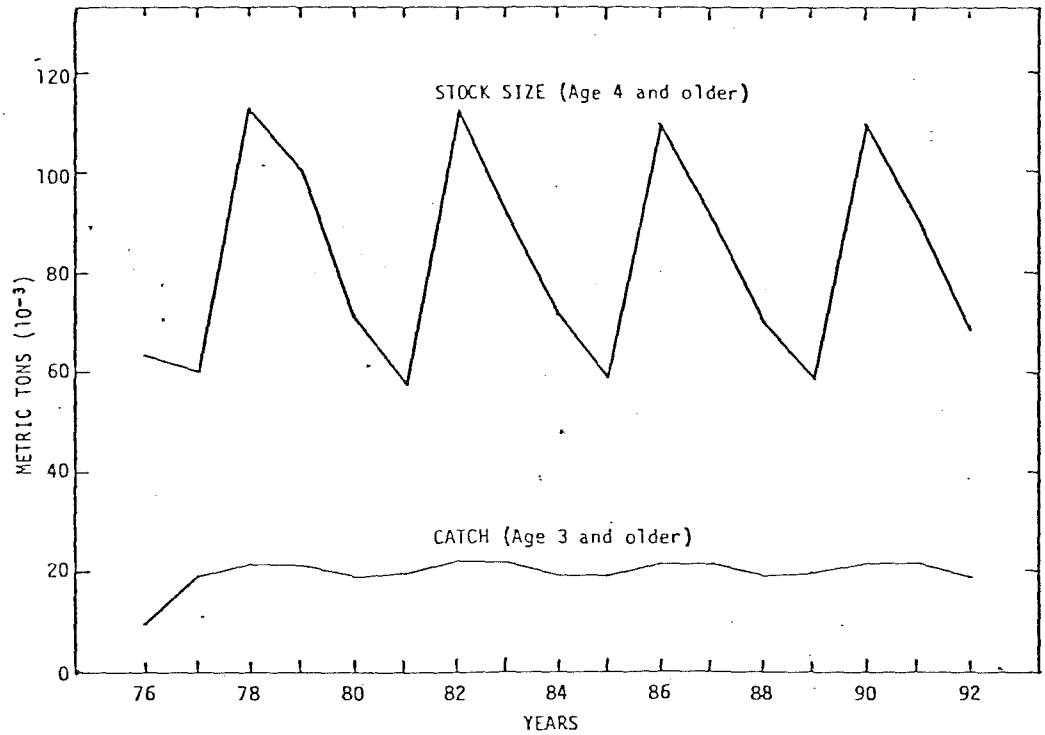

Fig. 5 Herring in Gulf of Me. simulated projections with fixed mortality at $F_{0.1}$, good recruitment (533×10^6 fish) every fourth year and poor recruitment (63.5×10^6) for the other years.

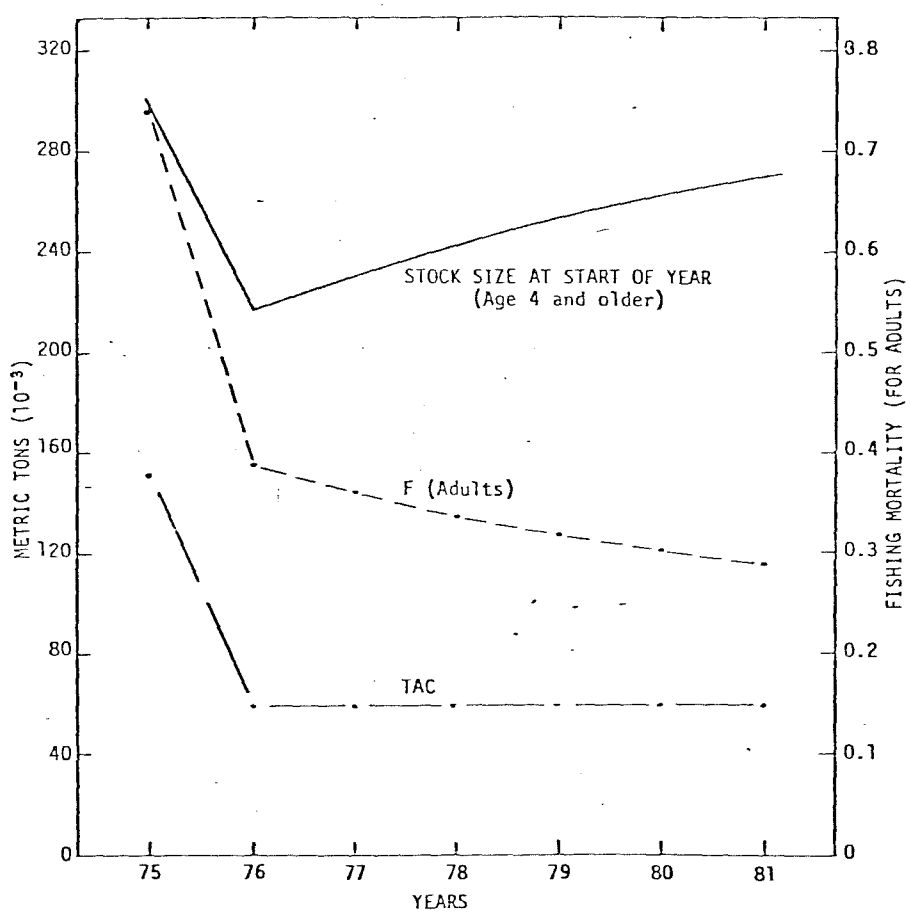

Fig. 6 Herring in Georges Bank: similated projections with constant recruitment of 550 million fish and TAC of 60,000 tons.

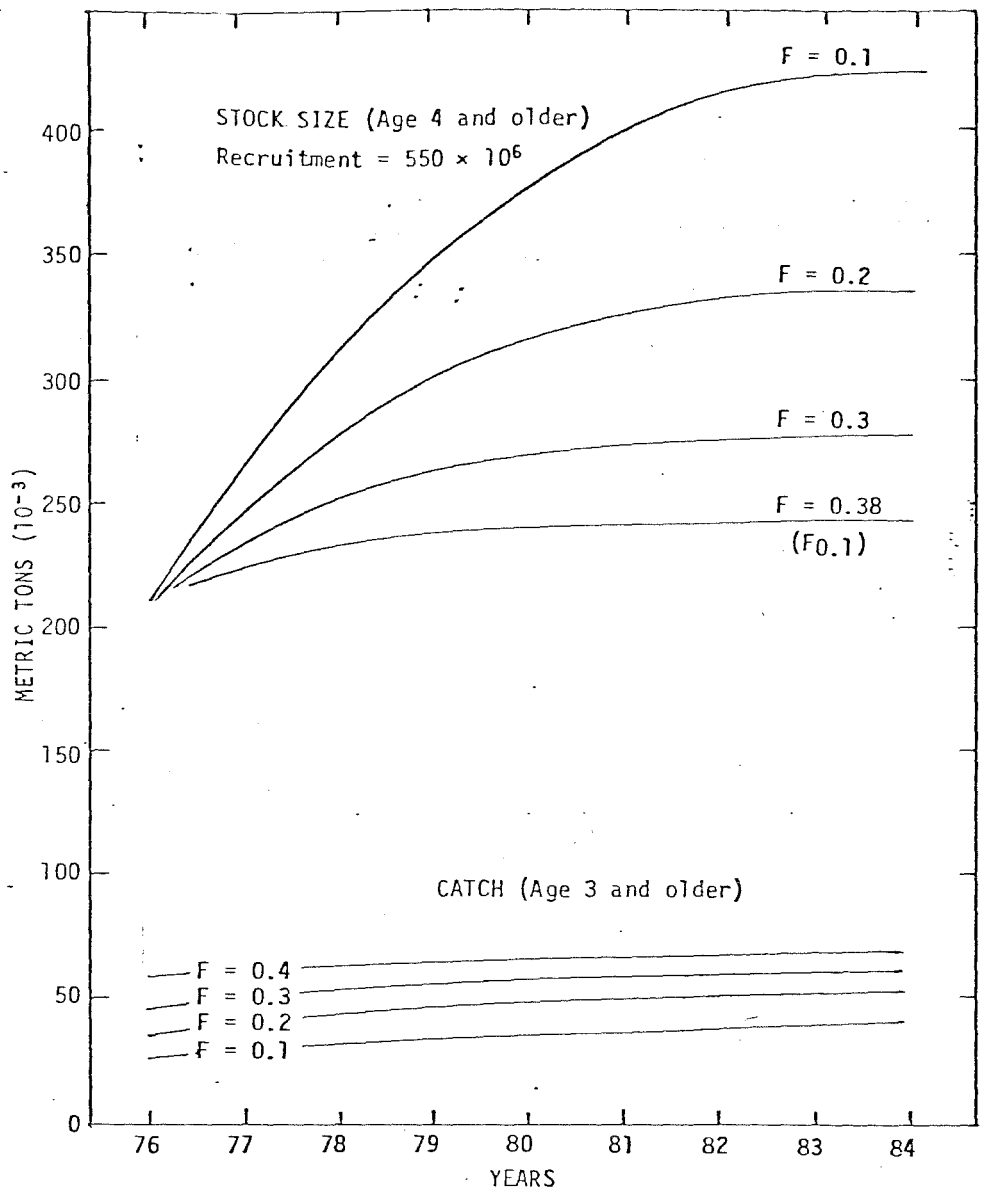

Fig. 7 Herring in George Bank: : simulated projections for four levels of fishing mortality with recruitment constant at 550 million fish.