ASSESSMENT OF BLUEFISH (*Pomatomus saltatrix*) OF 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 recreational fishery along the Atlantic coast of the United States (USA). 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). Commercial catches of bluefish have been miniscule compared to estimated recreational catches (Hayden and Anderson 1978), but concern over the possible expansion of the commercial fishery in response to potential foreign markets has, in part, prompted plans for the preparation of a fishery management plan for bluefish along the Atlantic coast of the USA by the Mid-Atlantic Fishery Management Council.

The purpose of this paper is to assess the current status of the bluefish resource along the Atlantic coast. Data and results presented include commercial and estimated recreational catches, USA research vessel autumn bottom trawl survey catch per tow (Cape Hatteras - Georges Bank), and estimates of maximum sustainable yield. Although previous investigations (Lund 1961, Wilk 1977) indicated multiple stocks along the Atlantic coast, bluefish in this paper are treated as a single population.

CATCHES

Hayden and Anderson (1978) reported commercial catches taken during 1960-77 in the area from Maine to Cape Hatteras, North Carolina (ICNAF Subarea 5 and Statistical Area 6 - SA5-6) and estimated recreational catches for that period and area based on results of marine angler surveys in 1960, 1965, 1970, and 1974 and the commercial/recreational catch ratios in those years. In this paper, commercial and recreational catches from Cape Hatteras to southern Florida are in-

cluded with those from the northern areas, and recreational catches in the northern areas are re-estimated.

USA commercial catch statistics were obtained from ICNAF Statistical Bulletins (Vol. 10-27), USA Statistical Digests (Fishery Statistics of the United States) (No. 53-68), and State Landings Reports (monthly and annual summaries for various states and years). Catches are given in Table 1 by the following geographical areas: North Atlantic, Middle Atlantic, and South Atlantic. The North Atlantic area extends from Maine through New York, the Middle Atlantic area extends from New Jersey through the northern district of North Carolina, and the South Atlantic area extends from the central and southern districts of North Carolina through southern Florida (excluding the Florida Keys). Catches for the North and Middle Atlantic areas combined represent the USA catch as reported to ICNAF for SA 5-6. Since the catch reported to ICNAF includes miscellaneous catches not contained in the state reports and also final instead of preliminary values, as are many of the state statistics, the ICNAF data were apportioned into North and Middle Atlantic components in proportion to the reported state landings from the two areas.

USA commercial catches (Table 1, Figure 1) increased rather gradually from 1,251 tons in 1960 to 4,872 tons in 1978. During 1960-72, catches were greater in the South Atlantic area than in either of the other two areas, averaging 46% of the total commercial catch. During 1973-78, catches were greatest in the Middle Atlantic, averaging 53% of the total.

Foreign catches of bluefish were reported during 1971-77, but were quite small, averaging less than 2% of the total commercial catch.

The recreational catch of bluefish was estimated by marine angler surveys for all three areas in 1960, 1965, and 1970 (Clark 1962, Deuel and Clark 1968, Deuel

1973) and for only the North and Middle Atlantic areas in 1974 (Deuel, pers. comm.). Catches for the North Atlantic were estimated to be 5,039, 28,709, 22,749, and 26,303 tons for 1960, 1965, 1970, and 1974, respectively; for the Middle Atlantic they were estimated to be 11,723, 7,217, 22,549, and 31,639 tons, respectively, for those years; and for the South Atlantic they were estimated to be 6,186, 5,121, and 8,740 tons for 1960, 1965, and 1970, respectively. These estimates indicate an increase in recreational catch along the Atlantic coast from 22,948 tons in 1960 to 54,038 tons in 1970 (Table 1), following the trend displayed by the commercial catch.

Ratios between the reported commercial and estimated recreational catches were reasonably constant from year to year within each area. Ratios for the North Atlantic were 0.0421, 0.0209, 0.0428, and 0.0302 for 1960, 1965, 1970, and 1974, respectively, and averaged 0.0340; for the Middle Atlantic the ratios were 0.0270, 0.0809, 0.0400, and 0.0726 for those years, respectively, for an average of 0.0551; for the South Atlantic the ratios were 0.1167, 0.1250, and 0.1241 for 1960, 1965, and 1970, respectively, and averaged 0.1219. Recreational catches in the years for which angler surveys were not conducted were estimated by applying the average of the ratios from each area to the commercial catch from that area. Estimated recreational catches as determined by this procedure underwent an increase from 21,031 tons in 1961 to 98,563 tons in 1978 (Table 1).

Total catches (commercial and estimated recreational) increased from about 22,400 tons in 1961 to 103,400 tons in 1978. During 1960-78, the estimated recreational catch averaged about 94% of the annual total catch.

RELATIVE ABUNDANCE

Relative abundance indices for bluefish were calculated from USA research vessel autumn bottom trawl survey results in terms of stratified mean catch per tow (kg). Indices were given by Hayden and Anderson (1978) for 1967-77 for

three ecological zones (Georges Bank, Southern New England, and Middle Atlantic) and for the total area. These values as well as the indices for 1978 are presented in Table 2. Sampling strata included in each ecological zone are indicated in Table 2 and illustrated in Figure 2. Catch per tow for the entire area from Cape Hatteras through Georges Bank underwent a sharp increase from an average of 0.08 kg during 1967-70 to a peak of 1.54 kg in 1974 (Table 2, Figure 3). Aside from the abrupt rise in 1974 and a sharp drop to 0.48 kg in 1976, the index has remained relatively steady since 1971, averaging 0.78 kg (excluding 1974 and 1976). Indices within each ecological zone have exhibited considerable year-to-year variability, but the index for the combined area, although not lacking variability, documents a pronounced improvement in bluefish abundance since the late 1960's. Similar variability in survey catch-per-tow indices has been observed for other schooling species such as Atlantic mackerel (Anderson and Paciorkowski 1978) which are characterized by discrete rather than continuous distribution patterns. Nevertheless, as in the case of mackerel, bottom trawl survey catch-per-tow indices have successfully monitored trends in stock abundance.

MAXIMUM SUSTAINABLE YIELD

Estimates of the maximum sustainable yield (MSY) of bluefish along the Atlantic coast were computed utilizing a generalized stock production model developed by Fox (1975). At equilibrium, this model is expressed as

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

where U_i is the catch per effort in year i, $\bar{f}_i$ is average fishing effort, and a, b, and m are parameters. Equation (1) becomes the logistic model (Schaefer 1954, 1957) when m = 2 and the Gompertz exponential model (Fox 1970) as m approaches 1.

This model requires annual catch and fishing effort data, but unfortunately

fishing effort (or commercial or recreational catch per effort) data for bluefish are currently unavailable. In place of catch per effort as a measure of population size, USA autumn bottom trawl survey catch-per-tow (kg) values were employed. As an alternative to fishing effort (ratio between catch and catch per effort), the ratio between catch and survey catch per tow, termed the relative exploitation index (Anderson and Paciorkowski 1978), was utilized. Survey catch-per-tow (kg) values for the Georges Bank-Cape Hatteras area for 1967-78 were divided into the total catch estimates for those years to obtain relative exploitation indices (Table 3). Since the survey values for 1968 and 1970 were exceptionally low compared to adjacent values and deviated from the increasing trend, they were replaced by the 1967-69 and 1969-71 mean values, respectively, for the purpose of calculating relative exploitation indices.

Equilibrium conditions were approximated by averaging the relative exploitation indices (fishing effort) 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 Sandy Hook Laboratory (NMFS) indicated a maximum age of 7 years with the bulk of the fish consisting of ages 1-3; young-of-the-year bluefish were also collected but not aged (Wilk, pers. comm.). Other studies (Younger and Zamos 1955, Briggs 1962) showed that young-of-the-year have accounted for 20-90% of the entire recreational catch of bluefish taken from shore. Averaging periods of 2 years, 3 years, and 4 years were chosen to approximate equilibrium conditions assuming an age span of exploitable fish corresponding to 4, 6, and 8 years.

For each data set of catch and averaged relative exploitation indices, the model was allowed to iterate through successive values of m, beginning at m = 1, 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 = 1.27 and m = 1.41, respectively, indicating equilibrium curves more closely resembling the Gompertz rather than the logistic model. The 4-year averaging period resulted in m = 0.30 which resembles an asymptotic yield model (m = 0). The curves showing the relationship between equilibirum yield and relative exploitation are plotted in Figure 4. Estimates of MSY were 85,800 tons using a 2-year averaging period, 92,100 tons using a 3-year period, and 87,600 tons using a 4-year period. These results indicate close agreement regardless of the averaging period assumed. However, the actual data points agree more closely to the curves based on the 2- and 3-year averaging periods than the curve based on the 4-year period.

DISCUSSION

Commercial and estimated recreational catches of bluefish have undergone approximately a 4-fold increase during 1960-78. Although the actual level of bluefish taken by the recreational fishery is largely unknown due to the imprecise nature of the marine angler surveys and the even greater uncertainty of the estimates obtained by applying mean commercial/recreational catch ratios to those years without surveys, the upward trend is undeniably evident.

Concurrent with the increase in catches has been the increase in relative abundance of bluefish as measured by the USA autumn bottom trawl survey catch-per-tow indices since the late 1960's to a relatively stable level in the 1970's. The survey results are limited, however, in two general respects. The data included in the catch-per-tow analysis were collected from trawl tows made only in waters deeper than 27 meters (Figure 2), whereas bluefish are very abundant in the

zone extending from shore out to this depth. Secondly, the survey data were collected only in the area north of Cape Hatteras which represents only about half of the distributional range of bluefish along the Atlantic coast. It is therefore possible that the increase in relative abundance as measured by the trawl survey may have reflected only or in part a northerly shift in distribution instead of an actual change in population size. In spite of these limitations, the increasing trend in commercial and recreational catches, particularly evident in the North and Middle Atlantic areas, tends to support the increase in abundance as suggested by the trawl survey results. The relatively uniform level of commercial and recreational catches in the South Atlantic area throughout 1960-78 would tend to nullify the hypothesis of a distributional shift.

Estimates of MSY ranging from 85,800 to 92,100 tons (average of 88,500 tons) suggest that total catches estimated for 1975-78 of from 80,400 to 103,400 tons (average of 88,200 tons) are at about the MSY level, with the 1978 catch over 10,000 tons in excess of the highest MSY estimate. Since the MSY estimates are only as reliable as the data on which they are based, they must be evaluated with caution. If, for example, the recreational catches presented in this paper are overestimated and the magnitude of error is proportionally the same in all years, the MSY estimates will be proportionally lower. If, on the other hand, the catch estimates are seriously in error but lack any year-to-year consistency in the error, the effect on the MSY estimates would be dependent on the general direction of the error (up or down) but is somewhat uncertain. Assuming, however, the former case where catches may not be as large as estimated, the results of the MSY analysis suggest that current levels of catch, whether they are higher or lower than reported here, are at about the MSY level.

Surplus production models such as the one used to estimate MSY in this paper disregard, among other things, yearly environmentally-induced fluctuations in populations. 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. Both of these studies, as well as the work by 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. Accordingly, it must be concluded that current catch levels of bluefish may not be sustainable and if continued may result in a decline in abundance.

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Table 1. Bluefish catch (tons) along the Atlantic coast of the United States during 1960-78.

	USA Commercial				USA Recreational					
Year	North[1] Atlantic	Middle[2] Atlantic	South[3] Atlantic	Total	North[1] Atlantic	Middle[2] Atlantic	South[4] Atlantic	Total	Other countries	Total
1960	212	317	722	1,251	5,039[5]	11,723[5]	6,186[5]	22,948	-	24,199
1961	264	396	741	1,401	7,765	7,187	6,079	21,031	-	22,432
1962	423	877	956	2,256	12,441	15,917	7,842	36,200	-	38,456
1963	397	808	917	2,122	11,676	14,664	7,523	33,863	-	35,985
1964	365	427	889	1,681	10,735[5]	7,750[5]	7,293[5]	25,778	-	27,459
1965	599	584	640	1,823	28,709[5]	7,217[5]	5,121[5]	41,047	-	42,870
1966	583	723	964	2,270	17,147	13,122	7,908	38,177	-	40,447
1967	358	410	930	1,698	10,529	7,441	7,629	25,599	-	27,297
1968	364	637	1,152	2,153	10,706	11,561	9,450	31,717	-	33,870
1969	667	605	1,007	2,279	19,618[5]	10,980[5]	8,261[5]	38,859	-	41,138
1970	973	902	1,085	2,960	22,749[5]	22,549[5]	8,740[5]	54,038	-	56,998
1971	788	930	888	2,606	23,176	16,878	7,285	47,339	23	49,968
1972	646	1,044	1,221	2,911	19,000	18,947	10,016	47,963	18	50,892
1973	854	1,751	1,245	3,850	25,118[5]	31,779[5]	10,213	67,110	214	71,174
1974	794	2,296	1,283	4,373	26,303[5]	31,639[5]	10,525	68,467	99	72,939
1975	782	2,794	964	4,540	23,000	50,708	7,908	81,616	103	86,259
1976	489	2,963	958	4,410	14,382	53,775	7,859	76,016	1	80,427
1977	1,059	2,213	874	4,146	31,147	40,163	7,170	78,480	4	82,630
1978	1,840	1,968	1,064	4,872	54,118	35,717	8,728	98,563	-	103,435

[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]Estimated from angler survey; remaining years interpolated.

Table 2. Stratified mean catch per tow (kg) of bluefish in USA autumn bottom trawl surveys during 1967-78.

Year	Georges Bank (strata 13-25)	Southern New England (strata 1-12)	Middle Atlantic (strata 61-76)	Total (strata 1-25, 61-76)
1967	0.00	0.00	0.34	0.10
1968	0.00	0.03	0.00	0.01
1969	0.00	0.37	1.32	0.15
1970	0.00	0.17	0.00	0.06
1971	0.53	0.87	0.51	0.67
1972	0.84	1.38	0.00	0.81
1973	0.89	0.73	0.85	0.79
1974	2.72	0.91	0.65	1.54
1975	1.17	0.48	1.09	0.87
1976	0.16	0.64	1.69	0.48
1977	0.36	1.58	0.54	0.82
1978	0.94	0.43	0.79	0.72

Table 3. Estimated catch, autumn survey catch per tow, and relative exploitation index for bluefish along the Atlantic coast of the United States during 1967-78.

Year	Catch (tons)	Survey catch per tow (kg)	Relative exploitation index[3]
1967	27,297	0.10	272,970
1968	33,870	0.13[1]	260,538
1969	41,138	0.15	274,253
1970	56,998	0.41[2]	139,020
1971	49,968	0.67	74,579
1972	50,892	0.81	62,830
1973	71,174	0.79	90,094
1974	72,939	1.54	47,363
1975	86,259	0.87	99,148
1976	80,427	0.48	167,556
1977	82,630	0.82	100,768
1978	103,435	0.72	143,660

[1]Mean of 1967 and 1969.

[2]Mean of 1969 and 1971.

[3]Ratio between catch and survey catch per tow.

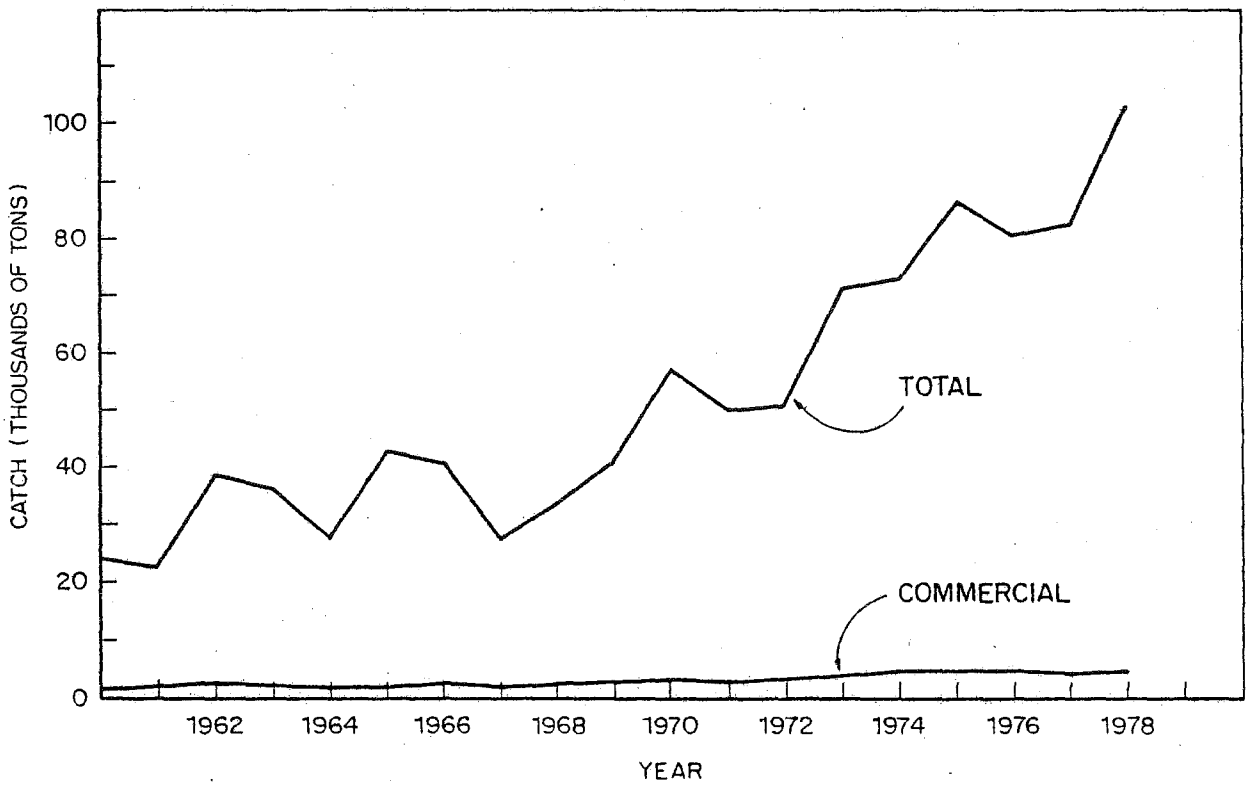

Figure 1. Total (USA recreational, USA commercial, and foreign) and USA commercial catch of bluefish along the Atlantic coast of the United States.

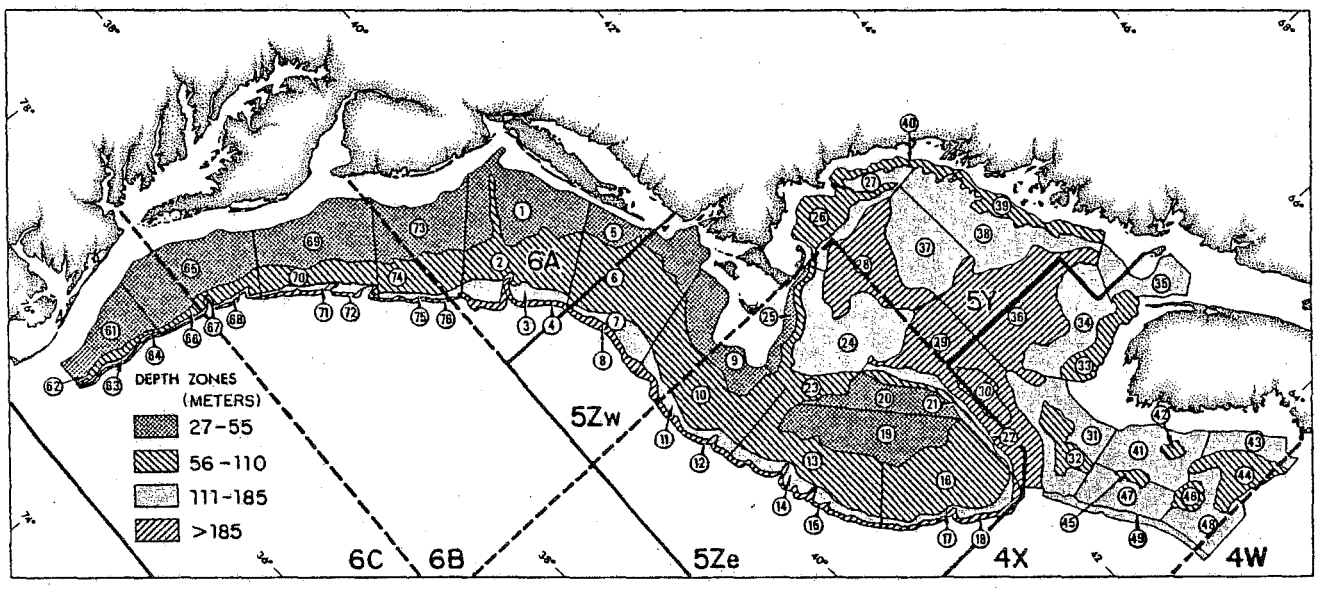

Figure 2. Sampling strata used in the USA research vessel bottom trawl surveys.

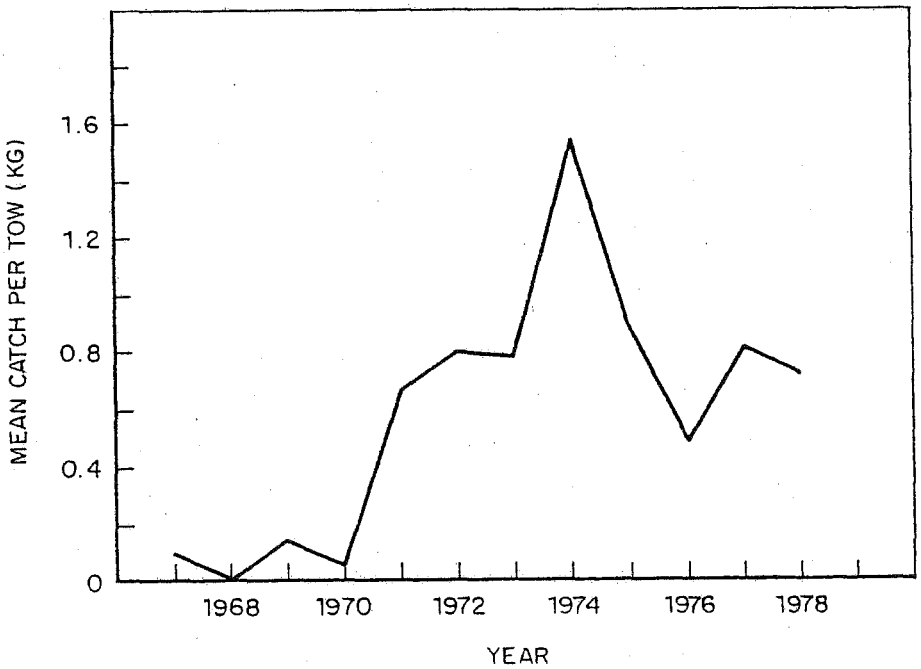

Figure 3. USA research vessel autumn bottom trawl survey catch per tow (kg) of bluefish (strata 1-25, 61-76).

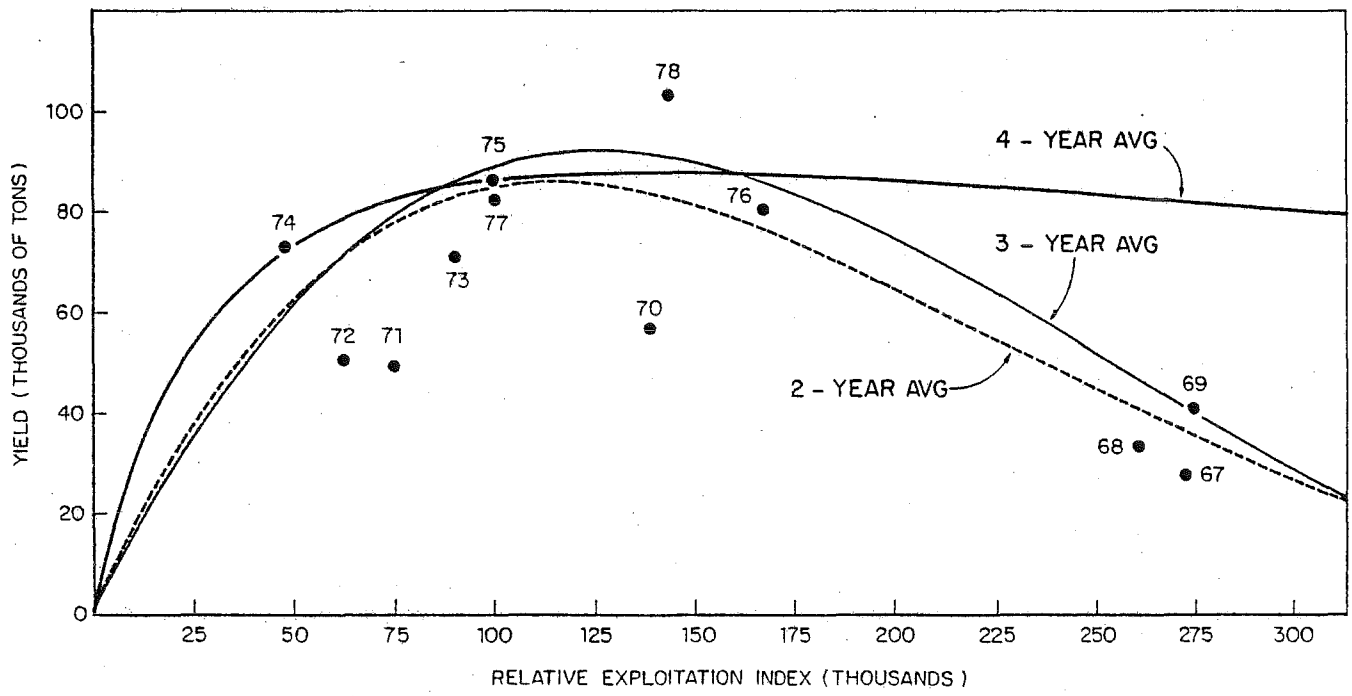

Figure 4. Relationship between equilibrium yield and relative exploitation of bluefish using 2-year, 3-year, and 4-year averaging periods for relative exploitation. Actual data points are plotted.