Potential Impact of PCB's on Bluefish, *Pomatomus saltatrix*, Management

PETER J. ELDRIDGE and G. MALCOLM MEABURN

Introduction

Bluefish, *Pomatomus saltatrix*, support a large recreational fishery along the Atlantic coast of the United States. Since 1979, anglers along the Atlantic coast have landed more bluefish (by weight) than any other marine species (Anonymous, 1989). Although the commercial catch increased steadily from 1960 through 1988 from 2.7 to 16.2 million pounds, approximately 90% of the total catch was taken by recreational fishermen (Anonymous, 1989). In 1988 and 1989, recreational catches of bluefish declined about one-half from levels of the early 1980's (USDOC, 1991).

Peter J. Eldridge is with the Southeast Regional Office, National Marine Fisheries Service, NOAA, 9450 Koger Blvd., St. Petersburg, FL 33702. G. Malcolm Meaburn is with the Charleston Laboratory, Southeast Fisheries Science Center, NMFS, NOAA, P.O. Box 12607, Charleston, SC 29422

ABSTRACT—Since 1979, anglers along the U.S. Atlantic coast have landed by weight more bluefish, Pomatomus saltatrix, *than any other marine species. A fishery management plan has been developed jointly by three fishery management councils and the Atlantic States Marine Fisheries Commission to preserve the bluefish resource. Major objectives of the plan include prevention of recruitment overfishing and reduction in waste of bluefish. In 1985, a Federal survey found PCB concentrations in larger bluefish (over 500 mm fork length) that exceeded the U.S. Food and Drug Administration tolerance level of 2 parts per million. Harvest strategies are presented in this article to protect the reproductive capability of bluefish while minimizing human health risks associated with dietary intake of PCB's.*

The present status of bluefish along the Atlantic coast is not well understood. Although commercial landings statistics have been gathered since 1880, recreational statistics have been collected only since 1979 (Table 1). Records of commercial landings and anecdotal accounts suggest that the abundance of bluefish has varied considerably in the past, especially north of Cape Hatteras (Hildebrand and Schroeder, 1928; Bigelow and Schroeder, 1953).

A Fishery Management Plan (FMP) was developed jointly by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic, the New England, and the South Atlantic Fishery Management Councils, with the Mid-Atlantic as lead (Anonymous, 1989). The major goal of the FMP is to preserve bluefish along the Atlantic coast. Primary objectives include:

1) Increase understanding of the condition of the stock and of the fishery.

2) Provide the highest availability of bluefish to U.S. fishermen while maintaining, within limits, traditional uses of bluefish (defined as commercial fishery not exceeding 20% of the total catch).

3) Provide for cooperation among the coastal states, the various regional marine fishery management councils, and Federal agencies involved along the coast to enhance the management of bluefish throughout its range.

4) Prevent recruitment overfishing.

5) Reduce the waste in both the commercial and recreational fisheries.

Table 1.—Atlantic coast commercial bluefish landings and recreational bluefish catch for 1979–88 in thousands of pounds[1].

Year of landings	Commerc. catch	Recreation. catch	Total catch	Percent commercial
1979	12,410	140,565	152,975	8
1980	15,118	153,468	168,586	9
1981	16,460	128,344	144,804	11
1982	15,944	124,722	140,666	11
1983	15,773	138,580	154,353	10
1984	11,862	86,701	98,563	12
1985	13,255	99,157	112,412	12
1986	13,951	130,877	144,828	10
1987	14,767	109,510	124,277	12
1988[2]	16,239	56,498	72,737	22
Mean catch	14,578	116,842	131,420	11

[1]Type A, B1, and B2 fish. Source: Anonymous, 1989: Table 12.
[2]Type A and B1 fish. Source: USDOC, 1991

The biologically driven objectives of the FMP do not take into consideration any management strategies that could be used to limit the consumption of bluefish found to contain unacceptable concentrations of environmental contaminants in their edible parts. There is a particular need to recognize that contamination of bluefish from polychlorinated biphenyls (PCB's) has been widespread over the past two decades and, while not a health problem for the general public, has been cause for concern among population groups who catch and consume large quantities of bluefish. Thus, implicit in the second FMP objective listed above and consistent with the other four objectives is a necessary constraint to minimize the risk of dietary exposure to PCB's.

Public awareness and concern over PCB's in bluefish led to an extensive survey of the Atlantic Coast fishery during 1984–86 (NOAA/FDA/EPA, 1986, 1987). It was found that only large bluefish, defined as >500 mm fork length (FL), contained PCB concentrations exceeding the Food and Drug Administration (FDA) tolerance level of 2 parts per million (ppm). The Federal agencies involved in the survey concluded that individuals who consume fish obtained from traditional commercial sources are adequately protected through application of the 2 ppm tolerance. However, the interpretive report of the survey (NOAA/FDA/EPA, 1987) noted that actions might be needed to control the PCB intake of persons who frequently eat large bluefish, e.g., some recreational fishermen and their families.

The presence of PCB's in bluefish is an important human health issue that should be taken into account in any management strategy designed to optimize yield of this species. The remainder of this report will explore alternative harvest strategies which incorporate safeguards for consumers of bluefish.

Stock Structure

There are at least two known spawning seasons and areas for bluefish along the Atlantic coast (Collins and Stender, 1987; Nyman and Conover, 1988). Wilk (1977) and Kendall and Walford (1979) reported the existence of spring spawners (April and May) in the South Atlantic region along the inner edge of the Gulf Stream from southern Florida to North Carolina and summer spawners (June through August) off the central U.S. Atlantic coast (i.e., Cape Hatteras to Cape Cod). These conclusions were based in part on the spatial-temporal distribution of larval bluefish (Norcross et al., 1974). Wilk (1977) and Kendall and Walford (1979) postulated that spring spawners, which spawn south of Cape Hatteras, produce juveniles which enter estuaries along the central U.S. Atlantic coast primarily north of the Cape. Juvenile bluefish tagged in the summer in Long Island Sound have been recaptured in the fall in southeastern U.S. coastal waters (Lund and Maltezos, 1970). In spite of uncertainty concerning stock structure of bluefish, fishery managers have assumed that there is only a single Atlantic stock.

Contaminant Status

The Federal PCB survey in 1985 (NOAA/FDA/EPA, 1986, 1987) sampled bluefish from North Carolina to Massachusetts stratified by season and size. Small fish were defined as those <300 mm FL; medium were 301–500 mm FL; and large fish were those >500 mm FL. No bluefish sampled in either the small or medium size category exceeded the FDA tolerance level of 2 ppm. However, PCB levels in some large fish at every sampling site exceeded the tolerance level (NOAA/FDA/EPA, 1987).

Fishermen in the southeastern United States may be exposed to a lower PCB risk because of the smaller size of fish captured there. Similarly, anglers in New England and central U.S. Atlantic coastal areas, who traditionally catch pan-size fish, would have minimal exposure. Conversely, anglers who concentrate on large fish in New England and along the central U.S. Atlantic coast may experience the greatest risk because of the size of their catch. Since consumption data for recreational anglers are not available, it is impossible to quantify the degree of risk to anglers who consume their catch.

Yield Per Recruit

Normally, yield-per-recruit (Y/R) analyses are used to develop fishing strategies to maximize yield in weight given various combinations of age at first capture (tau), growth, natural mortality, and fishing rates. However, traditional analysis may not be appropriate for bluefish because fish >500 mm FL may contain unacceptable levels of PCB's. Thus, utilization strategies should consider the potential impacts of PCB's in bluefish. Simply stated, fishing pressure should be concentrated on smaller (safer) fish due to the human health risk from PCB's. Larger fish could still be used as trophy fish while considerable benefits could also be gained by hook-and-release policies for larger fish. Hook-and-release strategies should be constrained by fishing mortality induced by this practice.

As stated, a major issue in fishery management is what degree of fishing can be sustained by a resource before it experiences recruitment failure. Although there is a general consensus that it is necessary to prevent recruitment failure by limiting fishing pressure, there is little agreement concerning the level of fishing pressure that should be employed to achieve that goal. In the case of bluefish, Crecco et al. (1987), using an equilibrium model, suggested that fishing pressure should not exceed 0.50 or recruitment declines could occur. This is supported by Slobodkin's (1973) observation that a 40–60% reduction of stock gives MSY for a wide range of values of theoretically assumed density dependence. Because of concern about recruitment overfishing, the Y/R analyses included a level of fishing pressure of F = M for all fishable age groups in order to produce a standard yield in which to compare alternative yield strategies. It is assumed that a F = M fishing strategy would optimize yield while safeguarding the reproductive capacity of bluefish (Tyurin, 1969; Mace and Sissenwine, 1989).

In the model presented here, alternative harvest strategies were directed toward applying greater fishing pressure on fish <500 mm FL because fish of this size contain relatively smaller amounts of PCB's and are not judged to be a human health risk. Conversely, fishing pressure was reduced on fish >500 mm FL because many of these fish have unacceptable levels of PCB's. Fish >500 mm FL are mostly age 5 or older although some 4-year-old fish will reach 500 mm FL. For this reason, fishing pressure in the model was reduced beginning with age-4 fish. Age-5 and older fish were judged fully exposed to PCB's and were assigned whatever the reduced fishing rate was for that harvest strategy (Table 2).

Results

Yield-per-recruit analyses were run by a Ricker Y/R program described by Paulik and Bayliff (1967). Input data are given in Table 2. The present version of the program was modified by the South Carolina Wildlife & Marine Resources Department to use on an IBM[1] compatible personal computer.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 2.—Input values for Ricker yield-per-recruit bluefish analyses.

Age	Weight at age (Pounds)	Inst. nat. mortality rates	Age at first capture	Inst. fish. mortality rates	Harvest strategy one	Harvest strategy two	Harvest strategy three	Harvest strategy four
1	0.24	0.20	1.0	0.10	1.0	1.0	1.0	1.0
2	1.32	0.25	2.0	0.15	1.0	1.0	1.0	1.0
3	3.11	0.30	3.0	0.20	1.0	1.0	1.0	1.0
4	5.26	0.35	4.0	0.25	1.0	0.3	0.3	0.5
5	7.48	0.40	5.0	0.30	1.0	0.1	0.3	0.5
6	9.57	0.45	6.0	0.35	1.0	0.1	0.3	0.5
7	11.44	0.50	7.0	0.40	1.0	0.1	0.3	0.5
8	13.05		8.0	0.45	1.0	0.1	0.3	0.5
9	14.30			0.50	1.0	0.1	0.3	0.5
10	15.51			0.55	1.0	0.1	0.3	0.5
11	16.41			0.60	1.0	0.1	0.3	0.5
12	17.13			0.70	1.0	0.1	0.3	0.5
13	17.71			0.80	1.0	0.1	0.3	0.5
14	18.17			0.90	1.0	0.1	0.3	0.5
15	18.54			1.05	1.0	0.1	0.3	0.5
				1.20				
				1.40				

Table 3.—Population parameters for bluefish cohorts in the absence of fishing given different instantaneous rates of natural mortality.

Insta. natural mortality rate	Cohort biomass (Pounds)	Total cohort number	Mean age for cohort	Mean weight of individuals
0.20	383,477	55,030	5.44	6.97
0.25	260,482	45,183	4.50	5.77
0.30	186,528	38,578	3.85	4.84
0.35	139,129	33,862	3.39	4.11
0.40	107,181	30,332	3.03	3.53
0.45	84,761	27,596	2.76	3.07
0.50	68,505	25,415	2.54	2.70

Relative harvest levels were compared for various combinations of tau, harvest strategies, and natural and fishing mortality rates. If the full fishing rate was applied to an age group, it was given a multiplier of one. If a partial fishing rate was applied it was given a multiplier of less than one, such as 0.1, 0.3, or 0.5. The fishing mortality rate for any given age group is the product of the fishing rate times the multiplier for that age group. The biomass of survivors for the respective fishing strategies was also computed. The initial number for each cohort was 10,000 age-1 fish (See Table 3 for cohort parameters in the absence of fishing). Standard yields for combinations of tau and instantaneous fishing and natural mortality rates are given in Table 4. Also given in Table 4 are relative yields for F = 2M vs. F = M. Natural mortality rates were chosen to include all likely estimates of M.

Because some bluefish >500 mm FL contain unacceptable levels of PCB's, it is possible to minimize human health risks by limiting exploitation of bluefish >500 mm FL (age 4 and older). The results of such a strategy were evaluated by employing harvest strategy two (HS 2) in which 4-year-old fish experience 30% of the fishing mortality rate exerted on age 1–3 year-old fish and fish aged 5 or greater sustain 10% of the rate of age 1–3 fish. Results in relative yields are given in Table 5. The first row of each set of computations gives the standard yield when F = M. The second row gives the yield corresponding to an instantaneous total mortality rate of Z = 0.70 , i.e., the "best" estimate of Z for bluefish at this time (Anonymous, 1989). The highest yield is shown in row three followed by a strategy that would produce about 90% of the standard yield (row 4).

Harvest strategy three (HS 3) reflects the case when full fishing pressure is exerted on 1–3 year old fish while all fish 4 years or older experience 30% of the full fishing pressure. Table 5 shows that when Z = 0.70, relative yields increase by 16–34% as fishing pressure increases.

Tables 6 and Figure 1 illustrate the impact of tau on yield. Most important, the level of fishing pressure that is required to maximize yield is directly related to tau. This is particularly true when tau is increased from one to two. For example, when tau = 1 and M = 0.20, the use of HS 2 results in a relative yield of 0.47; whereas, when tau = 2, the relative yield is increased 45% to 0.68. However, the increase in yield requires a doubling of the fishing rate which illustrates clearly the tradeoff between fishing rate and tau.

Relative yields are also influenced greatly by the harvest strategy (Table 6). However, differences in relative

Table 4.—Standard bluefish yields when F = M or 2M and all fishable age groups experience equal fishing mortality, but taus vary.

Inst. natural mortality rate	Inst. fishing mortality rate	Age at first capture (Tau)	Standard yield (Pounds) F = M	Yield when F = 2M (Pounds)	Relative yield F = 2M vs. F = M
0.20	0.20	4	26,349	31,518	1.20
0.20	0.20	3	26,021	29,167	1.12
0.20	0.20	2	24,092	24,507	1.02
0.25	0.25	3	21,447	23,993	1.12
0.25	0.25	2	19,824	19,983	1.01
0.30	0.30	3	17,910	20,234	1.13
0.30	0.30	2	16,631	16,849	1.01
0.35	0.35	3	15,161	17,394	1.15
0.35	0.35	2	14,216	14,577	1.03
0.40	0.40	3	12,990	15,175	1.17
0.40	0.40	2	12,350	12,870	1.04

Table 5.—Comparison of yields between harvest strategy one (standard) and harvest strategies two and four.

Inst. natural mortality rate	Inst. fishing mortality rate	Age at first capture (Tau)	Relative yield HS[1] 2	Inst. fishing mortality rate	Age at first capture (Tau)	Relative yield HS[1] 4
0.20	0.20	4	Standard (26,349)			
0.20	0.50	3	0.67	0.50	3	0.90
0.20	1.40	3	0.97	1.40	5	1.22
0.20	1.05	3	0.90	1.40	3	1.04
0.25	0.25	3	Standard (21,447)			
0.25	0.45	2	0.64	0.45	3	0.88
0.25	1.40	3	1.03	1.40	4	1.15
0.25	0.90	3	0.89	1.40	3	1.10
0.30	0.30	3	Standard (17,910)			
0.30	0.40	2	0.62	0.40	3	0.76
0.30	1.40	3	1.07	1.40	3	1.14
0.30	0.90	3	0.90	0.60	3	0.91
0.35	0.35	3	Standard (15,161)			
0.35	0.35	2	0.60	0.35	2	0.71
0.35	1.40	3	1.11	1.40	3	1.17
0.35	0.90	3	0.91	0.60	3	0.89
0.40	0.40	3	Standard (12,990)			
0.40	0.30	2	0.56	0.30	2	0.65
0.40	1.40	3	1.14	1.40	3	1.20
0.40	0.90	3	0.92	0.70	2	0.89

[1]HS = harvest strategy.

Table 6.—Comparison of yields among harvest strategies two, three, and four.

Inst. natural mortality rate	Inst. fishing mortality rate	Age at first capture (Tau)	Relative yield	Harvest strategy
0.20	0.45	1	0.47	2
0.20	0.35	1	0.58	3
0.20	0.30	1	0.66	4
0.25	0.50	1	0.50	2
0.25	0.40	1	0.59	3
0.25	0.35	1	0.66	4
0.30	0.55	1	0.53	2
0.30	0.45	1	0.60	3
0.30	0.35	1	0.67	4
0.35	0.55	1	0.56	2
0.35	0.45	1	0.62	3
0.35	0.40	1	0.68	4
0.40	0.60	1	0.59	2
0.40	0.45	1	0.64	3
0.40	0.45	1	0.69	4
0.20	0.90	2	0.68	2
0.20	0.55	2	0.77	3
0.20	0.45	2	0.84	4
0.25	1.20	2	0.74	2
0.25	0.70	2	0.80	3
0.25	0.50	2	0.86	4
0.30	1.40	2	0.81	2
0.30	0.90	2	0.84	3
0.30	0.60	2	0.88	4
0.35	1.40	2	0.88	2
0.35	1.40	2	0.89	3
0.35	0.80	2	0.91	4
0.40	1.40	2	0.94	2
0.40	1.40	2	0.96	3
0.40	1.40	2	0.97	4
0.20	1.40	3	0.97	2
0.20	1.40	3	1.04	3
0.20	1.40	3	1.05	4
0.25	1.40	3	1.03	2
0.25	1.40	3	1.10	3
0.25	1.40	3	1.12	4
0.30	1.40	3	1.07	2
0.30	1.40	3	1.14	3
0.30	1.40	3	1.17	4
0.35	1.40	3	1.11	2
0.35	1.40	3	1.17	3
0.35	1.40	3	1.21	4
0.40	1.40	3	1.14	2
0.40	1.40	3	1.20	3
0.40	1.40	3	1.24	4

Table 7.—Partial summary of parameter ranges associated with harvest strategies two, three, and four.

Instant. natural mortality range	Inst. fishing mortality range	Harvest strategy	Age at first capture (Tau)	Relative yield range
0.20–0.35	0.45–0.55	2	1	0.47–0.56
0.20–0.35	0.90–1.40	2	2	0.68–0.88
0.20–0.35	0.90–1.05	2	3	0.90–0.91
0.20–0.35	1.40–1.40	2	3	0.97–1.11
0.20–0.35	0.35–0.45	3	1	0.58–0.62
0.20–0.35	0.55–0.80	3	2	0.77–0.87
0.20–0.35	0.50–0.70	3	3	0.90–0.94
0.20–0.35	1.40–1.40	3	3	1.04–1.17
0.20–0.35	0.30–0.40	4	1	0.66–0.68
0.20–0.35	0.45–0.80	4	2	0.84–0.91
0.20–0.35	0.30–0.45	4	3	0.89–0.91
0.20–0.35	1.40–1.40	4	3	1.05–1.21

yields among strategies decrease as M increases. For example, when tau =1 and M = 0.20, the difference in yield between HS 2 and HS 4 is 40% but when tau = 3 and M = 0.35 the difference is only 9%. The reader should note that F also varies considerably in these comparisons. However, only maximum yields for tau and F combinations are compared in Table 6; thus, one should not expect F to remain constant.

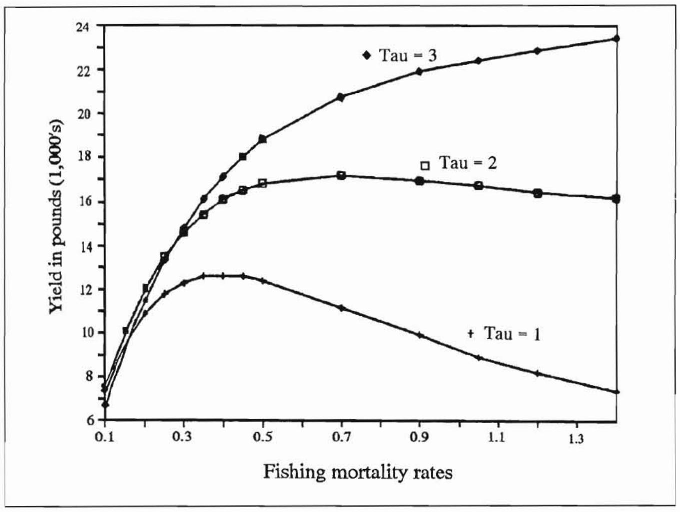

Figure 1.—Effect on yield by varying tau when M = 0.25 and harvest strategy three was used (yield in thousands of pounds).

Some of the harvest results are summarized in Table 7 to emphasize management options that have the twin objectives of safeguarding recruitment potential while reducing risks inherent in consumption of larger bluefish. The following general conditions are evident:

1) Relative yield increases from 3 to 40% when going from HS 2 to HS 6, depending upon tau.

2) Relative yield increases approximately 25–100% when tau increases from one to three (Fig. 1).

3) For HS 3 and HS 4, a range of 77–91% of the standard yield is obtained when tau = 2 and the starting fishing rate varies between 0.45 and 0.80.

4) For HS 3 and HS 4, a range of 89–94% of the standard yield is obtained when tau = 3 and the starting fishing rate varies between 0.30 and 0.70.

Relative yields and quantity of surviving biomass for different management strategies are presented in Table 8. It should be noted that there is a standard yield for both tau = 2 and tau = 3. This was done because the yield when tau = 2 is always less than when tau = 3 given the harvest strategies illustrated in Table 2.

The most prominent result shown in Table 8 is that when F initially equals or exceeds twice the values of M and tau = 2, the fraction of original biomass remaining is always less than 0.25, which may lead to recruitment failure. However, relative yields in these cases are comparable to other strategies. It is apparent that, under steady state conditions, initial harvests by themselves are not good indicators of stock condition because catches are based on past recruitment and fishing effort. In contrast, future stock abundance may be dependent almost entirely upon recruitment, which can be derived only from adequate spawning biomass, i.e., the complement of yield.

Discussion

Major objectives of the bluefish FMP include reduction of waste and prevention of recruitment failure. As noted previously, larger bluefish are more likely to contain PCB's. Because larger females spawn more frequently and contribute substantially more eggs than

Table 8.—Alternative yield strategies to optimize physical yield while maintaining adequate spawning biomass.

Yield type	Fraction of virgin biomass remaining	M	F	Tau	Harvest strategy	Relative biomass	Yield in pounds	Relative yield
S	0.48	0.20	0.20	4	1	1.00	26,349	1.00
S	0.41	0.20	0.20	3	1	1.00	26,021	1.00
S	0.34	0.20	0.20	2	1	1.00	24,092	1.00
A	0.41	0.20	0.50	3	2	1.01	21,204	0.81
A	0.43	0.20	0.30	2	2	1.26	16,064	0.67
A	0.33	0.20	0.40	2	2	0.98	17,807	0.74
A	0.37	0.20	0.50	3	3	0.90	23,688	0.91
A	0.43	0.20	0.30	3	4	1.05	23,556	0.91
A	0.23	0.20	0.55	2	2	0.69	18,973	0.79
A	0.21	0.20	0.55	2	3	0.62	20,323	0.84
A	0.22	0.20	0.45	2	4	0.64	22,231	0.92
S	0.42	0.25	0.25	3	1	1.00	21,447	1.00
S	0.34	0.25	0.25	2	1	1.00	19,824	1.00
A	0.43	0.25	0.55	3	2	1.03	17,682	0.82
A	0.46	0.25	0.30	2	2	1.38	13,116	0.66
A	0.37	0.25	0.40	2	2	1.10	14,745	0.74
A	0.39	0.25	0.55	3	3	0.94	19,442	0.91
A	0.44	0.25	0.35	3	4	1.07	19,333	0.90
A	0.20	0.25	0.70	2	2	0.61	16,585	0.84
A	0.19	0.25	0.70	2	3	0.56	17,229	0.87
A	0.23	0.25	0.50	2	4	0.69	18,450	0.93
S	0.43	0.30	0.30	3	1	1.00	17,910	1.00
S	0.34	0.30	0.30	2	1	1.00	16,631	1.00
A	0.56	0.30	0.40	3	2	1.30	12,213	0.68
A	0.48	0.30	0.30	2	2	1.43	10,923	0.66
A	0.39	0.30	0.40	2	2	1.15	12,431	0.75
A	0.45	0.30	0.60	3	2	1.04	15,042	0.84
A	0.42	0.30	0.60	3	3	0.97	16,310	0.91
A	0.46	0.30	0.40	3	4	1.07	16,160	0.90
A	0.23	0.30	0.60	2	4	0.67	15,761	0.88
S	0.45	0.35	0.35	3	1	1.00	15,161	1.00
S	0.34	0.35	0.35	2	1	1.00	14,216	1.00
A	0.60	0.35	0.40	3	2	1.33	9,997	0.66
A	0.51	0.35	0.30	2	2	1.47	9,246	0.65
A	0.42	0.35	0.40	2	2	1.24	10,632	0.75
A	0.49	0.35	0.60	3	2	1.09	12,512	0.83
A	0.47	0.35	0.60	3	3	1.03	13,480	0.89
A	0.48	0.35	0.45	3	4	1.07	13,727	0.91
A	0.20	0.35	0.80	2	4	0.59	13,818	0.91

do smaller females, they appear to have more reproductive value than smaller spawners. Thus, the dual objectives of reducing waste and minimizing the possibility of recruitment failure may be achieved by partitioning F among age groups as demonstrated by the Y/R analyses. It should be noted that overall F in the Y/R analyses was compared to an F = M strategy as represented by the standard yield. The analyses showed that fishing pressure should be kept minimal on 1-year-old and 5-year-old and older bluefish to obtain an acceptable yield while at the same time minimizing the capture and consumption of bluefish likely to present a human health risk. Further, if the resource were to decline rapidly in an unexpected manner, fishing pressure should be lessened on 2-year-old fish.

Present bluefish management measures do not address the PCB problem. Yet, PCB's are legally classified as unavoidable environmental contaminants for which there is a temporary tolerance of 2 ppm in the edible portions of fish and shellfish. Consequently, public health agencies have the authority to restrict or close a fishery, including the bluefish fishery, based on the concentrations of PCB's found in fish samples. Recreational fishermen and their families who regularly consume large quantities of large bluefish, may be exposing themselves needlessly to PCB residues. If fishery managers continue to ignore the PCB problem, public health agencies may be forced to act by default. Their most likely action would be to close the fishery and prohibit the sale of larger bluefish. Both courses of action would cause substantial economic dislocation, especially for the recreational for-hire sector (charter and headboats). The alternative yield strategies described earlier would provide managers with an opportunity to minimize dietary exposure to PCB's without closing the fishery or decreasing the pleasure of the sport.

Given the complex nature of fishery management decisions, it is unlikely that an optimal fishing strategy, such as harvest strategy three, could be implemented immediately. Rather, a partial implementation strategy, such as harvest strategy four, may be more acceptable. The advantage of such a course of action would be to change gradually, but with deliberate speed, the present conduct of the fishery and to obtain empirical evidence of the results of such a policy.

Recommendations and Research Needs

The following recommendations and research studies are suggested:

1) Implement a management program based either on harvest strategy three or four to minimize the capture of larger bluefish.

2) Implement a minimum size limit for bluefish to minimize the catch of 1- and possibly 2-year-old fish.

3) Maintain an appropriate commercial quota.

4) Implement a bag limit that a) constrains F less than M and b) encourages anglers to retain only smaller fish by assigning points to different size fish as is done in some states for waterfowl (Nelson and Low, 1977). For instance, in a 100-point system fish >500 mm FL could be assigned a value of 50 points; whereas, fish <500 mm FL could have a value of 10 points. In this scenario the angler can vary the size and number of fish caught, provided that the sum of the catch does not exceed 100 points.

5) Institute a statistical and monitoring program that will enable managers to track the bluefish resource and evaluate the impacts of management measures.

The above program would permit managers to safeguard the reproductive stability of bluefish while minimizing any potential health risk associated with consumption of bluefish contaminated with PCB's. Management measures can be refined and improved while additional research is undertaken to improve our understanding of bluefish contamination and dynamics.

Because it is uncertain if bluefish found south of Cape Hatteras belong to the stock of bluefish north of Cape Hatteras, it is important that PCB data be collected for bluefish in the southeastern United States and Gulf of Mexico using the sampling procedures employed in the 1984–86 survey. Some sampling should also be carried out north of Cape Hatteras because the earlier PCB data are becoming outdated. Further, to assess the health risk to recreational fishermen, it is recommended that a survey be conducted to obtain detailed consumption data for bluefish as well as other species that are important to recreational and commercial fishing interests.

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