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STATUS OF ATLANTIC HERRING RESOURCES IN THE GULF OF MAINE REGION - 1982

by

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Summary

Coastal Maine herring landings increased from 45,902 mt in 1980 to 48,245 mt in 1981. Due to the occurrence of a succession of strong year classes (1976, 1977, 1979), herring resources in the Gulf of Maine appear to have recovered from reduced levels noted during the last decade. The fixed gear fisheries, typically selective for age 2 herring, were dominated by the 1979 year class (39,588 mt) during 1981. Landings of age 2 herring in 1981 were the highest since 1962. Purse seine landings in coastal Maine waters were comprised primarily of the 1976 and 1977 year classes which contributed 53% and 26%, respectively, of the mobile gear landings in 1981 (3,334 mt). Preliminary 1982 coastal Maine herring landings (January-September inclusive) were 18,541 mt, a 51% reduction relative to 1981 landings during the same period. Decline in 1982 landings is considered to be due to reduced availability to the inshore fixed gear fisheries.

Landings in the Western Gulf of Maine (Jeffreys Ledge) mobile gear fishery were 15,321 mt in 1981, a 58% decline over the 1980 level of 36,175 mt. Decline in the 1981 landings was primarily attributed to decreased demand. The 1977 and 1976 year classes contributed 7,914 (52%) and 5,356 (35%) mt, respectively, to western Gulf of Maine landings in 1981. Preliminary landings in the 1982 Jeffreys Ledge fishery during January-September 1982 were 6,330 mt, a 47% decline relative to 1981 landings during the same period.

Year class abundance estimates (age 3) based on multiple linear regression of catches at ages 1-3 on abundance at age 3 determined by virtual population analysis indicate that the 1977 year class is comparable in size to the strong 1976 year class in the Gulf of Maine and the 1978 year class is among the weakest on record. The 1979 year class at age 2 is predicted to be comparable to the strong 1963 and 1966 year classes at age 2.

Recruitment of the strong 1976 and 1977 year classes to the spawning stock (age 4+) in the Gulf of Maine during 1981 is assumed to result in a marked increase in spawning stock biomass (80,000 mt) relative to the estimated 1979 level of 38,300 mt. With recruitment of the 1979 year class to the spawning stock, projected spawning stock would be approximately 103,000 mt in 1984 assuming a fishing mortality rate corresponding to $F_{0.1}$ (0.36) on ages 3 and older.

INTRODUCTION

The Atlantic herring (*Clupea harengus*) is widely distributed in the western North Atlantic, occurring in continental shelf waters from Labrador to Cape Hatteras. Atlantic herring support important fisheries throughout their range, particularly within the Gulf of Maine, Bay of Fundy, Gulf of Saint Lawrence, and off Nova Scotia and Newfoundland. In addition, Georges Bank sustained an extensive fishery, primarily prosecuted by distant water fleets, during 1961-1976. Drastic declines in abundance were evident in the Georges Bank fishery by 1976, followed by a complete stock collapse in 1977. Although juvenile herring have been exploited since the last century, large scale development of fisheries for adult[1] herring has occurred only within the last two decades, notably on Georges Bank, in the Western Gulf of Maine, and on the Scotian Shelf (Figure 1).

The stock structure of Atlantic herring in the Northwest Atlantic has not been totally defined, however, evidence for discrete stocks based on differences in meristic characters, incidence of parasite infestation, and analysis of tag return data has been provided (see review by Anthony and Waring 1980). Iles and Sinclair (1982) proposed that larval retention areas formed by stable hydrographic frontal zones during autumn result in stock isolation and separation.

[1]Fisheries for adult herring are considered to be directed at age 3 and older fish by mobile gear (purse seine, pair trawls, demersal trawls) in this paper.

Overwintering migrations of juvenile herring from coastal Maine waters to Cape Cod Bay-Southern New England have been documented (Speirs 1977, Chenoweth et al. 1980). Almeida and Burns (1978) further demonstrated overwintering of adult herring tagged in the western Gulf of Maine-Nantucket Shoals area in the Southern New England - Mid-Atlantic region. Accordingly, the coastal Maine juvenile herring fisheries and adult herring fisheries in the western Gulf of Maine (including NAFO Subdivision 5Zw and Subarea 6) were considered to be interdependent for assessment purposes in the present analysis.

Seasonal intermixture of herring stocks throughout the Nova Scotia - Gulf of Maine region has been demonstrated (Almeida and Burns 1978, Stobo 1982) although the level of mixing has not been quantified. To account for possible exploitation of multiple stocks by the respective fisheries throughout the Cape Hatteras - Nova Scotia region during different phases of the annual migration, a pooled area analysis is also provided.

To account for the presumed contribution of the Georges Bank stock to the coastal fisheries in the pooled area option, the discounting procedure of Anthony et al. (1981) was followed. The ratio of estimated age 3 abundance for the pooled Cape Hatteras - Nova Scotia region excluding Georges Bank to age 3 abundance including Georges Bank was determined and the contribution of the Georges Bank stock to the pooled stock at ages 1 and 2 was then assumed to equal this ratio (Anthony et al. 1981).

MANAGEMENT

Herring resources within NAFO Subareas 5 and 6 have been regulated by the New England Fishery Management Council (NEFMC) since 1978 under the provisions of the Fishery Management Plan (FMP) for Atlantic herring. Quota allocations for domestic fishermen were established for a July 1-June 30 fishing year with limits of 8,000 mt and 10,000 mt of age 3 and older herring imposed within NAFO Division 5Y (excluding Maine territorial waters) and Division 5Z Subarea 6, respectively. Seasonal suballocations were devised based on summer-fall (July-November) and winter-spring (December-June) fishing patterns. No foreign fishery allocations were established nor were provisions for management of juvenile herring (ages 1-2) resources specified.

The FMP for Atlantic herring was subsequently amended effective in March 1980 to increase quota allocations for NAFO Division 5Y and to establish separate quotas north and south of Cape Elizabeth, Maine (43 34′N) within Division 5Y (Figure 1). Total allowable catches of 10,470 mt and 22,530 mt for age 3 and older herring were set in 5Y north and 5Y south (including Div. 5Z and SA6, respectively, for the July 1 - June 30 fishing year. The amendment further eliminated the exemption for catches of ages 3+ herring within Maine territorial waters.

Due to massive quota overages during 1980, the difficulty in coordinating complementary management programs within state territorial waters, and the prospect of further quota overages in 1982, the National Marine Fisheries Service (NMFS) recommended

withdrawl of the FMP for Atlantic herring in August 1982. Provisions for preparation of a new management plan are currently being developed.

CATCH STATISTICS

Coastal Maine Fishery

Coastal Maine herring landings increased from 45,902 mt in 1980 to 48,245 mt in 1981, the highest catch level since 1963. However, landings remain below the 1950-65 mean level of 57,316 mt (Table 1). Stop seines and weirs (fixed gear) accounted for 93% and 98% by weight and number, respectively, of the 1981 yield with the remainder attributable to purse seine catches in western and central Maine (Figure 2, Table 2). Fixed gear landings were dominated by the 1979 year class which comprised 87% by weight and 96% by number of stop seine weir catches. Landings of age 2 herring along the Maine coast in 1981 (39,588 mt) were the highest observed since 1962 (Table 3).

Purse seine catches in coastal Maine waters were comprised primarily of the 1976 and 1977 year classes, contributing 53% and 26%, respectively, of mobile gear landings by weight in 1981 (Table 2). The 1979 year class contributed 12% in weight and 42% in number to mobile gear landings (Table 2).

In contrast, the 1978 year class comprised just 4% by weight in 1981 coastal Maine mobile gear landings, indicating low abundance of this year class.

Preliminary 1982 landings during January-September inclusive for the coastal Maine fishery were 18,541 mt, a 51% decline relative to the catch of 37,681 mt during the same period in 1981. Landings from the mobile gear component accounted for 61% of total landings during January-September 1982, in marked contrast to the same period in 1981 during which mobile gear landings comprised 7% of total landings. Reduced landings in the fixed gear fisheries in 1982 have been attributed to reduced availability (J. Chenoweth, personal communication)[2].

Western Gulf of Maine

The 1982 catch of 15,321 mt in the western Gulf of Maine mobile gear (purse seines and pair trawls) fishery represented a 58% decline over 1980 landings of 36,175 mt (Table 4). Market constraints during 1981 reportedly strongly influenced this fishery, which is selective for adult herring. The 1981 catch represented a 43% decline relative to 1970-1980 mean level of 26,639 mt.

The 1977 and 1976 year classes contributed 7,914 mt (52%) and 5,356 mt (35%), respectively, of the 1981 landings in this fishery. Catch levels of the 1978 year class at age 3 comprised just 1% of total landings by weight and were the poorest in the Jeffreys Ledge fishery since 1967 (Table 4), again consistently indicating low abundance of this year class.

[2]J. Chenowith, Maine Department of Marine Resources, W. Boothbay Harbor, Maine 04575.

Preliminary landings during January-September (inclusive) 1982 were 6,330 mt, a 47% reduction relative to landings during the same period in 1981. Reduced preliminary landings in 1982 may reflect the combined influence of depressed market conditions, and reduced abundance. The 1976 and 1977 year classes must sustain the fishery in 1982 since the 1978 year class appears to be extremely poor and the 1979 year class is not fully recruited to the western Gulf of Maine fishery.

Cape Hatteras-Nova Scotia

Herring landings in NAFO Subareas 5 and 6 and Subdivision 4WX declined 17% in 1981 (171,024 mt) from 206,877 mt in 1980 (Table 1), primarily due to declines in the adult herring fisheries in the western Gulf of Maine (Tables 1, 4) and in southwest Nova Scotia (Table 1). In contrast, increases were noted in the coastal Maine and New Brunswick (Subdivision 4Xb) juvenile herring fisheries (Table 1). Fixed gear fisheries in NAFO Subdivision 4Xa off Nova Scotia declined, however, during 1981 (Sinclair et al. 1982). The 1979 year class did not appear as strong in Canadian catches (Sinclair et al. 1982) as in coastal Maine catches. A similar discrepancy was noted for the 1977 year class which appeared strong in USA catches but moderate in Canadian landings.

1982 HERRING RESEARCH SURVEY

A research vessel survey, specifically designed to estimate relative abundance of Atlantic herring was conducted by the Northeast Fisheries Center (NEFC) during 18 January - 12 February 1982. The survey area extended from Atlantic City, New Jersey, to Mount Desert Island, Maine, to a maximum depth of 55 m (Figure 3). Sampling strata were comprised of NEFC inshore and offshore standard strata. A 15-minute tow at 6.5 km/hr was made at randomly preselected stations with a No. 36 Yankee otter trawl. Standard NEFC research vessel survey techniques (Grosslein 1969) were used to process samples. Atlantic herring were measured to the nearest millimeter (fork length) and age composition of a random subsample determined by subsequent examination of otoliths.

Atlantic herring were obtained at 108 of 300 stations occupied during the cruise. Station locations at which herring were obtained are provided in Figure 3.

Stratified mean number per tow for ages 1-12 for the entire survey region is provided in Figure 4. Survey results indicate that the 1976 year class may be stronger than the 1977 year class in the Gulf of Maine (Figure 4); however, catch rates in the coastal Maine fishery indicated slightly higher abundance of the 1977 year class. The 1978 year class appears considerably weaker than the 1976-1977 year classes as indicated by catches in the juvenile herring fisheries. Both the 1979 and 1980 year classes appear to be relatively strong based on survey results, however,

the lack of a time series of winter surveys for comparison precludes adequate interpretation of these results. A similar survey is planned for 1983 to provide comparative results.

YEAR CLASS STRENGTH

Anthony (1972) suggested that catches in the juvenile herring fisheries may provide an index of relative year class strength and demonstrated a close relationship between total coastal Maine catch and standardized catch-per-unit effort for selected stop seine fishermen. Anthony and Waring (1980) further indicated that catches in the coastal Maine fisheries may be employed in recruitment predictions using a multiple linear regression approach. Although annual variation in availability and market conditions may influence landings of juvenile herring, the lack of independent indices of relative abundance requires considerable reliance on catches in the fixed gear fisheries for evaluation of the resource status.

Predictive linear multiple regressions were employed to forecast abundance at age 3 for the Gulf of Maine (coastal Maine and Jeffreys Ledge) and the pooled analysis options. Abundance at age 3 was determined by a preliminary virtual population analysis (VPA) in which terminal fishing mortality rates were assumed to equal the mean fishing mortality rates during 1975-1978 as determined by Waring and Anthony (1981) and Anthony et al. (1981) for the Gulf of Maine and pooled area options, respectively. Age 3 abundance was then regressed on catches of

age groups 1-3 for each cohort for the 1962-1976 year classes in the Gulf of Maine option and for the 1964-1976 year classes in the pooled analysis option. The model was of the form:

$$N_3 = a + b_1C_1 + b_2C_2 + b_3C_3$$

where N_3 is the abundance at age 3, C_1-C_3 are the catches at ages 1-3 for a given cohort and a_1, b_1, and b_3 are model coefficients.

In addition, abundance at age 2 (N_2) was regressed on catches of ages 1-2 (C_1,C_2) for a given cohort to provide a prediction of age 2 abundance in 1981 for each option using the model:

$$N_2 = a + b_1C_1 + b_2C_2$$

Parameter estimates and associated standard errors are provided in Table 5 and the relationship between observed and predicted abundance (age 3) estimates is given in Figures 5 and 6.

It should be noted that since stock size estimates derived by VPA are related to catches by the function:

$$N = Z\ C\ [F\ (1-\exp\ (-(F+M))]^{-1}$$

(where N is the estimated stock size; Z, F and M are the instantaneous rates of total, fishing and natural mortality respectively; and C is the catch), catch and estimated abundance have not been independently derived and can be expected to be highly correlated. Further, independent variates are related by the catch equation and the function:

$$N_t\ \exp(-(F+M))$$

resulting in colinearity among independent variates. Relatively high standard errors associated with model coefficients, despite high coefficients of determination (Table 5), reflect

intercorrelation of the independent variables. Parameter estimates must therefore be considered to be biased and unstable. Despite difficulties in parameter estimation, the predictive capability of the model is not adversely affected by multicolinearity within the range of values used to derive the model (Neter and Wasserman 1974, pp. 341-345).

Gulf of Maine Option

Year class abundance at age 3 estimated by virtual population analysis averaged 450 million fish (50,000 mt) for the 1962-1966 cohorts (Figure 5), increasing to 790 million fish (100,000 mt) with recruitment of the 1970 year class. Age 3 abundance subsequently declined to an average of 200 million fish (24,000 mt) for the 1971-1975 year classes. The 1976 year class at age 3 was estimated to equal 580 million fish (70,000 mt) and is therefore among the strongest on record.

Predicted year class strengths based on multiple linear regression of abundance at age 3 on catches at ages 1-3 for the 1977 and 1978 year classes were 660 and 50 million fish, respectively (Figure 5). Predicted abundance of the 1979 year class at age 2 was 1,650 million fish.

Minimum probable estimates of year class strength may be derived by determining fishing mortality rates implied by varying levels of assumed cohort size. It is unlikely that the 1977 and 1978 year classes were less than 500 and 25 million fish at age 3, respectively, since fishing mortality rates in excess of F=1.0 would be implied, considerably exceeding previous age 3 mortality

estimates (range: F=0.14-0.80 during 1965-1977). Similarly, it is probable that the 1979 year class in the Gulf of Maine exceeded 1,200 million fish, since a fishing mortality rate in excess of F=1.5 would be implied at lower stock levels.

Pooled Area Option

Age 3 abundance peaked in 1973 with recruitment of the strong 1970 year class (4,400 million fish, 370,000 mt; Figure 6) Year class strength at age 3 declined sharply to a mean of 760 million fish (60,000 mt) for the 1971-1975 cohorts. The 1976 year class was estimated to equal 3,200 million fish (300,000 mt).

Predicted year class strengths at age 3 for the 1977 and 1978 year classes for the pooled area analysis were 1,100 and 340 million fish, respectively (Figure 6). Predicted abundance of the 1979 year class at age 2 was 4,000 million fish.

Minimum estimates of the 1977 and 1978 year classes by evaluation of implied fishing mortality rates were 725 and 80 million fish, respectively, since F levels in excess of 1.0 would be necessary to produce the observed levels of catch. The minimum probable level of the 1979 year class at age 2 derived was 1,300 million fish; lower estimated year class size would imply a fishing mortality rate in excess of F=1.5, considerably higher than levels observed in the fishery to date.

FISHING MORTALITY

Fishing mortality rates were determined by virtual population analyses for the stock options described previously. Terminal fishing mortality rates used in this analysis for the 1977-1979 year classes (ages 2-4) were derived by determining the instantaneous rate of fishing mortality corresponding to the estimated exploitation rate [ratio of catch to predicted abundance at age 2 (1979 year class) or age 3 (1977-78 year classes)] for each cohort. Terminal fishing mortality rates for age 1 herring and age groups 6-11 were assumed to equal the geometric mean fishing mortality rate during 1970-1978. Due to the relatively small contribution of ages 6-11 herring to total catches, VPA results were not sensitive to terminal fishing mortality rates assigned to these age groups.

Gulf of Maine Option

Increased levels of fishing mortality for age 2 and older herring determined by VPA have been evident since 1976 (Table 6). Although fishing mortality rates derived for the most recent years are sensitive to terminal fishing mortality rates employed in the analysis, these estimates indicate that the increase in landings since 1976 may be due, in part, to increased fishing mortality levels. Fishing mortality rates since 1975 considerably exceed the $F_{0.1}$ level of F=0.24 for a combined juvenile-adult herring fishery assuming a constant natural mortality rate of M=0.2 (Fogarty et al. 1982).

Pooled Area Option

Estimated fishing mortality rates for recent years on age 2+ herring declined from peak values noted during 1976-77 (Table 7) although this fishing mortality remains in excess of $F_{0.1}$ levels as determined by Sinclair et al. (1982) and Fogarty et al. (1981).

STOCK SIZE

Gulf of Maine Option

Steady declines in stock biomass (age 4+) were evident during 1967-1973 (Table 6, Figure 7). Recruitment of the 1970 year class to the spawning stock biomass in 1974 resulted in recovery to 120,000, but biomass levels during 1974-1981 remained considerably below the 1967-1970 mean level of 170,000 mt. Recruitment of the 1976 and 1977 year classes to the spawning stock at their assumed levels are expected to result in an increase in age 4+ biomass relative to the low 1978-1979 mean of 50,000 mt.

Pooled Area Option

Spawning stock biomass (4+) in the pooled area analyses averaged 710,000 mt during 1965-1970 and declined sharply to 230,000 mt in 1973 (Table 7, Figure 8). Biomass subsequently increased to an average of 570,000 mt during 1974-1976. Assumed abundance levels of the 1976-1977 year classes are expected to result in a recovery in spawning stock relative to the low levels during 1978-79.

CATCH AND STOCK SIZE PROJECTIONS

Short-term projections of catch (age 3+) in 1983 and spawning stock biomass (age 4+) at the beginning of 1984 were made for the Gulf of Maine and pooled analyses options for fishing mortality rates ranging from 0.1 to 1.0 based on stock size estimates for 1982 and assuming constant fishing mortality during 1982 and 1983 for each level of F. Age 3 recruitment during 1983 and 1984 was taken as the geometric mean recruitment during 1965-1977; recruitment of the 1979 year class was based on predicted year class strength adjusted for mortality in 1981.

Projected catch levels in 1983 and spawning stock biomass in 1984 for the Gulf of Maine analysis are provided in Figure 9. With an $F_{0.1}$ level of F= 0.36 on ages 3 and older, projected catch in 1983 would be approximately 33,000 mt and resulting spawning stock biomass at the beginning of 1984 would be 103,000 mt. This spawning stock projection represents a 29% increase over the assumed 1981 level of 80,000 mt, due primarily to recruitment to the spawning stock of the 1979 year class.

Projected catches (age 3+) in 1983 and spawning stock size (age 4+) at the beginning of 1984 for the pooled analysis option (discounted for Georges Bank) are provided in Figure 10 for a range of fishing mortality rates. Assuming a fishing mortality rate (age 3+) equal to the $F_{0.1}$ level of F=0.36, the projected 1983 catch would be approximately 135,000 mt. Spawning stock biomass in 1984 would be approximately 460,000 mt.

DISCUSSION AND CONCLUSIONS

Increased catch levels in the coastal Maine fisheries during 1978-1981 were the result of a succession of strong year classes (1976, 1977 and 1979). Coastal Maine herring landings increased 5.1% in 1981 relative to the 1980 yield of 45,902 mt. Preliminary 1982 landings during January-September declined by 51% relative to the same period during 1981, due primarily to reduced availability. Landings from the Jeffreys Ledge fishery declined markedly from 36,175 mt in 1980 to 15,321 mt in 1981; this reduction is perceived to reflect decreased demand rather than decreased abundance or availability. Further reductions in landings during January-September 1982 were evident in the western Gulf of Maine.

Historically, strong year classes have been widely distributed in the Gulf of Maine - Nova Scotia area and there has been considerable correspondence in relative year class size throughout the region (Anthony and Waring 1980). However, several recent year classes, notably the 1977 and 1979 cohorts, appeared considerably stronger in the coastal Maine fisheries than in Division 4WX, possibly reflecting shifts in distribution or differences in survival and subsequent recruitment to the juvenile herring fisheries. The pooled area assessment eliminates the difficulty in determining the stock composition of the respective fisheries and is unaffected by small scale shifts in distribution which may considerably alter the implications of

individual area assessments in the Gulf of Maine - Nova Scotia region. The pooled area assessment indicates lower relative year class strength for the 1977 and 1979 cohorts than the Gulf of Maine analysis, suggesting a more conservative evaluation of the current status of the resource. Application of the pooled analysis for management purposes, however, requires allocation among various user groups, a complication which is obviated in the individual area assessments.

Year-class strength predictions based on catches in the fixed gear fisheries indicate that the 1977 year class in the Gulf of Maine (660 million fish at age 3) is comparable to the strong 1976 year class while the 1978 year class (50 million fish at age 3) is among the weakest on record. Catches of the 1979 year class in the coastal Maine fishery at ages 1 and 2 results in a predicted year-class strength at age 2 of 1,640 million fish, comparable to the strong 1963 and 1966 year classes in the Gulf of Maine. Increased availability of the 1979 year class cannot be discounted, however, possibly resulting in an overestimate of stock size based on catch rate information alone.

Stock size predictions for the pooled (Nova Scotia - Cape Hatteras excluding Georges Bank) analysis option indicate that the 1977 year class is approximately 1.11 billion fish at age 3. The 1978 year class is predicted to be 340 million fish. Predicted stock size of the 1979 year class at age 2 (4.0 billion fish) for the pooled analysis option was of moderate size, reflecting the lower representation of this year class in Canadian catches relative to the coastal Maine catches.

Due to the lack of alternative abundance indices based on independent measures of population size, catch rates in the fixed gear fisheries have been used in determination of relative year class strengths. However, annual variation in availability to fixed gear and restraints imposed by market factors must be recognized. Stock size predictions must, therefore, be evaluated with respect to any ecological and economic factors which may influence catch rates.

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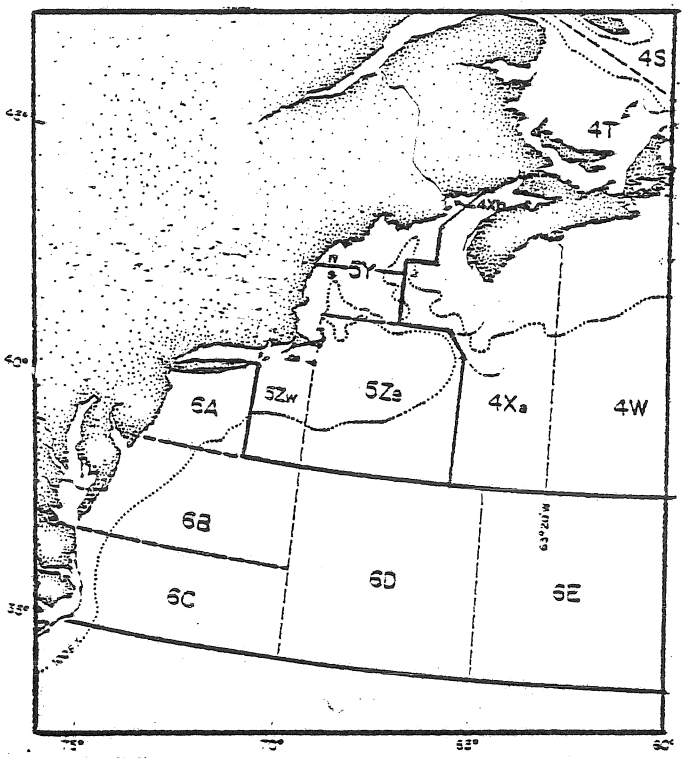

Figure 1. Location of statistical boundary areas relevant to herring assessment.

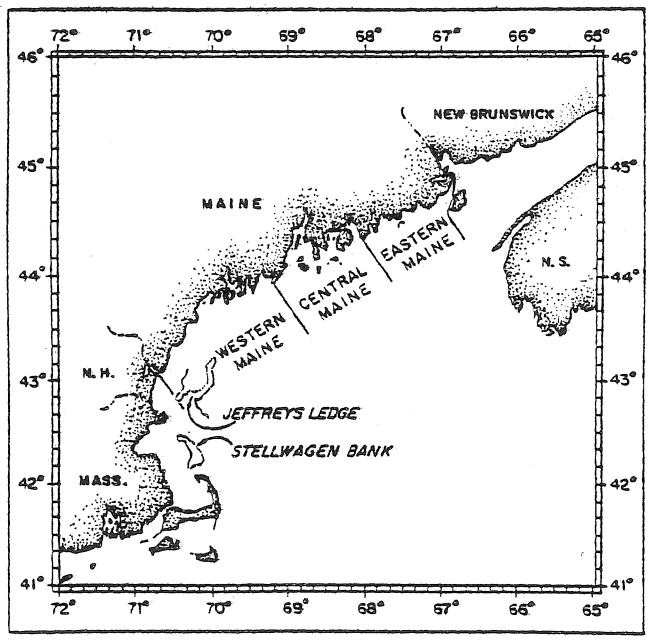

Figure 2. Location of Maine herring statistical areas and western Gulf of Maine fishing region.

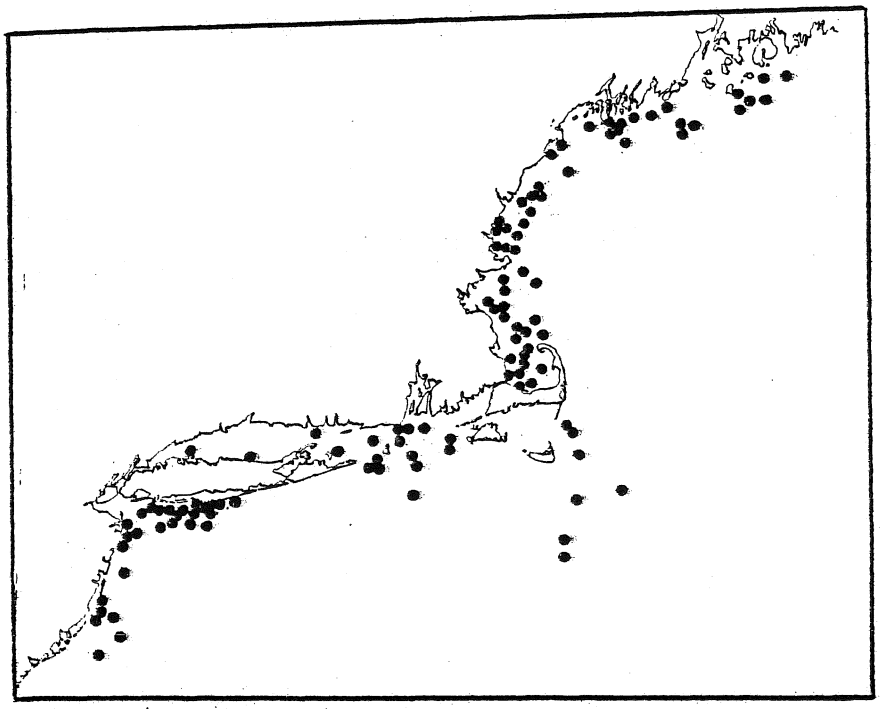

Figure 3. Location of herring catch sites during 1982 winter survey.

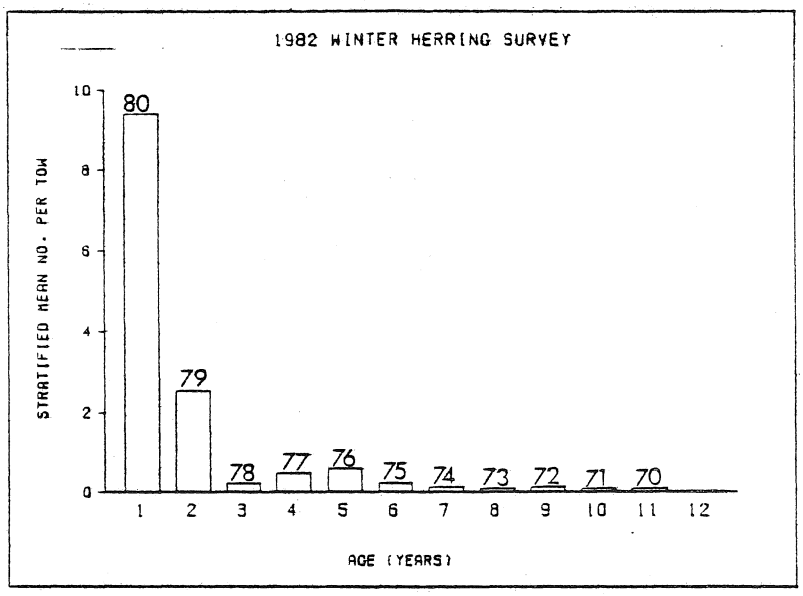

Figure 4. Stratified mean number per tow by age group for 1982 winter herring survey.

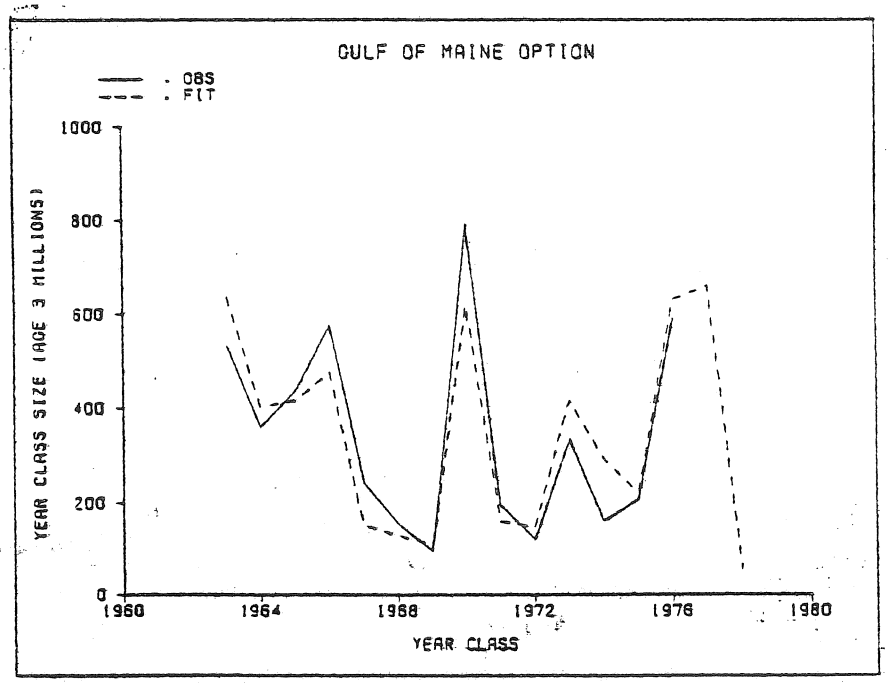

Figure 5. Observed and predicted year class size at age 3 based on multiple regression of year class size from VPA on catches in the juvenile herring fisheries. (Gulf of Maine option).

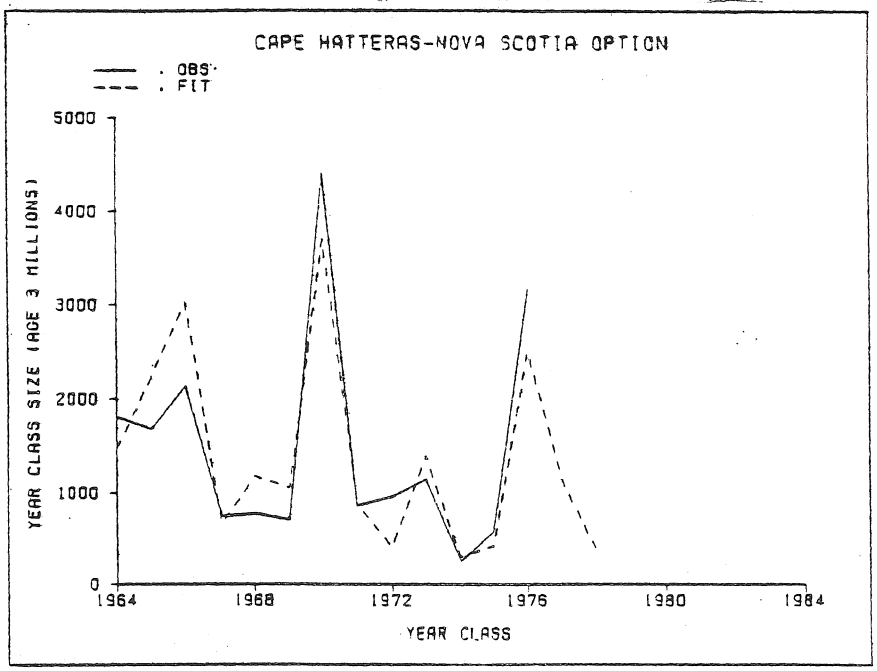

Figure 6. Observed and predicted year class size at age 3 based on multiple regression of year class size from VPA on catches in the juvenile herring fisheries (Pooled Area option).

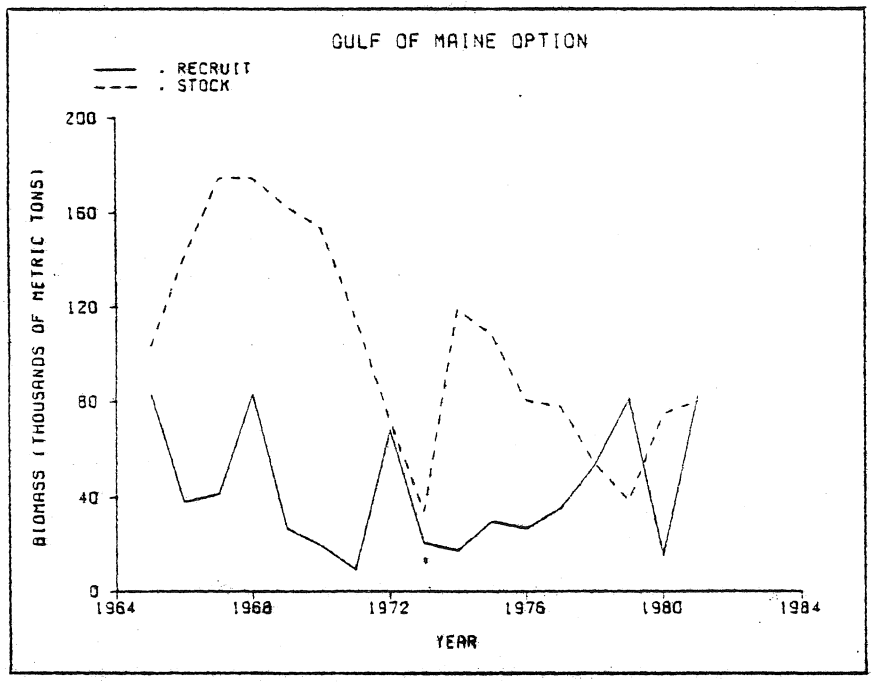

Figure 7. Stock size (age 4+ biomass) and recruitment (age 2 biomass) for Gulf of Maine option.

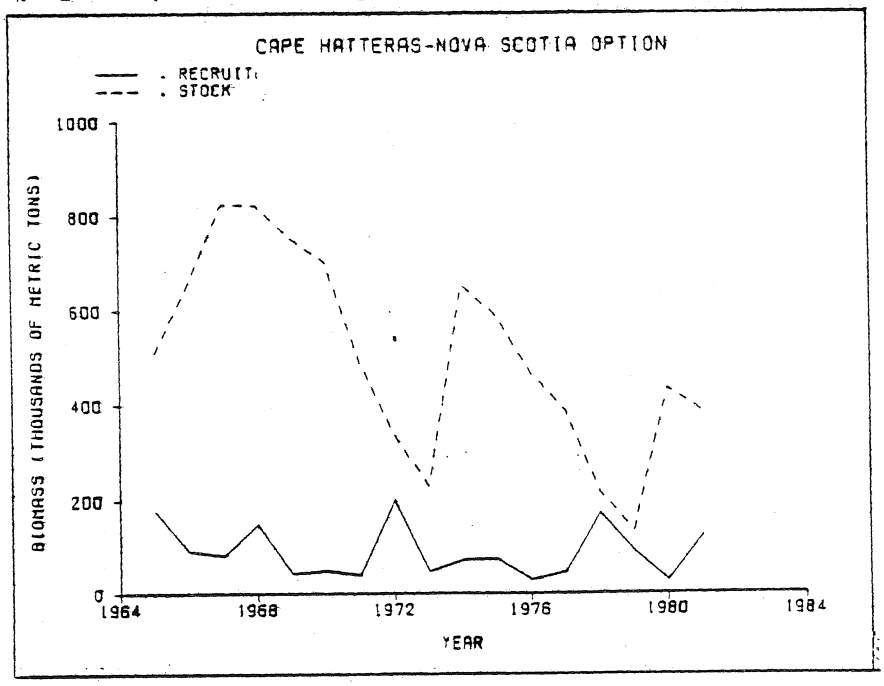

Figure 8. Stock size (age 4+ biomass) and recruitment (age 2 biomass) derived by VPA for the pooled area option.

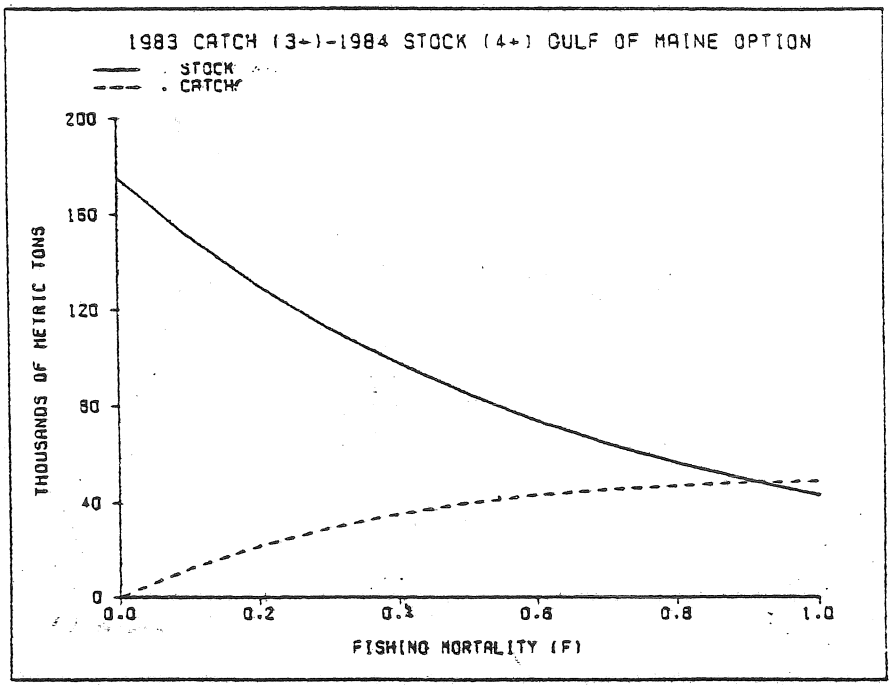

Figure 9. Projected 1983 catch (age 3+) and stock size in 1984 (age 4+) for Gulf of Maine option.

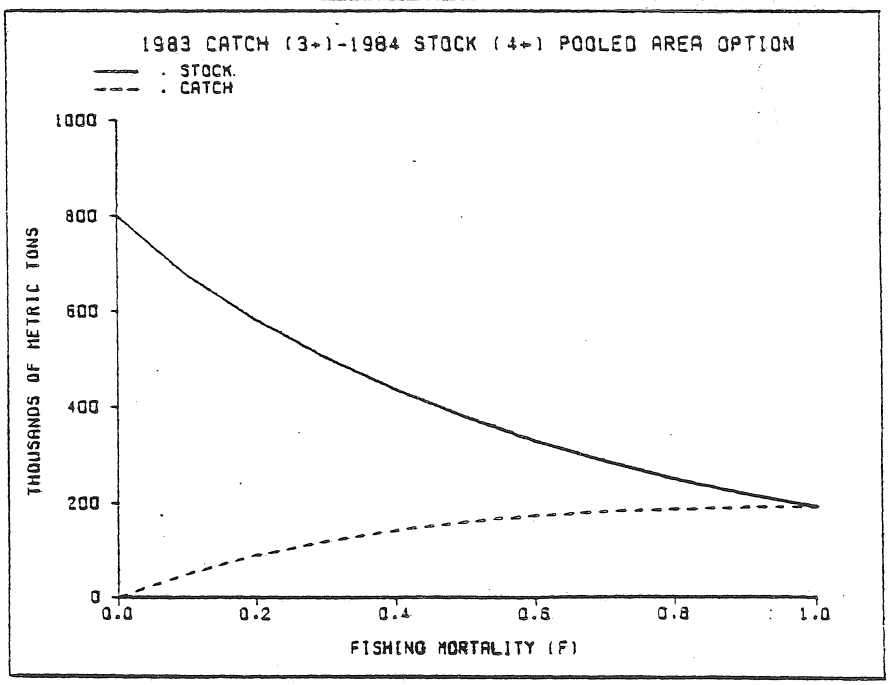

Figure 10. Projected 1983 catch (age 3+) and stock size in 1984 (age 4+) for pooled area option.

ble 1. Herring catches in major fishing areas between southwest Nova Scotia and Cape Hatteras.

AR	Maine Coastal Fishery	Western Gulf of Maine Fishery	Georges[1] Banks	New[2] Brunswick	Nova Scotia[2]	Total
			METRIC TONS			
50	90,557	3,661		62,981[3]		157,199
1	34,411	1,305		51,316[3]		87,032
2	79,139	1,598		62,399[3]		143,136
3	58,337	2,032		44,961[3]		105,330
4	64,067	1,303		46,716[3]		112,086
5	43,506	1,561			33,313[3]	78,380
6	66,494	2,058		21,533	22,712	112,797
7	68,623	3,007		33,733	27,114	132,477
8	80,759	3,182		18,854	46,444	149,239
9	53,037	1,472		47,762	28,771	131,042
60	59,348	1,126		49,563	32,216	142,253
1	24,131	3,178	67,655	18,614	41,272	154,850
2	69,376	2,485	152,242	34,403	35,367	293,873
3	66,895	3,217	97,968	36,237	23,393	227,710
4	26,295	8,815	131,438	45,023	41,405	252,976
5	32,088	2,635	42,882	49,101	70,639	197,345
6	26,178	4,360	142,704	61,450	124,681	359,373
7	28,490	7,807	218,743	50,920	135,853	441,813
8	30,205	31,900	373,598	75,368	154,139	665,210
9	23,852	32,406	310,758	39,741	137,250	544,007
70	15,581	40,187	247,294	30,589	175,633	509,284
1	12,407	38,575	267,347	17,528	124,233	460,090
2	19,513	42,918	174,190	32,720	153,428	422,769
3	16,400	15,926	202,335	22,102	120,093	376,856
4	19,143	18,098	149,525	30,733	139,170	356,669
5	15,182	21,076	146,096	31,971	142,745	357,068
6	30,195	20,124	43,502	30,046	114,006	237,874
7	32,357	17,891	2,157	34,723	115,935	203,063
8	29,857	18,558	2,059	45,361	89,353	185,188
9	40,218	23,546	1,270	41,021	55,182	161,237
80	45,902	36,175	1,700	14,969	108,131	206,877
1	48,245	15,321	672	20,448	86,338	171,024

Incorporates USA 5Z catches

1965-80 revised Canadian catches as per Dr. Mike Sinclair, Division of Fisheries and Oceans, Halifax, Canada.

cannot be separated into New Brunswick and Nova Scotia fishery components

Table 2. 1981 Maine Coastal herring fishery age composition by area and gear type

Gear/Area	1980 1	1979 2	1978 3	1977 4	1976 5	1975 6	1974 7	1973 8	1972 9	1971 10	1970 11	Total
	YEAR CLASS AND AGE											
	Catch in Metric Tons											
Fixed Gear												
Western	-	4,705.8	126.4	-	-	-	-	-	-	-	-	4,832.2
Central	49.9	15,073.8	160.6	-	-	-	-	-	-	-	-	15,284.3
Eastern	57.7	19,406.4	1,132.2	1,772.6	2,071.4	262.7	-	-	-	-	91.9	24,794.9
Total	107.6	39,186.0	1,419.2	1,772.6	2,071.4	262.7	-	-	-	-	91.9	44,911.4
Mobile Gear												
Western	-	-	0.8	39.2	41.5	4.7	2.4	1.3	-	0.3	1.2	91.4
Central	-	401.8	125.1	817.9	1,725.8	103.3	20.3	20.8	17.6	-	10.0	3,242.6
Eastern	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	401.8	125.9	857.1	1,767.3	108.0	22.7	22.1	17.6	0.3	11.2	3,334.0
	107.6	39,587.8	1,545.1	2,629.7	3,838.7	370.7	22.7	22.1	17.6	0.3	103.1	48,245.4
	Catch in Numbers (10^3)											
Fixed Gear												
Western	-	80,869.9	1,132.1	-	-	-	-	-	-	-	-	82,002.0
Central	3,323.4	378,238.3	2,125.0	-	-	-	-	-	-	-	-	383,686.7
Eastern	5,732.4	408,953.9	9,626.3	9,038.6	8,280.6	804.1	-	-	-	-	223.4	442,659.3
Total	9,055.8	868,062.1	12,883.4	9,038.6	8,280.6	804.1	-	-	-	-	223.4	908,348.0
Mobile Gear												
Western	-	-	7.6	290.7	238.4	20.5	9.3	4.6	-	0.9	4.0	576.0
Central	-	8,420.0	833.1	3,583.2	6,350.6	290.7	54.4	49.7	37.4	21.3	-	19,640.4
Eastern	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	8,420.0	840.7	3,873.9	6,589.0	311.2	63.7	54.3	37.4	22.2	4.0	20,216.4
	9,055.8	876,482.1	13,724.1	12,912.5	14,869.6	1,115.3	63.7	54.3	37.4	22.2	227.4	928,564.4

Table 3. Maine coastal fishery catch at age in numbers x 10^6.

YEAR	AGE 1	2	3	4	5	6	7	8	8+	Total
1947	106.3	1,091.5	274.3							1,472.1
1948	415.8	1,107.2	412.1							1,935.1
1949	955.9	939.8	265.8							2,161.5
1950	30.5	1,310.9	672.9							2,014.3
1951	1,428.0	266.2	70.9							1,765.0
1952	441.0	1,493.4	252.2							2,186.6
1953	1,673.2	607.9	176.1							2,457.2
1954	655.7	793.8	410.0							1,859.5
1955	707.1	595.8	124.8							1,427.7
1956	543.6	1,234.7	271.8							2,050.1
1957	285.5	1,505.5	193.8							1,984.8
1958	414.2	1,364.6	390.3							2,169.1
1959	229.6	688.5	378.3							1,296.5
1960	85.8	1,446.9	200.4							1,733.1
1961	229.2	387.0	39.5							655.7
1962	51.9	2,238.4	37.5							2,327.8
1963	73.7	771.8	497.9							1,343.4
1964	97.9	474.9	32.3	22.7	1.0					628.8
1965	40.9	932.9	57.8	2.4	4.2					1,038.2
1966	21.0	291.7	208.5	2.2	10.1	1.3	0.4	0.2		535.2
1967	21.5	268.1	122.1	33.7	17.7	3.5			1.8	468.4
1968	7.8	877.3	151.6	5.6	2.0		0.1			1,044.4
1969	5.7	216.6	249.0	11.5	0.6	0.5	0.3	0.2	0.2	484.5
1970	1.9	183.1	45.2	17.2	8.4	3.4	1.7	1.6	0.5	263.0
1971	109.0	61.9	17.7	21.0	7.8	1.6	0.5	0.4	0.3	220.1
1972	0.2	338.9	7.1	3.1	1.2	1.4	0.9			352.6
1973	10.6	154.9	72.4	1.1	0.8	0.4	0.5	0.2	0.2	241.5
1974	30.5	174.9	52.6	20.8	1.2	0.3				280.3
1975	35.2	171.8	25.2	4.7	5.5	0.4			0.4	243.2
1976	24.8	310.1	111.4	6.4	5.3	5.8	0.4	0.2	0.6	463.9
1977	76.2	429.7	71.4	13.1	2.6	1.9	6.8	0.1	0.1	601.0
1978	50.5	324.1	57.9	7.8	10.5	1.2	2.1	8.6	0.5	463.0
1979	3.3	747.0	131.7	9.0	0.9	1.3	0.9	0.4	0.5	895.0
1980	65.1	222.5	253.0	48.8	1.6	0.4		0.2	0.2	591.8
1981	9.1	876.5	13.7	12.9	14.8	1.1	0.1	0.1	0.3	928.6

Table 4. Catch of herring at age (mt) in the Western Gulf of Maine 1967-1981

Years	AGES 2	3	4	5	6	7	8	9	10	11	12	Total Ages 2+
1967	1.7	47.2	510.9	1567.1	3083.6	2166.9	162.9	105.6	74.1	87.0		7807.0
1968	44.6	2494.7	2853.5	5881.8	6377.7	6972.8	5006.3	919.5	620.6	728.5		31900.0
1969	145.3	5867.9	1080.7	2101.1	5230.2	7097.5	6144.6	3421.7	553.5	763.6		32406.0
1970	260.3	1265.0	4153.4	3532.4	5635.5	6483.3	6127.9	7838.2	2249.8	2641.2		40187.0
1971	49.3	3202.0	3645.7	6676.8	7875.8	6468.4	4290.1	3149.7	1479.0	1736.2		38575.0
1972	959.1	2426.3	7085.7	9710.3	10560.7	8062.9	2980.8	423.5	463.0	245.7		42918.0
1973	144.1	2484.1	1012.2	2531.3	3427.4	3207.5	2171.2	676.7	137.4	134.1		15926.0
1974	234.9	1682.2	10824.9	1530.6	1253.2	958.3	847.6	414.9	243.3	84.4	23.7	18098.0
1975	20.4	2222.7	3345.7	12078.9	1180.6	1027.3	609.5	377.8	170.2	142.8		21076.0
1976	3.8	2696.2	2374.3	2383.2	11084.5	995.6	195.6	285.1	56.3	41.7	8.8	20124.0
1977	60.3	640.8	3939.5	1814.8	1964.4	8714.1	520.6	68.8	99.7	53.4	14.6	17891.0
1978	203.9	2087.3	1880.1	5194.3	1010.6	1575.3	5980.4	287.3	136.4	56.8	36.9	18558.2
1979	181.5	4665.9	6863.5	3668.2	4077.9	818.6	1036.3	2106.6	91.0	0.1	0.7	23507.7
1980	33.5	4611.2	19218.6	5307.8	1990.6	2778.8	281.8	172.8	1728.1	31.6	15.3	36174.7
1981	7.6	184.5	7914.4	5356.2	893.0	397.2	346.2	0.0	28.6	193.2	0.0	15320.9

Table 5. Multiple linear regression coefficients (standard errors in parenthesis), F ratio for regression, Durban-Watson statistic (D) test for autocorrelation, and coefficient of determination (R^2) for regression equations of age 3 abundance on catch at age in the juvenile herring fisheries.

	Model Coefficient						
Analysis	a	b_1	b_2	b_3	F	D	R^2
Gulf of Maine age 3	70.083 (48.536)	4.205 (.8594)	-0.2697 (.18198)	1.944 (.6065)	18.7**	1.084+	0.849
Pooled Area age 3	451.724 (312.980)	1.649 (1.191)	-1.6423 (.66955)	5.622 (1.096)	14.9**	1.778+	0.832
Gulf of Maine age 2	165.607 (73.727)	5.257 (1.435)	1.2982 (.19681)		53.9**	1.398+	0.907
Pooled Area	511.522	1.941	2.2622		6.8*	2.107+	0.575

*p .05; **p .01

+Durban-Watson test indeterminant

ns non-significant

TABLE 6. ATLANTIC HERRING VPA - GULF OF MAINE OPTION

YEAR	AGE 1	2	3	4	5	6	7	8	9	10	11+	100% RECRUITMENT MEAN F	AGE
				FISHING MORTALITY									
1965	0.048	0.939	0.191	0.009	0.027	0.000	0.001	0.004	0.024	0.000	0.000	0.645	2+
1966	0.023	0.547	0.558	0.010	0.048	0.011	0.015	0.021	0.005	0.030	0.000	0.373	2+
1967	0.012	0.439	0.470	0.180	0.152	0.111	0.092	0.027	0.344	0.273	1.000	0.327	2+
1968	0.013	0.860	0.555	0.152	0.232	0.265	0.268	0.291	0.213	0.813	1.000	0.650	2+
1969	0.013	0.590	0.769	0.144	0.135	0.279	0.327	0.352	0.574	0.710	1.000	0.521	2+
1970	0.009	0.735	0.286	0.208	0.232	0.407	0.791	0.879	1.193	1.147	1.000	0.516	2+
1971	0.070	0.468	0.368	0.411	0.417	0.665	1.009	1.430	1.409	1.258	1.000	0.550	2+
1972	0.000	0.343	0.325	0.835	0.886	1.153	1.158	1.155	0.990	1.666	1.000	0.458	2+
1973	0.027	0.539	0.143	0.156	0.546	0.786	1.237	1.515	1.192	0.756	1.000	0.317	2+
1974	0.045	0.863	0.469	0.242	0.282	0.518	0.363	0.604	0.801	0.691	1.000	0.472	2+
1975	0.058	0.384	0.483	0.328	0.323	0.576	0.812	0.553	1.157	1.274	1.000	0.380	2+
1976	0.031	0.996	0.590	0.464	0.384	0.366	0.511	0.451	0.847	0.382	1.000	0.712	2+
1977	0.062	1.063	0.796	0.411	0.682	0.526	0.577	0.676	0.504	0.691	1.000	0.873	2+
1978	0.028	0.410	0.600	0.496	0.764	0.736	0.940	1.076	1.242	2.365	1.000	0.494	2+
1979	0.010	0.703	0.385	0.728	0.811	0.783	1.432	1.353	0.663	0.938	1.000	0.631	2+
1980	0.035	1.544	0.682	0.802	1.009	0.942	1.416	2.006	1.378	1.304	1.000	0.926	2+
1981	0.047	0.866	0.376	0.260	0.476	0.617	0.552	0.790	0.695	1.000	1.000	0.752	2+

YEAR	1	2	3	4	5	6	7	8	9	10	11+	AGE 4+ NUMBERS	WGHTUNAD
				STOCK SIZE									
1965	969.2	1664.3	365.4	292.6	171.4	34.5	12.7	2.7	0.5	0.0	0.0	514.4	103.1
1966	1031.5	756.7	532.8	247.1	237.6	136.5	28.9	10.5	2.2	0.4	0.0	663.2	141.4
1967	2045.9	825.9	358.4	249.6	200.4	185.5	110.7	23.3	8.4	1.8	0.3	779.9	174.4
1968	661.6	1656.2	435.8	183.5	170.7	141.0	135.9	82.7	18.6	4.9	1.1	738.3	174.6
1969	483.5	534.8	574.1	204.8	129.0	110.9	88.5	85.2	50.6	12.3	1.8	683.0	162.8
1970	225.9	391.0	242.8	217.8	145.3	92.3	68.6	52.3	49.0	23.3	4.9	653.5	153.3
1971	1781.5	183.3	153.5	149.4	144.8	94.3	50.3	25.5	17.8	12.2	6.1	500.2	114.8
1972	490.5	1360.4	94.0	86.9	81.1	78.1	39.7	15.0	5.0	3.6	2.8	312.3	71.5
1973	434.9	410.0	790.1	55.6	30.9	27.4	20.2	10.2	3.9	1.5	0.5	150.2	33.9
1974	758.3	346.5	195.9	560.7	39.0	14.6	10.2	4.8	1.8	1.0	0.6	632.7	118.4
1975	691.1	593.3	119.7	100.3	360.2	24.1	7.1	5.8	2.1	0.7	0.4	500.8	107.9
1976	901.4	534.1	330.7	60.5	59.2	213.6	11.1	2.6	2.7	0.6	0.2	350.4	80.1
1977	1387.7	715.8	161.5	150.1	31.2	33.0	121.2	5.4	1.4	1.0	0.3	343.6	77.6
1978	2037.8	1067.5	202.3	59.7	81.5	12.9	16.0	55.8	2.3	0.7	0.4	229.1	54.0
1979	377.1	1623.4	580.3	90.9	29.7	31.1	5.1	5.1	15.6	0.5	0.1	178.0	38.5
1980	2081.5	305.5	658.3	323.4	35.9	10.8	11.6	1.0	1.1	6.6	0.2	390.6	74.8
1981	217.6	1645.8	53.4	272.6	118.7	10.7	3.5	2.3	0.1	0.2	1.5	409.6	80.0

YEAR	1	2	3	4	5	6	7	8	9	10	11+	TOTAL
				CATCH AT AGE								
1965	40.9	932.9	57.8	2.4	4.2	0.0	0.0	0.0	0.0	0.0	0.0	1038.3
1966	21.0	291.7	208.5	2.2	10.1	1.3	0.4	0.2	0.0	0.0	0.0	535.4
1967	21.5	868.1	122.7	37.3	25.7	17.7	8.8	0.6	2.2	0.4	0.2	505.2
1968	7.8	877.9	169.8	23.6	32.2	29.9	29.1	19.0	3.2	2.5	0.6	1195.5
1969	5.7	218.1	282.8	24.9	14.8	24.6	22.5	23.0	20.2	5.7	1.0	643.4
1970	1.9	186.7	54.9	37.2	27.4	28.2	34.4	28.1	31.6	14.7	2.9	448.0
1971	109.0	62.6	43.1	45.9	45.1	42.0	29.4	18.0	12.4	8.1	3.5	419.1
1972	0.2	360.4	23.8	45.2	43.8	49.4	25.1	9.5	2.9	2.7	1.6	564.6
1973	10.6	156.2	95.7	7.3	11.9	13.7	13.3	7.4	2.5	0.7	0.3	319.5
1974	30.5	184.1	67.0	109.8	8.7	5.4	2.8	2.0	0.9	0.4	0.3	412.1
1975	35.2	172.7	41.9	25.6	90.5	9.6	3.7	2.3	1.4	0.4	0.2	383.5
1976	24.8	310.3	134.9	20.5	17.2	59.8	4.1	0.9	1.4	0.2	0.1	574.0
1977	76.2	432.1	81.4	46.2	14.1	12.3	48.6	2.5	0.5	0.4	0.2	714.6
1978	50.5	327.3	83.6	21.3	40.0	6.2	9.0	33.9	1.5	0.6	0.2	574.0
1979	3.3	751.2	169.0	43.1	15.2	15.5	3.6	3.5	6.9	0.3	0.0	1011.7
1980	65.1	223.2	298.2	163.8	21.0	6.1	8.2	0.8	0.8	4.4	0.1	791.6
1981	9.1	876.7	15.3	56.8	41.1	4.5	1.3	1.2	0.1	0.1	0.9	1007.0

TABLE 7. ATLANTIC HERRING VPA - POOLED AREA (EXCLUDING GEORGES BANK AND DISCOUNTED FOR AGES 1 AND 2).

YEAR	AGE 1	2	3	4	5	6	7	8	9	10	11+	100% RECRUITMENT MEAN F	AGE
					FISHING MORTALITY								
1965	0.047	0.320	0.115	0.196	0.132	0.096	0.050	0.069	0.009	0.000	0.000	0.249	2+
1966	0.030	0.292	0.429	0.124	0.399	0.147	0.178	0.313	0.252	0.303	0.000	0.328	2+
1967	0.079	0.253	0.228	0.287	0.214	0.357	0.315	0.090	0.162	0.152	0.700	0.260	2+
1968	0.055	0.612	0.345	0.132	0.425	0.235	0.436	0.421	0.530	1.078	0.700	0.458	2+
1969	0.052	0.427	0.632	0.202	0.280	0.309	0.324	0.301	0.405	0.485	0.700	0.421	2+
1970	0.233	0.495	0.234	0.504	0.500	0.386	0.599	0.443	0.643	0.675	0.700	0.459	2+
1971	0.024	0.371	0.465	0.453	0.490	0.518	0.645	0.627	0.648	0.395	0.700	0.467	2+
1972	0.004	0.187	0.174	0.812	0.785	0.912	0.731	0.734	0.602	0.468	0.700	0.278	2+
1973	0.017	0.328	0.229	0.354	0.440	0.618	0.638	0.588	0.690	0.435	0.700	0.283	2+
1974	0.018	0.671	0.266	0.343	0.287	0.352	0.345	0.282	0.620	0.418	0.700	0.448	2+
1975	0.050	0.532	0.386	0.301	0.392	0.510	0.432	0.345	0.335	0.356	0.700	0.444	2+
1976	0.046	1.082	0.505	0.433	0.431	0.424	0.385	0.344	0.567	0.223	0.700	0.599	2+
1977	0.092	0.731	0.727	0.627	0.676	0.636	0.603	0.437	0.308	0.343	0.700	0.678	2+
1978	0.082	0.366	0.407	0.507	1.049	0.976	0.753	1.031	0.679	0.437	0.700	0.433	2+
1979	0.008	0.730	0.253	0.441	0.604	0.793	0.880	0.785	1.251	0.570	0.700	0.493	2+
1980	0.071	0.482	0.551	0.471	0.614	0.735	0.736	0.829	1.623	0.912	0.700	0.510	2+
1981	0.060	0.423	0.242	0.332	0.473	0.502	0.477	0.400	0.442	0.366	0.700	0.414	2+

YEAR	1	2	3	4	5	6	7	8	9	10	11+	AGE 2+ NUMBERS	WGHTUNAD
					STOCK SIZE								
1965	3765.6	5753.2	1606.9	1792.3	543.0	130.6	41.4	11.1	1.2	0.0	0.0	9879.8	823.7
1966	3328.0	2942.4	3420.9	1173.2	1206.3	389.6	97.1	32.3	8.5	1.0	0.0	9271.2	1036.7
1967	6349.0	2644.5	1799.1	1823.7	848.0	662.7	275.3	66.5	19.3	5.4	0.6	8145.2	1060.0
1968	1797.9	4805.3	1680.9	1172.7	1120.1	560.8	379.8	164.4	49.8	13.5	3.8	9951.2	1114.6
1969	2007.2	1393.1	2134.2	975.1	841.4	599.5	362.9	201.2	88.4	24.0	3.7	6623.5	977.2
1970	1920.2	1559.6	744.1	928.5	652.3	520.7	360.5	214.9	121.9	48.3	12.1	5162.9	815.2
1971	8083.0	1245.8	778.5	482.1	459.2	323.8	289.7	162.1	112.9	52.5	20.1	3926.8	591.8
1972	1788.2	6463.1	703.8	400.5	250.8	230.3	158.0	124.5	70.9	48.3	28.9	8479.1	593.6
1973	2843.5	1457.5	4391.0	484.2	145.5	93.6	75.7	62.2	48.9	31.8	24.8	6815.3	646.0
1974	2967.2	2290.4	859.5	2859.3	278.3	76.7	41.3	32.7	28.3	20.1	16.9	6503.6	796.1
1975	1175.2	2386.5	958.4	539.3	1660.6	171.1	44.2	24.0	20.2	12.5	10.8	5827.5	743.1
1976	1878.6	915.3	1147.9	533.4	326.8	918.5	84.1	23.5	13.9	11.8	7.1	3982.3	591.6
1977	7437.0	1469.0	254.1	567.5	283.2	173.9	492.1	46.9	13.6	6.5	7.8	3314.5	452.9
1978	3753.4	5556.1	578.8	100.6	248.1	118.0	75.4	220.4	24.8	8.2	3.7	6934.1	436.7
1979	837.2	2832.5	3156.1	315.3	49.6	71.2	36.4	29.1	64.4	10.3	4.3	6569.1	491.5
1980	5201.1	680.6	1118.1	2005.8	166.1	22.2	26.4	12.4	10.9	15.1	4.8	4062.3	548.5
1981	1181.1	3065.2	344.1	527.7	1025.8	73.6	8.7	10.3	4.4	1.8	5.0	5966.6	529.5

YEAR	1	2	3	4	5	6	7	8	9	10	11+	TOTAL
					CATCH AT AGE							
1965	156.2	1435.0	158.0	289.9	61.1	10.8	1.8	0.7	0.0	0.0	0.0	2113.6
1966	89.6	678.5	1089.4	124.7	362.1	48.4	14.4	7.9	1.7	0.2	0.0	2417.1
1967	435.6	538.3	333.7	414.9	148.3	181.2	67.9	5.2	2.6	0.7	0.3	2128.7
1968	87.5	2012.9	446.6	131.7	354.1	107.0	122.5	51.6	18.7	8.2	1.8	3342.5
1969	92.9	442.0	916.0	162.3	187.1	145.0	91.5	47.7	26.8	8.4	1.7	2121.4
1970	362.6	556.3	141.3	336.0	234.7	152.2	148.7	70.3	52.9	21.7	5.6	2082.3
1971	173.3	352.2	264.3	160.5	162.6	119.6	126.1	69.2	49.4	15.6	9.3	1502.1
1972	7.1	1000.1	102.2	204.6	125.3	126.8	75.2	59.3	29.3	16.5	13.4	1759.7
1973	43.2	371.6	817.6	131.6	47.3	39.5	32.7	25.3	22.4	10.2	11.4	1552.8
1974	47.9	1026.3	182.9	757.6	63.1	20.8	11.0	7.3	12.0	6.3	7.8	2142.9
1975	52.1	900.2	280.0	127.7	491.5	62.4	14.2	6.4	5.3	3.4	5.0	1948.0
1976	76.6	558.0	415.7	171.1	104.4	289.7	24.5	6.2	5.5	2.2	3.3	1657.2
1977	591.1	699.1	120.3	242.2	127.5	74.9	204.0	15.1	3.3	1.7	3.6	2083.0
1978	266.9	1551.5	176.7	36.6	148.6	67.7	36.6	130.7	11.2	2.7	1.7	2430.8
1979	6.1	1345.5	642.7	102.6	20.6	35.8	19.6	14.5	42.5	4.1	2.0	2236.1
1980	325.1	237.8	433.2	687.7	69.8	10.6	12.6	6.4	8.1	8.3	2.2	1801.0
1981	62.4	1247.1	67.2	135.8	353.1	26.5	3.0	3.1	1.4	0.5	2.3	1902.6