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Increasing demand has put heavy pressures on the American lobster supply. Here two economists analyze proposed management measures.

The American Lobster Fishery: Economic Analysis of Alternative Management Strategies

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The increasing pressure of world demand for fishery products has led to more intensive exploitation of, and, at the same time, to increasing concern over, the marine environment. One recent study predicts that world demand for many species fished by U.S. fishermen will outstrip the maximum world supply potential before 1985 (Bell et al., 1971). Many management strategies used to protect fishery resources from overexploitation have resulted in inefficient use of gear and equipment, as shown by Crutchfield and Pontecorvo (1969). Recently, the National Marine Fisheries Service initiated a State-Federal partnership to develop alternative management strategies so that scarce fishery resources will be used wisely. The purpose of this article is to point out the economic impact of some selected management strategies for the U.S. inshore American lobster fishery. In the course of our analyses, we shall try to describe in simplified terms just how economists go about the task of assessing the economic impact of various management policies. It should be made quite clear that this analysis is intended to predict the effects of alternative actions *without recommending or endorsing any specific policy*. Also, the management strategies tested are not meant to be exhaustive, and there may be others that are worthy of consideration.

THE BIOECONOMIC MODELING PROCESS

Before any specific management strategies are considered, it is first necessary to understand just how a fishery functions from both the economic and biological points of view *without* extensive management intervention by government. This gives us a benchmark from which the economic impact of various management policies can be measured. Economic researchers first attempt to develop a bioeconomic model which will explain the most important behavioral factors for a fishery over some period of time, such as ex-vessel prices, fishing effort, earnings, and catch under conditions of free access to the fishery resource. The "model" consists of a series of mathematical relationships which hopefully approximate the economic behavior of those participating in the fishery. The predictive power of such models is greatly influenced by each of the building blocks, such as the hypothesized relation between catch and effort or catch and ex-vessel prices. The reader should remember that these models only attempt to consider the most important factors for a fishery and necessarily omit factors of lesser importance over the long run.

Although the technicalities of a bioeconomic model will not be discussed here, it should be pointed out that the researcher essentially attempts to explain the determinants of the demand and supply of fish harvested from a given resource.[1] Supply or catch is directly determined by the size of the fishery biomass and the number of vessels fishing the resource. The number of vessels and fishermen fishing the resource is determined by the overall level of consumer demand for the fishery product. Consumer demand is determined by income per capita, population, and ex-vessel prices relative to other protein substitutes. As demand expands over a period of time owing to the expansion of population and/or income, ex-vessel prices will increase, an event which in turn produces an increase in returns to existing vessels and fishermen. The rise in earnings induces more vessels into the fishery, thereby expanding catch given the biological limitation of the resource. The resource limitation is built into the model by relating catch to fishing effort or number of vessels fishing the resource. As fishing effort expands, the catch will eventually reach a maximum yield. Further fishing will reduce catches. Therefore, the concept of maximum sustainable yield (MSY) is the largest number of pounds of fish that can be caught on a long-run an-

[1]For the reader who is interested in a more technical discussion of the bioeconomic model, consult Richard F. Fullenbaum and Frederick W. Bell, "Economic Impact of Alternative Management Strategies for the Northern Lobster Fishery," *Fishery Bulletin* (in press).

nual basis with a given level of fishing effort without impairing the viability of the stock.

The bioeconomic model does permit overfishing the resource where the level of fishing effort is greater than that necessary to harvest MSY. In this case, catch will usually be less while fishermen and vessels will be more than necessary to take MSY. This situation represents a waste of capital and labor. The model will allow us to answer such questions as the following: What is the economic impact of a sudden increase in imports? What will happen to the fleet if the rate of growth of U.S. population slows? What is the impact of increases in per capita income on ex-vessel prices? Let us now turn to some of the basic elements in constructing a bioeconomic model for the American lobster fishery.

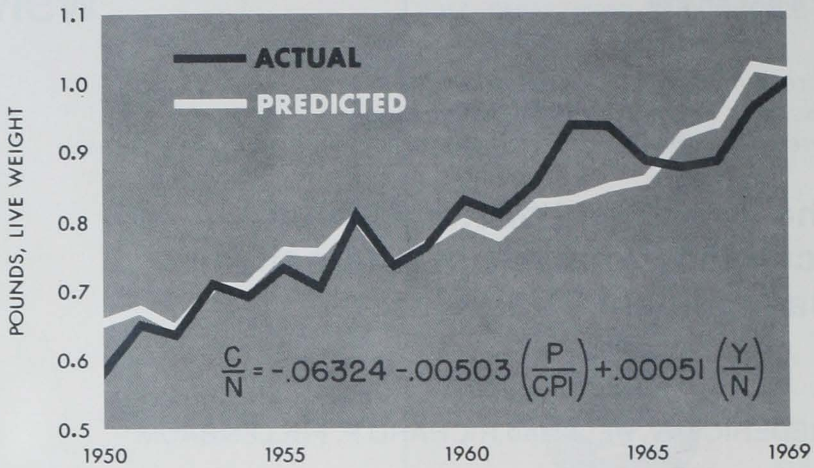

Figure 1.—Actual and predicted per capita consumption of all lobsters, 1950-69. C/N = per capita consumption of all lobsters; P/CPI = real ex-vessel price (or actual ex-vessel price of lobsters) divided by CPI (1967 = 100); and Y/N = real disposable income per capita.

ESSENTIAL BIOECONOMIC RELATIONS FOR THE U.S. AMERICAN LOBSTER FISHERY

A. The Demand for Lobsters

As indicated above, consumer demand for the fishery product is the driving force behind the expansion of a fishery which leads, on occasion, to overfishing. Over the 1950-69 period, U.S. per capita consumption of all lobsters (American, spiny, etc.) increased from 0.585 to 0.999 pounds, live weight (Table 1). The rate of growth in per capita consumption was approximately 2.4 percent per year. This was in sharp contrast to overall U.S. per capita consumption of food fish, which remained relatively constant over the same period at 10 to 11 pounds. The increased consumption came primarily in the imported spiny lobster category. The rapid growth in the consumption of lobsters produced a rise in ex-vessel prices of 4.8 percent per year which exceeded the growth in all consumer prices, which averaged 1.7 percent per year. What were the determinants of the per capita consumption of lobsters? A statistical analysis was made in which the following factors were related to per capita consumption of all lobsters:

1. ex-vessel price of American lobsters relative to the general price level in the U.S. economy; and
2. real per capita disposable personal income (standard of living).

In prior statistical tests, it was found that crab and shrimp prices as well as meat and poultry prices were not significantly related to the per capita consumption of lobsters. It was anticipated that per capita consumption of lobsters would fall if ex-vessel prices increased faster than the general price level and would rise owing to increasing real per capita income. Figure 1 shows the estimating accuracy of our statistical equation, which is consistent with our expectations. This relates the per capita consumption of all kinds of lobsters to ex-vessel prices and per capita income over the 1950-69 period. According to the analysis, a 10 percent increase in lobster prices will reduce per capita consumption by roughly 4 percent. However, a 10 percent increase in per capita income would increase per capita consumption about 15 percent. The consumer demand analysis for lobsters indicated that despite rising lobster prices, per capita consumption increased owing to the rise in the standard of living. This provided strong economic incentive to expand the domestic lobster fisheries.

B. The Supply of American Lobsters

Although the demand for *all* lobsters was considered above, for management purposes we want to focus on one component of the total supply: the inshore U.S. American lobster stock, which is located primarily along the North Atlantic States. The number of traps fished in this fishery expanded from approximately 579,000 in 1950 to 1,061,807 in 1969, an annual rate of growth of 3.6 percent. This largely resulted from the rising demand pressures discussed above. Dow et al. (1961) showed the strong relation between the catch per trap of American lobsters and two important factors: (1) the total number of traps fished, and (2) seawater temperature. That is, catch per trap falls as the total number of traps fished increases. However, within certain ranges, catch per trap is increased by increases in seawater temperature which cause lobsters to grow more rapidly. It should be noted that the

Table 1. — Economic variables associated with the U.S. inshore American lobster fishery, 1950-69.

Year	Catch by traps	Value	Traps fished	Catch per trap	Ex-vessel price	Ex-vessel price divided by consumer price index	Per capita consumption of lobsters	Per capita disposable personal income divided by consumer price index	Consumer price index (1967 = 100)	Mean annual seawater temperature at Boothbay Harbor Maine
	Thousand pounds	*Thousand dollars*	*Number*	*Pounds*	*Cents per pound*	*Cents per pound*	*Pounds (live weight)*	*Dollars*		*Degrees Fahrenheit*
1950	22,914	8,283	578,930	39.6	36.1	50.1	.585	1,892	72.1	49.3
1951	25,749	9,328	512,812	50.2	36.2	46.6	.651	1,888	77.8	51.4
1952	24,681	10,469	544,730	45.3	42.4	53.4	.638	1,909	79.5	50.2
1953	27,509	10,687	569,081	48.3	38.8	48.5	.710	1,976	80.1	52.0
1954	26,628	10,250	628,209	42.4	38.5	47.8	.690	1,969	80.5	50.3
1955	27,886	11,003	669,229	41.7	39.5	49.2	.734	2,077	80.2	50.0
1956	25,386	11,584	666,887	38.1	45.6	56.1	.704	2,141	81.4	48.6
1957	29,358	11,263	688,815	42.6	38.4	45.6	.806	2,136	84.3	48.8
1958	26,143	12,890	753,503	34.7	49.3	56.9	.736	2,114	86.6	47.4
1959	27,752	14,043	856,794	32.4	50.6	58.0	.763	2,182	87.3	47.0
1960	29,345	13,657	844,110	34.8	46.5	52.5	.830	2,185	88.7	47.9
1961	25,621	13,662	895,098	28.6	53.3	59.5	.810	2,214	89.6	47.3
1962	26,728	13,770	909,318	29.4	51.5	56.9	.855	2,280	90.6	46.6
1963	27,210	15,299	866,900	31.4	56.2	61.3	.938	2,333	91.7	47.9
1964	26,844	17,689	904,233	29.7	65.9	70.9	.935	2,459	92.9	46.9
1965	24,737	18,764	949,045	26.1	75.9	80.3	.884	2,578	94.5	45.8
1966	25,606	19,517	947,113	27.0	76.2	78.4	.873	2,680	97.2	45.7
1967	22,098	18,162	907,956	24.3	82.2	82.2	.882	2,751	100.0	45.1
1968	26,918	20,648	966,335	27.9	76.7	73.6	.960	2,827	104.2	46.6
1969	26,930	22,997	1,061,807	25.4	85.4	77.8	.999	2,851	109.8	48.0

Sources: *Fishery Statistics of the United States*, various years, U.S. Department of Commerce, Bureau of Labor Statistics, and Robert Dow.

traps fished series is not an exact measure of fishing effort since it is not adjusted for days fished or extent of utilization. However, this series can serve as a rough proxy because, in general, when traps increase, trap days increase also. For the 1950-69 period, Figure 2 shows the estimating accuracy of our statistical equation which relates catch per trap to the total number of traps fished and seawater temperature. Over the 1950-69 period the catch per trap decreased because of a rise in traps fished and a fall in seawater temperature. For the 1969 level of seawater temperature (i.e., 48° F), the estimated maximum sustainable production or yield of the inshore American lobsters from the resource was approximately 28.7 million pounds (live weight). This would have required approximately 1.011 million lobster traps to catch. It would appear that the inshore American lobster fishery has sufficient traps to catch MSY and, therefore, is fully capitalized.[2] This "estimate" agrees fairly well with 31 million pounds indicated in the Master Plan Essay (U.S. Department of the Interior, 1970). Based upon this analysis, there is every indication that the inshore American lobster resource is fully exploited.

The only other critical variable needed in our bioeconomic model is the opportunity cost, or returns necessary to make it profitable for vessels and fishermen to fish for lobsters. An updated sample of cost and earnings for lobster boats indicated that a fulltime boat *must* have earned approximately $13,191 per year in 1969 in order to cover fixed and operating expenses and have an adequate return to both capital and labor to make it profitable for them to stay in the industry or fishery. This dollar estimate of opportunity cost is admittedly quite crude, and the National Marine Fisheries Service is presently working on better estimates through a contract with the University of Maine.

[2]The word "capitalized" is a shorthand expression that represents inputs of vessels, fishermen, gear, and technology which are employed to harvest a fishery resource. In the case of inshore American lobsters, there is enough gear (i.e., traps), boats, and fishermen to harvest MSY; therefore, the fishery is fully capitalized.

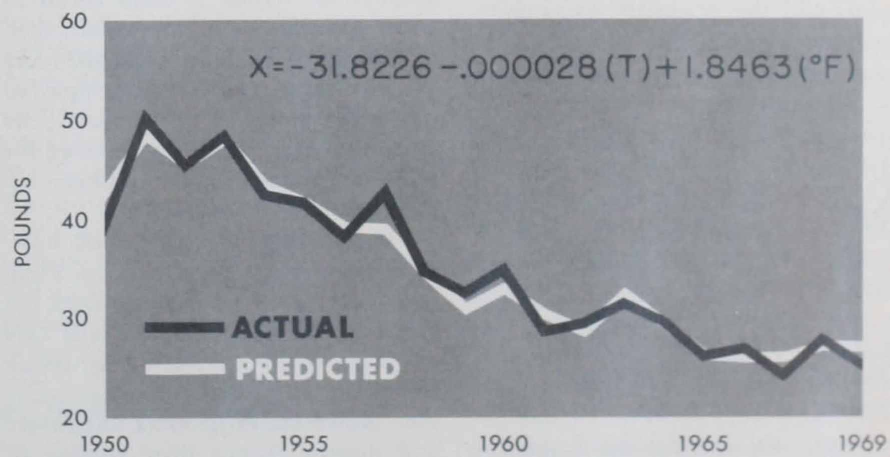

Figure 2.—Actual and predicted catch per trap of all inshore American lobsters, 1950-69. X = catch per trap; T = number of traps; °F = mean annual seawater temperature.

ECONOMIC IMPACT OF SELECTED MANAGEMENT ALTERNATIVES

Up to this point, we have been concerned largely with building a bioeconomic model that considers all the important variables. The model is based upon the fact that open access to the American lobster fishery is permitted. All states restrict gear to pots and traps. Each state (Maine, Massachusetts, New Hampshire, and Rhode Island) has a minimum lobster length requirement; permitted minimum lengths vary from $3\frac{1}{16}$ to $3\frac{3}{16}$ inches. Although there are various other restrictive regulations, e.g., prohibitions on catching egg-bearing females, their effect on the fishery is nominal and certainly less important than the size limitations. *We are, however, taking the array of existing regulations as given.*

We shall consider the economic impact of five alternative policies that could be adopted to manage the entire inshore American lobster fishery. These management strategies assume that some central authority such as a regional commission could impose these regulations. Further, the following strategies are meant to be illustrative and do not exhaust all possible alternatives. Also, two other management strategies suggested by Reeves (MS.) and Sinclair (1961) will be reviewed. As other management strategies are suggested by industry, government, and the academic community, the model formulated above may be used to predict their impact. The specific objectives of these management strategies will be discussed below. All strategies have two common objectives: (1) to protect the resource from overexploitation and (2) to allow maximum freedom for operators to function in a free enterprise fashion.

A. Freeze on Existing (1969) Fishing Effort by Placing a License Fee on Traps

Under this scheme, the regulatory authority would calculate a license fee on traps (approximately 1.069 million in 1969) which would keep the level of fishing effort constant despite an increase in the demand for lobsters. A license fee could not be levied on the individual vessel because this would not control the number of traps fished per vessel. The increased cost of operations due to the license fee would make it uneconomical for vessels to enter the fishery even if ex-vessel prices had increased. In essence, the license fee would siphon off increased revenue (or profits) from an increase in ex-vessel prices, assuming the latter increase faster than the cost of operations. For purposes of illustration, let us assume that we desire to manage the inshore American lobster fishery commencing in 1974. Given the trends in U.S. population, personal income, consumer prices, lobster imports, and other domestic production to the year 1974, it would be necessary to place an estimated annual license fee of $3.34 on each lobster trap fished. The regulatory authority would collect over $3.56 million which could be used to finance resource research, enforcement, and surveillance.

The bioeconomic model discussed above was used to estimate the necessary license fee. It should be emphasized that these calculations are merely rough estimates and only serve to give the reader some idea of the magnitude of such taxation. The illustrative license fee is also based upon an extrapolation of trends 5 years ahead of 1969. If we did nothing, it is estimated that the catch would be lower and more fishermen and traps would be employed in the fishery by 1974. Obviously, the situation would worsen as demand for lobsters expanded and the fishery became increasingly overfished.

The licensing fee plan does, however, have many disadvantages. First, a license fee on traps fished does not really get at the utilization rate. One might expect that a license fee on an individual trap might induce fishermen to fish each trap more intensively and thereby reduce their number of traps. At this point, we do not have any information or utilization rates whereby the license fee could be adjusted upward if utilization increased. Second, enforcement and surveillance might be difficult along the coastline from Maine to North Carolina. Third, and most important, the quantitative tools and projected figures needed to calculate a license fee are at best crude and would have to be used each year for computation of the license fee.

B. Reduce the Existing Level of Fishing Effort to that Necessary to Harvest MSY by Placing a License Fee on Traps

With this scheme, the regulatory authority would calculate a license fee on traps which would reduce the level of existing effort to that necessary to harvest MSY (estimated to be about 1.011 million traps) despite an increase in demand for lobsters. Because we are actually reducing fishing effort as opposed to freezing it at the 1969 level, the estimated 1974 license fee per trap must be higher, or $5.54; actual catch will not be significantly higher. The regulatory authority would receive approximately $5.58 million in license fee revenue. However, this plan has all the disadvantages of a general license fee plan discussed under an alternative one.

C. Reduce the Existing Level of Fishing Effort to that Necessary to Make the Marginal Cost of Landing Equal to Ex-Vessel Price by Placing a License Fee on Traps[3]

The idea here is to obtain the greatest "net economic benefit" and was

[3]For most industries, output will expand in response to demand up to the point where the marginal cost of production (i.e., additional cost of producing one more unit of output) is equal to the price received in the marketplace. This is considered an efficient level of production. In the fishing industry, the condition does not hold because of the common property nature of the resource coupled with resource limitations. Marginal cost pricing is never achieved in fishing, and it is argued by some economists that regulations should be so structured to achieve this objective.

suggested by such economists as Crutchfield and Pontecorvo (1969). If a regulatory authority had tried this for the year 1971, it would have had a drastic impact on the fishery as the number of full-time equivalent vessels and traps would have been reduced by approximately 40 percent. To accomplish this objective, an estimated 1974 license fee of $22.43 per trap would be needed. This would yield the regulatory authority approximately $13.3 million in revenue.

From an economic point of view, it is argued that this management strategy will result in the most efficient operation of the fishery if fishermen and vessels can easily move to other fisheries or industries. However, this strategy may be particularly unwise in rural areas such as Maine where labor mobility is low. A drastic cutback in the number of fishermen may increase social problems where the cost would greatly exceed any benefits derived from such a management strategy. Therefore, this management strategy is difficult, if not impossible, to justify on economic grounds for many rural areas where the fishing industry is located and also has the same disadvantages as a general license fee plan on traps as discussed above.

D. Issue "Stock Certificates" to Each Vessel Owner Based on Average Catch over the Last Five Years while Freezing the Existing Level of Fishing Effort

Under this scheme, the historic rights of each fishing firm would be recognized. In a manner similar to a private land grant procedure, the regulatory authority would simply grant each fisherman a "private" share of an existing resource or catch. The stock certificate would be evidence of private ownership. Individual fishermen would be free to catch up to their allotted share through the use of pots or other biologically permissible technology; or, if they desired, trade their stock certificates to others for cash.

Suppose the regulatory authority were to freeze the level of fishing effort at the 1969 level and distribute the catch via a stock certificate to the existing fishermen. It should be pointed out that the regulatory authority fixes effort when it selects a given catch. The selected catch could be either MSY or any other level of catch deemed by the regulatory authority not injurious to the viability of the stock. The expansion in demand for lobsters by 1974 would generate excess profits for those individual fishermen who were initially endowed with the property right. By 1974, it is estimated that a full-time lobsterman would be earning $10,278 a year of which $1,878 would be excess profits (i.e., above opportunity cost). If profits become excessive, a license fee could be levied on the fishermen holding stock certificates to insure against increasing abnormal returns and providing the regulatory authority with funding to conduct scientific investigations and enforcement.

It should be noted that this plan is identical to the licensing scheme which freezes effort at the 1969 level. However, in the latter case excess profits are taken by the regulatory authority, while for this strategy fishermen are allowed to hold onto the profits generated in the fishery. Since many fisheries are located in rural areas where earnings are traditionally low, this strategy might be justified on the basis that it will raise income levels and thereby help improve living standards to levels comparable to those received in urban areas. This management strategy would, of course, be popular with those already in the fishery. However, new entrants would have to buy stock certificates from those initially in the fishery. This would pose certain questions of equity and legal precedent which are beyond the scope of this article.

E. No Management Strategy

When considering the economic consequences of alternative management strategies (A through D), it is always wise to assess the results of doing nothing. This gives policymakers a better perspective in evaluating the benefits from taking action.

The consequence of doing nothing would be overcapitalization by 1974 with an expansion in the number of full-time equivalent fishermen and traps fished. Over 96,000 excess traps would be in the fishery, and the catch would fall to 28.1 million pounds. The fishery would grow increasingly overcapitalized and the resource greatly overexploited as demand increased for lobsters during the 1970's. On economic grounds, these results are hardly acceptable because more fishermen and vessels will be catching less.

F. Other Suggested Management Strategies

Reeves (MS.) proposed a hike in license fees to "eliminate" marginal or part-time fishermen. He suggested that the present $10 yearly fee in Maine be raised $10 a year over the next 9 years to a limit of $100. In 1969, a little less than one-half of the lobster fishermen were part-time. As defined by Reeves, a part-time lobster fisherman is one who gains less than one-half of his annual income from lobstering.

The first step in most suggested limited entry schemes is usually to restrict the fishery to full-time utilization of capital and labor. Two problems occur with this policy. First, the part-time fishermen may represent the most efficient way of taking the catch. If so, the full-time fishermen may be eliminated by increased license fees. Second, license fees do not directly control fishing effort since fishermen may fish more traps. However, Reeves went on to argue strongly for limiting the number of traps each fisherman is allowed to set. It is not quite clear whether anyone knows the optimum number of traps per vessel.

Rutherford, Wilder, and Frick

(1967) in their study of the Canadian inshore lobster fishery endorsed the system suggested by Sinclair (1961). They stated:

> An alternative management system is that suggested by Sinclair (1961) for the salmon fisheries of the Pacific coast. This would use the licensing of fishermen to limit entry into the fishery. In the first stage, lasting about 5 years, licenses would be reissued at a fee but no new entries would be licensed and it would be hoped that during the period there would take place a reduction in the labor and capital input, to take the maximum sustainable catch of salmon at a considerably lower cost. After the end of the first stage, licenses would be issued by the government under competitive bidding and only in sufficient numbers to approximate the most efficient scale of effort; the more competent fishermen would be able to offer the highest bids and it would be expected that the auction would recapture for the public purse a large portion of the rent from the fisheries that would otherwise accrue to the fishing enterprises under the more efficient production conditions in the fishery.
>
> An arbitrary reduction in the number of fishermen by restriction of licenses to a specified number would entail injustice and inequity as well as grave administrative problems in determining who should be allowed to continue fishing. The auctioning of licenses to exploit a public property resource is justifiable in a private enterprise system of production, particularly when the state is incurring heavy expense to administer and conserve the resource; the recovery by the state of some part of the net economic yield by means of a license fee on fishermen (or on the catch) would recoup at least part of such public expenditures, or could be used to assist former fishermen [see strategies discussed above], for instance, by buying their redundant equipment. A license fee on fishermen through the auctioning of licenses has, at least, the merit of using economic means instead of arbitrary regulations to achieve a desired economic objective—the limitation of fishing effort to increase the net economic yield from the fishery. Regulations have to be enforced, usually at considerable cost, but economic sanctions tend to be, if not impartial, at least impersonal and automatic in their operation. (pp. 99-100)

Actually, this latter management scheme is similar to the licensing scheme, but uses an auction rather than a direct license fee.

CONCLUSIONS

The purpose of this article was to explain the use of bioeconomic models in assessing alternative management strategies. For this purpose the data were less than optimal. However, this does not mean that we cannot take steps in the direction of fishery management. In fact, these steps must be taken to protect the resource from destruction and to achieve a better use of vessels and fishermen. It is hoped that the following conclusions will provide a helpful framework in which to consider the merits of limited entry.

A. For the inshore American lobster resource we see every indication that the fishery has achieved MSY and is fully capitalized. This has been brought about by a rapid expansion in effort (i.e., traps fished) produced by (1) free access to the resource, (2) a rising market for lobsters of all species, and (3) a secular decline in seawater temperature.

B. We have presented the bioeconomic impact of alternative management strategies to both conserve and use the resource efficiently. The choice of which strategy to pursue is in the public domain and beyond the scope of this paper. However, the economic alternatives have been pointed out.

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