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Herring Assessment for the Gulf of Maine (ICNAF Division 5Y) Stock

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Introduction

The increasing harvest of adult herring in the Gulf of Maine (ICNAF Division 5Y) combined with low catches of juveniles in recent years has caused concern. An assessment of the current status is thus necessary for recommending appropriate management measures.

Stock Identification

Meristic and immunogenetic studies have indicated that the Gulf of Maine stock is distinct from that in the Georges Bank-Middle Atlantic area (Anthony and Boyar, 1968; Ridgway *et al.*, 1969). Although pockets of spawning herring exist in several areas along the Maine coast, the major concentrations (in ICNAF Division 5Y) appear at present to be in the Jeffreys Ledge-Stellwagen Bank area (Figure 1). The juveniles found along the west side of the Bay of Fundy have been considered as possibly recruiting to the Gulf of Maine adult stock although evidence for this is not definitive. There is some indication that the fishery in eastern Maine is different from other fisheries within the Gulf of Maine as it collapsed earlier. Because of these indefinite situations some of the analyses reported in this paper are applied to various combinations of the 5Y-west side of the Bay of Fundy catches.

Current Trends

The traditional U.S. herring fishery in the Gulf of Maine has changed greatly in recent years (Table 1 and figure 2). The juvenile catch (fish 1-3 years old) is less than one-sixth of what it was in the period ranging from the late 1940's through early 1960's, and the sardine industry has had to rely primarily on imports (Table 2) and older fish (Table 3) to meet market demands. An adult fishery of sizable proportions has also developed in the western portion of the Gulf of Maine beginning in 1967. This adult fishery has concentrated on Jeffreys Ledge, Stellwagen Bank and adjacent areas while the U.S. juvenile fishery as it has existed historically, is limited to the Maine coastline. The U.S. catch of adults remained small until 1970, and a large portion of the total adult catch is imported by the U.S. herring industry.

ICNAF 5Y Juvenile Fishery

The decrease in abundance of recent year classes is indicated by the decline in total catch of juveniles and also by other indices of abundance. The decline of the herring catches by section of the Maine coast is given in Figure 3. The catch of herring used for lobster bait is not included in

Figure 3 but the amount of herring used for this purpose is small i.e. only 257 metric tons in 1971, of which 254 metric tons were imported from Canada.

The eastern Maine catch began to decline in the early 1950's and seemed to have reached a static low level of about 5 thousand metric tons during the sixties but dropped unexpectedly nearly to zero in 1970 and 1971.

The catch of herring in western Maine steadily increased from 1951 to 1958 and provided a good fishery until 1964. The catches of sardines since 1964 were the poorest in western Maine since 1951. The average annual catch for 1947 through 1960 was 20 thousand metric tons as compared with 13 thousand metric tons for the years 1961 through 1967 and 6 thousand metric tons from 1968-1970.

The estimates of year class strength for western Maine herring were obtained from catch per effort data. Since fishing effort in suitable units was not available from the commercial fishing statistics of the Maine fishery a group of stop seine fishermen were selected and their catch per effort was followed through the fishery. Many fishermen, especially stop seiners, appear in the fishery only sporadically and were not considered a reliable function of effort. Therefore, only those fishermen reporting catches for 5 years or more were used to provide an index of effort. This amounted to only 63 (29%) stop seiners for western Maine out of a maximum of 230 stop seiners. Because of the differences in catch among sections of the Maine coast, differences in environment and possible difference in stock composition, the estimation of relative stock abundance was done separately for western, central and eastern Maine.

Following the reasoning of Beverton and Holt (1957) and later that of Robson (1966) it is possible to obtain least square estimates of relative density which are also maximum likelihood estimates if the within-class distribution of density factors are normal with constant variance (Robson, 1966).

The catch per effort for each fisherman was assumed to be equal to $q_i \bar{N}_j \varepsilon_{ij}$ where q_i is the catchability coefficient for the ith fisherman, N_j is the average stock size in number in the jth area and ε_{ij} is a log-normally distributed random variable (Robson, 1966). Taking natural logarithms and expressing the parameters in terms of standard catchability coefficients and average stock sizes:

$$\ln(C_{ij}/f_{ij}) = \ln q_s + \ln \bar{N}_s + [\ln q_i - \ln q_s] + [\ln \bar{N}_j - \ln \bar{N}_s] + \varepsilon'_{ij}$$

or $$Y_{ij} = \mu + \alpha'_i + \beta'_j + \varepsilon'_{ij}$$

where $$\mu = \ln q_s + \ln \bar{N}_s, \quad \alpha'_i = [\ln q_i - \ln q_s], \quad \beta'_j = [\ln \bar{N}_j - \ln \bar{N}_s]$$

Estimates of biased relative density are calculated from a least squares procedure as

$$\hat{D}_j = e^{\hat{\beta}'_j} = e^{[\beta_j - \beta_s]} = e^{[\ln(C/f)_j - \ln(C/f)_s]} = \frac{(C/f)_j}{(C/f)_s}$$

The estimates are biased since they are estimated as logarithms (Laurent, 1963). Finally an unbiased estimate of relative density is computed as:

$$\hat{D}_j = e^{\hat{\beta}'_j} [1 - \text{variance } (\hat{\beta}'_j)/2]$$

Standardization catches per fisherman for western and central Maine are shown in Figure 4 and Table 4 along with the total Maine catch of stop seines and weirs and the catch per number of stop seines. The western Maine decline is more consistent than central Maine in recent years but the central Maine catch has been declining generally since 1950 while the western Maine catch per man actually increased in the early fifties. The catch per man for both central and western Maine were combined into an adjusted index and compared with the total Maine herring catch by stop seines and weirs in Figure 5. The agreement between the total catch and the adjusted index is very good.

The similar slope of the catch per stop seine and weirs and the adjusted index of abundance indicates a fixed fishing intensity on the average. Many of the stop seine fishermen fish for other species when herring are not plentiful but are always looking for herring. When herring appear, fishing effort is placed on herring rather than on another species. So in this respect fishing intensity can be considered to be constant.

All indices of abundance indicate drastic declines, up to an order of 90% of the peak year classes of the 1950's. There is a very obvious and steady decline in abundance since 1958 except for 1962 and 1963 when the strong 1960 year class and fairly strong 1961 year class came into the fishery. The preliminary data for 1971 show that herring abundance also significantly declined in 1971 over that already existing in 1970. The estimated juvenile catch of 7.5 metric tons in 1971 was the lowest catch since 1938, and may be compared with the average annual catch of 64,000 metric tons during the fifties.

ICNAF 5Y Adult Fishery

Table 1 gives the catch in Division 5Y divided into juvenile and adult herring. The U.S. catch of adult herring before 1967 averaged about 2,000 metric tons each year except for 1964 and 1949 when 8,179 and 5,259 metric tons were caught, respectively. In 1967 the total catch jumped to nearly 17,000 metric tons, and increased steadily to 46,208 metric tons in 1970. The age composition of herring in this adult fishery as estimated from U.S. samples has reflected the decline in the abundance of recent year classes. The 1961 and older year classes have supported this fishery since its development. In 1967 and 1968 much of the fish caught were of ages 3-5. In 1969 and 1970, the fishery landed mostly herring of ages 7 and older (Figure 6). Of the recent year classes only the 1966 year class has contributed significantly to the catch providing 27%, 15% and 19% of the catch in 1969, 1970 and 1971. Other recent year classes entering the fishery appear to be smaller than older year classes. The juveniles occurring inshore probably provide the major source of recruitment to the 5Y adult population, and it is shown above that the 1963-1968 year classes are relatively very low in abundance. Therefore, we may expect that when the year classes 1960-1962 have passed through the fishery, the stock and then the catch will decline. This would be true even without the presently increasing fishing levels.

New Brunswick Fishery

It is possible that the juvenile herring found on the west side of the Bay of Fundy in ICNAF Division 4X are part of the Gulf of Maine stock complex. Recently Canadian biologists have made preliminary estimates of that portion of the 4X catch caught on the New Brunswick side of the Bay of Fundy since 1963 (Table 5, Iles, 1972). The weir catch consists mainly of two and three year old fish and has declined drastically from 1968. The 1971 catch of 9,500 metric tons is only about one fourth of what it was in 1968. The Canadian winter purse seine fishery on the New Brunswick side of the Bay of Fundy depends on herring 10-12 cm in total length. This fishery also declined in 1971 to 3,500 metric tons compared to 18,000 metric tons in 1970.

Regulatory restrictions taken jointly by Canada and the U.S. on the harvest of small fish entered into effect late in 1971 but prior to the major fishery on one year old fish. These restrictions may have been primarily responsible for a decline of this magnitude (Personal communication, T. D. Iles).

The number of age 2 herring caught by the New Brunswick weir and purse-seine fisheries is very large totaling over 4.6 billion fish in 1968. From monthly catches and length frequencies by month, the numbers of age 2 herring were estimated that were caught in both the weir and purse seine fisheries. The purse seine catch of age 2 herring is made from January through March while the weir catch is taken during the remainder of the year. The weir catch was fairly constant from 1963 to 1969 probably due to a relatively stable fishing intensity. The purse seine catch increased from 7.4 to 51.7 thousand metric tons from 1963 to 1968 and then declined to 21.7 thousand metric tons in 1969 probably due to changes in fishing intensity. Purse seine effort is known to have increased during the sixties while weir effort remained steady or perhaps declined.

Estimates of Mortality

Estimates of juvenile fishing mortality can be obtained by comparing juvenile catches (Table 6) with the mean stock sizes. The latter were estimated from the adult catches. The number of adults caught was determined from the weight harvested using the age composition and the following weights at age as determined from United States samples:

Age	Weight in grams
2	30
3	115
4	160
5	200
6	244
7	273
8	288
8+	324

The numbers of adult herring caught by year class are presented in Table 7.

A minimum estimate of mean stock size at age 2 was obtained from

$$\bar{N}_2 = C_3 \exp(M) + C_4 \exp(2M) + \ldots\ldots + \frac{C_t Z_t \exp[(t-2.5)M]}{F_t (1-\exp[-Z_t])}$$

for year classes 1962-1965 assuming fishing mortality rates of 0.4 and 0.6 in year t. This equation assumes that the year class is still being fished (Pope, 1971). For the 1960 and 1961 year classes I assumed the year classes are no longer being fished and the estimate of mean stock size was obtained from

$$\bar{N}_2 = C_3 \exp(M) + C_4 \exp(2M) + \ldots\ldots + \frac{C_t Z_t \exp[(t-2.5)M]}{F_t}$$

also assuming F's of 0.4 and 0.6 in year t. The estimates were made according to three assumptions of natural mortality (M); constant values of 0.2,

0.3, and an increase in M with age of 0.15, 0.15, 0.15, 0.25, 0.36, 0.47, 0.58, 0.69, 0.81 and 0.92 for age 2 through 11. The mean stock sizes at age 2 are given in Table 8.

Dividing the catch of age 2 herring by this mean stock size provides an estimate of fishing mortality. Table 8 gives 6 different sets of estimates of fishing mortality for each year class under different assumptions of parentage of juvenile populations. The catch of age 2 herring is combined over western and central Maine; all of Maine; and Maine and New Brunswick combined. The estimates of F are very high, especially for the 1960 year class if one assumes that the New Brunswick juvenile catch recruits to the adult 5Y fishery.

Other estimates of mortality occurring in the Maine herring fishery are also large. Catch curves of age 2 herring by week, adjusted for moon phase were examined for mortality. Juvenile herring are more vulnerable during the dark of the moon so that adjustment by moon phase was necessary when analyzing catches on a short time basis. Table 9 gives the estimate of total mortality for both western and central Maine. The original estimates were made for varying amounts of time but the estimates of Z in Table 9 are for a 10-week period in all cases. These estimates are large even assuming that the fishery lasted only 10 weeks. The juvenile herring along the Maine coast are generally taken during June and July but in some years, some age 2 herring may be caught in September and October as well. So, in some years these values are underestimates. On the other hand, there is some evidence that the decline in catch during the hot summer months is not entirely due to fishing mortality but, to some degree, to the movement of the herring to deeper waters or eastward along the Maine coast. Catch curves in this situation overestimate the total mortality rates.

Another estimate of mortality was attempted from a comparison of catch per effort from age 2 to age 3. Such a method is very difficult to apply to the Maine herring fisheries due to size selectivity of the fishery, vulnerability changes due to phases of the moon, lack of total effort data and perhaps availability of age 3 herring to the inshore fishery. Rough estimates were attempted, however, by weighting by moon phase and using relative estimates of fishing effort. The relative densities of the Maine herring fishery are relative values of catch per unit effort for all selected fishermen for each year compared to a standard year. Standardized catch per unit effort was obtained for each year by multiplying the standard catch per effort value by the relative density for each year. The standardized catch per unit effort value was then divided into the total catch for that year for that section of the Maine coast giving a standardized total effort value. Table 10 describes this procedure for the western section of Maine. The catches of age 2 and age 3 herring adjusted for moon phase were divided by this effort. The decline in catch per effort from age 2 to age 3 thus, provided an estimate of mortality. Again, all estimates were very high. Few herring are caught at age 3 along the Maine coast. This may be due to the high mortality at age 2 or simply that age 3 herring are less available in the inshore areas. Even when age 3 herring are available in the inshore areas, age 2 herring are generally preferred due to their smaller size for canning as sardines. The estimates of mortality, therefore, from the decline in catch per effort are overestimates, at least in some years.

Despite obvious uncertainties about the reliability of the data, all mortality estimates are large; the fishing rate is probably well over 0.65.

Estimates of Adult Stock Sizes

In order to obtain a rough estimate of the relation of stock size to harvest in the adult fishery, the following approximations were made:

1) Juvenile herring stock sizes were estimated by applying the catch equation separately to the juvenile catch in 5Y and in 5Y plus the weir catches from the west side of the Bay of Fundy assuming estimates of F of 0.6 and 0.8 with an M of 0.2 in the juvenile fishery.

2) Natural mortality rates of M of 0.2 and 0.3 were applied over the years to the numbers remaining after the juvenile fishery, to arrive at an adult stock at age 4.

The results of these computations are presented in Table 11. From the late 1940's through the early 1960's, the annual Maine sardine catch averaged 65,000 metric tons - approximately 1.8 billion fish. About 28,000 metric tons (917 million herring) of this total were age 2 herring caught per year from year classes 1945 through 1959. In the period from 1962 to 1965, year classes 1960-1963 provided an annual catch of 1.0 billion fish. The increase in annual catch over earlier years was due to the two good year classes of 1960 and 1961. After these year classes passed through the juvenile fishery, the catches of age 2 herring declined greatly so that year class 1964-1967 provided annual catches of only 296 million herring per year. Year classes 1968-1969 continued the decline producing only 186 million age 2 fish annually. The fisheries on the west side of the Bay of Fundy took 43,000 metric tons (2.1 billion) of herring annually during the years 1963-1965; 62,000 metric tons (3.4 billion) of herring annually during the years 1966-1969 and 23,000 metric tons (1.4 billion) of herring during the years 1970 and 1971. The majority of fish (54%) were taken in the winter purse seine fishery. This fishery took very small herring, approximately 15-17 months old of 10-11 centimeters in total length and only about 15 grams in weight. The weir fishery along the west shore of the Bay of Fundy caught herring a few months older, but also of very small size. The number of herring taken in the New Brunswick purse seine and weir fisheries in 1966-1968 was 15% more than the catch of herring from ICNAF Division 5Y and Subarea 6 from 1961 to 1971 and from Division 5Y from 1967-1971 combined. Approximately 9 billion herring have been harvested from the Georges Bank fishery since 1971 while approximately 12 billion herring have been taken in the New Brunswick purse seine fishery since 1963. This fishery was discontinued by Canada in 1971 as a conservation measure, thereby reducing the fishing mortality greatly on these young herring.

The trade off between the 5Y juvenile (age 2) and adult fishing (age 5) can as a rule of thumb be considered to be in the ratio of 1:3.5. That is, a reduction in catch of 1,000 metric tons of juveniles would be the equivalent of a reduction of 3,500 metric tons of adults in that either one would allow the same increase in spawning stock. This comes about from the sevenfold increase in weight from two to five years of age (30 grams at age 2, 200 grams at age 5) combined with a natural mortality rate (0.2) which would reduce the number of juveniles in half over this period of 3 years. The trade off between the juvenile weir fishery of New Brunswick and adult fishing (age 5) can be considered to be in the ratio of 1:5 (20 grams at age 2, 200 grams at age 5 and reduction in number by 50%).

The age 2 stock sizes in Table 11 for New Brunswick were calculated after the purse seine fishery had ended for each year or about the first of April. This was necessary due to changes in purse seine effort and the instability of fishing mortality. The fishing mortality rates of 0.6 and 0.8 appear to be realistic for the other fisheries on the juvenile herring. Table 11 indicates a rapid decline in age 4 stock size for year classes 1964 and after from the large stock sizes of year classes 1945 to 1963. The average stock size for year classes 1964-1967 for the 5Y juvenile fishery is only 15% to 20% of that of year classes 1960-1963. The decline in the New Brunswick herring stock sizes was a little slower to occur, declining by about 22% for year classes 1964-1967 and by an additional 55% for year classes 1968-1969.

The average adult catch of herring in 5Y was 110 million fish in 1967-1968, which increased to 161 million in 1969-1970 and 209 million by 1971. It is obvious that the adult harvest of herring can not continue to increase or even to remain at the present very high levels as the stock size declines. An adult harvest of 200 million fish under levels of recruitment currently observed in the juvenile fishery is approaching the levels whereby the harvest may take in excess of the recruits to the adult fishery. The estimates of mortality rates in Table 8 indicate that probably not all of the herring providing the juvenile fishery on the west side of the Bay of Fundy recruit to the 5Y adult fishery while probably all of the herring (or an equivalent number from some other area) providing the Maine fishery do recruit to the adult 5Y fishery. An exact catch quota cannot, therefore, be proposed. Even if all of the herring supporting the juvenile fisheries of 5Y and the west side of the Bay of Fundy did recruit to the 5Y adult fishery, a catch of 40,000 metric tons could not be maintained. The good year classes of 1960-1963 accounted for only 21% of the catch in 1971 and should be out of the fishery by 1972. In 1972, year classes 1968 and 1969 will be expected to provide a significant portion of the catch (on the basis of the 1971 age composition-about 25% of the total catch). By 1973 the 1964-1967 year classes will be reduced in size where the contribution of the poor 1968 and 1969 year classes will be even more important.

At present, the best judgement would suggest reduction of adult catches below the current 40,000 metric tons level and maintainance of juvenile catches at current low levels. The latter would allow a good recruiting year class to increase the size of the adult stock. Although the fastest recovery of stock size would result from a cessation of fishing, a quota, at least, lower than the present catch is required to allow for adult stock maintenance if juvenile mortalities are fairly low and recruitment does not fall even further.

Literature Cited

Anthony, V. C., and H. C. Boyar. 1968. Comparison of meristic characters of adult herring from the Gulf of Maine and adjacent waters. Int. Comm. Northw. Atlant. Fish., Spec. Publ., 5: 61-98.

Pope, J. G. 1971. An investigation of the accuracy of virtual population analysis. Int. Comm. Northw. Atlant. Fish., ICNAF Res. Doc. 116.

Ridgway, G. J., R. D. Lewis and S. Sherburne. 1969. Serological and biochemical studies of herring populations in the Gulf of Maine. Int. Council for Exploration of the Sea. Committee Memorandum No. 24: 1-13.

Table 1 . Catch of herring in ICNAF Subarea 5Y in metric tons.

Year	Juvenile	Adult				Grand
	U.S.	U.S.	Canada	Other	Total	Total
1930	33,548	3,940	------	------	3,940	37,488
1931	25,304	3,574	------	------	3,574	28,878
1932	14,510	2,580	------	------	2,580	17,090
1933	19,856	1,621	------	------	1,621	21,477
1934	No data	No data	------	------	No data	No data
1935	23,107	1,447	------	------	1,447	24,554
1936	No data	No data	------	------	No data	No data
1937	22,658	1,313	------	------	1,313	23,971
1938	7,283	2,214	------	------	2,214	9,497
1939	31,572	2,513	------	------	2,513	34,085
1940	17,244	2,676	------	------	2,676	19,920
1941	32,931	No data	------	------	No data	32,931
1942	42,637	2,561	------	------	2,561	45,198
1943	25,941	1,329	------	------	1,329	27,270
1944	37,243	598	------	------	598	37,841
1945	41,999	705	------	------	705	42,704
1946	36,336	929	------	------	929	37,265
1947	65,486	1,084	------	------	1,084	66,570
1948	76,437	2,315	------	------	2,315	78,752
1949	74,029	5,259	------	------	5,259	79,288
1950	90,557	3,661	------	------	3,661	94,218
1951	34,411	1,305	------	------	1,305	35,716
1952	79,139	1,598	------	------	1,598	80,737
1953	58,337	2,032	------	------	2,032	60,369
1954	64,067	1,303	------	------	1,303	65,370
1955	43,506	1,561	------	------	1,561	45,067
1956	66,494	2,058	------	------	2,058	68,552
1957	68,623	3,007	------	------	3,007	71,630
1958	80,759	3,182	------	------	3,182	83,941
1959	53,036	1,472	------	------	1,472	54,508
1960	59,111	1,126	------	------	1,126	60,237
1961	23,310	3,178	------	------	3,178	26,488
1962	69,307	2,371	114	------	2,485	71,792
1963	66,895	2,990	------	227	3,217	70,112
1964	19,537	8,179	636	------	8,815	28,352
1965	31,029	2,605	30	------	2,635	33,664
1966	25,052	4,313	47	------	4,360	29,418
1967	21,461	9,697	6,601	450	16,748	38,209
1968	29,891	11,585	21,497	76	33,158	63,049
1969	22,659	6,028	10,106	16,000	32,134	54,793
1970	11,119	18,061	17,912	9,000	44,973	56,092
1971 1/	7,541	27,131	13,000	7,000	47,131	54,672

1/ Preliminary

Table 2 . Utilization of herring by U.S. industry (metric tons).

YEAR	SARDINES		ME. LOBSTER BAIT		OTHER (mainly reduction, some food & bait)		TOTALS		
	U.S.	Import	U.S.	Import	U.S.	Import	U.S.	Import	Grand
1957	48,707	5,316	6,033	none	16,890	18,456	71,630	23,772	95,402
1958	49,680	1,655	6,898	17	27,362	15,903	83,940	17,575	101,515
1959	43,906	9,785	4,444	115	6,158	19,450	54,508	29,350	83,858
1960	43,354	9,253	9,150	105	7,733	24,346	60,237	33,704	93,941
1961	21,720	3,827	1,983	24	2,785	15,881	26,488	19,732	46,220
1962	52,180	5,425	10,238	8	9,260	22,720	71,678	28,153	99,831
1963	38,623	4,992	17,234	669	14,028	14,957	69,885	20,618	90,503
1964	23,439	3,727	1,318	5,755	2,959	34,643	27,716	44,125	71,841
1965	24,930	9,223	1,859	1,739	6,845	42,559	33,634	53,521	87,155
1966	21,263	14,070	3,216	696	4,886	55,355	29,365	70,121	99,486
1967	24,773	19,179	1,896	1,933	4,489	38,649	31,158	59,761	90,919
1968	27,286	30,059	3,221	2,631	10,969	57,177	41,476	89,867	131,343
1969	22,607	15,600	1,186	3,175	4,894	33,319	28,687	52,094	80,781
1970	15,884	12,194	122	3,872	13,084	30,135	29,180	46,201	75,381

Table 3. Percentage age composition by weight, of Maine herring landings.

	AGE								
Year	1	2	3	4	5	6	7	8	8+
1947	2.09	49.63	48.28						
1948	5.68	35.90	58.42						
1949	16.20	40.41	43.39						
1950	0.31	33.84	65.85						
1951	52.36	23.39	24.25						
1952	6.77	56.38	36.85						
1953	34.34	31.32	34.34						
1954	9.47	31.17	59.36						
1955	20.03	44.22	35.75						
1956	7.96	50.09	41.95						
1957	4.69	63.83	31.48						
1958	5.57	45.31	49.12						
1959	4.22	29.80	65.98						
1960	1.6	63.8	34.6						
1961	11.2	60.4	28.4						
1962	0.9	93.0	6.1						
1963	1.1	26.8	72.1						
1964	4.6	63.3	15.3	15.8	1.0				
1965	1.4	76.9	18.3	1.1	2.3				
1966	0.7	25.2	69.6	1.0	2.3	0.8	0.3	0.1	
1967	0.9	26.6	50.5	17.5	---	2.8	---	---	1.7
1968	0.7	52.7	43.9	1.5	1.2				
1969	0.3	28.1	66.7	3.7	0.3	0.4	0.3	0.1	0.1
1970	2.0	42.5	26.7	16.3	3.3	4.6	2.0	1.8	0.8
1971	6.41	38.50	14.64	-----	1.09	17.91	6.47	9.00	5.98

Table 4 . Indices of abundance of juvenile herring in ICNAF subarea 5Y for recent years.

Year	Maine catch by stop seine and weirs (MT)	Catch per stop seine in Maine (MT)	Standardized catch per effort of age 2 herring	
			Western Maine	Central Maine
1952	74,124	262	897	2,417
1953	50,592	177	1,081	1,379
1954	57,445	190	1,347	1,258
1955	40,587	170	999	859
1956	59,890	272	1,585	1,444
1957	61,888	224	1,203	1,585
1958	73,463	289	1,492	1,500
1959	48,577	198	1,289	940
1960	49,909	212	688	1,323
1961	16,966	132	457	503
1962	56,324	244	983	1,647
1963	45,643	247	1,004	1,421
1964	21,984	152	767	474
1965	24,878	149	420	1,098
1966	15,391	116	213	802
1967	11,838	94	426	968
1968	19,226	148	320	1,226
1969	7,531	91	392	265
1970	3,157	71	136	623

Table 5. Bay of Fundy, New Brunswick herring catches.

	Weirs			Purse seine		
Year	Metric tons (1000's)	Numbers (millions)	Mean fish weight(gms)	Metric ton (1000's)	Numbers (millions)	Mean fish weight(gms)
1963	28,193	1,034	27.3	7,421	422	17.6
1964	27,332	966	28.3	17,573	1,260	13.9
1965	31,704	1,335	23.7	17,320	1,211	14.3
1966	35,604	1,659	21.5	25,745	1,689	15.2
1967	29,774	1,360	21.9	26,067	1,952	13.4
1968	31,969	1,607	19.9	51,680	2,954	17.5
1969	25,657	1,258	20.4	21,717	995	21.8
1970	15,704	1,120	14.0	17,630	1,263	14.0
1971	9,543	318	30.0	3,533	122	29.0
Average			22.1			15.9

Table 6. Total catch of Maine herring and New Brunswick sardine herring (millions of fish).

	AGE									
	1	2	3	4	5	6	7	8	8+	Total
WESTERN MAINE										
1961	18.6	132.7	20.2							171.5
1962	20.9	745.3	28.1							794.3
1963	29.8	322.3	179.2							531.3
1964	23.4	246.1	10.1	2.9	0.5					283.0
1965	31.2	196.0	24.3	0.4	0.2					252.1
1966	11.6	127.1	44.8	1.8	2.3	1.3	0.4	0.2		189.5
1967	1.4	58.7	23.1	4.9	---	2.0	---	---	1.8	91.9
CENTRAL MAINE										
1961	203.6	226.4	7.9							437.9
1962	20.3	992.9	3.1							1016.3
1963	30.8	242.6	239.5							512.9
1964	66.9	186.9	17.9	8.1						279.8
1965	3.6	362.1	17.3	0.4						383.4
1966	4.0	60.2	51.1	0.5	7.3					122.1
1967	7.9	96.4	75.3	10.7	17.7	1.3				209.3
EASTERN MAINE										
1961	7.0	27.9	11.4							46.3
1962	10.8	500.1	6.3							517.2
1963	13.1	206.9	79.3							299.3
1964	7.6	41.9	4.3	11.7	0.5					66.0
1965	6.2	374.7	16.3	1.6	4.0					402.8
1966	5.4	104.4	112.7	----	0.4					222.9
1967	12.2	113.0	23.7	18.1	---	0.2				167.2
NEW BRUNSWICK[1]										
1962	230.0	1157.5	113.2	48.4	3.7	1.5				1554.3
1963	129.1	1143.4	111.7	65.3	4.6	1.9				1456.0
1964	300.3	1583.3	227.0	108.6	5.1	2.1				2226.4
1965	254.7	1981.7	202.5	96.1	7.8	3.2				2546.0
1966	258.5	2485.0	360.8	226.1	12.3	5.1				3347.8
1967	571.1	2330.0	281.6	116.9	9.0	3.8				3312.4
1968	695.9	3411.5	328.4	115.9	6.9	2.8				4561.4
1969	248.8	1749.1	173.1	73.9	5.4	2.2				2252.5
1970	521.1	1557.6	193.4	102.9	5.3	2.2				2382.5

[1]Age composition of eastern Maine catches applied to New Brunswick weir catches. Age Composition of purse seine catches obtained from monthly length frequencies.

Table 7 . Numbers of herring in 1000's caught in the 5Y adult fishery.

	YEAR CLASS														
Year	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Total
1967	359.2	700.4	736.3	1,412.1	17,582.5	28,669.3	15,895.2	6,336.4	680.7	43.5					72,415.6
1968		1,960.1	2,412.4	3,166.3	18,387.3	27,974.2	29,280.1	29,458.2	17,467.2	17,734.4	563.9				148,404.2
1969			1,684.8	2,603.7	11,027.5	21,123.5	26,617.9	22,475.8	9,850.1	6,191.9	39,044.4	1,722.3			142,341.9
1970				2,666.0	13,774.1	27,992.6	23,344.2	26,942.5	26,835.0	18,349.5	26,369.6	9,326.9	3,419.3		179,019.7
1971					3,733.1	8,461.6	12,692.4	18,440.9	30,331.6	42,326.6	39,134.9	26,117.7	26,639.2	730.1	208,608.0
Total	359.2	2,660.5	4,833.5	9,848.1	64,504.5	114,221.2	107,829.8	103,653.8	85,164.6	84,645.9	105,112.8	37,166.9	30,058.5	730.1	750,789.4

Table 8. Estimates of juvenile fishing mortality assuming that all juveniles recruit to the 5Y adult fishery. Juvenile mean stock sizes calculated according to fishing mortalities (F_T) in the terminal year of catch of 0.4 and 0.6.

	YEAR CLASS											
	1960		1961		1962		1963		1964		1965	
	F_T		F_T		F_T		F_T		F_T		F_T	
	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
Estimated mean stock size at age 2 (millions)												
Assuming M=.2	764	761	492	458	461	419	562	505	487	420	489	412
M=.3	1,081	1,069	903	827	776	691	817	726	701	590	504	427
M varies	1,508	1,410	1,177	1,023	774	663	684	598	532	449	476	399
Age 2 catch from western and central Maine (millions)	1738		565		433		558		187		155	
$\hat{F}$ assuming M=.2	2.27	2.28	1.15	1.23	0.94	1.03	0.99	1.10	0.38	0.44	0.32	0.38
M=.3	1.61	1.63	0.63	0.68	0.56	0.63	0.68	0.77	0.27	0.32	0.31	0.36
M varies	1.15	1.23	0.48	0.55	0.56	0.65	0.82	0.93	0.35	0.42	0.33	0.39
Age 2 catch from all of Maine (millions)	2238		772		475		933		292		268	
$\hat{F}$ assuming M=.2	2.93	2.94	1.57	1.69	1.03	1.13	1.66	1.85	0.60	0.70	0.55	0.65
M=.3	2.07	2.09	0.85	0.93	0.61	0.69	1.14	1.29	0.42	0.49	0.53	0.63
M varies	1.48	1.59	0.65	0.75	0.61	0.72	1.36	1.56	0.55	0.65	0.56	0.67
Age 2 catch from Maine and New Brunswick (millions)	3309		1741		2138		2805		2694		2551	
$\hat{F}$ assuming M=.2	4.33	4.35	3.54	3.80	4.64	5.10	4.99	5.55	5.53	6.41	5.22	6.19
M=.3	3.06	3.10	1.93	2.11	2.76	3.09	3.43	3.86	3.84	4.57	5.06	5.97
M varies	2.19	2.35	1.48	1.70	2.76	3.22	4.10	4.69	5.06	6.00	5.36	6.39

Table 9 . Estimates of total mortality rates from catch curve analysis of the Maine juvenile fishery for a 10-week period (95 percent confidence intervals in parentheses).

Year	Total Mortality Rate	
	Western Maine	Central Maine
1953	1.50 (1.488, 1,503)	0.83 (0.829, 0.836)
1954	1.48 (1.474, 1.485)	1.18 (1.173, 1.181)
1955	1.54 (1.528, 1.541)	1.31 (1.300, 1.310)
1956	1.74 (1.732, 1,743)	1.23 (1.225, 1.231)
1957	2.51 (2.500, 2.517)	1.16 (1.160, 1.165)
1958	1.20 (1.200, 1.207)	0.90 (0.894, 0.899)
1959	1.99 (1.979, 2.000)	1.18 (1.176, 1.184)
1960	1.45 (1.447, 1.458)	0.78 (0.777, 0.781)
1961	1.32 (1.311, 1.325)	0.76 (0.755, 0.764)
1962	1.59 (1.587, 1.595)	0.79 (0.785, 0.788)
1963	1.71 (1.699, 1.711)	0.93 (0.931, 0.938)
1964	0.75 (0.744, 0.750)	0.93 (0.928, 0.939)
1965	1.04 (1.039, 1.051)	1.05 (1.049, 1.056)
1966	0.64 (0.631, 0.640)	0.91 (0.902, 0.914)
1967	0.78 (0.778, 0.789)	0.79 (0.785, 0.792)

Table 10 . Determination of relative effort for Western Maine from relative densities calculated from 63 selected stop seine fishermen and estimates of Z from declines in catch per effort for Western and Central Maine.

WESTERN MAINE

Year	Relative density	Catch per fisherman (metric tons)	Total catch (metric tons)	Relative effort (stop seine units)	Catch in numbers (1000's) Age 1	Age 2	Age 3	Year class	Estimate of Z Catch per effort Age 2	Age 3	$\hat{S}$	$\hat{Z}$
1953	4.108	1,081.4	18,258.72	16.88	424,201	192,234	36,382	1951	11,388.27	6,911.66	0.6069	0.50
1954	5.118	1,347.3	22,543.07	16.73	254,427	311,869	115,632	1952	18,641.30	1,597.08	0.0857	2.46
1955	3.795	999.0	18,829.97	18.85	191,144	256,282	30,105	1953	13,595.86	6,981.26	0.5135	0.67
1956	6.023	1,585.5	23,350.00	14.73	205,951	464,558	102,834	1954	31,538.22	2,759.32	0.0875	2.44
1957	4.572	1,203.5	21,445.00	17.82	161,314	408,060	49,171	1955	22,898.99	7,347.36	0.3209	1.14
1958	5.670	1,492.6	31,135.00	20.86	293,722	450,687	153,266	1956	21,605.32	14,347.39	0.6641	0.41
1959	4.899	1,289.6	24,243.00	18.80	186,841	191,605	269,731	1957	10,191.76	3,421.87	0.3357	1.09
1960	2.617	688.9	18,268.00	26.52	42,246	334,575	90,748	1958	12,615.95	777.85	0.0617	2.79
1961	1.737	457.2	11,662.00	25.51	15,993	143,864	19,843	1959	5,639.51	922.62	0.1636	1.81
1962	3.735	983.2	27,253.30	27.72	23,413	701,617	25,575	1960	25,310.86	5,023.94	0.1985	1.62
1963	3.815	1,004.3	19,629.60	19.55	26,606	347,328	98,218	1961	17,766.14	331.31	0.0186	3.98
1964	2.916	767.6	12,873.70	16.77	25,124	244,032	5,556	1962	14,551.70	2,050.74	0.1409	1.96
1965	1.598	420.7	9,093.80	21.62	28,635	168,793	44,337	1963	7,807.26	1,362.52	0.1745	1.75
1966	0.811	213.5	7,731.00	36.21	12,422	122,285	49,337	1964	3,377.11	844.09	0.2499	1.39

CENTRAL MAINE

Estimate of Z Catch per effort Age 2	Age 3	$\hat{S}$	$\hat{Z}$
12,320.75	8,045.58	0.6530	0.43
20,802.55	3,895.45	0.1873	1.68
15,633.09	5,945.68	0.3803	0.97
29,109.31	4,504.90	0.1548	1.87
38,876.43	5,864.98	0.1536	1.87
27,302.91	3,463.17	0.1195	2.12
15,725.72	2,465.34	0.1568	1.85
29,859.93	214.19	0.0072	4.93
5,054.22	159.46	0.0315	3.46
50,093.33	11,011.38	0.2918	1.52
12,267.99	1,116.77	0.0910	2.40
5,723.51	2,239.44	0.3913	0.94
27,010.43	4,290.38	0.1588	1.84
8,288.65	2,872.87	0.3466	1.06

Table . Population sizes and removals from the Gulf of Maine herring stock (numbers in millions).

Year classes	Average age 2 catch (millions)	Age 2 stock size at beginning of year (millions)	Age 2 fishing mortality rate	Age 2 natural mortality rate	Age 4 stock size at beginning of year (millions)
Based on 5Y Juvenile Catches only					
1945-1959	917	2220	.6	.2	605
	917	2317	.6	.3	507
	917	1813	.8	.2	335
	917	1890	.8	.3	277
1960-1963	1032	2497	.6	.2	770
	1032	2609	.6	.3	650
	1032	2040	.8	.2	467
	1032	2127	.8	.3	391
1964-1967	296	718	.6	.2	163
	296	748	.6	.3	131
	296	587	.8	.2	76
	296	610	.8	.3	57
1968-1969	186	449	.6	.2	130
	186	470	.6	.3	107
	186	367	.8	.2	77
	186	383	.8	.3	60
Based on 5Y plus the West Side of the Bay of Fundy Juvenile Catches					
1960-1963	1904	4609	.6	.2	1410
	1904	4813	.6	.3	1279
	1904	3764	.8	.2	856
	1904	3924	.8	.3	792
1964-1967	1497	3624	.6	.2	1076
	1497	3784	.6	.3	1005
	1497	2960	.8	.2	670
	1497	3085	.8	.3	623
1968-1969	670	1624	.6	.2	506
	670	1694	.6	.3	460
	670	1326	.8	.2	320
	670	1381	.8	.3	290

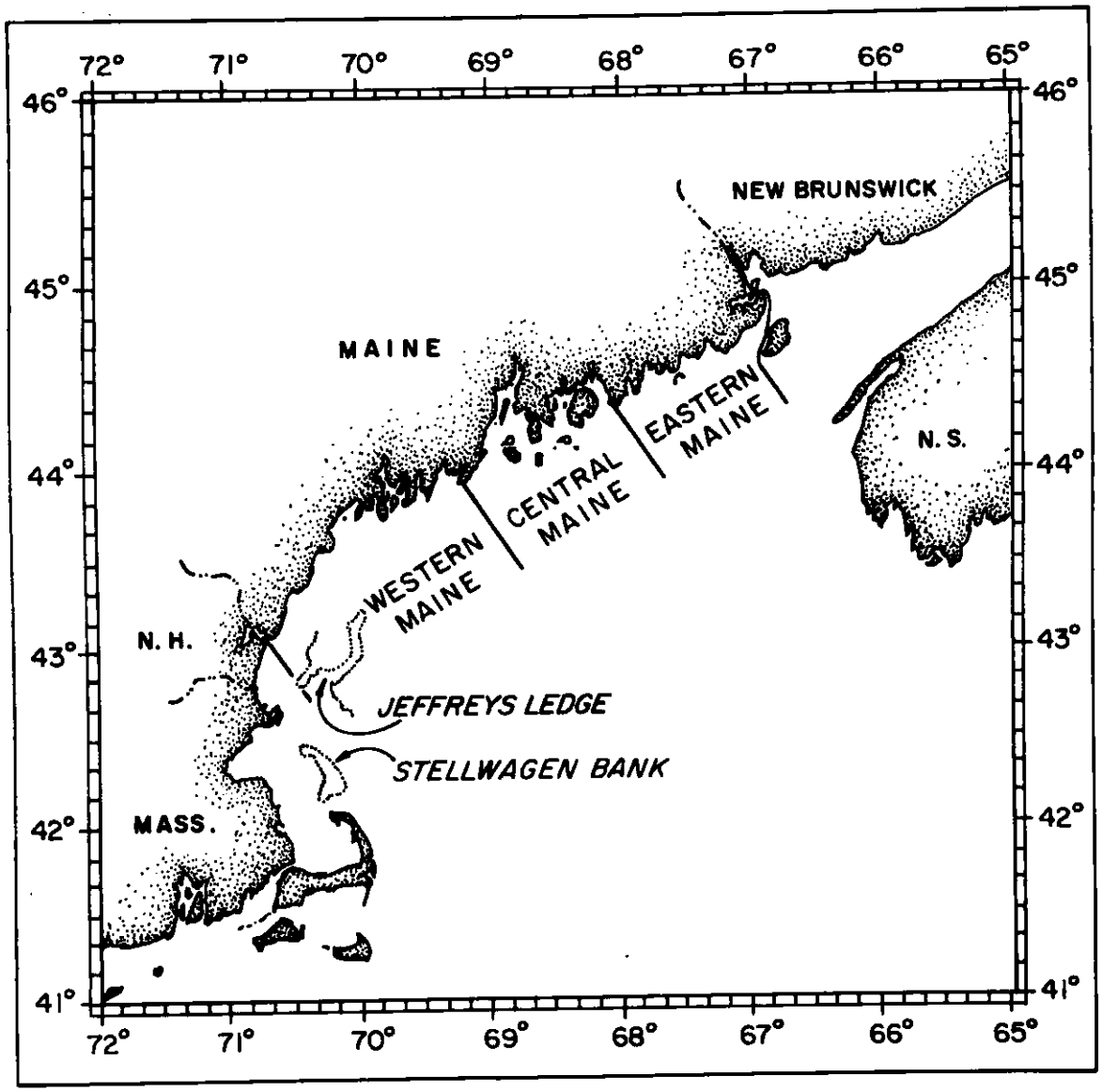

Figure 1. Areas of adult herring fishery (Jeffreys Ledge- Stellwagen Bank) and juvenile herring fishery (eastern, central and western Maine) in Division 5Y.

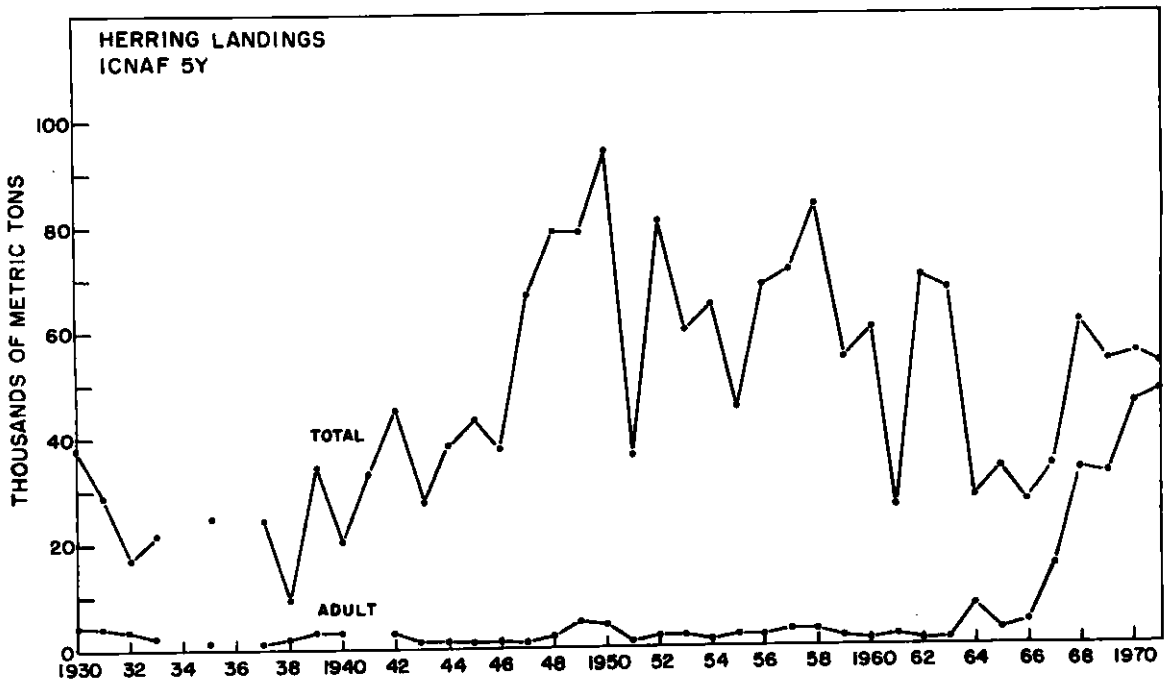

Figure 2. Herring landings from ICNAF Division 5Y showing the development of the adult fishery.

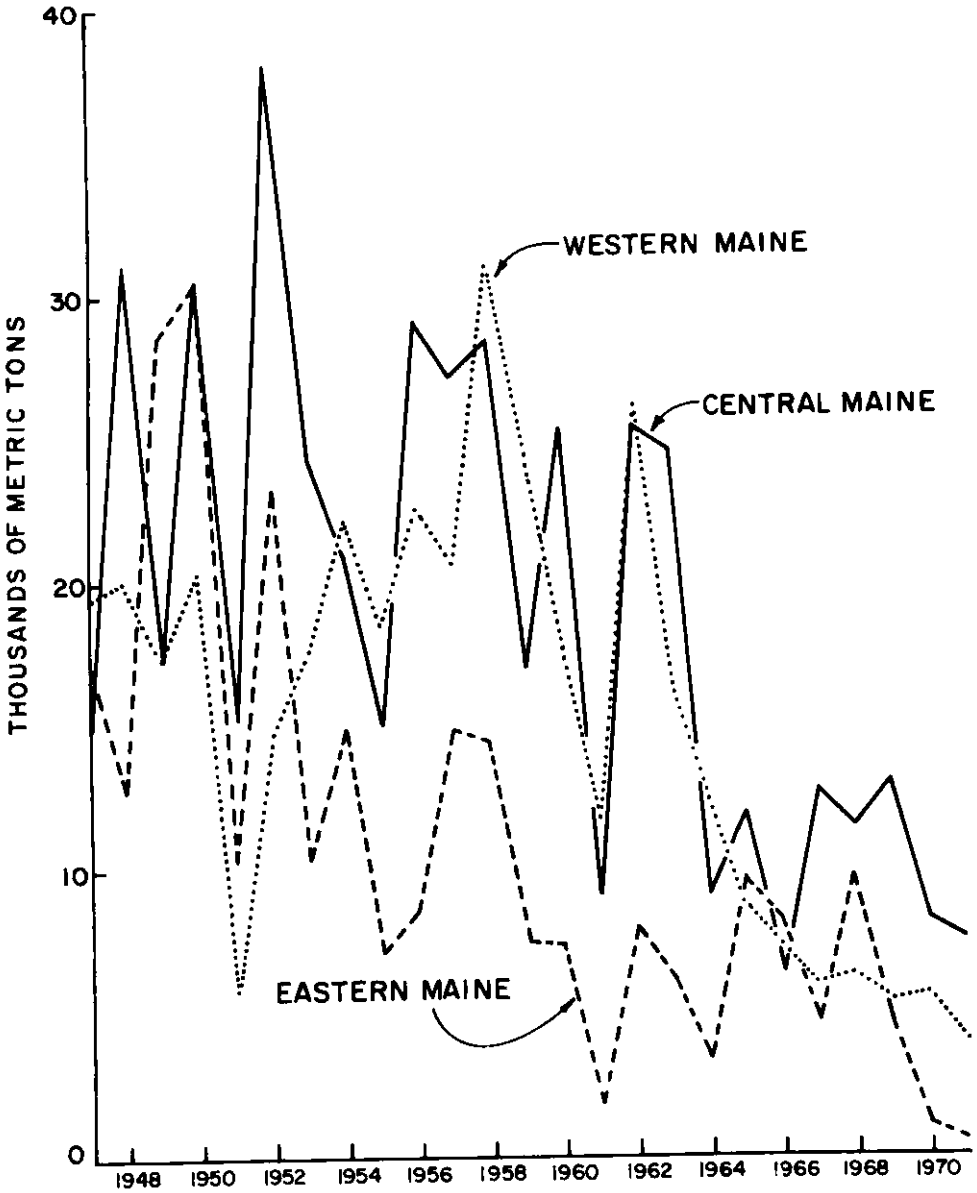

Figure 3. Catch of herring (except for lobster bait) along the Maine coast.

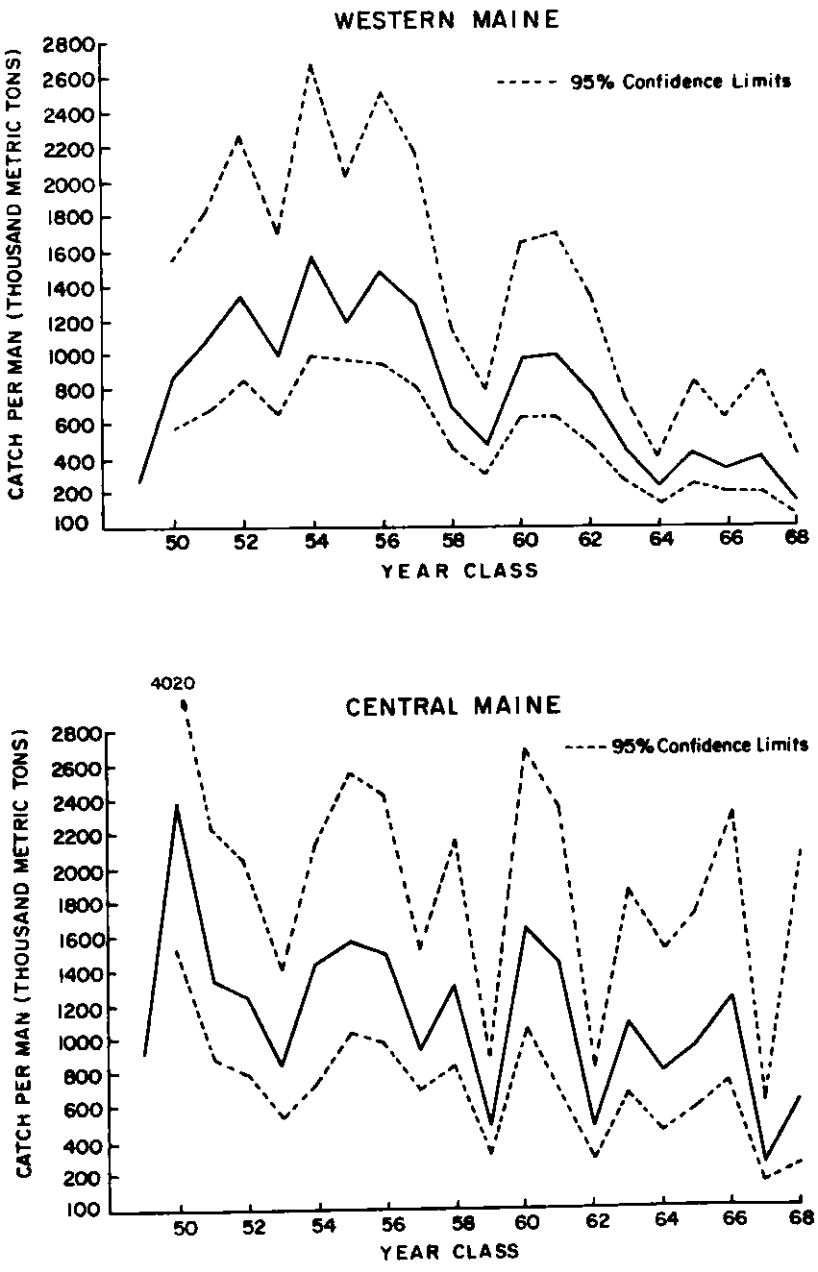

Figure 4. Standardized catch of herring per selected stop seine fisherman per year for western and central Maine.

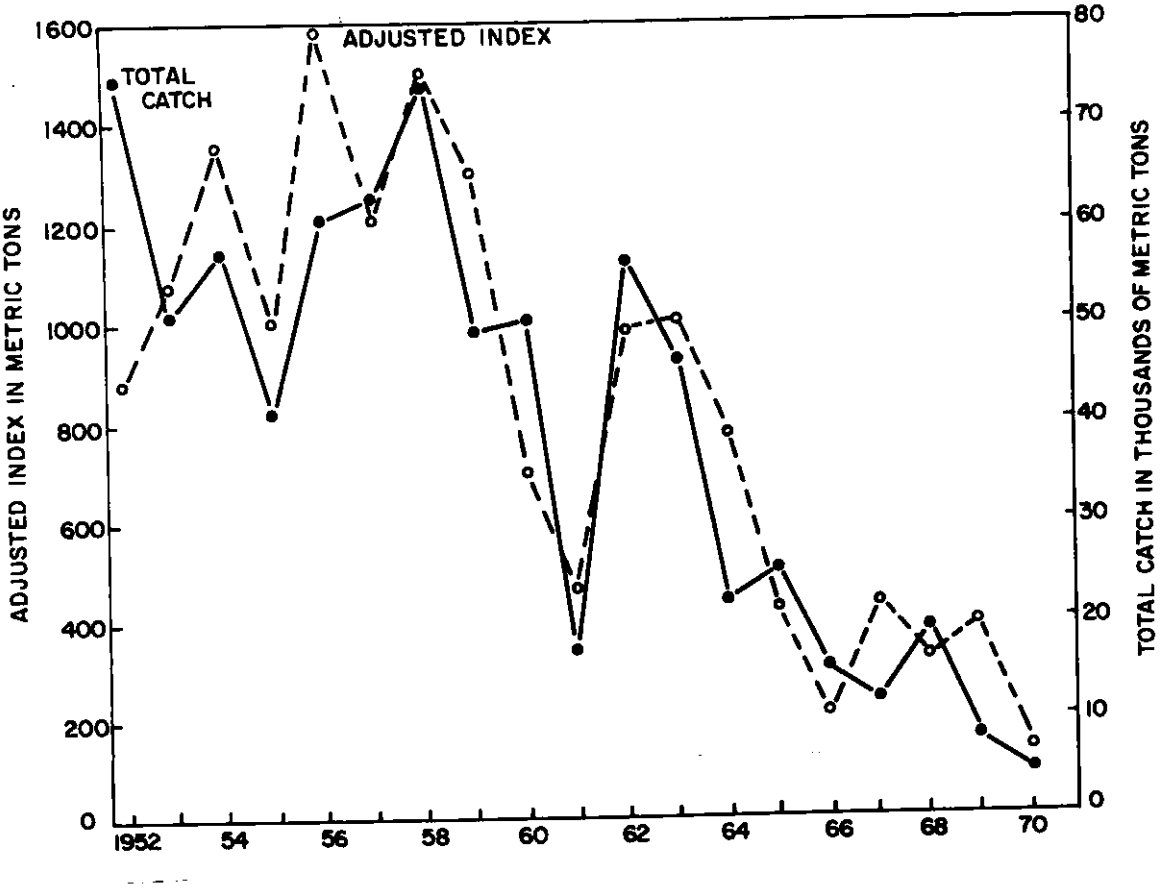

Figure 5. Adjusted index of catch per stop seine fisherman from both central and western Maine compared with the total catch of herring from stop seines and weirs.

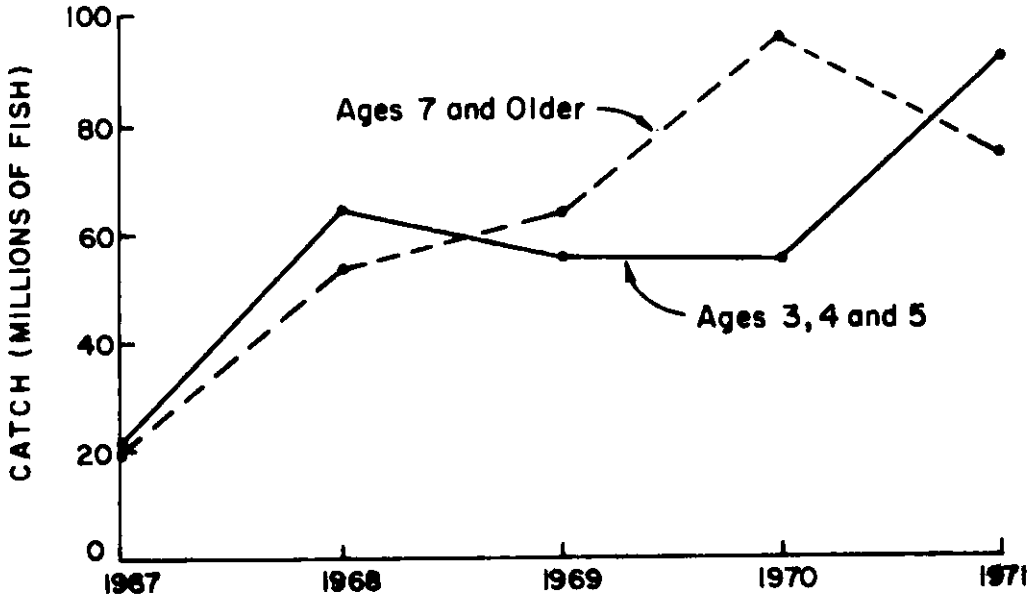

Figure 6. Catch of adult Atlantic herring from southwestern Gulf of Maine, ICNAF Division 5Y, showing the dependence on older fish in 1969 and 1970.