Pacific Coast Groundfish Management: Evolution and Prospects

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SUMMARY

Although federal management of Pacific coast groundfish strongly resembles previous state and international management programs, the current fishery management plan (FMP) contains important new elements as well. The groundfish FMP adopts state fishing gear regulations, but seeks more coastwide uniformity. As in previous international agreements, foreign fishing is limited to Pacific whiting and jack mackerel (with minimum incidental catch of other groundfish), and is prohibited in areas sensitive to U.S. interests. Development of major domestic rockfish and joint venture fishing has changed the fishery and has challenged the management system to devise approaches to new problems.

Annual harvest quotas or "guidelines" were established for several commercial species. These are based on "optimum yield" estimates derived from biological stock assessments. A major advance in the FMP is its flexible procedure for modifying the annual harvest guidelines in response to new information and changing fishery conditions. Individual vessel trip catch and frequency limits, designed to extend the rockfish fishery over the year, represent another important innovation. These regulations affect not only the pace and volume of catch, but also the distribution of catch among size-classes of vessels. In addition, the individual vessel trip limit reduces the economic incentive for greater vessel catching capacity.

Further progress could be made in setting optimum yield objectives and in addressing economic objectives of management. The FMP's optimum yield discussion ignores ecological interactions among species, and it treats aggregate yield from a mix of rockfish species as the sum of the yields from individual stocks. This is because there are no quantitative ecological models. Research suggests that optimum yields

for individual species should not be independent of the quantity and mix of other species being fished. Further, even if each species is ecologically independent, in multi-species harvesting some species are fished at greater or lesser rates than they would be in a single species harvest. Development of multi-species optimum yields should be high on the research agenda.

To generate greater net economic benefits, access must be limited either with license limitation or with individual fisherman quotas. License limitation provides minimal control over the excess vessel investment. Licenses do not replace the various harvest quotas, however, since the multi-species fleet would still over-fish individual species.

To forestall excessive capital investment among licensees, some meaningful control over up-grading fishing technology and vessel replacement is needed. "Individual fisherman quotas" eliminate the need for these controls by designating the quantity of fish to be caught by each fisherman. Despite the possible additional administrative and enforcement costs of individual quotas, this approach should be seriously considered for Pacific coast groundfish.

INTRODUCTION

During four years development, the Pacific Fishery Management Council (PFMC) worked out an innovative and ambitious plan for Pacific coast groundfish. The final plan covers a broad variety of fish species taken by the whole gamut of fishing methods (trawls, pots, lines and gill nets). It addresses fish stocks in all stages of development and depletion. It establishes harvest guidelines for the more heavily exploited fish stocks, and includes a variety of regulatory methods to assure that these guidelines are met. Finally, and possibly most important, the groundfish fisheries management plan (FMP) provides flexible procedures for altering harvest guidelines and associated regulations in response to new information.

Both the FMP and the periodic reports compiled by the Groundfish Management Team (hereafter called "the team") provide comprehensive documentation of the fish harvests, fishing fleet, and management alternatives considered. Therefore, I provide only a brief background summary on the fishery and plan in this paper. Beyond that summary, I describe the underlying management policy and anticipate modifications that might be necessary to meet reasonable biological and economic objectives.

In reviewing and evaluating the management effort I focus on two particular aspects: setting "optimum yields" and the possible introduction of limited access to the groundfish fishery. These are two prevalent and controversial topics in fisheries management. Consideration of these demands intense scrutiny of basic assumptions and objectives and comprehensive analysis of economic and ecological systems. Further development of a coherent policy for Pacific coast groundfish management requires careful examination of these issues. My objective here is not to present detailed proposals for changing groundfish management. Rather, I will suggest some approaches for further consideration, and contribute to public discussion of these issues--a discussion that must precede any effective consensus in support of revised management strategies.

SCOPE OF THE GROUNDFISH PLAN

The groundfish FMP covers commercial and recreational fishing in the three to 200 mile zone of five International North Pacific Fisheries Commission (INPFC) statistical areas on the Pacific Coast (Figure 1). Only one significant area of the groundfish fishery -- Puget Sound-- is not covered by the plan. Total shoreside and joint venture harvests increased from 57,000 mt in 1976 to 187,000 mt min 1982, and then declined slightly to 170,000 mt in 1983 (Table 1). The recent decline was primarily due to the decreased catch of widow rockfish.

Gross ex-vessel value of shoreside landings grew rapidly from 1976 through 1982 caused both by rising prices and increasing catch. Nominal ex-vessel price-per-ton for domestic groundfish peaked at $532/mt in 1979, dropped about 23 percent from 1979 to 1980, and then climbed back almost to the 1979 level by 1983. After adjustment for inflation, however, the 1983 average ex-vessel price is 24 percent below the 1979 price, and lower than the average 1976 price. These changes in gross value of landings are caused both by fluctuations in the market for fish and by changing species composition in the catch. Higher-priced species, like sablefish and the soles, account for an decreasing proportion of the total harvest, while lower-priced species, like rockfish, account for an increasing share.

During the same time span, from 1976 to 1983, foreign catch off of Washington, Oregon and California fell from 225,000 mt to nothing. During 1984, both Polish and Soviet fishing fleets are gaining renewed access to the Pacific coast whiting fishery. Preliminary indications are that around 30,000 mt will be released for foreign fishing this year. Joint venture fishing, arranged primarily through one firm (Marine Resources Company) grew rapidly after 1978. Current projections indicate that the 1984 catch may reach 100,000 mt, for the first time exceeding shoreside landings.

Eighty-four species are currently listed in the groundfish management unit. For practical purposes these can be roughly divided into five categories: rockfish, Pacific whiting, sablefish, other roundfish, and flatfish. Table 2a presents the distribution of catch by species groups and among the INPFC statistical areas, while Table 2b displays the catch by gear type. Of the $70.4 million in 1982 ex-vessel revenue, 82 percent was earned by trawl vessels, 6.7 percent by fishermen using fish pots and traps, and the remainder by vessels using longline and other gears. About 15 percent of the dollar value of trawl vessel sales were from over-the-side deliveries for joint venture fishing companies operating foreign-owned processing ships.

Pacific whiting, which accounts for the largest harvested tonnage, is caught primarily by domestic fishing vessels in joint venture operations. Rockfish, the second leading species group, includes Pacific Ocean perch, shortbelly rockfish, widow rockfish and the so-called Sebastes complex. The Sebastes complex is dominated by yellowtail and canary rockfish in the INPFC Vancouver and Columbia areas and by chilipepper and boccacio rockfish in the Monterey and Conception areas. The principal species in the flatfish group are Dover sole, English sole and petrale sole. Sablefish, accounting for the fourth largest tonnage, is caught by a large number of fish pot fishermen as well as by trawl gear. Pacific cod and lingcod dominate the "other roundfish" category. Other miscellaneous fish in the FMP

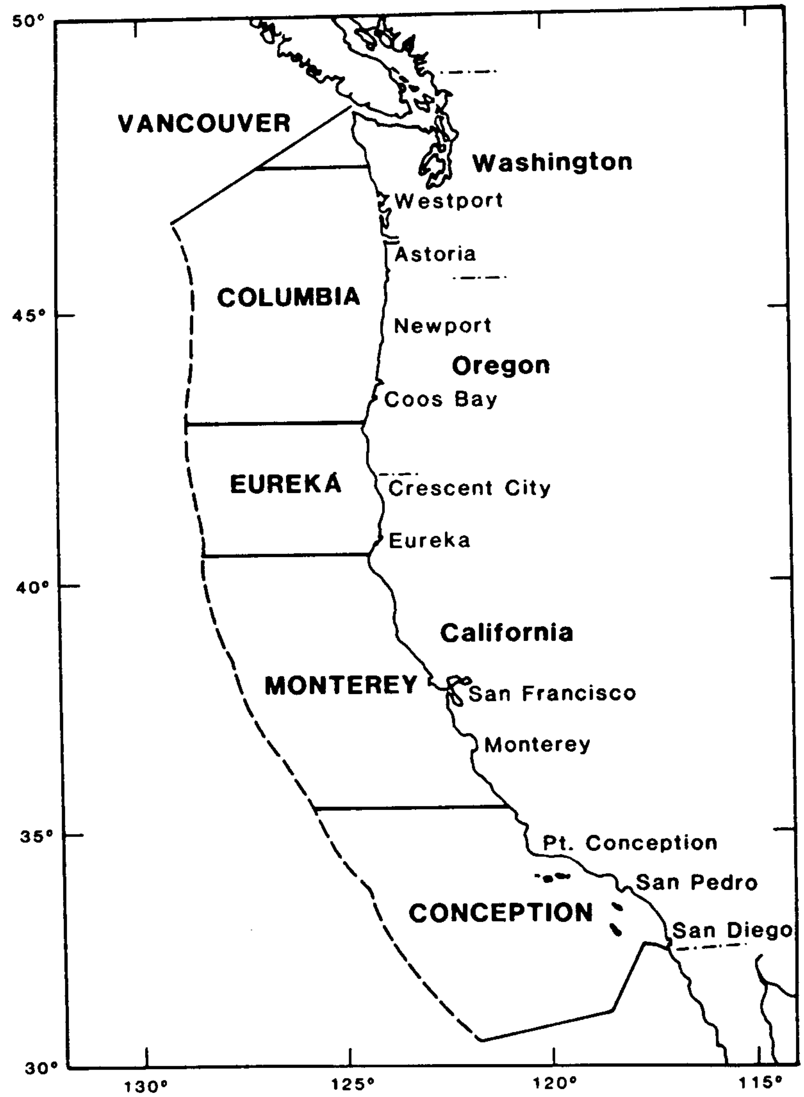

Figure 1. Pacific Coast groundfish management areas.

Table 1. 1975-1983 Pacific Coast groundfish harvest, quantity and ex-vessel value

Year	Domestic Harvests				Foreign[1]	
	Shoreside		Joint Venture			
	1,000 mt	$ mil.	1,000 mt	$ mil.	1,000 mt	$ mil.
1976	57.0	19.4	-	-	255.0	unk.
1977	59.8	20.7	-	-	118.0	unk.
1978	71.6	34.5	0.9	0.1	98.0	13.3
1979	90.0	47.9	8.8	1.2	117.0	15.9
1980	87.9	37.1	26.8	3.3	44.6	5.5
1981	103.9	46.8	43.8	6.3	70.9	10.2
1982	119.0	60.0	67.7	10.4	7.3	1.1
1983	97.7	52.2	72.1	10.2	-	-

1 Foreign fishery value calculated on assumption that price is equal to joint venture average price per metric ton.

Sources: 1976 data from Pacific Coast Groundfish FMP, p. 8-3.
1977-1980 data from C. Korson, Economic status of the Washington, Oregon, and California groundfish fishery in 1981. NMFS, Southwest Regional Office, Termnal Island, CA.

1981-1983 harvest quantities from PACFIN Report No. 002.

1981-1983 ex-vessel values from PACFIN Report No. 022.

Table 2a. 1982 Pacific Coast commercial groundfish harvests by INPFC area by species group (metric tons)

Species Group	Vancouver	Columbia	Eureka	Monterey	Conception
Rockfish	6693	27336	8170	14996	4466
Sablefish	2422	6348	3791	5083	946
Pacific whiting	30646	36410	8407	115	tr
Other roundfish	1361	1986	559	848	163
Flatfish	3860	14157	7411	6643	563
Others	107	109	99	143	111
Total	45089	86346	28437	27828	6222

Source: PACFIN Report No. 001. Includes joint venture catch.

Table 2b. 1982 Pacific Coast commercial groundfish harvests by gear type and species group (metric tons)

Species Group	Groundfish Trawls	Pots & Traps	Shrimp Trawl	Gill-Nets	Hook & Line
Rockfish	55646	30	1091	1639	3247
Sablefish	10159	6494	79	144	1657
Pacific whiting	75577	-	-	-	1
Other roundfish	4264	5	95	180	353
Flatfish	32419	1	128	45	11
Others	374	1	2	145	38
Total	178,439	6531	1395	2153	5307

Source: PACFIN Report No. 009.

are the various sharks, skates, rays, rattails, and jack mackerel taken north of 39° N. latitude.

The number of domestic fishing vessels active in the groundfish fishery changed rapidly from 1976 to 1983 (Table 3). Of particular

Table 3. Groundfish fleet size, 1976-1982

Year	Number of Vessels with Specified Gear:		
	Otter Trawl	Pot/Trap	Longline
1976	269	36	N/A
1977	286	60	N/A
1978	351	119	N/A
1979	472	207	N/A
1980	458	116	205
1981	409	66	191
1982	443	82	208

Sources: 1981 and 1982 Status Reports on the Pacific Coast groundfish fishery, compiled by C. Korson, NMFS, Southwest Regional Office; and PACFIN Report No. 022, PFMC Source Report: Commercial Groundfish Estimated Dollar Values of Landed Catch.

significance is the trawler fleet, which increased by 174 vessels. Most of the new vessels entering the fleet were larger, more powerful vessels with improved navigation, high-speed winches, stern ramps and mid-water trawling capability. These vessels tend to focus on the high-output, but lower-unit-value fisheries such as widow rockfish and Pacific whiting. Some of these vessels also participated in joint venture catches. Because of the ex-vessel prices and very high costs of borrowing capital, many of these newer vessels encountered financial difficulties.

SYNOPSIS OF FMP CONTENT

The Pacific coast groundfish FMP provides a lengthy discussion of alternatives to and implementation procedures for those measures chosen by the Pacific Fishery Management Council. I find the following five elements to be the most essential features of the plan.

BIOLOGICAL YIELDS

For each important groundfish stock, the team established a level of "maximum sustainable yield" (MSY), defined as the "average over a reasonable length of time of the largest catch which can be taken

Table 4. Pacific Coast groundfish harvests, estimated maximum sustainable yields and allowable biological catch (ABC) (metric tons)

Species	Annual Harvest 1976	1982	1983	Estimated MSY	1984 ABC
Pacific Ocean perch	2,336	893	1,659	5,300	1,550
Widow rockfish	-	25,445	9,904	10,714	9,300
Shortbelly rockfish	-	3	1	44,250	10,000
"*Sebastes* complex"	20,051	35,515	35,919	33,000	28,000
Boccacio	unk	unk	unk	6,100	6,100
Canary	unk	4,296	3,654	5,900	2,700
Chilipepper	unk	unk	unk	2,300	2,300
Yellowtail	unk	8,715	8,887	5,000	3,200
Remaining rockfish	unk	unk	unk	unk	13,700
Sablefish	7,028	18,592	14,533	13,400	13,400
Pacific whiting					
Shoreside	trace	1,023	1,051		
"Joint Venture"	0	67,465	72,100	175,500	175,500
Foreign Catch	231,000	7,089	0		
Pacific cod	2,165	910	597	unk	3,100
Lingcod	2,542	3,809	4,146	7,000	7,000
Other roundfish	5,187	4,918	4,762	10,100	10,100
Dover sole	13,179	20,916	19,819	19,000	19,000
English sole	4,488	2,771	2,336	4,500	4,500
Petrale sole	2,816	2,619	2,193	3,200	3,200
Other flatfish	4,690	11,691	9,581	15,400	15,400
Totals	295,482	193,550	169,329	341,664	300,050

Sources: 1976 harvests from Groundfish FMP, Table 8. 1982 and 1983 harvests from PACFIN Report No. 002. MSY estimates from the FMP, Table 13 and various reports of the Groundfish Team. ABC's and OY's from the 1984 regulations (Federal Register, Vol. 49, No. 5; January 9, 1984 pp. 1060-1061).

Notes: · "*Sebastes* complex" is all rockfish except Pacific Ocean perch, widow and shortbelly rockfish, and *Sebastolobus* sp.
· unk = unknown harvest level.

continuously from a stock" (FMP p.2-5). Due to variations in recruitment, ocean conditions and other uncontrolled factors, however, it may not be desirable to catch the MSY each year. Accordingly, the FMP defines "acceptable biological catch" (ABC) as the "seasonally determined catch that may differ from MSY for biological reasons". ABC may be lower then MSY for depleted stocks, like Pacific Ocean perch, and it may be higher than MSY for newly exploited stocks, like widow rockfish.

The FMP lists estimated MSY and ABC for sixteen principal species and species groups in each of the INPFC areas of the Pacific Coast groundfish fishery (Table 4). These estimates rely upon analyses ranging from detailed, long-term assessments to "first approximations". For Pacific whiting, for example, there are extensive studies by Soviet and U.S. scientists that support the estimated MSY of 175,000 mt. Ichthyoplankton and hydroacoustic/trawl survey information permitted the team to estimate the proportions of the total MSY occurring in each INPFC area. At the other extreme, only rudimentary stock assessments are available for lingcod, Pacific cod, "other flatfish", "remaining rockfish" or sablefish. Estimated ABCs are sometimes set as a proportion of recent annual harvest rates, where the proportion chosen is based upon collective judgement of the team as to the impact of recent harvest levels on the stock. Evidence used in this judgement includes anecdotal accounts from fishermen, estimated catch-per-efforts, changes in length or age composition in landings, and how long catch levels have been sustained.

OPTIMUM YIELD

For all but five groundfish species, "optimum yield" is defined as the amount taken with "legal gear". In other words, the optimum amount is the quantity harvested during a year by fishermen using gear that meets specifications in the plan. This approach to OY is applied to most of the rockfish species, all the flatfish, Pacific cod, lingcod and miscellaneous species. Gear restrictions are expected to protect juvenile fish and to maximize the yield-per-recruit for most of the species. Bag limits on recreational catch are three lingcod per day and 15 rockfish per day.

The FMP lists three main reasons for adopting the non-numerical OY approach. First, the fish stocks covered were not thought to be significantly depleted by commercial fishing at the time the FMP was developed. Second, this multi-species fishery naturally experiences simultaneous harvest of more than one target species and occasional large by-catches of non-target species. Grouping many species under a non-numerical OY "allows the flexibility to manage for maximum yield from the group as a whole rather than the maximum yield from each species". Third, management without using numerical quotas was expected to allow the existing fishery to continue with least impact on "fishermen's freedom".

A variety of special circumstances are cited by the groundfish plan as reasons to assign numerical OYs to some species. For Pacific whiting, widow rockfish, and shortbelly rockfish, the reason is that "they can be caught with mid-water trawls with minimal by-catches". Pacific Ocean perch is "severely depleted and requires special management consideration". For sablefish: "much of the catch is by directed effort with stationary gear", and "harvests in the Monterey Bay area deserve special attention". Optimum yields for these five in 1984 are equal to the ABCs listed in Table 4, except for sablefish. The sablefish OY is 17,400 mt, 30 percent greater than the ABC.

The PFMC selected a 20-year re-building schedule for Pacific Ocean perch, requiring a low catch level barely exceeding expected incidental catches. For widow rockfish the OY significantly exceeded the MSY during the 1982 and 1983. Presumably, the extent to which OY exceeds MSY determines the rate at which a virgin fish stock is fished down to MSY or some other desirable equilibrium level. As shown in Table 4, the 1984 ABC for widow rockfish is slightly below MSY. This reflects apparent biological over-fishing in some management areas.

BIOLOGICAL ASSESSMENT AND "POINTS OF CONCERN"

Because many of the stock assessments in the groundfish FMP were first-cut, preliminary estimates, and because the non-numerical OY procedure cannot completely protect all important fish stocks from over-fishing, the plan establishes a "groundfish management team" to continually monitor the status of each species and species group. This team is to look for "signs of biological stress", and to report to the council regarding appropriate management measures when a "point of concern" is reached. Specific conditions triggering the point of concern include: biomass falling below the level producing MSY, recruitment falling substantially below replacement level, fishing mortality exceeding that required to take the acceptable biological catch, catch for the year exceeding the acceptable biological catch, and other abnormalities occurring in the biological characteristics of the stock.

After considering the team's report and evaluating comments received during a subsequent public hearing, the council may recommend new management measures to the Northwest Regional Director of the National Marine Fisheries Service. If concurring, the Regional Director will publish proposed regulations, and allow adequate time for public comment before implementing the new regulations. This procedure permits significant flexibility in formulating regulations to achieve the biological conservation of fish stocks consistent with the optimum yields and allowable biological catches established by the council in the plan. Regulations can be changed without going through the full FMP amendment process.

FLEXIBILITY IN SETTING HARVEST GUIDELINES

The "Points of Concern" mechanism allows fast response to biological conservation problems, but does not allow for increases in OY or ABC. The FMP has other procedures, however, for in-season and between-season upward adjustments in OYs and ABCs. If the groundfish management team concludes that increasing catch of a species will not "stress" that or any other species, the team may recommend that the council increase OY or ABC. As with the point of concern, the FMP lists a series of criteria for triggering the upward adjustment in harvest guideline. These criteria include biological factors such as: low fishing mortality rate relative to MSY, large recruitment, large biomass relative to MSY, and any other pertinent factor.

Upward adjustments in numerical OYs are limited to 30 percent during any given year, while reductions under the points of concern procedure are not limited. Upward adjustments of more than 30 percent in a year must be implemented through a full FMP amendment process, which can taken 250 to 300 days. The council may recommend more than one upward adjustment in a year, so long as the sum of all increases does not exceed 30 percent of the original optimum yield. Acceptable biological yields may be changed by any amount. Consequently, the PFMC/NMFS regulations have much greater flexibility in regulating the harvest of non-numerical OY species.

REGULATIONS TO ACHIEVE OPTIMUM YIELD

The optimum yields and acceptable biological catch levels in the FMP represent the maximum recommended catches. A numerical OY is a legal quota, and the fishery regulations must assure that this level of catch is not exceeded during a given calendar year. Although ABC is not a legal quota, it may be taken as a "harvest guideline" for non-numerical OY species. The PMFC has formulated specific regulations to assure that catches do not exceed harvest guidelines for the Sebastes complex, a non-numerical OY species group.

As noted, most species are not assigned numerical OYs. Harvests of these species are regulated only by restrictions on legal gear, area closures, and recreational bag limits. "Legal gear" is defined by extensive and specific requirements regarding: the construction and mesh size in trawl net cod ends (specific to type of trawl operation and region), size and use of chafing gear, size of rollers or bobbins on groundfish trawls, locations for set nets (trammel and gill nets), and escape panels in fish traps. In addition, both traps and longlines must be attended at least once every seven days, and both must also be marked at the surface at each terminal end of the groundline with a pole and flag, light, radar reflector and a buoy displaying clear identification of the owner.

For species having numerical OYs, or for which there is a "point of concern", the "legal gear" requirements are supplemented by additional fishing regulations. The generic form of regulation is prohibiting additional landings once the OY or ABC is attained (for example, a fishing season closure). Because of the in-season flexibility built into the groundfish plan, however, the council may decide that increasing OY is more justifiable than closing the fishery. The FMP also seeks to prevent wasting fish by allowing minimal incidental catches occurring after the harvest guideline is reached. For example, fishing vessels are limited to a "trip limit" of 5,000 lb of sablefish whenever 95 percent of the OY is reached in a management area. The 1982 trip limit for Pacific Ocean perch, which is managed as a strictly incidental catch, was 10,000 lb or 10 percent of the total fish landed.

In 1979, well before the FMP was officially implemented, the domestic trawl catches exceeded established ABCs for Pacific Ocean perch and Dover sole in the Vancouver area, Pacific Ocean perch, canary rockfish, yellowtail rockfish and Dover sole in the Columbia area, and sablefish coastwide. Also, widow rockfish catches substantially exceeded the original ABC estimate in 1981. Warnings of "biological stress" provoked varied responses from the PFMC/NMFS management authorities.

No additional regulations were developed to manage the flatfish species even though the Dover sole harvest continued to slightly exceed the coastwide ABC in 1982 and 1983. The "legal gear" measures protected small flatfish, and the amount by which catch exceeded ABC was trivial in view of the low precision of the biological assessment. This presumably justifies the council's lack of action on flatfish.

When sablefish catch was projected to substantially exceed the team's initial OY estimate in 1982, the council imposed a trip limit of 3,000 lb for the last three months of the year. The OY was raised from 13,400 mt to 17,400 mt (by 30 percent). The 1982 catch total was even greater than this new OY. The sablefish regulations were augmented in 1983 by a 22 in. minimum size limit in all areas north of Point Conception (excluding Monterey Bay). The incidental catch allowance for undersize fish has varied, but is currently 5,000 lb per fishing trip. The council's intention is to close the fishery after the OY is reached. But the market for sablefish in 1984 seems to have declined to the point that the fishery is unlikely to take the ABC.

The council has modified regulations on Pacific Ocean perch harvests to keep that stock on its 20-year rebuilding schedule. In some INPFC areas the annual catch was projected to exceed the area's ABC. In November, 1983 the Columbia area was closed to Pacific Ocean perch fishing, but the 5,000 lb or 10 percent by weight trip limit was retained in other areas. The 1983 harvest reached 1,659 mt, 7 percent greater than the coastwide ABC. In July 1984 the council further recommended that the Pacific Ocean perch trip limit be changed to 5,000 lb or 20 percent by weight, whichever is less. This last variant of the incidental trip limit regulation was designed to prevent smaller trawl vessels from making daily fishing trips specifically targeting on the 5,000 lb of perch.

Much recent council management activity has involved widow rockfish and the *Sebastes* complex. Harvest guidelines for these are implemented mainly through trip catch limits, trip frequency limits, incidental catch allowances, and season closures. Following the groundfish management team's recommendations, *Sebastes* complex ABCs are established in two geographic areas separated by 43° N. latitude (later changed to 42° 50'). The area north of this line roughly corresponds to the Vancouver and Columbia INPFC areas, while the southern range includes Eureka, Monterey and Conception. In each area the trip limits are calculated to allow the fleet to fish all year, assuming usual seasonal patterns of fishing, without exceeding the OY. If the OY is reached, then the fishery is closed.

Annual widow rockfish harvests grew from 4,293 mt in 1979 to almost 28,000 mt in 1981, dropped to about 25,000 mt in 1982, and fell to 9,900 mt in 1983. During 1980-1982 the PFMC temporarily permitted the OY to substantially exceed the estimated MSY of about 11,000 mt. The widow rockfish fishery was exploiting a virgin biomass of relatively old fish. The temporarily high annual fishing rates were expected to reduce the standing biomass, presumably to levels that might sustain a near-MSY harvest.

Maximum use of the FMP provisions for in-season flexibility is evident in the history of rockfish regulations. A coastwide trip limit of 75,000 lb, was imposed on widow rockfish from mid-October, 1982 through February of 1983. The trip limit was reduced to 30,000 lb in

March of 1983 and further reduced to 1,000 lb in September. In 1984, the widow rockfish trip limit started out at 50,000 lb, but was reduced to 40,000 lb in May. Trip frequency for widow rockfish was limited to one per week beginning in January, 1984. Each of these regulatory actions was preceded by reports and recommendations from the groundfish management team, industry advisors and scientific and statistical committee.

The fisheries for other rockfish species developed close on the heels of that for widow rockfish. A 40,000 lb trip limit for the Sebastes complex with maximum frequency of one per week was established in the Vancouver/Columbia area starting in March of 1983. In mid-September the trip limit for the Vancouver/Columbia area was reduced to 3,000 lb, while a limit of 40,000 lb per trip with no maximum frequency was specified for south of 43° N. The trip limit in the northern area was reduced to 15,000 lb once per week, or 30,000 lb once per two weeks (at the option of the vessel operator) in May of 1984. Although none of these trip limits could be expected to precisely attain the OY over an entire year, they do represent an innovative attempt to simultaneously satisfy both the OY and year-around fishery objectives.

EVOLUTION OF MANAGEMENT REGULATIONS UNDER THE FMP

Commercial fishing regulations evolved fairly rapidly during the first two years of the plan's operation, largely because stock assessments found increasing evidence of over-exploitation as the fishery expanded. An additional impetus for regulatory change was the PFMC's decision to extend fishing seasons over as much of the year as possible. The objective of this is to avoid disrupting the flow of fresh groundfish fillets in domestic markets supplied by the Pacific Coast fishery. To do this and keep the annual catch within harvest guidelines requires that the rate, not just the annual amount, of catch be regulated. Individual vessel trip limits and trip frequency limits were selected as the mechanism for retarding the harvest rate. This is a significant and important change from the traditional "fishing season" regulation wherein participating fishermen are unrestricted regarding catch on individual fishing trips.

Catch and frequency limits on fishing trips have two main effects: they re-allocate economic returns among the various size-classes of vessels, and they improve opportunities for private firms to reduce costs of fishing. When trip limits are low enough to lengthen the fishing season, smaller vessels should take a larger share of the annual catch than they would otherwise, and their profitability should improve relative to that of new, larger vessels. Recognizing the higher minimum per-trip harvest requirements of large trawlers, the groundfish regulations allow fishermen to catch twice the per-trip limit of Sebastes, if they make such trips fortnightly rather than weekly. This somewhat lessens the re-allocation effect. But it cannot compensate larger vessels entirely, since the higher fixed costs of owning and operating a large vessel need to be spread over a greater annual revenue. In sum, the new, more powerful vessels are designed to take advantage of profit opportunities related to large harvest volumes that the trip catch and frequency limits preclude. To maintain year-around fishing and greater trip limits, the number of fishing vessels must be reduced.

A trip limit approach also causes a qualitative change in the traditional form of competition for fish. With free access to the "common property" fish stock, a vessel's ability to harvest more rapidly usually translates into a larger share of the total harvest. With both catch per trip and trip frequency limited, increased fishing vessel capacity is no longer rewarded immediately with a larger share of the catch. Under trip limits, a vessel's expected annual harvest depends upon the annual harvest guideline and the number of participating vessels. This assumes, of course, that the trip limit is smaller than the typical catch-per-trip taken before the limit was imposed. When the council first established a widow rockfish trip limit in 1982, the level chosen (75,000 lb) was not a significant constraint, even on larger vessels.

The 1984 widow rockfish management regulations include an aggregate catch quota of 9,300 mt, a trip limit of 40,000 lb (18.14 mt), and a trip frequency of one per week. Subtracting 100 mt reserved for incidental catch after the widow rockfish season closure, these regulations create 507 weekly vessel quotas. If there are 70 vessels participating in the fishery, they can fish a average 7.25 weeks each on widow rockfish, and each vessel has the opportunity to harvest about 133 mt of fish. This 133 mt is not specifically assigned to individual vessels. So there is still competition among vessels; but the competition will be different from before. A given vessel operator can take 18.14 mt as fast as possible each week, or he can fish at a slower (and possibly less costly) pace, or he can intersperse widow rockfish fishing with other forms of fishing during a given week. Overall, I would expect the widow rockfish harvest to generate a greater net economic return than before, due to somewhat lower fishing costs. Also, the rockfish fillets may bring a greater net return because they are produced at a more even pace, over a longer season.

Similar qualitative change in competition among commercial fishermen may be encouraged by the Sebastes complex trip limit and trip frequency regulations, and to a lesser extent the Pacific Ocean perch and sablefish incidental catch trip limits. The potential increased economic value from these trip limits is small, and this does not represent a shift toward economic efficiency objectives in groundfish management. It does represent a perceptible movement away from annual harvest quotas that encourage irrational and costly harvest methods.

OPTIMUM YIELD CONSIDERATIONS

As I noted in the introduction, further development of coherent groundfish management requires that optimum yield receive attention. Two aspects need to be discussed: the nature and function of optimum yield in the management regime, and the criteria for setting OY in a multi-species fishery. I will provide some insight into these issues, indicating why I think they are important and how the existing management framework deals with them.

NATURE AND FUNCTION OF "OPTIMUM YIELD"

The Magnuson Fishery Conservation and Management Act (FMCA) followed the International Law of the Sea in designating optimum yield as a central management objective. Since much has already been written about the optimum yield concept, it is unnecessary to belabor that discussion here. The American Fisheries Society Symposium on Optimum

Sustainable Yield (Roedel 1975) and the NMFS-sponsored National Workshop on the Concept of Optimum Yield (Orbach 1977) provide extensive guidance. Optimum yield, as a management objective, is largely an elaboration of the more narrowly defined concept of maximum sustainable yield. It is supposed to encompass economic, ecological and social factors, but development of practical techniques for determining OY in specific instances has been slow. As lamented by P.A. Larkin (1977), even a concerted attempt to explain optimum yield tends to become an "eclectic mishmash that was all things to all people".

To avoid this "mishmash", a specific and explicit presentation is needed. Since economic factors have been most extensively considered in commercial fisheries, the prospects seem brightest for introduction of economics into optimum yield. Quantitative economic models for fishery management are available, many developed specifically for fishery management plans (for example Anderson 1981). Given proper information regarding market prices, fishing costs, and a biological yield model, standard analytical methods are used to determine maximum sustained level of economic yield.

Economic efficiency, in its broadest sense, is the focus of this approach. In principle, economic efficiency requires a proper balance of greater fish production and greater production of a variety of other things that could be produced instead of fish. In the words of James Crutchfield (1977), "optimal utilization of fishery resources, like optimal utilization of any other natural resource, cannot be divorced from optimal utilization of all inputs--natural resources, capital, labor, and technological knowledge--in meeting the multitude of competing demands for all goods and services".

The groundfish FMP does incorporate some economic factors in setting OYs, but it does so clumsily and inexplicitly. With its great reliance on MSYs and ABCs as optimum yields, the Pacific coast groundfish FMP appears to seek maximized physical yield. But the management record belies this simple interpretation. No remedial action was taken by the council or NMFS when shortbelly rockfish and Pacific whiting harvests fell far short of the stated optimum yield. These shortfalls were not alarming, in my interpretation, because the nominal OYs are not intended to represent optimal catch levels. Both the PFMC and the industry advisors implicitly understand that optimum yield of shortbelly rockfish is far less than the stated 10,000 mt, and that the OY for Pacific whiting was substantially below the nominal 175,000 mt.

These numerical OYs are better understood as maximum, biologically safe levels of fish harvest. From an economic standpoint, harvest levels are desirable only if the price equals or exceeds the fishing cost: if there is a "market" for the fish. Since the domestic fishery could not profitably exploit these fish stocks, the real optimum is some undefined amount less than the stated OY. The substitution of "biologically safe" for "optimum", however, confuses the <u>concept</u> of an optimum catch level with the <u>process</u> of regulation. The <u>maximum</u> safe level may logically function as an upper limit, or harvest quota. Whether quotas and optimum yields need be the same is debatable.

Without involving economic and other factors in setting optimum yields, moreover, "biological factors" are often stretched and twisted to accommodate all kinds of management concern. Caution in the face of resource uncertainty, avoiding foreign fishing allocations, and political division of the catch among competing groups are some of the management motives hidden under the guise of "biological" conservation. To those who understand the role of biological research and stock assessment, the management process appears to be ad hoc. One rationalization is that "optimum yield is whatever the council decides it is". This may be procedurally correct, but it fails to meet the need for well-informed, understandable management criteria.

For non-sustained harvest levels, development of an economic rationale for optimum yield is even more essential. The FMP's discussion of widow rockfish and Pacific Ocean perch management provides no convincing biological reasons for choosing particular rates of growth or decline in the underlying fish stocks. Yet the rate of stock reduction, or "dis-investment", was chosen when widow rockfish OYs were set during 1980-1982. Similarly, the 20-year rebuilding schedule for Pacific Ocean perch implies an investment rate that pays off in future economic returns. If explicit criteria for these non-equilibrium harvest strategies were developed, management policy would be more transparent to reviewers, and the council less subject to misunderstanding and criticism (see Gunderson 1983).

MULTI-SPECIES ASPECTS OF OPTIMUM YIELD

Since ecological interactions are important in determining sustainable yields from a species complex, fishery managers have long struggled with the need for acceptable criteria in managing multi-species assemblages. Whole workshops have been devoted to investigating multi-species approaches to fisheries management (Mercer 1982; Hobson and Lenarz 1977). Prominent fisheries scientists warn against the errors caused by artificially compartmentalizing the fishery by managing individual species (Silvert and Dickie 1982). Collecting and analyzing appropriate data to make practical use of eco-systems models, however, has proved too difficult for most fishery research efforts. The groundfish FMP does not explicitly consider the ecological interactions among species. It seems to assume that each species stock is biologically independent. This is implicit in establishing ABCs for each species in each management area.

For various species that are linked by technological and economic factors, however, the FMP does make provisions for multi-species harvesting. The groundfish plan introduces the notion of species "targeting". A species is a "target" if it can be caught predominantly in pure loads. A trawl net, for example, will usually encounter more than one groundfish species in a given area, depth or mode of operation. By appropriate manipulation of the time of day, area, speed, depth and other operational factors, however, a fishing vessel skipper can often "target" on one or two species.

Disagreement undoubtedly exists as to when, and under what conditions fishermen can accurately target on some species. But, as a general rule, the mid-water schooling species, such as widow or shortbelly rockfish and Pacific whiting, can be caught in nearly pure tows. Similarly, the *Sebastes* complex can usually be caught without serious incidental catch of other species; but there is less agreement on the extent to which trawl vessels can target a particular species in the complex. In contrast, important members of the flatfish group tend to be caught in mixes with several commercial species (Adams and Lenarz, unpublished manuscript). This technological interdependence is addressed in the FMP by lumping some species into groups. Species that can apparently be "targeted" are given separate optimum yields.

As a provisional approach to multi-species optimum yield, this raises some further questions. First, how can the optimum yield for a species group, like the Sebastes complex, be derived from the "acceptable biological catches" of the constituent species? If there are ecological interactions among the species, or if the different species stocks are optimally exploited at different fishing rates, this may be quite difficult. Second, what is the best way to prevent the wastage of incidentally-caught fish of a prohibited species, or of a species whose quota has already been filled? Assuming that targeting is imperfect, some incidental catch of a numerical OY species may be taken while fishing for other species.

To date, the harvest guidelines from grouped species are constructed from the sum of ABCs for the species. This is a questionable practice. If two species are harvested simultaneously (the same fishing effort applies to both stocks), the optimum level of aggregate catch (or effort) for the mixed harvest would equal the sum of the individual species optima only by extraordinary coincidence. Only if exactly the same level of fishing effort achieves the optimum yield for each species would there be a simultaneous optimum. In any other case, the optimum multi-species harvest must be less than the summed optima for the individual species, considered separately. Full use of more abundant species would likely require that less abundant and less productive species stocks be fished to less than the MSY level. Thus grouping several species to establish harvest guidelines requires adoption of a "second best" approach that cannot achieve the maximum total yield from the group. By this reasoning, the optimum yield for the Sebastes complex must be lower than the sum of the MSYs for yellowtail, canary, boccacio, chilipepper and other rockfish. The groundfish FMP recognizes this fact, but does nothing about it.

Another problem for multi-species fisheries is that of incidental catch regulations. Species with individual quotas cannot always be caught in pure loads. Consequently, some widow rockfish or Sebastes complex species, for example, will be caught by vessels targeting other fish. This inadvertent incidental catch will occur even after a quota is reached and target fishing stops. Mortality due to handling the fish is very high, so discarded fish are generally not returned to the stock for later harvest, but are wasted. The manager's dilemma is how to enforce a harvest quota, and prevent the wastage of discards, while not unduly burdening the fishermen with gear and other restrictions on efficient harvest practices.

In their examination of alternative incidental catch controls, Marasco and Terry (1982) adopt an approach that minimizes the economic cost of incidental catch. The direct "cost" of discards is approximately measured by the ex-vessel value of discarded catch. Regulations to prevent incidental catch, however, involve two other costs: those incurred by management authorities in surveillance and enforcement, and costs borne by fishermen if they are forced to fish in less productive fishing areas or times, or with gear that provides lower gross earnings. It is not necessarily desirable to eliminate incidental catch, even though this would minimize the direct cost of discards, because the administrative costs incurred by management authorities and fishermen might exceed the value of the fish saved.

Minimizing costs in incidental catch regulation would be part of a coherent multi-species harvest policy with two main affects. First, incidental catch would be considered in setting OYs and size limits of fully-used fish stocks. If the cost of avoiding small sablefish in the Dover sole fishery exceeds the value of sablefish saved, for instance, the incidental catch limit on small sablefish should be raised. Second, this would affect the design of an operational quota system. When a known percentage incidental catch is not worth avoiding, that catch can be subtracted from the directed fishery quota and reserved specifically for incidental catch.

Current groundfish management regulations seem to have adopted an approach quite close to this for Sebastes and sablefish, and I would not focus on this as a major problem. It may become a problem however, if the domestic fisheries for Pacific whiting and shortbelly rockfish develop to their potential. When low rates of incidental catch are applied to very large harvest volumes, the incidental catch of some depleted species, like Pacific Ocean perch, may equal or exceed the designated harvest guideline. Managers need to be prepared to decide when to relinquish particular objectives relating to species, like Pacific Ocean perch. Although this species is high-priced and has great prominence in the history of the fishery, a time may come when the costs of avoiding incidental catch and waste of discarded fish exceed the economic value of the fishery for that species. It might be useful to have some agreed criteria for deciding when and if a species should be re-assigned to a multi-species aggregate or non-numerical OY group.

LIMITED ACCESS PROSPECTS

Limiting access to commercial fisheries has become increasingly acceptable to managers and industry. A variety of industry and scientific groups have urged the Pacific council to consider limited access in the groundfish fishery. Over the past two decades this interest has been attributable to several motives: increased economic efficiency in the commercial fisheries, increased income for successful vessels, easing pressures on management caused by over-built fleets, and in some cases improved conservation of stocks. Current high interest in groundfish limited access can also be attributed to the increased experience in the Canadian, Australian, Alaskan and Pacific coast fisheries, as well as the poor financial performance of many recently-built trawl vessels.

Adopting such a significant change in the groundfish regulatory approach would require long and careful deliberation of limited access concepts and options. The generic options are thoroughly reviewed in the recent reports of Meyer (1983), Pearse (1982), Sturgess and Meany (1982), Stokes (1979), and Rettig and Ginter (1978). While I do not intend to make any specific proposals in this paper, I think it is useful to review the principles involved and to consider how limited access might apply to Pacific coast groundfish.

RATIONALE FOR LIMITED ACCESS

The general case for limiting fishery access builds upon the well-known deficiencies of open competition for "common property" fish stocks. Without regulations, competitive commercial fishing fleets tend to economically and biologically over-fish. The principal reason for stock depletion with open access competition is that individual fishermen cannot control aggregate harvest rates. When many firms catch fish in competition with others, no individual act of conservation is likely to pay-off for that individual. With common property fish stocks, economic rationality on the part of individual fishermen does not favor fish stock conservation. This lack of opportunity to invest in fish stocks, not lack of knowledge and inclination, explains the lack of private conservation action.

To determine appropriate yields for important commercial fish stocks, fishery scientists devise quantitative concepts expressing the biological potential, such as MSY. Applying annual catch quotas to the open-access fishery may adequately insure biological conservation. But the basic economic incentives of the individual fishermen are largely unchanged. Instead of competing for dwindling stocks, the open competition is for a conserved stock. Individual incentive for conservation action remains weak, and economic rewards go to those fishermen who find ways to increase their individual catches, so long as their increased fishing costs do not exceed increased ex-vessel revenues. As ex-vessel prices rise, increased potential fishing profits attract additional investments in fishing capacity by both new and continuing participants.

Obviously, the degree to which the over-built fishing fleet becomes a real concern depends upon the potential net difference between costs and revenues. Pacific salmon provides the extreme example of very high ex-vessel prices teamed with potentially miniscule harvest costs. To prevent rapid stock depletion management strategy has forced the harvesters into technically inefficient operations. Even with severe restrictions on catch, fishing seasons, and harvest technology salmon fleets tend to be unreasonably large. Consequently, it is not surprising that limited entry was introduced first, and has been used most extensively, in salmon fisheries on the Pacific Coast.

Like the harvest quota, however, limiting the number of participants in a competitive fishery does not change the economic incentives of individual fisherman. Although the number of competitors is limited, fishermen still find it profitable to increase fishing capacity as long as the cost of such increase falls below the potential increase in revenue. Soon after the salmon limited entry program was introduced in British Columbia, managers had to impose various sorts of capacity limits on fishing operations. Economic studies showed that increased investment in capacity of the limited fleet was a substantial threat to economic returns from the fishery (Fraser 1979; Pearse and Wilen 1979).

Similarly, license limitation programs in Australian fisheries have been forced to include stringent fishing vessel capacity controls. In the northern prawn fishery, for example, fishing licenses can be transferred and even consolidated, so long as the new vessel has no more capacity than previous license holder's (Colin Grant, personal communication). To maintain a significant level of "economic rent", the regulators may have to continually anticipate and forestall technical innovations that, while increasing an individual's harvest capacity, simply raise the total cost of taking a fixed harvest. The economic evaluation of license limitation systems is not complete, but the debate has now turned to whether any substantial economic benefit will accrue from the program in the long run. Simply limiting the number of licensed fishermen does not assure improved economic performance of fisheries.

In recent years, economists have focused on forms of limited access that more directly address the underlying common property problem. The key is to establish a set of institutions that lessen individual incentives to compete for increased catch through expanded fishing capacity. "Racing for fish" needs to be replaced by incentives for low-cost production of available yield. There are two basic alternatives. First, quantitative rights to harvest fish (also called "individual fisherman quotas") could be established to allocate optimum yield. These rights can mimic conventional property rights established for other natural resources. Second, landings fees or royalties could be set to discourage excessive fishing capacity and effort. In a Canadian fisheries context, Pearse (1982) is a well known proponent of individual fisherman quotas; and Stokes (1983) developed this approach during discussions of north Pacific halibut license limitation.

The main advantage of the individual fisherman's quota is that it eliminates the basic economic incentive leading to overcapitalization of the fishing fleet. With a known, quantitative share of the allowable harvest, a commercial fisherman will no longer be strongly encouraged by the profit incentive to competitively increase his fishing power. Instead, the fisherman is encouraged to adopt fishing vessels and fishing methods that permit taking the licensed catch at the lowest cost. The individual fisherman's profit incentive is made consistent with overall cost minimization. Further, permitting transfer of quantitative rights in private market transactions would encourage broader economic efficiency by facilitating the redistribution of harvest rights to those fishermen most able and/or willing to harvest at low cost. Market prices of individual quota certificates would be expected to reflect the potential profits from fishing. Like prices for other natural resource commodities, the price for a harvest quota would represent a cost of doing business to the purchaser and a source of income to the seller.

Royalties on fish harvests could be an alternative to quantitative harvest rights, or they could be used in conjunction with quantitative rights as suggested by Pearse (1982; p. 94-95). As a direct cost of fishing the royalty would discourage excessive investment in fishing power. If the royalty rate is roughly equivalent to the hypothetical market price for a quantitative harvest right, the same incentive for cost minimization would occur under the two alternative approaches.

Two primary elements distinguish royalties from quantitative rights. First, government administrators, rather than private markets, would set the value paid per unit harvested. Second, with royalties the net economic value of harvesting fish would accrue to the public treasury rather than appearing as net income earned by private fishing businesses. To establish royalty rates with correct cost minimizing incentives, public administrators will have to collect and evaluate cost and revenue data from fishing operations. Interpretation of such data can be technically difficult because of the variety of crew share arrangements, non-cash transactions, bonus payments, and variability in harvest rates among vessels and over time. Fishermen opposed to a royalty system would not be inclined to provide the more accurate information.

To avoid this estimation problem, management agencies might dispose of quantitative fishing rights in a public auction. Again, this substitutes the competitive market for administrative computation. This is the way the U.S. Forest Service and the U.S. Minerals Management Service dispose of timber harvesting and mining rights on public land. But there are essential differences between these rights and any prospective fish harvesting rights. Mineral and timber sales confer exclusive rights to sever the minerals or timber from the land, while any prospective fishing rights would retain certain characteristics of the "commons". A right to harvest, say 10,000 mt of Pacific whiting, could be established as a salable right, but the harvest of fish is still from a common pool.

Another practical problem with royalties is that they are distinctly political. Like taxes, they are established and modified through legislative action. Royalties would not be viewed as a permanent feature of the fishery, but as a point for continual negotiation, lobbying, and tinkering.

In contrast, once quantitative rights are established, the competition for fish that now fuels political tinkering would no longer be a continual source of instability. Competition for fish among gear types, regions, and cultural groups would no longer fuel political debate and be a constant source of instability for the fishery. Through time and custom, such rights might assume the legitimacy of private property. As noted by Anthony Scott (1984) the community would then be expected to uphold the validity of fishing rights, help protect them from trespass, and support their exchange and subdivision by standard property right mechanisms.

Further, once the rights are established, their holders will have an interest in the long-term health of the fishery. They will be more willing to make the short-term sacrifices often required to conserve fishery resources. Therefore, the beneficial affects of establishing property rights and the corresponding conservation responsibilities are most evident with the individual harvest rights approach.

PROSPECTS FOR APPLICATION TO THE GROUNDFISH FISHERY

License limitation tends to follow conventional fishery regulation, focusing on fish stocks rather than fishing fleets (Stokes 1979). Licensing programs for Pacific coast salmon, herring and abalone, and for Australian prawns and rock lobsters exhibit this characteristic. If fishing capacity is specific to a species, a stock, or a coherent group of stocks, the "fishery" may be identified by a fish stock or stocks for management purposes. In this case, one can determine how the number of licenses issued is likely to effect fishing capacity, economic yield, and estimated optimum fleet size. When several distinct gear groups and many varieties of multi-purpose fishing vessels are involved, as in Pacific coast groundfish, it is not so simple.

First there is the problem of usefully defining the groundfish fleet. The fleet currently includes many part-time vessels that are used for a number of fisheries. They shift at seasonal or longer intervals among shrimp, rockfish, bottom-trawling, and joint venture fishing. If the crab catch rate is high, some vessels shift from groundfish into Dungeness crab for the winter season. Also, salmon trollers and crab pot fishermen can catch groundfish incidentally. The line between included and excluded vessels, required for licensing, must be carefully drawn. If the definition is too all-inclusive, neither the fleet nor capacity is limited. To limit capacity and still allow great variety in commercial fishing strategies, separate licenses could be issued for distinctive segments of the fishery. Southern California gill nets, Monterey Bay fish traps, sablefish/halibut longliners, mid-water trawlers, and shrimp/bottomfish trawlers are some likely categories. Each category has a characteristic locale, harvests a characteristic mix of species, and uses a distinctive gear. But there will necessarily be a significant overlap in species and stocks exploited by license categories.

Beyond the problem of fleet definition, a license limitation approach is not particularly well-adapted to the flexibility normally exercised in multi-purpose fishing operations. As noted in Huppert (1979), the ability to shift among substitute fishing modes may be essential to the long-run economic survival of these kinds of vessels. Trawlers move between shrimp and groundfish as the fish stocks and market conditions affect revenue-per-day-fished. To license a vessel just for shrimp, or to deny groundfish licenses to vessels that have recently fished only shrimp, could be disastrous to those vessels and economically inefficient. Flexibility in license transfer, division and consolidation among vessels might address this need for shifting among fishing activities. Whether or not this could be accomplished without a cumbersome and costly administrative apparatus remains to be seen.

The other side of this coin is that limiting licenses to fish cannot effectively control the amount of fishing for any given fish stock so long as multi-species fishing remains significant. For example, no reasonable limit to the mid-water trawl fleet alone could produce appropriate harvest levels for Pacific Ocean perch. If fishing rates are uncontrolled by license limitation, conservation of fish stocks must still be sought through direct harvest limits, such as annual quotas. Imposing licensing on top of traditional harvest controls could only reduce the potential for fishing fleet over-capitalization. Finally, to be successful, this approach to economic efficiency in commercial fishing would require either strict limits on technological upgrading of fishing vessels and gear, or a license buy-back or vessel retirement plan to cancel the expanding harvest capacity.

In sum, license limitation has three principal drawbacks as an economic regulation for Pacific groundfish. First, it requires substantial supplementary regulation to assure fish stock conservation. Controlling aggregate multi-species fishing capacity does not prevent significant over-fishing of more economically profitable fish stocks. Second, additional controls, besides licenses, must be placed on fishing capacity. License limitation does not eliminate economic incentives for individual fishermen to increase investments in fishing capacity that are superfluous in the aggregate. Finally, licensing programs would tend to restrict license-holders to specific fish stocks or other sub-units of the fishery and may unreasonably restrict the use of more flexible, multi-purpose vessels. On a positive note, license limitation is one attempt to limit the cost of "inputs" to the fishery. There may be sub-units of the fishery (mid-water trawlers, or sablefish traps?) that could be economically regulated by license limitation.

Properly controlled and enforced, individual fisherman quotas could overcome many drawbacks of the license limitation approach. Since quotas would be issued for individual species, the quota system would automatically incorporate biological conservation as well as economic efficiency objectives. Assuming marketability of quota rights, vessel operators can choose to fish a mix of species or operate in the combination of fisheries that most suits them. A vessel owner with quantitative rights in widow rockfish, for example, could sell these rights and move into a nearshore fishery or to an Alaskan fishery. Similarly, fluctuations in the shrimp fishery may cause a flow of vessels between the shrimp and groundfish trawl fisheries. With quantitative rights, this flux can be accommodated by an exchange of individual quotas; no vessel need to eliminated completely from either fishery. In this respect, the individual quota system is much more flexible, while the license system essentially assigns a certain number of vessels to each fishery.

Individual quotas have two major benefits: fishing vessels have greater operational flexibility and there is increased potential for harvesting industry efficiency. Such quotas may, however, be expensive to enforce. Under-reporting and mis-reporting of species will directly affect the quota system's credibility. For this reason, enforcement will have to be on an individual vessel basis, catch sampling will have to be quite refined, and sample timing carefully guarded. If biological yields are defined on sub-areas of the fisheries, the individual quotas will have to follow suit. Whether enforcement becomes a major problem depends largely on whether the system creates conservation-minded fishermen who police themselves.

Enforcement is a problem, but the groundfish fishery would seem more likely candidate for quantitative rights than, say, the salmon fishery, simply because detection of serious transgressions would be easier. Unloading tons of fish from a trawl vessel is difficult to conceal. This, and the relatively small number of locations where unloading occurs, should make enforcement manageable.

The individual quota approach could be introduced on a partial basis. Without causing any serious dislocation in the trawl fleet, individual quotas could be assigned for Pacific Ocean perch, widow rockfish, Pacific whiting or any other species for which there is a firm optimum yield estimate. Reservations on the part of fishermen and managers could be tested in this way without converting the entire management system at once. License limitation, in contrast, tends to be a once-and-for-all, all-inclusive event. By testing the approach on a particular fish stock, preferably one that is fully used and subject to "target" fishing, both managers and fishermen could learn what specific adaptations to make in the system.

CONCLUSION

Groundfish management on the Pacific Coast has evolved a detailed set of administrative procedures and regulations, based substantially upon the preceding state and international regulations, and keyed to the biological conservation needs of the principal commercial fish stocks. The Pacific Fishery Management Council pioneered development of "framework" management plans, incorporating specific rules for modifying the optimum yield, acceptable biological catch levels and harvest regulations both within and between fishing seasons. In this, and in its breadth of coverage, the Pacific Coast groundfish FMP can be judged a substantial, state-of-the-art management document.

There is room for further improvement in two aspects: incorporating multi-species considerations and non-biological objectives in setting levels of optimum yield, and restructuring the fishing rights by limiting access to achieve a greater degree of economic efficiency. Since multi-species fishing, and multi-purpose fishing vessels are common in the Pacific coast fishery, it seems clear that more attention should focus on determining ecological implications of fishing for the stocks that are heavily exploited by the commercial fishery. For example, Pacific whiting may be a major predator of shrimp, juvenile fish or other stocks. This could have a major bearing on optimum yield for whiting fishery. Also, the problem of aggregating several optimum yields from jointly fished species (such as in the *Sebastes* complex) needs further consideration. Simple models of multi-species fisheries suggest that the optimum for the mixed stock should not, as suggested in the FMP, equal the sum of the maximum yields for the individual constituent stocks. These problems of biological optimum yield are on the leading edge of fishery management practice.

While the FMP contains various sections and references to non-biological criteria for optimum yield, close scrutiny of the management regime reveals very little explicit consideration of economic and social fishery objectives. In regard to the non-equilibrium optimum yield policies for Pacific Ocean perch and widow rockfish, this has left the managers with no rigorous foundation for fishing strategies chosen. Application of well-known economic principles to the choice of re-building and stock liquidation strategies could help to bolster the council choices. This would require more systematic information regarding the economic effects of deliberately altering the fish stock size over time--an aspect of management policy currently not well-expressed by the static, biological MSY and ABC guidelines.

Besides improving the substance and appearance of procedures under the existing management system, it would be useful to consider adopting limited access. Based upon a review of the two most likely alternatives, license limitation and individual fisherman quotas, it appears that both would have strengths and weaknesses in the Pacific coast groundfish context. License limitation has generic weaknesses, requiring supplementary restrictions on annual harvests and on technological upgrading of fishing capacity among licensed vessels. Besides improving the substance and appearance of procedures under the existing management system, it would be useful to consider limiting access. Based upon a review of the two most likely alternatives, license limitation and individual fisherman quotas, it appears that both would have strengths and weaknesses in the Pacific coast groundfish context. License limitation has the generic weakness that it leaves unaltered the individual fisherman's economic incentive to compete for shares of the harvest through costly expansion of fishing power. Consequently, annual harvest quotas for the fishery are still needed. Further, to achieve a reasonable degree of cost minimization with a licensing program requires supplementary restrictions on technological upgrading of fishing capacity. Individual fisherman quotas could avoid some of these difficulties. Given a known share of an annual allowable harvest, fisherman are encouraged to seek lower fishing costs in order to improve profits. Still, license limitation is now widely understood and relatively easy to enforce. As a first step in limiting access to the fishery, limiting licenses for groundfish would probably provide some useful control over further increases in fleet overcapitalization.

The logic of individual quotas seems strong, but there is no substantial experience to back it up. Consequently, the drawbacks and weaknesses may not be properly anticipated. Aside from the difficulty in achieving acceptance of a new approach, one problem might be enforcing individual quotas. Whether this and other problems would militate against individual fisherman quotas is not known. Fortunately, the approach could be introduced one step at a time, so that discovering and correcting errors could be part of the system.

In summary, groundfish management on the Pacific coast has come a long way in the past four years. A most ambitious and innovative management plan has been implemented, and the success of biological conservation objectives seems assured. Fine-tuning the optimum yield concepts to incorporate multi-species interactions is a logical next step for the research program. Serious consideration of alternative forms of limited access should begin immediately so that future decisions on this can proceed swiftly and with a reasonable chance of success.

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