SOUTHWEST FISHERIES CENTER

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POTENTIAL ECONOMIC BENEFITS OF LIMITED ACCESS IN THE PACIFIC COAST TRAWL FISHERY: A LINEAR PROGRAMMING APPROACH

by

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1. Introduction

Limiting access to commercial fisheries is frequently proposed as a remedy to the economic inefficiency of competitive harvest in an open access fishery. Properly implemented, limited access will encourage the fishing industry to reduce fishing costs, thus creating a source of surplus economic value. This value can be collected as rent by public agencies, or it can be collected as profits by private industry. As a practical matter, justification of a new limited access regime requires a demonstration that the potential economic surplus is large enough to balance the social and economic adjustment costs likely to occur. In anticipation of the need for such information during future discussions of limited access, our objective is to compute potential economic return and optimum fishing fleet size for the Pacific coast trawl fleet.

Because social and political objectives will weigh heavily in management programs, we do not expect limited access systems to adhere strictly to economic efficiency criteria or to seek to maximize economic value. Political decisions determine whether any economic surplus will be generated. Thus our optimum fleet computation is not intended to describe an actual limited access program. Instead, it represents the optimum solution for a hypothetical centralized owner/manager of the fishery who seeks a maximum profit from the fishery. Our estimate of potential economic surplus is useful as an economic benchmark for program evaluation, and it stands as an estimate of social opportunity cost in the event that limited access is not adopted.

Linear programming (LP) is an efficient procedure for calculating optimum activity levels in a multidimensional linear economic system. Several recent studies apply LP techniques to multispecies fisheries.

Brown, et at (1978), Siegel, et al (1978), and Overholtz (1985) all use linear programming to analyze the New England trawl fishery. In New England and on the Pacific coast several species are caught simultaneously by trawl fishing gear. The New England trawl studies assume that fishing is directed toward target species while "bycatch" of other species is taken in smaller quantities. Brown uses an LP to calculate the maximum quantities of directed fishing quotas consistent with overall catch limits; Overholtz calculates the maximum yield for multispecies assemblages on Brown's bank. Siegel calculates the fishing fleet capacity needed to maximize gross sales value of the catch while meeting eleven total catch quotas.

The Pacific trawl fishery model developed below differs from these earlier studies in two essential respects: (1) economic surplus, not total catch or gross value of catch, is taken as the objective; and (2) groundfish fishing is represented as a fixed proportions multiproduct technology, not as a set of target fishing activities involving bycatch. Due to technological interdependencies groundfish trawling produces a species mix that varies among vessel length classes, areas and seasons. This is pure joint harvesting. Midwater trawling for Pacific whiting, pink shrimp fishing and crab fishing are taken as pure single species operations. These different assumptions on fishing technology are further explained in Section 3. The main consequence of joint production of groundfish is that separate management for individual species is not possible.

The following section describes important features of the Pacific coast groundfish trawl fishery. Section 3 introduces elements of the LP model with particular emphasis on assumptions, sources of data and constraints. The mathematical representation of the model is reviewed briefly. Section 4 discusses the results of linear programming solutions including the analysis of sensitivity, and the final section discusses the usefulness of the analysis for management planning in the Pacific coast trawl fishery.

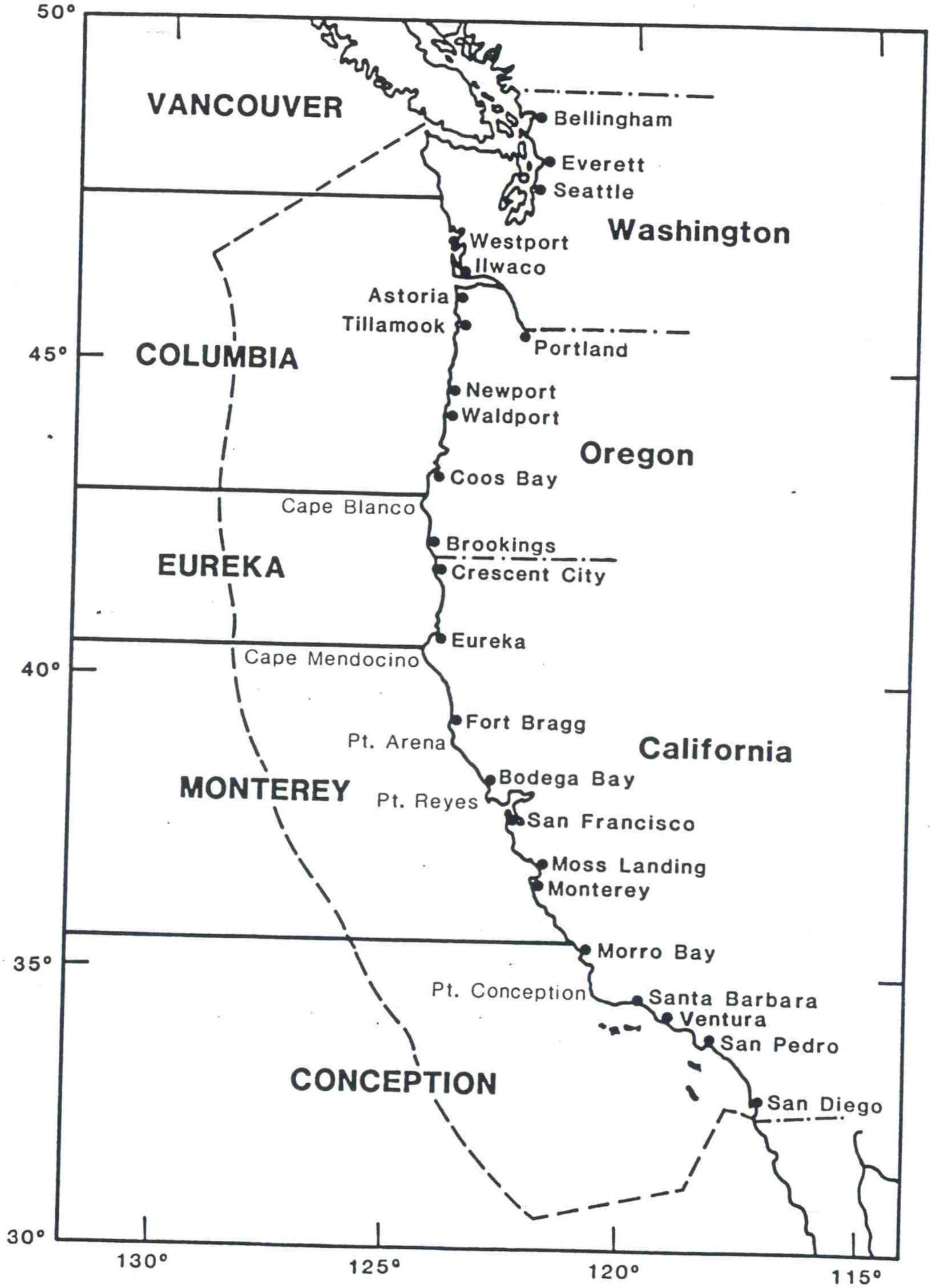
2. The Pacific Coast Trawl Fishery

This section identifies the fish stocks important to the trawl fishery, summarizes the biological information on sustainable annual harvests, describes the trawl fleet's physical and economic characteristics, and demonstrates a simple model for computing economic surplus from the fishery.

Both the fishing fleet and the fish stocks are distributed among three major areas of the Exclusive Economic Zone off the Pacific coast (Figure 1). The northernmost area consists of the International North Pacific Fisheries Commission's (INPFC) Columbia area and a portion of the Vancouver area. This region includes several major coastal fishing ports as well as Bellingham and Blaine, Washington in Puget Sound. So far as possible, the trawl fleet and groundfish harvests taking place strictly in the internal waters of Puget Sound have been deleted from data used in this analysis. The middle area is INPFC's Eureka area, which includes the major southern Oregon and northern California ports. The southernmost area considered is Monterey, which covers central California. We have not included the Conception area because little groundfish trawling occurs there.

2.1 Fish stocks and Groups

For simplicity groundfish species are grouped into the eight categories listed in Table 1. Dover sole, sablefish, widow rockfish, and Pacific whiting are treated as separate species, because they are important individual species and because they are treated separately in management


50°
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VANCOUVER
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EUREKA
MONTEREY
CONCEPTION
Washington
Oregon
California
Bellingham
Everett
Seattle
Westport
Ilwaco
Astoria
Tillamook
Portland
Newport
Waldport
Coos Bay
Cape Blanco
Brookings
Crescent City
Eureka
Cape Mendocino
Fort Bragg
Pt. Arena
Bodega Bay
Pt. Reyes
San Francisco
Moss Landing
Monterey
Morro Bay
Pt. Conception
Santa Barbara
Ventura
San Pedro
San Diego

regulations. The "other flatfish" group includes English and petrale sole, flounders and sand dabs; "other rockfish" includes the Sebastes complex (canary, yellowtail, bocaccio, chilipepper, and others) and Pacific ocean perch. Pacific cod and ling cod form a separate group, because they are quite different from the flatfish and rockfish species. Miscellaneous groundfish species include various sharks, skates, rays, grenadiers, arrowtooth flounder, and others.

Total allowable catches for each species and species group listed in Table 1 are adapted from Pacific Fishery Management Council (PFMC,1985) as adjusted to reflect assumed allocation of harvest to non-trawl gear. Harvest is allocated to trawls based upon the 1981-84 average proportion in each area for each species group. Division of the allowable catches into the three areas also follows the PFMC recommendations. Where the PFMC does not divide allowable catch into INPFC areas, our geographic division is based upon the distribution of catch among areas during the 1981-84 period. See Appendix 3 for details.

2.2 Trawl Fleet Characteristics

Pacific coast trawlers come in a wide range of sizes and vintages. The following five length classes incorporate almost all of the active vessels.

Length Class	Coast Guard Reg. Length	Length Overall	NUMBER OF VESSELS IN 1984 - Ground-fish Only	Shrimp Only	Mixed Catch	Total
1	40 - 49 ft.	43 - 53 ft.	86	6	14	106
2	50 - 59 ft.	54 - 64 ft.	102	10	6	118
3	60 - 69 ft.	65 - 74 ft.	92	33	13	138
4	70 - 79 ft.	75 - 85 ft.	42	11	2	55
5	80 - 95 ft.	86 - 102 ft.	11	1	0	12

Vessels in the two smaller classes are generally older, are often wooden-hulled, and make inshore trips of limited duration. Because they are less seaworthy in rough weather the smaller vessels typically spend less time at sea during the winter. Intermediate-sized and large vessels are generally newer, steel-hulled vessels having greater cruising speed and range. They can more easily make trips of longer duration, are less hampered by rough weather, and can participate in a greater variety of fisheries (including Pacific whiting joint ventures).

As noted above many trawl vessels participate in the pink shrimp fishery. Shrimp fishing is seasonally concentrated in the spring-fall season, and it exhibits marked annual variation due to fluctuations in the pink shrimp populations. Shrimpers use special trawl nets with a minimum of 1-1/2 inch mesh. Because only small incidental amounts of groundfish can be landed legally with shrimp nets, shrimp fishing is distinct from groundfish fishing.

Some of the smaller vessels replace their trawl nets with crab pots to participate in the Dungeness crab fishery during the late fall and winter. The amount of crab fishing by trawl vessels is fairly insignificant and varies widely with crab population abundance. Because these alternate fisheries are important to the economic operation of trawl vessels, they are included in the analytical model along with groundfish trawling. Consequently, the optimum fleet size computed by the LP model represents a groundfish/shrimp/crab trawl fleet.

Six different production processes or fishing modes may be identified for the fleet based upon the above discussion: (1) multispecies groundfish trawling in the Vancouver-Columbia area, (2) multispecies groundfish trawling in the Eureka area, (3) multispecies groundfish trawling in the Monterey area, (4) single-species pink shrimp trawling, (5) single-species

Dungeness crab pot fishing, and (6) single-species joint venture fishing for Pacific whiting. The Pacific coast trawl fishery is thus a multiproduct industry with six separate harvesting processes.

3. Elements of the Linear Programming Model

To implement an LP we need to specify (1) appropriate decision variables, (2) a linear objective function, and (3) an appropriate set of linear constraints. Following a general discussion of the applicability of linear programming to the groundfish fishery, each of these three steps is explained in detail below.

A linear programming approach to optimum fishing disregards several potentially important nonlinearities in the economic and biological relationships. The underlying bioeconomic model is one of static equilibrium. Thus fish prices do not respond to changes in annual harvests; inputs prices do not vary with total use; fish stock densities and harvest rates do not depend upon the level of harvest; and fishing technology is unchanging. These conditions are inconsistent with standard market demand curves, input supply curves, and population dynamics models. The appropriate scope of the LP approach is therefore quite limited. The results are strictly applicable only if the fishery is very small relative to both aggregate product demand and input supply, and if the range of total harvests analyzed is too small to significantly alter fish stock abundances. The Pacific coast trawl fishery probably comes close to satisfying the economic smallness criteria, but the annual harvests certainly affect fish abundance. Thus the results are only approximate, with the degree of error increasing as the solution deviates from the baseline conditions observed in the early 1980's. In the authors' view, serious error is unlikely to arise from the assumption of constant prices and technology. Solutions to the LP which fail to meet many of the biological constraints on harvests, however, undoubtedly understate the potential economic surplus available from the fishery because they do not incorporate the increasing catch rates normally associated with fish stock growth.

Solutions of LP's tend to be sensitive to small changes in assumptions. A computed optimum fleet size, for example, may vary greatly with rather small numerical differences in assumed costs and catch rates. This characteristic of LP modelling leads practitioners (e.g. Bradley et al) to consider sensitivity analysis to be one of the most important LP capabilities, a feature that contributes significantly to its usefulness as a tool to support managerial decision. Analysis of sensitivity to assumed fishing costs, catch rates and available yield allows the optimum fleet and economic surplus estimates to be expressed as a range, rather than as a hard and fast set of numbers.

Another characteristic of LP analysis is that it ignores the historical pattern of operations in the fishery. In the words of J.G. Shepherd and D.J. Garrod (1980) the LP method "happily makes large changes in the pattern of allocation in pursuit of small advantages." Since changes from the status quo may be costly, these small advantages may be insufficient to justify adopting associated management policies that disrupt the fishing fleets. Our analysis addresses this issue by examining additional constraints that require the computed optimum fleet to be similar to the existing fleet. Both total fleet size and vessel size distribution within the fleet are examined in this way.

3.1 Decision Variables

The decision variables in our groundfish trawl fishery LP are (1) the number of vessels in each of five size classes and (2) the number of weeks fished by each vessel size class allocated to each fishing mode in each season. These variables are denoted:

N_k = Number of vessels in size class k,

W_{jks} = Number of weeks fished in mode j in season s byall vessels in size class k.

Since there are five vessel size classes, six fishing modes, and four seasons, there are 120 W_{jks}'s to be computed. Adding the numbers of vessels, yields a total of 125 decision variables in the full LP. In order to assure that only whole number of vessels are assigned, a special form of LP, mixed-integer programming, is utilized.

3.2 Objective Function

The objective selected for the model is to maximize economic surplus generated by the fleet:

$$(1) \qquad Z = \sum_{kjs}\sum\sum \left(\sum_i P_{ij} A_{ijks} - C_k \right) W_{jks} - \sum_k N_k F_k$$

where Z = net profit or economic surplus,

P_{ij} = ex-vessel price of species i in mode j,

A_{ijks} = tons of species i in mode j harvested per week by a vessel of class k in season s,

C_k = variable costs per week for a vessel insize class k,

F_k = fixed costs per year for a vessel in size class k.

Economic surplus computed by this formula is analogous to the trawl fleet earnings calculated in section 3.6 below.

3.3 Constraints

Two kinds of constraints are imposed: (1) those representing limits of biological productivity, and (2) those representing limits on fishing activity of trawlers. The first set of constraints imposes the total allowable catch for each species:

(2) $$\sum_{k}\sum_{s} A_{ijks} W_{jks} < Q_{ij} \qquad \text{for all } i \text{ and } j;$$

where Q_{ij} is the annual allowable catch for species i in mode j. For Pacific whiting, pink shrimp, and Dungeness crab the allowable catch is not sub-divided into geographic areas. Numerical values for the Q_{ij} are taken from the allowable catches in Table 1.

The second set of constraints requires that the total weeks fished by all vessels in a particular size class during a season be consistent with assumed limits on weeks fished per vessel and number of vessels in the fleet. For each size class and season there is one constraint as follows:

(3) $$\sum_{s} W_{jks} - N_k W^*_{ks} < 0 \qquad \text{for all } j \text{ and } k;$$

where w^*_{ks} is the maximum number of weeks a single vessel in size class k can fish during season s. These maximum weeks are taken from Table 2.

The optimum economic surplus and allocation of fishing weeks can be computed assuming proportionate reductions in the number of vessels in each size class. A sequence of LP solutions with this additional restriction should provide insight into the effects of a fleet reduction program that maintains the original size composition in the fleet. This restriction imposes a particular size composition on the fleet through equality constraints for the number of vessels in each size class. With this set of equality constraints the numbers of vessels are predetermined, leaving only the 120 W_{jks}'s as decision variables.

3.4 Implications of the Linear Harvest Technology

The technical coefficients, A_{ijk} , in the catch constraints reflect the assumed joint production technology for multispecies groundfish fishing. This assumption is fairly strong and possibly unrealistic. It differs markedly from the targeting technology assumed in other studies of multispecies trawl fisheries, such as Brown (1978) and Overholtz (1985). Trawl vessel operators undoubtedly do target upon various species by choice of timing, depth, towing speed and gear configuration. Hence, in actuality the species mix in groundfish trawling is chosen by the fishing captain. Also, the eight-dimensional vector of catch rates we take as a fixed technology is actually an average of many different species mixes that were experienced during base period, 1981 and 1982.[1]

Although species targeting in Pacific coast trawling has been the subject of some special studies[2], information is not available to support a satisfactory analysis of target fishing in the coastwide fishery that we are addressing. Our results are especially dependent, therefore, on the assumption of constant patterns of target fishing. Whether or not the model results need substantial qualification due to this simplifying assumption depends upon (1) whether we want to evaluate management changes that would directly alter the pattern of species targeting, and/or (2) whether without direct control on target fishing the management regime would indirectly entice fishermen to alter their pattern of fishing. Since there is currently no means of monitoring the amount of target fishing, it is reasonable to assume that management controls on target fishing or the quantities of catch by target category need not be considered. Even so, induced changes in fishing patterns might cause substantial deviations in fishing patterns from those observed durng the 1981-82 base period.

The observed mix of species taken by trawlers represents a complex economic decision reached jointly by fishermen and processors. Due to altered profit opportunities, the optimal species mix would change following any shift in relative fish prices, fishing costs, market demands, fish abundance or availability, and fishing regulations. With constant economic conditions the fishing fleet would not rationally make any systematic change in fishing patterns. However, it is not reasonable to believe that conditions will remain literally constant over long periods of time. In particular, we anticipate that implementation of a limited access system would cause some systematic changes in fish stocks and relative profitabilities of different vessel sizes.

Even though we lack forecasts of future conditions, economic logic tells us something about the probable effects of change conditions. With unchanged trawl fishing technology, the initial pattern of fishing would remain feasible. We would expect the pattern of species targeting by the fleet to deviate from the initial pattern only if it improves profits of fishermen or processors. Increased fish abundance or reduced excess fishing capacity under limited access, for example, might make it profitable to shift to a different mix of species targeting. The important point, however, is that voluntary changes in targeting would raise profits from the level attained with the initial pattern of targeting. The actual economic surplus achievable under limited access, therefore, would be at least as large as that calculated under the assumption that fishing patterns remained fixed. Thus we conclude that our model will not overestimate, and probably will underestimate the actual economic surplus available under limited access.

3.5. Information Sources and Parameter Values

It is clear from the LP model description that we need numerical values for fish prices, fixed and variable fishing costs, maximum fishing weeks, harvest rates, and aggregate catch constraints. This section briefly describes the available information and the numerical procedures used to establish these values.

Average prices for groundfish species are taken from the PACFIN management data base maintained at the Northwest and Alaska Fisheries Center in Seattle. Pink shrimp and Dungeness crab prices are derived from Korson (1985a) and Korson (1985b). These are all exvessel prices per short ton. As with other dollar-denominated quantities in the LP program, the prices are for 1984.

The cost of building, maintaining and operating trawl vessels have been reckoned through direct examination of financial statements for trawlers and secondary information from various sources. For each vessel size class the costs are divided into variable and fixed costs. Variable costs include the costs of fuel, oil, provisions, gear, crew and captain's share, payroll expenses, maintenance and repairs, ice, salt, bait, and miscellaneous. Fixed costs include capital costs (depreciation and opportunity cost of capital), hull and liability insurance, and taxes other than income taxes. Variable costs, expressed as the average per week of fishing, are assumed to remain constant across fishing seasons. Fixed costs are expressed as a fixed amount per vessel per year. As described in Appendix 2, cost estimates are derived from 1980-1983 data. To be consistent with recent 1984 fish prices the costs are adjusted to 1984-equivalent dollars using the GNP implicit price deflator (Table 4).

Weeks fished by trawl vessels were computed from the Pacific Fishery Information Network (PACFIN) research data base maintained at the Southwest

Fisheries Center in La Jolla, California. Each "week" of fishing represents one calendar week in which at least one commercial landing was recorded. Each week is assigned to groundfish, shrimp or crab fishing based upon which category accounts for the greater value of landings during the week. Appendix 1 provides additional information on computation of weeks fished. The assumed maximum number of weeks that vessels can fish is derived from 1981-82 PACFIN, and from personal communications with joint venture fishing companies.

The PACFIN Research data base was also used to compute harvests per week fished for each vessel size class and season in the three multispecies groundfish trawl modes, the pink shrimp trawl mode, and the Dungeness crab pot fishing mode. To reduce the influence of a single year, the data were averaged for 1981 and 1982. Details of these computations as well as tables showing harvest rates are presented in Appendix 1. Similar harvest rates were calculated for the sixth mode, joint venture fishing for Pacific whiting, based upon information from private companies and financial reports.

The overall harvest constraints were derived by two separate methods. For the eight groundfish species groups the harvest constraints represent average annual sustainable yields as determined by the Pacific Fishery Management Council's groundfish management team. Most of the constraints are equivalent to the Acceptable Biological Catches (ABC's) established for 1985. Because we have no estimates of sustainable yield for pink shrimp and Dungeness crab, recent harvest levels are adopted as constraints. The pink shrimp harvest constraint represents the average total catch for 1981-82, which is close to the the recent 12-year average pink shrimp harvest. Average annual trawl fleet catch in 1981-82 was also used to establish the

Dungeness crab harvest constraint. See Appendix 3 for details on the harvest constraints.

3.6 Estimated Base Level Earnings for Trawl Fleet

The total economic surplus generated by the trawl fishery is defined as the harvest value minus the fishing costs. Sometimes called the net economic value or economic rent, this measure of value is exactly equivalent to the objective adopted for the LP (Equation 1). To establish a baseline against which to judge potential improvements, we calculated the value of the economic surplus under the following conditions:

(1) Harvests of each species in each area by each size class of vessel are computed by multiplying the 1982 trawler "weeks fished" times the 1981-82 average weekly harvest rates.

(2) Exvessel prices in 1984 (Table 3) are used to determine gross exvessel value of harvests.

(3) Baseline variable cost equals the number of weeks fished in 1982 in each vessel size class times estimated weekly operating cost in 1984 dollars for that size class.

(4) Annual fixed cost is equal to the sum across vessel size classes of the number of vessels times estimated fixed cost in 1984 dollars.

This is simply an application of Equation (1) using weeks fished in 1982, trawl fleet size in 1984 and the cost, price and harvest rate parameters adopted for the LP. The resulting estimate of economic surplus is $ -10.25 million. This large negative value reflects a fishing fleet that was significantly overbuilt during the 1977 through 1982 period. Allowable rockfish harvests fell sharply during the latter half of that period due to cropping down of previously unfished populations of widow, yellowtail and canary rockfish. Also, pink shrimp harvests fell from a peak of 42 thousand short tons in 1978 to an average of 17 thousand short tons in 1981-82. This baseline economic surplus should be far less than that possible under the optimum conditions determined by the LP model.

4. Results

To facilitate interpretation of the linear programming results presented in Tables 5 through 12, the 1984 trawl fleet size, estimated profits, weeks fished and so forth for the 1984 baseline fleet are listed in the first column of Table 5. Most of the LP models assume that the 1981-82 average pink shrimp harvest and the 1984 whiting joint venture harvest are catch constraints (Table 5 column 3). Under these assumptions the optimum trawl fleet contains 265 vessels, a 38 percent reduction from the baseline 1984 fleet size. Economic surplus is about $12 million ($22 million greater than the basline) and optimum number of fishing weeks is 9041 (23 percent smaller than under the 1984 baseline). Slightly more than one-third of the profit is due to multispecies groundfish fishing, about one-quarter comes from shrimp fishing, about one-quarter is from joint venture operations, and only one-tenth from crab fishing.

Sensitivity of the results to the size of the joint venture whiting and pink shrimp fisheries is examined in Tables 5 and 6. With no joint venture fishery and an average pink shrimp fishery (Table 5, Col. 4), the optimum trawl fleet would have 238 vessels and would generate $7.6 million in profits annually. Adding a 1984-level joint venture fishery increases the optimum fleet to 265 vessels and the annual profit to $11.96 million. If the joint venture fishery grows to take the entire whiting MSY, the optimum fleet would have 338 vessels earning $17.7 million in profits. This wide variation in optimum results depending upon the JV fishery level indicates that the model is quite sensitive to this assumption. Because the joint venture fishery employs foreign processing vessels, however, the likely size of that fishery depends on both domestic politics and foreign economic policies as well as the standard economic factors addressed in this paper. This makes it difficult to have great confidence in any particular JV assumption. The most realistic assumption may be that the joint venture fishery stays at about the current level, harvesting 87,134 short tons annually.

The sensitivity of the mixed integer programming results to underlying resource conditions is examined in Table 6. Although the assumption that the shrimp harvest equals the 1981-82 average of 17,218 short tons seems reasonable, historical flucuations in the pink shrimp population make it important to assess the sensitivity of the results to variations in the shrimp fishery. Table 6 shows that the optimum trawl fleet is extremely sensitive to plus or minus 50 percent variation in the size of the pink shrimp catch but is little affected by equivalent variations in crab catch. This is not surprising considering the shrimp fishery normally accounts for about 35 percent of the maximum possible profit, while the crab fishery contributes only 14 percent of the profit.

Also documented in Table 6 are the effects of changing two assumptions about which we have less reliable information --the weeks fished constraint and the rockfish catch rates. Increasing the maximum weeks of fishing for every size class by one week per season causes a very slight reduction in optimum fleet size, a slight increase in optimum number of fishing weeks and a $1.56 million increase in profit. We initially assumed with little evidence that rockfish catch rates in 1984 would have fallen from the calculated 1981-82 average catch rates in proportion to the declining fish populations. However, analysis of catch rates for schooling fish populations suggests that catch rates would actually fall less than in proportion to fish abundance. The sensitivity of the LP to rockfish catch rates thus becomes a key concern. As noted in Table 6, a combined increase of 50 percent in widow rockfish and 30 percent in other rockfish catch rate results in $2.5 million in extra profit but only an 8 percent increase in optimal fleet size. We conclude that the optimum fleet size is not particularly sensitive to rockfish harvest rates.

Except where explicitly noted all the linear programming results presented in Tables 7 through 12 were computed assuming a common set of resource constraints and conditions, including the average 1981-82 pink shrimp catch constraint, joint venture whiting constraint at the 1984 catch level, estimated 1984 rockfish (and other species) catch rates and catch constraints as presented in Appendix 1 and Table 1.

Sensitivity of the linear program to fishing cost parameters is examined in Table 7. The optimum fleet configuration and optimum number of weeks fished are little affected by plus and minus 10 percent changes in fixed costs. A plus and minus 30 percent variation, however, causes a 45 percent reduction and 21 percent increase in optimum fleet size respectively. The asymmetric response to variation in fixed cost is due to binding constraints on allowable catches. Decreased costs are associated with small increases in fleet size because the allowable catches in the more profitable modes and seasons are already fully taken. A 30 percent increase in fixed costs, however, makes it unprofitable to utilize some season/area/mode combinations previously profitable. Decreased fixed costs cause a moderate increase in the optimal number of Class 1 vessels.

The optimum fleet contains none of the baseline fleet's Class 1, Class 3 or Class 5 vessels. That the largest and the smallest size categories are uneconomic is consistent with informal observations and testimony concerning the fishing fleet. More surprising perhaps is the lack of mid-sized, 60-69 ft. trawlers in the optimum fleet. Evidently, the increased harvest rates of Class 3 over Class 2 trawlers are insufficient to justify the proportionally greater increase in fishing costs. Obviously, a shift from the baseline fleet to the optimum fleet would require a radical change in fishing fleet composition.

The degree to which the catch constraints are utilized is indicated in Table 8. Four cases are presented: the optimal trawl fleet with three different levels of JV fishery, and the baseline fleet with an optimal allocation of weeks fished. In all cases shown the widow rockfish, other rockfish, shrimp, and crab resource constraints are nearly or completely taken. Joint venture whiting harvests always equal the constraint assumed. The 1984 fleet, but none of the optimum fleets, harvests all of the available sablefish. Because it has a larger number of vessels and greater number of weeks fished, the 1984 fleet harvests more of almost every species than does the optimum fleet.

For those resources that are fully utilized, the LP computes "shadow prices" representing the marginal contribution of additional harvestable quantities to the economic surplus. An additional ton of widow rockfish sustainable yield, for example, would add $218 to the annual economic profit of the fishery in the Vancouver/Columbia area, nothing to the Eureka area fishery, and $533 to the Monterey area fishery. (Table 9). If the harvest constraints could be expanded through enhancement activities, these shadow prices would represent the commercial economic benefit of enhancement. Since enhancement of groundfish species is generally considered infeasible, the shadow price has a different implication. The species with high shadow prices will be the most intensely sought, and they would command the highest prices under a transferable IFQ's system. Under aggregate quota fishing regulations the highest priced species might require the closest enforcement effort.

The distribution of weeks fished by fishing mode and vessel size class for the optimum fleet is shown in Table 10. As compared to the baseline fleet, the overall level of fishing weeks decreases by about 23%. Obviously, all of the fishing is done by the second and fourth vessel size classes: 63% in the second size class and 37% in the fourth size class. The most important change in the distribution of fishing weeks by mode occurs for pink shrimp fishing, groundfish trawling in the Eureka area, and joint venture fishing for whiting. The proportion of fishing weeks allocated to pink shrimp fishing increases from 22% in the baseline fleet to 38% in the optimum fishery. In contrast the proportion of fishing weeks allocated to groundfish declines by almost one-third. The proportion of weeks fished for joint venture whiting almost doubles from 7% to 13%.

Because a shift from the base year 1984 fleet to the optimum vessel size distribution could be an exceedingly disruptive change, one could not recommend that fishery managers seek such a shift simply based upon the linear programming model. Examination of less radical changes in the fleet is appropriate. The first attempt (not shown in the Tables) was to calculate an optimum with a fleet equal to the 1984 fleet with the Class 1 and Class 5 vessels deleted. This would represent about the right fleet reduction, but would leave the main part of the fishing fleet untouched. Also, we thought that inclusion of the non-optimal mid-size vessels might entail only a small sacrifice in profit. With this modified 1984 baseline fleet we calculated a maximum aggregate surplus of $570 thousand -- a 93 percent reduction in profit from the overall optimum. Thus it seems that the mid-size vessels are very definitely uneconomic.

Another less disruptive procedure is to progressively reduce the overall number of vessels while preserving the distribution among size classes observed in 1984. This might correspond to a license limitation program which prohibits replacing vessels with different sized vessels. If the program encourages attrition from the fleet, the fleet could shrink in total numbers as illustrated by Table 11. The fleet profit figures in the last row of Table 11 correspond to the maximum possible with optimum allocations of weeks fishing among seasons and modes and the specified trawl fleets. A fleet reduction procedure of this sort can achieve a maximum of only $7.30 million in economic surplus, and it takes a 40 percent reduction to get even this.

The final set of results shown in Table 12 demonstrates the economic importance of maintaining a multipurpose fishing fleet. Columns 1 through 3 of Table 12 show the optimum vessel numbers, total profit, and weeks fished for three hypothetical specialized fishing fleets. These represent the solution to three linear programming models, each of which assumes that its fishing fleet harvests only (1) multispecies groundfish and crab, or (2) pink shrimp, or (3) joint venture whiting (1984 level). As shown each of these three separately optimized fleets could be profitable. But the sum of the three fleets would contain 149 more vessels, would yield $3.78 million less in annual profits, and would fish 1061 weeks more than an optimal multipurpose fleet. This suggests that a limited access program seeking to improve economic efficiency and/or fishing profits should not create divisions in the fleet based upon exclusive licensing for groundfish, shrimp and joint venture whiting fishing.

5. Summary and Discussion

This application of linear programming analysis to the Pacific coast trawl fishery yields approximate magnitudes of the economic surplus and fishing fleet size consistent with economically efficient harvest methods. Since the fixed, linear harvest technology assumed does not consider possible adjustments in species targeting (which would probably occur under optimized harvest control), the estimated maximum profit of roughly $12 million represents a lower bound to the potential economic surplus available from the trawl fishery. To achieve this economic surplus for the trawl fleet would require that other gear types be limited to their historic shares of groundfish harvests.

Additional important conclusions are apparent from the linear programming results. First, maximum economic surplus occurs with a trawl fleet that is roughly 38 percent smaller than the fleet existing in 1984. The exact size of the optimum fleet depends largely upon the size of the pink shrimp and joint venture whiting fisheries, but is also heavily influenced by variable fishing costs. The optimized fleet would consist of 50-59 ft. and 70-79 ft. trawlers. These results are relatively insensitive to variations in fixed costs, weeks available for fishing per year per vessel, crab catch rates, and rockfish catch rates. Furthermore, the optimum trawl fishery would not fully utilize the available sustainable yields of Dover sole, other flatfish, Pacific cod and ling cod, sablefish or miscellaneous species. It would fully or nearly completely utilize the sustainable yields of widow rockfish, other rockfish, pink shrimp and Pacific whiting to the extent permitted by joint venture fishery. Thus an optimally designed fishing fleet would put less fishing pressure on some fish stocks.

An important remaining question is whether the estimated surplus value under a hypothetical centralized manager could be generated under more traditional forms of economic organization. It is already widely understood that competitive fishing with open access property rules leads to zero net economic value (see Rettig and Ginter, 1978). The estimated annual economic loss of $10 million under our baseline conditions is partly a reflection of this open access resource characteristic, but it is also due to the rapid fleet expansion of the late 1970's combined with subsequent declines in pink shrimp and rockfish populations. Thus with no change in fishing regulations, the trawl fleet should experience a period of adjustment during the mid- to late 1980's in which the fleet size would fall and the aggregate fleet earnings would return to a breakeven level. This shrinkage will be very sluggish, however, since the loss of financial capital associated with unprofitable vessel operations does not convert quickly into physical loss of vessels so long as operating costs can be covered by gross revenues. New owners and new financing arrangements should keep most vessels in operation long after the original owner or bank has written off the investment. Based upon the fleet profits associated with successive reductions in a trawl fleet of constant size distribution (Table 11), the fleet might be expected to shrink between 10 and 20 percent.

A license limitation program could call for a freeze on new entry coupled with a requirement that replacement vessels be no larger than the original vessels. As license holders retire, the fleet would shrink below the breakeven level. Licenses would be issued to new operators once the fleet achieves an optimum size. Our experiment with this form of license limitation (Table 11) suggests that an optimum economic fleet would be 40% smaller than the fleet in 1984 and would earn a little over $7 million in profit.

Even these estimated profits may be too optimistic. Economic theory and actual experience in the British Columbia salmon fishery suggest that emerging profits under a license limitation system induce fishermen to dissipate profits through various forms of vessel upgrading. Still, as Anderson (1985) has recently argued, a license-limited fishery may yield greater economic benefits than the open access fishery. The extent to which net economic benefits under license limitation will fall short of the centralized owner/manager's depends upon the shape of the fishing cost functions. If marginal costs of harvest experienced by vessel operators rise rapidly as catch increases, then there will be little incentive for fishermen to dissipate potential profits through excessive competition for catch shares. If marginal costs are constant or only slightly rising, then most of the potential profit will be dissipated. The linear production technology assumed by the linear programmin model makes it impossible to investigate this issue further here.

A transferable Individual Fisherman Quota (IFQ) affords a more innovative means to generate the potential economic surplus from the trawl fleet. Christy (1973), Pearse (1979) and others have shown that a properly operating IFQ system could theoretically mimic the efficiency of a free market system. Decentralized decision-making with private property rights in the fishery would replace the centrally managed free access system. This system would require modifications in fisheries law enforcement and would benefit from enhanced legal standing for private rights in fish stocks. If fishing rights could be defended in court and exhanged by legal contract, rights holder would gain access to the social systems designed to protect and enhance resource production in traditional pursuits like farming and forestry. Such a radical break with traditional fishery systems might entail significant disruptions of both private business operations and government bureaucracies. The potential $12 million in groundfish fishing profits may be too small to justify the social costs of changing the property institutions in fisheries. But the adjustment costs would be transitory, and these costs should be examined before decisions are made on limiting access.

The LP model presented in this report does not provide ultimate answers to the big management issues, but it does provide approximate answers to the narrower issue of potential net economic benefits from limited access. The results regarding optimum fleet size, vessel size distribution, and profits are contingent on a variety of conditions including fish stock sizes and harvest rates, fish prices, and fishing technology. While the generality of the numerical results is limited by the accuracy of the assumptions, the sensitivity analysis provides some basis for confidence that fleet profits could be achieved in the neighborhood of those estimated. Because numerical models of this sort fail to consider biological variability, technological change and important non-linear economic responses to prices and and other variables, they cannot be used to design definitive management systems. Also, it is important to develop systems that are capable of adapting to new knowledge and new conditions. This presents a real challenge requiring additional analysis and policy formulation.

Table 1. Total Allowable Catches for Groundfish Species, and Assumed Catch Constraints for Pink Shrimp and Dungeness Crab.

Species	Vancouver-Columbia	Eureka	Monterey	Total
	- - - - - - - - - - shorts tons - - - - - - - - - -			
Dover sole	15,318	8,816	5,510	29,644
Other flatfish	6,643	2,877	3,319	12,839
Cod & Lingcod	7,801	537	1,098	9,436
Widow rockfish	7,270	1,429	1,549	10,248
Other rockfish	13,563	2,965	9,461	25,989
Sablefish	3,502	1,924	1,776	7,207
Pacific whiting	-	-	-	209,380
Miscellaneous	10,113	1,309	1,591	13,013
Pink Shrimp	-	-	-	17,218
Dungeness crab	-	-	-	2,477

Table 2. Assumed Maximum Number of Weeks Fished per Vessel by Season and Size class

Size Class	Winter	Spring	Summer	Fall	All Year
1	6.25	9.0	9.31	6.0	30.5
2	7.64	9.18	9.73	6.6	33.15
3	9.13	10.0	9.21	9.07	37.41
4	10.0	10.0	9.67	10.0	39.67
5	11.0	11.0	11.0	11.0	44.0

Table 3. Exvessel Prices of Trawl-caught Fish and Shellfish. Price per ton in 1984 dollars. Source: PACFIN Management Data base.

Species	Vancouver -Columbia	Eureka	Monterey	Joint Venture
Dover sole	456.4	483.3	459.5	
Other Flatfish	561.2	553.0	552.0	
Cod & Lingcod	501.3	536.0	515.2	
Widow rockfish	452.0	428.0	452.0	
Other rockfish	497.2	467.0	450.0	
Sablefish	402.8	377.3	335.0	
Whiting	138.0	126.7	182.5	149.4
Pink shrimp	- - - - -	1325.0	- - - - -	
Dungeness crab	- - - - -	2284.6	- - - - -	

Table 4. Average annual Fixed Costs and Weekly Variable Costs for Pacific Trawl Vessels. (1984 dollars)

	Class 1	Class 2	Class 3	Class 4	Class 5
Weekly Variable Cost	$ 2638	3795	5518	5669	13,895
Annual Fixed Cost	45,990	49,639	78,535	83,952	110,550

Table 5. Results of Mixed Integer Programming for the Pacific Trawl Fleet.

	Baseline Fleet In 1984[1]	Optimum Fishery[2] JV Takes Whiting MSY	1984 JV Harvest	With No JV Fishery
Number of Vessels				
Class 1	106	0	0	0
Class 2	118	245	180	180
Class 3	138	0	0	0
Class 4	55	93	85	58
Class 5	12	0	0	0
Total Number	429	338	265	238
Profit($million)	-10.25	17.7	11.96	7.61
Proportion from:[3]				
Shrimp fishing	.324	.180	.267	.362
Crab fishing	.038	.081	.109	.143
JV fishing	.306	.475	.263	.000
Groundfish	.332	.264	.360	.495
Total Weeks	11,763	11,034	9,041	8,054
Proportion in:				
Shrimp fishing	.218	.320	.380	.440
Crab fishing	.044	.042	.050	.060
JV fishing	.074	.280	.130	.000
Groundfish	.664	.358	.440	.500

[1] The 1984 Baseline fleet does not represent an optimum distribution of fishing weeks. The number and size distribution of vessels represents the 1984 fleet while the distribution of weeks fished is taken from the 1982 PACFIN research data base. All prices and costs used in calculating profits are in 1984 dollars.

[2] Various Joint Venture harvest constraints all assume pink shrimp harvest constraint equals average 1981-82 catch.(17,218 short tons).

[3] This is the proportion of operating profit (or net revenue), not economic profit. Fixed costs of vessels are not allocated among fisheries in calculating this proportion.

Table 6. Sensitivy analysis: LP Results with Variations in Shrimp and Crab Catches, Weeks Available for Fishing and Rockfish Catch Rates. Assumes 1984 JV Fishery.

	Shrimp Catch[1] +50%	Shrimp Catch[1] -50%	Crab Catch[2] + 50%	Crab Catch[2] - 50%	Increase Weeks[3]	Increase Rockfish[4]
Number of Vessels						
Class 1	0	0	0	0	41	0
Class 2	231	178	179	180	160	229
Class 3	0	0	0	0	0	0
Class 4	93	55	89	81	73	56
Class 5	0	0	0	0	0	0
Total Fleet	324	233	268	261	274	285
Profit($ mil.)	12.26	11.42	13.46	10.47	13.52	14.49
Proportions						
Shrimp fishing	.358	.146	.264	.270	.260	.268
Crab fishing	.097	.123	.154	.059	.104	.100
JV fishing	.232	.305	.247	.283	.250	.244
Groundfish	.313	.427	.336	.389	.386	.388
Total Weeks	10,774	7,807	9,188	8,891	10,102	8,475
Proportions						
Shrimp fishing	.495	.223	.370	.390	.355	.416
Crab fishing	.043	.059	.075	.026	.045	.054
JV fishing	.102	.180	.123	.135	.113	.146
Groundfish fishing	.360	.538	.432	.449	.487	.384

1 Shrimp catch constraint varied from 25827 to 8609 short tons.
2 Crab catch constraint varied from 3715 to 1239 short tons.
3 Number of weeks a vessel can fish is increased by one week per quarter.
4 Widow rockfish catch rate increased by 50% and Other rockfish catch rate increased by 30 percent.

Table 7. Sensitivity Analysis: LP Results for Various Levels of Annual Fixed Costs and Weekly Variable Costs. Assumes 1984 JV Fishery and 1981-82 Average Pink Shrimp Catch.

	Variations in Fixed Costs				Variable Costs	
	-10%	-30%	+10%	+30%	+20%	-20%
Number of Vessels						
Class 1	44	59	0	0	0	49
Class 2	177	178	144	79	10	174
Class 3	0	0	0	0	0	0
Class 4	81	83	96	66	95	79
Class 5	0	0	0	0	0	0
Total Number	302	320	240	145	105	302
Profit ($million)	13.58	17.24	10.39	7.77	5.84	20.36
Proportion from:						
Shrimp fishing	.261	.268	.277	.158	.216	.254
Crab fishing	.104	.101	.113	.152	.167	.104
JV fishing	.250	.243	.270	.369	.400	.251
Groundfish	.385	.387	.340	.319	.217	.391
Total Weeks	10,028	9,969	8,573	5,237	3,615	10,158
Proportion in:						
Shrimp fishing	.355	.362	.386	.160	.263	.353
Crab fishing	.046	.046	.054	.088	.127	.045
JV fishing	.114	.113	.129	.229	.301	.113
Groundfish	.485	.479	.431	.523	.309	.489

Table 8. Percent of Harvest Constraints Utilized by Optimum Fleet Assuming Pink Shrimp Harvest Constraint Equals 1981-82 Average Catch and Various Levels of JV Whiting Harvest.

Species-Area	Optimum Fleet with Whiting JV Harvest Equal to:			1984 Trawl Fleet with Optimized Fishing Weeks
	MSY	1984 Level	Zero	
Dover Sole:				
Vancouver/Columbia	44	44	44	63
Eureka	17	20	29	52
Monterey	87	87	84	72
Other Flatfish				
Vancouver/Columbia	86	87	87	100
Eureka	12	11	7	16
Monterey	36	36	35	46
Cod & Lingcod				
Vancouver/Columbia	15	15	15	22
Eureka	8	18	54	59
Monterey	23	23	21	62
Widow Rockfish				
Vancouver/Columbia	100	100	100	100
Eureka	42	49	73	66
Monterey	100	100	100	100
Other Rockfish				
Vancouver/Columbia	100	100	100	89
Eureka	100	100	100	100
Monterey	38	38	36	56
Sablefish				
Vancouver/Columbia	63	63	63	99
Eureka	32	42	77	100
Monterey	99	100	92	100
Pacific Whiting	100	100	N/A	5
Miscellaneous				
Vancouver/Columbia	1	1	8	3
Eureka	3	8	25	25
Monterey	6	6	6	7
Pink Shrimp	100	100	100	100
Dungeness Crab	100	100	100	100

Table 9. Shadow Prices of Resource Constraints for Optimal Fleet, Assuming 1984 JV Whiting Catch and 1981-82 Average Pink Shrimp Catch.

Species	Vancouver -Columbia	Eureka	Monterey	Joint Venture
Dover Sole	0	0	0	
Other Flatfish	0	0	0	
Cod & Lingcod	0	0	0	
Widow Rockfish	218.45	0	533.32	
Other Rockfish	83.29	86.57	0	
Sablefish	0	0	169.87	
Whiting	0	0	50.89	0
Miscellaneous	0	0	0	
Pink Shrimp	---------- 89.87 ----------			
Dungeness Crab	---------- 1232.79 ----------			

Note: Shadow prices are from linear programming model with the fleet size and vessel distribution set equal to that of the optimum fleet.

Table 10. Optimum Weeks Fished by Area and Vessel Size Class for the Optimum Trawl Fleet with 1984 JV Whiting Catch and 1981-82 Average Pink Shrimp Catch.

Area	Vessel Length Class (Coast Guard Length in feet) 0-49	50-59	60-69	70-79	80-	Total
Van-Col	0	1757	0	580	0	2337 (26%)
Eureka	0	0	0	381	0	381 (4%)
Monterey	0	1263	0	0	0	1263 (14%)
Joint Venture	0	456	0	710	0	1166 (31%)
Shrimp	0	2207	0	1227	0	3434 (38%)
Crab	0	0	0	460	0	460 (5%)
Total	0	5683	0	3358	0	9041
Col. percent	0%	63%	0%	37%	0%	

Table 11. Fleet Profits with 10 to 90 percent reductions in vessel numbers, Assuming 1984 Size Distribution of Vessels, 1984 Level of JV Whiting Catch, and 1981-82 Average Pink Shrimp Catch.

Trawl Fleet	Class 1	Class 2	Class 3	Class 4	Class 5	Total	Fleet Profit
	- - - - - - Number of Vessels					- - - - - - -	$ million's
1984 Base	106	118	138	55	12	429	3.60
-10%	95	106	124	49	11	385	5.52
-20%	85	94	110	44	10	343	6.49
-30%	74	83	97	39	8	301	7.11
-40%	64	71	83	33	7	258	7.30
-50%	53	59	69	28	6	215	7.20
-60%	42	47	55	22	5	171	6.87
-70%	32	35	41	17	4	129	6.49
-80%	21	24	28	11	2	86	5.79
-90%	11	12	14	6	1	44	2.99

[1] Baseline is 1984 trawl fleet with an optimal allocation of fishing weeks across seasons, areas and fishing modes.

Table 12. Comparison of Specialized and Multipurpose Optimum Trawl Fleets Assuming 1984 JV Harvest and 1981-82 Average Pink Shrimp Harvest.

	Groundfish/ Crab Only Fleet	Shrimp Only Fleet	JV Whiting Only Fleet	Total for Three Fleets	Change from Multipurpose Fleet
Number of Vessels					
Class 1	61	0	0	61	+61
Class 2	36	154	77	267	+87
Class 3	0	0	0	0	0
Class 4	42	0	0	42	-43
Class 5	0	0	0	0	0
Total Number	139	154	77	370	+105
Profit ($million)	4.12	.217	3.85	8.18	-3.78
Weeks Fished	4,724	3,929	1,449	10,102	+1061

FOOTNOTES

[1] Denoting A_i as the average catch per week for species i in a given area and season, and A_{ij} as the catch rate for species i when targeting species j, the relationship between the two is

$$A_i = \sum_j (w_j/w)A_{ij}.$$

where w is the number of weeks fished overall and w_j is the number of fishing weeks targeted on species j. The ratio of target weeks to total weeks acts as a weighting factor, making the left hand side of the equation a weighted average of eight catch rates during target fishing.

[2] S. Hanna, Descriptive analysis of Oregon groundfish logbook and fish ticket data, 1976-1981. Unpub. report for the Northwest and Alaska Fisheries Center, Seattle.

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APPENDIX 1 - Catch Rates and Weeks Fished by Trawl Fleet

This appendix describes the harvest data available and the computations required to estimate catch rate for the linear programming model. Estimates of multispecies catch rates and numbers of weeks fished are required for the analysis. These are derived from the PACFIN Research data base for 1981 and 1982. Days at sea for joint venture vessel are derived from informal communications with joint venture companies, and from annual revenues reported in the trawler cost and earning data base described in Appendix 2.

Because the PACFIN data base documentation is available in Huppert, Thomson and Iacometti (1984) and Huppert and Thomson (1985), only a brief description of the source data is needed here. Data summaries for each Pacific coast trawl vessel are constructed from State-supplied fish ticket and vessel characteristics files. Each fish ticket represents a single, shoreside landing for a given vessel. These records are aggregated into weekly data records for trawl vessels. Each record contains the following information: (1) year and week number, (2) vessel ID code, (3) Coast Guard registered length and gross registered tons for the vessel, (4) port code, (5) gear code, (6) total tons landed and total exvessel value of landings for the week, (7) weekly tons and exvessel value for ten species groups - salmon, Dover sole, other flatfish, rockfish, cod and lingcod, sablefish, Pacific whiting, shrimp, crab and miscellaneous.

All vessels reported using any trawl gear (bottom trawl, roller trawl, midwater trawl, or shrimp trawl) are included in the full weekly data file. Each record is then assigned to one of four fishing modes: (a) multispecies groundfish fishing, (b) shrimp fishing, (c) crab fishing, or (d) other. These assignments are based upon whether more than fifty percent of the exvessel revenue for the week comes from groundfish, shrimp, crab or other species. Vessels that fish solely in Puget Sound or that do not land groundfish are excluded from averaged data reported below. Number of weeks fished in each category, tabulated by INPFC area, season and trawl vessel size class for 1982 are displayed in Tables A1.10 - A1.11.

Weekly catch rates were computed for each of the three main fishing modes. To focus on the active groundfish trawl fleet, multispecies catch rates were calculated only for vessels showing at least 20 weeks of groundfish fishing. Because rockfish catches were not routinely broken down into primary categories in 1981-82, additional manipulations were necessary to develop widow rockfish catch rates. Total rockfish landings were divided into widow rockfish and "other" rockfish based upon the proportion of widow rockfish reported in each area and season by the PACFIN management data base. Representative harvest rates for the early 1980's were calculated by averaging the weekly catch rates for 1981 and 1982. These average weekly landings of groundfish species by season, area and vessel size class are presented in Tables A1.1 - A1.8. Average weekly landings for crab and shrimp by vessel size class and season are displayed in Table A1.9.

Number of joint venture fishing weeks was computed by dividing total days at sea for joint venture operations by seven. Because the joint venture logbooks have not been processed, the actual Pacific whiting catch by JV trawlers was not available. Joint venture vessels' catch rates are indirectly computed. The difference in total revenue between the financial statements and PACFIN research file for each year for JV vessels is assumed to represent revenue earned entirely from JV operations. The JV revenue is next divided by the JV price per ton to provide implicit tons caught per year for each vessel size class for which data are available. This tonnage is divided by the corresponding size classes' weeks fished (converted from days absent measures supplied by MRC). This annual measure of tons harvested per week is evenly apportioned between the Spring and Summer quarters. The Fall and Winter quarters display zero JV catch rates in the PACFIN management data file, and consequently, the corresponding technical coefficients are set equal to zero.

Table A1.1 Dover sole trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - short tons			- - - - - - - - - - - -	
Vancouver-Col.					
- Winter	1.99	1.84	2.60	2.93	0.01
- Spring	2.69	2.08	2.88	2.65	0.00
- Summer	3.95	2.90	2.05	0.98	0.40
- Fall	2.67	2.56	1.67	1.32	1.03
Eureka					
- Winter	1.90	2.69	2.61	4.25	0.00
- Spring	3.97	5.55	3.42	8.18	0.00
- Summer	5.29	4.98	3.25	5.54	0.00
- Fall	2.13	4.04	2.51	3.99	0.00
Monterey					
- Winter	1.50	3.83	2.86	3.47	0.00
- Spring	2.19	4.48	3.27	1.92	0.17
- Summer	1.44	3.24	1.88	1.29	0.01
- Fall	1.37	3.97	2.27	0.79	0.00

Table A1.2 Other flatfish trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - - short tons			- - - - - - - - - -	
Vancouver-Col.					
- Winter	1.47	1.74	1.24	0.57	0.01
- Spring	2.49	2.54	1.33	0.42	0.00
- Summer	1.43	3.09	1.45	0.46	0.31
- Fall	1.60	1.77	1.15	0.48	0.57
Eureka					
- Winter	1.60	1.02	0.65	1.01	0.00
- Spring	1.37	1.10	0.42	0.36	0.00
- Summer	1.10	0.85	0.29	0.42	0.00
- Fall	0.41	0.93	0.39	0.51	0.00
Monterey					
- Winter	0.95	0.94	1.03	1.50	0.63
- Spring	0.85	0.61	0.88	1.15	0.38
- Summer	1.44	0.96	1.37	1.99	0.61
- Fall	0.84	1.04	1.28	2.17	0.61

Table A1.3 Cod and ling cod trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - -	short tons	- - - - - - - - -		
Vancouver-Col.					
- Winter	0.23	0.34	0.17	0.19	0.09
- Spring	0.57	0.61	0.60	0.42	0.03
- Summer	0.72	0.62	0.68	0.55	0.24
- Fall	0.29	0.59	0.43	0.23	0.53
Eureka					
- Winter	0.11	0.03	0.15	0.11	0.04
- Spring	0.20	0.18	0.59	0.26	0.08
- Summer	0.41	0.32	0.85	0.62	0.02
- Fall	0.13	0.11	0.27	0.33	0.00
Monterey					
- Winter	0.10	0.19	0.18	0.17	0.36
- Spring	0.38	0.46	0.53	1.18	0.79
- Summer	0.55	0.61	0.94	1.68	1.25
- Fall	0.36	0.28	0.29	0.68	0.50

Table A1.4 Widow rockfish trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - -	short tons	- - - - - - - - -		
Vancouver-Col.					
- Winter	0.53	1.11	4.11	7.59	11.82
- Spring	0.84	1.20	2.90	5.70	10.72
- Summer	1.01	1.63	3.58	6.36	7.51
- Fall	0.61	1.62	2.67	5.33	5.80
Eureka					
- Winter	0.19	0.33	1.41	1.69	1.87
- Spring	0.20	0.40	0.61	1.22	3.26
- Summer	0.38	0.50	1.36	2.22	8.34
- Fall	0.22	0.27	0.81	.090	2.02
Monterey					
- Winter	1.03	1.30	2.60	3.13	3.42
- Spring	0.69	0.68	1.20	1.51	1.36
- Summer	1.05	0.92	0.70	1.42	1.41
- Fall	0.79	0.76	1.12	1.30	2.17

Table A1.5 Other rockfish trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - -	short tons	- - - - - - - - -		
Vancouver-Col.					
- Winter	0.68	1.52	4.67	8.62	8.63
- Spring	1.22	1.54	3.35	7.83	16.58
- Summer	1.39	4.88	4.16	7.82	12.76
- Fall	0.81	2.15	3.24	6.52	8.28
Eureka					
- Winter	1.10	1.79	4.01	8.37	5.28
- Spring	0.68	1.22	2.46	4.67	12.41
- Summer	1.10	1.49	4.49	6.35	14.67
- Fall	0.59	0.89	3.13	4.22	3.54
Monterey					
- Winter	2.56	2.78	6.39	6.98	10.54
- Spring	1.73	1.96	3.77	5.47	5.11
- Summer	2.82	3.12	4.43	8.32	10.58
- Fall	3.39	3.44	4.36	5.82	12.17

Table A1.6 Sablefish trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - -	short tons	- - - - - - - - -		
Vancouver-Col.					
- Winter	0.22	0.25	0.61	0.31	0.00
- Spring	1.21	1.38	0.96	0.87	0.15
- Summer	1.57	1.15	1.18	0.88	0.52
- Fall	0.57	0.96	0.52	0.36	0.35
Eureka					
- Winter	0.87	1.12	0.51	1.72	0.00
- Spring	1.80	1.96	1.27	2.10	0.00
- Summer	2.63	2.52	2.32	3.16	0.00
- Fall	0.74	1.32	0.93	1.61	0.00
Monterey					
- Winter	1.68	1.33	1.01	0.89	0.08
- Spring	1.91	1.87	1.71	1.64	1.83
- Summer	2.53	1.99	1.64	1.22	1.06
- Fall	1.15	1.89	2.05	1.81	0.17

Table A1.7 Whiting trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	short tons				
Vancouver-Col.					
- Winter	0.00	0.00	0.00	0.00	0.00
- Spring	0.00	0.00	0.02	0.30	0.00
- Summer	0.00	0.00	0.00	0.48	0.00
- Fall	0.00	0.00	0.00	0.00	0.00
Eureka					
- Winter	0.00	0.00	0.00	0.12	0.00
- Spring	0.00	0.38	0.00	5.14	0.00
- Summer	0.17	0.43	0.00	1.59	5.60
- Fall	0.00	1.00	0.00	1.26	0.00
Monterey					
- Winter	0.00	0.00	0.00	0.00	0.00
- Spring	0.00	0.00	0.03	0.00	0.07
- Summer	0.00	0.00	0.00	0.10	0.01
- Fall	0.00	0.00	0.01	0.01	0.01

Table A1.8 Miscellaneous species trawl catch per week. Ave. for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	short tons				
Vancouver-Col.					
- Winter	0.01	0.02	0.03	0.05	0.00
- Spring	0.31	0.04	0.12	0.12	0.00
- Summer	0.07	0.03	0.08	0.06	0.00
- Fall	0.03	0.04	0.03	0.05	0.01
Eureka					
- Winter	0.10	0.14	0.06	0.08	0.00
- Spring	0.06	0.11	0.03	0.51	0.00
- Summer	0.12	0.13	0.09	0.69	0.00
- Fall	0.02	0.10	0.05	0.19	0.00
Monterey					
- Winter	0.10	0.08	0.06	0.14	0.14
- Spring	0.03	0.10	0.03	0.09	0.15
- Summer	0.04	0.16	0.12	0.15	0.09
- Fall	0.03	0.04	0.05	0.13	0.14

Table A1.9 Shrimp, crab and JV whiting trawl catch per week. Average for 1981-82.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
	- - - - - - - - -	short tons	- - - - - - - - - -		
Pink Shrimp					
(All areas)					
- Winter	1.07	1.00	1.28	3.07	0.00
- Spring	3.41	4.85	6.36	7.41	7.45
- Summer	2.92	4.62	5.46	6.08	1.57
- Fall	2.66	3.35	3.83	4.59	2.44
Dungeness crab					
(All Areas)					
- Winter	1.02	1.15	1.23	2.25	0.00
- Spring	0.60	0.54	0.10	0.00	0.00
- Summer	2.02	2.31	1.79	3.75	0.00
- Fall	2.92	3.27	3.26	5.39	2.34
Joint Venture Whiting					
(All areas)					
- Spring		60.81	77.45	84.75	
- Summer		60.81	77.45	84.78	

Table A1.10 Weeks fished for multispecies groundfish in 1982.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
Vancouver-Col.					
- Winter	287	228	330	119	22
- Spring	407	300	355	143	23
- Summer	392	289	390	164	39
- Fall	254	156	255	125	32
Eureka					
- Winter	118	138	65	53	4
- Spring	175	203	56	74	1
- Summer	216	231	54	99	5
- Fall	105	125	52	56	11
Monterey					
- Winter	180	241	126	49	22
- Spring	210	191	92	28	11
- Summer	190	203	95	32	9
- Fall	169	216	101	28	11

Table A1.11 Weeks fished by trawlers for pink shrimp and Dungeness crab in 1982.

	Class 1 40-49 ft.	Class 2 50-59 ft.	Class 3 60-69 ft.	Class 4 70-79 ft.	Class 5 80 - 95 ft.
Pink Shrimp					
- Winter	0	0	0	1	0
- Spring	246	222	607	168	3
- Summer	192	189	605	156	0
- Fall	21	24	112	25	0
Dungeness Crab					
- Winter	116	71	14	3	0
- Spring	0	10	0	0	0
- Summer	6	0	0	0	0
- Fall	93	38	10	18	0
JV Whiting					
- Winter	0	0	0	0	0
- Spring	0	0	71	99	41
- Summer	0	0	153	376	132
- Fall	0	0	0	0	0

APPENDIX 2 -- FISHING COSTS FOR PACIFIC COAST TRAWLERS

Trawl vessel financial statements were obtained from a variety of sources. Most came from confidential NMFS files for vessels in the Capital Construction Fund and in the Fishing Vessel Obligation Guarantee Program. These were coded and placed into a computer data base to facilitate summarization and storage. Data covering the years 1980, 1981, 1982 and 1983 were selected for this cost analysis, and financial statements pertaining to a partial year or covering more than one vessel were discarded. Also discarded were vessels with large discrepancies in reported total revenue between financial statements and PACFIN estimates.

Vessels are grouped into five 10-foot intervals based upon Coast Guard registered length. Because this measure of length is less familiar to some people than length overall (LOA), approximate equivalent intervals in LOA are indicated below. The conversion between Coast Guard length and length overall is based upon the following estimated linear relationship reported in Huppert, Thomson and Iacometti (1984).

Length Overall = 0.743 + 1.066(Coast Guard Length) R^2=.925

The number of trawl vessels included in the sample for each year is indicated in Table A2.1.

Average values among the 174 vessel-years were computed by length class for each of the following cost categories.

(a) Total Revenue - total reported vessel earnings from all sources, including sales of fish, charters, etc.

(b) Petroleum - Annual expenditures for petroleum products (fuel, oil, lube)

(c) Pay - Annual reported crewshare, captain's share, employee benefits, retirement, etc.

(d) Maintenance - Expenses reported as vessel maintenance or repair

(e) Other variable costs- Costs associated with gear, truck and auto, dues and FMA assessments, bait, ice, salt, equipment, off-loading, supplies (not provisions), licenses and permits, haulout, leasing of moorage, professional services, phone & utilities, and etc.

(f) Depreciation - Total depreciation expense listed for the fishing vessel on the income tax or financial reporting forms.

(g) Interest - Vessel interest cost plus other general interest expenses

(h) Taxes - Tax payments other than income tax.

(i) Insurance - Insurance payments associated with vessel.

(j) Historical Vessel Purchase Price - This is the base value from which annual depreciation is computed for tax purposes. It does not necessarily equal the new price of the vessel (since many vessels change hands after entering the fleet) and it will not equal vessel construction cost except in the first year of use.

Entries in Table A2.2 represent average reported values for 174 vessel-years. For some vessel-years, particular categories of cost were not reported. Consequently, the actual sample sizes for various cost estimates are smaller than 174. For example, the vessel price was missing from about twenty-five percent of the vessel-years. Most of the other cost categories were unreported in from one to six vessel-years.

WEEKLY REVENUES AND VARIABLE COSTS

Annual revenues earned and variable costs incurred are closely related to the amount of fishing activity. Our only reliable indicator of fishing activity level is the number of weeks fished computed from the PACFIN Research Data base. These figures are available only for the years 1981 and 1982. Variable costs per week of fishing were computed for these years for the sub-sample of trawl vessels occurring in both the financial information data base and the PACFIN Research Data base. A total of 87 vessels-years of information met these criteria. Average weekly revenues and costs for this sub-sample are displayed in Table A2.3.

For purposes of the optimum fleet size calculations, it is assumed that variable costs per week are unaffected by number of weeks fished per year. Thus, a vessel's annual variable expense will increase proportionately with weeks of fishing. So long as net cash flow per week is positive, a greater level of fishing activity will allow the vessel owner to accumulate more earnings to cover fixed costs.

FIXED COSTS - TAXES, INSURANCE AND CAPITAL COSTS

Various fixed costs associated with owning, maintaining and operating a fishing vessel do not vary proportionately with the amount of fishing activity. Since most of the expense in the category "Taxes other than income tax" and the annual insurance premiums appear to be independent of level of fishing activity, these have been placed in fixed costs. Other fixed costs are associated with the opportunity cost of capital and the depreciation of vessels and gear. Average values for depreciation and interest expense from the cost and earnings study (Table A2.2) do not accurately represent these costs due to the peculiarities of income tax law and variations in treatment of these items by accountants. For example, beginning in 1982 some accountants began taking advantage of the new Accelerated Cost Recovery System (ACRS). Also, the annual interest payments recorded will be highly dependent upon whether the vessel owner self-financed the vessel or obtained a bank mortgage. If mortgaged, the vessel's annual interest payments will depend upon interest rates prevailing when the vessel was financed.

Ideally we would like to apply uniform procedures to calculate the annual opportunity cost of capital and the depreciation associated with the hull, deck equipment, fishing gear, engine and electronics incorporated in the fishing vessel. We do not have the requisite detailed information to calculate these costs for each category of equipment. One approximate measure of capital cost is the annual payment needed to amortize a loan over the period in which a vessel normally depreciates. The loan principal should equal the price of a the new vessel. The payment covers interest cost on the remaining balance plus annual reduction in principal. These reductions in principal are equivalent to depreciation charges associated with capital investments. This amount is calculated from the following standard formula for annualized loan payments:

$$A = iP(1+i)^n/((1+i)^n-1);$$

where A is the annual payment required,
P is the loan principal,
i is the annual rate of interest,
n is the number of years over which the loan is amortized.

The formula is applied to inflation-adjusted vessel acquisition prices for trawl vessels in our cost and earnings sample augmented by information provided by J. Crutchfield (1985, forthcoming). A loan period of 15 years and an interest rate of 8.5 percent are assumed.

Table A2.1. Number of trawl vessels included in the cost and earnings data during 1980 - 1983.

Length Class	Class 1	Class 2	Class 3	Class 4	Class 5
Coast Guard Registered Length	40-49 ft	50-59 ft	60-69 ft	70-79 ft	80-95 ft
Length Overall	43-53 ft	54-64 ft	65-74 ft	75-85 ft	86-102 ft
1980 (N=44)	6	13	16	5	4
1981 (N=45)	8	14	16	6	1
1982 (N=53)	11	16	19	6	1
1983 (N=32)	5	9	10	5	3
Total (N=174)	30	52	61	22	9

Table A2.2. Annual Accounting Costs for Pacific Coast Trawlers(based on 174 annual financial statements covering 1980, 1981, 1982 and 1983). Costs adjusted to 1981 dollars using GNP Price Deflator.

	Class 1	Class 2	Class 3	Class 4	Class 5
CG Length	40-49 ft	50-59 ft	60-69 ft	70-79 ft	80-95 ft
Variable Costs					
Petroleum	17,091	23,936	30,071	38,606	55,228
Pay	39,955	51,266	66,912	101,624	124,107
Maintenance	8,126	10,956	16,661	19,633	31,643
Other Variable	21,135	24,579	30,844	37,440	60,579
Sub-Total	86,307	110,737	144,488	197,303	271,557
Fixed Costs					
Depreciation	14,458	27,208	41,710	35,924	74,891
Interest	10,514	24,317	24,531	27,862	45,671
Insurance	8,763	11,233	13,756	15,793	25,872
Taxes	1,392	1,625	2,015	1,495	3,278
Total Fixed	35,127	64,383	82,012	81,074	149,712

Table A2.3. Estimated Average Exvessel Revenues, Variable Costs, Vessel AcquisitionCostsandAnnual Capital Costs forTrawlVessels in 1981 dollars. (Apparent discrepancies in column sums and other computations are dueto round-off errors and differences in sub-sample sizes for various cost components.)

	Class 1	Class 2	Class 3	Class 4	Class 5
Total Revenue/year	$126,109	185,069	261,669	355,997	603,131
Weeks Fished/Year	32.7	34.6	35.4	38.3	43.0
Revenue per week	3863	5366	7782	9306	16,680
Petroleum	510	646	975	1,408	1,754
Pay	944	1,623	2,315	3,088	6,228
Maintenance	232	322	513	565	1,299
Other variable	475	563	821	811	2,119
Total Variable Cost	2309	3322	4831	4963	12,164
Mean Vessel Acquisition Cost	250,885	254,981	441,515	468,386	563,570
Annual Insurance	8763	11,233	13,756	15,793	25,872
Other Taxes	1392	1,625	2,015	1,495	3,278
Capital Costs[1]	30,106	30,597	52,981	56,206	67,628
Total Annual Fixed	40,261	43,455	68,752	73,494	96,778

[1] Capital cost calculated as annual loan amortization cost applied to vessel acquisition cost. Loan period is 15 years, and interest rate is 8.5 percent.

APPENDIX 3 - Calculation of Catch Constraints for the Trawl Fleet

The objective in calculating catch constraints for each of the eight groundfish species groups, pink shrimp and Dungeness crab is to place a reasonable annual limit on trawler's annual harvest. This means that the constraint should be consistent with estimated sustainable yields, with the availability of species to trawlers, and with harvests by other gear types. Also, we want to assign portions of the coastwide sustainable yield to the three INPFC areas. This geographic spreading of the harvest will prevent the LP from simply concentrating the catch in one area of highest harvest rate. The basic source document for sustainable yields is Pacific Fishery Management Council (1985) Status of the Pacific Coast Groundfish Fishery through 1985 and Recommended Acceptable Biological Catches for 1986. Proportion of harvest by trawl gear is taken from the PACFIN Groundfish Management Data Base maintained at the Northwest and Alaska Fisheries Center in Seattle.

Sustainable Yields

The first task is to establish annual yields for each of the eight species groups. The final figures accepted for this study are displayed in Table A3-1. Derivation for each species is described below.

Dover sole - The total coastwide yield and the individual area yields are identical to the 1985 ABC's and 1986 Recommended ABC's in PFMC (1985, p.20 and p. 26)

Other Flatfish - The 1985 and 1986 English, Petrale and other sole ABCs are added together for each area. Since the PFMC did not allocate English sole ABC to areas, we apportioned it based upon the average 1981-84 distribution of landings among areas.

Pacific Cod and Lingcod - Again, the two yield estimates and distributions among areas come directly from PFMC's 1985 and 1986 ABCs. The two are simply added together.

Widow rockfish - 1986 ABC is adopted as total widow rockfish yield, and the apportionment among areas is based on average 1981-84 landings distribution.

Other rockfish - 1986 ABCs for Other rockfish and Pacific Ocean Perch were summed to get the yields in Table A3-1. Because there is no commercial fishery for shortbelly rockfish, we have not included it in the model at all.

Sablefish - The 1985 ABC for sablefish is used instead of the lower 1986 ABC because is it closer to the long run MSY.

Pacific whiting - Estimated MSY of 190,000mt is adopted as the constraint based upon the analysis in PFMC (1985, p.1-7). This is substantially below the 1986 ABC. Whiting is not apportioned among areas because the fishery tends to migrate with the concentrations of fish.

Miscellaneous Species - The ABC for 1986 by area is adopted.

Trawl Fleet Harvest Constraints

To determine the harvest constraints applying to the Pacific coast trawl fleet we need to (1) allocate an appropriate portion of sustainable groundfish yields to the trawl fishery, and (2) allocate a portion of the pink shrimp and Dungeness crab harvest to vessels from the groundfish trawl fleet. The first task is accomplished by applying historical average fractions of catch to the sustainable yields in Table A3-1. Proportions of catch of groundfish species groups by trawlers were calculated for the 1981-84 period (Table A3-2). Multiplication of these proportions by the corresponding sustainable yields results in the groundfish catch constraints in Table A3-3.

apportioning crab and shrimp catches to trawlers involved the following:

<u>Pink shrimp</u> - The average of 1981 and 1982 annual coastwide harvests is adopted as an initial constraint on catch. Shrimp abundance varies widely, but catches in 1981-82 were near average for the past 12 years. For pink shrimp the average annual catch is not necessarily a reasonable estimate of sustainable annual catch.

<u>Dungeness crab</u> - The annual crab catch constraint equals the average 1981-82 landings by trawl vessels. Since catch by trawl vessels is a small portion of the crab catch and accounts for only a small portion of earnings by the trawl fleet, this crude procedure seems adequate.

Table A3-1. Sustainable Yields for Groundfish Species.[1]

Species	Coastwide	Vancouver-Columbia	Eureka	Monterey
	metric tons			
Dover sole	27,900	13,900	8,000	5,000
English sole[2]	1,500	628	411	461
Petrale sole	3,200	1,700	500	800
Other sole	7,700	3,700	1,700	1,800
Other flatfish		6,028	2,611	3,061
Pacific Cod and lingcod	10,100	8,100	500	1,100
Widow rockfish[2]	9,300	6,597	1,297	1,406
Other rockfish	31,450	12,650	2,800	9,700
Sablefish[1]	12,300	6,355	2,238	2,751
Pac. whiting	190,000	-	-	-
Miscellaneous	14,700	9,500	1,200	2,000

1 For some species a portion of the coastwide sustainable yield is allocated to the INPFC Conception area, which is not shown.

2 English sole, widow rockfish and sablefish are allocated to the INPFC areas based upon average proportion of landings in each area during the 1981-1984 period.

Table A3-2. Proportions of groundfish species taken by trawl gear during 1981-84.

	Vancouver-Columbia	Eureka	Monterey
Dover sole	100%	100%	100%
Other flatfish	99.9%	99.9%	99.9%
Pacific Cod and lingcod	87.4%	97.4%	90.6%
Widow rockfish	100%	100%	100%
Other rockfish	97.3%	96.1%	88.5%
Sablefish	50%	78%	58.6%
Pac. whiting	100%	100%	100%
Miscellaneous	95%	98.2%	99%

Table A3-3. Trawl Harvest constraints for the Linear Program.

Species	Total	Vancouver-Columbia	Eureka	Monterey
	- - - - - - - -	- metric tons -	- - - - - -	- - - - - -
Dover sole	26,900	13,900	8,000	5,000
Other flatfish	11,651	6,028	2,611	3,012
Pacific Cod and lingcod	8,563	7,079	487	997
Widow rockfish	9,300	6,597	1,297	1,406
Other rockfish	23,584	12,308	2,691	8,585
Sablefish	6,536	3,178	1,746	1,612
Pac. whiting	190,000	-	-	-
Miscellaneous	11,809	9,177	1,188	1,444
Pink Shrimp	15,607	-	-	-
Dungeness crab	2,245	-	-	-