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# A PRELIMINARY ASSESSMENT OF THE STATUS OF BLUEFISH (*Pomatomus saltatrix*) ALONG THE ATLANTIC COAST OF THE UNITED STATES

by

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## INTRODUCTION

The bluefish (*Pomatomus saltatrix*) has become the most important species to the marine recreational fishery along the Atlantic coast of the United States (US). Its importance has developed in recent years as a result of an increase in the number of anglers (Clark 1962, Deuel and Clark 1968, Deuel 1973, Ridgely and Deuel 1975), an apparent improvement in abundance, and decreased abundance of other desired species such as striped bass (*Morone saxatilus*) (McHugh 1977, Freeman 1978).

The bluefish is a migratory, pelagic, schooling species found throughout the world in most temperate and warm temperate coastal regions except the eastern Pacific (Briggs 1960). Along the Atlantic coast of the US, bluefish are distributed between Nova Scotia and Texas, moving northward in the spring and summer and southward in the autumn and winter. They are most abundant during the summer between Cape Cod and Cape Hatteras and during the winter off southeastern Florida (Wilk 1977).

Bluefish grow to at least 14 years of age (Wilk 1977), when they average about 87 cm and 8.4 kg. Bigelow and Schroeder (1953), however, reported a specimen of about 115 cm (3 ft 9 in) and 12.2 kg (27 lb). They are ferocious predators, feeding on a wide variety of fish and invertebrates (Wilk 1977).

Various studies indicate multiple stocks of bluefish along the Atlantic coast of the US. Lund (1961) identified six different stocks between Massachusetts and Florida based on meristic characteristics of young fish. Kendall and Walford (1979) found, from collections of larvae, that bluefish appear to spawn in two major areas at different times: shoreward of the Gulf Stream from Florida to Cape Hatteras during April-May and to a lesser extent during the autumn and winter; and in continental shelf waters between Cape Cod and Cape Hatteras in July-August. Wilk (1977) distinguished two populations which tend to mix during part of the year but separate for spawning based on differences in (1) first-year growth determined from scales and (2) body proportions. Since it is beyond the scope of this paper to assign catch statistics to separate stocks, bluefish along the Atlantic coast are herein treated as a unit stock.

The purpose of this paper is to assess the status of bluefish along the Atlantic coast of the US. Data and results presented include commercial and estimated recreational catches, relative abundance indices from National Marine Fisheries Service (NMFS) research vessel autumn bottom trawl surveys, and an estimate of maximum sustainable yield (MSY).

## MATERIALS AND METHODS

US commercial catches of bluefish for 1960-79 were obtained from ICNAF (International Commission for the Northwest Atlantic Fisheries) Statistical Bulletins (Vol. 10-28), US Statistical Digests (Fishery Statistics of the United States) (No. 53-68), State Landings Reports (monthly and annual summaries for various states and years), and from NMFS Northeast Fisheries Center (NEFC) data files. For the purpose of describing the regional distribution of commercial catches in a manner corresponding to the areas for which recreational catch estimates were reported, catches were separated by the following geographical areas: North Atlantic, Middle Atlantic, and South Atlantic. The North Atlantic was defined as the area extending from Maine through New York, the Middle Atlantic as the area from New Jersey through Cape Hatteras, North Carolina (through Beaufort County), and the South Atlantic as the area extending from Cape Hatteras through southern Florida (excluding the Florida Keys). Catches for the North and Middle Atlantic areas combined represent the US catch reported to ICNAF (replaced in 1980 by NAFO - Northwest Atlantic Fisheries Organization) for Subarea 5 and Statistical Area 6 (SA 5-6). Since the catch reported to ICNAF/NAFO included miscellaneous catches not contained in the state reports and represented final instead of preliminary US statistics, as were many of the state statistics, the ICNAF/NAFO data were considered the most accurate and were apportioned into North and Middle Atlantic components in proportion to the reported state landings from the two areas. Catches of bluefish by other countries were obtained from ICNAF Statistical Bulletins.

Various marine angler surveys provided estimates of the US recreational catch of bluefish for all three areas in 1960, 1965, 1970, and 1979 (Clark 1962, Deuel and Clark 1968, Deuel 1973, and Deuel[1]), for the North and Middle Atlantic areas in 1974 (Deuel, see footnote 1), and for the South Atlantic area in 1975 (Deuel, see footnote 1). Estimates of the weight of the total catch were obtained for all the above years

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[1]David G. Deuel, Resource Statistics Division, National Marine Fisheries Service, Washington, DC, personal communication.

except 1979. Catches for 1979 (results are for November 1978 - October 1979 but are considered herein to represent 1979) were estimated by the NMFS Marine Recreational Fishery Statistics Survey in terms of numbers of fish for three categories (landed, released, and harvested)[2], with the sum representing the total catch. Mean weights were obtained only from fish in the landed category. Therefore, to convert numbers of fish estimated for all three categories into weight, and lacking definitive information, it was assumed that mean weights determined for landed bluefish were also applicable to released and harvested bluefish.

Estimates of recreational catch in all areas and years except 1979 are considered to be overestimates. A more accurate value in each case is considered to be 50% of the original estimate. Rationale for this judgment is described in the RESULTS section. Catches in years lacking surveys were estimated by applying commercial/recreational catch ratios from adjacent years (see RESULTS section for additional detail on this procedure).

Stratified mean catch-per-tow (kg) indices for bluefish were calculated for 1967-79 from NMFS, NEFC research vessel autumn bottom trawl surveys based on catch data in strata 1-25 and 61-76 (Figure 1). Surveys have been conducted between Nova Scotia and Cape Hatteras based on a stratified random sampling design (Cochran 1953, Clark and Brown 1977) with strata constituting different depth zones and areas (Grosslein 1969). Survey methods, procedures, and gear are described by Grosslein (1974) and Clark (1979).

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[2]Landed - whole fish; released - caught and released; harvested - headed, gutted, filleted, etc. Complete mortality assumed herein for released fish.

Estimates of MSY for bluefish along the Atlantic coast were computed by fitting a generalized stock production model (Pella and Tomlinson 1969) to survey catch-per-tow indices and weighted average relative exploitation indices using the method (PRODFIT program) developed by Fox (1975). At equilibrium, the model is expressed as:

$$U_i = (a + b\bar{f}_i)^{\frac{1}{m-1}} \tag{1}$$

where $U_i$ is the survey catch-per-tow index in year i, $\bar{f}_i$ is the weighted average relative exploitation index in year i, and a, b, and m are parameters estimated by the program.

The model normally requires annual catch and fishing effort data; however, both commercial and recreational fishing effort and catch-per-unit-effort (CPUE) data are currently unavailable for bluefish. In place of CPUE, as a measure of stock size, NEFC autumn bottom trawl survey catch-per-tow (kg) values were employed. As an alternative to fishing effort, the ratio between catch and survey catch per tow, defined as the relative exploitation index (Anderson and Paciorkowski in press), was utilized.

Equilibrium conditions were approximated by averaging the relative exploitation indices over the number of years that a year class contributes significantly to the fishery. Gulland (1969) suggested that this averaging period be equivalent to half the age span of the species in the exploited phase of the fishery. Richards (1976) examined a sample of 64 bluefish caught by recreational fishermen in Long Island Sound in 1975 and determined ages from 2 to 7 years. Analysis of over 16,000 bluefish sampled during 1964-67 by personnel at the NMFS, NEFC, Sandy Hook Laboratory indicated a maximum age of 7 years with the majority of fish consisting of ages 1-3; young-of-the year bluefish were also collected but not aged (Wilk[3]). Other studies (Younger and Zamos 1955, Briggs 1962) showed that young-of-the-year fish have accounted for 20-90% of the entire recreational catch of bluefish taken from shore in the New York-New Jersey area. Averaging periods of 2, 3, and 4 years were chosen to approximate equilibrium conditions assuming an age span of exploitable fish corresponding to 4, 6, and 8 years.

## RESULTS

### Commercial catch

US commercial catches of bluefish along the Atlantic coast of the US increased gradually from 1,251 metric tons (tons) in 1960 to 5,523 tons in 1979 (Table 1, Figure 2). During 1960-70 and 1972, catches in the South Atlantic area exceeded those in either of the other two areas, averaging 46% of the total commercial catch. During 1971 and 1973-79, catches were greatest in the Middle Atlantic area, averaging 51% of the US total.

Catches of bluefish by other countries were reported during 1971-77, but were quite small, ranging from 1 to 214 tons and averaging less than 2% of the total annual commercial catch.

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[3]Stuart J. Wilk, National Marine Fisheries Service, Northeast Fisheries Center, Sandy Hook Laboratory, Highlands, NJ, personal communication.

Recreational catch

US recreational catches of bluefish were estimated from marine angler surveys to be 5,039, 28,709, 22,749, 26,303, and 17,997 tons for 1960, 1965, 1970, 1974, and 1979, respectively, for the North Atlantic area; 11,723, 7,217, 22,549, 31,639, and 16,346 tons for 1960, 1965, 1970, 1974, and 1979, respectively, for the Middle Atlantic area; and 6,186, 5,121, 8,740, 3,351, and 843 tons for 1960, 1965, 1970, 1975, and 1979, respectively, for the South Atlantic area. These estimates suggest a total recreational catch in the North and Middle Atlantic areas (no estimate for the South Atlantic area in 1974) of 16,762, 35,926, 45,298, 57,942, and 35,186 tons in 1960, 1965, 1970, 1974, and 1979, respectively. These results indicate a continuous increase in catch from 1960 to 1974, which appears to represent a valid trend given the steady growth in recreational fishing activity during this period coupled with an apparent improvement in stock abundance as suggested by research vessel survey results (Table 2, Figure 3). However, the apparent sharp decrease in estimated catch in the North and Middle Atlantic areas of over 40% from 1974 to 1979 is not consistent with the earlier trend and does not appear to represent actual conditions in the recreational fishery for bluefish. Angler participation has maintained its increasing trend, and recreational bluefish catches over the past 5 years have, in fact, probably increased along the Atlantic coast (Lyman[4]). Consequently, it is concluded that bluefish catches determined

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[4]Henry Lyman, Publisher, The Salt Water Sportsman, 10 High Street, Boston, MA, personal communication.

from marine angler surveys conducted prior to the 1979 NMFS Marine Recreational Fishery Statistics Survey were overestimated.

The 1960, 1965, and 1970 national saltwater angling survey results were based on angler memory recall of catch for an entire year. The 1974 and 1975 regional angling surveys employed different methods than utilized in the previous surveys and relied on memory recall for 2-month periods. Catch estimates obtained from all of these surveys were additionally characterized by considerable statistical variability. Personnel familiar with the conduct of these past surveys and involved in reporting the results (Deuel, see footnote 1) have acknowledged that the catch estimates were probably overestimated due, in part, to the lengthy recall periods. A study conducted in southern California in 1977 (Hiett and Worrall 1977), which examined the ability of marine recreational fishermen to recall catch and effort over time, found that fishermen interviewed 15-60 days following given fishing trips overestimated their catch by 33-123%. The 1979 national survey results were based on on-site interviews to obtain catch data for individual fishing trips (although angler participation and effort data were obtained from telephone surveys conducted at 2-month intervals), and, consequently, should be more accurate than the previous results. Preliminary results also indicate a considerable reduction in statistical variance for the 1979 estimates compared to previous estimates (Deuel, see footnote 1).

In view of the supporting evidence, it was assumed that the recreational catch estimates for 1960, 1965, 1970, 1974, and 1975 were overestimated by 100%. This correction factor was chosen not only because it fell within the range of values determined by Hiett and Worrall (1977), but because it resulted in adjusted catches which exhibited a steadily increasing trend judged by those knowledgeable in the recreational fishery (Lyman, see footnote 4) to more closely represent actual conditions. At the present time, there is no basis for a more precise determination of a correction factor, and the value used (100%) must be considered only approximate.

Adjusted recreational catch estimates for bluefish along the Atlantic coast by area are given in Table 1. Catches in years when surveys were not conducted were also estimated in order to develop a continuous series of catch data, primarily for the purpose of estimating MSY. It was found that the most consistent basis for estimating recreational catches in the intervening years was US commercial/recreational catch ratios from years with surveys. In the North Atlantic area, commercial/recreational catch ratios were 0.084, 0.042, 0.086, 0.062, and 0.060 in 1960, 1965, 1970, 1974, and 1979, respectively. Ratios in the Middle Atlantic area were 0.054, 0.162, 0.080, 0.150, and 0.182 in 1960, 1965, 1970, 1974, and 1979, respectively, and in the South Atlantic area were 0.233, 0.250, 0.248, 0.575, and 1.747 in 1960, 1965, 1970, 1975, and 1979, respectively. These ratios (by area) were applied to the commercial catches in the preceeding and succeeding two years, with several exceptions, to estimate recreational catches. The means for 1970 and 1974 were used for 1972 in the North and Middle Atlantic areas. To eliminate estimates which differed markedly from apparent trends, the 1965 ratio was used for 1968 in the North Atlantic, the 1965 ratio was used for 1962 in the Middle Atlantic, and in the South Atlantic, the 1975 ratio was used for 1977 and the 1975 and 1979 mean was used for 1978.

Estimated recreational catches of bluefish along the Atlantic coast exhibited an upward trend from about 11,500 tons in 1960 to about 41,900 tons in 1978, decreasing somewhat to 35,200 tons in 1979 (Table 1, Figure 2). Catches were relatively stable during 1973-77, averaging about 31,500 tons annually, but then increased to an average of about 38,600 tons in 1978-79. On an area basis, catches in the North Atlantic exceeded those in each of the other two areas in 1963-70, 1973, and 1977-79, averaging about 54% of the annual total in those years. Catches in the Middle Atlantic were greatest of any area in 1960-62, 1971-72, and 1974-76, averaging about 50% of the total. Estimated catches in the South Atlantic were less than in the other areas, averaging 21% in 1960-72 and only 5% in 1973-79. Catches in the South Atlantic ranged between 800 and 4,900 tons, while averaging about 3,000 tons per year, and exhibited a pronounced drop beginning in about 1973, whereas estimated catches in the North Atlantic varied from 2,500 to 30,400 tons (average of 11,400 tons) and in the Middle Atlantic from 2,500 to 19,800 tons (average of 9,500 tons). The estimated catches in the North Atlantic fluctuated markedly between 7,900 and 30,400 tons during 1976-79. It is uncertain whether these fluctuations are indeed real, as these estimates are based solely on commercial catch levels in those years.

The 1979 estimate was 17,997 tons (51%) in the North Atlantic, 16,346 tons (47%) in the Middle Atlantic, and only 843 tons (2%) in the South Atlantic. The catch, in terms of numbers of fish, was an estimated 21,887,000, of which 14% was released by anglers. For the landed portion (46%) of this total, the average weight was 1.61 kg for the entire Atlantic coast (0.44 kg in the South Atlantic, 1.96 kg in the Middle Atlantic, and 1.55 kg in the North Atlantic).

Total catch

Total catches (commercial and estimated recreational) increased from about 12,700 tons in 1960 to 46,800 tons in 1978 and decreased to 40,700 in 1979. Catches were relatively constant during 1973-77, averaging about 36,000 tons per year, before increasing in 1978-79. During 1960-78, the estimated recreational catch averaged about 89% of the annual total catch. In 1979, the recreational catch comprised about 86% of the total harvest.

Relative abundance

Stratified mean catch-per-tow (kg) indices for bluefish calculated from NEFC research vessel autumn bottom trawl survey results for the area from Georges Bank to Cape Hatteras are given in Table 2 and Figure 3. Catch per tow underwent a sharp increase from an average of 0.08 kg during 1967-70 to a peak of 1.54 kg in 1974. Aside from the abrupt rise in 1974 and the sharp drop to 0.48 kg in 1976, the index remained relatively constant during 1971-78, varying between 0.67 and 0.87 and averaging 0.78 kg (excluding 1974 and 1976). Catch per tow increased from 0.72 kg in 1978 to 1.08 kg in 1979.

Maximum sustainable yield

Relative exploitation indices (ratios between estimated total catches from Maine to Florida and NEFC survey catch-per-tow indices for the Georges Bank - Cape Hatteras area) were calculated for 1967-79 (Table 3). Since the survey indices for 1968 and 1970 were exceptionally low relative to adjacent values (Table 2) and deviated markedly from the increasing trend, means for 1967 and 1969 and for 1969 and 1971, respectively, were used instead of the 1968 and 1970 values for calculating the relative exploitation indices. Since there is substantial variability associated with the survey catch-per-tow data for most species (i.e. 95% confidence intervals are of the order of ±50% of the mean) (Grosslein 1971), individual indices are imprecise, but when viewed over time do monitor population trends quite well (Clark and Brown 1977). This appears to be the case for bluefish, and since the series of survey indices suggests a pronounced increase in stock abundance, smoothing of the 1968 and 1970 data points is considered valid. Failure to adjust these two values results in abnormally excessive relative exploitation indices for those years which was probably not indicative of actual conditions.

The generalized stock production model was allowed to iterate through successive values of m, beginning at m = 1, for each data set of catch and averaged relative exploitation indices (averaging periods of 2, 3, and 4 years), until convergence at a minimum residual sum of squares was achieved. The 2-year and 3-year averaging periods resulted in best fits of the data at m = 0.69 and m = 1.17, respectively, indicating models closely resembling the Gompertz exponential model ($m \rightarrow 1$) (Fox 1970). The 4-year averaging period resulted in $m = 1.49$ which produced a model approximately mid-point between the logistic model ($m = 2$) (Schaefer 1954, 1957) and the Gompertz model. The estimated equilibrium relationships between relative abundance and relative exploitation and between yield and relative exploitation are illustrated in Figures 4 and 5, respectively.

Utilizing a 4-year averaging period, the 1967-69 data points contribute very little to fitting the model to the data. Even though the relative exploitation indices from these years are used in estimating average relative exploitation for 1970, the averaging procedures gives a progressively greater weight to each succeeding year from 1967 to 1970 (i.e. 1967 is weighted by 1, 1968 by 2, 1969 by 3, and 1970 by 4), and the relative abundance indices for 1967-69 are not considered. The resulting fitted model produces a flat-topped asymptotic ($m = 0$) yield curve. To alleviate this situation, a dummy data point was used for 1966 which assumed relative abundance to be the same as in 1967, thus implying a relative exploitation index of 244,700.

Estimates of MSY were 40,700 tons using a 2-year averaging period, 47,300 tons using a 3-year period, and 54,100 tons using a 4-year period. The average of these estimates is 47,400 tons. Optimal levels of relative exploitation corresponding to these MSY estimates are 50,500, 70,700, and 83,600, respectively. Although the actual data points agree more closely to the curves (Figures 4 and 5) based on the 2-year period than on the 3- or 4-year periods, it is uncertain from a biological standpoint which averaging period is more representative of actual conditions in the fishery. Therefore, it can only be surmised that the best estimate of MSY lies somewhere within the range of values determined.

## DISCUSSION

Catches of bluefish along the Atlantic coast of the US have undergone a marked increase since 1960. Commercial catches increased 4.4 times from 1960 to 1979, and estimated recreational catches improved by a factor of 3.7 during 1960-78. The 1979 recreational catch estimate represents the most accurate assessment of that component of the overall harvest in the 20-year time-series, although the imprecise nature of the earlier marine angler surveys coupled with the adjustment made herein to the pre-1979 recreational estimates results in considerable uncertainty regarding the actual level of recreational bluefish catches since 1960. In spite of this uncertainty, an upward trend in catch is clearly evident.

Concurrent with the increase in catches has been the increase in relative abundance indices, computed from NMFS, NEFC research vessel autumn bottom trawl survey results, since the late 1960's to a relatively stable level in the 1970's. The survey indices are limited, however, in several respects. The data included in the catch-per-tow analysis were collected from trawl tows made only in waters deeper than 27 m (Figure 1), whereas bluefish are very abundant in the zone extending from shore out to this depth. Bluefish, being pelagic, are not as susceptable to capture by a bottom trawl as are the typically demersal species. The low catch rates in the survey series, as well as the observed year-to-year variability in the catch-per-tow index, certainly attest to this fact. Similar variability in survey catch-per-tow indices has been observed for other pelagic, schooling species such as Atlantic mackerel (*Scomber scombrus*) (Anderson and Paciorkowski in press) which, in addition to being in mid-water or near the surface at certain times of the day as a result of diel vertical migration, are characterized by a clustered rather than a continuous distribution pattern. Nevertheless, as in the case of Atlantic mackerel, bottom trawl survey catch-per-tow indices have successfully monitored trends in stock abundance. Lastly, the survey data base pertains only to the area north of Cape Hatteras which represents only about one-half of the distributional range of bluefish along the Atlantic coast. In spite of the various limitations of the bottom trawl survey data base for bluefish, at the present time it represents the only means of measuring relative abundance of this species.

The increasing trend in commercial and recreational catches (Figure 2) coupled with an increase in the survey catch-per-tow index since the late 1960's strongly suggests that bluefish have increased in abundance along the Atlantic coast since the 1960's. Since survey abundance indices are lacking for the southern portion of the distributional range of bluefish, it is not certain whether an increase has occurred in all areas. It is possible that improved catches and survey indices north of Cape Hatteras reflect, in part, merely a northerly shift in distribution. The pronounced decline in estimated recreational catches in the South

Atlantic since the early 1970's, at a time of generally increasing angler effort in all areas, suggests the possibility of a distributional shift. Water temperature in the area between Cape Hatteras and the Gulf of Maine has exhibited a general warming since the 1960's (Davis 1979) which corresponds to the increases in catch and in research vessel survey catch per tow in the same region. Prior to 1971, bluefish were absent from survey catches on Georges Bank, but peaked there in 1974 as did water temperature (Davis 1979). General observations indicate a greater occurrence of bluefish in other northerly areas, such as along the coast of Maine, in the 1970's. Such evidence, as well as results of previous studies (Lund and Maltezos 1970, Olla and Studholme 1971), suggests that temperature is very important in determining the distribution of bluefish. Available information indicates, therefore, a strong probability that the recent warming trend contributed significantly to increases in catch and apparent abundance of bluefish in waters north of Cape Hatteras. Bigelow and Schroeder (1953) document the fact that bluefish abundance has historically undergone extreme fluctuations in the northern part of its range, as reflected by catches and general availability in the Gulf of Maine area.

Even though available data are insufficient to establish whether bluefish have increased in abundance along the entire Atlantic coast since the 1960's or have merely undergone a northerly shift in distribution in response to a warming trend, it is clear that bluefish have become more available in the area north of Cape Hatteras resulting in improved research vessel survey catches and greatly increased recreational and commercial catches.

Since the MSY estimates reported herein are based on rather imprecise data, they must be regarded as approximate and evaluated with caution. For example, if the catch estimates for all years are in error by a similar magnitude and direction, the MSY estimates are proportionately in error. The wide range in the relative exploitation indices used in the production model analysis (the largest being nearly 8 times greater than the smallest) is a major factor contributing to the shape and fit of the model to the data. However, even without the 1967-69 data points, which would reduce the range by over one-half, the MSY estimates do not change significantly, only the shape of the equilibrium curves.

Considering the MSY values determined herein ranging from 40,700 to 54,100 tons, the total estimated catches of 46,800 and 40,700 tons in 1978 and 1979, respectively, appear to be at about the MSY level. The fact that current catches appear to be at or near MSY is of less concern than the current level of fishing effort. Since MSY represents an average level of expected catch over time, annual catches should range above and below that level in response to changes in stock abundance as long as fishing effort remains below or does not exceed the level necessary to generate MSY. The relative exploitation index (herein comparable to fishing effort) in 1979 was 37,700 units, or 25% less than the level corresponding to the lowest of the MSY estimates. However, relative exploitation during the last five years (1975-79) averaged 52,300 units, or slightly in excess of that at the lowest MSY estimate, indicating that recent levels of effort as well as catch may be at or near MSY.

Surplus production models such as the one used herein to estimate MSY disregard, among other things, environmentally-induced fluctuations in population abundance from year to year. Doubleday (1976) and Sissenwine (1977) have shown that in a fluctuating environment, the long-term average yield will probably be lower than the MSY predicted by a generalized stock production model. These studies, as well as the work of Beddington and May (1977), indicate that fishing mortality should be maintained below $F_{MSY}$, the rate which will theoretically produce MSY, to reduce the probability of stock decline.

The concept of MSY has been widely criticized by fishery scientists during recent years (e.g. Larkin 1977, Sissenwine 1978). Aside from the conceptual difficulties, there are many pitfalls associated with the estimation of MSY. The traditional models ignore stochastic effects and time delays. The fitting procedure usually assumes equilibrium and applies unproven manipulations to the data to approximate an equilibrium situation. In the case of bluefish, the data itself are highly suspect. Several unverified assumptions are made to estimate total catch. Fishing effort data are lacking; therefore, research vessel survey data are used to determine an index of fishing effort. Survey data are variable, particularly for a pelagic species like bluefish. Furthermore, since the survey results apply to only a portion of the range of bluefish, changes in catch rates may reflect changes in the distribution pattern (perhaps a northerly shift) as well as in abundance. If the former is the case, estimates of MSY reported herein would be too high. Nevertheless, an estimate of MSY is usually sought by fishery managers (particularly as a result of the mandate of FCMA). Therefore, an attempt to estimate MSY using traditional methods is presented in this paper.

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Table 1. Bluefish catch (tons) along the Atlantic coast of the United States during 1960-79.

| | US commercial | | | | US recreational | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | North Atlantic[1] | Middle Atlantic[2] | South Atlantic[3] | Total | North Atlantic | Middle Atlantic | South Atlantic[4] | Total | Other countries | Total |
| 1960 | 212 | 317 | 722 | 1,251 | 2,520[5] | 5,862[5] | 3,093[5] | 11,475 | -- | 12,726 |
| 1961 | 264 | 396 | 741 | 1,401 | 3,143 | 7,333 | 3,180 | 13,656 | -- | 15,057 |
| 1962 | 423 | 877 | 956 | 2,256 | 5,036 | 5,414 | 4,103 | 14,553 | -- | 16,809 |
| 1963 | 397 | 808 | 917 | 2,122 | 9,452 | 4,988 | 3,668 | 18,108 | -- | 20,230 |
| 1964 | 365 | 427 | 889 | 1,681 | 8,690 | 2,636 | 3,556 | 14,882 | -- | 16,563 |
| 1965 | 599 | 584 | 640 | 1,823 | 14,354[5] | 3,608[5] | 2,560[5] | 20,522 | -- | 22,345 |
| 1966 | 583 | 723 | 964 | 2,270 | 13,881 | 4,463 | 3,856 | 22,200 | -- | 24,470 |
| 1967 | 358 | 410 | 930 | 1,698 | 8,524 | 2,531 | 3,720 | 14,775 | -- | 16,473 |
| 1968 | 364 | 637 | 1,152 | 2,153 | 8,667 | 7,962 | 4,645 | 21,274 | -- | 23,427 |
| 1969 | 667 | 605 | 1,007 | 2,279 | 7,756 | 7,562 | 4,060 | 19,378 | -- | 21,657 |
| 1970 | 973 | 902 | 1,085 | 2,960 | 11,374[5] | 11,274[5] | 4,370[5] | 27,018 | -- | 29,978 |
| 1971 | 788 | 930 | 888 | 2,606 | 9,163 | 11,625 | 3,581 | 24,369 | 23 | 26,998 |
| 1972 | 646 | 1,044 | 1,221 | 2,911 | 8,730 | 9,078 | 4,923 | 22,731 | 18 | 25,660 |
| 1973 | 974 | 1,996 | 1,245 | 4,215 | 15,710 | 13,307 | 2,165 | 31,182 | 214 | 35,611 |
| 1974 | 820 | 2,369 | 1,283 | 4,472 | 13,152[5] | 15,820[5] | 2,231 | 31,203 | 99 | 35,774 |
| 1975 | 872 | 2,704 | 964 | 4,540 | 14,065 | 18,027 | 1,676[5] | 33,768 | 103 | 38,411 |
| 1976 | 489 | 2,963 | 958 | 4,410 | 7,887 | 19,753 | 1,666 | 29,306 | 1 | 33,717 |
| 1977 | 1,092 | 2,282 | 874 | 4,248 | 18,200 | 12,538 | 1,520 | 32,258 | 4 | 36,510 |
| 1978 | 1,821 | 1,944 | 1,064 | 4,829 | 30,350 | 10,681 | 916 | 41,947 | -- | 46,776 |
| 1979 | 1,081 | 2,969 | 1,473 | 5,523 | 17,997[6] | 16,346[6] | 843[6] | 35,186 | -- | 40,709 |

[1]Atlantic coast from Maine to and including New York.

[2]Atlantic coast from New Jersey to Cape Hatteras, NC.

[3]Atlantic coast from Cape Hatteras, NC to southern Florida excluding the Florida Keys.

[4]Atlantic coast from Cape Hatteras, NC to southern Florida including the Florida Keys.

[5]Angler survey estimate (divided by 2); remaining years interpolated (see text).

[6]NMFS Marine Recreational Fishery Statistics Survey estimate.

Table 2. Stratified mean catch per tow (kg) of bluefish in NMFS, NEFC autumn bottom trawl surveys during 1967-79, strata 1-25 and 61-76.

| Year | Catch per tow |
|---|---|
| 1967 | 0.10 |
| 1968 | 0.01 |
| 1969 | 0.15 |
| 1970 | 0.06 |
| 1971 | 0.67 |
| 1972 | 0.81 |
| 1973 | 0.79 |
| 1974 | 1.54 |
| 1975 | 0.87 |
| 1976 | 0.48 |
| 1977 | 0.82 |
| 1978 | 0.72 |
| 1979 | 1.08 |

Table 3. Estimated catch, autumn survey relative abundance index (catch per tow), and relative exploitation index for bluefish along the Atlantic coast of the United States during 1967-79.

| Year | Catch (tons) | Relative abundance index (kg/tow) | Relative exploitation index[3] |
|---|---|---|---|
| 1967 | 16,473 | 0.10 | 164,730 |
| 1968 | 23,427 | 0.13[1] | 180,208 |
| 1969 | 21,657 | 0.15 | 144,380 |
| 1970 | 29,978 | 0.41[2] | 73,117 |
| 1971 | 26,998 | 0.67 | 40,296 |
| 1972 | 25,660 | 0.81 | 31,679 |
| 1973 | 35,611 | 0.79 | 45,077 |
| 1974 | 35,774 | 1.54 | 23,230 |
| 1975 | 38,411 | 0.87 | 44,151 |
| 1976 | 33,717 | 0.48 | 70,244 |
| 1977 | 36,510 | 0.82 | 44,524 |
| 1978 | 46,776 | 0.72 | 64,967 |
| 1979 | 40,709 | 1.08 | 37,694 |

[1] Mean of 1967 and 1969.

[2] Mean of 1969 and 1971.

[3] Ratio between catch and relative abundance index.

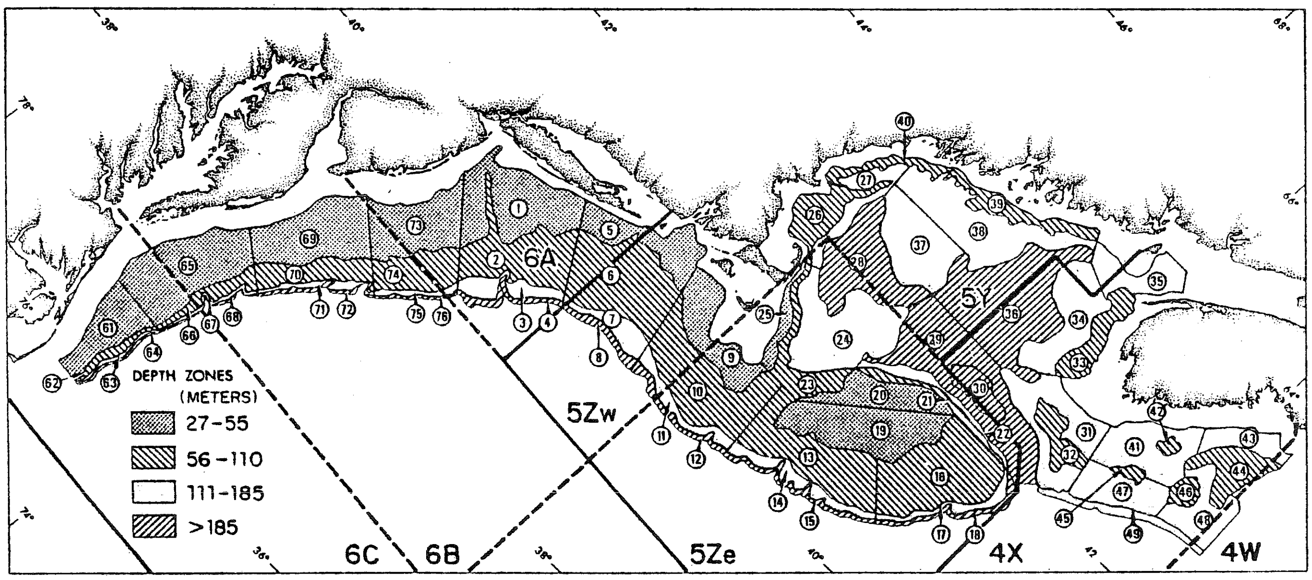


Figure 1. Sampling strata used in the NMFS, NEFC research vessel bottom trawl surveys.

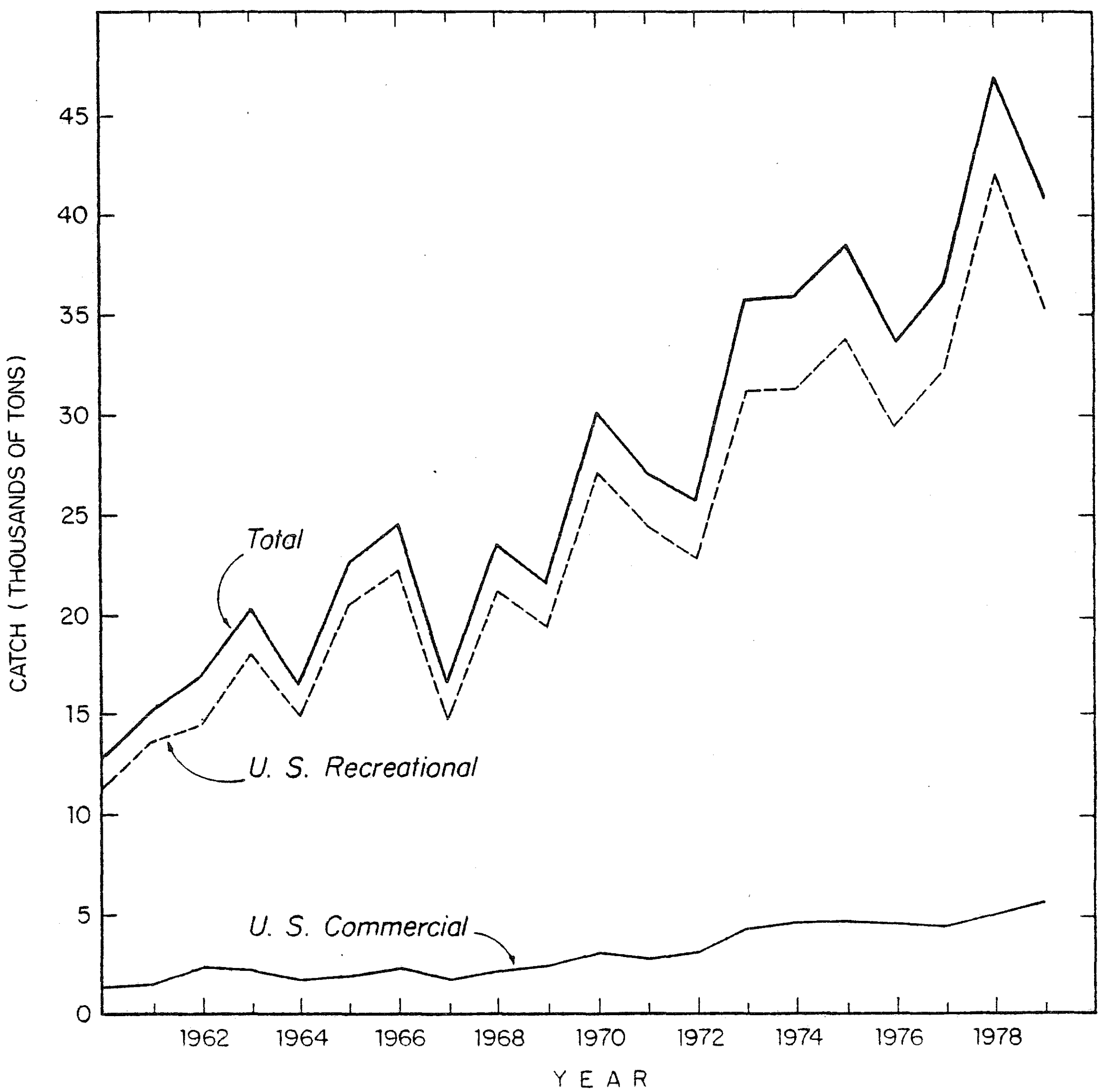


Figure 2. US recreational, US commercial, and total catch of bluefish along the Atlantic coast of the United States.

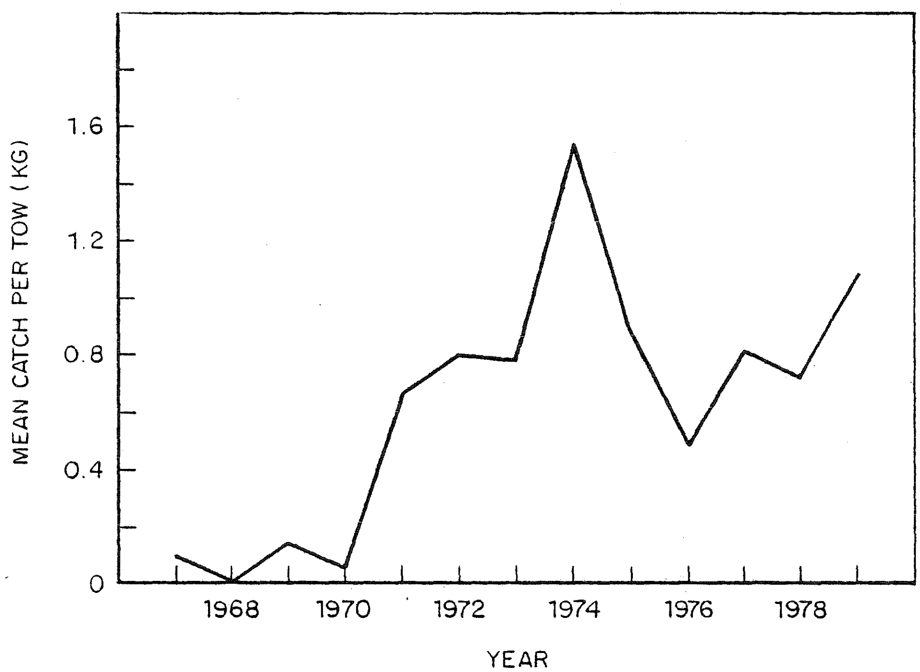


Figure 3. NMFS, NEFC research vessel autumn bottom trawl survey catch per tow (kg) of bluefish (strata 1-25, 61-76).

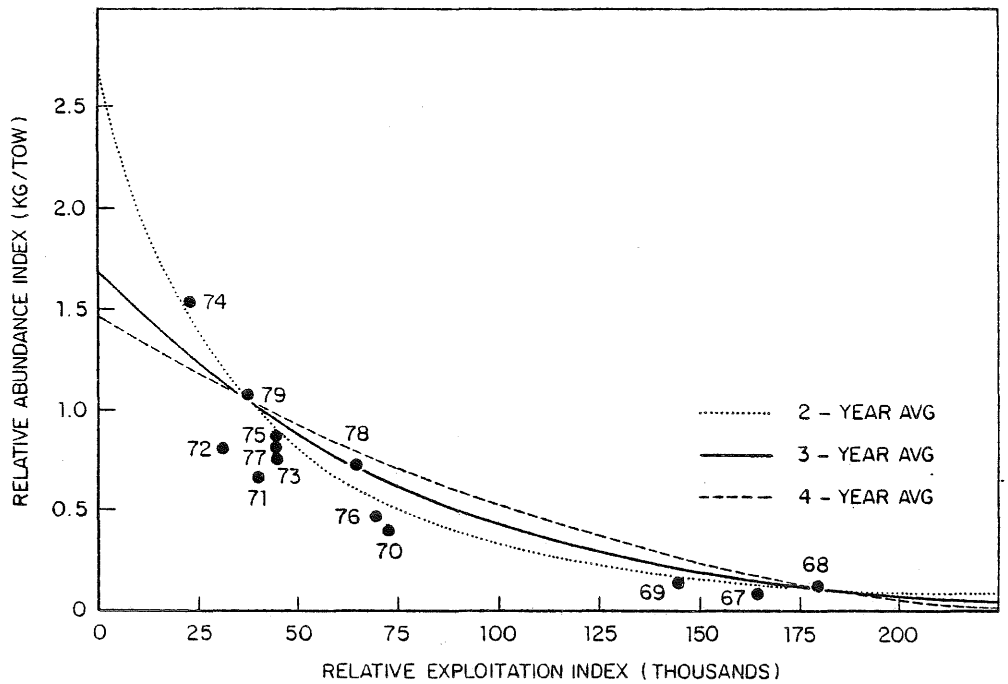


Figure 4. Equilibrium relationship between relative abundance and relative exploitation for bluefish along the Atlantic coast of the US using 2-year, 3-year, and 4-year weighted averaging periods for relative exploitation. Actual data points are plotted.

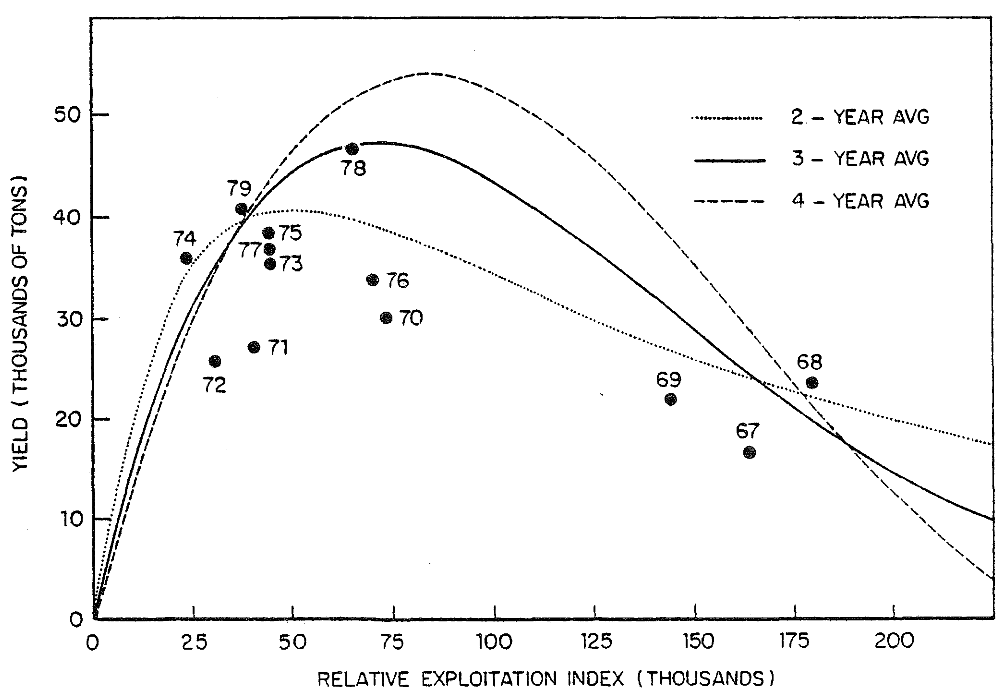


Figure 5. Equilibrium relationship between yield and relative exploitation for bluefish along the Atlantic coast of the US using 2-year, 3-year, and 4-year weighted averaging periods for relative exploitation. Actual data points are plotted.