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STATUS OF BLUEFISH ALONG THE ATLANTIC COAST, 1982

BY

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Spawning of bluefish occurs in two major areas along the Atlantic coast: south of Cape Hatteras and in the Middle Atlantic Bight. Juveniles move inshore to bays and estuaries from Florida to Cape Cod. Most bluefish are mature by age 2, and the sex ratio remains 1:1 (males:females) for all age groups. Growth is rapid, especially during the first growing season.

Existing regulations on bluefish catch focus on minimum size limits imposed by many states along the Atlantic coast, and limits on foreign catch in the FCZ. A bluefish fishery management plan currently being prepared by the Mid-Atlantic Fishery Management Council proposes unrestricted harvest for US recreational anglers, an allowance for limited expansion of the conventional commercial fishery, and restrictions on the use of "non-conventional" commercial gear (e.g., purse seines and otter trawls).

The recreational and commercial catches of bluefish have been increasing over the past 2 decades. Tagging studies conducted in the late 1960's along the Atlantic coast indicate that the fishing mortality rate for younger age groups (ages 1-3) was 45-70% per year; fishing mortality was much less for older age groups (ages 4+). More than 90% of the total harvest of bluefish along the Atlantic coast is by recreational anglers. Age samples from the fisheries indicate that all ages (ages 0+) are harvested.

NEFC inshore and offshore trawl surveys have also had increasing catch rates of bluefish during the 1970's. Most of the

bluefish caught in the inshore surveys have been less than 30 cm (12 in) in length (presumed age 0). The offshore survey catches have included equal numbers of fish less than and fish greater than 30 cm (12 in). Older bluefish (> 55 cm or 21.7 in) appear to be more vulnerable to capture in the offshore surveys than younger age groups, probably because of their distribution habits.

Catch per tow of bluefish in the fall inshore survey north of Cape May appears to be an adequate index of recruitment, since it is correlated with commercial and recreational harvests 2-4 years later. This index shows that recruitment has been relatively high in recent years and projections for commercial and recreational harvest in 1983 and 1984 are favorable. Maximum sustainable yield (MSY) estimates based on a stock production model are between 60 and 69 thousand tons (133 and 153 million lb). An alternative MSY estimate, assuming a direct relationship between recruitment and subsequent catch, is the median catch along the Atlantic coast for the period 1960-1982; this level is 42-56 thousand tons (93-123 million lb). Based on recent findings that do not support critical assumptions of the production model, and based on the correlation of recruitment to subsequent catch, the estimate based on median catch is considered the more appropriate MSY value.

INTRODUCTION

The estimated catch of bluefish (Pomatomus saltatrix) in the recreational fishery along the Atlantic coast of the US increased in number by 1.5 times and weight by 2.6 times between 1960 and 1980 (Figure 1). Reported commercial landings (by weight) in Atlantic coastal states increased by more than 5 times during the same time period. In 1980, bluefish was one of the three finfish species most sought by recreational anglers along the Atlantic coast (US Department of Commerce 1983). Bluefish accounted for an estimated 15% of all fish landed along the coast by recreational anglers that year; in terms of weight the species accounted for an estimated 34%. The Mid-Atlantic Fishery Management Council (MAFMC), stimulated by possible expansion of the commercial fishery, recently drafted a coastwide fishery management plan for bluefish (MAFMC 1982).

The first comprehensive summary of the biology and fisheries data on bluefish along the Atlantic coast was prepared by Wilk (1977). Shortly thereafter, Hayden and Anderson (1978) presented a concise summary of the status of bluefish in the Gulf of Maine and Middle Atlantic areas. Anderson (1980) used reported commercial landings, estimates of recreational landings, and stock abundance indices to estimate maximum sustainable yield (MSY) for bluefish along the Atlantic coast. Based on the range of MSY estimates, Anderson concluded that the fishery was operating at or near the MSY level. Since Anderson's analysis, both the commercial and recreational landings have continued to increase.

This document assesses the current status of bluefish along the Atlantic coast. Topics covered include current and projected management regulations, catch statistics, biology, stock abundance, recruitment, mortality estimates, and yield. A re-examination of the maximum sustainable yield analysis performed by Anderson (1980) is also presented.

MANAGEMENT

Existing Regulations

State regulations on the catch of bluefish in territorial waters (0-4.8 km offshore) are listed in Table 1. All of the Atlantic coastal states, except Delaware, require a permit or license for the commercial harvest of bluefish, and some states have additional restrictions on gear and season (MAFMC 1982). Connecticut, New York, New Jersey, Maryland, South Carolina, and Florida have minimum size limits for their commercial fisheries of either 9 or 10 in (22.9-25.4 cm). Maryland is the only state with a minimum size limit for its recreational fishery (8 in, 20.3 cm). Bluefish achieve a length of 8-10 in (20-25 cm) by the end of their first growing season (see Age and Growth section).

The Magnuson Fishery Conservation and Management Act of 1976 (MFCMA) has been the only federal law that provides for management of bluefish. A preliminary management plan (PMP) has restricted the foreign catch of bluefish, included in the "other species" category since 1 March 1977. Foreign fishing, however, has never had much influence on the total catch of bluefish along the Atlantic coast (see Catch Statistics section).

Proposed Regulations

A fishery management plan (FMP) for bluefish along the Atlantic coast has been prepared by the Mid-Atlantic Fishery Management Council. The objectives of the plan are: (1) to "increase understanding of the condition of the stock and the fishery;" and (2) to "provide the highest availability of bluefish to US recreational fishermen while maintaining, within limits, traditional uses of bluefish, recognizing some natural stock fluctuations are inevitable" (MAFMC 1982).

The bluefish FMP, although not yet approved by the Department of Commerce, would allow use of hook and line, conventional gill nets, traps, haul seines, and pound nets to conduct a directed fishery for bluefish in the FCZ. Fishermen using these gear would be allowed an unlimited harvest in the FCZ. For other gear, a waiver of gear restrictions would have to be obtained from NMFS if the waiver is consistent with the objectives of the plan. This management approach would allow for some growth of the commercial fishery from the current 11% of total catch, as estimated by the MAFMC (1982), to 20%. Waivers for restricted gear would be granted based on projected landings by non-restricted gear. Other facets of the FMP include a 10% by-catch limit in other fisheries, no foreign fishery, and a log book requirement for operators of party and charter boats that catch more than 100 lb (45.4 kg) of bluefish per trip.

CATCH STATISTICS

Statistics relating to the commercial and recreational fisheries for bluefish along the Atlantic coast are reported by the Mid-Atlantic Fishery Management Council in their draft management plan for bluefish (MAFMC 1982). The statistics are updated and summarized in this section.

Recreational Fishery

Estimates of recreational catch along the entire Atlantic coast are available from 4 national surveys conducted by NMFS and its predecessor agency: 1960 (Clark 1962), 1965 (Deuel and Clark 1968), 1970 (Deuel 1973), and 1980 (US Department of Commerce 1983). Regional surveys conducted in 1974 from Maine to Cape Hatteras, North Carolina, and in 1975 from Cape Hatteras, North Carolina, to Florida are also available (D. Deuel, NMFS, Washington, DC, personal communication). Statistics reported in the 1979 survey (US Department of Commerce 1980) have been withdrawn by NMFS pending re-evaluation. Overall, survey estimates indicate a steady rise in the number of bluefish caught along the Atlantic coast, the total weight of bluefish landed, and the average weight of caught fish (Table 2).

Anderson (1980) assumed that recreational catch estimates prior to the 1979 survey were overestimated by 100%. His assumption was based on a study of angler recall (Hiett and Worral 1977) and interviews with individuals who were knowledgeable about the fishery. The design of the surveys beginning in 1979 was intended to reduce the overestimate by reducing the recall period to less than 3 months. If Anderson (1980) is correct in his assumption that the recreational catch in 1960, 1965, and 1970 was one-half of that reported by anglers, then the increase in the recreational catch of bluefish over the past 20 years has been even more dramatic.

Statistics from the most recent available survey (1980) are summarized in Table 3 showing the relationships between catch of bluefish and distance from shore and between catch and mode of fishing. An estimated coastwide average of 23% of the bluefish were caught by recreational anglers in the Fishery Conservation Zone (FCZ, 3-200 nautical miles, 4.8-320 km, from shore). The remaining 77% were caught within 3 nautical miles (4.8 km) of the coast. In the South Atlantic Region (North Carolina to Florida east coast), only 1% of the bluefish were caught in the FCZ and over 90% were caught in inland waters. Inland waters include sounds, inlets, tidal portions of rivers, bays, and estuaries.

The South Atlantic states have typically landed smaller fish than states to the north (Table 2). In 1960, 27% (by number) of the bluefish were landed in the South Atlantic states (Clark 1962); whereas, in 1980 this proportion dropped to 12% (US Department of Commerce 1983). The increase in the average weight of bluefish caught between 1960 and 1980 (Table 3) is probably due to the increasing number of bluefish caught in the North and Middle Atlantic states over the 20-year period.

Approximately one-half (49%) of the estimated number of bluefish caught in the 1980 recreational fishery were caught from private or rented boats operated by the renter (i.e., no crew provided). The mode of fishing that ranked second in terms of number caught was fishing from the beach/bank in the North Atlantic Region (Maine to New York) and South Atlantic Region, and fishing from party/charter boats in the Middle Atlantic Region (New Jersey to Virginia).

Commercial Fishery

Reported commercial landings of bluefish along the Atlantic coast from 1931-1982 are listed, by state, in Table 4. In years when the recreational angling surveys were conducted coastwide (1960, 1965, 1970, and 1980), reported commercial landings (weight) were approximately 7% of the total catch (Table 5). In the most recent year for which recreational fishing estimates are available (1980), reported commercial landings were approximately 10% of the total.

All states along the Atlantic coast have had an increasing trend in reported commercial landings of bluefish during recent years (Table 4). Owing to the fish's migratory habit, the commercial fishery is seasonal. Reported landings peak in the summer and fall in the New England and Middle Atlantic states, and peak during winter and early spring in the South Atlantic states (MAFMC 1982). Otter trawls, gill nets, pound nets, trap nets, and haul seines account for the majority of reported commercial landings.

During 1974-1981, an estimated 79% of the reported commercial landings were within 3 nautical miles (4.8 km) of shore (MAFMC

1982). However, the proportion caught in the FCZ rose steadily during this time period. In 1981, 37% of the commercial catch of bluefish was in the FCZ.

BIOLOGY

Stocks

Lund (1961) identified six races(stocks) of bluefish along the Atlantic coast basing separation on meristic counts of the number of gill rakers on the first branchial arch. During warmer months, these races are found as follows: (1) Massachusetts to New York; (2) New Jersey; (3) Delaware; (4) Chesapeake Bay to Cape Lookout, North Carolina; (5) Cape Lookout, North Carolina to perhaps Georgia; and (6) Florida.

Wilk (1977), using morphometric characters and scale peculiarities, concluded that two stocks of bluefish exist off the Atlantic coast. One stock is present in the Middle Atlantic Bight during the spawning season, and the other stock is off of North Carolina. Early life history information collected by Kendall and Walford (1979) also indicate that two genetically-distinct stocks may exist.

Spawning

Spawning activity of bluefish occurs in two major areas along the Atlantic coast (Figure 2). In April and May, spawning occurs near the inner edge of the Gulf Stream from southern Florida to North Carolina (Kendall and Walford 1979). From mid-May to mid-

September, spawning occurs in the Middle Atlantic Bight (Colton et al. 1979). In a survey conducted off the mouth of Chesapeake Bay, 80% of the bluefish eggs collected were in water further than 55.6 km (30 nautical miles) from shore (Norcross et al. 1974). The results from this study indicated that both temperature and salinity cued spawning activity.

Most bluefish are mature by age 2 (Deuel 1964a). A 1:1 ratio between males and females at each age was found to exist in all areas and years based on samples collected during 1963-1968 from the recreational and commercial fisheries along the Atlantic coast (Wilk 1977). Fecundity data, collected by Morse (NEFC, Sandy Hook Laboratory, unpublished) from 96 fish between 56 and 85 cm FL off New Jersey in 1978, indicate a linear relationship between fork length and number of eggs per female for bluefish in 56-80 cm size range (Figure 3).

Migration

Bluefish follow a seasonal migration pattern along the Atlantic coast (Figure 2); movement is north in the spring and south in the fall (Wilk 1977). During winter, a large proportion of the adult migratory population is believed to be on the outer continental shelf (Hamer 1959, Lund and Maltezos 1970), while small bluefish move southward along the coast (Lund and Maltezos 1970). Wilk (1977) noted a tendancy for the summer range of bluefish to shift further north as they increased in size.

Coastal migration may be quite extensive. A bluefish tagged in the New York Bight was recovered in the Gulf of Mexico (Miller

1969). Another tagged fish released off New York was recovered off Cuba (Bigelow and Schroeder 1953). These data indicate that some mixing of Atlantic coast stocks may occur.

Age and Growth

Bluefish eggs hatch in about 2 days at 20 C (68 F), yolk-sacs are absorbed in another 4 days when the larvae are about 3.0 mm in length, and the larvae attain their full complement of adult fin rays at a length of about 14.0 mm (Hardy 1978). Larvae are found offshore between Cape Cod, Massachusetts, and Palm Beach, Florida, during every season of the year and are strongly associated with the surface (Kendall and Walford 1979). Movement is inshore as the growing seaon progresses (Norcross et al. 1974). Larvae have been sampled in lower Chesapeake Bay (Pearson 1950) and in Narragansett Bay (Herman 1963), but their occurrence in near-shore waters is relatively uncommon.

Juvenile bluefish, commonly called "snappers," are found along ocean beaches, in tidal inlets, estuaries, creeks, and in rivers during early summer in Florida (Padgett 1967) and late summer and fall farther north (Mansueti 1955). Bluefish rely chiefly on estuarine habitat during the juvenile life stage (Kendall and Walford 1979). Growth of juveniles is rapid. They may attain a length of 175-200 mm (7-8 in) by late September of their first year (Lippson and Moran 1974).

Although few in number, length-frequency samples collected by the NMFS at major commercial ports in the Northeast indicate that gear commonly used inshore exclusively (pound nets) captures bluefish in the 20-30 cm (7.9-11.8 in) size range (Table 9). Gear that is used inshore and close to shore (gill nets and haul seines) captures bluefish in the 30-60 cm (11.8-23.6 in) size range, and gear that is used exclusively offshore (purse seines and otter trawls) captures fish up to 80 cm (32 in) in size.

Von Bertalanffy growth equation coefficients are listed in Table 6 for bluefish sampled from the Gulf of Mexico and the southeastern Atlantic coast (Barger MS), from North Carolina (Lassiter 1962), and the Atlantic coast (Wilk 1977). The length at annulus formation for age 1 fish ranged from 148 mm (5.8 in) FL for North Carolina fish to 321 mm (12.6 in) FL for fish from the Gulf of Mexico. A graphic representation of the growth curves upon which the growth equation coefficients were based is presented in Figure 4.

Length-weight relationships for bluefish are available from a number of sources (Table 8). For comparative purposes, data relating length to weight were fit using a power curve function:

$$W = aL^b \qquad (1)$$

where W = weight (g) and L = fork length (mm). The bluefish sampled in the Gulf of Mexico showed slightly less weight for a given length than bluefish sampled along the Atlantic coast (Figure 5).

Scale samples collected by NMFS from the summer and fall recreational fishery for bluefish in New Jersey during 1978

(1,753 samples) and 1979 (2,214 samples) provide an indication of the age composition of the fishery. The results (Table 9) indicate that the range of ages was 0 to 9 years, with the most common age being 2 years. Age 0 fish ranged in size from 9 to 26 cm (3.5 to 10.2 in); only one fish out of 104 less than 30 cm (11.8 in) was determined to be older than age 0. The lengths at ages correspond quite poorly to the growth curves shown in Figure 4. Even accounting for an additional year on the growth curves because the curves represent lengths at annulus formation, the recreational fishery measurements are still consistently higher than the growth curve values.

Another indication of age composition of bluefish caught in the recreational fishery is the relationship between the average weight of bluefish landed, as determined in the recreational surveys, and the corresponding age, based on the growth curve and length-weight relationships. The average weights of 0.97-1.60 kg (2.1-3.5 lb) (Table 2) correspond to ages of 2 and 3 years (tables 7 and 8).

Trophic Relationships

Many fish species are observed in bluefish stomachs including butterfish, menhaden, round herring, sand lance, silverside, Atlantic mackerel, anchovy, Spanish sardine, young weakfish, silver hake, spotted seatrout, Atlantic croaker, sea lamprey, and spot; invertebrates include shrimp, lobster, squid, crab, and annelid worms (Richards 1976; Grant 1962; Deuel 1964b; Wilk 1977). In estuaries, such as the lower Hudson River, juvenile bluefish feed on bay anchovy, white perch, American shad, river herring, and striped bass (TI 1976). Bluefish were present in stomach samples taken from shortfin mako sharks (Stillwell 1981) and blue sharks (Kohler and Stillwell 1981), but it is believed that other large piscivores (tunas, swordfish, wahoo, etc.) are also predators on bluefish (Wilk 1977).

An annotated list of 33 known parasites of bluefish was compiled by Anderson (1970). Newman et al. (1972) describe the aerobic macroflora of the bluefish intestine. "Fin rot" disease has been noted on bluefish sampled in the New York Bight (Mahoney et al. 1973).

STOCK ABUNDANCE AND RECRUITMENT

Bottom trawl surveys have been conducted by the Northeast Fisheries Center (NEFC) off the northeastern US coast since 1963 in offshore waters (> 27 m depth) and since 1972 in inshore waters (< 27 m depth). The ALBATROSS IV and DELAWARE II have been used for the offshore surveys since 1963 and inshore surveys since 1974; the ATLANTIC TWIN was used for inshore surveys in 1972 and 1973. A "36 Yankee" trawl equipped with 41 cm rollers has been used in all summer aod autumn surveys, and in all spring surveys before 1973 and after 1981. A "41 Yankee" trawl equipped with 30-46 cm rollers was used in the spring surveys during 1973-1981. Both trawls employed 13 mm codend liners. A 30 minute tow was made at each station at a vessel speed of 6.5 km/hour (3.5 knots) in all surveys. Additional information concerning the surveys is provided by Grosslein (1969), Azarovitz (1981), and

Clark (1981).

Catches of bluefish have been essentially limited to the autumn surveys, and have ranged from Cape Cod to Cape Hatteras (Figure 6). Therefore, autumn survey data were used to calculate catch per tow indices of abundance. The catch-per-tow index is the stratified mean of the average catch-per-tow within each stratum of a defined set of strata, weighted by the surface area of each stratum in the set.

Offshore Survey Abundance Index

Bluefish have been sampled in almost all offshore survey strata less than 111 m in depth; the stratified mean number per tow and stratified mean weight per tow of bluefish have been increasing since the inception of the offshore survey from Cape Hatteras northward in 1967 (Figure 8 and Appendix I). Examination of the size distribution of the fish collected in the autumn surveys indicates that the increase in abundance has been due to an increase in bluefish 30 cm (11.8 in) or less in length since 1972 (Table 12). This size range represents chiefly young-of-the-year during the fall months (Nichols 1913; Wilk 1977; Kendall and Walford 1979), implying an increase in recruitment north of Cape Hatteras during the past decade.

Survey catches also show an increase in relative abundance above 55 cm (21.7 in) (Table 12), corresponding to ages 4+ (Figure 4). A larger proportion of the older age groups may be offshore and, therefore, more vulnerable to the offshore survey.

To compare the abundance indices (average number per tow and average weight per tow) derived from the offshore survey to landings in the recreational and commercial fisheries, recreational landings had to be interpolated for years when coastwide angling surveys were not conducted. Interpolation was accomplished using the ratios of commercial to recreational landings during the years of the coastwide recreational angling survey (1960, 1965, 1970, and 1980). Ratios were not derived separately for each survey region because of the split of the Middle Atlantic and South Atlantic regions at Cape Hatteras for the 1960, 1965, and 1970 recreational surveys and a split at the Virginia-North Carolina border in the 1980 survey. The interpolated values for the entire Atlantic coast are provided in Table 13.

The offshore abundance index (stratified mean number per tow) is correlated with the estimated total catch (weight) of bluefish along the Atlantic coast (1967-1981) in the same year ($r=0.610$, $df=13$, $P<0.02$). The index for age 0 bluefish is correlated to landings in the same year ($r=0.605$, $df=13$, $P<0.02$). The index for age 1 and older bluefish exhibited statistically significant correlations to the landings from 3 years to 1 year prior to the year of the index (Table 14), reflecting the higher relative abundance of age 4 and older bluefish in the survey catches. No significant correlations ($P>0.05$) were detected between the stratified mean weight per tow index and estimated landings. However, the correlations with number per tow suggest that the offshore abundance indices for bluefish may reflect catch levels in adjacent years, implying that catch may be directly related to stock size.

Inshore Survey Abundance Index

Consistent use of the same trawl and survey strata in the inshore survey began in 1974; survey data prior to that year are not used in this analysis. Number per tow of bluefish less than 30 cm (11.8 in) in length (presumed age 0) in the fall inshore surveys (Table 15) has been approximately 10 times higher than catch of the same size group in the fall offshore surveys conducted during the same year (Table 12), reflecting a more inshore distribution of this age group during the period of the autumn surveys. Every inshore survey stratum between Cape Cod and Cape Hatteras sampled in the autumn surveys, except one, contained bluefish less than 30 cm (11.8 in) in length between 1974 and 1980 (Figure 9 and Appendix II). Relatively high densities of young bluefish were encountered in strata off eastern Long Island, off the mouth of the Hudson River, off New Jersey between Atlantic City and Cape May, and from the Delmarva Peninsula to Cape Hatteras.

The length-frequency distributions of the inshore survey samples of bluefish show two size groups for fish under 30 cm (11.8 in) in length (Table 15); one is at approximately 20 cm (7.9 in) and the second is at 5-10 cm (2.0-3.9 in). The larger size group probably represents juveniles that were spawned south of Cape Hatteras in the spring, and the smaller size group represents fish that were spawned in the mid-Atlantic area during the summer. This conclusion was reached by Kendall and Walford (1979), who also observed the two size groups in their survey of juvenile bluefish.

Recruitment

Criteria for establishing a recruitment index include whether or not the index is representative of the recruit stock and whether or not the index can be related to indices of later-age stock abundance or catch. The value of a recruitment index lies in its usefulness in predicting future catch, spawning stock, and/or total stock levels.

The relatively large number of presumed age 0 bluefish caught during the fall inshore surveys (an average of 95% of the total catch of bluefish, Table 15) indicates that this time series may be more suitable as a recruitment index than the offshore survey time series. Since the abundance patterns in the inshore survey data base for survey strata north of Cape May (strata 1-23, 45, and 46, Figure 9) appear different from the patterns for survey strata south of Cape May (strata 24-44, Figure 9), a separate index of abundance was developed for each strata set (Appendix II).

Several categories of landings were compared to the abundance indices (Table 16). These measures include the estimated total landings and reported commercial landings of bluefish along the Northeast coast (Maine to North Carolina) and the entire Atlantic coast. The abundance indices for the strata set north of Cape May were positively correlated with estimated total landings south of North Carolina and commercial landings in the FCZ in the same year and with commercial and total landings along the entire coast and along the Northeast coast 2, 3, and 4 years subsequent to the year of the index. The 2- and 3-year lags correspond to the average age of the commercial and recreational catch, as discussed in the Age and Growth section.

It appears, therefore, that the stratified mean number per tow from the inshore survey north of Cape May may be a useful index of recruitment to the coastal fisheries. The index may represent a northern extension of the range of coastal waters occupied by age 0 bluefish during years of relatively good production. The strata set south of Cape May exhibits no detectable correlations ($P > 0.05$) with the landings categories.

The stratified mean number per tow north of Cape May in 1981 was the second highest in the time series (1974-1981). The catch of bluefish in the commercial and recreational fisheries along the Atlantic coast should, therefore, be relatively high in 1983 and 1984. The limited time series of inshore survey data gives no indication of poor recruitment in recent years (Figure 10).

MORTALITY

Two tagging studies conducted during the 1960's provide the only available data that are adequate for estimating mortality rates for bluefish along the Atlantic coast. One study (Deuel MS) used dorsal loop tags (70% of tags released) and internal anchor tags (30% of tags released) to mark 15,699 bluefish in coastal waters from Florida to Massachusetts during 1963-1967. Almost all the fish tagged (98%) were between 20 and 50 cm (7.9 and 19.7 in) in length, and almost all (97%) were released off New York, northern New Jersey, Virginia, North Carolina, and Florida. A total of 1,064 tags (7%) was returned.

The other tagging study (Lund and Maltezos 1970) was more limited in scope. Carlin tags were placed on 4,224 bluefish that were released in waters off Connecticut, New York, and Rhode Island during 1964-1969. Most of the released fish (82%) were between 50 and 78 cm (19.7 and 30.7 in) in length. The proportion of tags returned was 2.3% (97 tags). A summary of the tag return data from both studies is provided in Table 10.

Total Mortality

Estimates of the total instantaneous annual mortality rate (Z) were obtained by using the slope of the regression of the logarithm of annual tag returns versus year (Figure 6), as suggested by Ricker (1975). Using the tagging data collected by Deuel (MS), the estimate of Z is 1.37, which corresponds to an annual mortality rate of 75% (Table 11). The estimate of Z based on tagging data collected by Lund and Maltezos (1970) is 1.17, corresponding to an annual mortality rate of 69%.

The estimates of total mortality incorporate tag loss, which serves to inflate the values. Deuel (MS) found that all tags returned after 17 months at large were anchor tags, i.e., none were dorsal loop tags. Unfortunately, he did not summarize the data on tag returns by tag type.

Fishing Mortality

Fishing mortality rates were estimated using a method suggested by Ricker (1975; equations 4.9-4.12) for tagging data that contains errors which may affect the estimate of total mortality, but not the rate of fishing mortality. These errors are caused by tag loss, tagging-related mortality, and emigration of fish from the fishing area.

If the loss of tags occurs at an instantaneous rate, U, then the total instantaneous rate of tag disappearance, Z', can be expressed as

$$Z' = F + M + U, \qquad (2)$$

where F is the instantaneous rate of fishing mortality and M is the instantaneous rate of natural mortality. The rate of tag disappearance for the entire experimental period is A', and the rate of recovery of tagged fish with tags still attached, u', equals FA'/Z'. An estimate of F that is unbiased by tag loss is then

$$F = u'Z'/A'. \qquad (3)$$

The apparent exploitation rate, u', is the ratio of all the tags recaptured during the experimental period to the sum of the number of marked fish at the beginning of each time interval in the period

$$u' = \sum_{i=1}^{n} R_i / T \sum_{i=1}^{n} (S')^{n-1}, \qquad (4)$$

where T is the total number of tagged fish released, R_i is the number recaptured in time interval i, and S′ is the apparent survival rate ($Z' = -\ln S'$).

Two approaches were used to estimate the instantaneous rate of fishing mortality (F): (1) using the total number of tags returned in each annual interval, thus estimating an annual F; and (2) using the number of tags returned in each monthly interval during the initial year following tag release, thus estimating a monthly F. To maximize sample size, data from the studies were combined over years. An estimate for the proportion of tags returned by anglers (tag return rate) is unavailable, so a tag return rate of 50 percent was used.

Estimates of F derived by either approach (annual or monthly) were consistent for both data bases (Table 11). The monthly F′s (0.10 for the smaller fish and 0.03 for the larger fish) were approximately one-twelfth of the annual F′s (1.21 for the smaller fish and 0.31 for the larger fish), indicating a comparable rate of fishing mortality among months and years.

A much lower estimate of F were derived for the larger fish tagged by Lund and Maltezos (1970) than for the smaller fish tagged by Deuel (MS). The difference in fishing mortality rates was probably caused by a greater vulnerability of the smaller fish to the inshore fishery. As discussed in the Migration section, smaller fish remain inshore all year, while older bluefish have an inshore-offshore migration pattern. Tag returns from the smaller fish covered the initial 8 months during the first year at large, while tag returns from the larger fish covered only the initial 4 months during the first year at large.

Natural Mortality

An estimate of the instantaneous rate of natural mortality (M) can be obtained by subtracting F from Z (Ricker 1975). For the smaller bluefish tagged by Deuel (MS), the range of M is 0.2 to 0.7. The range of M for the larger fish tagged by Lund and Maltezos (1970) is 0.9 to 1.0. As with the estimate of Z, however, the estimate of M is probably biased high because it incorporates tag loss and tagging-related mortality.

YIELD

Yield per Recruit

One method of examining the potential impact of proposed management measures on a stock is a yield per recruit analysis. This analysis examines the projected yield in weight from a single recruit, balancing growth and mortality. Input variables for the analysis include age at recruitment to the fishery, age-specific natural and fishing mortality rates, and weight at age. The method used to calculate yield per recruit was first introduced by Thompson and Bell (1934). The method calculates the value of F that produces maximum yield (in weight_) for a given value of M; both F and M can be age-specific. Computations were performed with a computer program developed by Rivard (1982), based on the description provided by Ricker (1975).

In the analysis, all fish are fully recruited to the fishery at age 6 months and are caught in appreciable numbers up to age 7, which coincides with the oldest age sampled by Wilk (1977). The fishing mortality pattern was based on age-specific estimates of F derived from tagging studies (Table 11); i.e., F's for ages 4-7 were one-fourth of the F's for younger ages. Values of 0.3, 0.5, and 0.7 were used for the instantaneous natural mortality rates, which were assumed constant for all age groups.

Assuming full recruitment to the fishery at six months of age, the value of F that results in the highest yield is 0.42 (0.11 for ages 4-7) for M=0.3, 0.51 (0.13 for ages 4-7) for M=0.5, and 0.65 (0.16 for ages 4-7) for M=0.7 (Figure 11). Estimates of F from data collected in the 1960's (Table 11) indicate that the fishery may have been operating above this range of F's during that time. Delaying age at recruitment into the fishery from 6 months to 2 years, while holding the F level within this range of F's, would increase yield per recruit by 1.2-1.5 times (Figure 12). According to Wilk (1977), the size associated with this age is 35.0 cm (13.8 in). Delaying recruitment until fish have grown older than two years would cause a decline in yield, as losses due to natural mortality would be greater than the gains in growth.

Re-evaluation of the MSY Estimate

Maximum sustainable yield (MSY) is another measure of potential population response to changes in fishing pressure. Anderson (1980) estimated MSY from the NEFC fall offshore survey data,.

reported commercial landings, and estimated recreational landings, using a method developed by Fox (1975) for the generalized stock production model of Pella and Tomlinson (1969).

At equilibrium, the model is expressed as

$$CPUE_i = (a + b\bar{f}_i)^{\frac{1}{m-1}} \qquad (5)$$

where $CPUE_i$ is the catch per unit effort of the stock in year i; $\bar{f}_i$ is the weighted average fishing effort over the years that a year class contributes significantly to the fishery; and a, b, and m are constant parameters of the model. The Fox method uses an equation-fitting routine that optimizes for all three constant parameters simultaneously.

Catch per unit effort and fishing effort data are currently unavailable for bluefish. Instead, Anderson (1980) used the NEFC autumn offshore survey catch (kg) per tow as an index of catch per unit effort for the Atlantic coast population, and the ratio of the total catch along the Atlantic coast to the catch per tow as an index of fishing effort (termed the relative exploitation index). Relative exploitation indices were averaged over 2, 3, and 4 years to approximate equilibrium conditions.

The analysis performed by Anderson (1980) was redone using the same method, but with several changes in the data base. Two additional years of data were added (1980 and 1981), and the estimates of recreational catch between survey years were re-interpolated using a linear change in the ratio of commercial to recreational landings, as opposed to using the same ratio for adjacent years to the survey years. The linear interpolation results in less bias if the trend in the ratio of commercial to recreational landings is unknown.

In the present analysis, a 4-year averaging period for relative exploitation indices was not used, since this necessitated creation of a dummy 1966 data point. Finally, two sets of catch data were used in the re-analysis; one set contained the original recreational survey estimates of bluefish landings, and the other set assumed that the survey estimates for 1960, 1965, and 1970 were double the true values, as assumed by Anderson (1980).

The MSY determined from for the data set containing the original survey estimates is 68,859 tons (152 million lb) for the 2-year averaging period. The 3-year averaging period resulted in an asymtotic yield curve (m=0) giving unrealistic values for MSY and the optimal exploitation index. With the data set containing the reduced estimates of recreational landings, MSY estimates were 64,860 tons (143 million lb) for the 2-year averaging period and 60,287 tons (133 million lb) for the 3-year averaging period. Yield curves for the two data sets are plotted in Figure 13.

In order to estimate MSY, several assumptions concerning the data base are necessary. Recent findings indicate that one of the more critical assumptions, that the NEFC fall offshore surveys measure relative abundance of all age groups in the bluefish stock, is not met. As discussed in the Offshore Survey Abundance Index section, bluefish sampled in the autumn surveys exhibited an increase in catch per tow beyond 55 cm (21.7 in) in length, suggesting that older fish were more vulnerable to the survey. Therefore, the fall survey probably does not provide a representative measurement of bluefish stock abundance for all age groups. The fall inshore survey abundance index for bluefish has been represented almost entirely by young-of-the-year fish; therefore, it does not provide an adequate index of overall stock abundance.

Alternative Approach to Estimating MSY

An alternative approach for estimating MSY is to use a value that represents the median recruitment level. This approach reduces the possibility of overexpanding the fishery when recruitment levels are high. In the absence of absolute abundance estimates for age 0 bluefish, the median catch level for the years 1960-1982 was chosen to reflect recruitment levels during that time period. The correlations of the age 0 abundance index to subsequent catch categories (Table 16) indicate that the yield curve for bluefish (Figure 13) may be simply a reflection of recruitment. The points on the right-hand side of the yield curve (1967-1969) represent years when recruitment was presumed lower than subsequent years (see Recruitment section). Furthermore, recruitment indices increased during the latter part of the time period (Figure 10), indicating that fishing mortality has not been of sufficient intensity to cause a decline in recruitment.

The median catch level for bluefish (1960-1982) is approximately 56,000 tons (123 million lb) assuming the original recreational survey estimates are correct, and approximately 42,000 tons (93 million lb) assuming the estimates of recreational landings in 1960, 1965, and 1970 are double the true values. Therefore, an alternative estimate of MSY is 42,000-56,000 tons (93-123 million lb), which is approximately three-fourths of the estimate based on the production model.

DISCUSSION

During the past decade, catch and recruitment indices for bluefish along the Atlantic coast have been increasing. Fishing pressure on bluefish does not appear to be waning and probably will not subside until other desirable species, such as striped bass and weakfish, increase in abundance. The Chesapeake Bay stock of striped bass, a major contributor to the recreational fishery along the Northeast coast, is currently experiencing the worst levels of production on record (Boreman and Austin MS).

If the direct relationship between recruitment and subsequent catch is true, the stock will be in danger if fishing effort continues at the current level (or increases) and recruitment declines. The direct relationship implies that MSY estimates derived from the stock production model may overestimate the true value because they are strongly influenced by the years of relatively high catch. The relationship also implies that MSY may be an inappropriate measure of optimum exploitation of bluefish, since yield may not be sustainable with varying levels of recruitment.

The NEFC inshore survey data appear to provide an adequate index of recruitment, but fishing effort indices are still unavailable. Maintaining records of fishing effort along with catch, even for a component of the fishery, may provide estimates of fishing effort that could be related to catch and recruitment. Another possible method of determining the relationship between catch and population abundance is estimation of spawning stock size from egg and larval survey data, similar to the analysis performed by Berrien et al. (1981) for Atlantic mackerel. This method will be investigated during the coming year.

Also in the coming year, a study of bluefish distribution is planned by investigators at the State University of New York at Stony Brook. The study will compare distributions, based on NEFC survey data, with environmental variables in an effort to determine which variables may affect bluefish abundance and migratory behavior. NEFC staff also plan to age bluefish scale samples obtained from the surveys and from port sampling to better define the age-length relationship and age stucture of the population off the Northeast coast.

Fishing and total mortality rates used in this study were derived from tagging data obtained in the 1960's. The appropriateness of these data for explaining recent trends is questionable, especially in light of the increase in catch and recruitment experienced since the time of the tagging studies. Tagging data accumulated since 1964 by the American Littoral Society through a volunteer tagging program is currently being processed by the NEFC. These data may be useful for determining current fishing mortality rates for the bluefish population and may even give an indication of the trend in fishing mortality since the 1960's. During the coming year these data will be evaluated for their usefulness in analyzing the characteristics of the bluefish recreational fishery.

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Table 1. State Regulations Concerning the Catch of Bluefish

State	Commercial Fishery	Recreational Fishery
Maine	Permit or license Gear restrictions	None
New Hampshire	Permit or license Gear restrictions	None
Massachusetts	Permit or license Gear restrictions	None
Rhode Island	Permit or license	None
Connecticut	Permit or license Gear restrictions Minimum size (9 inches)	None
New York	Permit or license Gear restrictions Minimum size (9 inches)	None
New Jersey	Permit or license Gear restrictions Minimum size (9 inches)	None
Delaware	Gear restrictions	None
Maryland	Permit or license Gear restrictions Minimum size (8 inches)	Minimum size (8 inches)
Virginia	Permit or license Gear restrictions	None
North Carolina	Permit or license Gear restrictions	None
South Carolina	Permit or license Gear restrictions Minimum size (10 inches)	None
Georgia	Permit or license Gear restrictions	None
Florida	Permit or license Gear restrictions Minimum size (10 inches)	None

Table 2. Comparison of Bluefish Statistics Collected in Marine Recreational Angling Surveys Conducted From 1960 to 1980

Year	Region	Number (000's)	Weight (000 kg)	kg/fish
1960[1]	NA	4,831	5,039	1.04
	MA	11,748	11,725	1.00
	SA	7,181	6,187	0.86
	Total	23,760	22,951	0.97
1965[2]	NA	15,501	28,714	1.85
	MA	6,269	7,219	1.15
	SA	8,070	5,122	0.63
	Total	29,840	41,055	1.38
1970[3]	NA	10,693	22,753	2.13
	MA	12,351	22,553	1.83
	SA	12,851	8,741	0.68
	Total	35,895	54,047	1.51
1980[4]	NA	7,423	10,606	1.43
	MA	22,420	41,793	1.86
	SA	7,547	7,285	0.97
	Total	37,390	59,684	1.60

NA = ME-NY; MA = NJ-Cape Hatteras, NC (VA in 1980);
SA = Cape Hatteras, NC (NC in 1980)-FL (east coast).

[1]Clark 1962
[2]Deuel and Clark 1968
[3]Deuel 1973
[4]US Department of Commerce 1983

Table 3. Estimated 1980 Recreational Catch of Bluefish (000's) by Distance from Shore and Mode of Fishing

Category	N. Atl.[1]	M. Atl.[2]	S. Atl.[3]	Total
Distance from Shore				
Inland	5,102 (74%)	10,822 (54%)	4,702 (91%)	20,626 (66%)
Territorial	290 (4%)	2,582 (13%)	391 (8%)	3,263 (10%)
FCZ	1,482 (22%)	5,701 (28%)	72 (1%)	7,255 (23%)
Unknown	549	3,315	2,381	6,245
Total	7,423	22,420	7,546	37,389
Mode of Fishing				
Bridge/Pier/Jetty	1,380 (19%)	3,178 (14%)	1,007 (13%)	5,565 (15%)
Beach/Bank	1,979 (27%)	2,900 (13%)	1,861 (25%)	6,740 (18%)
Party/Charter	1,192 (16%)	5,433 (24%)	47 (1%)	6,672 (18%)
Private/Rental	2,872 (39%)	10.909 (49%)	4,631 (61%)	18,412 (49%)
Total	7,413	22,420	7,546	37,389

[1]ME - NY

[2]NJ - VA

[3]VA - FL (East Coast)

Table 4. Reported commercial landings (000 kg) of bluefish in Atlantic coast states.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	TOTAL
1960	0.	0.	7.	15.	2.	188.	201.	0.	5.	59.	279.	0.	0.	494.	1250.
1961	0.	0.	8.	22.	5.	229.	210.	0.	9.	133.	341.	0.	0.	444.	1402.
1962	0.	0.	15.	50.	15.	344.	495.	4.	29.	238.	433.	2.	0.	632.	2256.
1963	0.	0.	21.	37.	24.	316.	373.	10.	19.	287.	369.	52.	0.	617.	2125.
1964	0.	0.	19.	41.	27.	306.	245.	0.	3.	179.	234.	143.	0.	545.	1743.
1965	0.	0.	65.	49.	27.	470.	395.	0.	3.	93.	319.	38.	0.	388.	1847.
1966	0.	0.	58.	33.	25.	423.	457.	0.	8.	110.	372.	72.	0.	614.	2172.
1967	0.	0.	32.	36.	28.	249.	228.	0.	8.	54.	403.	22.	0.	611.	1671.
1968	0.	0.	39.	37.	28.	261.	347.	0.	64.	109.	396.	11.	0.	866.	2159.
1969	0.	0.	68.	56.	38.	508.	309.	0.	24.	101.	395.	2.	0.	943.	2445.
1970	0.	0.	77.	147.	39.	727.	483.	0.	31.	293.	225.	4.	0.	928.	2952.
1971	0.	0.	123.	123.	38.	549.	444.	0.	64.	277.	262.	6.	0.	737.	2624.
1972	0.	0.	169.	142.	22.	455.	368.	0.	26.	552.	530.	0.	0.	851.	3115.
1973	27.	0.	252.	126.	44.	640.	403.	1.	125.	1318.	911.	1.	0.	718.	4566.
1974	14.	0.	177.	121.	40.	484.	455.	3.	254.	1423.	990.	0.	0.	577.	4538.
1975	5.	0.	249.	173.	7.	404.	581.	7.	126.	1490.	896.	1.	0.	463.	4402.
1976	0.	0.	204.	110.	10.	272.	581.	5.	233.	1890.	615.	0.	0.	626.	4547.
1977	0.	0.	229.	111.	6.	447.	634.	15.	238.	1437.	1057.	5.	0.	680.	4859.
1978	15.	1.	362.	170.	25.	792.	719.	18.	147.	1243.	884.	5.	0.	558.	4938.
1979	30.	0.	257.	147.	23.	731.	721.	23.	145.	1390.	1545.	6.	0.	611.	5629.
1980	44.	2.	230.	166.	24.	675.	635.	73.	186.	1234.	2469.	2.	0.	799.	6540.
1981	47.	19.	219.	229.	3.	581.	832.	89.	189.	1036.	2998.	1.	1.	914.	7158.
1982	52.	28.	455.	302.	54.	781.	890.	232.	121.	1149.	1946.	4.	1.	882.	6897.

Table 5. Comparison of Reported Commercial Landings to Estimated Recreational Landings (000 kg)

Year	Mode	Region[1] N. Atl.	M. Atl.	S. Atl.	Total	%
1960	Commercial	213	317	722	1,252	5.2
	Recreational[2]	5,039	11,725	6,187	22,951	94.8
	Total	5,252	12,042	6,909	24,203	
1965	Commercial	611	596	640	1,847	4.3
	Recreational[3]	28,714	7,219	5,122	41,055	95.7
	Total	29,325	7,815	5,762	42,902	
1970	Commercial	988	878	1,085	2,951	5.2
	Recreational[4]	22,753	22,553	8,741	54,047	94.8
	Total	23,741	23,431	9,826	56,998	
1980	Commercial	1,140	2,129	3,270	6,539	9.9
	Recreational[5]	10,606	41,793	7,285	59,684	90.1
	Total	11,746	43,922	10,555	66,223	
Average	Commercial	738	980	1,429	3,147	6.6
	Recreational	16,778	20,823	6,834	44,435	93.4
	Total	17,516	21,803	8,263	47,582	

[1]N. Atl. = ME - NY; M. Atl. = NJ - Cape Hatteras, NC (1980 recreational and commercial = NJ - VA); S. Atl. = Cape Hatteras, NC - FL (east coast) (1980 recreational and commercial = NC - FL)

[2]Clark 1962

[3]Deuel and Clark 1968

[4]Deuel 1973

[5]US Department of Commerce 1983

Table 6. Length-Frequencies of Bluefish Sampled in Major Northeast US Ports, by Gear

FL (cm)	Gear				
	Pound Net[1]	Gill Net[2]	Haul Seine[3]	Otter Trawl[4]	Purse Seine[5]
16-20	9	0	0	0	0
21-25	239	0	0	72	0
26-30	41	0	0	11	0
31-35	17	73	42	0	0
36-40	0	73	13	3	0
41-45	0	163	1	11	0
46-50	0	237	24	37	0
51-55	0	125	3	124	0
56-60	0	10	3	39	0
61-65	0	2	0	0	9
66-70	0	1	0	0	57
71-75	0	0	0	0	48
76-80	0	0	0	0	5
81-85	0	0	0	0	0
Total	306	432	86	297	119

[1]Pound net samples: June 1982, 1983 (Hampton, VA)
[2]Gill net samples: July-October, 1980-1982 (Pt. Pleasant, NJ)
[3]Haul seine samples: August 1982 (Amagansett, NY)
[4]Otter trawl samples: October 1980 and June 1983 (Cape May, NJ), October 1982 (Pt. Pleasant, NJ)
[5]Purse seine samples: June 1982 (Cape May, NJ)

Table 7. Von Bertalanffy Growth Equation* Coefficients for Various Stocks of Bluefish

Stock	L_{inf}	K	t_0	Source
N. Gulf of Mexico	752	0.214	-1.601	Barger MS
Southern US Atlantic	839	0.184	-0.992	Barger MS
North Carolina (Spring Spawn)	1285	0.103	-1.366	Lassiter 1962
North Carolina (Summer Spawn)	675	0.342	0.249	Lassiter 1962
Atlantic Coast	897	0.226	-0.123	Wilk 1977

$$^{*}\; l_t = L_{inf}(1 - e^{-K(t - t_0)}),$$

where l_t = length (mm) at beginning of year t; L_{inf} = average asymptotic length (mm); K = Brody growth coefficient; and t_0 = the (hypothetical) age at which the fish would have been zero length.

Table 8. Length-Weight Relationships for Various Stocks of Bluefish

Stock	Coefficient* a	b	Source
Long Island Sound	5.22E-5	2.808	Richards 1976
Atlantic Coast	3.24E-5	2.855	Wilk 1977
Southern US Atlantic	1.49E-5	2.985	Barger MS
North Carolina	2.45E-5	2.903	Lassiter 1962
N. Gulf of Mexico	4.70E-5	2.790	Barger MS

*Coefficients for equation: W = aL., where W = weight (g) and L = fork length (mm).

Table 9. Length- and Age-Frequencies of Scale Samples Collected from the New Jersey Recreational Fishery for Bluefish during 1978 and 1979

FL (cm)	Age in Years 0	1	2	3	4	5	6	7	8	9	Total
<u>1978</u>											
1-10	0	0	0	0	0	0	0	0	0	0	0
11-20	0	0	0	0	0	0	0	0	0	0	0
21-30	0	0	1	0	0	0	0	0	0	0	1
31-40	0	83	13	0	0	0	0	0	0	0	96
41-50	0	10	297	19	0	0	0	0	0	0	326
51-60	0	0	314	164	8	1	0	0	0	0	487
61-70	0	0	5	181	273	119	28	3	1	0	610
71-80	0	0	0	1	52	87	47	26	15	3	231
81-90	0	0	0	0	0	0	0	1	0	1	2
Total	0	93	630	365	333	207	75	30	16	4	1753
<u>1979</u>											
1-10	1	0	0	0	0	0	0	0	0	0	0
11-20	88	0	0	0	0	0	0	0	0	0	88
21-30	15	1	0	0	0	0	0	0	0	0	16
31-40	0	7	50	0	0	0	0	0	0	0	57
41-50	0	5	350	4	1	0	0	0	0	0	360
51-60	0	0	437	437	16	0	0	0	0	0	890
61-70	0	0	3	194	222	40	5	0	0	0	464
71-80	0	0	0	0	89	166	52	18	9	0	334
81-90	0	0	0	0	0	2	0	1	1	0	4
Total	104	13	840	635	328	208	57	19	10	0	2214

Table 10. Tag Returns from Bluefish Tagged and Released Along the Atlantic Coast

Period	NY, NJ, NC, SC, FL	Tagging Area LI Sound	Total
Months-at-large			
0-1	513	22	535
1-2	220	12	232
2-3	97	10	107
3-4	46	3	49
4-5	26	1	27
5-6	9	0	9
6-7	9	0	9
7-8	4	0	4
8-9	1	0	1
?	39	23	62
Years-at-Large			
0-1	964	71	1035
1-2	80	23	103
2-3	11	1	12
3-4	5	1	6
4-5	4	1	5
5-6	0	0	0
No. Tagged	14749	4224	18973

Data from Deuel (MS)

Data from Lund and Maltezos (1970)

Table 11. Estimates[1] of the Instantaneous Rate of Fishing (F) Based on Bluefish Tagging Data, Assuming 50 Percent of the Recaptured Tags are Returned

Tagging Area	Z′(365 days)	F(30 days)	F(365 days)
NY, NJ, NC, SC, FL[2] Small fish: 20-50cm	1.37 ($r=0.94$, $P<0.02$)	0.10	1.21
Long Island Sound[3] Large fish: 50-78 cm	1.17 ($r=0.89$, $P<0.05$)	0.03	0.31
Combined	1.35 ($r=0.94$, $P<0.02$)	0.09	1.01

[1]See text for derivation of estimates

[2]Data from Deuel (MS)

[3]Data from Lund and Maltezos (1970)

Table 12. Stratified Mean Catch (000 per tow) of Bluefish Sampled in the NEFC Fall Offshore Surveys

Year	Length (cm) 1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-72	73-78	79-81
1967	0	0	0	0	0	0	0	0	0	0	24	48	0	0
1968	0	0	0	0	0	0	0	0	0	14	0	0	0	0
1969	0	0	0	0	0	0	28	28	52	0	0	24	14	0
1970	0	0	0	0	0	0	0	0	0	19	0	0	0	19
1971	0	0	0	0	0	0	0	0	26	70	89	21	0	0
1972	0	0	0	0	0	0	8	0	13	47	72	72	6	0
1973	0	0	130	939	18	0	0	14	0	0	25	99	39	0
1974	0	0	14	393	24	8	0	0	0	48	57	157	47	0
1975	0	0	0	30	24	32	6	13	18	30	16	67	54	5
1976	0	0	15	694	244	205	66	8	6	33	68	6	27	0
1977	24	0	20	311	21	6	0	0	7	7	21	80	50	0
1978	0	0	0	0	0	9	6	0	0	0	18	80	43	6
1979	0	0	0	0	10	0	0	4	20	34	68	45	72	14
1980	0	0	0	18	9	9	0	0	0	41	30	24	16	0
1981	0	0	43	1087	73	0	0	0	8	20	20	27	21	17
Average	2	0	15	231	28	18	8	4	10	24	34	50	26	4

Table 13. Estimated Total Catch (000 kg) of Bluefish along the Atlantic Coast, 1964-1982

Year	Commercial	Recreational	Foreign	Total
1960	1, 251	22, 950	0	24, 201
1961	1, 401	26, 686	0	28, 087
1962	2, 256	44, 674	0	46, 930
1963	2, 123	43, 326	0	45, 449
1964	1, 743	37, 238	0	38, 981
1965	1, 847	41, 054	0	42, 901
1966	2, 172	46, 219	0	48, 391
1967	1, 671	34, 094	0	35, 765
1968	2, 159	42, 327	0	44, 486
1969	2, 445	46, 139	0	48, 584
1970	2, 952	54, 047	0	56, 999
1971	2, 624	43, 373	23	46, 020
1972	3, 115	47, 202	18	50, 335
1973	4, 566	63, 859	214	68, 639
1974	4, 538	58, 932	99	63, 569
1975	4, 402	53, 354	103	57, 859
1976	4, 547	51, 674	1	56, 222
1977	4, 859	51, 967	4	56, 830
1978	4, 937	49, 873	0	54, 810
1979	5, 629	53, 867	0	59, 496
1980	6, 540	59, 684	5	66, 229
1981	7, 158	65, 073	0	72, 231
1982	6, 895	62, 682	-	69, 557

Table 14. Correlations between Catch (number) per Tow of age 1+ Bluefish in the NEFC Autumn Offshore Survey and Estimated Total Landings along the Atlantic Coast

Years from landings to NEFC survey	r-value (df = 13)	Significance level
0	0.270	P<0.330
1	0.553	P<0.032
2	0.519	P<0.047
3	0.576	P<0.025

Table 15. Stratified Mean Catch (000 per tow) of Bluefish Sampled in the NEFC Fall Inshore Surveys

Year	Length (cm)													
	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-72	73-78	79-84
1974	619	9	1918	6405	487	217	132	0	0	0	0	20	16	0
1975	34	160	3265	8821	252	166	158	378	355	227	49	162	165	0
1976	1097	221	22114	17569	2059	320	560	41	71	127	99	0	28	21
1977	1439	339	23135	32311	487	140	74	23	106	36	53	113	63	12
1978	50	1400	1709	2409	3439	2337	77	17	86	119	186	85	0	0
1979	0	936	11219	48593	1510	398	827	599	939	275	133	122	0	126
1980	259	9290	2556	25655	6374	1882	207	0	75	77	32	72	123	16
1981	0	2934	41819	52613	3676	236	703	89	81	137	269	71	119	40
Average	437	1911	13467	17720	2286	712	342	143	214	125	103	81	64	27

Table 16. Correlations(r-values) between the Abundance Index (Stratified Mean Number per Tow) for Bluefish from the NEFC Fall Inshore Surveys (Cape May to Cape Cod) and Commercial and Recreational Harvest, 1974-1982

Landings Measure	Years from Index to Landings Measure				
	0 (df=7)	1 (df=6)	2 (df=5)	3 (df=4)	4 (df=3)
Total landings					
- Atlantic coast	0.164	0.466	0.838*	0.854*	0.757
- ME to NC	-0.149	0.316	0.879**	0.793	0.646
- SC to FL	0.722*	0.594	0.648	0.904*	0.923*
Commercial Landings					
- Atlantic coast	0.631	0.694	0.833*	0.940**	0.880*
- 0 to 3 miles	0.274	0.670	0.494	0.920**	0.590
- FCZ	0.723*	0.493	0.839*	0.502	0.656
- ME to NC	0.632	0.715*	0.855*	0.932**	0.870*
- SC to FL	0.554	0.507	0.593	0.888*	0.914*

*P<0.05

**P<0.01

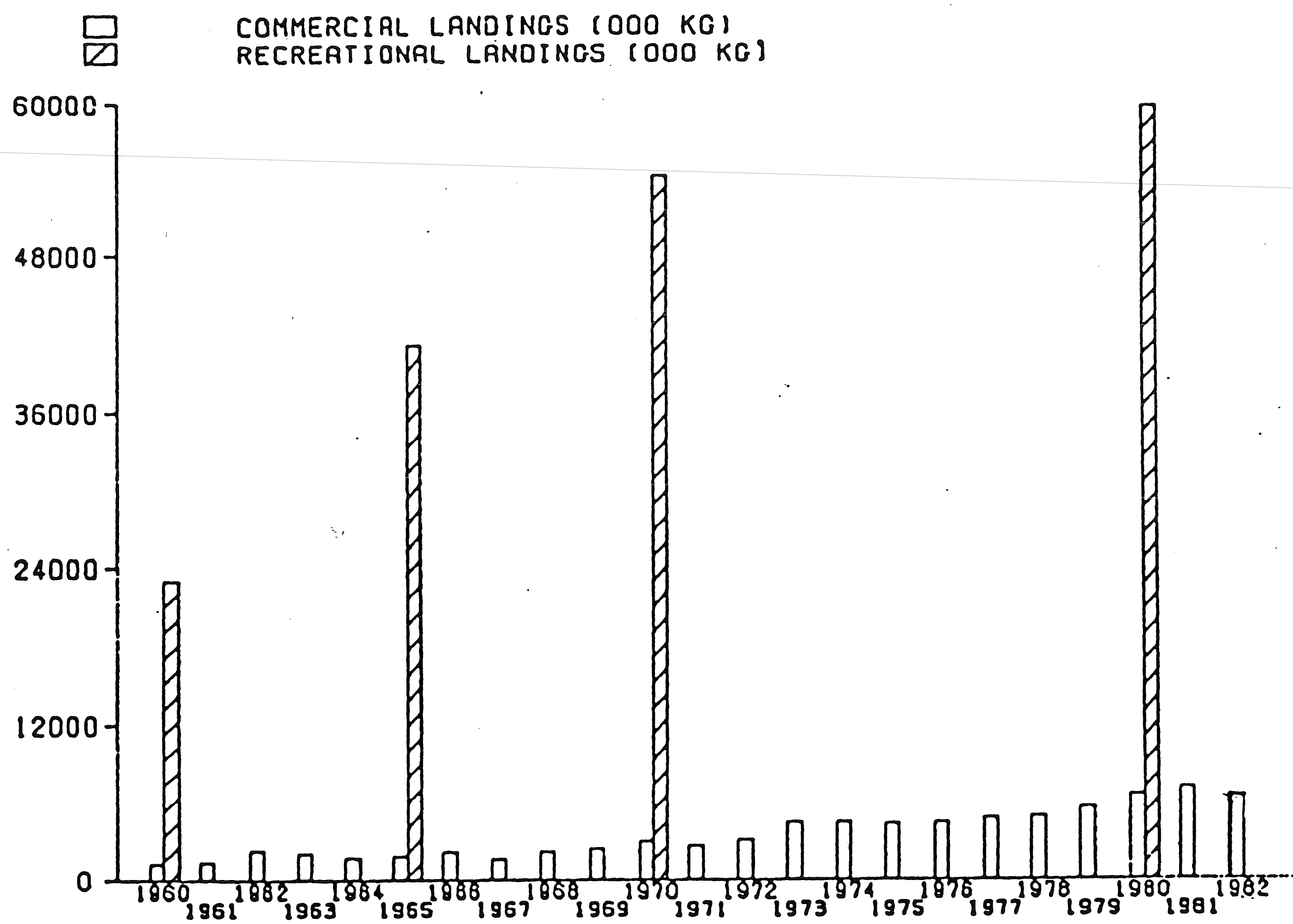


Figure 1. Reported US commercial landings and estimated US recreational landings of bluefish along the Atlantic coast, 1960–1982.

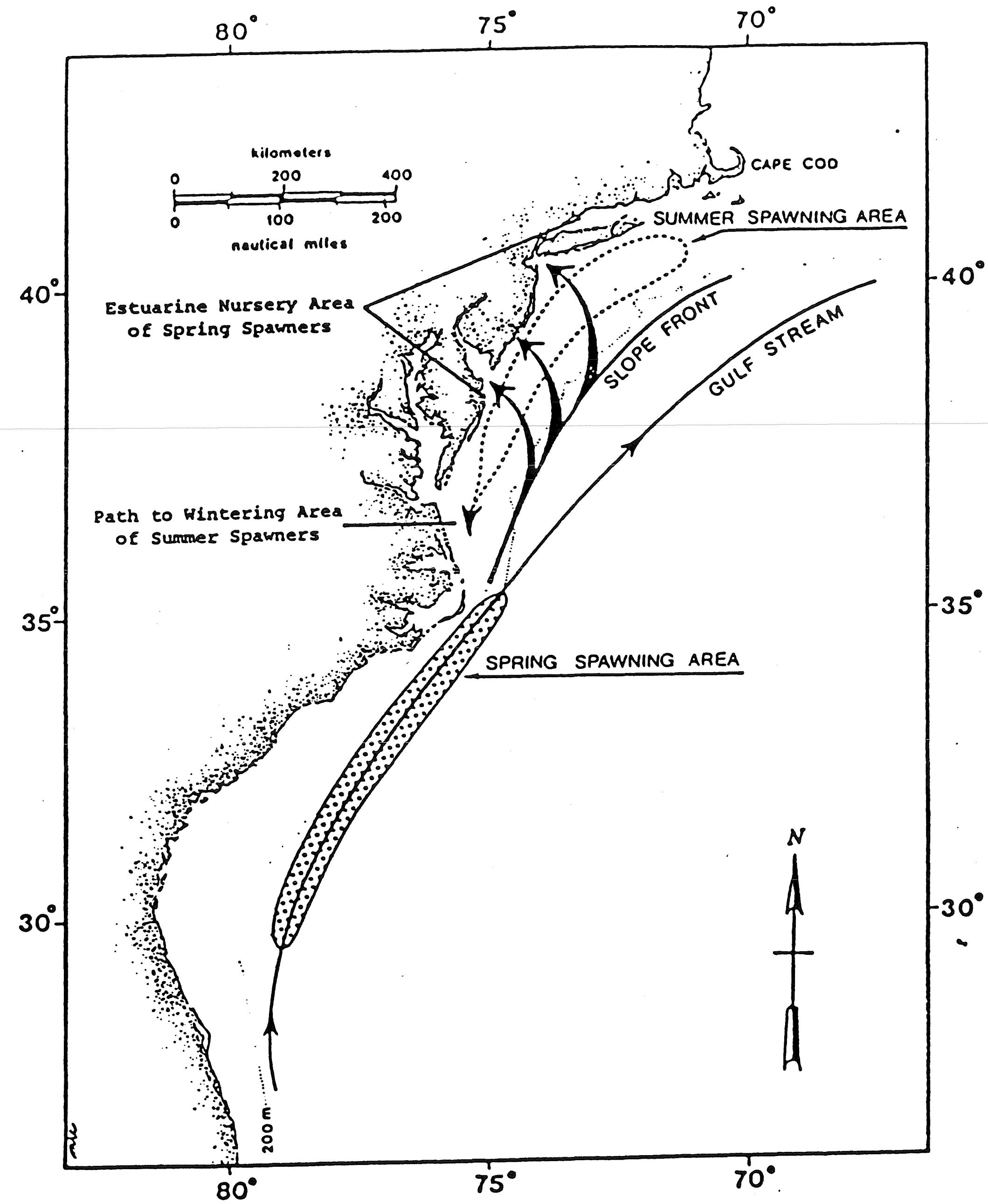


Figure 2. Spawning areas and migration patterns for bluefish along the Atlantic coast (from Kendall and Walford 1979).

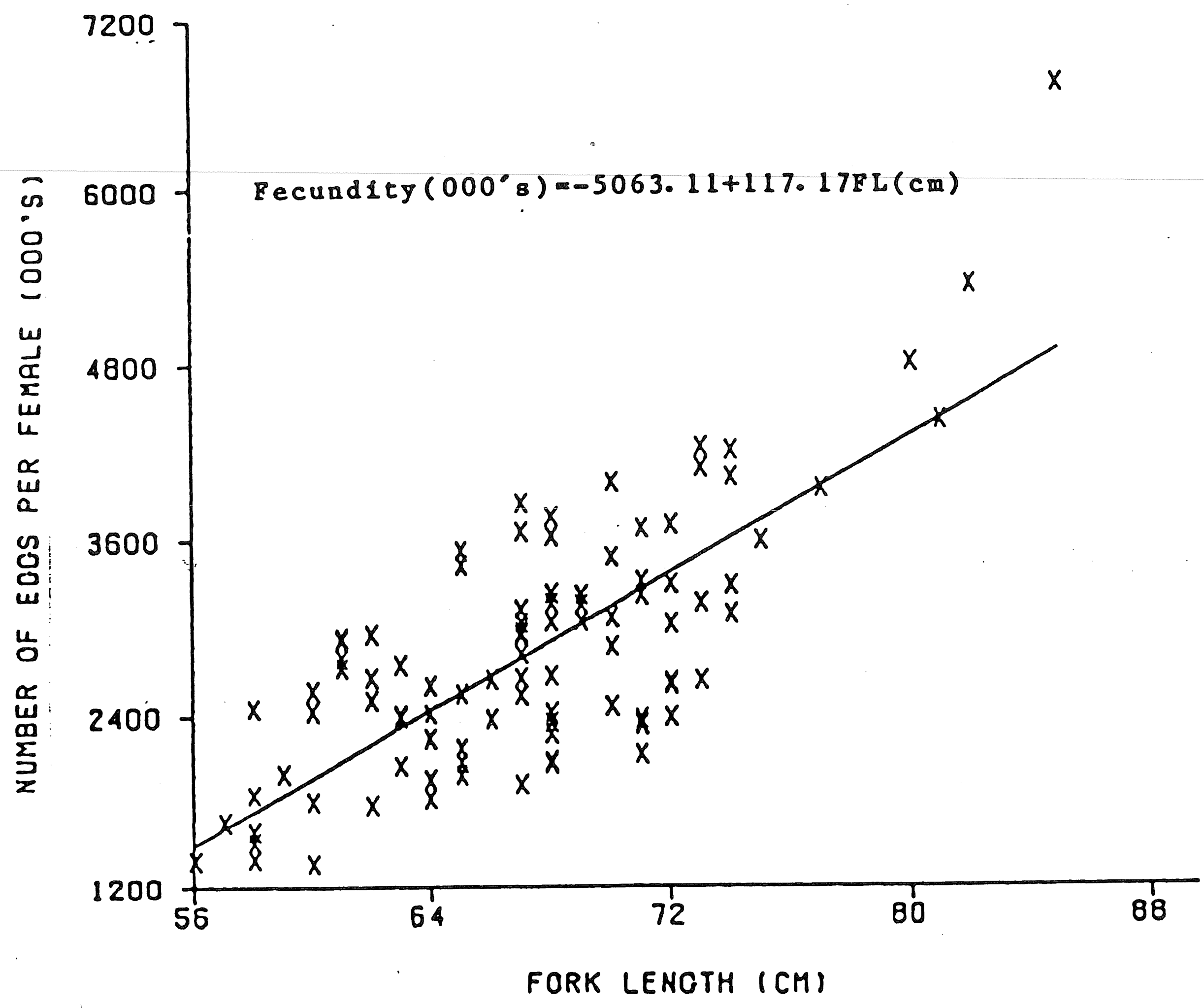


Figure 3. Relationship between fecundity and body length for bluefish captured in waters off New Jersey in 1978.

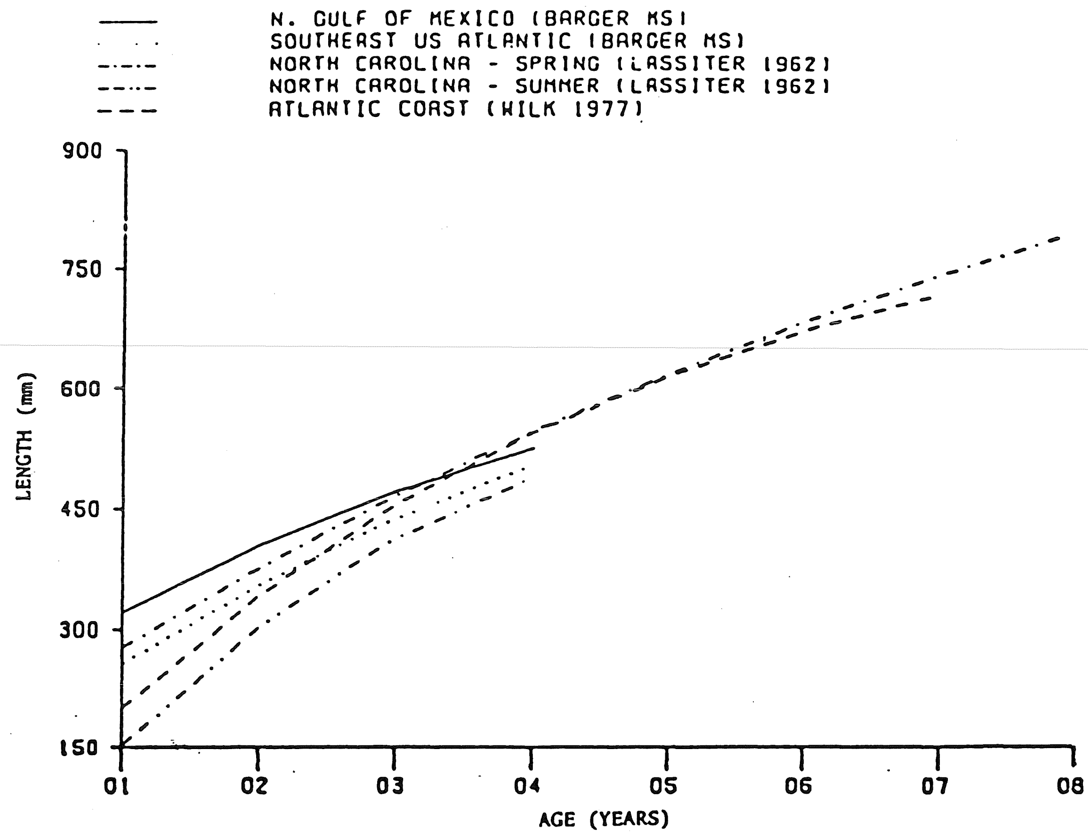


Figure 4. Growth curves for bluefish from various areas.

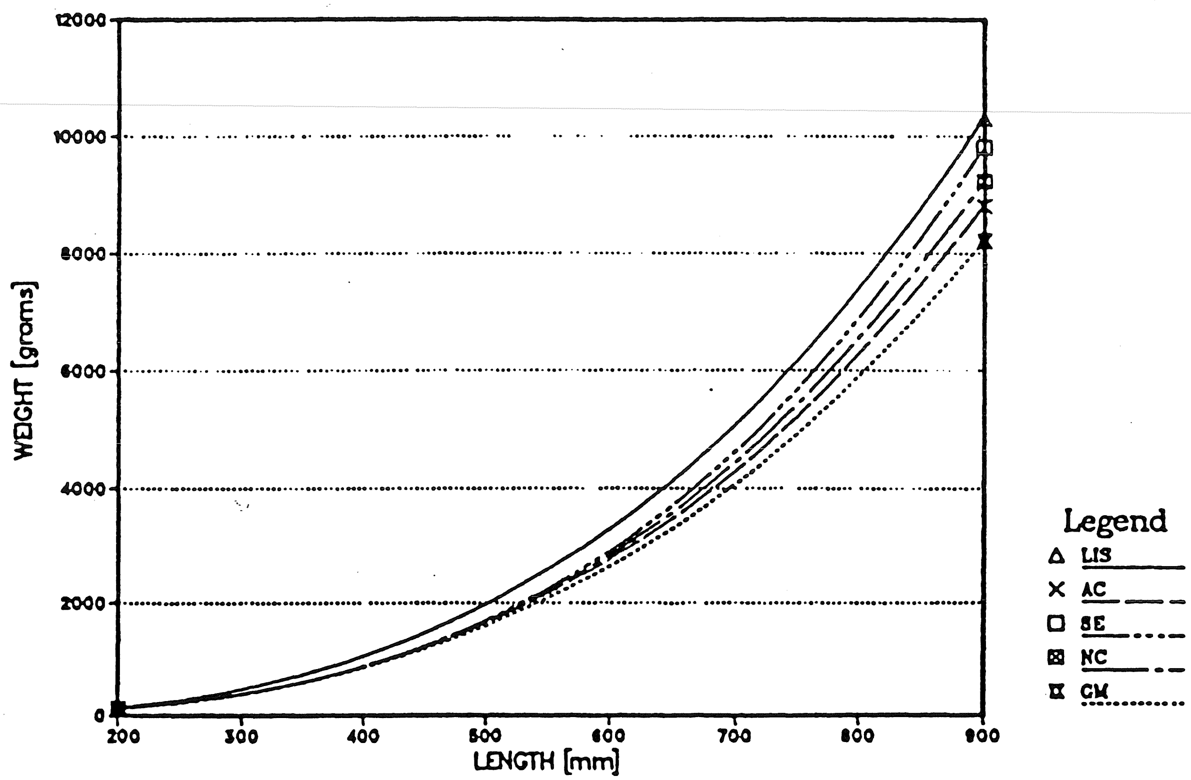
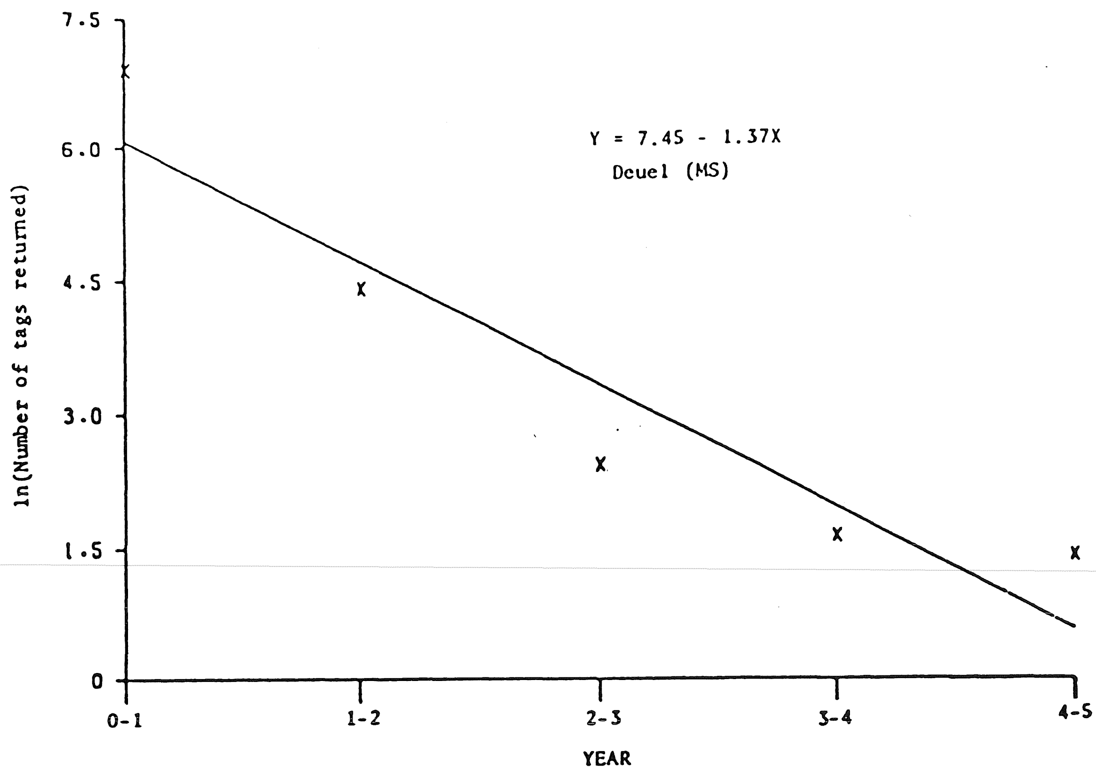


Figure 5. Length-weight relationships for bluefish from various areas. LIS = Long Island Sound (Richards 1976); AC = Atlantic coast (Wilk 1977); SE = southeast US Atlantic coast (Barger MS); NC = North Carolina (Lassiter 1962); GM = northern Gulf of Mexico (Barger MS).



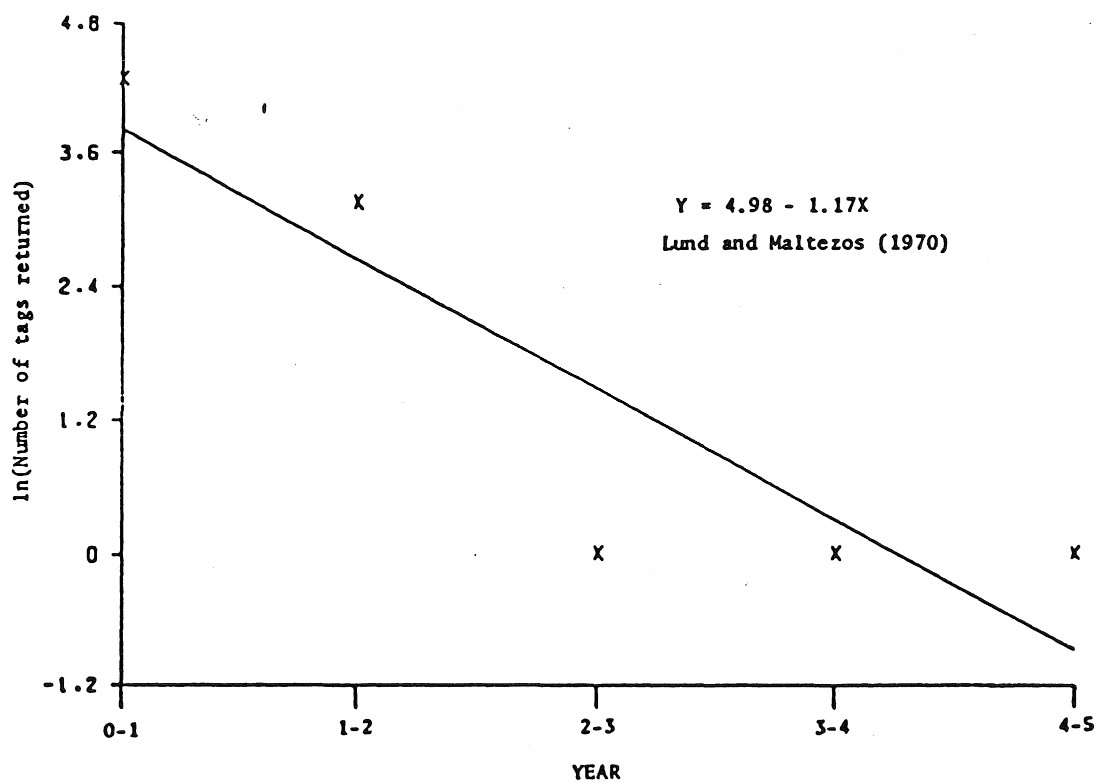


Figure 6. Annual returns of tags from bluefish released in Long Island Sound (Lund and Maltezos 1970) and in various areas along the Atlantic coast (Deuel MS).

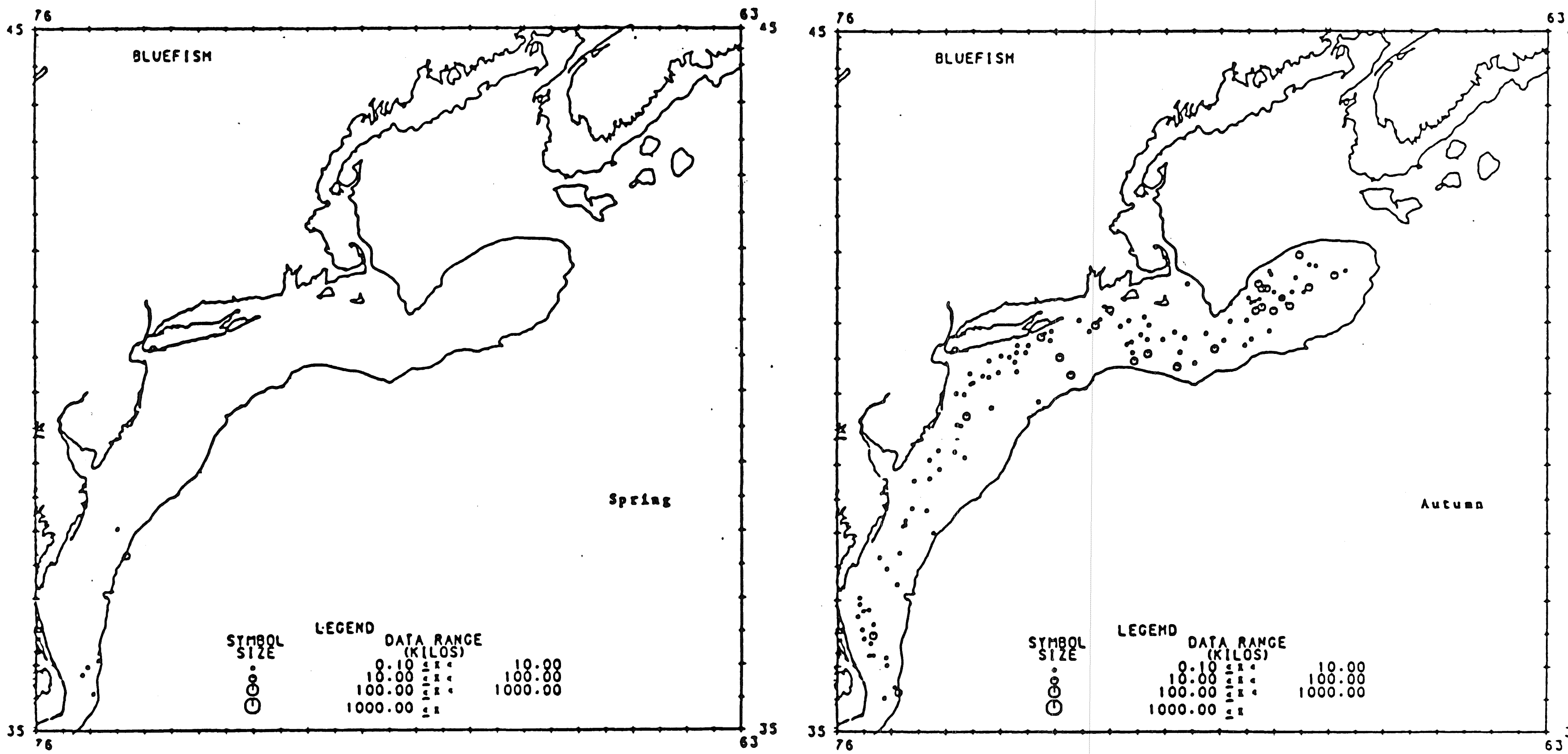


Figure 7. Catch (weight) of bluefish in NEFC spring and autumn offshore surveys, 1965-1977.

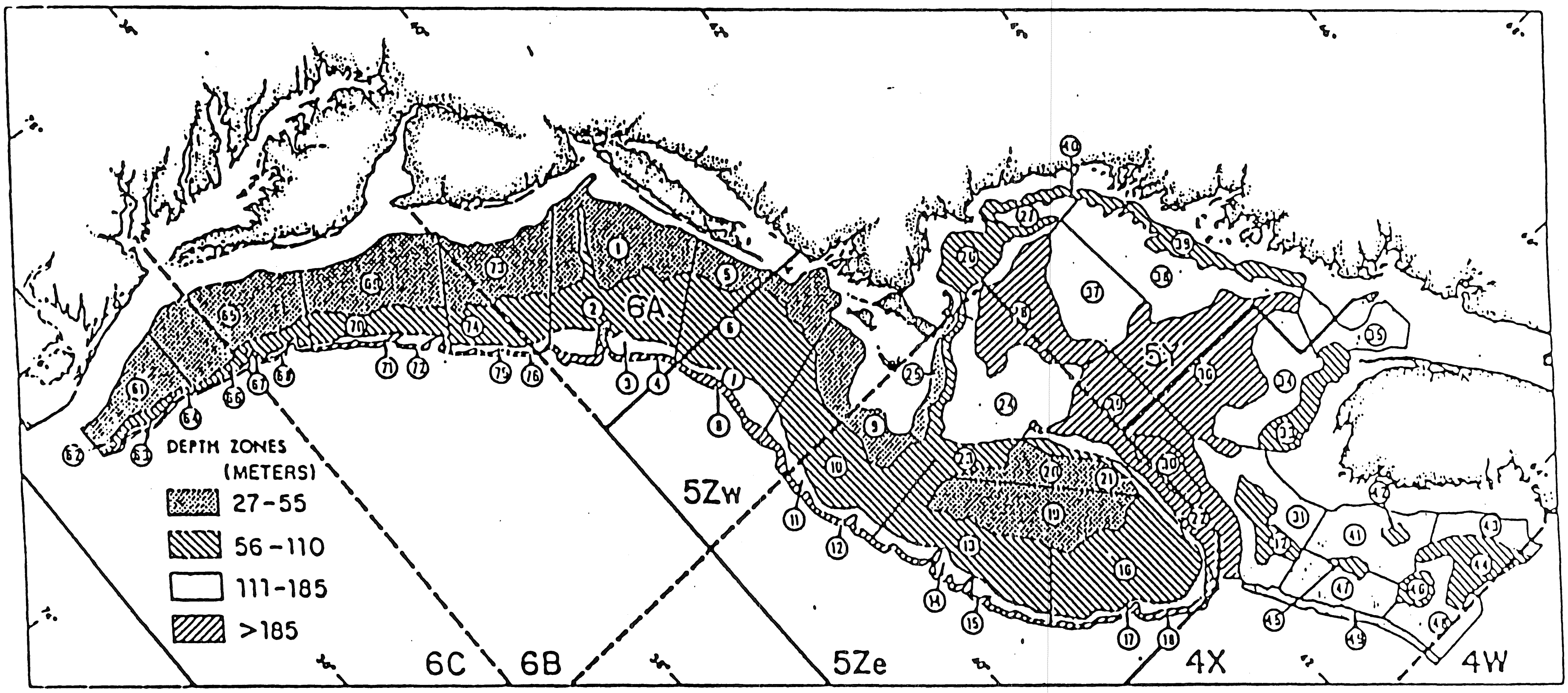


Figure 8. Sampling strata used in the NEFC offshore (>27 m depth) bottom trawl surveys.

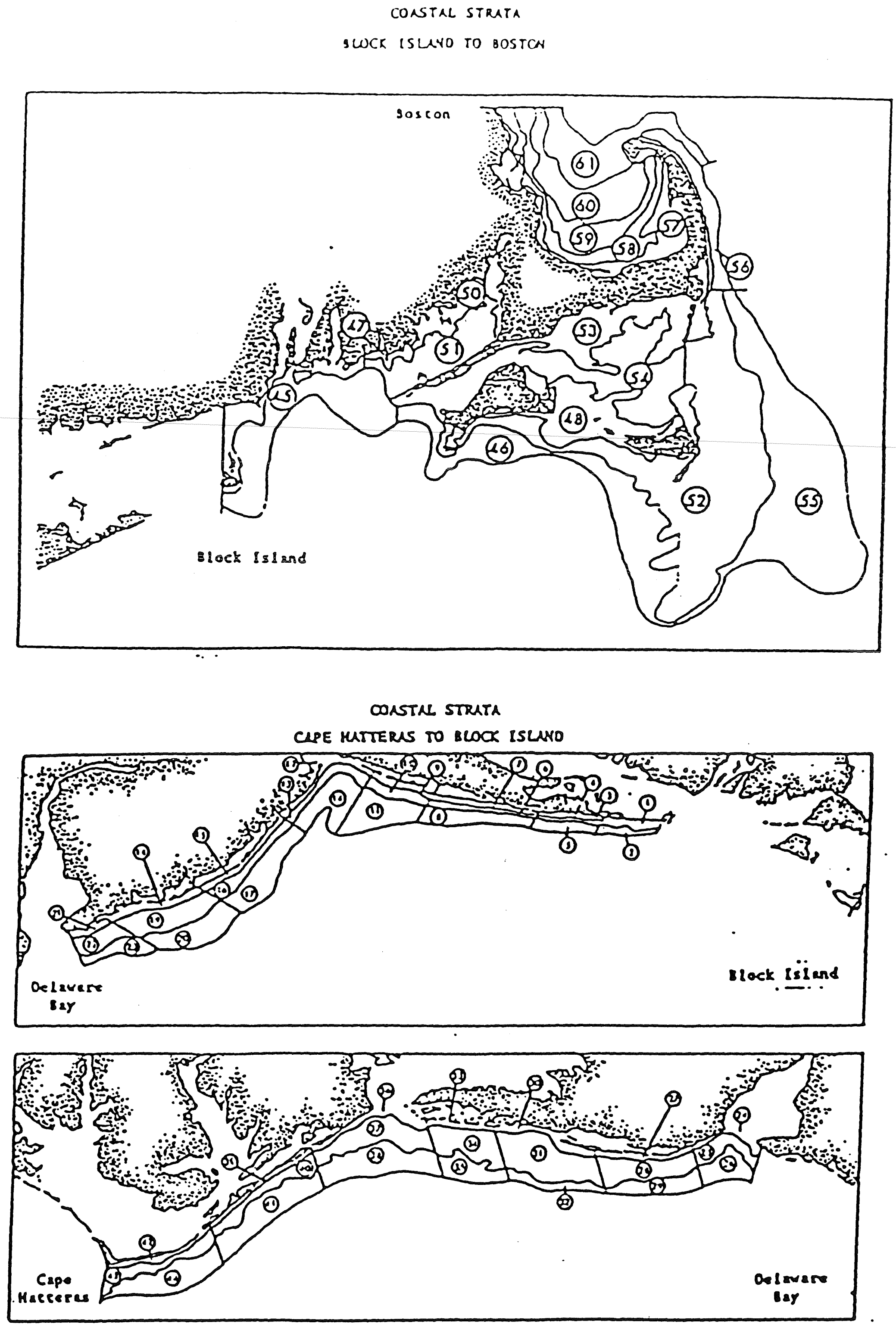


Figure 9. Sampling strata used in the NEFC inshore (<27 m depth) bottom trawl surveys.

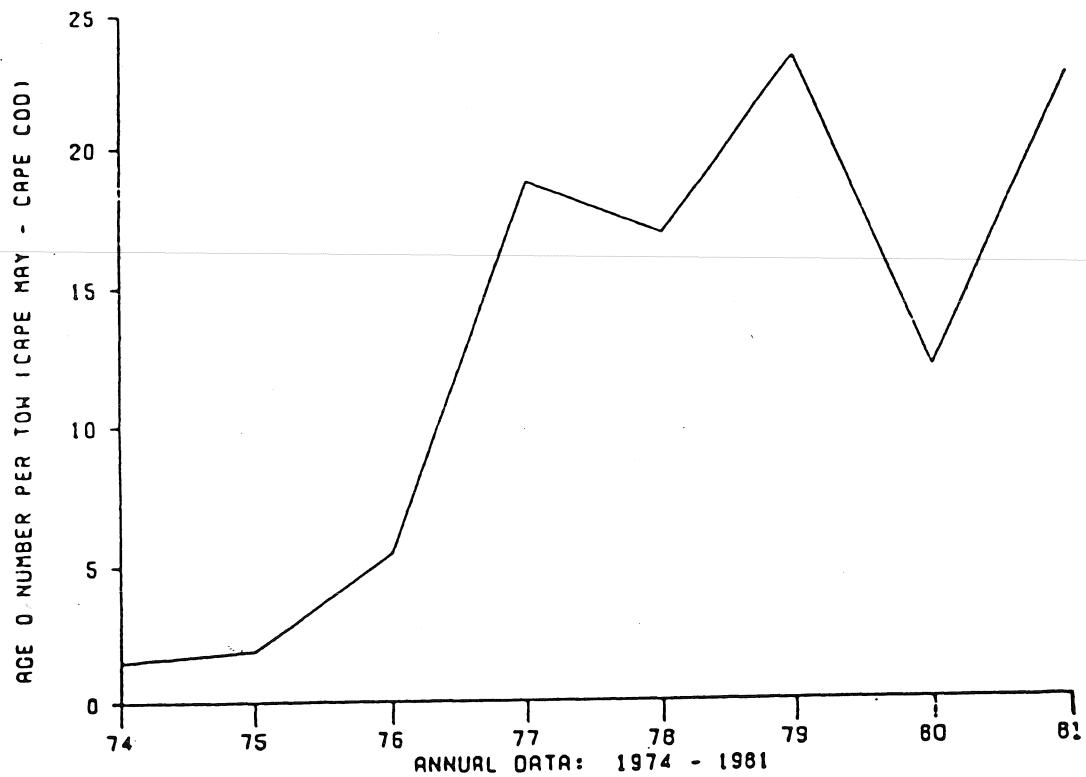


Figure 10. Number of age 0 bluefish caught per tow between Cape May and Cape Cod in the autumn inshore survey.

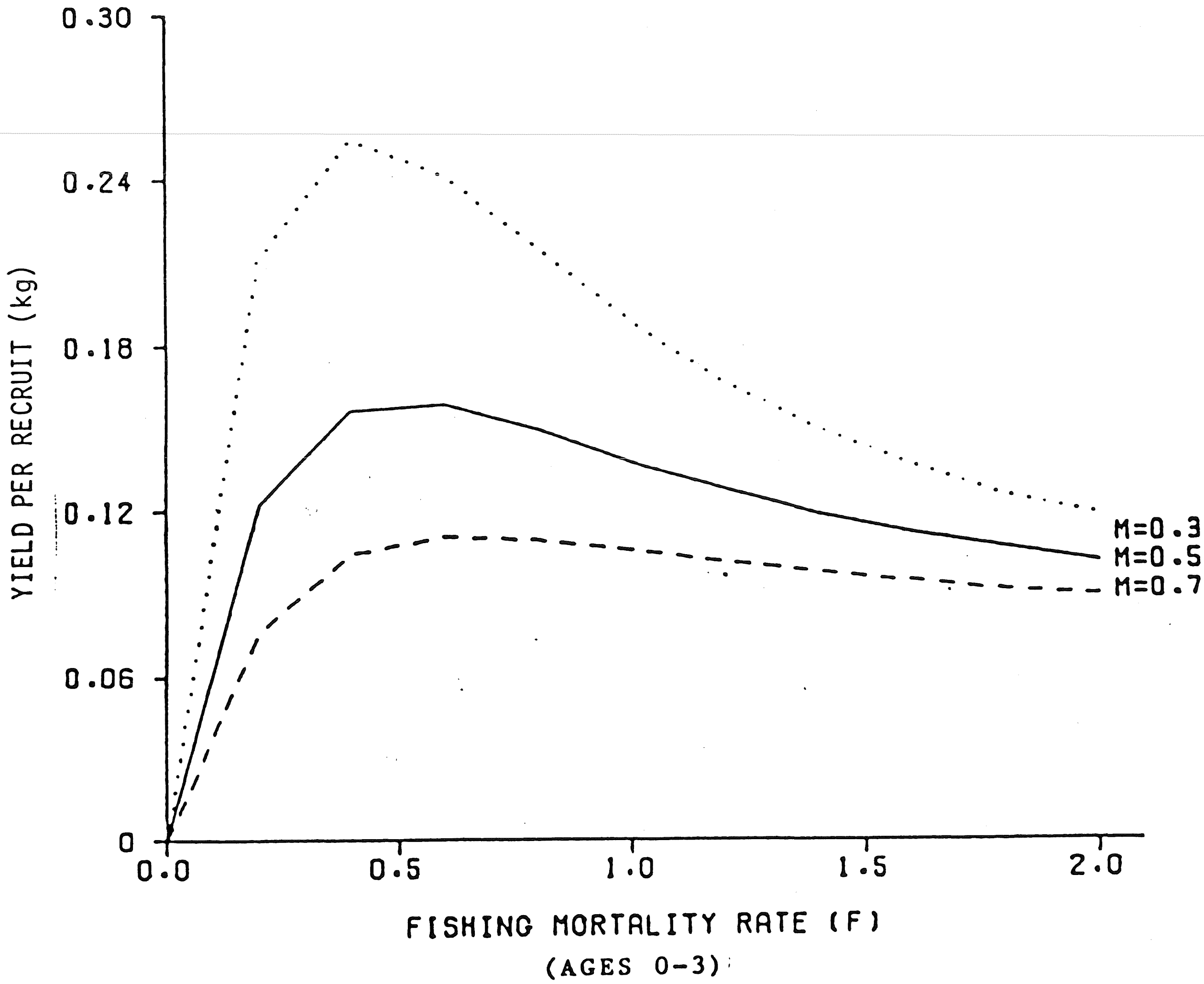


Figure 11. Yield per recruit assuming full recruitment to the fishery at 6 months of age and the value of F for ages 4+ equal to one-fourth of the value for younger ages.

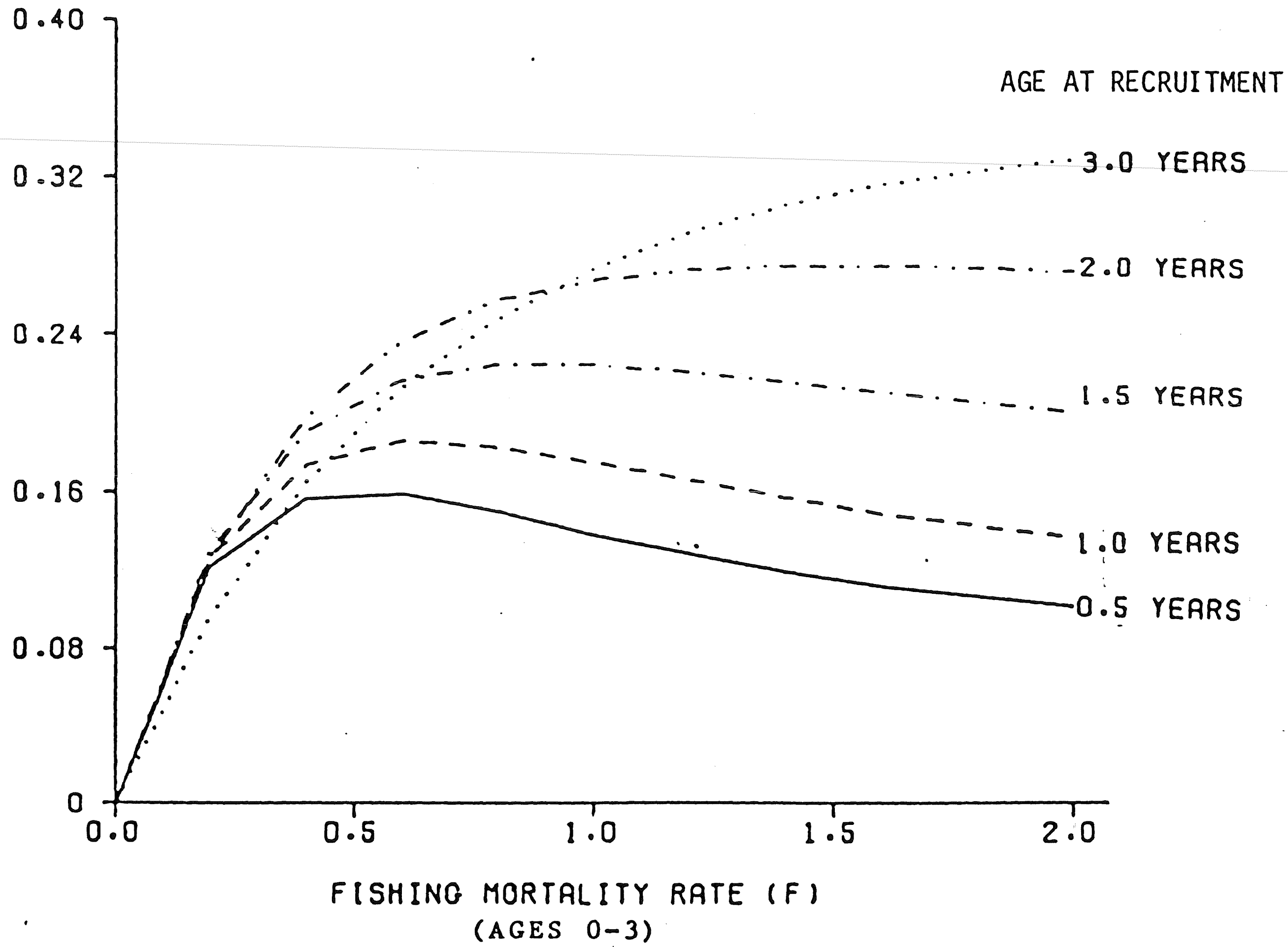


Figure 12. Yield per recruit with varying ages of recruitment to the fishery and assuming the value of F for ages 4+ equal to one-fourth of the value for younger ages (M=0.5).

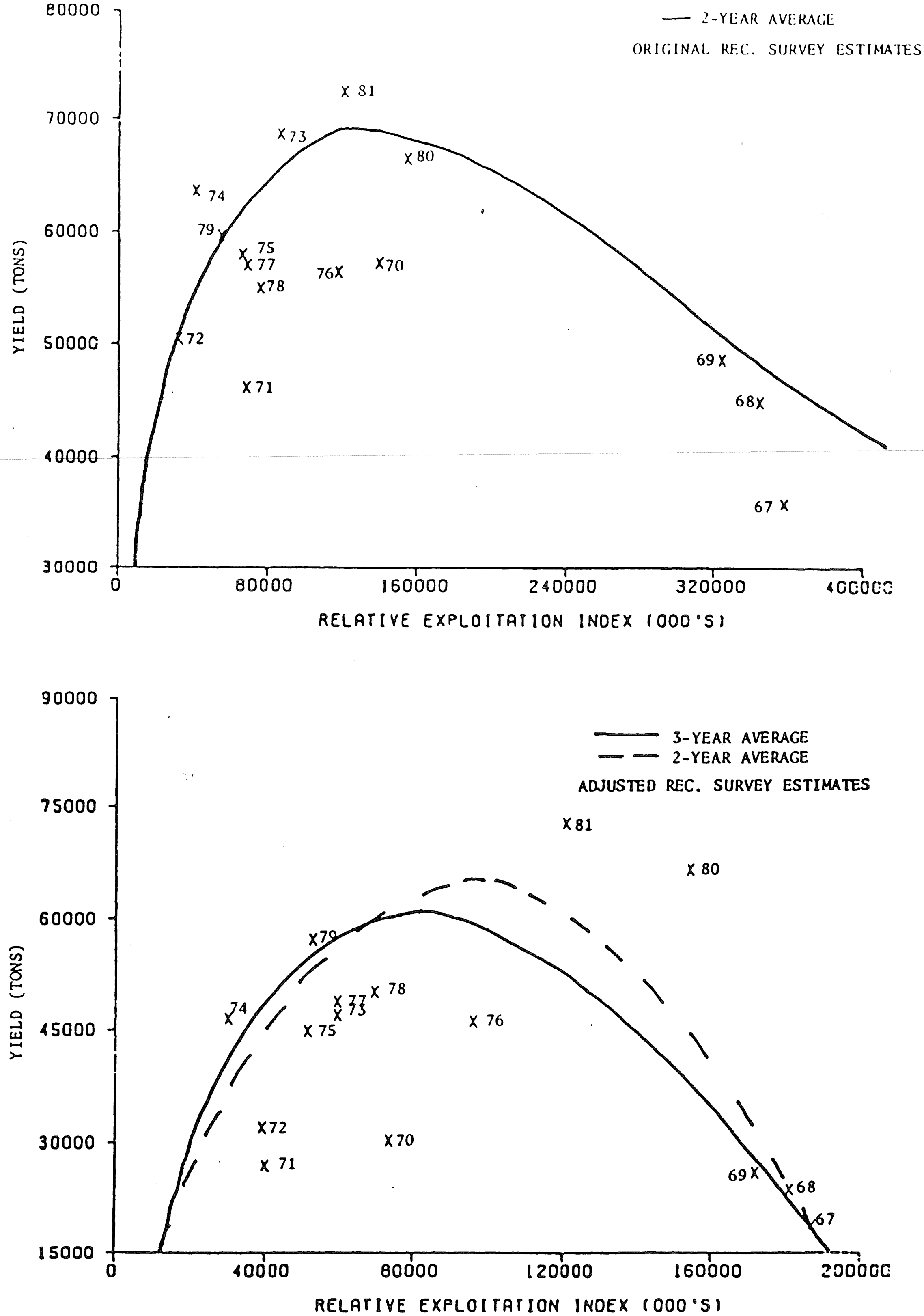


Figure 13. Yield curves for bluefish along the Atlantic coast fitted with the generalized stock production model.

Appendix I. Average catch (number) per tow of bluefish in the bottom trawl survey conducted offshore (>27 m depth) between Cape Hatteras and Cape Cod by the Northeast Fisheries Center.

Stratum	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Total
1	0	0	0.3	0	0.5	0.6	0.5	0.3	0.4	0.4	0.7	0.3	0	0.3	0.1	5.0
2	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0.1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7
5	0	0	1.0	0.4	0.5	1.1	0.2	0.3	0	0.7	0.6	0	0.8	1.5	0.8	8.[illegible]
6	0	0	0	0	0	0.5	0	0.1	0.2	0	0	0.4	0	0	0	1.2
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0.1	0	0	0.1	0.4	0	1.0	0.2	0	0.2	0	0.5	0.2	0.8	3.5
10	0	0	0	0	0.8	0.3	0.4	0.5	0	0.4	1.0	0	0.3	0	0	3.7
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0.1	0	0	0	0.1	0	0.1	0.4	0.1	0	0.8
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0.3	0	0	0	0.1	0.6	0	0	1.0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0.9	0.1	2.9	1.1	0	0.4	0.4	0.8	0.6	0	7.2
20	0	0	0	0	1.0	1.0	2.3	0.2	0.7	0.2	0.1	0.6	0.5	0.5	0.1	7.2
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0.8	0	0	0	0	0	0	0.5	1.7	0	0.5	3.5
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0.3	0	0	0	0	0	0	0.5	0	0	2.0	2.8
61	0	0	21.0	0	0	0	7.3	0.5	1.4	39.8	3.0	0	0	0	17.3	90.3
62	0	0	0	0	0	0	0	0	9.0	0	0	0	0	0	0	9.0
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	13.4	6.6	0.3	0.1	4.3	0.1	0	0.4	10.0	35.2
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0.3	0	0	0	0.3	0	0.3	0.2	0.1	0.8	0.1	0	0.3	0	0	2.4
70	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0.3
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0.1	0	0.2	0	0.6	0	0.2	0	1.0	0.5	0.3	1.0	0.4	0	0.6	4.9
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 - 25 61 - 76	0.0	0.0	0.7	0.0	0.2	0.2	1.3	0.8	0.3	1.4	0.5	0.2	0.3	0.2	1.3	
kg/tow	0.1	0.0	0.2	0.1	0.7	0.8	0.8	1.5	0.9	0.5	0.8	0.7	1.1	0.4	0.6	

Appendix II. Average catch (number) per tow of bluefish in the bottom trawl survey conducted inshore (< 27 m depth) between Cape Cod and Cape Hatteras by the Northeast Fisheries Center

Stratum	1974	1975	1976	1977	1978	1979	1980	1981	Total
1	0	2.0	0	0	0	243.0	0	5.0	250.0
2	1.0	0	1.5	0	0	19.5	0	8.0	30.0
3	0	2.0	0	19.0	674.0	4.0	0	0	699.0
4	4.0	1.0	4.5	7.5	49.0	0.5	1.0	25.0	92.5
5	3.5	3.5	20.5	3.5	1.0	4.0	2.5	117.5	156.0
6	0	3.0	0	0	0	0	0	507.0	510.0
7	0	12.7	0	1.5	2.7	67.5	0.5	53.8	138.7
8	7.3	0.5	3.0	0	3.0	3.5	1.0	2.5	20.8
9	0	5.5	28.0	51.0	0	12.0	0	31.0	127.5
10	0.5	1.0	15.5	18.5	2.5	20.0	29.0	43.5	130.5
11	1.3	0.3	13.5	3.0	1.5	8.3	0.5	7.0	35.4
12	0	0	27.0	3.0	23.0	4.0	242.0	15.0	314.0
13	19.5	3.7	10.5	1.5	4.5	1.0	131.0	2.5	174.2
14	0.3	1.0	0	0.5	6.5	4.0	5.0	0	17.3
15	0	0	0	9.0	1.0	1.0	0	131.0	142.0
16	3.5	8.0	6.7	3.5	1.5	54.5	1.0	42.5	121.2
17	0.3	0.7	1.0	0.5	6.5	0.5	0.5	5.0	15.0
18	0	11.0	17.0	9.0	157.0	7.0	0	92.0	293.0
19	0.5	4.3	1.5	209.0	61.0	182.0	10.0	13.0	481.3
20	0	0.5	1.5	0.5	0	1.0	11.0	21.5	36.0
21	0	1.5	103.0	0	2.0	5.0	7.0	0	118.5
22	2.0	0.5	1.5	1.0	3.0	0	9.0	2.0	19.0
23	0	3.0	1.0	0.5	2.0	0.5	3.5	34.5	45.0
45	0	0.5	0	0	6.0	6.0	0.5	2.0	15.0
46	0	0	0	0.5	5.0	0	0.5	0	6.0
1 - 23 45 & 46	1.5	1.9	5.4	18.7	16.8	23.3	12	22.6	
24	0	8.5	64.0	0	7.0	0	4.0	0	83.5
25	3.3	6.5	62.0	2.5	10.5	0	72.5	79.0	236.3
26	0.5	7.0	2.0	1.0	19.5	0	9.5	1.5	41.0
27	0	1.5	4.0	39.0	29.0	18.0	42.0	377.0	510.5
28	12.7	1.0	89.0	91.0	46.0	24.5	26.5	358.5	649.2
29	0	0.5	9.0	271.5	33.0	0.5	0.5	539.5	854.5
30	0	2.0	4.0	0	0	0	27.0	67.0	100.0
31	11.7	1.3	352.5	375.5	1.0	1.5	342.0	538.5	1624.0
32	51.0	0	214.0	223.0	1.0	0.5	0	2.5	492.0
33	0	0	80.0	90.0	14.0	1.0	5.0	97.0	287.0
34	2.7	3.5	0.5	44.0	0.5	8.0	53.5	254.0	366.7
35	6.5	115.5	13.0	82.0	0	6.5	4.5	55.5	283.5
36	28.0	0	34.0	62.0	4.0	0	1.0	4.0	134.0
37	11.0	3.0	3.0	62.0	8.5	130.5	0	17.5	235.5
38	41.5	171.0	55.5	127.0	17.5	0	0	0	412.5
39	0	42.5	0	101.0	10.0	0	0	859.0	1012.5
40	9.5	35.0	19.5	7.5	42.5	0	0	23.0	137.0
41	2.8	31.5	39.0	14.0	9.5	0	0	80.0	176.8
42	0	10.0	30.0	115.0	0	0	0	1619.0	1774.0
43	0	21.0	139.5	25.5	1.5	0	0	261.5	449.0
44	39.5	1.7	4.0	6.5	0	0	0	53.0	104.7
24 - 44	13.0	22.8	68.9	90.1	12.6	14.5	39.8	183.2	
1 - 46	7.8	13.4	40.5	58.1	14.5	18.4	27.3	111.2	
kg/tow (1-46)	1.5	5.6	5.7	6.4	5.8	7.1	7.2	-	