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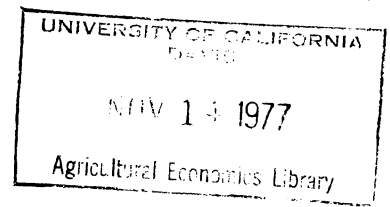
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Distribution Effects of Fisheries Policy:
An Empirical Example of the
New England Sea Scallop Fishery*

by

Marilyn A. Altobello**

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**Assistant Professor, Department of Agricultural Economics, University of Arizona Tucson.

Introduction

The commercial fishery is an industry of relative importance in the United States. In 1976, landings by U.S. vessels at U.S. ports amounted to 5.4 billion pounds and were valued at 1.4 billion dollars (figure 1). In spite of the economic significance of the industry, only recently has any notable national policy been developed which addresses itself to the problem of managing marine fishery resources.

In the Fishery Conservation and Management Act of 1976, Congress declared that the fish off the coasts of the United States, more specifically, the migratory species, the bottom-dwellers or demersal species, and the anadromous species, which spawn in U.S. rivers or estuaries, were valuable and renewable natural resources. The major provisions of this Act are as follows:

(i) to conserve and manage the fishery resources of the United States by establishing a Fishery Conservation Zone or "200-mile limit", effective March 1, 1977.

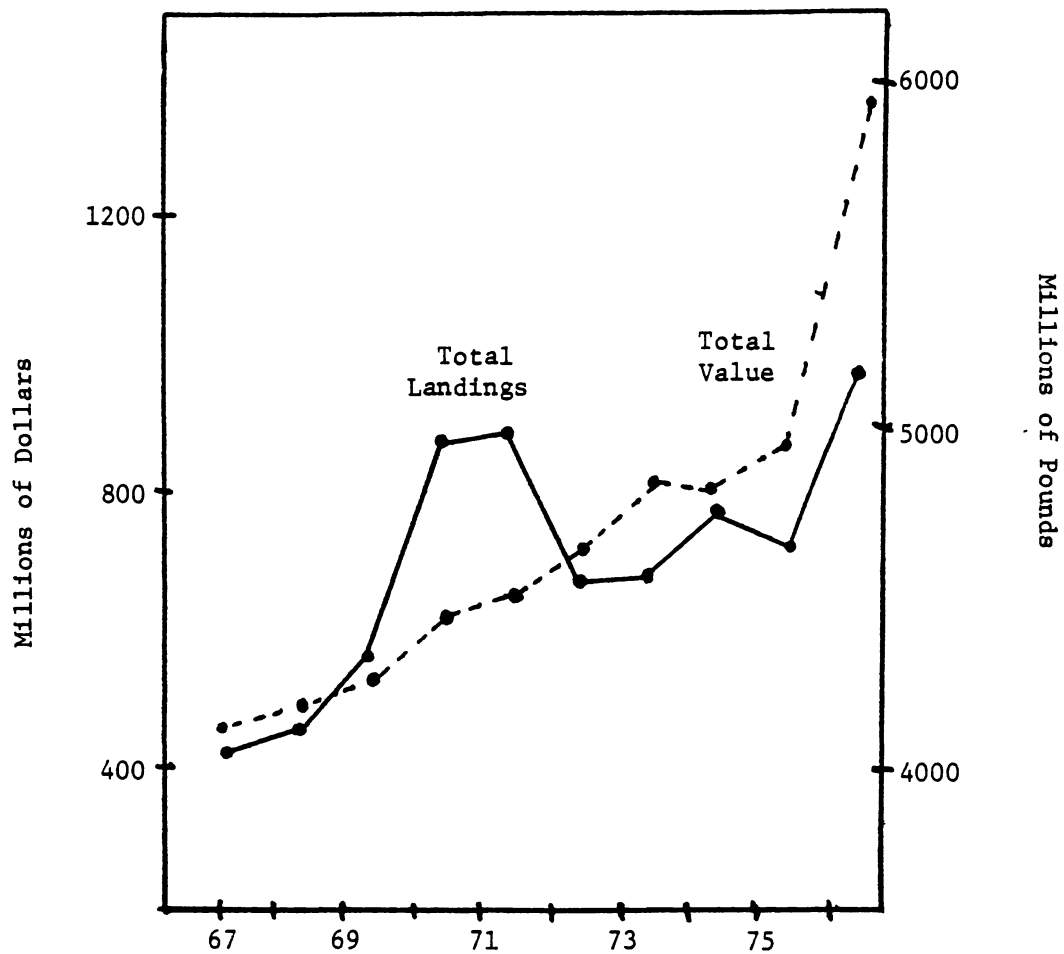
(ii) to provide for the preparation and implementation of fishery management plans such that the optimum yield from each fishery will be achieved and maintained.

(iii) to establish Regional Fishery Management Councils to prepare, monitor, and revise plans for achieving and maintaining optimum yield from the fishery.

(iv) to determine the total allowable level of foreign fishing, if any, in U.S. coastal waters.

Implementation of the provisions of the Fishery Conservation and Management Act will undoubtedly have a number of economic implications. One important result of a national fishery policy will be its effect on the distribu-

Figure 1
U.S. Commercial Landings, Quantity
And Value, 1967-1976



Source: National Marine Fisheries Service,
Fisheries of the United States

of income accruing from the commercial harvesting of the various marine fishery resources. However, since the Act has only recently come into effect, it is as yet too early to assess its full economic impact on the industry. This paper, using past trends in the New England sea scallop fishery as a basis for analysis, investigates the potential income distributional effects of implementing optimal management strategies in accordance with national policy.

Specific Example: The New England Sea Scallop Fishery

One fishery which is likely to be affected by the implementation of a management plan under the Fishery Conservation and Management Act of 1976 is the New England sea scallop fishery. The sea scallop (*placopecten magellanicus*) is a disc-shaped bivalve mollusk which is harvested in the coastal waters off Canada and the northeastern United States by vessels of both nations. Major sea scallop beds are located on Georges Bank, an area approximately 100 miles east of Cape Cod, and the principal U.S. port receiving sea scallops is New Bedford, Massachusetts.

The sea scallop fishery has been of economic importance especially in New England where, from 1952 to 1965, approximately 13 percent of the value of all fish and shellfish landed was attributable to the harvest of sea scallops. In more recent years, however, various factors such as increased operating costs of New England sea scallop vessels, increased competition from Canadian vessels, and lowered natural abundance have combined to bring about a decline in the relative importance of the New England sea scallop fishery. During the years 1966 to 1975 the proportion of the annual value of New England commercial fishery landings attributable to sea scallops had dropped to an average of 9 percent. The situation improved somewhat in 1976, when nearly 12 million pounds of sea scallops valued at 22.2 million dollars were landed in New England

(table 1). Nearly all of these were landed at New Bedford, and they represented 13 percent of the total value of fish and shellfish landed in New England.

In 1976, an amount representing approximately 90 percent of the total value of sea scallops landed in the U.S. was harvested in coastal waters 12-200 miles of U.S. shores. Thus with the passage of the Fishery Conservation and Management Act of 1976, the more productive sea scallop beds fell under U.S. jurisdiction, and under the provisions of the Act, the preparation of a plan for managing these sea scallop beds was required. However, the northern third of Georges Bank has been claimed by Canada as well as the U.S. Consequently no decision regarding the total allowable level of fishing effort for either country has been or will be made until an agreement on the division of the fishing grounds is reached by the United States and Canada.

Methodology for Determining Income Distributional Impacts of Fishery Management Policy on the New England Sea Scallop Fishery

At this time, there is no official proposed management plan for sea scallops pending a Canadian-U.S. agreement. However, an intertemporal bio-economic model of the sea scallop fishery has been developed which could be of use in determining optimum yield and in deriving optimal management strategies for the fishery.

The first step in model development was defining the objectives of the fishery management program and the appropriate constraints. Next, the biological and economic functional relationships required for model construction were specified. For the sea scallop fishery, these included the biotechnical function, yield or production functions, demand functions, and cost estimates. Parameters for each equation were then estimated and substituted into the model. The model was then solved for numerical values of the decision and resource stock variables which optimized the

Table 1
Landings and Value of Landings of Sea Scallops
at New England* Ports,

Year	Landings (10 ³ Pounds)	Value of Landings (10 ³ Dollars)	Average Value Per Pound (Dollars)
1967	7,025	5,438	.77
1968	7,938	8,850	1.11
1969	5,107	5,636	1.10
1970	4,467	6,028	1.35
1971	4,346	6,418	1.48
1972	4,422	8,628	1.95
1973	3,949	7,072	1.79
1974	4,611	7,174	1.56
1975	7,080	13,380	1.89
1976	11,959	22,230	1.86

*Maine, Rhode Island, Massachusetts

Source: National Marine Fisheries Service

objective function. Model solutions then served as a basis for analyzing the effects on income distribution of implementing a selected management policy in accordance with the provisions of the Fishery Management and Conservation Act of 1976. The remainder of this section will discuss in more detail the design and development of the model.

Firstly, we assume the existence of a central decision-maker (i.e., Regional Fishery Management Council) that is seeking to achieve optimum yield from the fishery, in accordance with the Fishery Conservation and Management Act of 1976. We also assume that this objective is consistent with maximizing:

(i) the sum of discounted net revenues accruing from the commercial harvesting of the Georges Bank sea scallop fishery by Canada and the United States over a specified time period, $T-1$ years, and

(ii) a specified terminal resource stock function, subject to a constraint imposed by the rate of population change of the sea scallop resource. In order to more formally express the objective function and constraints outlined above, relevant economic and biological relationships must be specified.

The biotechnical function is defined as follows:

$$N_{t+1} = g(N_t) - Y_{c,t} - Y_{u,t} \quad (1)$$

where N_t \equiv total stock of sea scallops on Georges Bank in units of biomass in year t

$Y_{c,t}$ \equiv Canadian landings of sea scallops from Georges Bank in units of biomass in year t

$Y_{u,t}$ \equiv U.S. landings of sea scallops from Georges Bank in units of biomass in year t .

Equation (1) simply implies that the population of sea scallops in one year is a function of the previous year's population size minus landings.

Secondly the production or yield functions for Canada and the U.S. are specified as follows:

$$\text{Canada: } Y_{c,t} = \phi_{c,t} (E_{c,t}, E_{u,t}; N_t) \quad (2)$$

$$\text{U.S. : } Y_{u,t} = \phi_{u,t} (E_{u,t}, E_{c,t}; N_t) \quad (3)$$

where N_t , $Y_{c,t}$ and $Y_{u,t}$ are defined above and:

$E_{c,t}$ \equiv number of days Canadian vessels fished for Georges Bank sea scallops in year t

$E_{u,t}$ \equiv number of days U.S. vessels fished for Georges Bank sea scallops in year t .

Equations (2) and (3) define Canadian and U.S. yield as functions of N_t and both $E_{c,t}$ and $E_{u,t}$. Here it is assumed that congestion externalities exist implying:

$$\frac{\partial Y_{c,t}}{\partial E_{u,t}} < 0 \text{ and } \frac{\partial Y_{u,t}}{\partial E_{c,t}} < 0.$$

The inverse demand function is important for determining industry total revenues and is given as follows:

$$P_t = r_t - sQ_t \quad (4)$$

where P_t is defined as average ex-vessel price per pound of sea scallop meats in year t ; Q_t is the quantity of sea scallop meats landed at New England and Canadian ports in year t ; and r_t and s represent the intercept term and slope respectively.

Finally cost equations are specified for both Canada and the U.S.:

$$C_{c,t} = k_{c,t} \cdot E_{c,t} \quad (5)$$

$$C_{u,t} = k_{u,t} \cdot E_{u,t} \quad (6)$$

where $E_{c,t}$ and $E_{u,t}$ are defined above and where $C_{c,t}$ and $C_{u,t}$ represent total costs incurred respectively by Canadian and U.S. vessels fishing for sea scallops on Georges Bank in year t , and $k_{c,t}$ and $k_{u,t}$ represent daily operating costs respectively for Canadian and U.S. sea scallop vessels on Georges Bank.

Parameters of equations (1) - (4) were estimated using time series data provided by the U.S. Department of Commerce, National Marine Fisheries Service (NMFS) and the International Commission for Northwest Atlantic Fisheries (ICNAF). Values of $k_{c,t}$ and $k_{u,t}$ in (5) and (6) were derived from the results of a study conducted by Doherty, Draheim, White and Vaughn, and from NMFS estimates of average costs and earnings of selected New Bedford scallop vessels. These specified and estimated biological and economic relationships were then utilized in constructing the management model in the following manner:

Substituting $(Y_{c,t} + Y_{u,t})$ for Q_t in (4) and then multiplying by $(Y_{c,t} + Y_{u,t})$ yielded an expression for total revenue accruing to U.S. and Canadian sea scallop fishermen in year t . Subtracting the right-hand sides of (5) and (6) (total cost incurred by Canadian and U.S. fishermen) from total revenue and substituting the right-hand sides of (2) and (3) for $Y_{c,t}$ and $Y_{u,t}$ defined an expression for net revenue in year t :

$$NR_t = [r_t - s(\phi_{c,t}(E_{c,t}, E_{u,t}; N_t) + \phi_{u,t}(E_{c,t}, E_{u,t}; N_t))] \cdot [\phi_{c,t}(E_{c,t}, E_{u,t}; N_t) + \phi_{u,t}(E_{c,t}, E_{u,t}; N_t)] - k_{c,t} \cdot E_{c,t} - k_{u,t} \cdot E_{u,t} \quad (7)$$

Introducing a discounting factor ρ^t , where $\rho = \frac{1}{1+r}$ and $0 \leq r \leq 1$, adding a terminal resource stock function, $F(N_T)$, summing net over $T - 1$ years and substituting the right-hand sides of (2) and (3) for $Y_{c,t}$ and $Y_{u,t}$ in (1) resulted in the following complete problem:

$$\begin{aligned} \text{Max } \Pi = & \sum_{t=0}^{T-1} \rho^t \{ [r_t - s(\phi_{c,t}(E_{c,t}, E_{u,t}; N_t) + \phi_{u,t}(E_{c,t}, E_{u,t}; N_t))] \cdot [\phi_{c,t}(E_{c,t}, E_{u,t}; N_t) + \phi_{u,t}(E_{c,t}, E_{u,t}; N_t)] - k_{c,t} \cdot E_{c,t} - k_{u,t} \cdot E_{u,t} \} \\ & + F(N_T) \end{aligned} \quad (8)$$

subject to:

$$N_{t+1} - g(N_t) + \phi_{c,t}(E_{c,t}, E_{u,t}; N_t) + \phi_{u,t}(E_{c,t}, E_{u,t}; N_t) = 0 \quad (9)$$

After substituting the estimated parameters in (8) and (9), specifying a terminal stock function (in this case, $F(N_T) = Z \cdot N_T$ where Z represents a relative weight), and choosing a time period which implies a value for T , the problem became one of maximizing a nonlinear objective function subject to nonlinear constraints. More specifically values of $E_{c,t}$ and $E_{u,t}$ were chosen to maximize (8) subject to (9), and these implied values for N_t .

Model Solutions

In using the model outlined above to analyze the New England sea scallop fishery, the period 1964-1968 was selected, "optimal" values of $E_{c,t}$, $E_{u,t}$ and N_t were determined for this period, and the potential effects on income distribution of adopting an optimal program for the management of sea scallops were estimated.

As the historical data indicate (table 2), this time period proved to be an interesting one in the history of the fishery. Canadian fishing effort remained relatively stable over the five-year period, averaging 6351 vessel days per year while that of the U.S. was relatively high in 1964 at 6656 days, but declined sharply to 3156 days in 1965. Also during this time period, there was a reduction in the population of sea scallops by more than one-half, from approximately 36.2 million pounds of edible meats in 1964 to 15.3 million pounds in 1969.

Table 2

Actual Values of $E_{c,t}$ and $E_{u,t}$, 1964-1968, and N_t , 1964-1969

t (Year)	$E_{c,t}$ (Vessel Days)	$E_{u,t}$ (Vessel Days)	$E_{c,t} + E_{u,t}$ (Vessel Days)	N_t (10^5 Lbs.) (Edible Meats)
1964	6723	6656	13379	362
1965	5749	2156	7905	254
1966	5524	1001	6525	164
1967	6785	1870	8655	158
1968	6972	1938	8910	155
1969				153
	Σ 31753	Σ 13621	Σ 45374	

Two "optimal" solutions generated by the model are compared with the actual data in figures 2 and 3. The results of the first solution, Optimal 1, were such that in any one year, optimal fishing effort for either Canada or the United States was zero. In the second solution, Optimal 2, upper and lower bounds of 8000 and 1000 were assigned to $E_{c,t}$ and $E_{u,t}$. This resulted in a reduction of less than 3 percent in the value of the objective function, but a more equitable distribution of fishing effort between Canada and the U.S.

The values of $E_{c,t}$, $E_{u,t}$, and N_t from both solutions were then used to derive Canadian and U.S. landings ($Y_{c,t} + Y_{u,t}$), and these in turn were used to compute optimal prices, P_t , over the five-year period (figures 4 and 5).

In comparing both model solutions with actual data, it is apparent that optimal aggregate fishing effort for both the United States and Canada was less than that which actually occurred over the five-year period. Also the model solutions indicate that a more preferred strategy would have been to harvest a greater number of sea scallops in 1964, and fewer in subsequent years.

Figure 2
Canadian and U.S. Effort
($E_{c,t} + E_{u,t}$)

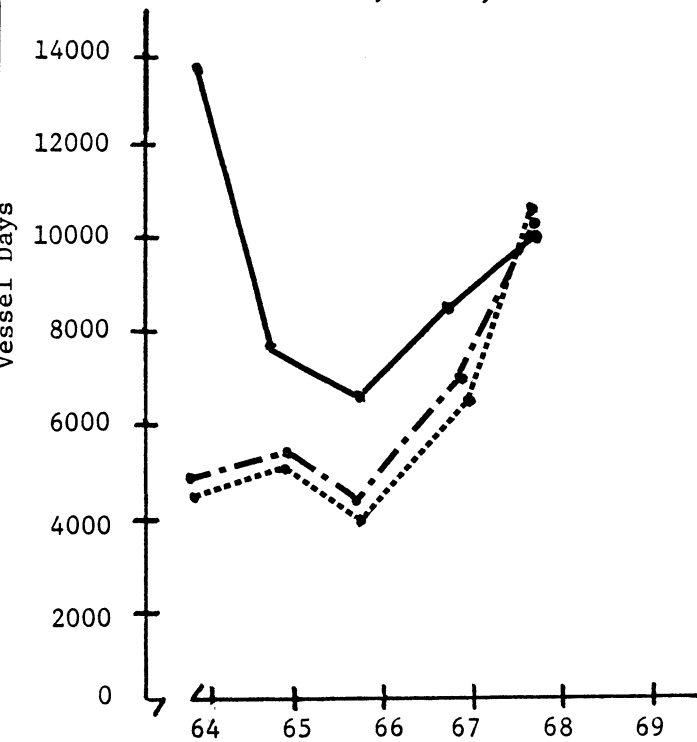


Figure 3
Scallop Stock
(N_t)

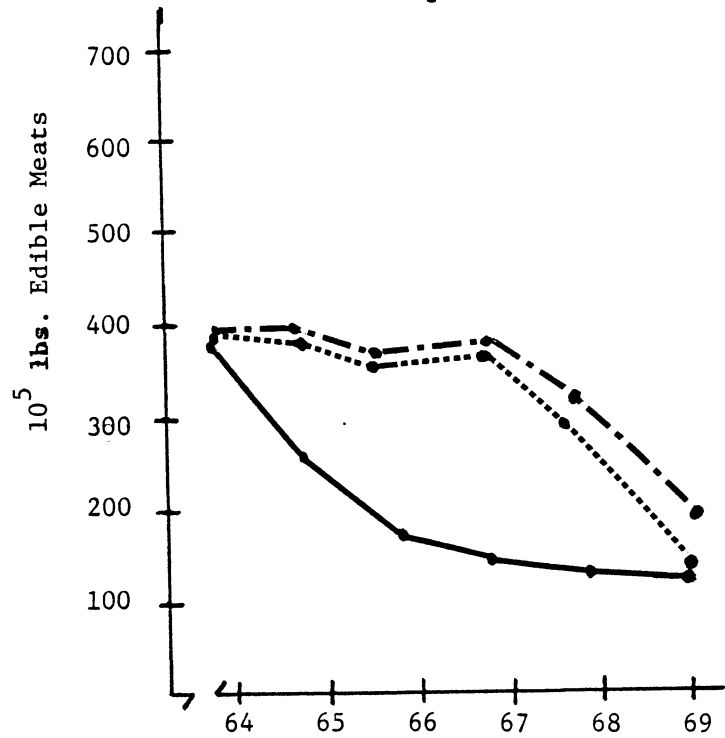


Figure 4
Canadian and U.S. Landings
($Y_{c,t} + Y_{u,t}$)

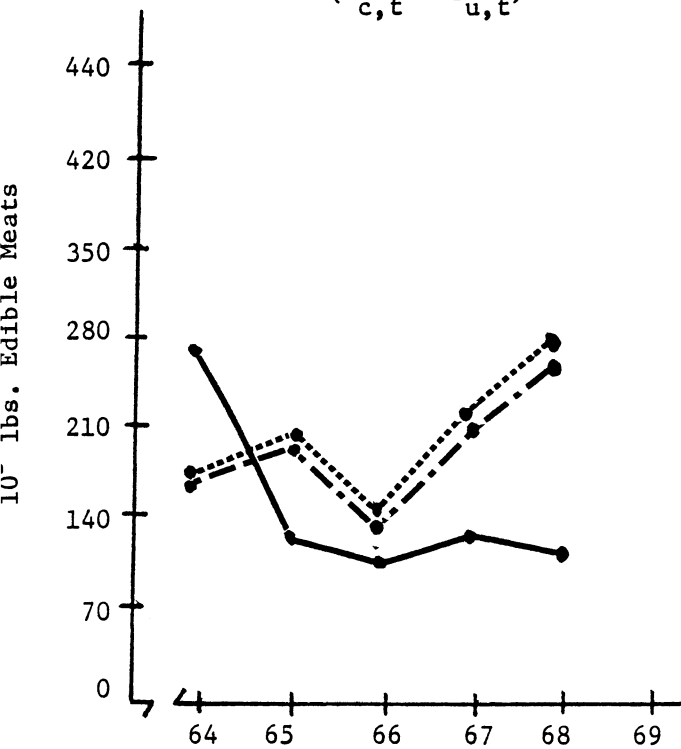
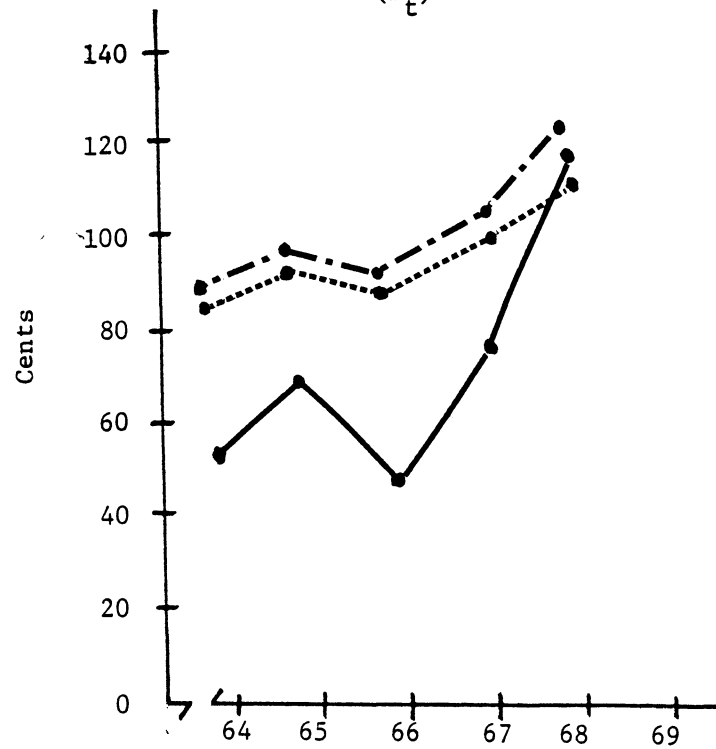


Figure 5
Ex-vessel Price Per Pound
(P_t)



— Actual

..... Optimal 1

- . - . - . Optimal 2

Effects of Potential Fishery Management Programs
on the Distribution of Net Income

Implementation of a fishery management program for sea scallops based on the results outlined above would most certainly effect the distribution of net income accruing to Canadian and U.S. fishermen. From the model solutions presented in the previous section, it is possible to estimate the potential income distributional effects of such a program.

By substituting values of the variables generated by optimal solutions 1 and 2 into the following expression:

$$NI_t = P_t(Y_{c,t} + Y_{u,t}) - k_{c,t} \cdot E_{c,t} - k_{u,t} \cdot E_{u,t} \quad (10)$$

and evaluating for each year in the time period 1964-68, it is possible to derive estimates of aggregate net income which would have accrued to U.S. and Canadian fishermen had one of the management schemes been implemented. These values are given below and compared with estimates of net income actually accruing to Canadian and U.S. sea scallop fishermen during the time period.

Net Income Accruing to U.S. and Canadian Sea Scallop Fishermen

Year	Actual	Optimal 1	Optimal 2
1964	7.3	10.4	10.2
1965	4.2	11.6	11.4
1966	2.0	8.3	8.1
1967	4.7	14.1	13.7
1968	<u>7.9</u>	<u>19.4</u>	<u>18.7</u>
	26.1	63.8	62.1

The differences in the magnitude and the distribution over time of net income are evident. If Optimal 1 had been implemented, it is estimated that total net income accruing to U.S. and Canadian fishermen over the 5-year period would have been more than twice the actual. Also, more net income - approximately 65 percent of the total - would have been earned in the last three years of the period as opposed to the 56 percent actually earned in 1966-1968. At best, these figures are rough estimates but they do not indicate the gains in net income which could occur if a management scheme for sea scallops were implemented.

Directions for Future Research

The potential effects of fishery management policy on the distribution of net income among sea scallop fishermen have been demonstrated. The Fishery Conservation and Management Act has only recently been enacted, and fishery management plans are just now being proposed for various species. However, before effective fishery management plans can be developed, more research in the area is needed.

In accordance with the Act, policymakers need to determine:

- (1) Optimal yield for a species
- (2) The level of fishing effort required to achieve optimal yield
- (c) Allocation of fishing effort among U.S. fishermen
- (d) Allowable level of foreign fishing in U.S. territorial waters
- (e) The income distributional effects of any proposed management scheme.

The fishery management model outlined in this paper provides a basis for the quantitative analyses required for implementing an actual marine fishery management program. There are, however, some problems associated with constructing such a management model. These are related to data

collection, model construction and solution, and selection of policy instruments.

Firstly, there is a dearth biological data and other information describing the population dynamics of commercially harvested marine species. Other data-related problems include reconciling measures of catch, fishing effort, and vessel costs as compiled by various countries. Secondly, the existence of interdependencies among the variables of the system may create problems in specifying biotechnical and economic relationships and in estimating the parameters of these relationships. Thirdly, the mathematical properties of specific objective and constraint functions might pose problems in deriving numerical solutions. Lastly, once the optimal level and allocation of fishing effort have been determined, the appropriate tools for achieving this optimum, such as taxes, licensing, quotas, and limiting seasons, must be selected.

With the advent of extended jurisdiction and the formation of Regional Fishery Management Councils, the institutional framework now exists for developing and implementing specific fishery management programs. The problems mentioned here suggest areas in which the National Marine Fisheries Service, in cooperation with the universities, and international organizations, such as the United Nations and the International Commission for the Northwest Atlantic Fisheries (ICNAF), should intensify research efforts.

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