NOT FOR QUOTATION

A Bio-Economic Rationalization of a Fishery

by

William E. Schaaf

Ernest W. Carlson

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I. A Bio-Economic Rationalization of a Fishery

The decline of Atlantic menhaden landings since 1962 has raised the question as to whether or not the decline was due to overfishing. In this report, however, we have not relied on this concept as a guide to proposing management. Instead, we have asked the question, given the present fishery, how can it be improved for the menhaden industry and the nation. We will show that modest, but reasonable gains can be expected from management in terms of both higher yields and lower costs of operation. The management strategies we are suggesting may restore the fishery to its former large catches, but we will refrain from asserting this.

The analysis we will discuss suggests that if recruitment is constant, a decreased fishing mortality on young fish from Chesapeake Bay southward and an increased fishing mortality on older fish to the north would increase the Atlantic catch and decrease operating costs. The change needed to accomplish this would represent an initial loss to the Industry but would be compensated by greater catches at lower operating costs in a short time. We must emphasize that this analysis is intended only as a guide to show how the Atlantic menhaden industry could be managed for greater yields. The numerical results depend upon some assumptions which require verification and some estimates of mortality rates and growth rates which may become more precise. The results can provide only an insight into expected trends from management and should not be considered exact predictions of future yields.

II. Population Dynamics

In any population of fish, the higher the total mortality rate the lower the average age. For instance, if 50% die every year, then only 13% of a year class survive beyond age 3; and if 75% die every year, then only 2% survive beyond age 3. In harvesting a population of fish some fraction of the total mortality rate is due to fishing (called "rate of exploitation"). For a fixed total mortality rate, the higher the rate of exploitation, the greater the yields to fishermen since fewer fish die from natural causes and more are caught. Thus, yield increases with increased rate of mortality due to fishing (called "rate of fishing", or F). If the rate of mortality from natural causes (M) is constant, then as F increases, the population becomes younger; more fish are caught (because F is increasing), and more younger fish are caught. The yield increases up to a certain level not only because more fish are caught, but also because the younger fish have a higher relative growth rate than older fish. If F increases too much, however, the yield declines; because, even though more fish are caught, they are so young that their total weight cannot equal the total weight of fewer larger fish. So, in general, we can anticipate the type of relation between F and the expected yield from each recruit entering the fishery to be like that shown in figure 1. Further, it can be seen that some balance point occurs between F and M resulting in a maximum yield per recruit. The exact shape of the curve depends upon the natural mortality rate and the growth rate. One of the prime requisites for understanding and achieving rational management of a fishery is to be able to estimate the total mortality rate, and to separate the total rate into F and M.

It is much more difficult for a fishery biologist to estimate the total yield to a fishery, because this depends upon the number of recruits entering. The number of recruits should depend upon the number of fish of spawning age in the population, which is determined by the total mortality rate. But often recruitment is fairly constant even though a wide range occurs in the number of spawners. Also environmental conditions can cause large fluctuations in recruitment from a constant number of spawners.

Often, however, it is possible to make some sound management judgements based entirely upon the yield per recruit concept discussed above. We calculated some curves of yield per recruit for the Atlantic menhaden fishery using average age specific weights and the estimate of natural mortality of 35%. We also calculated yield per recruit for M equal to 25 and 40%, but since these curves were not qualitatively different from those for 35%, we present only the latter results.

Results from simulating the entire Atlantic coast menhaden fishery, by fishing on all ages, are shown in figure 1. We assumed that only 70% of F was applied to 1 year old fish and only 10% of F applied to age-0 fish. The maximum yield per recruit occurs at an F of 0.7.

With an F of 0.7 and an M = 35%, we would expect 11.5% of the population to be greater than age-2. During the last four years, the catch of fish greater than 2 has averaged 6.5% of the total catch. Assuming that the age distribution of the catch estimates the age distribution of the population, this would imply an F of about 1.0. A 36% reduction in F would, by allowing the population to get older, result in a 3% increase in the yield per recruit.

These calculations imply a management strategy for an equilibrium population and fishery along the entire coast. The yield per recruit curve looks considerably different if we simulate a fishery just in Chesapeake Bay and the South Atlantic (including the N.C. fall fishery). We did this by applying fishing rates to only the first four age classes (0 through 3). Again, we imposed 70% of F on age-1's and 10% on 0's. These results are shown in figure 2.

We observe that for any F the yield per recruit is considerably below that resulting from an entire fishery. However, there is no maximum point on the curve; yields continue to rise with increasing F. This is a general result from fishing on only younger age classes. Here, a 36% reduction in F from 1.1 to 0 results in an 8% reduction in landings.

III. Economics of F

The fishing mortality or F in the above models is generated by the industry as it deploys its vessels and catches fish. In all of our analyses we have assumed that F is directly proportional to the number of vessel weeks of effort fished. The deployment of a vessel for a season is expensive and it is reasonable to assume that industry wants to receive the highest returns possible for its expenditures in operating vessels. The preceding figures indicate that if the fishery is operated as a southern fishery, the yield to the industry from a recruit is only two thirds of what it would be if the fishery generated the same fishing mortality over the whole fishery.

In addition to weighing more, fish of the same age taken from the northern fishery tend to have higher product yield. The average value per ton of fish from the middle Atlantic is 18% more valuable than Bay fish. The south Atlantic fish average 11% less valuable than Bay fish because they produce less oil.

The industry could decide that it was in its best interest to reallocate fishing effort to make better use of the menhaden resource. This reallocation would result in a smaller total number of fish being caught, but this total number of fish must necessarily be composed of fewer southern fish and more northern fish. Industry also might find that it could make this transition and operate at a smaller cost than at present.

There are many problems associated with changing patterns of fishing to obtain a higher yield from the resource. One major problem is that a reduction of effort, in present high effort areas, will initially result in a reduced catch in these areas. This means that some plant and equipment that would otherwise be operating might be idle. Vessels could, of course, be reallocated in later periods so that few of them would be permanently idle.

Two possible transition paths from the estimated current fishing levels of 1.1 to a fishing level of 0.7 are shown in figures 3 and 4, under the assumption that all year classes are the same size. We will assume as a first approximation that costs (including a nominal profit) are proportional to fishing mortality and that at the present time the revenues from the sale of fish are equal to the cost of producing them.

With no change in current fishing activity the fishery will produce 77 grams per recruit each year. Over the next 14 years there will be a total production of 1,078 grams from the 14 recruits, at a cost of 1,078 grams. Under the above assumptions, the fish will be sold for what it costs to produce them so that no profits above a nominal profit will be generated by the industry.

In the transition path illustrated in figure 3, fishing mortality is dropped from 1.1 to 0.7 in one period and then held there. This drop in fishing would represent a reduction in cost of approximately 36 percent in the year that the drop took place and in subsequent years. There would be an initial drop in catch and revenues of 26 percent. The catch would reach present levels in four years and would continue to increase in the following years until it had reached equilibrium in year 8, at approximately 3 percent above present levels. Over the next 14 years, the fishery would produce 1,068 grams from 14 recruits with a cost of 637 grams. The difference of 431 grams between catch and costs would represent profit for the industry expressed in weight of fish.

The second transition path is illustrated in figure 4. This strategy shows what might be done if industry took a more cautious attitude toward managing the fishery. In this strategy fishing activity is reduced in steps of 0.05 (approximately 5 percent) per year until it reaches .7. This drop of activity reduces catch in the first year to 76 grams from its previous level of 77 of 1.4 percent. Catch would drop very little from current levels throughout the transition period. Total catch over a 14-year period would be 1,060 grams. Total costs over the period would be 782 grams. Industry profits would be 278 grams of fish.

Either course of action would seem to be very attractive to the industry. The prospective returns are high enough so that some risk would appear to be justified.

Experiments indicate that the first transition path described above will give the highest returns to the industry, of several alternatives that we have examined. The actual costs and returns depend upon the pattern of recruitment to the fishery. If the shift in fishing mortality were undertaken as poor year classes were entering, the apparent losses in catch would be much higher. If, on the other hand, the management experiment was undertaken as a series of good year classes were entering the fishery, the immediate effect of the reduction in fishing mortality would not be apparent in the catch.

IV. The Reduction of F

At the present time, as all of you know, there is no agreement at the national level for reducing the fishing mortality for Atlantic menhaden. While industry is presently precluded by anti-trust laws from negotiating a reduction internally, it is possible that the states concerned could be persuaded to help the industry negotiate reductions in fishing mortality and in enforcing the agreement. It is likely, however, that the rationalization of the menhaden fishery will have to await the passage of bills now being considered in Congress for effective overall management to take place. If it becomes possible to change fishing patterns we should prepare ourselves by calculating their effects.

It is difficult to regulate fishing mortality directly. The best and probably only way to approximate its regulation is by quotas. Quotas can be derived by utilizing pre-recruit survey data, age composition of the previous year's catch data, and migration data from tagging studies. By applying the target fishing mortality with estimates of natural mortality, the target catch in numbers from each year class could be derived. By multiplying these numbers by average weight for each age, a desired overall quota in tons could be derived.

IV. c. 1. Age/Geographic Stratification

The age stratification of the menhaden population along the Atlantic coast increases from south to north, and within an age group the average size increases with latitude. This means, for instance, that a larger percent of 3's are caught in the middle Atlantic region (Delaware and New Jersey) than in Chesapeake Bay, and the 3's that are caught in the middle Atlantic average 47% heavier. An historic comparison of landings in the middle Atlantic and Chespeake Bay will show the effect of this biological characteristic of the menhaden population. During the five consecutive peak years of the fishery, 1955-1959, the average number of fish landed at middle Atlantic ports was 1/3 the number landed at Chesapeake Bay; but the weight landed averaged 2.5 times the weight in Chesapeake Bay.

This phenomena complicates the application of a catch quota to the fishery. A single quota cannot be applied without regard to where, along the coast, the fish are taken. A single quota taken entirely in the south Atlantic would kill more fish, hence result in a higher F.

Under equilibrium conditions and fishing at an F which maximizes the yield per recruit (0.7), 31% of the catch by weight should come from fish of age-3 and above. This means that % of the quota, under equilibrium, should be landed north of Chesapeake Bay.

IV. c. 2. Quota - Who

Obviously, if the quotas were allocated by area without further adjustment some firms would have smaller catches than they do at present, even though the industry as a whole would have increased catches. We believe that the industry could find a way of compensating those who would lose the most to rationalize the fishery. For example, airline companies have found a way to assist each other during strikes. Since an airline operating the same routes but not on strike would make more by carrying passengers who would have flown on the airline on strike, a portion of this increased revenue is transferred to the airline on strike. The menhaden industry could do somewhat the the same by either direct compensation from increased industry profits, or reciprocal processing agreements.

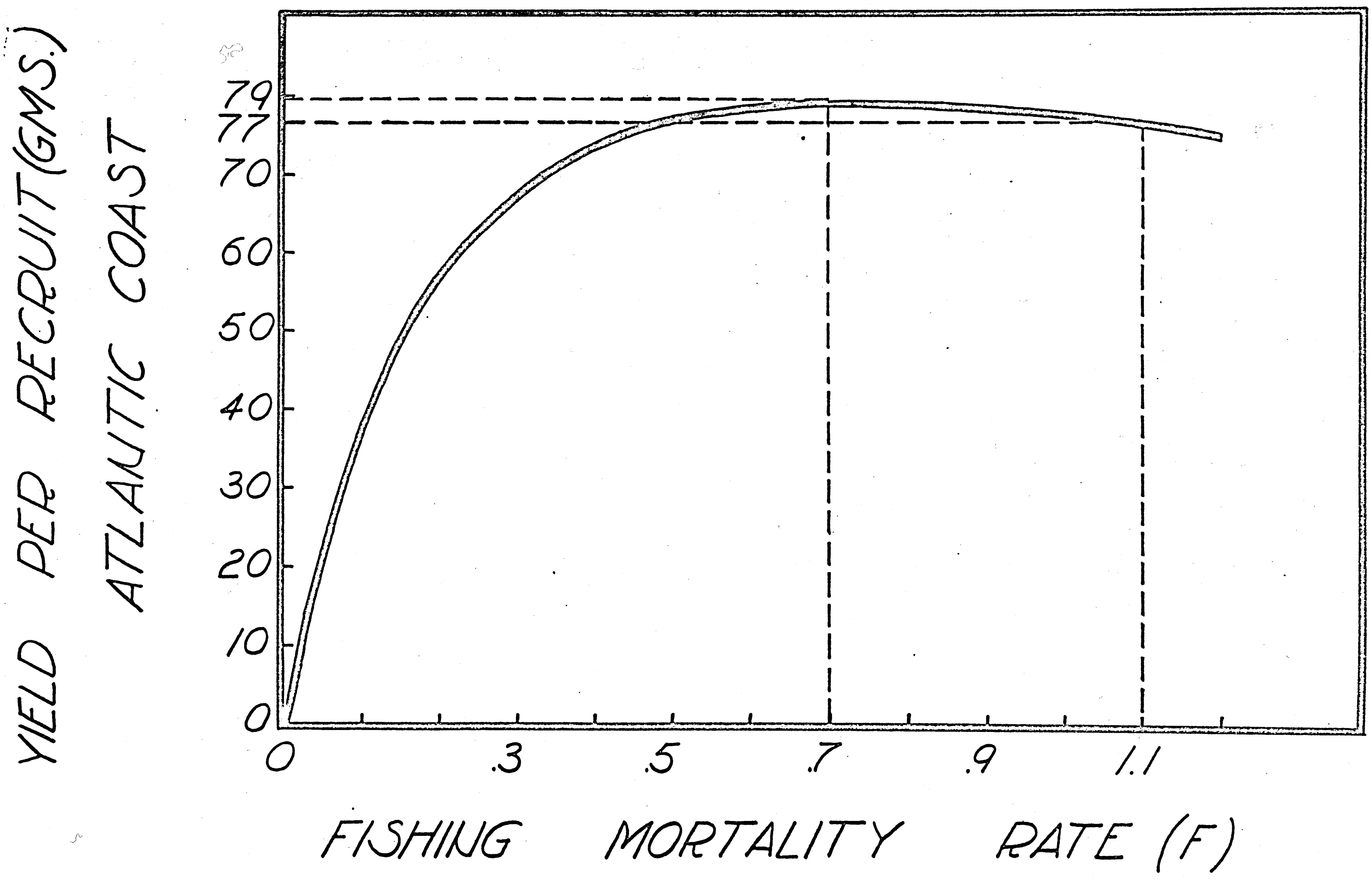
V. Summary of Benefits from Management

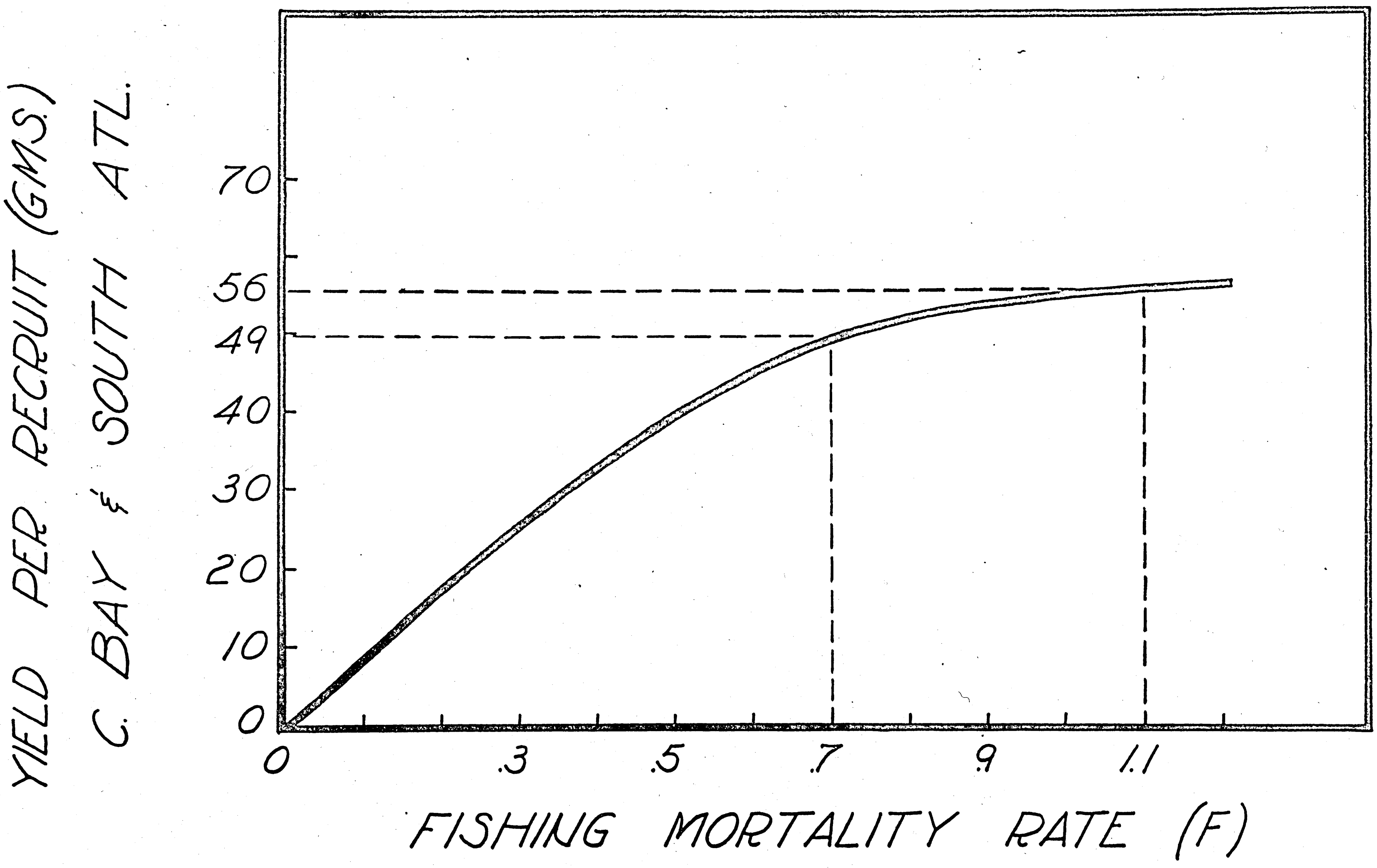
The benefits from management of the Atlantic menhaden will be summarized from the industrial and national aspects. Some benefits can be classified as near certain and others as speculative. The models and data indicate that at least as much and probably more tonnage as is currently being taken from each entering year class can be taken at a 35% reduction in cost. This indicates that although the industry will not necessarily be any larger, it may be more prosperous. The social benefit from this, is that it is always in society's interest to produce products at less cost. This frees resources, in this case primarily people, to produce in other industries. In addition, because of the age stratification of menhaden more products will be produced from the same tonnage of fish landed, if the fishery is managed. This would mean an increase in value of the final product of from 15-20% even if there were no change in total catch.

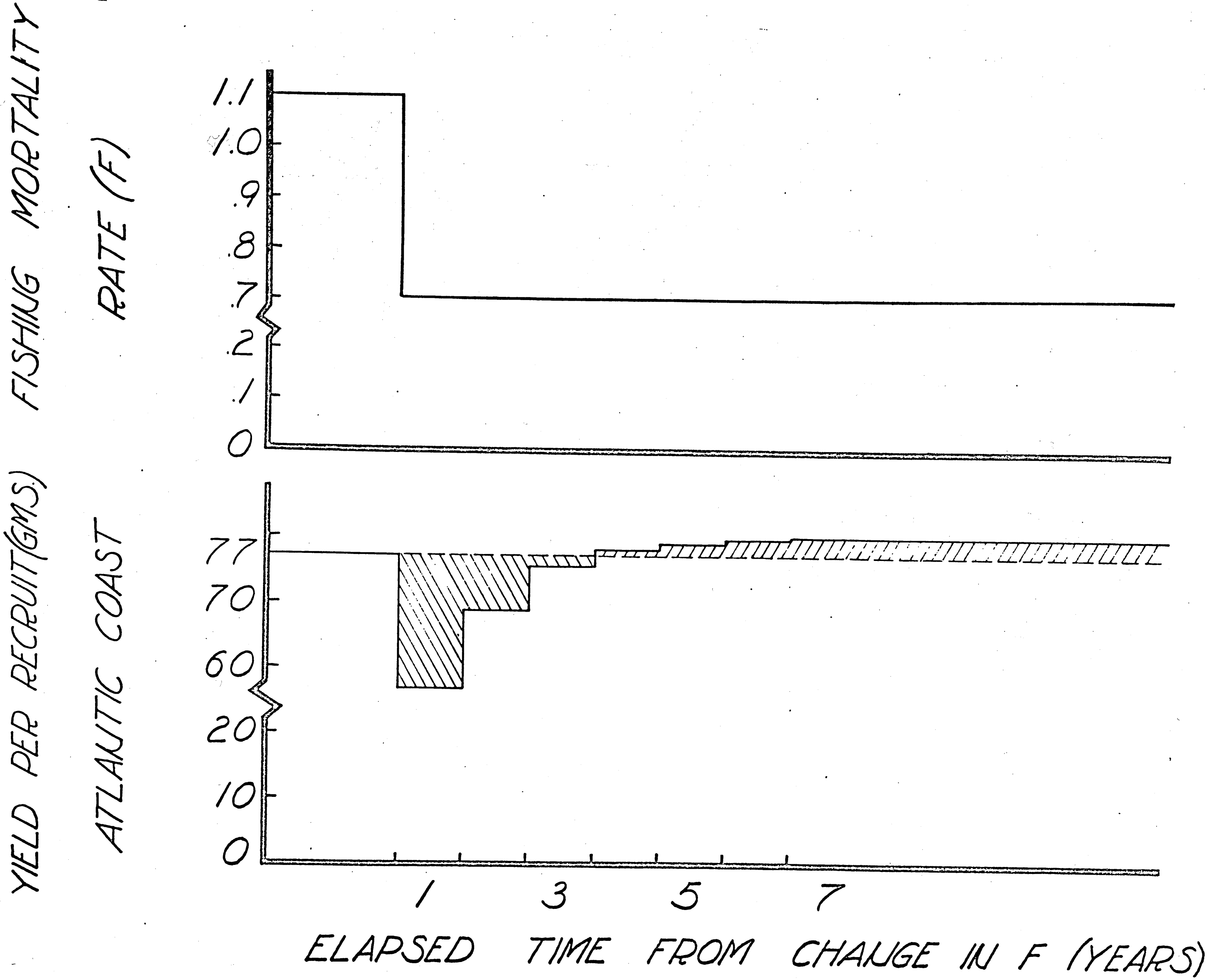
All of our analyses up to this point have dealt with what is certain to happen to a single year class of fish by manipulating the fishing mortality rate. The arguments also apply to all age classes simultaneously, given constant recruitment and assuming that the natural mortality rate does not change. However, there are other benefits which could potentially result from reducing F. As pointed out above, reducing the mortality rate allows more fish to reach older ages. An F of 1.1 results in 7% of the population being of spawning age (3 and older); an F of 0.7 results in 12% being spawners. More spawners should result in more recruits to the population. Adding more recruits to the population allows larger yields with the same F.

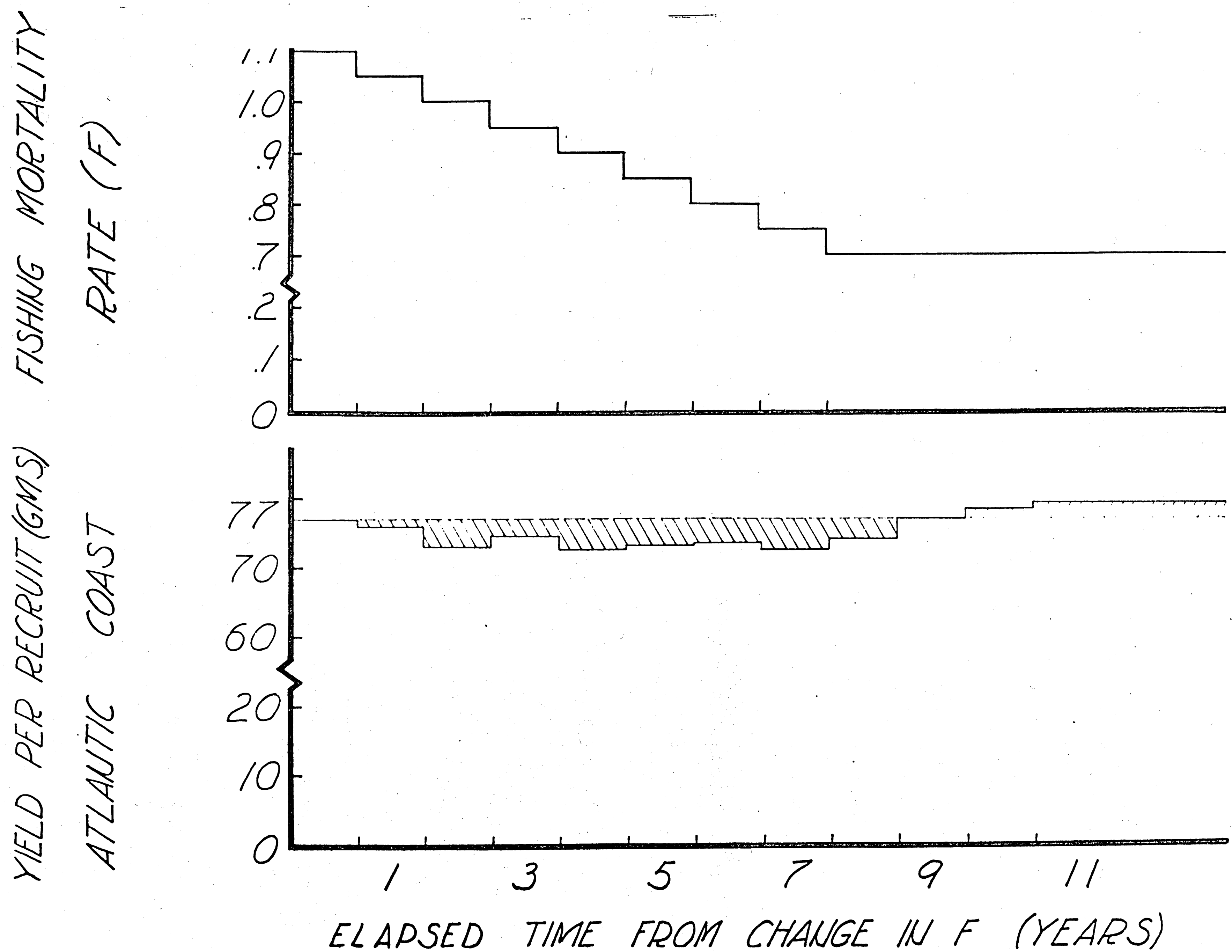
The relation between number of spawners and number of recruits is complicated and certainly not linear; but with very low abundance of spawners we should not expect large year classes to be produced under average environmental conditions. Since 1965, the catch of spawning age fish has averaged only 14% of the previous nine years and resultant recruitment since 1964 has averaged 44% of the previous nine years. If recruitment could be doubled by increasing the number of spawners, we could expect much greater returns to the industry.

The reduction in operating cost, increased value of the product, and potential increases in recruitment, taken together, indicate that the benefits from menhaden management are substantial and that the industry might wish to work together in order to expedite the institution of a management scheme beneficial to the entire industry.


YIELD PER RECRUIT (GMS.)
ATLANTIC COAST
79
77
70
60
50
40
30
20
10
0
0
.3
.5
.7
.9
1.1
FISHING MORTALITY RATE (F)


YIELD PER RECRUIT (GMS.)
C. BAY & SOUTH ATL.
70
56
49
40
30
20
10
0
0
.3
.5
.7
.9
1.1
FISHING MORTALITY RATE (F)


FISHING MORTALITY RATE (F)
1.1
1.0
.9
.8
.7
.2
.1
0
YIELD PER RECRUIT (GMS.) ATLANTIC COAST
77
70
60
20
10
0
1
3
5
7
ELAPSED TIME FROM CHANGE IN F (YEARS)


FISHING MORTALITY
RATE (F)
1.1
1.0
.9
.8
.7
.2
.1
0
YIELD PER RECRUIT (GMS)
ATLANTIC COAST
77
70
60
20
10
0
1
3
5
7
9
11
ELAPSED TIME FROM CHANGE IN F (YEARS)