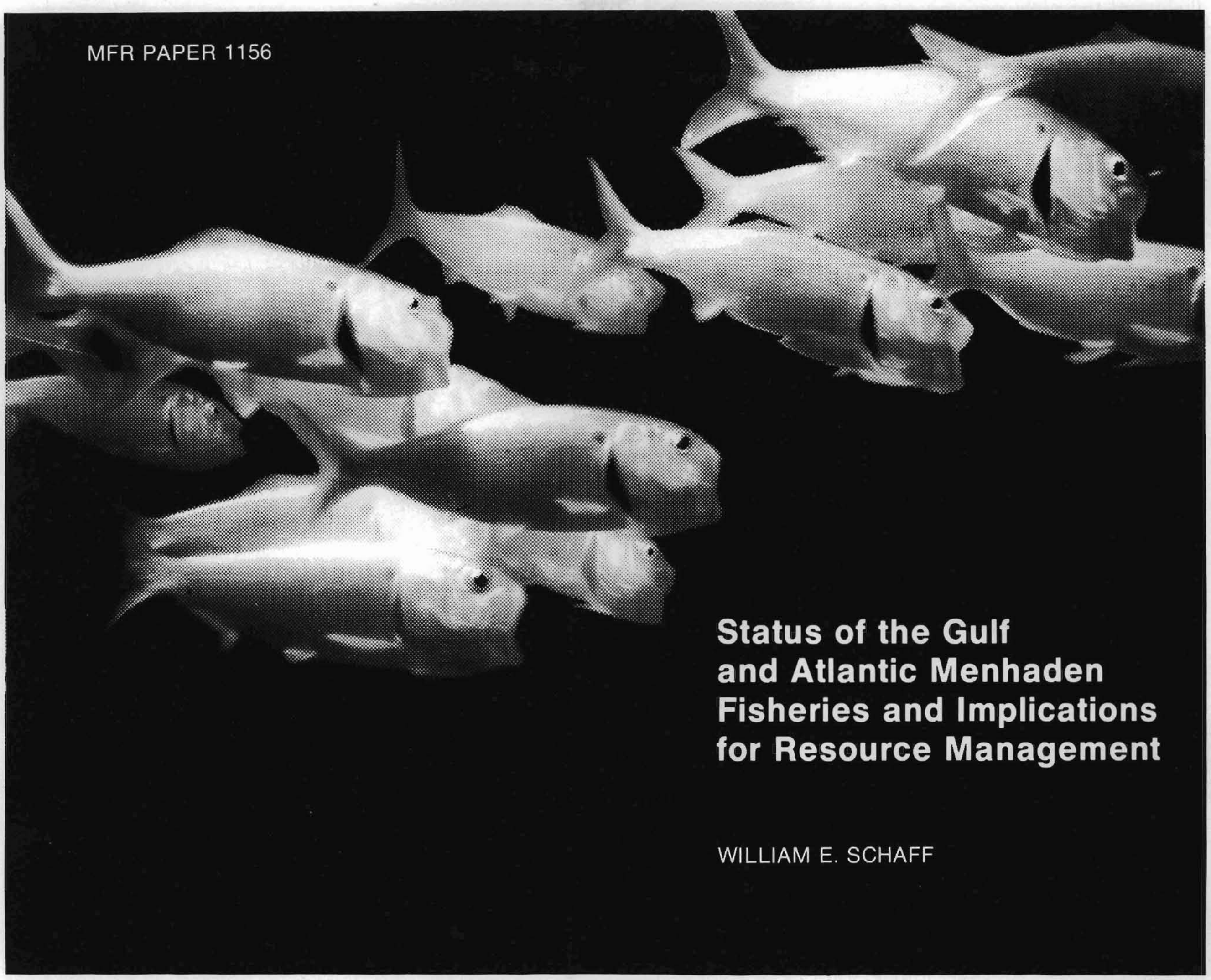

MFR PAPER 1156

Status of the Gulf and Atlantic Menhaden Fisheries and Implications for Resource Management

WILLIAM E. SCHAFF

ABSTRACT—The history and status of federal biological studies of Atlantic menhaden, Brevoortia tyrannus, *and Gulf menhaden,* B. patronus, *are discussed in relation to fisheries management. The historical development of the two fisheries indicates 1) the dangers of overfishing, 2) the positive effects of reducing effort in an overexploited fishery, and 3) the potential benefits of limiting effort in a productive fishery. Several issues crucial to developing specific management plans are discussed according to biological principles. This leads to a concept of management that requires fishery models that can specify alternative plans. Implicit with this concept is a willingness to adopt minimal management that can be implemented soon and is flexible. Models of the two menhaden fisheries are presented to support implementation of initial catch quotas before limiting effort. Both fisheries offer a favorable opportunity for establishing a management plan for wise utilization of resources. The ideas presented here are to direct attention to the need for management and to serve as guides toward management alternatives.*

INTRODUCTION

At a time when there is much discussion regarding the management of our Atlantic and Gulf menhaden fisheries it seems necessary and appropriate to discuss, as concisely as possible, the need for management, the status of the stocks and the data base for such assessment, historical precedents for management, and some key management issues. The issues discussed in this paper are not exhaustive but are considered to be of primary importance from a restricted point of view.

The purpose of the paper is to summarize our knowledge of the menhaden fisheries; the problems, as we view them; some tentative solutions based upon a traditional biological view; and to indicate problem areas which preclude a complete or optimal management plan. It is intended as a prototype for the interdisciplinary dialogue which will be necessary to achieve wise utilization of one of our great natural resources.

The scope of this issue paper will be confined to a rather traditional biologist's view of the resource and its response to harvesting at various levels of intensity, particularly the total

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yield and the yield per unit of fishing effort. Those issues dealing with biological management will be discussed in greater detail, while issues dealing with the economics of the industry, social values, or political institutions will be mentioned where appropriate, but not dealt with specifically.

The needs for management will be demonstrated more fully when dealing with the historical trends in catch and effort for each fishery and with the models and deductions from biological data, but some introductory remarks may put the needs in perspective. First is the expressed desire for management, by some segments of the industry. The current industry attitude appears to seek a management plan that will involve cooperation between States, Federal agencies, and the industry, a concept we endorse. There is some anxiety in industry about possible new investment, overcapitalization, and eventual resource depletion. Some industry representatives have actively worked toward establishing a management subcommittee of the Gulf States Marine Fisheries Commission (GSMFC) that can formulate and propose regulations. Fishery biologists consulting for industry also endorse management. Secondly, the history of landings in both fisheries demonstrates the benefits to be gained by regulating fishing effort at a level which will produce the maximum sustainable value. Many people feel that the Gulf fishery is near its peak, and they would rather restrict it now than suffer a collapse similar to the Atlantic. Finally, we have many precedents among marine fisheries that have declined. Unfortunately, most examples are of fisheries that have not been managed at all, with attendant economic extinction. The great Pacific sardine reduction fishery is a good example. The extensive experience with the North Sea trawl fishery for many species, its depletion, rehabilitation with reduced effort during the war, and subsequent depletion again, led Michael Graham (1949) to state the Great Law of Fishing:

> "So, even the fisheries that have never seemed to be troubled by 'depletion' take their place beside the overfished ones; they are only saved by their limited market, which prevents free fishing, thus saving the fishery by imposing a limit, just as the overfished ones could be saved by only fishing up to a limit. If there is no other limit, Nature will impose one: the limitation of unprofitableness.
>
> "The Great Law of Fishing can be stated in a few words: 'Fisheries that are unlimited become unprofitable.' "

In spite of much experience which lends credence to the Great Law, we should not have blind faith in a converse law, that limiting effort will restore profit to a fishery, although here again we have some experience indicating this to be true. Fishery management, per se, and as usually practiced, is rarely a panacea for either the resource, consumer, or the industry. Fisheries under management have collapsed, or at least become unprofitable. What we do have is a belief that doing something—if we do it cautiously—is better than doing nothing. What we need is courage to try uncontrolled experiments and wisdom to be flexible in our planning.

Purse boats beginning a set on a 70-ton school of menhaden. (Photograph by Hall Watters, Standard Products Co., Southport, N.C.)

HISTORY AND PURPOSE OF FEDERAL BIOLOGICAL STUDIES

Interest in menhaden as a national resource was stimulated after World War II by the increased use of fish meal for feed supplements and for export, and the decline of the Pacific sardine fishery. During 1952-54 most of the plant owners and managers of the Atlantic coast menhaden industry were convinced that a scientific investigation of the resource would benefit them by determining the biological characteristics and population structure of menhaden. In 1955 an investigation of Atlantic menhaden was undertaken with the primary objectives of determining the causes of natural fluctuations in abundance and the extent to which these fluctuations were predictable. The program was an extension of preliminary studies conducted in the middle Atlantic area since 1952. By 1959 some characteristics of the fishery were known: 1) fluctuations in abundance resulted principally from variations in year-class strength, determined after the year-class entered the fishery; 2) estuaries are nurseries and their preservation and maintenance are essential to the menhaden resource; and 3) juvenile abundance in estuaries could provide estimates of year-class strength before recruitment into the fishery. Also, by 1959 it was the provisional conclusion that the Atlantic menhaden resource was being overexploited. Industry action with National Marine Fisheries Service (NMFS) support was able to get Congressional additions to the budget annually from 1964 to 1969. Extensive tagging studies, increased surveys of estuarine nurseries, and a full-scale investigation of the Gulf fishery provided further information on population structure and size.

These studies resulted in extensive data files on catch, effort, age and size composition, and life history (migration patterns, stock homogeneity, and fecundity) from which we infer such dynamic characteristics of the stocks as growth, recruitment, and mortality rates. As a result of apportioning mortality rates between fishing and natural causes, the purpose of our studies has naturally expanded to include the effects of fishing on the stocks.

Scientific articles, written and oral reports, working conferences, personal meetings, and correspondence have maintained regular and frequent communication between the menhaden research staff, State and other Federal agencies, and the menhaden industry. Ninety articles on some aspects of the menhaden resource have been published since 1955. Of these, 30 have reported on the fishery, catch, effort, and size composition, or analyzed the growth, mortality, migrations and other dynamics of the populations. Several meetings a year have been held with the menhaden industry since 1953 at which research plans and results were discussed. Reports and conferences with State agencies, directly or through the Atlantic States Marine Fisheries Commission, GSMFC, and Gulf and Caribbean Fisheries Institute occurred one or more times each year. The Washington office of NMFS was involved in the preparation for these meetings and frequently participated in them. Recently these meetings have focused increasingly on management discussions. In the past 12 months there have been two meetings with the NMFS central office, three with industry, and several with the GSMFC that dealt specifically with resource management.

HISTORICAL BACKGROUND OF THE FISHERIES

The purse-seine fishery for menhaden began on the Atlantic coast after the Civil War. Catching efficiency undoubtedly increased somewhat by World War I as the carrier vessel fleet was steadily transformed from sail to steam and then to gasoline power; the towed purse boats were equipped with gasoline engines, and seine size increased. Methods of catching menhaden apparently changed very little between the two World Wars. The modern fishery began to develop after World War II, with the increased demand for fish meal and oil. There was a fairly continuous increase in number, size, and efficiency of harvesting gear, including spotting aircraft, up to about 1960.

The annual landings of Atlantic menhaden have shown a classic response to a progressively developing fishery. Landings increased fairly steadily to a peak in 1956 (Fig. 1) and then declined as the harvesting rate exceeded the growth rate of the menhaden population (the annual net increments of biomass from recruitment and growth of individual fish). The population, and hence landings, have

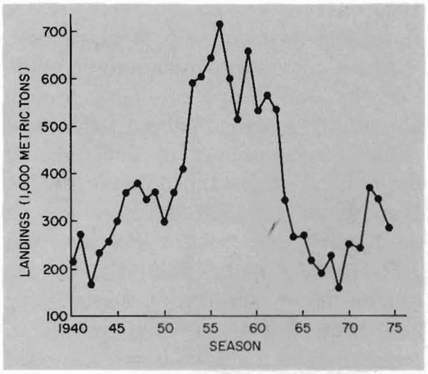

Figure 1.—Atlantic menhaden purse-seine landings in thousands of metric tons, 1940-1974.

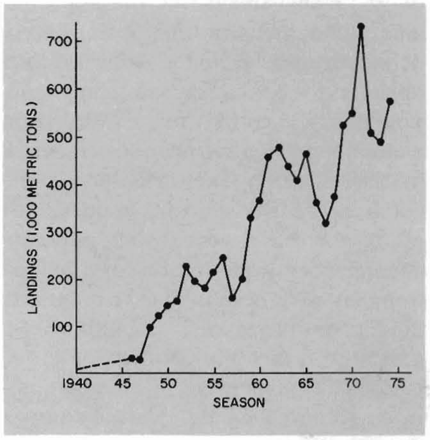

Figure 2.—Gulf menhaden purse-seine landings in thousands of metric tons, 1946-1974.

recovered greatly since the "bottom" in 1969. This is undoubtedly due, at least in part, to a 54 percent reduction in observed fishing effort, enhancing our belief in the efficacy of controlling the amount of effort.

The Gulf fishery began to expand in about 1947. Its technical development paralleled the post-World War II development of the Atlantic fishery, although there were time lags of a couple of years in some of the innovations tried first in the Atlantic (in general, most companies on the Gulf were and are the same as those on the Atlantic).

The landings on the Gulf show a trend (Fig. 2) since 1946 that is remarkably similar to that on the Atlantic, though of course starting at virtually zero rather than at about 200,000 metric tons. The Gulf fishery eventually reached a technically more advanced state than the Atlantic, with newer, larger, and more powerful vessels. Refrigerated vessels were introduced in 1956 and formed the majority of the fleet by

1964. These vessels allowed greater range and time on the fishing grounds.

Much consideration should be given to why the Gulf landings, though apparently peaking in about 1970, have shown no signs yet of declining so dramatically as in the Atlantic, in the face of a technical development of harvesting and processing at least equal to the Atlantic. Surely, part of the reason lies in imposing the increasing harvesting rates on a virgin stock, instead of on a stock already exposed to a substantial harvesting rate. Part of the reason may lie in some rather overt "management" by the industry. The same industry that experienced economic disaster on the Atlantic coast appears to be closely watching and voluntarily limiting the effort. For example, after a tremendous increase in the catch in 1971 (the maximum catch ever), the industry reduced its effort the next year by 5 percent. Though part of the reason for a reduction may have been induced by market, labor, or processing conditions, it indicates a flexible industry that is cautiously responsive to fluctuations in the resource supply. And, of course, the stock fluctuations in the Gulf are more apparent since there are fewer age classes in the fishery.

In summary, the history of these two fisheries indicates clearly enough 1) the danger of overfishing, 2) the positive effect of reducing effort in an overexploited fishery, and 3) the potential benefit of limiting effort in a healthy fishery.

MANAGEMENT ISSUES

In order to stimulate thinking that can lead to cooperative planning for management, with inputs from all concerned parties, it should be helpful for one party to discuss its views on several issues which are perceived, generally, to be crucial in developing specific plans. We should begin at the beginning by defining what we, as fishery biologists, mean by management. Our technical definition of fishery management is "controlling the rate of fishing," also called the fishing mortality rate. This fishing mortality rate is, for a given average population abundance, proportional to the catch. Conversely, for a given catch, it is inversely proportional to the average abundance. Fishing effort is defined and measured to be proportional to the fishing mortality rate. So, we can control the fishing mortality rate by controlling either the total catch or the total fishing effort. Sometimes we think of controlling not only the total fishing mortality rate but the rate applied to specified age groups in the population. This, of course, will affect the total rate and is a refinement of concept which will not be considered at this time.

Controlling (setting the level of) the fishing mortality rate, hence the average abundance of the stock and the catch from it, is done to benefit people, not fish. These social benefits can be ordinated, and range from gaining additional resources for consumers, on one end of the scale, through maximizing expected profits for the industry, or total physical yield, to preventing resource collapse, on the other end of the scale, for the benefit of future consumers and fishermen. Figure 3 is a schematic diagram of these social benefits, and is only a general example of the type of relation between catch and effort that we expect in many fisheries. The specific curves for Atlantic and Gulf menhaden will be presented in the next sections. At the left hand side we see that, with no effort, the catch is zero and the population size is at the maximum the environment will support. As effort increases, the population (numbers) decreases and the catch increases, since a larger fraction of the population is being harvested. This continues up to E_{max}, where the catch is maximized. If effort is fixed at any level then theoretically the catch will equal, on the average, the amount shown on the graph. At some point, however, labelled E_{crit} in Figure 3, the population will not be able to balance the weight removed by fishing, with new growth; the new growth comes from recruits entering the fishery and the growth of individuals. A hypothetical cost curve was drawn in the graph just to show three points: 1) if harvesting cost is proportional to effort and if the value of the catch is proportional to the weight of the catch, there is obviously some effort level (E_{opt}) where profits (equal to catch minus cost) are maximized, and this point is, in general, to the left of the point where catch is maximized; 2) so long as the value of the catch is greater than cost, effort in an uncontrolled fishery will expand until average profit is zero; when profit is negative, effort is removed; and 3) if the economic break-even point (EBEP) is to the right of the biological break-even point (BBEP), the fishery will collapse unless effort is limited (by factors other than free market competition) to some value below E_{crit}.

The concept of management espoused here is not one of "government, meddling in the economic affairs of industry," but one of developing models of the fishery which specify alternatives and, with cooperation from all concerned parties (State and Federal governments, and industry), decide the appropriate mix of social benefits as the objectives of effort limitations. This concept is not radically different from an industry concept of economic regulation which, though not often stated explicitly, goes something like the second point

Purse boats alongside as the catch is pumped into the hold of the carrier vessel.

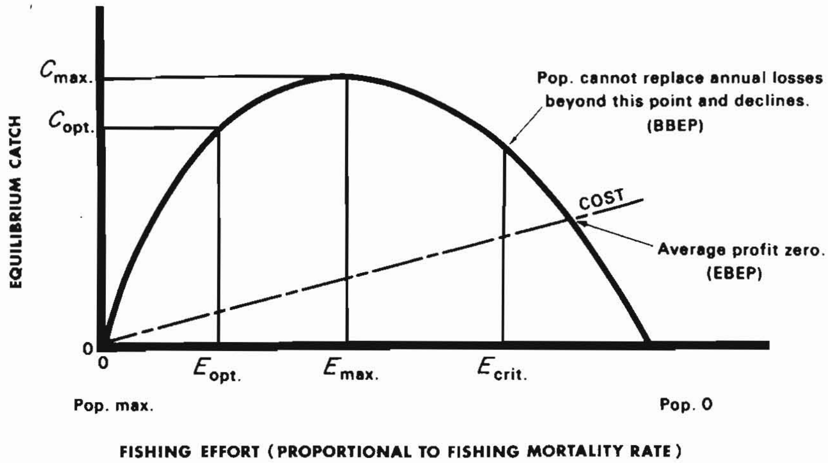

Figure 3.—Equilibrium catch as a function of fishing effort, with biological break-even point (BBEP). A hypothetical cost curve is drawn with an economic break-even point (EBEP). Several management alternatives are shown: 1) Economic catch (C_{opt}) at optimum effort (E_{opt}); 2) Maximum sustainable catch (C_{max}) at corresponding effort (E_{max}); 3) A critical amount of effort (E_{crit}) that reduces the population and resultant catch to a level below which it cannot replace itself.

in the above paragraph. Allowing the fishery to be controlled only by the economics of free market competition, however, does two things: it assures that 1) the average profit for the whole industry will be zero, a great social cost in terms of lower landings at higher cost, and "wastage" of excess labor and capital, and 2) there is no mechanism that provides for protection of the resource, since if either costs go down or value goes up new effort can afford to enter the fishery and eventually may exceed the BBEP. This second point is an expressed concern of the industry, at this time of greatly increased fish meal prices.

There are two further considerations in deciding objectives for fishery management. As indicated in the above paragraph, a management plan with a single objective often results in more than one social benefit. Moving from E_{crit} to E_{max}, the effort required to harvest the maximum sustainable yield, in Figure 3, would simultaneously increase the catch and profit, protect the resource, and probably decrease the number of jobs. The objectives chosen also will influence the methodology of regulating the fishing mortality rate. We have seen that the fishing mortality rate can be controlled, in general, either by limiting the effort or the catch. Management discussions frequently center on methods, but we believe objectives should be discussed as well, since a specified objective determines, at least partially and in general, the method. If we have a purely biological objective, such as achieving the maximum sustainable catch, it will be sufficient to regulate the catch. If we have any form of economic rationalization as our management objective, it is necessary to limit the amount of effort, and to do so in a manner that does not deter harvesting efficiency.

It is easier, politically and operationally, to limit the catch, and there are few disadvantages in doing so. As with any management plan, flexibility is necessary. A constant catch will not necessarily achieve a constant and desired fishing mortality rate if the population size is changing greatly for reasons independent of the fishery (e.g., unusual recruitment or changes in the natural mortality rate). Another disadvantage of catch quotas is that, in general, they lead to overcapitalized fisheries. The major difficulties with limiting effort are: 1) overcoming the legal barrier of limiting open access to a common property resource; 2) the actual mechanics of changing, and accounting for, the amount of effort—particularly with changes in gear efficiency; and 3) if effort is being limited to maximize profit, there is the problem of variability in the economic parameters and in determining the proper discount rate.

In view of the time-consuming technical difficulties of implementing any management scheme, the policy difficulties of determining an optimum strategy (which we believe can only be approached on a trial basis rather than determined once-and-for all initially), and the inherent volatility of many fisheries; we suggest adopting a philosophy of opting for minimal management objectives, implementing them as soon as possible, and building in as much flexibility as possible. This can be achieved by setting catch quotas initially, while we work on the problem of limiting effort. Catch quotas should be expansionary (i.e., allow for annual increases) in fisheries that show no signs of overfishing. They should be restrictive in overfished stocks. This means quotas should be at, or slightly below, what the effort is capable of harvesting, if effort is greater than E_{max} and less than E_{crit}. If effort approaches E_{crit}, quotas should be set considerably below what the effort can harvest, to allow the stock size to increase. The ultimate objective of manipulating the catch quota should be to drive fisheries toward, and maintain them near, the maximum sustainable catch. The implications of this philosophy, as applied to the menhaden fisheries, will be discussed in the next two sections dealing with analyses of the fisheries.

Both the Atlantic and Gulf menhaden fisheries present a favorable opportunity for establishing a management plan for the maximum, safe, and profitable utilization of the resources. They are free from many of the complexities that plague management decisions in many of our large, valuable fisheries. Both fisheries are 1) wholly domestic, 2) single species, 3) harvested and processed with the same technology, 4) well studied, and 5) vertically integrated. The differences between them and relative priority for management will be deferred to the following sections, which will specify the biological aspects of management plans.

We recognize the great need for other inputs, especially economic. Any existing scheme of exploitation of a renewable resource is a form of management. Unrestricted application of capital (fishing effort) results in a certain yield taken with an associated cost to industry and society. Any alternative management scheme also has associated costs. The fundamental question is whether the benefits from a specified management scheme are economically superior to the existing scheme. In other words, various management alternatives should be specified economically. The choice of a particular scheme may be based ultimately on considerations in addition to pure economics. For example, it may be economically feasible, and desirable, for an industry with a high discount rate to fish a particular stock to extinction, but society may be entitled to a low discount rate for high demand goods that are likely to become scarce in the future. On the other hand, in an unregulated fishery the population level at which unit price equals unit harvesting cost may be sufficiently large to be sustainable. Answers to these questions require knowledge of costs, revenues, and discount rates. In addition, we must evaluate the social costs of research, implementation of regulations, and decreased yields (if they exist) from no regulation. All of these must be evaluated against the present and future value of the fishery.

There must be a parallel development of plans, which are continuously modified, and institutional mechanisms for implementing the plans. This will take the full cooperation of biologists, economists, fishermen, administrators, and State and Federal legislators. The fisheries commissions of the Gulf and Atlantic States might serve as the coordinators. They should actively solicit recommendations, review them, and encourage States to implement those they endorse.

AN ANALYSIS OF THE GULF MENHADEN FISHERY

There has been one technical publication (Chapoton, 1971) on the Gulf fishery, which attempted to analyze trends in catch and effort, and to model the effects of fishing on the stock and expected yields, in relation to effort. A Schaefer-type, or linear surplus yield model was presented which was fitted to data from 1946 to 1970. Based on the published model (Fig. 4), the average equilibrium catch can be estimated from effort by the following formula:

$$\text{Catch} = 2.12(\text{Effort}) - 0.0026(\text{Effort})^2$$

This model would predict a maximum sustainable yield of 430,000 metric tons with 408,000 vessel-ton weeks (the units of effort used).

This type of model which requires only catch and effort data provides a minimum amount of insight into the dynamics of the stock and should be used with a great deal of caution in formulating any management plans. Deducing the long-term response of the stock to exploitation from a model of this sort is extremely uncertain, unless information on age structure, growth rates, and mortality rates is considered also. One especially troublesome technical difficulty with this approach is the sensitivity of the parameters (which determine the maximum catch and associated effort) to the data set included in the calculations. An estimation of the maximum catch is especially uncertain when there are no data points on the descending portion of the curve. Hence the model should continue to be updated and recalculated every year. Figure 4 shows the model updated by the inclusion of only 2 years, 1971 and 1972. We see that it predicts a much greater maximum sustainable yield (MSY), 478,000 metric tons with 460,000 vessel-ton weeks, than an estimate of 430,000 metric tons only 2 years previously. If catches had been limited in 1970 to something near the estimate of MSY at that time, the industry would have suffered losses totaling about 130,000 metric tons. Even the current estimate of MSY, as a quota, would have seriously underestimated actual yields during the last 3 years. This example is intended to motivate the rationale for a quota system described next, and to demonstrate our concern not only for protecting the resource but minimizing industry losses as well, in this extremely valuable fishery.

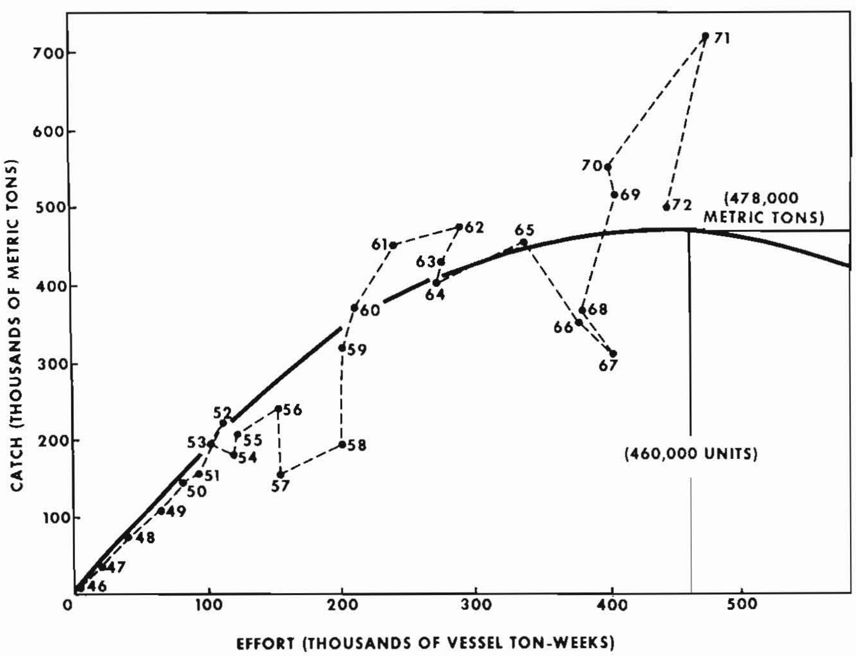

Figure 4.—Estimated average sustainable yield of the Gulf menhaden purse-seine fishery, 1946-1972. A maximum sustainable yield of 478,000 metric tons is shown with 460,000 vessel ton-weeks of effort.

MANAGEMENT RECOMMENDATION FOR THE GULF MENHADEN FISHERY

For reasons mentioned in the section on management issues, we propose a quota system as an initial step toward managing this fishery. In light of the above example, the system must not be too restrictive, but must allow for expansion, until there is clear evidence that we have reached, or

Menhaden reduction plant near Beaufort, N.C.

slightly passed, the peak of production. Setting annual quotas would simply allow the industry to approach the peak systematically and gradually, with fixed catches each year. Effort must be closely monitored each year to help us determine the validity of our estimated MSY. Even when we are more certain of the MSY, it might be necessary to adjust the quota frequently in response to fluctuations in the size of incoming year classes. Gradually increasing the quota past our predicted MSY is predicated on the assumption that Gulf menhaden, which have a high reproductive potential, are resilient enough to withstand overfishing (i.e., removing more than the annual surplus) for a couple of years. Thus we can set liberal quotas, which would not penalize the industry.

By way of example, if we were to initiate such a system for 1975, we would set a quota that is based on our current estimate of MSY (478,000), plus an increment based on statistical confidence limits around this point estimate. The upper value of MSY with 80 percent confidence is 520,000 metric tons. The industry should be able to land this catch with no great increase in effort, say 10 percent greater than the estimated 460,000 vessel-ton weeks, unless we have greatly overestimated the potential productivity of the stock. We would certainly not recommend this large an increase in effort in 1 year, since, in general, it is much more difficult to remove excess effort than it is to gradually increase effort. If the quota were not landed for a couple of years, with a reasonable amount of effort, then it should be revised downward nearer the actual catches. This system could be implemented immediately if an official organization, say the GSMFC, would propose a quota and the industry would agree to voluntarily abide by it. The Atlantic Estuarine Fisheries Center currently monitors daily catch records on a short time basis and would know if and when the quota is reached.

There are several advantages from this quota system. Firstly, it would discourage entry of "new" effort. The extremely favorable economic condition of the Gulf fishery has already attracted the interest of investors outside the traditional industry. We are fairly certain that the existing industry already has a capability to fully utilize the resource; and if new companies were to enter, it should be, from a resource point of view, only by buying out existing companies. Annual quotas also eliminate uncertain fluctuations in yield, which appears to us to be an advantage, though we are not capable of evaluating this economically. Perhaps the greatest advantage, however, is that a control mechanism will exist which, hopefully, will prevent gross overfishing and a large decline in the resource and landings. At this time we cannot quantify the benefits from management. The proposed immediate plan would require no new funds.

Analysis of this fishery is only beginning and is extremely incomplete at this time. The immediate greatest research needs for fuller understanding of this fishery, and to which we are directing our attention are: 1) valid information on the age structure of the population from which we can deduce mortality rates, 2) an assessment of our measure of effort to determine if it is proportional to apparent mortality and directly influences population abundance, and 3) valid techniques to quantify the strength of incoming year classes upon which quotas can be modified.

ANALYSIS OF THE ATLANTIC MENHADEN FISHERY

We have a more detailed understanding of the Atlantic fishery, due to more data and more analyses. As we shall see, this does not necessarily ease the task of developing rational management plans. There are complexities in this fishery, discussed below, which make a simple quota system less suitable for management, though we still recommend such an approach as a first step.

Schaaf and Huntsman (1972) summarized much of the analysis that has been done that bears directly on the dynamics of the stock and its response to harvesting at various rates. Two models are presented; a Schaefer-type, as used in the Gulf fishery, and a special form of what is usually called a dynamic pool model, which requires estimates of natural mortality rate, fishing mortality rate, growth rate, and a spawner-recruit relationship. The implications of these models for management and some of the difficulties of using them will be discussed here.

The first model predicts catch from effort by the following equation:

$$\text{Catch} = 1.247(\text{Effort}) - 0.000623(\text{Effort})^2$$

The estimated MSY from this model is 620,000 metric tons with 1,000 vessel-weeks of effort. Effort has been adjusted in the model for changes in gear efficiency, due to technical improvements and to a declining population. This ensures that the measure of effort used is proportional to fishing mortality. The method of adjustment required information on the age structure of the catches, so it has not been applied yet to the Gulf fishery. The greatest difficulty with using adjusted effort is translating it, on a real-time basis, back into units of observed effort. We will discuss this further when we present, below, an updated version of the model.

The dynamic pool model predicts a maximum sustainable yield of 400,000 metric tons instead of 620,000. We attribute this large difference primarily to the unusually abundant year classes of 1955, 1956, and 1958. These three year classes contributed the bulk of the large catches from 1955 to 1962. In fact, if one were to assume, somewhat arbitrarily, that catches from these year classes were only "average," then an estimated MSY would be only about 360,000 metric tons. The dynamic pool model however, incorporates the average recruitment expected from the number of spawners present, in calculating yields. It probably provides, therefore, a more representative picture of present sustainable yields from average year classes. The chief difficulty in using this model for immediate management planning is, again, one of translation. The model predicts yields for a given fishing mortality rate, and it is difficult to translate observed effort into a fishing mortality rate, on a real-time basis. It is only after a couple of years that we can estimate the mortality rate generated by a given amount of effort. We believe this model is useful, however, as a conceptual framework of stock dynamics against which to check deductions from simpler models. Also it permits deductions about equilibrium age composition of the stock, against which we can check the current status of the stock.

Since the publication of these models, we have updated the linear surplus yield model. In addition to adding 4 years of data, we have adjusted 6 more years of effort data, bringing the base year up to 1971. This makes the problem of translating observed effort into effective effort somewhat easier, since it is nearer in time to the base year and fewer changes have occurred. For 1972 and 1973 we assumed no change in efficiency and therefore did not adjust the effort. A Schaefer-type model fit to these data (Fig. 5) predicts an MSY of 560,000 metric tons, with 630 vessel-weeks of effort (1971 units). There appear to be two distinct eras of the fishery. From 1955 through 1962 the virtual population (i.e., total numbers caught out of a year class) averaged 3 billion fish (standard error equals 0.8 billion), and the weight landed annually during this period averaged 596,000 metric tons (standard error equals 25,000). From 1963 through 1973 catches averaged 266,000 (standard error equals 20,000) from virtual populations that averaged only 1.3 billion (standard error equals 0.1 billion). From 1968 through 1971 there has been a 30 percent reduction in effort, which we feel is partly responsible for allowing the catches to rebound to the current level of 350,000 metric tons. Catches for 1972 and 1973 are not only near the equilibrium yield curve shown in Figure 5 but are also near the average maximum level (400,000 metric tons) predicted from the dynamic pool model. Catches of 550,000 metric tons are probably not possible, with any level of effort, unless several large year classes enter the fishery. Even then, to achieve large landings would require a mortality rate low enough to allow larger numbers of fish to reach older ages and, hence, greater weight. The dynamic pool model indicates that, with maximum equilibrium catch, the fishing mortality rate would be such that 17 percent of the catch would come from ages 3 and greater. Low catches in the late 1960's were mostly of ages 1 and 2 years; in recent years the age composition of the catch has shifted toward older ages, but not quite enough. In 1972, 11 percent of the catch was 3 and greater. Figure 5 indicates that 950 vessel-weeks is sufficient to harvest the average equilibrium catch. The slight reduction in effort from 990 in 1973 to 950 might be sufficient to take advantage (in the long run) of exceptionally large year classes.

The point indicated on the far right (Fig. 5) is an estimate of what we above called the biological break-even point (BBEP). There is a fair amount of uncertainty involved in estimating the BBEP, especially for animals with life history patterns that permit large fluctuations in abundance. This estimate came from the dynamic pool model, by simulating the population through time and finding the maximum mortality rate (and associated yield) that the population can sustain without declining eventually to zero. Though we do not know how reliable this estimate is, we believe it is important to begin thinking about this critical point. There is reason to believe that the industry

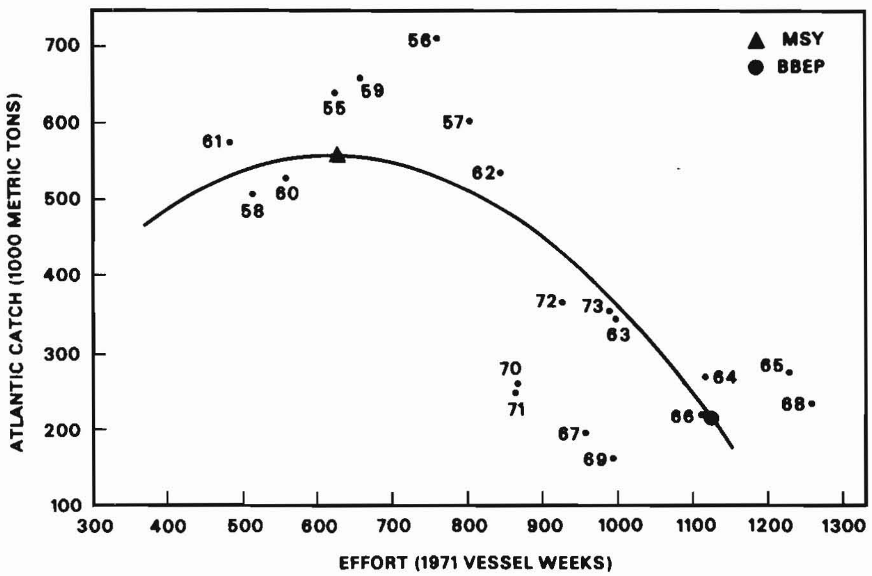

Figure 5.—Estimated average sustainable yield of the Atlantic menhaden purse-seine fishery, 1955-1973. A maximum sustainable yield (MSY) and the biological break-even point (BBEP) are shown.

approached this point in about 1964, when catches dropped into the 200,000 metric ton level for the first time since 1944, with about 1,100 vessel-weeks (adjusted to 1971). For the next 5 years, even though 50 percent of the observed effort was removed, the catches declined steadily to the lowest ever (161,400 metric tons in 1969). We can only speculate on what would have happened if the effort had stayed in the fishery. We know effort left the fishery for economic reasons; we are fairly certain it could now afford to stay in, even if catches dropped to 200,000 metric tons, with the currently higher fish meal and oil prices. A quota system for the Atlantic menhaden fishery must be responsive to a demonstrable need for resource protection.

MANAGEMENT RECOMMENDATION FOR THE ATLANTIC MENHADEN FISHERY

The 1973 point on the curve provides a reasonable starting place for implementing a quota system. According to the model, 990 vessel-weeks of effort should land, on the average, about 370,000 metric tons. The objectives of the plan should be to set quotas that: 1) discourage effort increases, which would result in lower catches in the long run, higher costs, and move the fishery nearer the BBEP, if not adequately controlled; and 2) encourage effort decreases, which could allow the population to rebuild and eventually allow increases in the quota. If effort stays at 990, we would recommend a quota of no more than 370,000 metric tons. If the quota were set below 370,000 the population might rebuild, and quotas could be increased gradually to 400,000 if effort is reduced. If effort should increase beyond 990 the quota should be reduced. If effort increases to 1,120 vessel-weeks without management, the quota should be less than 220,000 tons, because we are fairly sure the population could not sustain that level of harvest.

The fact that one population exists along the entire coast, that migrates north and south throughout its range, and that is stratified by age and size along the coast causes more than the usual kinds of allocation problems associated with a single quota. A fixed tonnage of fish removed from the population causes a higher mortality rate if composed of young fish than it does if composed of older fish, because there are more of them per ton. On the other hand, the natural mortality rate is high enough that maximum tonnage cannot be achieved by fishing only on the older ages. The maximum weight of a year class occurs between the ages of two and three, therefore this would be the optimum age at which to harvest fish. We believe that the only way to obtain the maximum yield from this fishery is by a geographical distribution of catches similar to that prevailing during the peak years (1953 to 1962).

SUMMARY AND CONCLUSIONS

Our menhaden fisheries are extremely valuable and an important source of protein. We have seen the Atlantic fishery decline significantly and partially rebuild. In the Gulf fishery we have seen the dramatic growth rate in landings begin to level off and the threat of excessive effort entering. We have recommended a limited scheme of management based on single quotas, that should prevent overfishing and economic difficulties for the industry while we jointly consider refinements that could optimize resource management plans. Both fisheries would be relatively easy to manage, compared to international, multispecies fisheries. Both fisheries could benefit: the Gulf, from prevention of collapse; the Atlantic, from increased yields at lower costs. The probability of achieving the benefits is high; the risks are low. The proposed immediate plan would require no new funds. We should all work together to ensure the maximum, safe, and economical utilization of this great natural resource.

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