An Economic Evaluation of Foreign Fishing Allocations

Eric Meuriot
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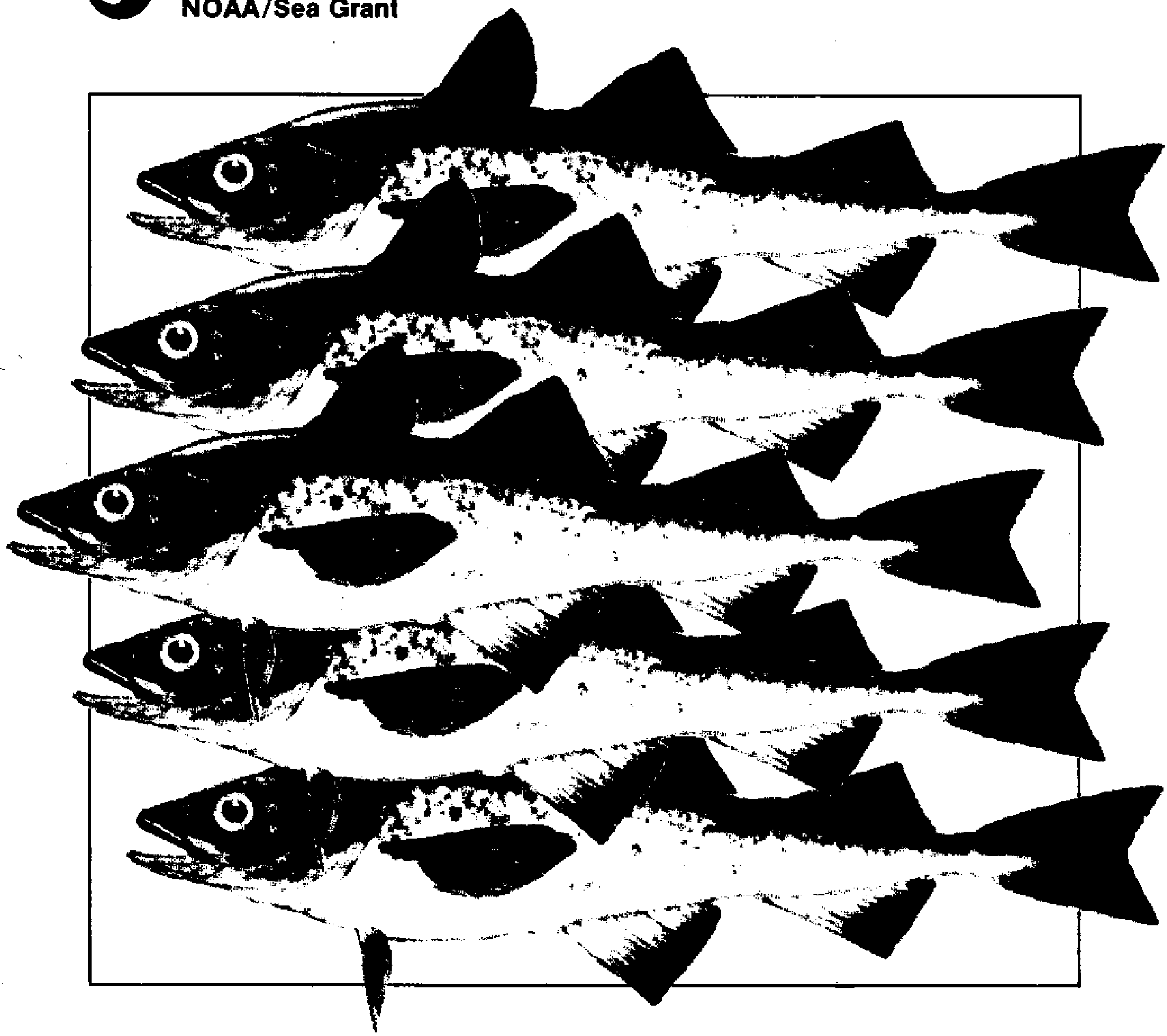
Resource Economics
NOAA/Sea Grant



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INTRODUCTION AND JUSTIFICATION FOR STUDY

Coastal state extension of national control into ocean areas has accelerated in recent years. In 1947, Chile and Peru were the first countries to extend their national jurisdiction on natural resources to a 200-mile limit. In 1969, only 15 out of 103 coastal states claimed limits exceeding 12 miles.[1] In 1981, 98 out of 135 coastal states claimed fishing limits exceeding 12 miles. As a result of this ocean enclosure process, by 1979 about 99 percent of the world's commercial fish catch was contained within these new fishing zones.

The distant-water fleets were the first affected by the widespread implementation of the new jurisdictions, since the coastal states have restricted foreign access to the fishing grounds in their jurisdiction. A recourse for the distant-water fleets is to harvest fish stocks not fully exploited by domestic fishermen in host jurisdictions. The access permit for these stocks can be obtained in exchange for the payment of fees,[2] the transfer of technology, or agreements on trade barriers and tariffs.

For the United States, the Fisheries Conservation and Management Act of 1976 (P.L. 94-265) and its amendment by the American Fisheries Promotion Act of 1980 (P.L. 96-561) established the framework for the definition of the Total Allowable Levels of Foreign Fishing (TALFF's), their allocation among foreign nations, and the minimum level of fees to be charged.

The TALFF for a fishery is determined annually on the basis of the prior year's TALFF adjusted by a reduction factor which depends, in part, on the projected domestic catch. That is, the TALFF's are determined by a rule directly linking the potential foreign catch to the domestic catch, which receives priority.

With respect to the allocation of these TALFF's, P.L. 96-561 specifies that:

> All such determinations shall be made by the Secretary of State and the Secretary on the basis of--
> (A) whether, and to what extent, such nations impose tariff barriers or nontariff barriers on the importation, or otherwise restrict the market access, of United States fish or fishery products;
> (B) whether, and to what extent, such nations are cooperating with the United States in the advancement of existing and new opportunities for fisheries trade, particularly through the purchase of fish or fishery products from United States processors or from United States fishermen;

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[1]Office of the Geographer, U.S. Department of State, Washington, D.C., May 1, 1981.

[2]A point of some dispute is whether such compensation can be regarded as a market exchange value or merely a recovery of costs incurred. At issue is whether a sovereign state can sell something over which it does not assert ownership.

(C) whether, and to what extent, such nations and the fishing fleets of such nations have cooperated with the United States in the enforcement of United States fishing regulations;
(D) whether, and to what extent, such nations require the fish harvested from the fishery conservation zone for their domestic consumption;
(E) whether, and to what extent, such nations otherwise contribute to, or foster the growth of, a sound and economic United States fishing industry, including minimizing gear conflicts with fishing operations of United States fishermen, and transferring harvesting or processing technology which will benefit the United States fishing industry;
(F) whether, and to what extent, the fishing vessels of such nations have traditionally engaged in fishing in such fishery;
(G) whether, and to what extent, such nations are cooperating with the United States in, and making substantial contributions to, fishery research and the identification of fishery resources; and
(H) such other matters as the Secretary of State, in cooperation with the Secretary, deems appropriate.[3]

Nations which receive an allocation may subsequently be granted access to a fishery when fees are paid by the owner or operator of the foreign fishing vessel. Concerning the determination of these fees, the law states:

> The Secretary, in consultation with the Secretary of State, shall establish a schedule of such fees which shall apply nondiscriminatorily to each foreign nation. The fees imposed under this paragraph shall be at least in an amount sufficient to return to the United States an amount which bears to the total cost of carrying out the provisions of the Act (including, but not limited to, fishery conservation and management, fisheries research, administration, and enforcement, but excluding costs for observers covered by surcharges under section 201(i)(4)) during each fiscal year the same ratio as the aggregate quantity of fish harvested by foreign fishing vessels within the fishery conservation zone during the preceding year bears to the aggregate quantity of fish harvested by both foreign and domestic fishing vessels within such zone and the territorial waters of the United States during such preceding year.[4]

Finally, discretionary authority is provided to place an observer on each foreign vessel engaged in fishing within the U.S. fishery conservation zone (FCZ).

A first set of options faced by the U.S. management concerns the share, between foreign participants and the U.S. Treasury, of the benefits of access. The options range from the recovery of the management and enforcement costs (as a minimum) to the collection of the totality of the gains of access. If the goal is to extract the full value of access, a procedure is needed to estimate the net benefits of access by country, vessel category, and fishery. A procedure is also necessary when

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[3] P.L. 96-561, Part C, Sec. 231.

[4] P.L. 96-561, Part C, Sec. 232.

management and enforcement costs are to be recovered. Part of these costs are fixed and must be apportioned among foreign participants via the fee schedule.

The share of the benefits of access must be evaluated in the short run--that is, in the absence of replacement of the fleet's capacity--as well as over the long run. Indeed, the development of the domestic catch may require long-term agreements with foreign nations on reducing trade barriers and tariffs, and long-term access guaranteed in return. This supposes the ability of the foreign nation to replace its harvesting capacity. Also, due to the differences in input costs between domestic and foreign fleets, reductions in foreign tariff barriers may not be sufficient to guarantee the profitability of the domestic fishing operations in substitution for the foreign ones.

A second set of management options concerns the institutional mechanism to be used for levying fees and allocating the TALFF's. The world's three largest distant-water fleets (Soviet, Japanese, and Polish)[5] are characterized by a high degree of concentration of their centers of decision. In 1979, these fleets accounted for almost 90 percent of the total foreign catch in the FCZ of the United States. In this case, the potential weakness of auctioning and bilateral negotiation systems is that they allow strategic behavior, including collusion among participants. The participants' knowledge of differences in valuation or of limited fleet capacity would also diminish the value of the auctions (or bids) or the extent of the trade concessions. Such allocation systems would be more effective if they were backed by independent estimates of access benefits.

Alternative systems set fixed fees based on the catch/allocation or effort quota, or a combination of both. Assuming perfect certainty and no enforcement costs, there is, a priori, no superiority of a system of fees based on catch over one based on effort. Under either system, it is necessary to determine the impacts of specific fee schedules on the foreign fishing activities, catches, net revenues, and the level of fees collected.

In the absence of a competitive market where fishing permits could be traded, estimation of access benefits and the reaction of fleets to different conditions imposed on entry have become important decision elements in the management of fisheries underexploited by local fishermen. The objective of this study is to develop a model which estimates foreign valuations of access and the impacts of alternative management decisions on the foreign fleets' activities.

While this study is compatible with rent extraction as a policy goal, it does not advocate any policy, nor is the usefulness of the study predicated on adoption of a rent extraction policy. We are skeptical that any quantitative method can fully capture the complexities of real world policy formulation. We do believe, however, that this study illustrates a useful approach to estimating values which are of some interest in the policy-making process.

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[5]Measured in terms of total tonnage of vessels over 500 gross registered tonnage (GRT), Lloyd's Register of Shipping, Statistical Tables, 1979.

REVIEW OF LITERATURE--FOREIGN VALUATION OF ACCESS

Foreign valuation of access has been studied by Vidaeus (1977) for the U.S. Atlantic herring fishery and by Crutchfield (1980) for the U.S. Alaska pollock fishery. Their approach is based on the change in consumers' surplus resulting from a change in fish allocation. However, they did not take into account the effect of alternative fishing grounds on the behavior of the foreign fleets nor the opportunity cost associated with the exploitation of a specific fishery.

Also, one of their major assumptions is that foreign governments will pay that portion of fees corresponding to the gain in consumers' surplus. However, for some countries the demand for access is the demand from the fishing companies and does not incorporate any consideration of consumers' surplus. This holds even if the agreements are reached through governmental channels. The revealed preferences, via import restrictions, of many nations give little weight to consumer surplus relative to producer surplus. Furthermore, in countries with central planning, the concept of consumer surplus is absent from the prevailing economic theory, and criteria such as currency availability or even profits might constitute a more appropriate basis for the evaluation of the gain of access.[6] There is, therefore, little evidence that governmental willingness to pay or subsidize is bounded, from either above or below, by consumers' surplus. While this study does not use the measure, it could be extended to do so. Because of this, we regard the study as complementary to the earlier studies we have described.

For the Northwest Africa fisheries, Christy (1979) assessed the potential value of access permits by the difference between total revenues and total costs which can be obtained through a restriction on fishing effort; that is, the economic rent derived from a control on the access to the fisheries. The evaluation is based on the hypothesis that entry led to zero producer surplus, at the margin, before the extension of fishery jurisdictions. In particular, all fishing vessels are supposed to yield identical economic results despite their differences in size, flag, or the type of directed fishery into which they are engaged. The acceptance of this theoretic situation corresponding to the long-run steady state under open-access conditions, homogeneous harvesting costs, and a common product market reflected the lack of economic information which, according to Christy, should be considerably improved, not only to determine fish product prices but also to measure fishing costs.

The above overview shows the lack of a detailed model for assessing the economic value to mixed foreign fleets of access to multispecies fish stocks. There is need for such a model as input into management decisions pertaining to the foreign fishing permits in extended jurisdictions.

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[6]Quoting Skwira (1970) from the Dalmor deep-sea fishing company (Poland): "The criterion of profit considers all factors which should be taken into account in the process of selecting the proper fishing ground."

MODELING PROCESS AND L.P. FORMULATION

We assume a management goal of efficient allocation of the fishery resources in order that the potential revenue from fees be made as large as possible. The objective is then the global maximization of the sum of net benefits. The constraints related to the total allowable catch (TAC) in the FCZ of the United States are common to all fleets, while the constraints on quotas in other zones and the harvesting and processing capacity limits are particular to each fleet.

In the case of linear economies, Dantzig and Wolfe (1961) and Kornai and Liptak (1965) first indicated through decomposition methods the equivalence between the global maximization of separate decision makers' objectives and the allocation, to them, of the resources controlled by a central management according to the criterion of efficiency. The conditions are that each decision maker or subsystem has a unique objective function, that these objective functions are similar, and, finally, that each subsystem selects its activities efficiently so as to optimize its objective function.

Extension of decomposition methods to the nonlinear situations can be realized but with reduced solution efficiency algorithms.[7] Extensions to the case of production externalities imposed by one system on another have been analyzed by Whinston (1964) and Hurwicz (1969). The basic idea is then to give each subsystem two sets of decision variables: its own level of activities and also the total output it proposes for other subsystems. The central management then sets not only a price for the resources under its control but also a unit charge to be paid by one subsystem for the requirement of production restrictions for the other subsystems. The externalities are thus treated as ordinary commodities which can be traded at a price.

The above discussion illustrates that a global optimization of different subsystems or fleets' objective does not necessarily presume that there exists a single manager for all the fleets. It may be presented as a computational procedure for problems where a center allocates the resources under its control among separate fleets according to the criterion of economic efficiency. The advantage of the global optimization is that it can usually be solved by efficient solution algorithms such as the simplex method in the linear case. This latter algorithm can also be used for nonlinear cases through separable programming.

Static Stock Effect

A nonlinear optimization problem in fisheries results from the static stock externality which exists for a fixed fish stock in the short run. Carlson (1969), Gates and Norton (1974), and Rothschild (1977) have shown

[7] See, for example, Lacaze (1976).

the distinction between the production function of an individual unit of effort and the aggregate production function in the short run. The justification is that if one vessel catches a proportion α of the stock considered as fixed in the short run, two vessels would catch something less than 2α. It can be compared to a drawing without replacement and implies a production function of the Mitscherlich-Spillman type. The nonlinearity was approximated using a technique of separable programming (Duloy and Norton, 1975).

In case of technological interdependences between fish stocks, a change in the total catch of a species results in a different row vector of catch per unit time (CPUT) fishing coefficients for that species[8] but also in a change in catch of the other species through the bycatch. The modification of the CPUT's for these other species depends, however, on the mix of fishing efforts, since each effort vector may have different bycatch coefficients. An optimal fishing strategy or mix of fishing effort vectors is given by the solution to the mathematical programming problem. The general framework for the determination of the short-run impacts of alternative U.S. management decisions on the foreign fleets' activities and valuation of access is represented in Figure 1. In this figure, two different levels of decisions with separate objectives and constraints but interacting variables can be distinguished. As indicated in Figure 1, the TAC's are taken as given. One can also introduce policy constraints in the model; for example, allocation to a given nation might be assigned upper or lower bounds. The global maximization model is run which determines for each fleet the optimal fishing strategies, catches, global benefits, and, for the U.S. management, the corresponding optimal allocations and fees. Alternatively, arbitrary allocations and/or fee schedules can be devised, and the expected reactions of the participants are deduced by the fishing strategies selected, catches, costs, revenues, and the fees paid.

The feedback effects of the participants' reaction on the CPUT's, in the case of congestion or static stock effect, and on the market prices, when these are endogenous, are expressed in Figure 1 by the dotted lines. Incorporation of these effects in the global maximization program yields a nonlinear problem which may or may not be amenable to solution via extensions of linear programming.

The framework is applied in the present study by the use of linear and separable programming. Table 1 presents a simplified L.P. tableau representing the activities of two vessel categories (1,2) catching a mix of two species (x,y). In this example, the only variable CPUT's are those corresponding to the catch of species x. Other simplifications stem from the fixed product prices and the absence of on-board processing.[9]

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[8]A row vector of CPUT represents here the CPUT's of a single species for different types of effort. A column vector of CPUT represents here the CPUT's of the main catch and bycatch species for one type of effort.

[9]However, in the application of this framework, the different types of on-board processing are explicitly considered for each vessel category.

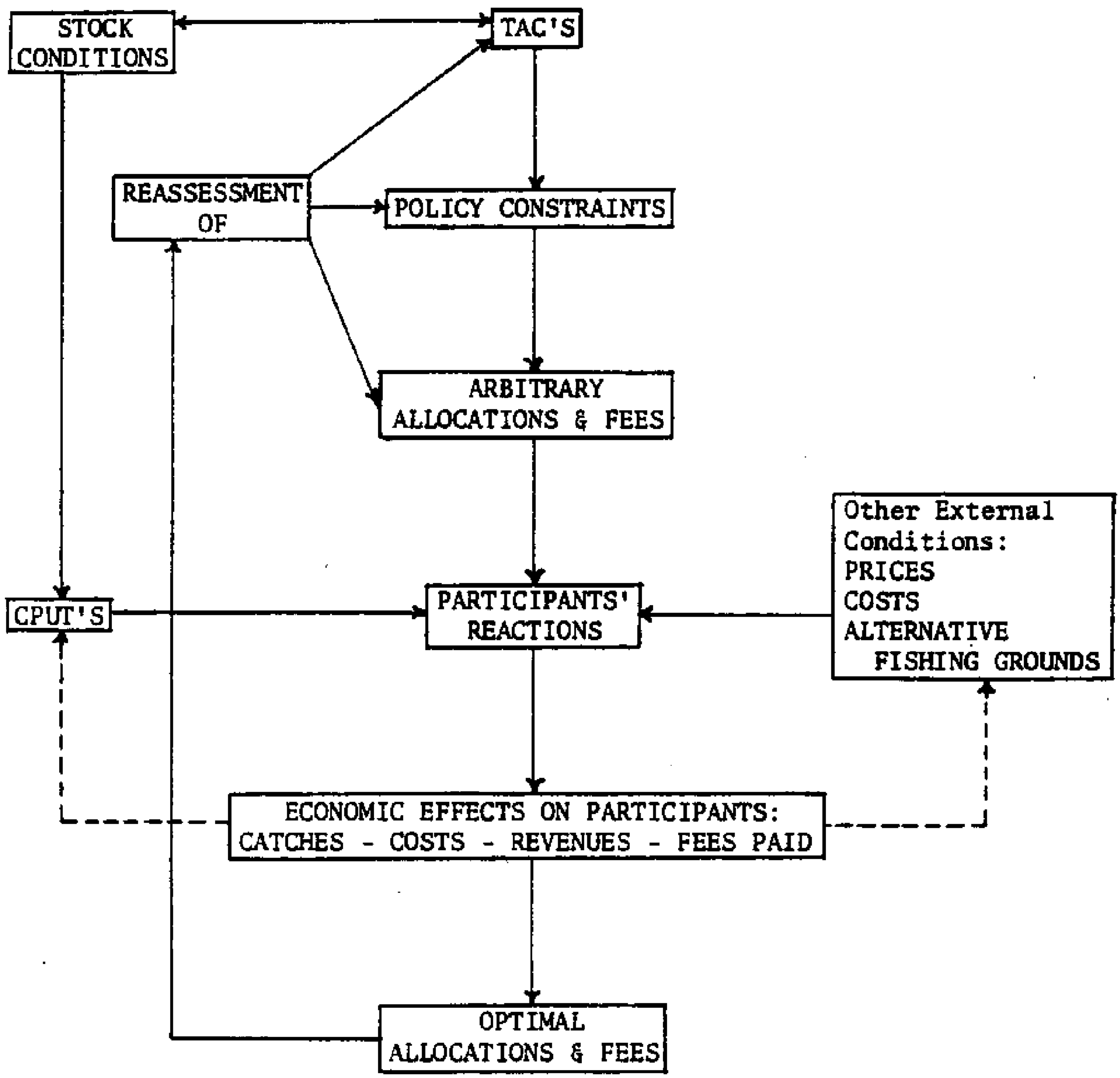

FIGURE 1. General Framework for the Management of Foreign Fishing Permits

TABLE 1. L.P. Formulation of the Static Stock Effects for One Species

	E^A	E^A	E^B	E^B	E^C	E^C	Landing x Lx	Landing y Ly	TOTAL CATCH A	TOTAL CATCH B	TOTAL CATCH C		RHS	DUAL PRICE
Objective Function	$-C_1$	$-C_2$	$-C_1$	$-C_2$	$-C_1$	$-C_2$	+px	+py				N		
Catch Species x	a^A_{1x}	a^A_{2x}	a^B_{1x}	a^B_{2x}	a^C_{1x}	a^C_{2x}	-1					$\geq$	0	ρx
Catch Species y	a_{1y}	a_{2y}	a_{1y}	a_{2y}	a_{1y}	a_{2y}		-1				$\geq$	0	ρy
Allocation Species x	a^A_{1x}	a^A_{2x}	a^B_{1x}	a^B_{2x}	a^C_{1x}	a^C_{2x}						$\leq$	TALFFx	πx
Allocation Species y	a_{1y}	a_{2y}	a_{1y}	a_{2y}	a_{1y}	a_{2y}						$\leq$	TALFFy	πy
Vessel 1 - Day Capacity	1		1		1							$\leq$	CAPA1	λ1
Vessel 2 - Day Capacity		1		1		1						$\leq$	CAPA2	λ2
NODE A	a^A_{1x}	a^A_{2x}							-CATCH A			$\leq$	0	μA
NODE B			a^B_{1x}	a^B_{2x}						-CATCH B		$\leq$	0	μB
NODE C					a^C_{1x}	a^C_{2x}					-CATCH C	$\leq$	0	μC
CONVEX									1	1	1	$\leq$	1	μ

Note: E = number of vessel-days
x,y = species x, species y
A,B,C = three different levels on the yield-total effort curve
Lx, Ly = landing of species x and y
1,2 = vessel category 1, vessel category 2
px,py = price of species x and y
a = catch per day
C_1, C_2 = operating costs of vessel 1 and 2

When the total level of catch of species x is less than or equal to the level CATCH-A (segment OA" in Figure 2), the CPUT of vessel 1 is a_{1x}^{A} for species x and a_{1y}^{A} for species y. The corresponding coefficients for vessel 2 are a_{2x}^{A} and a_{2y}^{A}. If the CPUT's of the different vessel categories have been computed for the level of fishing mortality and catch corresponding to point B, each component of the row vector of catch a_{x}^{A} is proportional to the corresponding component of the vector a_{x}^{B}, the coefficient of proportionality being the ratio $\frac{OA''}{OB''} + \frac{OA'}{OB'}$ (Figure 2).

The convex combination in Table 1 ensures that only linear combinations of adjacent points are considered on the piecewise linear function OABC approximating the yield-effort curve. There is thus an infinity of feasible catches per day which are approximations to the yield effort curve except at points A, B, or C, where the correspondence is exact. Extension of endogenous CPUT's to more than one species can be realized by following the procedure suggested by Duloy and Norton (1975).

The dual prices associated with each constraint in Table 1 express the value of relaxing the corresponding constraint. The dual prices ρ, π, and λ represent respectively the value of an additional unit of landing (equal to the market price), the value of an additional unit of species allocated (per unit resource rent), and the value of an additional vessel-day (per unit quasi-rent).

The dual prices (μ) associated with the constraints linking the CPUT's to different levels of fishing mortality stem from decreasing returns. They indicate the value of the externality caused by an additional unit of effort placed on the fishery. They can alternatively be viewed as the per-unit-of-catch willingness to pay of each fleet for a restriction in the catch of other fleets.

At the optimum, the implicit or imputed values—viz., the resource rent, the quasi-rent, and the imputed cost of the externality—are such that they exhaust the net stock. Since the net stock has been maximized, the implicit payments cannot be increased without inducing a non-optimal behavioral response among participants, and such responses would reduce net stock and potential fee revenue. The implicit values or dual prices could be extracted by the U.S. management for the activities taking place in the FCZ. In Figure 1 the "optimal" fees refer to these implicit payments. They are optimal in the sense that they exhaust all the net benefits of access when the allocations are set efficiently. If the allocations are arbitrary, the dual fees and, hence, fee revenue potential will be diminished.

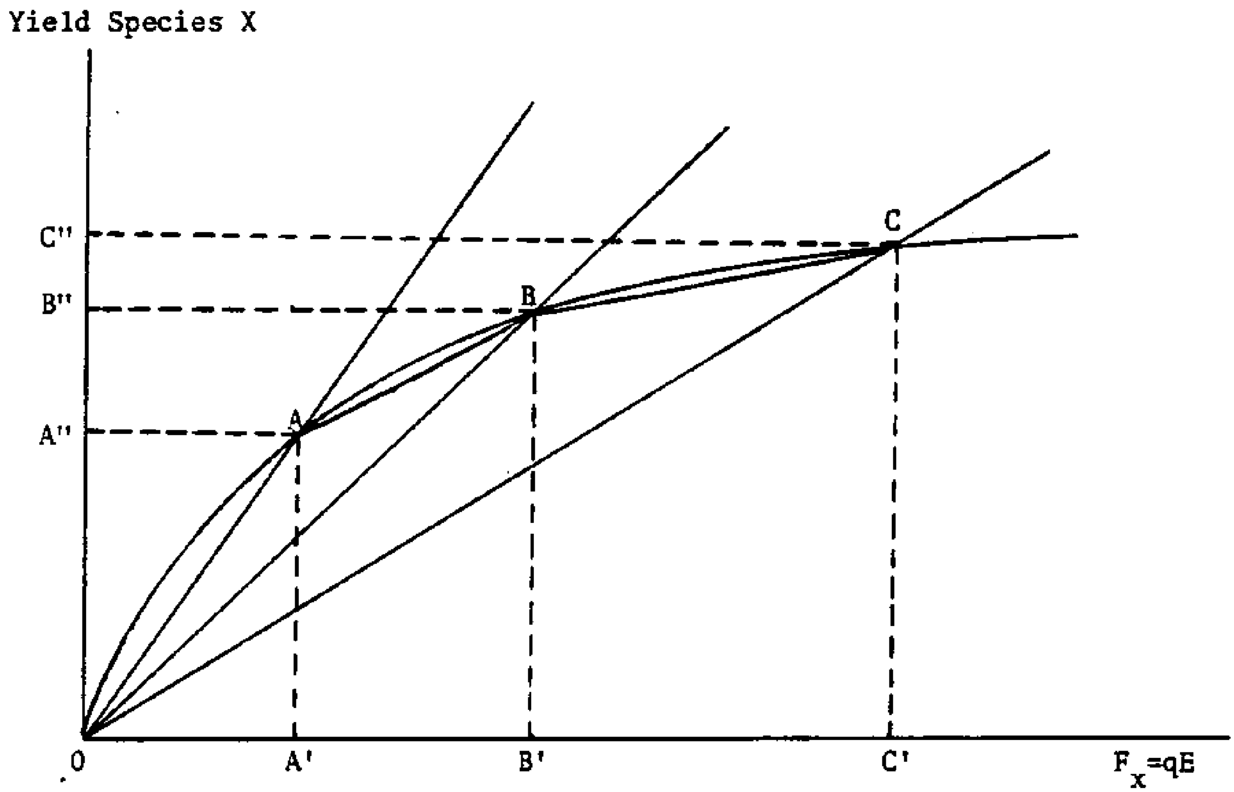

FIGURE 2. General Relation Between Yield and Fishing Mortality

MODEL APPLICATION

The model application in this study is limited to the fishing zones of the Bering Sea and Aleutian Islands, the Gulf of Alaska, and the Pacific Coast west of California (WOC). These fishing zones accounted for 96 percent of the 1979 foreign catch within the FCZ and are indicated in Figure 3.

Thirteen species or species groups are considered. The main species are pollock and, to a lesser extent, flounders (including arrow-tooth flounder, Greenland halibut, "other flounder," yellowfin sole), Pacific hake, Pacific cod, and Atka mackerel. These species accounted for 88 percent of the total foreign catch in 1979. Other species of interest are sablefish, Pacific Ocean perch, rockfish, jack mackerel, Pacific squid, and "other finfish."

The foreign fleets exploiting these fisheries in 1979 were chiefly the Japanese, Soviet, South Korean, and Polish fleets (94 percent of the foreign catch). However, the activities of the Soviet fleet have not been incorporated in the model, this fleet having been phased out from the FCZ of the United States in 1980 after the Afghanistan crisis. The vessel categories composing these fleets range from pair trawlers, Danish seiners, and small stern trawlers[10] associated with factory base ships (Japan) to independent medium stern trawlers[11] (Japan) and longliners (Japan, Republic of Korea). The large stern trawlers[12] (Japan, Republic of Korea, Poland) up to 5,500 gross registered tons (GRT) represent the remaining components of these fleets. In total, 19 vessel categories were specified to represent the activities of about 265 fishing vessels. These categories reflect observed differences in vessel size, type, and the degree of on-board processing.

The detailed data on CPUT's by vessel category, area, and season, the product prices by species and the estimated operating costs by vessel category and fishing area can be found in Meuriot (1981) together with a selected bibliography. In general, these data need improved accuracy. The dearth of ex-vessel prices for the products harvested in the U.S. zone prevented for example the inclusion of endogenous prices in the model. Such inclusion is necessary if one wishes the fee schedule to include consumer surplus. In the absence of recent information, no fishing ground alternative to those in the U.S. zone was considered. Also, the lack of data on prices and costs for socialist countries forced adoption of a different approach. For such countries, the minimum willingness to pay for fishing permits was assumed to be the value of the fees charged in 1979.

Finally, the domestic fishing activities are not represented in the model, since in 1979 the U.S. harvesting capacity, as defined by the U.S. management, amounted to only 4.2 percent of the total TAC's in the Bering Sea and 5.3 percent of the TAC's in the Gulf of Alaska.

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[10]Under 350 GRT.
[11]Between 350 GRT and 1,400 GRT.
[12]Over 1,400 GRT.

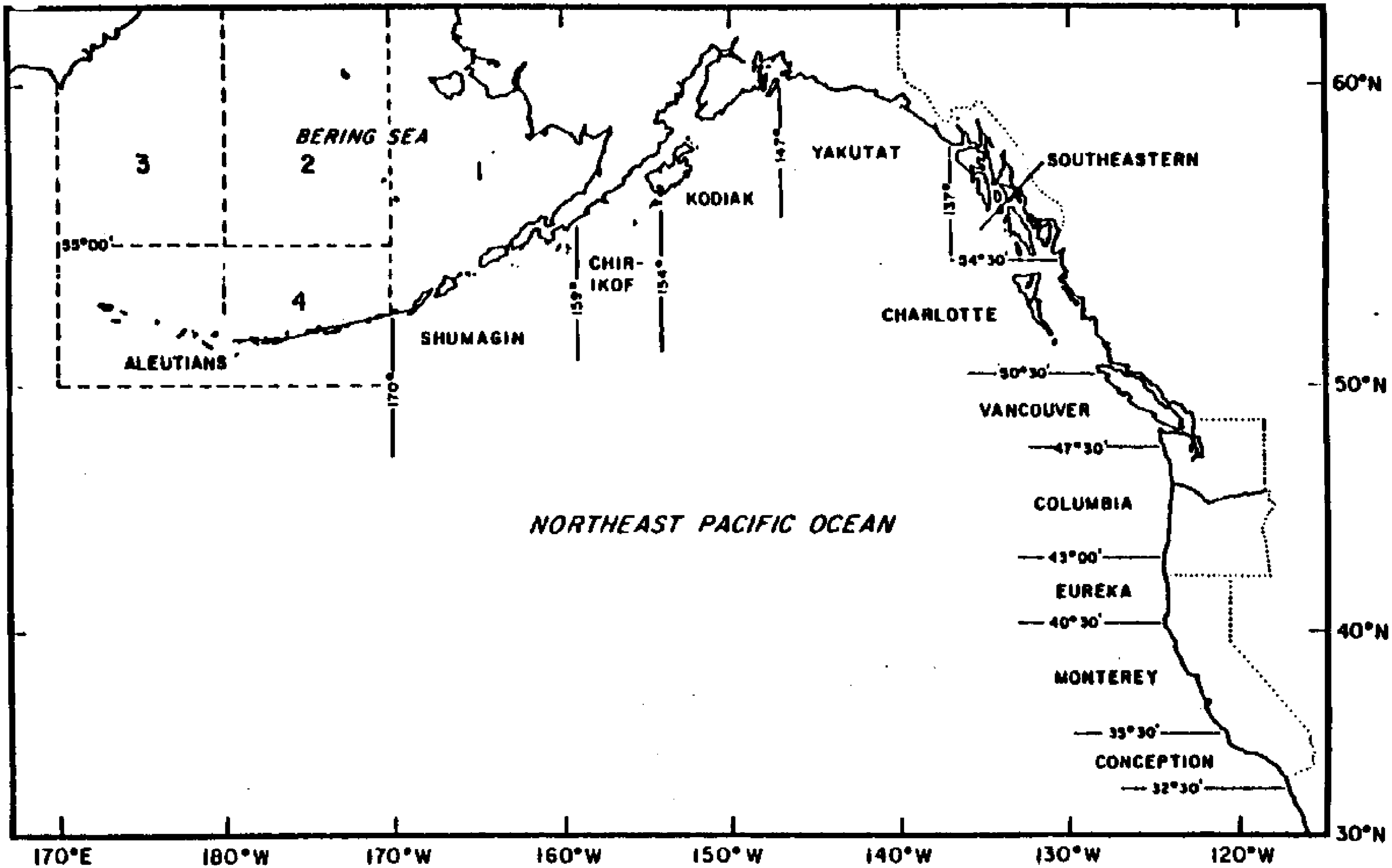

FIGURE 3. Statistical Areas Used to Subdivide the Northeast Pacific Ocean and Bering Sea. (The Washington-Oregon-California (WOC) zone refers to the Columbia and Eureka areas.)

Source: Nelson, et al. (1980).

RESULTS

For expository and computational reasons, the results are presented in two parts. In the first part, the CPUT's are fixed. The L.P. model then has 1,650 rows and 3,640 variables to represent the processing, landing, and quarterly fishing activities of Japanese, Korean, and Polish vessels divided into 19 vessel categories. Within a fishing area, a vessel category may have alternative target species. Sensitivity analyses are performed on prices, operating costs, vessel-day capacity, allocations, and fees. In a second part, the CPUT's are endogenous. The number of variables increases then by 29 percent and matrix density almost doubles.

Fixed CPUT's—Base Model Results

The aggregate figures on catch, revenues, and costs are given in Table 2 for the base model. All values are given in 1980 U.S. dollars. The total net benefits of access are $264 million for aggregate catches of 1,245,000 metric tons (MT) total for Japan and Korea. These catches yield an average net benefit of $212 per metric ton, which corresponds to 31.8 percent of total revenue. These are short-run access benefits; i.e., before deduction of financial and depreciation costs and before the payment of any fees. Japan receives the major part of the catch with 1.118 million MT and Korea receives 0.127 million MT. The 1979 catches by these nations were, respectively, 1.1 and 0.124 million MT. In the absence of fees, the net values of these allocations are $235 million for Japan and $29 million for Korea. These access benefits are equivalent, respectively, to $210 and $231 per metric ton of catch. The ratio of the net operating benefits (short run) to total revenues range from 25 percent to 36 percent. Poland receives an optimal allocation of about 63,000 MT, which represents a residual allocation. Access benefits for Poland are not listed in Table 2 because, as noted earlier, they were assumed to equal 1979 fees paid. Since 1979 fees were low relative to willingness to pay for Japan and Korea, the optimal solution allocates little to Poland.

The level and distribution of the fishing activities by vessel category, area, and season are shown in Table 3. The dual prices on the vessel-day capacity constraints are also indicated. There are on one hand the medium stern trawlers (J3, J4) and the longliners (JL) with idle capacity, and on the other hand the trawlers over 1,500 GRT and the motherships with a full use of their capacity. This is reflected in the value of the dual prices on the yearly capacity, the value of an idle vessel-day being zero.

The presence on a fishing ground of a mixed fleet is due, in part, to this limitation in the capacity of the large trawlers and motherships. It is also due to the differences in target species and composition of the vector of catch. The species which form the major part of the catch for some vessel categories may constitute only minor bycatch for other vessel categories. An example is the Alaska pollock, which represents 93 percent of the catch of the "surimi" trawlers and motherships but less than 17

TABLE 2. Catch, Revenues, Costs, and Net Benefits for the Base Model

Country	GRT	Area	FL	AT	PH	OF	SQ	PO	PC	SA	YF	PP	RO	A Total Catch	B Total Rev.	C Total Oper. Costs	D Net Benef.	D/B	B/A	C/A	D/A
							Metric Tons								Millions US $			%	$ US per MT		
Japan	3500-5500 Surimi	Bering	2468	8	2486	2143	1735	222450	3574	9	831	35		239739							
		GOA	193			172	34	38804	823			43	27	40096							
		Total												275835	155 3	110.7	44.6	28.7	562.9	401.2	161.7
Japan	1500-3500	Bering	6070	52		4237	352	3544	1385	76	24106	4761		44583							
		GOA	6695	290		1344	112	30079	652	244		2602	1023	43041							
		Total												87624	75.2	47.7	27.5	36.5	858.1	544.6	313.5
Japan	350-500	Bering	45149	607	3940	25271	1794	20416	10170	653	5273	1492		114765							
		GOA	2201	319		776		867	6909	1857		99	389	13417							
		Total												128182	143.5	106.6	36.9	25.7	1119.4	831.6	287.8
Japan	Mothership	Bering	19116	54	97	7539	117	535145	15217	13	2165			579465							
		Bering	2880			708		920	1449		41710			47667							
		Total												627132	372.8	246.9	125.9	33.7	594.4	393.7	200.7
Japan	Total Catch	Bering	75685	721	6523	39898	3998	782475	31795	751	74085	6288		1022219							
		GOA	8989	609		2292	146	69750	8384	2101		2744	1439	96554							
		Total												1118773	746.8	511.9	234.9	31.4	667.5	457.5	210.0
Korea	2500-5500	Bering	5302	21918	470	4602	357	52816	2401	184	19908	47	60	108065							
		GOA	3525	5		285	19	11545	69	18		1825	1772	19063							
														127128	84.9	55.5	29.4	34.6	667.6	436.3	231.3
Total Catch		Bering	80987	22639	6993	44500	4355	835291	34196	935	93993	6335	60	1130284							
		GOA	12514	614		2577	165	81295	8453	2119		4569	3211	115617							
		Total												1245901	831.7	567.4	264.3	31.8	667.5	455.4	212.1
Poland:	Catch	Bering						61043													
Total TALFF		Bering	88792	22640	7099	61815	5358	909136	39337	1356	99265	6335	118								
		GOA	14510	9946		4848	337	85631	9969	5446		7648	3871								

unit = vessel-day

TABLE 3. Base Model Results on Level and Location of Fishing Activities, Quasi-Rent and Vessel Replacement Costs

Fishing(i) Zone	Quarter	Type GRT(ii)	J9 4500 Surimi	J8 3500 Surimi	J7 3500	J6 2500	J5 1500	J4 500	J3 350	JL LLG	M1	M2	M3 Motherships	M4	M5	M6	K9 5500	K8 4500	K7 3500	K6 2500	P7 2500	
Bering I	I				229															89		
" "	II							339	677								188	82				
" "	III		640	69	251	135		1312		166	90			83		72			130	124	783	
" "	IV			138		314		527		400	70			37		90	256	168	130	124	783	
Bering II	I		556	514													40					
" "	II								2277	45							3					
" "	III			444								90	90	6	90		256					
" "	IV		220						3039			71	80	29	70							
Bering IV	I																215	168				
" "	II						259		1611													
" "	III						259			824												
" "	IV						162															
Shumagin	I																					
"	II																					
"	III								302									168				
"	IV		118							284												
Chirikof	I																					
"	II																					
"	III																					
"	IV		297				17			306												
Kodiak	I																					
"	II									201												
"	III					254																
"	IV				251	26																
Yakutat	I																					
"	II									50									40	40		
"	III																					
"	IV					48																
Southeast	II					67													83			
"	III																					
Columbia	(III)																					
Eureka	(III)																				54	
Total Vessel-Days			1831	1165	731	844	749	2178	7906	2276	160	161	170	155	160	162	958	586	383	377	1620	
Dual Price	I			1982													3314	205				
" "	II	U					2961		290													
" "	III	N	6867	3070	7100	6187	3059	2813		101	27509	8359	18814	16456	43280		7006	4766	7624	6629		
" "	IV	I			2961	309				828						30505	3461	503	949	1091		
" "	Year	T	11146	9245	957	1733	2187	0	0	0	31827	130743	174653	134946	120550	50101	2540	4365	9125	7353		
Quasi-Rent	Day	= U S	13542	11470	4411	4723	4172	1694	167	403	47301	135414	184613	144379	144984	67047	6214	5934	11908	9885		Total $190 million
Repl. Cost	Day(iii)	$	9618	7353			2286	1112	808	1165		83318	125422	118691	93062	53027	12881	10157	8816	7279		$147 million

(i) See Appendix A
(ii) See Appendices A and B
(iii) See Appendix B

percent of the medium vessels' catch.[13] Exclusive exploitation of Alaska pollock by the surimi trawlers and the motherships would prevent the harvesting of the other species, since the other vessel categories have also a bycatch of pollock.

The level of fishing activity by vessel category together with the associated dual prices determine the quasi-rent on the vessel capacity. When converted from a vessel-day to an annual basis, the quasi-rent can be directly compared to the annualized replacement costs. The results in Table 3 suggest that under conditions of guaranteed access a replacement of the Japanese surimi trawlers and motherships could be induced. For the largest Korean stern trawlers (K9, K8) this is not the case. It would depend on whether the catch per day of these vessels could be improved, since they are actually lower than the catch of the corresponding Japanese vessels.

An aspect of importance is the range over which the dual prices on vessel capacity are valid. For example, a 7.5 percent decrease in the total catch (Model 1) results in a drop of the quasi-rents by 50 percent for the Japanese fleet and 67 percent for the Korean fleet. With these quasi-rents, no vessel replacement would be induced. This variation means that even with guaranteed access, a modest level of uncertainty on the expected catch could prevent the replacement of aging vessels by foreign investments.

Simultaneously with the drop of the quasi-rents, the per unit rents on the fish stocks increase sharply. An example is given for the Alaska pollock in Table 4. In the area designated by the National Marine Fisheries Service as Bering I, a decrease of less than 1 percent in the allocation of pollock yields an increase (from zero) of $81 in the dual price or per unit rent on that species.

The sensitivity of the marginal valuations has implications for the management options concerning the basis for levying fees. At the optimum there is an equalization of the value of the marginal product of a factor for each non-zero activity. Thus, each vessel category used has an identical valuation for the fish stocks utilization, which is represented by the dual prices on the species. The valuation of vessel capacity used is also identical for the different fishing activities of the same vessel category but will usually be unequal between different vessel categories. That is, the quasi-rent will usually differ between vessel categories.

The uniformity of imputed values for the fish and the variations in vessel quasi-rent could be used in the fee structure. Specifically, the vector of dual prices on the species allocation could be used as a non-discriminatory poundage fee uniform for all vessel categories and gears. In addition, such fees would be compatible with an efficient allocation of the resources. However, in the base model the poundage fees to be collected by this procedure would amount to $74 million, while in Model 1 they would amount to $153 million. The distributional effects among the various vessel categories would also be different. Additional vessel fees could be designed to supplement the poundage fees. Their

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[13]"Surimi" constitutes deboned flesh which is washed and dewatered. The fish paste obtained is combined with spices and other ingredients and then baked, broiled, steamed, or boiled to make finished products such as "kamaboko."

TABLE 4. Catch and Dual Prices of Alaska Pollock by Area

Area	Species	Base Model		Model I	
		Catch	Dual Price*	Catch	Dual Price
BERING I	Pollock	348,784	-	346,716	81
BERING II	"	544,021	2	494,715	97
BERING IV	"	3,531	-	1,256	-
SHUMAGIN	"	22,091	57	21,984	130
CHIRIKOF	"	28,704	7	22,156	79
KODIAK	"	29,288	268	20,594	222
YAKUTAT	"	997	-	1,210	-
SOUTHEAST	"	220	-	220	-

*Note that access benefits will (usually) include both dual prices on the TALFF's and on vessel capacity (see text).

levels could reflect differences in quasi-rents, as noted above, or differences in administrative and enforcement costs.

Alternatively, optimal fees levied on a vessel-day basis regardless of the area and target species but accounting for differences in vessel category and season would amount to $190 million for the base model and $88 million for Model 1.

The total extraction of the net benefits would require a fee schedule that discriminated by vessel category, nationality, season, area, and composition of catch. This is judged impractical, since it means over 75 fee schedules for the base model.

It is also interesting to note that the poundage fees which the United States might receive under such a pricing policy may or may not correlate with "target species." The reason is that relatively modest changes in the species composition of TALFF's in a given area and season can radically alter the relative values imputed to the various species. Often it will be found that the target species is worth nothing; it is the bycatch quotas and/or gear restrictions which have value.

Fixed CPUT's--Sensitivity Analyses

Sensitivity analyses are performed here to depict the effects of changes in parameters not under the U.S. management: the product prices and the operating costs, as well as the impacts of different values given to the instrument variables, the allocations, and the fees.

- Prices

Three modifications of the set of prices used in the base model are analyzed. The case Price 1 reflects the impact of a 20 percent decrease in the Alaska pollock and Atka mackerel prices. The case Price 2 shows the change due to a 30 percent higher level of prices for the flounders, sablefish, rockfish, and "other finfish." The case Price 3 combines Price 1 and Price 2 cases.

The results show that a 20 percent decrease in the price of pollock and Atka mackerel (Price 1) yields a drop of 31 percent of the total net benefits, which amounts to $181 million (Table 5). The global level of activities of the large surimi trawlers and the motherships remains nevertheless almost unchanged. The distribution of the fishing activities among the various fishing grounds is slightly modified, the largest Japanese surimi trawlers also exploiting the hake fishery in the Eureka area (WOC). For the medium trawlers' activities, the number of fishing days diminishes by 20 percent.

As a result, the total catch decreases by only 40,000 MT, or about 3 percent. If only the excess of the net benefits over the replacement costs were to be extracted, the total amount of fees would be $38 million, or 5 percent of the total revenue.

In the case of Price 2, there is a 36 percent increase in net benefits for a 30 percent rise in the price of some species. The additional catch of about 30,000 MT over the base model stems from a 32 percent increase in the number of vessel-days for the medium vessels. When computed on a per metric ton basis, the increase in short-run benefits is about 13 percent.

The combination of the price modifications in Price 1 and Price 2 yields global net benefits close to those from the base model ($272 million

TABLE 5. Effects of Price Variations

	Base Model	Price 1	Price 2	Price 3
	--US$ millions--			
Total Revenue	831	722	961	866
Total Operating Costs	567	541	604	594
Net Benefits	264	181	357	272
Replacement Value	147	143	151	148
Benefits-Replacement Value	116	38	206	124
	--metric tons--			
total Catch	1,246,000	1,202,030	1,275,366	1,244,341
	--$ per metric ton--			
Revenue/MT	668	601	754	696
Operating Cost/MT	456	450	474	477
Net Benefit/MT	212	151	280	219
Benef.-Repl. Value/MT	93	32	162	100
Net Benefit/Revenue	32%	25%	37%	31%
Benef.-Repl. Value/Revenue	14%	5%	21%	14%

and $264 million, respectively). The medium vessels increase their number of vessel-days by 31 percent, the additional effort being located mainly in the area Bering IV (Tables 3 and 6).

These price modifications indicate that the activities of the large trawlers and motherships are rather stable, while the activities of the medium trawlers and the longliners are sensitive to changes. Also, the increase in the fishing activities of the medium vessels does not replace the activities of other vessel categories.

A comparison of the dual prices on the vessel capacity and the vessel replacement costs shows that, with a price of Alaska pollock 20 percent less than in the base model, there would be no vessel replacement for either the Japanese or the Korean fleet in the long run, other things being equal.

• Operating Costs

A sensitivity analysis on the effects of variations in the price of specific inputs such as fuel or labor could be performed. However, pending refinement of the data through further research, it seems simpler to deal only with total cost figures.

Three variants of relative operating costs structure are examined, with the global results presented in Table 7.[14]

The first variant (Cost 1a, Cost 1b, Cost 1c, Cost 1d) corresponds to four levels of increase in the operating costs of the motherships. The second variant adds to the preceding one an augmentation of the operating costs of the surimi trawlers (Cost 2a, Cost 2b, Cost 2c, Cost 2d).

The third variant combines a decrease in the operating costs of the 350 GRT trawlers and the longliners with the second variant (Cost 3a, Cost 3b, Cost 3c, Cost 3d).

Besides the expected decrease in the total net benefits when operating costs increase, a noteworthy result is the stability of the level and composition of the fishing activities. Up to an increase of 30 percent in the operating costs per fishing day, there is no modification in the choice of the optimal fishing activities. This is evident in the constant levels of total revenues and total catch. However, the ratio of the net benefits (before replacement costs) over total revenues drops from 28.7 percent to 11.4 percent for the surimi trawlers and from 33.7 percent to 19 percent for the motherships. Only when the increase exceeds 40 percent does substitution between fishing activities occur. While higher operating costs for the motherships and for the surimi trawlers did not significantly affect short-run fishing strategies, cost increases in excess of 10 percent would prevent vessel replacement in the long run.

The introduction of a simultaneous decrease in the operating costs of the 350 GRT trawlers and the longliners (Cost 3) does not affect the optimal level of activities of the surimi trawlers and motherships. There is only an increase in the level of activities of these medium trawlers and longliners (Table 8).

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[14]The changes in variable operating costs here refer to the part of the per vessel operating costs which vary continuously and linearly with vessel use. It excludes fixed (i.e., indivisible) operating costs.

TABLE 6. Effects of Price Variations on the Level and Location of Fishing Activities (Price 3)

unit= vessel-day

Fishing Zone	Quarter	Type GRT	J9 Surimi 4500	J8 Surimi 3500	J7 3500	J6 2500	J5 1500	J4 500	J3 350	JL LLG	M1	M2	M3 Motherships	M4	M5	M6		K9 5500	K8 4500	K7 3500	K6 2500		P7 2500
Bering I	I				229															49	124		
" "	II								287										156				
" "	III		509		251	135		1312		252	90			1		72		17		130	124		303
" "	IV			138		247		1312		221	70			67	47	90		256	148	130	124		
Bering II	I		423	514					1214														
" "	II							1285	1015	43													
" "	III		130	514								71	90	88	90			176					
" "	IV		214						1885			90	80		22								
Bering IV	I																	256	112				
" "	II						259		3263	268													
" "	III						259			415													
" "	IV						50		1948														
Shumagin	I																						
"	II																						
"	III								302										168				
"	IV		118							284													
Chirikof	I																						
"	II									181													
"	III																						461
"	IV		118				17			294													
Kodiak	I																						
"	II									201													
"	III					254																	
"	IV				251	26																	
Yakutat	I																						
"	II									31										59	6		
"	III																						
"	IV					48	164			190													
Southeast	II					134														15			
"	III																						
Columbia	(III)																						854
Eureka	(III)		318																				
Total Vessel-Day			1830	1166	731	844	749	3909	9914	2380	160	161	170	156	159	162		767	584	383	378		1618
Dual-Price			3049	2106	159	863	4022	838	0	0	22415	83092	93621	64051	63827	8051		0	1361	8011	6428		(unit=US $)
Dual-Price (Base Model)			11146	9245	957	1733	2187	0	0	0	31827	130743	174653	134946	120550	50101		2540	4365	9125	7353		(unit=US $)

TABLE 7. Effects of Operating Costs Variations

Title	Description of Variations	Total Revenue	Total Coperating Cost	Net Benefits	Δ Net Ben.	Total Catch
		------------US$ millions	------------	------------	%	mil.MT
Base Model	None	831	567	264	0	1.246
Cost 1a	Mothership Cost +10%	831	585	246	-7%	1.246
Cost 1b	Mothership Cost +20%	831	604	227	-14%	1.246
Cost 1c	Mothership Cost +30%	831	622	209	-21%	1.246
Cost 1d	Mothership Cost +40%	814	622	192	-27%	
Cost 2a	MSHP & Surimi Trawlers Cost +10%	831	594	237	-10%	1.246
Cost 2b	MSHP & Surimi Trawlers Cost +20%	831	622	209	-21%	1.246
Cost 2c	MSHP & Surimi Trawlers Cost +30%	831	649	182	-31%	1.246
Cost 2d	MSHP & Surimi Trawlers Cost +40%	776	619	157	-41%	1.138
Cost 3a	Cost 2a & J3,JL Cost -10%	840	595	245	-7%	1.258
Cost 3b	Cost 2b & J3,JL Cost -20%	867	637	230	-13%	1.290
Cost 3c	Cost 2c & J3,JL Cost -30%	870	654	216	-18%	1.287

TABLE 8. Effects of a 20% Decrease in Operating Costs on the Number of Vessel-Days for the 350 GRT Trawlers

Quarter	Cost 2b Vessel-Day	Cost 3b Vessel-Day
I	-	4,199
II	4,567	4,567
III	302	583
IV	3,032	4,567
Total	7,901	13,916

Besides tracing out the effects of a higher difference in the relative operating costs structure, this variant Cost 3 pursues another objective. It investigates the case where the operating costs of the medium trawlers and longliners are not necessarily evenly distributed over the year. In the base model results, Table 3, it can be seen that the 350 GRT trawlers do not operate in the first quarter and that their activities in the third quarter are reduced to 302 vessel-days. However, the number of vessel-days in the second quarter corresponds to the activities of 51 vessels which would thus be idle for half the year. If the cost per fishing day was recomputed to express the cost of vessels operating only half a year, it would be at too high a level to allow any fishing activity.

A more realistic way is to assume that the net benefits occurring in one season or area are used to cover indivisible operating costs, the operating costs in another season or area being therefore reduced. In a first step, the costs per fishing day are decreased artificially. In a second step, the net benefits are divided into two components: one covers the artificial decrease in operating costs, the other corresponds to the real benefits. Inclusion of indivisible costs in an average daily charge may distort decisions to fish on marginal fishing grounds.[15]

As an illustration, with an artificial decrease of 20 percent (Cost 3b), the number of fishing days of the medium trawlers and longliners increases by 46 percent. The resulting revenues and operating costs are $194.5 million and $126.3 million, respectively, leaving a net benefit of $68.2 million. Part of this net benefit is used to cover $25.9 million of artificially decreased operating costs. The true net benefit thus amounts to $42.3 million, or 21.7 percent of the total revenue.

• TALFF's and Fleets' Capacity

The impacts of the TALFF's variation is depicted in Table 9 for two sets of scenarios. Scenarios TALFF 1 to TALFF 6 represent the situation of different TALFF's with a fixed capacity of the foreign fleets. In scenarios TACAPA 1 to TACAPA 3 the capacity of the fleets increases jointly with the scenarios TALFF's.

The variations of the TALFF's are derived here from linear combinations of the whole vector of TALFF's used in the base model. It is clear that only a subpartition of the original vector could be allowed to vary. Also, the impact, if any, of the change in catch on the different stocks is beyond the scope of this study.

In the case of a decrease in the TALFF's, the diminution of the net benefits is less than proportional to the decrease in catch because the relatively less efficient fishing activities are dropped first. This is in the absence of any adjustment of the costs per fishing day for those vessel categories in the solution which do not operate during a whole year. With a 25 percent reduction (TALFF 4, Table 9), the level and location of the fishing activities undergo important modifications. The major differences in the location of the fishing activities are due to the large Japanese

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[15]An integer programming formalization of these adjustments is discussed later.

TABLE 9. Effects of TALFF and Fleet Capacity Variations

Title	CAPA Change	TALFF Change	Total Revenue	Total Operating Cost	Net Benefits	Δ Net Ben.	Total Catch	Δ Catch
	%	%	US$ millions	US$ millions	US$ millions	%	mil.MT	%
TALFF 1	0%	+30%	878	595	283	+7.5%	1.279	+2.6%
TALFF 2	0%	+20%	864	586	278	+5.5%	1.267	+2.6%
TALFF 3	0%	+10%	856	584	272	+3.5%	1.265	+1.5%
Base Model	Base	Base	831	567	264	Base	1.246	Base
TALFF 4	0%	-25%	685	461	224	-15%	1.045	-16%
TALFF 5	0%	-50%	463	305	158	-40%	.698	-44%
TALFF 6	0%	-75%	231	148	83	-68.5%	.348	-72%
TACAPA 1	+15%	+15%	957	652	305	+16%	1.433	+15%
TACAPA 2	+30%	+30%	1,081	737	344	+31%	1.620	+30%
TACAPA 3	+45%	+45%	1,205	821	384	+46%	1.806	+45%

surimi trawlers, which then operate in the WOC area catching hake, and to the activities of the Polish vessels phased out from the Bering Sea. The level of fishing activities is sufficient to guarantee the full use of the vessel capacity for only 8 vessel categories against 16 in the base model.

In the absence of a change in the capacity of the foreign fleets, the possibility of an increase in catch remains very limited. A vector of TALFF's set at a level 30 percent higher than in the base model leads only to a 2.6 percent augmentation of the total catch. The net benefits rise by 7.5 percent because of a change in the relative structure of the catch.

If the capacity of the fleets adjusts to the higher allocations (TACAPA), the catch increases in the same proportion as the allocations. The same change takes place for the net benefits. This linearity between total effort and catch, or between catch and net benefits, stems from the fixity of the CPUT's, regardless of the total level of effort applied in the different fisheries. The results obtained when this linearity assumption is relaxed will be discussed below.

• Arbitrary Fees

In the 1979 fee schedule, among the different fees charged (permit fee, poundage fee, foreign fee surcharge, and observer fee), by far the major component was constituted by the fees based on catch. Indeed, the poundage fees and foreign fee surcharges represented about 80 percent of the U.S. revenues, and amounted to $12.9 million.[16]

The potential effects of the poundage fee schedule proposed in the Federal Register for 1981 are analyzed here.[17] The fees are called "arbitrary" fees only in contrast to the "optimal" fees derived from the model under the form of dual prices. Of particular interest when this arbitrary fee schedule is applied are departures from an efficient resource utilization and the expected amount of fees to be collected.

The results summarized in Table 10 show that little modifications in the level and composition of the catch by vessel group result from the proposed fee schedule. Direct comparison with the results of the base model in Table 2 indicates that only the fishing activities of the medium stern trawlers and the longliners in the Bering Sea are affected. For these vessels, the total amount of catch decreases by 11 percent, but the net benefits before fees remain almost identical.

The results indicate that if the TALFF's were allocated according to the base model optimal allocations, the introduction of the arbitrary fee schedule would lead to a minor departure from the efficient use of the resources. Thus, the impacts concern mainly the distribution of the net benefits between foreign participants and the U.S. management. Note, however, that this result is based on the condition that the allocations be

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[16]NMFS, Office of Permit and Regulations, personal communication. For 1979, the figures were $0.9 million for the permit fees, $11 million for the poundage fees, $1.9 million for the foreign fee surcharge, and $2.4 million for the observer fees (all figures rounded to the nearest $100,000).

[17]Federal Register, Vol. 45, No. 221, November 1980, p. 74949-50.

TABLE 10. Effects of the 1981 Proposed Fee Schedule

Country	GRT	Area	FL	AT	PH	OF	SQ	PO	PC	SA	YF	PP	RO	A Total Catch	B Total Rev.	C Total Oper. Costs	D Net Ben before Fees	E Fees	F Net Ben after Fees	E/D	E/A
			Metric Tons												US $ Millions					%	$/MT
Japan	3500-5500 Surimi	Bering	2647	8	2486	2195	1732	221884	3578	9	48	34		234621							
		GOA	193			172	54	38801	823			43	27	40096							
		Total												274717	154.7	110.3	44.4	4.65	39.75	10.5	16.9
Japan	1500-3500	Bering	6070	52		4237	352	3544	1385	76	24106	4761		44583							
		GOA	6695	290		1344	112	30079	652	244		2602	1023	43041							
		Total												87624	75.2	47.7	27.5	2.17	25.33	7.9	24.76
Japan	350-500	Bering	39219	559	4383	23263	1581	18745	6655	653	5463	1484		102005							
		GOA	2083	318		776		857	6908	1864		66	385	13207							
		Total												115262	128.3	91.6	36.7	2.77	33.93	7.5	24.03
Japan	Mothership	Bering	19134	52	93	7684	114	534650	15293	14	2287			579321							
		Bering	2880			708		920	1449		41710			47667							
		Total												626988	372.8	246.9	125.9	11.57	114.33	9.2	18.45
Japan	Total Catch	Bering	69950	671	6962	38087	3779	779743	28360	752	73614	6279		1008197							
		GOA	8971			2292	144	69740	8383	2106		2711	1435	96009							
		Total												1104206	731	496.5	234.5	21.16	213.4	9	19.16
Korea	2500-5500	Bering	5249	22020	40	4814	443	52699	2400	184	20055	56	60	108020							
		GOA	3543	5		285	19	11550	70	20		1836	1776	19104							
		Total												127124	85	55.4	29.6	2.4	27.2	8.1	18.88
Total Catch		Bering	75199	22639	7002	42901	4222	832442	30760	936	93669	6335	60	1116217							
		GOA	12514	613		2577	163	81290	8453	2126		4547	3211	115113							
		Total												1231330	816	551.9	264.1	23.5	240.6	8.9	19.08
Poland		Bering	--	--	--	--	--	--	--	--	--	--	--	--							
Total TALFF		Bering	88729	22640	7099	61815	5358	909316	39337	1356	99265	6335	118								
		GOA	14510	9946		4848	337	85631	9969	5446		7648	3871								
1981 Proposed Fees		(US $/MT)	30	8	(8)	8	23	16.5	41	55	30	44	30								
1980 Fees (i)		(US $/MT)	13.9	7.8		2	11.3	7.7	14.7	55.9	13.9	13.9	13.9								

(i): Source: Federal Register, Vol. 45, No. 221, November 13, 1980, p. 74949-74950.

TABLE 11. Effects of Variations of the 1981 Proposed Fee Schedule

		Fee Base	Fee 1	Fee 2	Fee 3	Fee 4
A. Change in Fees		Base	+25%	+50%	+75%	+100%
B. Total Revenue	US$ millions	816	816	816	816	807
C. Total Cost	US$ millions	552	552	552	552	543.5
D. Benefit Before Fees	US$ millions	264	264	264	264	263.5
E. Fees	US$ millions	23.5	29.4	35.2	41.1	46.8
F. Benefit After Fees	US$ millions	240.5	234.6	228.8	222.9	216.7
G. Catch	millions of metric tons	1.232	1.232	1.232	1.232	1.223
E/D		8.9%	11.1%	13.3%	15.6%	17.8%
E/B		2.9%	3.6%	4.3%	5.0%	5.8%
E/G		$19/MT	$24/MT	$29/MT	$33/MT	$38/MT
F/B		29.5%	28.7%	28%	27.3%	26.8%
F/G		$195/MT	$190/MT	$186/MT	$181/MT	$177/MT

optimal. If allocations were made arbitrarily, this result would not necessarily hold.

With the proposed fee schedule, the average fee per metric ton of harvest ranges from $17 for the Japanese surimi trawlers to $24.8 for the other large Japanese trawlers. When the fees are computed relative to the amount of net benefits before fees or replacement costs, the range goes from 7.5 percent for the medium vessels to 10.5 percent for the surimi trawlers. That is, there is little discrimination between vessel group or country resulting from this fee schedule if equitable distribution is defined in terms of access benefits.

The total amount of fees collected is $23.5 million, which is more than twice the 1979 amount. This is before the Polish fleet activities are taken into account. The proposed fee schedule is indeed set at a higher level than the one for 1979, which was used to represent Poland's willingness to pay. There is therefore no fishing activity for Poland in the optimal solution.[18] New minimum levels of willingness to pay could be set for Poland and the model run again. Alternatively, it can be considered that the residual TALFF available for Poland is the 100,000 MT of hake harvested in the West of California area and 76,000 MT of Alaska pollock in the Bering Sea not harvested by Japan and Korea. The additional poundage fees collected would then amount to $2 million.

A sensitivity analysis on the proposed fee schedule (Table 11) reveals that, in the short run, no modifications of the fishing activities take place up to a 75 percent increase in the fee schedule. The amount of fees collected from Japan and Korea is then $41.1 million, representing 22.6 percent of the net benefits before fees. The net benefits after fees, but still before the payment of any fixed costs, amount to $222.8 million, or 84 percent of the base model net benefits before replacement costs.

With a 100 percent augmentation of the fee schedule, the only activities cut down are those of the Japanese 350 GRT freezer trawlers. The decrease in net benefits before fees is negligible. It may be concluded therefore that in the neighborhood of the base allocations chosen, the short-run derived demand for TALFF's is highly price inelastic.

Endogenous CPUT's—Base Model Results

To illustrate the effects of economic overfishing, the catch per day of Alaska pollock was made endogenous in the Bering Sea and Aleutian Islands fishing zones. The catch for that species represented about 70 percent of the total catch in the base model.

Four levels of instantaneous fishing mortality rate-catch-index of CPUT have been determined to approximate the yield-effort curve (Table 12). Level B corresponds to the 1979 data and is taken as a reference. Each component of the matrix of CPUT's representing the catch of pollock is then multiplied by the index of CPUT.

The different levels of catch are used as an upper limit for which the corresponding CPUT's are valid: up to a total catch of 0.481 million MT of pollock, the matrix of the original CPUT's multiplied by the index 1.046 is

[18]Recently announced increases in Polish food prices may increase willingness to pay estimates for Poland.

TABLE 12. Relations Between the Fishing Mortality F, the CPUT's, and the Catch

	F	Catch (mil. MT)	Index F	Index Catch	Index CPUT
Level A	.10	.481	50	52.3	104.6
Level B	.20	.920	100	100	100
Level C	.30	1.320	150	143.5	95.7
Level D	.45	1.855	225	201.7	89.6

with B = 6.2 million MT and M = .43.

Source: Bakkala et al. (1980), and Federal Register, Vol. 44, No. 244.

valid. If the catch is over 0.481 million MT and less than 0.920 million MT, a linear combination of the CPUT's corresponding to level A and the CPUT's corresponding to level B is feasible, and so on. Convexity and optimization ensures that, at most, two points will be optimum in a convex combination and if two points are involved they will be adjacent (Duloy and Norton, 1975).

The global impacts of the incorporation of the static stock effects are depicted in Table 13.

In the models discussed thus far, linearity ensured that proportional increases in allocations and fleet capacity yielded proportional increases in net benefits and potential revenues from fees. Incorporation of the diminishing returns yield effort curve in Figure 2 and Table 12 alters this proportionality result. For example, the results in Table 13 show that for a level of the TALFF 30 percent higher than in the base model, the net benefits and the catch of pollock increase by 25 percent instead of 30 percent. The dual price on the convexity constraint is the imputed marginal value or price of fish in the ocean. This price is sensitive to TALFF allocations and to available harvesting capacity.

It should be noted that the value of the net benefits is an approximation inferior or equal to the real net benefits, since it is derived from a linear combination of two sets of activities, as illustrated conceptually by the linear segments OA, AB, and BC in Figure 2. Calculations indicate, however, that the approximation is very good.

The results show also that only slight modifications in the valuation of access will occur due to the static stock effects as long as the TALFF's do not depart greatly from the base model level.

In the case of a 30 percent increase in the TALFF's, the net benefits amount to $333.4 million against $344 million in the absence of recognition of the externality. This difference may not be negligible when compared to the actual fees paid or to the fleet replacement cost.

These results must also be qualified because of their dependence on the relationship depicted in Figure 2 and Table 12. The relationship is shifted by natural mortality. The natural mortality coefficient used (0.43) was reported in the literature but is believed too high by some fisheries biologists. If this coefficient were in fact only 0.2, the change would increase the aggregate marginal physical productivity of fishing effort and lower the marginal cost of fish harvest by 19 percent. The direction of change which this suggests, other things being equal, is increased allocations and an increase in fishing effort. A given variation in TALFF allocations would also produce smaller variations in CPUT coefficients.

An important aspect of the results is that the amount of net benefits after the payment of fees could still be dissipated by the foreign fleets.

In the short run, the existence of uncaptured benefits may yield an excessive number of vessels for those categories in which there are idle vessels. The consequence is a decrease in the average number of fishing days per year per vessel. This would result in an increase in cost per fishing day and a decrease in annual revenue per vessel. In the limiting case, vessel quasi-rents can be zero.

In the long run, an increase in the number of vessels for those categories in which the uncaptured net benefits exceeds the replacement cost can be expected. If the TALFF's are unchanged, the number of fishing days decreases for each vessel, inducing also an increased cost per fishing day and decreased yearly revenue per vessel. The consequence is a reduction in rents and access benefits.

TABLE 13. Effects of Variations in TALFF's and Vessel-Day Capacity with Static Stock Effects

Change in TALFF	-75%	-50%	-25%	0%	+15%	+30%	+45%	+60%	+75%	+90%
Change in Vessel-Day Capacity	0%	0%	0%	0%	+15%	+30%	+45%	+60%	+75+	+90%
Net Benefits*	85.22	163.16	227.51	266.45	301.83	333.44	365.03	396.39	427.50	455.79
% Change in Net Benefits	-68%	-38.8%	-14.6%	0%	+13.3%	+25%	+37%	+48.8%	+60%	+71%
Dual Price on Convexity Constraint*			14.10	20.80	59.23	59.51	61.08	61.99	79.58	99.53
Dual Price on Catch Level A			29.30	43.21	123.08	123.65	126.92	128.81	165.35	206.81
Dual Price on Catch Level B			15.33	22.60	64.38	64.68	66.39	67.38	82.31	96.53
Dual Price on Catch Level C			10.68	15.75	44.87	45.07	46.27	46.96	60.28	75.39
Dual Price on Catch Level D			7.60	11.21	31.92	32.07	32.92	33.41	42.89	53.64
Level A (.481 millions MT)	1.0	1.0	.5504	.1891						
Level B (.920 " ")			.4496	.8109	.9322	.6781	.4191	.1580		
Level C (1.320 " ")					.0678	.3219	.5809	.8420	1.0	.8415
Level D (1.855 " ")										.1585
Catch of Pollock (Bering)**	.226	.453	.678	.837	.947	1.049	1.152	1.257	1.320	1.405
Catch of Other Species (All areas)**	.123	.244	.366	.462	.534	.604	.674	.744	.799	.870
Total Catch	.349	.697	1.044	1.299	1.481	1.653	1.826	2.001	2.119	2.275
% Change in Catch of Pollock	-73%	-46%	-19%	0%	+13%	+25.3%	+37.6%	+50.2%	+57.7%	+67.9%
% Change in Catch of Other Species	-73.4%	-47.1%	-20.8%	0%	+15.6%	+30.7%	+45.9%	+61%	+72.9%	+88.3%
% Change in Total Catch	-73.1%	-46.3%	-19.6%	0%	+14%	+27.2%	+40.6%	+54%	+63.2%	+75%
Index Catch Pollock/TALFF				1.0	.982	.964	.949	.939	.901	.884

* in millions $US.

**in millions metric tons.

A prediction of the minimum dissipation of the net benefits in the short run can be realized by the use of integer variables in the L.P. formulation. The integer variables represent a number of vessels and not a number of vessel-days. To each vessel are attributed the fixed operating costs. The variable operating costs are still set on a vessel-day or catch basis. The number of vessels in each category defines the upper limit for the number of fishing days. Due to the restriction in TALFF's, if the existing vessel number is specified as a constraint in the model, the extent of dissipation of the net benefits can be given by the model.

The results of the mixed integer programming formulation show a total of $166 million for Japan when the number of vessels operating in the FCZ is fixed to its 1979 level, each vessel group having a positive net benefit. In the base model, short-run access benefits for the Japanese fleet were $234 million in the absence of payment of fees. Thus, in the absence of control concerning the number of Japanese vessels operating in the FCZ of the United States, the short-run dissipation of the net benefits can correspond to a 30 percent decrease in net benefits.

The long-run tendencies could be suggested by the analysis of the shadow prices, but the prediction of the net benefits dissipation requires the modeling of the investment decision making, incorporating in particular risk and uncertainty.

However, from the U.S. standpoint this potential dissipation of the net benefits after the payment of fees may be of no concern. On one side, the resource conservation problem is solved through the TAC's or TALFF's. On the other side, the extraction of the maximum net benefits is still possible. The resulting effect would be a reduction in the fleet size down to the optimal size. An interesting conclusion from this concerns a policy decision not to extract access benefits. The residual left to the foreign fleet may be transitory unless accompanied by limited entry restrictions imposed by industry or by the governments involved. Thus, failure to extract access benefits is of benefit to none in the long run. In the case of a centralized allocation mechanism, the problem is to assess the optimal number of fishing days for representative vessels in each vessel category. From there the optimal fleet composition, level and location of the fishing activities, and the maximum net benefits are derived, as illustrated by the model presented in this study.

Another interesting aspect of the fees problem is the multi-level planning problem in which no level has control over all variables or policy instruments. If we take as given that catches by U.S. fishing vessels will be exempt from fees, then the long-run effect of an excessive foreign fee structure may be to stimulate joint ventures, whether or not such ventures are the most efficient means of harvest. The polar extreme of such a reaction would be all joint ventures. In this polar case, the foreign fee schedules would produce zero revenue to the U.S. Treasury. Thus, it is evident that the assumption of given TALFF allocations, while useful as a starting point, also leaves unanswered some interesting policy issues. A more complete multi-level programming model must include a richer mix of joint venture possibilities. As Candler and Norton (1977) have noted, the best that can be realistically achieved in multi-level problems is often radically inferior to that which appears attainable in single-level programming models.

SUMMARY AND CONCLUSIONS

The objective of this study is to estimate the value of permits for mixed foreign fleets exploiting multispecies fish stocks.

The results from the base model show that the potential fees which can be collected yearly are not negligible. Specifically, the net benefits of access for the Japanese and Korean fleets amount to $264 million in the short run. After payment of the vessel replacement costs, the net benefits in the base model amount to $117 million annually. The potential fees in the long run vary then between $38 million to $117 million per year, depending on the assumption made regarding the costs and prices. This is assuming unchanged stock conditions.

The dual prices on the resource and vessel-day constraints suggest that a system of fixed fees levied both on catch and on effort would have more flexibility than a system based only on catch or effort. A mixed fees schedule is also better able to extract a large share of the net benefits of access. Such a system is in application for the Canadian FCZ.

The sensitivity analyses revealed that changes in operating costs and prices may result in important variations in the level of activities of the medium-size vessels. However, the activities of the large trawlers and the motherships are little affected.

The effects of different values of the parameters on the medium vessels are to be considered with caution when the purpose is to predict level of activities. Indeed, the model supposes instantaneous reactions and adjustments of the fishing companies, while in reality there may be some inertia, mainly in the absence of alternative fishing grounds.

An interesting result of the study is that the proposed fee schedule for 1981 does not seem to lead to a departure from an efficient resource utilization if the optimal allocations are also made. This holds even if this proposed fees schedule is uniformly increased by 75 percent. This result reflects the fact that the United States can fix both prices and upper bounds on quantities. The total fees collected then amount to $41.1 million. With such fees, about 84 percent of the short-run access benefits (excluding vessel replacement costs) are kept by the foreign fleets. This result assumes, however, that uncaptured access benefits are not dissipated by an excess number of vessels entering the FCZ of the United States.

The above results are considered approximate, since the data used in the model require improvements. This would require an information and analysis system for estimating the costs and revenues of the foreign fishing activities in the FCZ and in the major alternative fishing grounds. An explicit treatment of joint ventures activities would also be necessary. An increase in fees may indeed induce increased joint ventures activities, since in that case no fees would be paid by the foreign operators. These joint ventures activities are of particular interest because they embody the potential of important developments of the domestic fishing activities. Further extensions of the present framework could incorporate risk or uncertainty and also deal with the implications of catch on the long-run status of the fish stocks and therefore net benefits of access.

APPENDIX A. SIMPLIFIED ALGEBRAIC FORMULATION OF THE GLOBAL OPTIMIZATION PROGRAM

$$\text{Maximize } \psi(\cdot) = \int_o^{x_i^{US}} \ldots\ldots \int_o^{x_I^{US}} p^{US}(\cdot)\, dx^{US} - \sum_m \sum_j \sum_g C_g^{US} * E_{mjg}^{US} + \sum_k^K \left(\sum_i^I p_i^k * x_i^k - \sum_m^M \sum_j^J \sum_g^G C_g^k * E_{mjg}^k\right)$$

Subject to:

catch constraints in the U.S. FCZ:

$$\sum_m^M \sum_g^G a_{imjg}^{US}(\cdot) * E_{mjg}^{US} + \sum_k^K \sum_m^M \sum_g^G a_{imjg}^k(\cdot) * E_{mjg}^k \leq \overline{TAC}_{ij}^{US}$$

for each $i = 1,\ldots,I$
$j \in J^{US}$

catch constraints in other zones:

$$\sum_m^M \sum_g^G a_{imjg}^k(\cdot) * E_{mjg}^k \leq \overline{QUOTAS}_{ij}^k$$

for each $k = 1,\ldots,K$
$i = 1,\ldots,I$
$j \notin J^{US}$

landing constraints:

$$x_i^k - \sum_m^M \sum_j^J \sum_g^G a_{imjg}^k(\cdot) * E_{mjg}^k * b_i \leq 0$$

for each $k = 1,\ldots,K,US$
$i = 1,\ldots\ldots,I$

vessel-days (effort) constraints:

$$\sum_m^M \sum_j^J E_{mjg}^k \leq \bar{\bar{E}}_g^k$$

for each $k = 1,\ldots,K,US$
$g = 1,\ldots\ldots,G$

non negativity constraints for the choice variables:

x_i^{US}, x_i^k, E_{mjg}^{US}, $E_{mjg}^k \geq 0$ for each i,j,g,m

Definition of Variables and Coefficients

E^{US}_{mjg}, E^{k}_{mjg} represent the effort (in terms of fishing days) of vessels of the U.S. and of fleet k with gear g on a target species m in the area j.

$a^{US}_{imjg}(\cdot)$, $a^{k}_{imjg}(\cdot)$ are the catch-per-unit-of-time (CPUT) of species i by U.S. and foreign vessels with gear g, target species m, in the fishing area j. In the short run, the CPUT's may be a function of total effort (static stock effects) or the number of vessels (congestion).

b_i is a coefficient converting the live weight into landed product weight.

C^{US}_{g}, C^{k}_{g} represent the cost per fishing day of U.S. and foreign vessels with gear g.

x^{US}_{i}, x^{k}_{i} express the quantities of species i landed by the U.S. and foreign vessels.

$p^{US}_{i}(\cdot)$, p^{k}_{i} are the price functions (or alternatively constant prices) of species i in the U.S. and in the foreign country k.

$\overline{TAC}^{US}_{ij}$ is the total allowable catch of species i in a fishing area under U.S. jurisdiction ($j \in J^{US}$).

$\overline{QUOTAS}^{k}_{ij}$ represents the quotas by country in alternative fishing zones not under U.S. jurisdiction ($j \notin J^{US}$)

Additional subscripts are used in the applied model to represent seasons and the various types of processing for each species by vessel category.

APPENDIX B. SPECIES CODES AND NAMES

TABLE B.1. Species Codes of Pacific Ocean Fishes

CODE	SPECIES
FL	Arrow-tooth flounder, Greenland halibut, Other flounder (NS)
AT	Atka mackerel
PH	Pacific herring
OF	Other finfish, Other finfish (NS)
SQ	Squid (NS)
PO	Pollock (walleye, Alaska)
PC	Pacific cod
SA	Sablefish (black cod)
YF	Yellowfin sole
PP	Pacific Ocean perch
RO	Idiot rockfish, Other rockfish (NS)
AC	Jack mackerel
HU	Pacific hake

TABLE B.2. Species Names

Finfishes	
Pollock (walleye, Alaska)........	Theragra chalcogramma
Pacific cod......................	Gadus macrocephalus
Sablefish (black cod)............	Anoplopoma fimbria
Pacific hake.....................	Merluccius productus
Turbot (Greenland halibut........	Reinhardtius hippoglossoides
Turbot (arrow-tooth flounder)....	Atheresthes stomias
Yellowfin sole...................	Limanda aspera
Other flounders (NS).............	Pleuronectiformes
Pacific ocean perch..............	Sebastes alutus
Other rockfish (NS)..............	Scorpaenidae
Lingcod..........................	Ophiodon elongatus
Atka mackerel....................	Pleurogrammus monopterygius
Jack mackerel....................	Trachurus symmetricus
Pacific herring..................	Clupea harengus pallasi
Pacific herring..................	Hippoglossus stenolepis
Steelhead trout..................	Salmo gairdneri
Pacific salmon (all species).....	Oncorhynchus spp.
Other finfish (NS)...............	Osteichthyes - Chondrichthyes
Idiot Rockfish...................	Sebastolobus spp.
Armorhead........................	Pentaceros richardsoni
Alfonsin.........................	Beryx splendens
Pompano dolphin..................	Coryphaena equisetis
Dolphin..........................	Coryphaena hippurus
Sailfish.........................	Istiophorus platypterus
Black marlin.....................	Makaira indica
Wahoo............................	Acanthocybium solanderi
Blue marlin......................	Makaira nigricans
Striped marlin...................	Tetrapturus audax
Shortbill spearfish..............	Tetrapturus angustirostris
Requiem sharks (NS)..............	Carcharhinidae
Broadbill swordfish..............	Xiphias gladius
Thresher sharks (NS).............	Alopiidae
Mackerel sharks (NS).............	Lamnidae
Hammerhead sharks (NS)...........	Sphyrnidae
Rattails (grenadiers)............	Coryphaenoides spp.
Other sharks (NS)................	Squaliformes

Invertebrates	
Tanner crab (opilio, snow, queen)........................	Chionoecetes opilio
Tanner crab (bairdi, snow, queen)........................	Chionoecetes bairdi
Tanner crabs (hybrid)............	
Other crabs......................	Chionoecetes species
Squid (NS).......................	Cephalopoda
Shrimp (NS)......................	
Octopus (NS).....................	Octopoda
Spiny lobsters (NS)..............	Palinuridae
Corals (NS)......................	
Scallops (NS)....................	Pectinidae
Snails (NS)......................	Gastropoda

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