Northwest Atlantic Fisheries Organization

Serial No. N457

NAFO SCR Doc. 81/XI/148

SCIENTIFIC COUNCIL MEETING - NOVEMBER 1981

Recent Trends in the Gulf of Maine Northern Shrimp Fishery

by

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ABSTRACT

The Gulf of Maine northern shrimp fishery is reviewed. Landings peaked at 12,800 tons in 1969, averaged approximately 11,000 tons from 1970-72, and declined precipitously thereafter; research vessel survey data indicate declines in biomass of from 80-90% during the 1970's. Commercial indices of relative abundance and data from Maine research vessel surveys indicate little if any recovery in recent years, although some improvement is evidenced by Northeast Fisheries Center (NEFC) surveys. Commercial landings increased from 400 tons in 1979-1980 to aproximately 1,000 tons in 1981, due primarily to increased effort. Management of this fishery became more intensive during the mid to late 1970's, culminating in closure of the fishery in 1978; in subsequent years, effort has been restricted to winter and spring.

INTRODUCTION

The northern shrimp (Pandalus borealis Krøyer) supports a small, but locally important, trawl fishery in the western Gulf of Maine. Northern shrimp were taken sporadically in the Gulf of Maine during the 1920's, although directed efforts did not begin until 1938 (Scattergood 1952), Subsequently, landings have fluctuated widely, increasing from

zero in the mid-1950's to an all-time high of 12,800 (metric) tons in 1969, averaged approximately 11,000 tons during 1970-1972, and then declined precipitously to an average of 400 tons during 1979-1980. Landings in 1981 increased to approximately 1,000 tons, primarily due to increased effort compared to 1979-1980 levels.

The complex life history of this species, pronounced fluctuations in abundance and uncertainty concerning biological parameters (e.g., mortality) have rendered assessment and management of the Gulf of Maine northern shrimp stock difficult. Assessment techniques used for other finfish and invertebrate stocks are obviously of limited applicability, and environmental factors which influence recruitment are not understood. Nevertheless, the Gulf of Maine experience does provide information which may be of value to researchers and managers in other areas.

This document updates previous information on the biology and distribution of northern shrimp in the Gulf of Maine and reviews assessment and management of the fishery.

NOTES ON BIOLOGY AND DISTRIBUTION

The life history of northern shrimp in the Gulf of Maine has been extensively studied by Haynes and Wigley (1969) and Apollonio and Dunton (MS 1969). Northern shrimp are protandric hermaphrodites, functioning first as males, and most Gulf of Maine individuals appear to require four years to complete the life cycle. "Primary" females, in which male characteristics never appear, are rare in the Gulf of Maine, although perhaps 20% of the population spawns as "secondary" females at age 2 (Haynes and Wigley 1969).

Larval shrimp hatch during winter in inshore or shoaler areas; hatching may begin as early as January, but peak activity occurs in late February and early March. After a pelagic phase of from 1-2 months, larval shrimp settle to the bottom, where they remain for over a year. With approaching maturation, age 2 (predominantly male) shrimp move offshore.

where they spawn in summer; they then pass through several "transitional" stages during the following winter and spring and spawn as females in the following summer (predominantly age 3). A distinct tendency is evident for transition and maturation of part of the population as females at age 2, however (Figure 1). Clutch size ranges from 800 to 3,400 eggs and is positively correlated with size (Haynes and Wigley 1969). Ovigerous females move onshore in late autumn and early winter, where hatching occurs. Spawning and hatching may be repeated in subsequent years although detailed information on longevity is unavailable for the Gulf of Maine.

Northeast Fisheries Center (NEFC) spring, summer, and autumn bottom trawl surveys during 1977-1979 indicate abundance to be highest in the southwestern portion of the Gulf of Maine (Figure 2), in agreement with previous observations (Wigley 1960; Haynes and Wigley 1969; Apollonio and Dunton MS 1969). The population also appears to be more concentrated in the extreme western portion of the Gulf in spring. Both tendencies seem to reflect temperature conditions; bottom temperatures tend to be coldest in the western portion of the Gulf (Davis 1978) and within that area are coldest inshore in wintertime and offshore during summer (Nickerson and Wright MS 1980). Apollonio and Dunton (MS 1969) reported heaviest summer concentrations to occur in the southwestern corner of the Gulf of Maine, and observed that "since lowest bottom temperatures in the summer are usually found in the western half of the Gulf.....there is perhaps a causal relation in the occurrence of largest numbers of shrimps in those waters". However, Haynes and Wigley (1969) attributed more importance to bottom characteristics, as in that study highest catches were observed to occur in areas of finegrained sediments, e.g., clay, silt, and silty sand, where organic carbon content was moderate to high.

COMMERCIAL FISHERY

The Gulf of Maine shrimp fishery has been conducted exclusively by the USA, although Canada has occasionally taken minor quantities off eastern Georges Bank and the USSR reported a catch of 7 tons from Georges Bank in 1975. USA landings rose from 2 tons in 1958 to an all-time high of 12,800 tons in 1969, averaged approximately 11,000 tons from 1970-1972, and then declined precipitously to 1978, when the

fishery was closed (Table 1, Figure 3). Landings during 1979-1980 averaged 400 tons, and preliminary data for 1981 indicate landings of 1,000 tons. The fishery has been subject to seasonal closures since 1975, but abundance has been so low in recent years that these regulations (with the exception of the 1978 closure) have probably not been restrictive.

Traditionally, this fishery was prosecuted primarily by small (≤50 GT) Maine trawlers in wintertime, and Maine accounted for almost all of the landings prior to 1969 (Table 1, Figure 3). In that year, however, fishermen in Gloucester, Massachusetts began to direct considerable effort towards northern shrimp and the relative proportion taken by Massachusetts vessels has since risen substantially. Prior to seasonal restrictions, Maine effort was directed predominantly towards ovigerous (age 3 and 4) females in inshore areas (often within the territorial sea) during wintertime, while Massachusetts vessels exploited both mature females in shoaler areas in winter and offshore concentrations of all age groups during the remainder of the year. Since 1975, the fishery has been conducted exclusively during winter and spring. Otter trawls have been the predominant gear employed, although substantial differences in trawl size and construction appear to exist between ports. A limited pot fishery was initiated in Maine coastal waters during the early 1970's, but landings never exceeded 2 percent of the total and by 1976 pot landings had declined to negligible levels.

Length-frequency distributions obtained from sampling of commercial landings during 1979-1980 are given in Figure 4. Distributions for Maine differ between years, with 1979 data indicating a higher proportion of (assumed) age 2 (primarily male) shrimp, which may reflect offshore shifts in effort in response to low abundance. In 1980, however, Maine landings consisted almost exclusively of older females as would be expected for this component of the fishery. Massachusetts data (Diodati MS 1979, MS 1980) suggest significant catches of age group 1 and 2 shrimp in both years; in 1980, these age groups accounted for 37% by number and 18% by weight of the total landings in February and March, and for April and May the corresponding percentages increased to 70% and 48%, respectively, reflecting offshore shifts in

effort to deeper areas (Northern Shrimp Scientific Committee MS 1980). Data for the mid-1970's indicate catches of age groups 1 and 2 in excess of 80% by number and 60% by weight during summertime.

Small amounts of other pandalid species, e.g. P. montagui and Dichelopandalus leptocerus, are occasionally taken commercially with P. borealis in the Gulf of Maine; however, such catches have generally comprised less than 5% of the total (by weight). In 1979 and 1980, P. montagui (the only other species observed) accounted for 7% and 8% of total landings by weight, respectively.

Commercial Abundance Index

Trends in abundance for 1964-1981 have been examined using interview data for Gloucester, Massachusetts, and Portland, Maine (data for remaining ports were very limited). An index was developed based on annual trip data for which 50% or more of the total catch consisted of shrimp. Effort was adjusted by vessel class to account for changes in fleet composition by applying coefficients derived from regressions (through the origin) of catch effort values by vessel class against corresponding values for a standard (34-50 GT vessels). Adjusted effort values were then summarized by year and divided into the appropriate catch values to obtain the index. Since some potential for bias existed due to seasonal changes in exploitation patterns, a similar index was also developed from winter (February-March) data (Table 2, Figure 5).

The annual index increased from 0.9 tons per standard day fished in 1964 to 3.0 tons in 1967-1968 and subsequently declined to 1.1 tons in 1977; the index rose sharply to 2.4 tons in 1979, but the 1980-1981 average was similar to that observed for 1976-1977 (1.3 tons; Table 2, Figure 5). Trends for the winter index were generally similar, although values were higher for peak years of the fishery. The sharp increase for 1979 may reflect the 1978 closure or changes in exploitation patterns. Since index values for 1980-1981 are comparable (1.2 and 1.4 tons for the annual index, respectively) it appears that the 1981 increase in landings is attributable primarily to increased effort compared to 1979-1980.

RESEARCH VESSEL SURVEYS

The State of Maine has sampled standard locations each August (in daytime) since 1968 (Figure 6) using a shrimp research trawl; specifications are as given

by Apollonio and Dunton (MS1969). This survey has been used to obtain data on trends in abundance, population age structure, and mortality rates.

The NEFC has conducted stratified random bottom-trawl surveys in the Gulf of Maine in autumn (beginning in 1963) and in spring (beginning in 1968); a summer survey was initiated in 1977. A "36 Yankee" groundfish trawl was used exclusively in these surveys until 1973, after which a "41 Yankee" trawl was used during spring. Both gears are equipped with 1.3 cm (0.5 inch) stretched mesh codend liners and rollers to make them suitable for use on rough bottom. Data for the western Gulf of Maine (strata 24, 26-28, and 37-40, Figure 7) have been used to calculate indices of relative abundance (stratified mean catch per tow, kg).

NEFC surveys are run on a 24-hour basis. In assessments prior to 1980, NEFC survey indices were calculated from data for daytime tows to compensate for diel changes in availability (due to vertical migrations associated with changes in light intensity). However, such behavior appears to vary by age group and season, e.g., ovigerous females do not appear to migrate vertically to any significant extent (Apollonio and Dunton MS 1969). Vertical migration may also be subject to modification by weather conditions and turbidity. NEFC studies in summer of 1980 and 1981 indicated no consistent patterns in diel availability between years. Therefore, NEFC indices are at present based on data from both daytime and nighttime tows. Trends for these indices are similar to trends for indices based on daytime tows; this would be expected in that the relative proportion of day and night tows has been relatively constant over time.

The Maine survey index (catch per tow at standard stations, Figure 6) declined more or less continually from 45.8 kg in 1968 to 4.8 kg in 1976 and has since fluctuated about a low level (Table 3, Figure 8). The NEFC spring survey index declined steadily from 10.6 kg per tow in 1968 to 1.3 kg in 1973, increased to 5.4 kg in 1975, and subsequently dropped sharply to 0.3 kg in 1978, but subsequent values have been substantially higher (Table 3, Figure 8). The autumn survey index fluctuated about an average of 3.2 kg during 1968-1972 but then declined more or less continually to 0.2 kg in 1977 before increasing to 0.5 kg in 1979-1980 (Table 3, Figure 8). The NEFC summer survey index increased from 0.3 kg in 1977 to 0.7 kg in 1979-1980 (Table 3). Thus, NEFC survey data suggest a recent increase in biomass, although index values for 1978-1980 remain considerably below levels observed during peak years of the fishery.

Maine summer survey catch-per-tow-at-age data for 1972-1981 (Schick et al., MS 1981; Northern Shrimp Technical Committee MS 1981) have been used in previous assessments to estimate mortality and stock size. Estimates of instantaneous total mortality (Z) averaged around 1.5 during 1972-1977 but have since declined (Table 4). The reduction observed for 1977-1979 coincides with closure of the fishery from May, 1977 to February of 1979 and the limited winter fishery in February and March of that year. Stock size estimates obtained in previous assessments (by application of exploitation rates derived from Maine survey data assuming instantaneous natural mortality (M) = 0.25) correlate reasonably well (r= 0.93) with NEFC autumn survey index values (Clark and Anthony 1981).

YIELD PER RECRUIT

The applicability of yield-per-recruit models to northern shrimp assessments is limited due to uncertainty concerning the necessary parameter estimates. Nevertheless, yield-per-recruit modeling does provide management insight in the Gulf of Maines situation.

The level of M for this stock is uncertain; Rinaldo (MS 1973) reported M to be 0.25 based upon regressions of Z upon total effort, and this value may be appropriate for younger ages although M appears to increase sharply after age 4 is attained (Haynes and Wigley 1969). Maine and NEFC survey data for 1977-1978 (collected during the period of closure) do suggest a relatively low M value for younger age groups. Unfortunately, there is little information on M for other northern shrimp stocks in the Northwest Atlantic. Fréchette and Labonte (1981) have obtained estimates of 0.39 between ages 2-3 and 0.64 for older ages (3+) in the Gulf of St. Lawrence, in reasonable agreement with expected patterns for the Gulf of Maine.

Yield-per-recruit calculations have been performed with the Ricker yield model (Ricker 1975: 258) under a series of options for M: constant at 0.25; constant at 0.25 prior to age 4 followed by a subsequent increase to 1.0; constant at 0.50, and constant at 0.50 prior to age 4, followed by a subsequent increase to 1.0. The model was run on predicted weight-at-age data obtained by fitting the von Bertalanffy growth equation to length-at-age data obtained in NEFC spring, summer, and autumn surveys in 1978-1979 and applying the appropriate length-weight equations reported by Haynes and Wigley (1969).

Biomass vectors under the assumption of zero harvest (Figure 9) differ considerably depending upon levels of M assumed, with peaks occurring at 4.2 years at M=0.25 and 3.0 years at M=0.50. Assuming a relatively low level for M prior to age 4, a late winter fishery (when age 4 females concentrate in shoaler areas) would contribute towards maximizing yield. Later winter harvests could also enhance recruitment prospects by reductions in mortality prior to hatching, as peak hatching activity in the Gulf of Maine occurs from mid-February to mid-March (Northern Shrimp Scientific Committee MS 1980). See also Rinaldo (MS 1976). Yield-per-recruit curves for 44 mm (1.75 inch) mesh trawls under the above assumptions relative to M are given in Figure 10; these tend to be flat-topped (with maxima evident only for options of M=0.25). There is no appreciable change in yield for any of these curves above F=1.0 and indeed higher levels of F would appear undesirable at current levels of abundance.

MANAGEMENT

The Gulf of Maine northern shrimp fishery is managed jointly by the participating states under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC). Under this arrangement regulations are established by the Commission and enforced by the participating states (Northern Shrimp Scientific Committee MS 1979). The Northern Shrimp Fishery Management Board of ASMFC, which includes the marine fisheries commissioners of Maine, New Hampshire, and Massachusetts and the Northest Regional Director of NMFS, retains management authority; the Northern Shrimp Scientific (now Technical) Committee, which includes scientists from the above states and NMFS, is responsible for providing assessments, management advice, and other information to the Board. Industry input is solicited on a continuing basis.

Management originated in 1972, when concern over declining landings led to examination of options to increase yield per recruit. Regulation of mesh size was identified as a desirable strategy, and accordingly the Committee conducted gear-evaluation studies in 1973-1974. Results indicated use of trawls with uniform stretched mesh sizes of 44 mm (1.75 inches) in both body and codend to be optimal with respect to retention of mature (age 3 and 4) females and release of smaller (age 1 and 2) males (Northern Shrimp Scientific Committee MS 1974) and accordingly regulations were implemented in 1975 requiring use of such gear which have been continued until the present (Table 5).

The Committee has also assessed this stock annually since 1974. Commercial

and research vessel survey data for 1974-1976 indicated that stock size and recruitment were declining rapidly and that stringent control of mortality was needed if abundance was to be stabilized. The Committee advised quotas of 4,200 tons for 1975 and 2,300 tons for 1976, the estimated maximum levels that could be harvested without further declines, and also recommended a March 15 to July 31 season for 1976 to enhance recruitment prospects (Northern Shrimp Scientific Committee MS 1979). Since the winter fishery has traditionally provided off-season employment for smaller vessels, and since winter product quality is optimal, these recommendations met with considerable opposition, and as a compromise a January 1 - April 15 season was established, followed by indefinite closure (Table 5). Subsequent assessments in 1976 and 1977 indicated further declines in abundance, leading to recommendations for continued indefinite closure (implemented in 1978, Table 5). Evidence for stabilization of abundance and industry pressure led to reopening of the fishery in February-March of 1979, and the season has been extended in subsequent years (Table 5). The Committee advised a late winter and early spring (February-March) fishery for 1980 and 1981 based on biological and yield per recruit considerations.

DISCUSSION

The Gulf of Maine northern shrimp stock declined precipitously in the early to mid-1970's and has since shown only slight, if any, improvement. Commercial abundance index values for 1980-1981 are comparable to those observed in 1976-1977; the Maine summer survey index has shown little change since 1977, although NEFC survey index values have increased somewhat. Available survey data suggest that stock biomass remains 80-90% below levels observed during the late 1960's. Increased landings for 1981 primarily reflect increased effort, as a threefold increase in standardized effort occurred between 1980 and 1981, while the commercial index changed very little.

The striking decline in abundance and recruitment during the early to mid-1970's has been attributed both to environmental (temperature) influences and to heavy fishing pressure. Annual mean bottom temperature in NEFC autumn surveys in the Gulf of Maine averaged 5.5°C during 1964-1966 and then increased more or less continually to 9.3°C in 1976, the highest observed in the NEFC survey time series (Davis, 1978, 1979). Temperatures have since declined somewhat but remain well above levels observed in the mid-1960's. Since

temperature and abundance of this species in the Gulf of Maine are inversely correlated (Dow 1963, 1964, 1966; Apollonio and Dunton MS 1969), environmental conditions may have exerted a significant adverse impact upon recruitment in recent years. Fishing pressure, which in terms of standardized effort also peaked in the early to mid-1970's, may also have contributed to declines in recruitment as well, although the relative impact of the two variables is difficult to quantify (Anthony and Clark 1980).

The nature of temperature influences upon recruitment is currently unclear. Stickney (MS 1977) was unable to demonstrate significant egg mortality within the range of 2^{o}-12^{o}C under laboratory conditions, and since ovigerous females would seldom if ever encounter temperatures as high as 12^{o}C in the western Gulf of Maine direct egg mortality would not be expected to be of major consequence. Above normal temperatures may affect recruitment indirectly e.g. by causing premature hatching (before adequate food supplies are available) or by enhancing survival of a parasitic dinoflagellate which attacks egg masses during the ovigerous period (Stickney MS 1977). The incidence of egg parasitism appears to have dropped considerably with recent declines in temperature (Stickney and Perkins MS 1979).

Recent stability in commercial indices and the Maine summer survey index and increases in NEFC survey indices, coupled with recent declines in temperature, suggest improved prospects for this resource, although the need for careful management is clearly evident. Recent assessment results do not demonstrate any adverse impact from the 1981 fishery, and a winter-spring season has again been implemented for 1982. Monitoring of the fishery and of trends in abundance and mortality will be continued.

ACKNOWLEDGEMENTS

The author thanks Frances Pierce of the Marine Department of Marine Resources and Richard Tichko of the New Hampshire Fish and Game Department for their assistance with processing samples collected in NEFC bottom-trawl surveys and Elizabeth Bevaqua of the NEFC Woods Hole Laboratory for her assistance with keypunching and storage of the resulting data files on magnetic tape. David Sampson of the Maine OMR and Alfonzo Thrower of the NEFC Woods Hole Laboratory also assisted with analyses of the Maine and NEFC survey data files.

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Table 1. Commercial landings (tons)[1] of northern shrimp in the western Gulf of Maine, by state, 1958-1981.

Year	Maine	New Hampshire	Massachusetts	Total
1958	2.3	-	0.0	2.3
1959	5.4	-	2.3	7.7
1960	40.4	-	0.5	40.9
1961	30.4	-	0.5	30.9
1962	159.7	-	16.3	176.0
1963	244.0	-	10.4	254.4
1964	419.4	-	3.1	422.5
1965	947.0	-	8.0	955.0
1966	1737.8	18.1	10.5	1766.4
1967	3141.1	20.0	10.0	3171.1
1968	6515.0	43.1	51.9	6610.0
1969	10992.9	58.1	1772.8	12823.8
1970	7712.8	54.4	2902.1	10669.5
1971	8354.7	50.8	2723.8	11129.4
1972	7515.6	74.8	3504.5	11094.9
1973	5476.7	59.9	3868.2	9404.8
1974	4430.7	36.7	3477.3	7944.7
1975	3177.0	29.5	2080.2	5286.7
1976	617.2	7.3	397.8	1022.3
1977	148.0	2.3	236.9	387.2
1978[2]	-	-	-	-
1979	32.9	2.3	451.3	486.5
1980	69.5	5.4	256.9	331.8
1981[3]	491.1	-	536.2	1027.3

[1]Source "Fisheries Statistics of the US" 1958-1975; New England commercial weighout/annual canvas data 1976-1981.

[2]Negligible due to closure from May 1977 to February 1979.

[3]Preliminary.

Table 2. Commercial abundance indices (tons per standard[1] day fished) for Gulf of Maine northern shrimp calculated from NMFS catch-effort data obtained in dockside interviews, 1964-1981.

Year	Annual Index[2]	Winter Index[3]
1964	0.93	1.15
1965	1.30	1.43
1966	2.81	3.49
1967	2.99	3.59
1968	2.99	2.56
1969	2.77	4.08
1970	1.67	2.34
1971	1.60	2.04
1972	1.53	1.86
1973	1.83	2.01
1974	1.77	1.67
1975	1.93	2.24
1976	1.46	1.59
1977	1.08	1.09
1978	-	-
1979	2.43	2.48
1980	1.20	1.04
1981	1.44	1.44

[1] Standard = 34-50 GT vessels.

[2] Calculated using trip data for Gloucester and Portland for which 50% or more of the total catch consisted of shrimp.

[3] Calculated using trip data for Gloucester and Portland for February and March for which 50% or more of the total catch consisted of shrimp.

Table 3. Research vessel survey abundance indices for Gulf of Maine northern shrimp, 1968-1981.

Year	Mean catch per tow (kg) Maine summer survey[1]	Stratified mean catch per tow (kg) NEFC bottom trawl surveys[2] Spring	Summer	Autumn
1968	45.8	10.57		3.16
1969	31.2	4.46		2.69
1970	40.8	2.09		3.66
1971	9.4	1.86		2.95
1972	7.0	1.44		3.33
1973	7.8	1.31		1.89
1974	4.9	2.16		0.75
1975	6.7	5.40		0.93
1976	4.8	0.67		0.58
1977	1.6	0.90	0.30	0.15
1978	3.2	0.27	0.38	0.41
1979	4.4	1.00	0.70	0.51
1980	2.7[3]	0.82	0.68	0.54
1981	3.0	2.61	-	-

[1] Mean catch per 30-minute tow (daytime).

[2] Stratified mean catch per 30-minute tow (day and night tows included), NEFC spring, summer, and autumn bottom-trawl surveys; data for strata 24, 26-28, and 37-40 used in calculating each index.

[3] Based on incomplete sampling

Table 4. Mean catch per tow at age (numbers) and estimates of instantaneous total mortality (Z) obtained during Maine summer surveys, 1972-1981.

Year	Age 1	2	3+	Total	Instantaneous Total Mortality (Z)[1]
1972	254	393	649	1296	
					1.09
1973	1079	643	349	2071	
					1.41
1974	566	302	241	1109	
					1.46[2]
1975	114	537	394	1045	
					1.65
1976	454	233	178	865	
					1.70
1977	120	61	75	256	
					0.17
1978	271	127	115	513	
					0.83
1979	227	313	106	646	
					-[3]
1980	334	72	62	468	
					-[3]
1981	159	154	50	363	

[1] Calculated as ln $\left(\frac{\Sigma \text{age 2+ in year i}}{\Sigma \text{age 3+ in year i+1}}\right)$

[2] Averaged over 1972-1977; not calculated directly due to introduction of a new survey vessel in 1975.

[3] Not calculated due to incomplete sampling in 1980.

Table 5. Management of the Gulf of Maine northern shrimp resource, 1972-1981

Year	Recommendation	Action Taken
1972	1. Adoption of mesh regulations 2. Establishment of count/lb limits 3. Establishment of closed seasons	1. Provision for gear evaluation studies
1973		1. Adoption of interim minimum mesh size regulation requiring use of trawls with stretched mesh sizes of not less than 38mm (1.5 inches) in body and codend
1974	1. Adoption of final minimum mesh size regulation 2. Restriction of 1975 harvest to 4,200 tons (9.2 million lbs)	1. Establishment of regulations requiring use of trawls with stretched mesh sizes of not less than 44mm (1.75 inches) in body and codend (effective October 1975) 2. Closure of the fishery from July-September 1975
1975	1. Restriction of 1976 harvest to 2,300 tons (5 million lbs) by seasonal closure and quota management 2. Continuation of mesh regulations	1. Open season from January 1-April 15, 1976, followed by indefinite closure 2. Continuation of mesh regulations
1976	1. Continuation of closure thru 1977	1. Open season from January 1 - May 15, 1977, followed by indefinite closure 2. Restriction of 1977 harvest to 1,600 tons (3.5 million lbs) 3. Continuation of mesh regulations
1977	1. Continuation of closure thru 1978	1. Continuation of closure thru 1978
1978	1. Continuation of closure thru 1979	1. Open season from February 1 - March 31, 1979, followed by indefinite closure 2. Continuation of mesh regulations
1979	1. Continuation of closure thru 1980, or if fishery opened, restriction of fishing to late winter and early spring (February-March) 2. Continuation of mesh regulations	1. Open season from February 15 - May 31, 1980, followed by indefinite closure 2. Continuation of mesh regulations
1980	1. Restriction of fishing to late winter and early spring (February-March) 2. Continuation of mesh regulations	1. Open season from January 1 - May 15, 1981, followed by indefinite closure 2. Continuation of mesh regulations
1981	1. Restriction of fishing to winter and early spring 2. Continuation of mesh regulations	1. Open season from January 1 - April 15, 1982, followed by indefinite closure 2. Continuation of mesh regulations

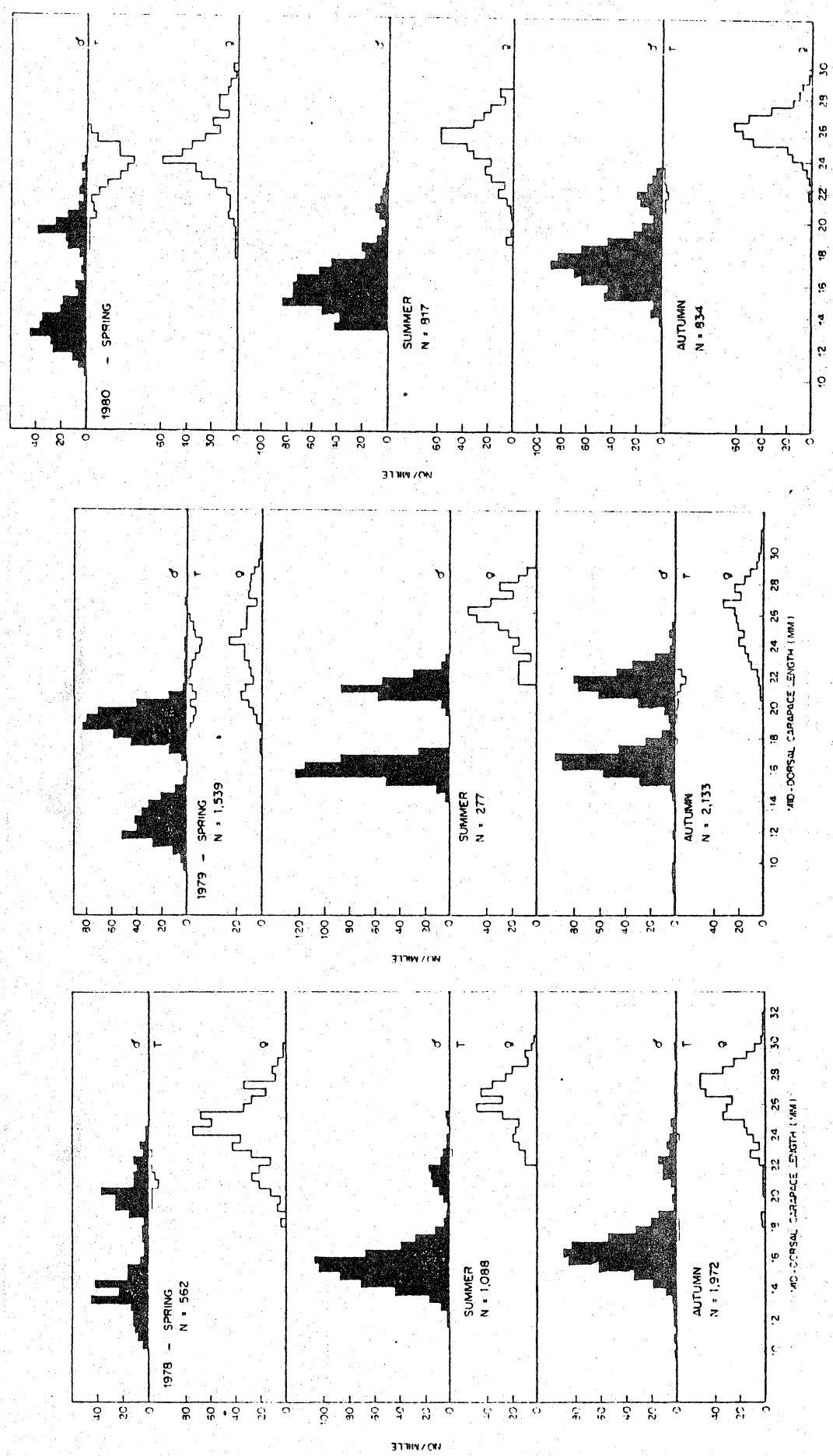

Figure 1. Length-frequency distributions of northern shrimp (Pandalus borealis) by sex in NEFC spring, summer, and autumn bottom trawl surveys, 1978-1980. Data are for individuals in subsamples examined for sexual characters.

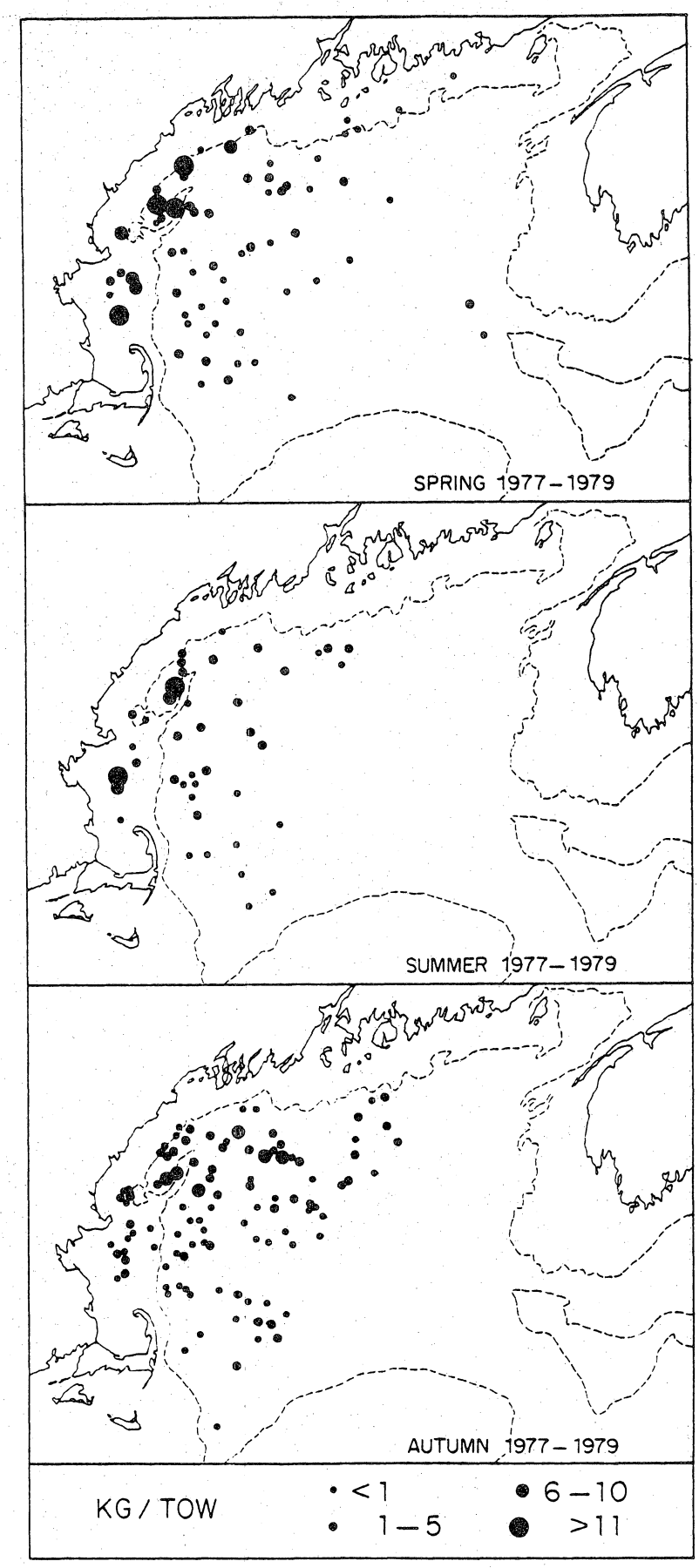

Figure 2. Distribution of northern shrimp (Pandalus borealis) in the Gulf of Maine as observed during NEFC spring, summer, and autumn bottom-trawl surveys, 1977-1979.

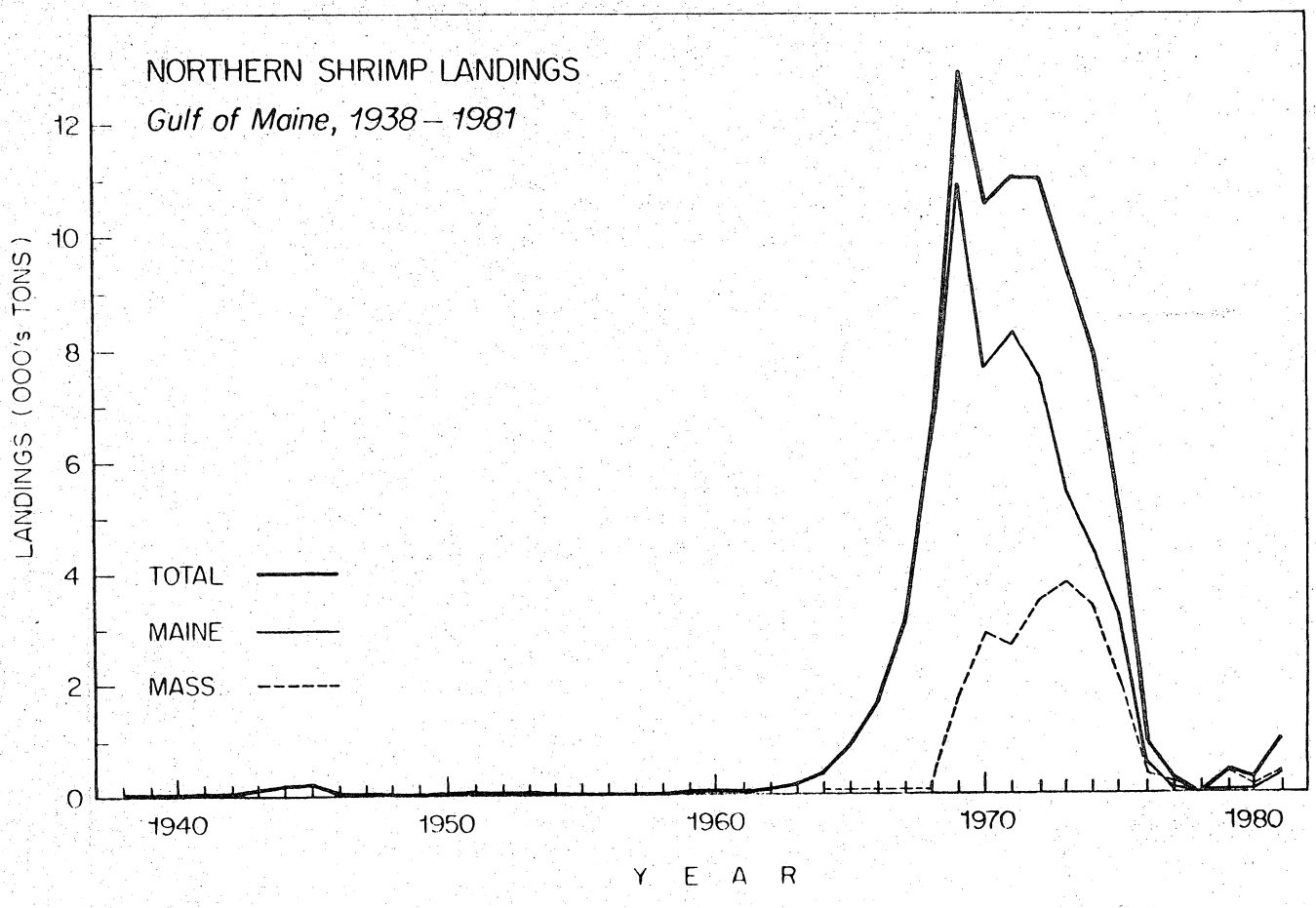

Figure 3. Gulf of Maine northern shrimp landings, 1938-1981.

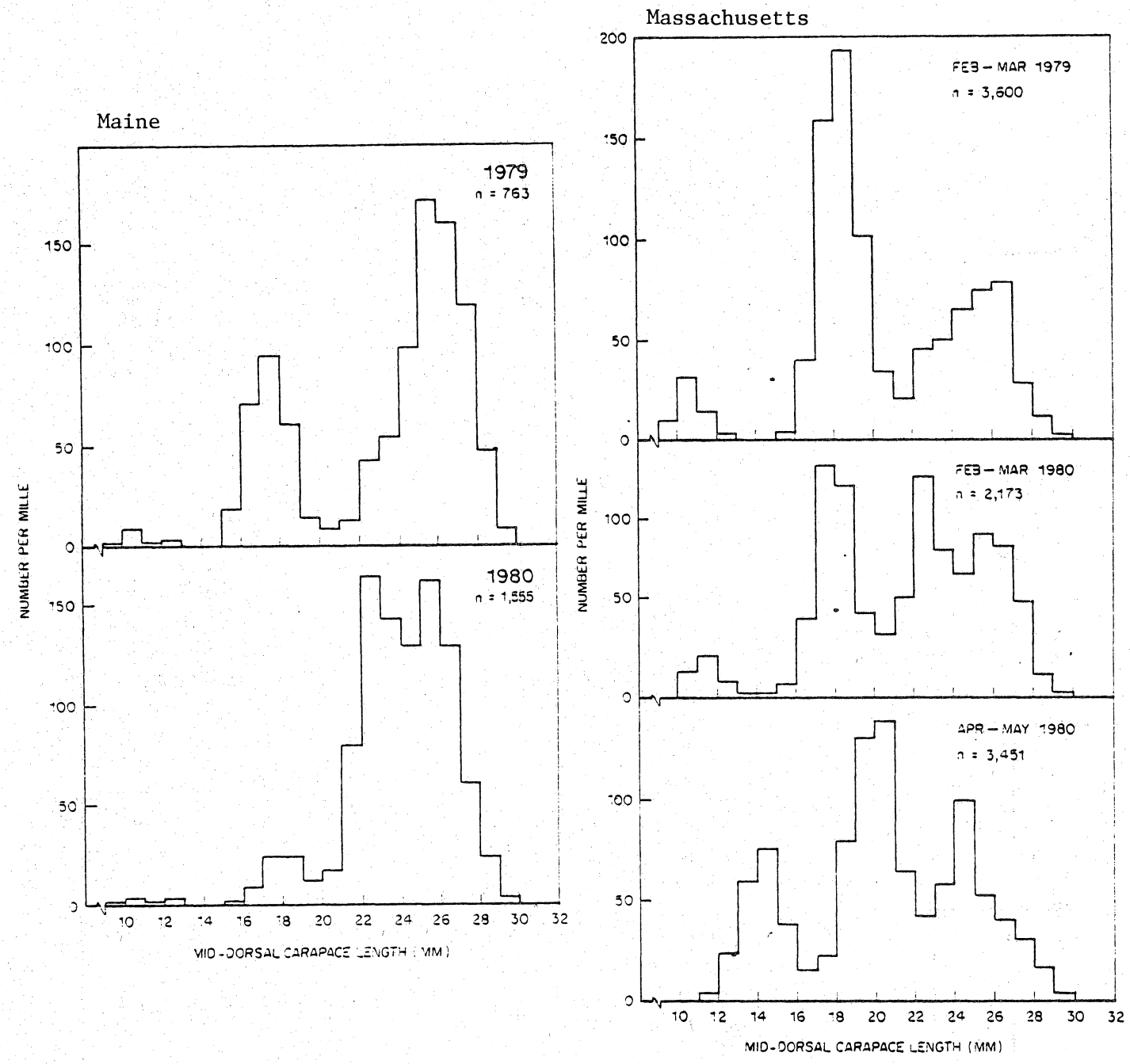

Figure 4. Length-frequency distributions of northern shrimp samples from Maine landings in February-March and Massachusetts landings from February-May, 1979-1980.

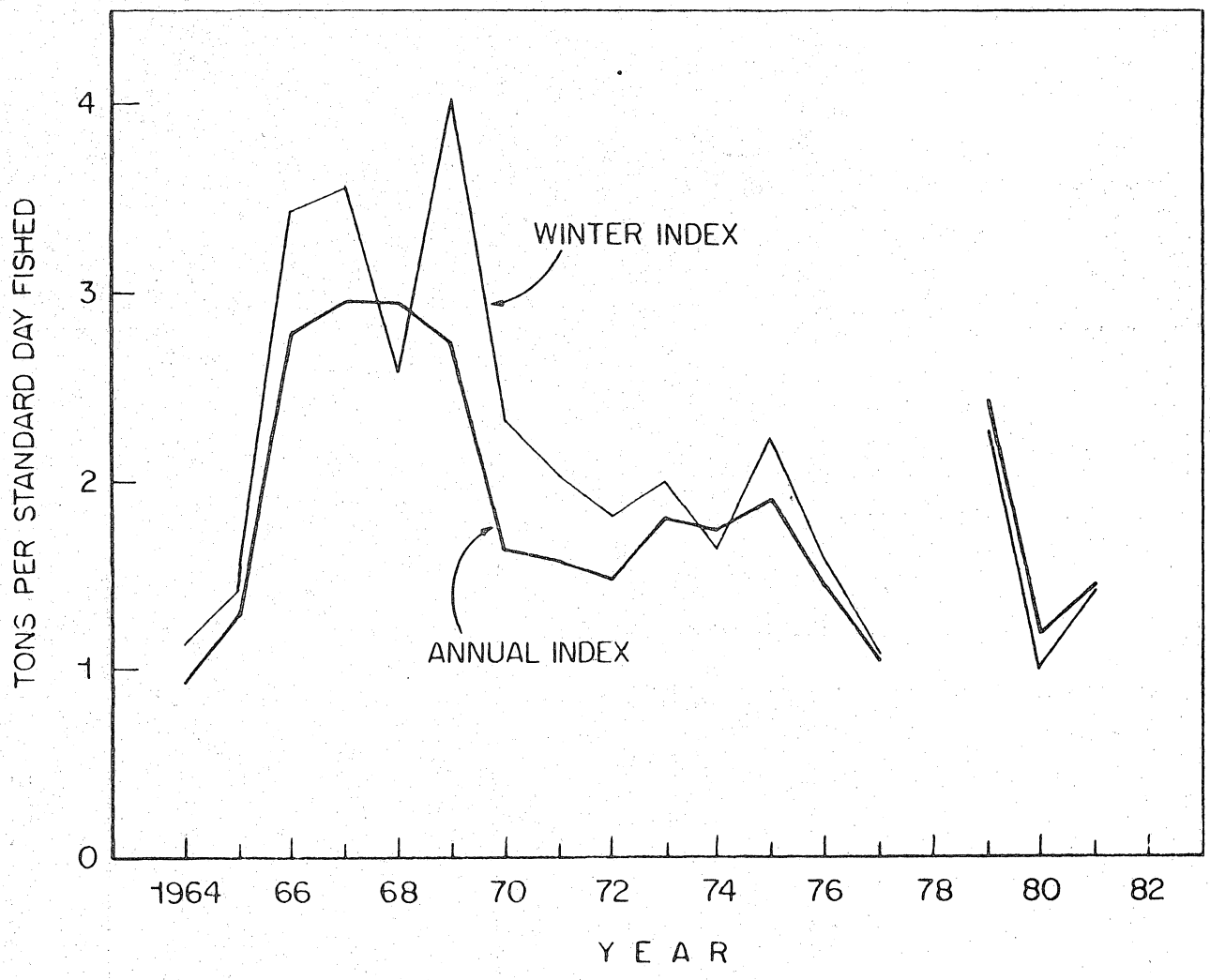

Figure 5. Commercial abundance indices for the Gulf of Maine northern shrimp fishery, 1964-1981, calculated from catch-effort data obtained in dock side interviews.

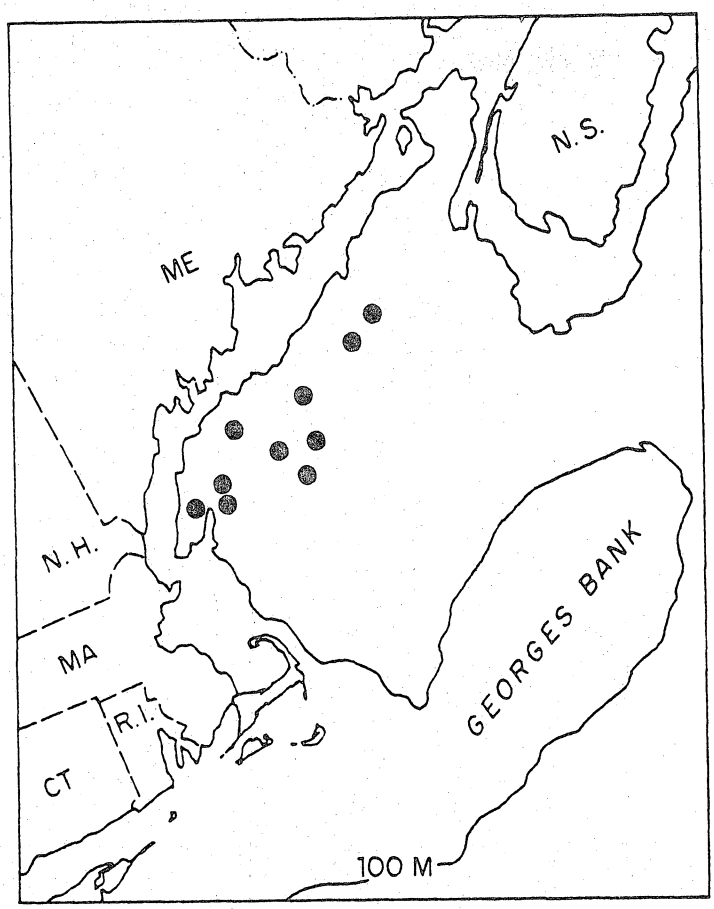

Figure 6. Locations of stations sampled during Maine August surveys, 1968-1981.

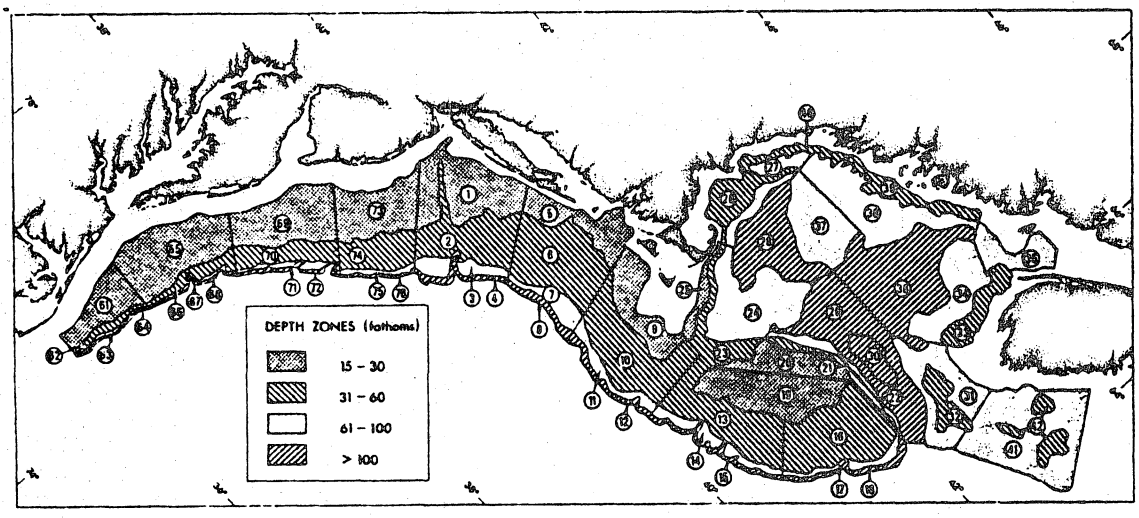

Figure 7. Strata used in NEFC spring, summer, and autumn bottom trawl surveys, 1963-1981.

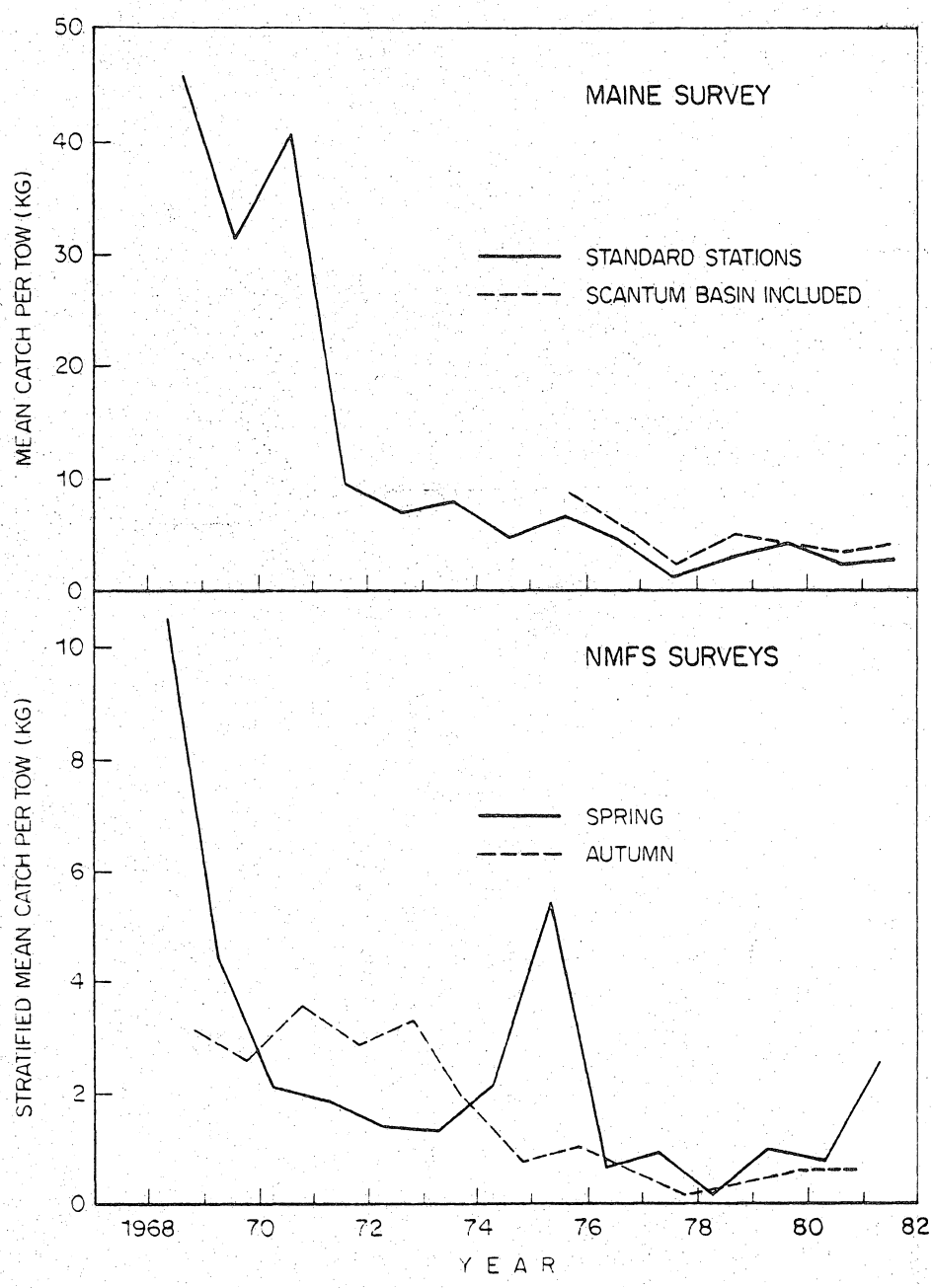

Figure 8. Indices of relative abundance calculated from Maine summer and NEFC spring, summer, and autumn bottom trawl survey data, 1968-1981.

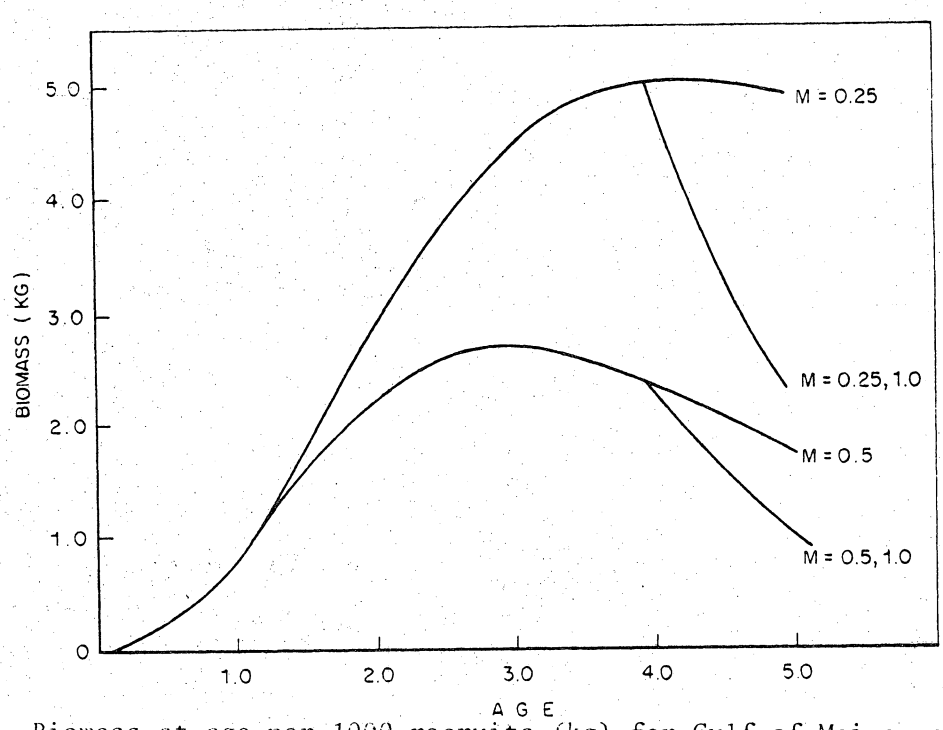

Figure 9. Biomass at age per 1000 recruits (kg) for Gulf of Maine northern shrimp in the absence of fishing calculated under different assumptions relative to instantaneous natural mortality (M).

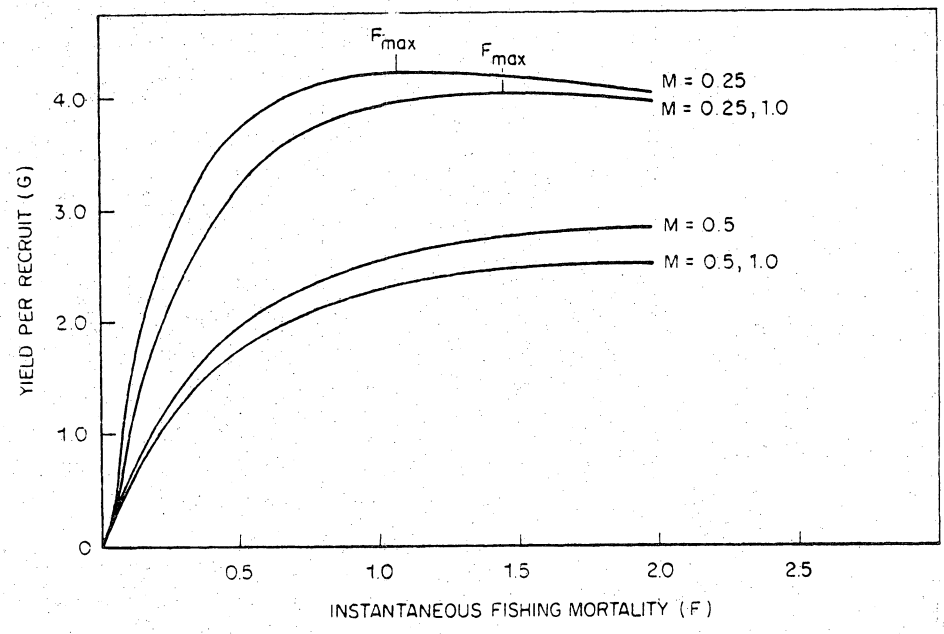

Figure 10. Yield per recruit (g) for Gulf of Maine northern shrimp assuming use of 44 mm (1.75 inch) trawls.