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BIOECONOMIC SIMULATION MODEL

OF THE WALLEYE POLLOCK FISHERY

IN THE GULF OF ALASKA

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ABSTRACT

A bioeconomic simulation model was used to evaluate the effect of alternative harvesting strategies on the biological status and profit potential of the walleye pollock (Theragra chalcogramma) fishery in the Gulf of Alaska. The simulation model, which projects future stock condition given likely catch and recruitment scenarios, integrates an age-structured population dynamics submodel with an economic submodel. The biological submodel describes temporal partitioning of the annual harvest between a January through April roe fishery that targets on prespawning aggregations in Shelikof Strait and the fishery that occurs during the rest of the year in the central and western gulf. The economic submodel includes cost and revenue functions for the harvesting sector.

Equilibrium biomass and profit were calculated for each of nine different annual quotas ranging from 50,000 to 250,000 metric tons, with varying allocations between the spring roe fishery and the summer/fall surimi/fillet fishery to investigate the impact of the timing of the harvest. In addition, variations in the annual quota levels were introduced for the first projected year of the 20-year simulations, on a select subset of the runs, to allow some insight concerning how the benefits from the stock are affected by the rate at which a strong year class is exploited during the first year it is available to the fishery.

Results of the simulations indicate that: 1) the timing of the harvest can be an important factor affecting stock condition when quotas are high and 2) a reduction in the quota for 1987, to protect the strong 1984 year class that was first available to the fishery in 1987, would reduce the discounted present value of profits from the fishery in the 20 year simulation.

CONTENTS

INTRODUCTION

In the past few years, the walleye pollock (*Theragra chalcogramma*) fishery in the Gulf of Alaska has changed dramatically. Since the early 1980s, there has been a sharp decline in the available biomass, due mainly to the movement through the fishery of five consecutive strong year classes (1975-79) followed by four much weaker year classes (1980-83). At the same time, there has been an increased demand for pollock, due in part to increased joint venture harvesting and processing capacity, increased numbers of domestic factory trawlers, and the establishment of groundfish processing plants on Kodiak Island and in the Aleutian Islands.

Management must now attempt to balance the need to allow the biomass to maintain a biologically "safe" population level and the need to sustain stable harvests of sufficient magnitude to support a viable domestic industry. The model described below can assist management in its successful pursuit of this goal.

A bioeconomic simulation model was used to explore selected impacts of adjustments in the timing of harvest for the Gulf of Alaska pollock fishery. The main objective of the study described in this report was to estimate the equilibrium biomass and profits resulting from various quotas and seasonal distribution of the quotas. Equilibrium biomass is defined here as the biomass at which the population stabilized by the end of the 20-year simulation. The model was also used to assess how profits are affected by changes in the exploitation rate for the most recently recruited year class.

The Gulf of Alaska walleye pollock stock is considered separate from that of the Bering Sea and Aleutian Islands, both from a biological and management viewpoint. Most of the gulf pollock resource lies within the North Pacific Fishery Management Council's Central and Western Regulatory Areas (Fig. 1). Research, mainly through National Marine Fisheries Service surveys, indicates that the majority of the spawning of pollock in the Gulf of Alaska pollock occurs in Shelikof Strait between January and April (Nelson and Nunnallee 1985). Even though there is evidence of other pollock concentrations in the gulf (Nelson and Nunnalee 1986), there is not enough data to estimate their magnitudes; thus a population estimate from Shelikof Strait is treated as a good indicator of the condition of Gulf of Alaska pollock as a whole. In addition, Shelikof Strait is the location of a significant commercial fishery during the roe season.

Prior to the 1970s, the biomass of this stock was believed to be increasing in abundance. In the 1970s, effort increased as foreign trawlers switched from depleted rockfish (Family Scorpaenidae) stocks to pollock (Alton and Megrey 1986). Beginning in 1981, the joint venture fishery (in which domestic fishing vessels deliver their catch offshore to foreign processing ships, mainly from Japan and Republic of Korea) rapidly replaced the foreign fishery (Alton and Megrey 1986). As recently as 1985 the pollock catch in the wholly domestic fishery was negligible, accounting for 3% of the total pollock catch (Gulf of Alaska Plan Team Report 1985). The domestic fishery of 1986, however, accounted for 14% of that year's catch. At the beginning of 1987, 100% of the quota, 87,700 metric tons (t), was allocated to the domestic fishery (Table 1 and Fig. 2). An additional 20,000 t was allocated as an experimental spring joint venture fishery outside of Shelikof Strait, but no catch was taken. The wholly domestic fishery ended up taking 39,000 metric tons in 1987, and a joint venture fishery was allowed late in the fall season.

Pollock is currently harvested and processed for three main products: surimi, fillets, and, during a portion of the spring harvest, roe. Surimi is an intermediate processed product used in a variety of final seafood products including imitation crab, shrimp, and scallops.

During the spring spawning season, roe is extracted from the sexually mature females and the flesh is subsequently processed into one of the two above-mentioned forms or discarded.

Pollock taken by the foreign or joint venture fisheries is processed and primarily consumed outside of the United States, with only a portion being returned to the United States for further processing or consumption. Pollock taken in the domestic fisheries is processed in the United States and consumed domestically or exported.

The primary management of this fishery has been through setting a total yearly quota and its allocation among the domestic, joint venture, and foreign fisheries by the North Pacific Fishery Management Council.

METHODS

Model Description

The simulation model, which projects the biological and economic conditions of the fishery as functions of catch and the proportion of the total catch that is taken in the roe fishery, integrates an age-structured population dynamics submodel with an economic submodel.

Biological Submodel

The biological submodel used in this study is essentially a temporally-partitioned, single-species dynamic model and has been used in three earlier studies (Alton and Rose 1985; Alton and Megrey 1986; Megrey and Alton 1986).

The model is configured to represent the Gulf of Alaska pollock fishery based on estimates of biomass and recruitment from hydroacoustic surveys conducted in Shelikof Strait. It provides estimates of population abundance (biomass and number) for each age group, ages 3-10. We assume that the fish are introduced into the fishery at age 3, and that after age 10 they are no longer available to the fishery due to natural mortality, fishing mortality, and changes in the species habits.

A temporal partitioning is built into the model to describe the two main harvest periods--an early roe fishery (January through April) that targets on prespawning aggregations in Shelikof Strait, and a second fishery that occurs during the rest of the year in the central and western gulf. For clarity, we will refer to the two harvesting periods as a spring or first fishery and as a fall or second fishery, even though harvesting occurs basically year-round.

Fishing mortality for individual age groups is calculated as the product of an age- and season-specific gear selectivity and an annual effort value. Estimates of gear selectivities are derived from foreign and joint venture commerical catch statistics using an age-structured stock assessment model (Megrey and Alton 1986). Annual estimates of fishing effort are calculated by the model as functions of the two policy (i.e., control) variables, the annual quota and its allocation between seasons.

A natural mortality rate of 0.4 is assumed for all eight ages in this model (Alton and Megrey 1986). The ratio of males to females in both the total population and harvest is assumed to be one-to-one. Other biological parameters required by the biological submodel include the initial population vector, average weight by age and season, recruitment, and estimates of sexual maturity by age. The maturity by age estimates provided by Miller et al. (1986) enabled us to calculate the amount of roe available in the harvest. The values of these parameters are shown in Figure 3 and Tables 2 and 3.

The model allows the user to vary the total annual harvest level by year, to partition the annual harvest by season, and within each season to allocate catch between types of operations, such as domestic and joint venture fleets.

Economic Submodel

The economic submodel describes the returns to the harvesting sector. Pollock is caught mainly by mid-water trawl but there are a variety of operations, using this method, which target on pollock. In the past, catcher/processors vessels, mothership arrangements, and vessels delivering to shore-based plants have been employed in the pollock fishery. Although there is a wide range in the productivity and profitability of individual vessels within each type and among the differing categories, we have used a representative vessel based mainly on a joint venture catcher boat to approximate the fleet. This approach was taken because the complexity of modeling the diverse trawl fleet was beyond the scope of this research, which is a first step in developing a Gulf of Alaska pollock management model.

The model will become more detailed as more information becomes available and as the industry and scientific community respond to the current model. The characteristics of our representative vessel are described in Table 4.

There is some question as to whether pollock is worth more in the spring fishery when it contains highly valued roe or during the fall fishery when the surimi and fillet recovery rates are higher. Due to this uncertainty, two sets of simulations were run. For the first set, it was assumed that the base ex-vessel price for each season is $100 per metric ton (t) and that a premium up to $20 is paid for roe-bearing pollock. The premium was set equal to the product of $20 and the percentage by weight of females that were fully mature. For the second set, an ex-vessel price of $100 was used for both seasons.

With both set of runs, the same general results hold. The numerical results reported in this paper are for the second set of runs with no premium paid for roe.

The price of $100 per metric ton is the average price for Gulf of Alaska pollock for 1980-87. Although Bering Sea pollock did experience a surge in price to $125 per metric ton in early 1987, and stayed higher through 1987, the price of pollock delivered in the gulf has remained fairly stable around this historical level.

Market prices were assumed to be exogenous to the model. We feel this assumption is valid because the amount of pollock that could be harvested in the gulf is small in comparison to the harvest in the Bering Sea fishery and elsewhere in the North Pacific, and also because there are a number of substitutes for pollock, especially in the production of fillets. The average catch from 1977 to 1986 in the Bering Sea was 1,019,977 t, compared to an average of only 161,029 t from the Gulf of Alaska.

Ex-vessel revenue to the fleet was calculated as base ex-vessel price times the amount harvested plus a variable premium paid for roe as appropriate.

Harvesting costs were calculated by multiplying the operating cost per unit effort by the amount of effort required to harvest the given quota. Effort was measured in terms of vessel year as a function of biomass by age class, the different catchability coefficients for each age class and season, and a density-dependent scaling factor. The scaling factor was derived from mean catch per minute and minutes per boat week for both seasons from actual vessels fully employed in fishing during 1985-86. In 1986, the catch per minute rate during the spring season was 0.135 t. This was approximately 50% higher than the catch rate of 0.091 t per minute for the second season of 1986. In addition, the mean boat week for the Shelikof Strait fishery was 4,652 minutes, as opposed to 2,905 minutes of fishing per boat week during the second season. These two factors combined gave a rate of 628 t per boat week for the first season's fishery and 264 t per boat week for the second.

The operating cost per unit effort (i.e., cost per vessel year) was held constant at $1.2 million. This cost includes a fixed cost of labor of $490,000 which is equal to the estimated crewshare payments per vessel year in the base period. It also includes an opportunity cost of capital of $200,000 which is 10% of the market value of the representative trawler. This means that if catch per vessel year is such that gross ex-vessel earnings equal $1.2 million, profit will equal zero but the crew, including the captain, is receiving its normal (i.e., base period) rate of return and the vessel owner is receiving a normal (i.e., 10%) rate of return on the investment in the vessel. However, with a higher catch per unit effort (CPUE) profit will be greater than zero and both the crew and the vessel owner are receiving higher than normal rates of return. Therefore, the use of constant costs per unit effort results in an aggregate measure of profits to both fishermen and vessel owners. If economic profits were positive, then the ability to earn above-average rates of return would attract additional capital and labor into the fishery until only a normal rate of return could be earned.

Given this adjustment process and the relative ease of entry and exit in this fishery, equilibrium profits are always expected to be zero and, hence, would provide no useful information regarding the preferability of various harvesting strategies. Therefore, the profits reported here reflect the potential profit that could accrue under various harvesting scenarios if there were restrictions on entry into this fishery.

A discount rate of 10% was used, and costs and prices were assumed constant. This is equivalent to assuming that costs and prices change at the same rate over time and that the real discount rate is 10%. Discounting the value of the stream of dollars received in the future allows us to compare those dollars with actual revenues received today. A 10% discount rate is often used for commerical fisheries, in part because it is a relatively risky endeavor.

Model Experiments

The structure of the model is versatile enough to allow us to look at a variety of policy questions. Given a set of alternate harvest paths, presumably chosen by management as desirable or most likely, then this model can rank the paths on the basis of maximum discounted returns to the fishery. All other things being equal, we would chose the path that generated the maximum discounted return.

However, the main purpose of this research was to provide insight concerning the potential effects of management alternatives involving timing of the fishery. Specifically, the model is intended to help answer two questions: 1) does the partitioning of the harvest between seasons have an impact on the equilibrium biomass and profits of the fishery? and 2) how are profits affected by the rate at which a strong year class is exploited during the first year that it is available to the fishery?

To address the first issue, we looked at a series of 20-year projections that calculated the equilibrium biomass and profits for each of nine different annual quotas ranging from 50,000 to 250,000 t. For each quota, the portion of total harvest taken during the first season was varied from zero to 100% of the total harvest, in increments of 10%. Heavy spring fishing in our model impacted the equilibrium biomass through two mechanisms: 1) the removal of a larger percentage of the population for a given level of catch due to lower average weights prior to spring and summer growth, and 2) the different gear selectivities of the two seasons. In addition, heavy spring fishing affects the profitability of the fishery because catch per unit effort, and possibly the value of pollock per unit of weight, are higher during the roe fishery.

To investigate the second issue, we introduced variations in the harvest levels for the year 1987 to determine the economic impacts of concentrating exploitation on the strong 1984 age class. For the years 1988 onward, we held catch constant to allow the biomass to reach the same terminal level for each harvest time path.

We then compared the present discounted value of the total profits generated by each catch time path to see which one produced the highest combined return to the fishery and the annual profit for 1987, the year in which the variation in harvest was allowed. For each allocation scenario, annual catch beyond 1987 was held constant at 200,000 t and was evenly split between the two seasons.

RESULTS

With smaller harvests (i.e., <125,000 t), the seasonal allocation did not appear to be critical with regards to the equilibrium biomass. The biomass for a 100% spring fishery stabilized at a level within 7% of the biomass for no spring fishery. However, the larger the overall harvest, the greater the impact of allowing a heavy spring harvest. For example, with an annual quota of 200,000 t and no roe fishery, the equilibrium biomass was 919,000 t, compared to an equilibrium biomass of 733,000 t when all of the 200,000 t catch was taken in the spring. This was a decrease of 186,000 t or 20%. At an annual harvest level of 250,000 t with the entire quota taken during a second season fishery, the biomass stabilized at 772,000 t compared to less than 100,000 t when the same quota was taken entirely during the spring.

The most profitable scenario considered consisted of a 200,000 t quota, with 100% spring fishery. The equilibrium biomass for this scenario was 733,000 t and the potential equilibrium profit for the fleet was $14.1 million. The results have been summarized in Figures 4 through 7. With the CPUE figures used in these runs, 200,000 t ends up being the most profitable quota to set regardless of the distribution of catch between the seasons.

Of the 99 possible harvest scenarios (i.e., 9 quotas and 11 seasonal partitionings), 57 left an equilibrium population in the range of 700,000 to 1,150,000 t. There remains some doubt as to the ability of a stock size below 700,000 t to produce strong year classes, while above 1,150,000 t the stock might begin to suffer from increased population density and increased intra-specific competition for available food sources (Megrey and Alton 1986). Also, in the Bering Sea this species has a demonstrated tendency towards cannibalism when adults and juveniles are in physical proximity; therefore, large biomasses could damage future recruitment if cannibalism were to occur in the Gulf of Alaska stock.

An additional series of model runs was done in which the fishing time per boatweek was constrained to be the same in both seasons.

By using 4,652 minutes per boatweek and thus catch rates of 628 t and 423 t per boatweek for the first and second season, respectively, the most profitable scenario is now 225,000 t and no spring fishery.

Increasing the minutes per boatweek during the non-Shelikof Strait season from 2, 904 to 4,652 minutes per boatweek reduces the number of vessels required to catch during that time of year and, thus, lowers the overall cost to the harvesting sector.

Conversely, if the vessels only fish 2,904 minutes per boatweek in both seasons, then the reduced catch rate of 392 t increases the number of vessel years required to catch the spring allocation and effectively increases the number of boat years required to harvest any allocation. Under this scenario, highest returns to the fishery can be obtained at an annual quota of 175,000 t with it all being taken in the spring.

To answer the question of the impact of concentrated exploitation of a single strong year class that follows a number of relatively weak year classes, we employed simulations that had variable quotas for the initial year prior to initiation of a constant harvest policy. The results indicate that of the five time paths considered, the straightline harvest of 200,000 t for 1987 on produced the highest present discounted profit. Due to the design of the model with the use of constant average recruitment, the equilibrium biomass stabilized at the same level and with the same percentage of mature stock.

In addition, the 200,000 t harvest also produced the highest annual profit for 1987. As we increased the amount harvested in 1987, the amount of profit increased and the biomass decreased for 1987. However, the profit increased at a faster rate than the biomass decreased over the five scenarios. In none of the cases did the biomass decrease from 1987 to 1988. A comparison of the annual biomass and profit for the five time paths can be found in Figure 8. Although the yield from the 1984 year class could be increased by reducing the annual quota in 1987, it appears that the cost, due to reduced yield from the other previous year classes which are also available to the fishery, is high enough to offset the potential gain from delaying effort on the 1984 class.

DISCUSSION

It is interesting to note that the results correspond fairly closely with what has been happening in this fishery. The most profitable equilibrium quota is 200,000 t and the average harvest for the past 6 years was 196,000 t. Of course, there are differences in timing between the model's optimal catch scenario and current practice.

While this approach does shed some light on how the resource should be managed, it does not provide a clear decision-making rule. There are an infinite number of management strategies to be considered. This study only estimated the best path from among the small group chosen for examination and with some very limiting assumptions. To estimate the optimal harvest strategy, we need to set up a mathematical model that will determine the optimum quotas given a series of biological and economic constraints.

One of our future projects will be to incorporate a formal optimization algorithm into the model based on existing information and the given constraints.

Before attempting to do that, however, we will attempt to identify some of the drawbacks and limitations of this model. Given the current fluctuations in the fishery, it is hard to predict what type of operations will emerge as the most profitable in the future. To increase the scope of this model and to make our results more accurate, we will attempt to redefine the sectors to allow for activity from all three types of operations: motherships, catcher/processors, and shore-based operations. Although this modification should improve the accuracy of the estimates generated, it will still not allow for analysis of any individual or specific operation. Many of the vessels involved in the pollock fishery in the North Pacific fish in both the Bering Sea and the Gulf of Alaska and it is plausible that some of the shore-based operations in the Gulf of Alaska will receive pollock caught in the Bering Sea. It is beyond the scope of our study at this time to try to create a model that incorporates the interactions or dependencies that might make an individual skipper decide to fish in the Gulf of Alaska as opposed to the Bering Sea. However, we do feel it is important to obtain more detailed information in order to distinguish between the shorebased and the at-sea operations. In addition to redefining the sectors, we will concentrate on getting better estimates of certain parameters such as recruitment, age-specific roe recovery rates, and differences in catch per unit effort and thus cost per unit effort for harvesting in different seasons.

We feel this model provides the best available estimates of the impact of quota changes on profitability of the pollock fishery. In addition, it highlights areas where further research is necessary to develop a model to assist fishery managers in assuring the success of both the actual stock and the sectors utilizing that stock.

Table 1.--Quota, catch and biomass for Gulf of Alaska pollock 1977-87 in metric tons.

		Catch				Biomass
Year	OY	Foreign	JV	Domestic	Total	Estimates
1977	150,000	117,835	0	228	118,063	no survey
1978	168,800	96,328	34	1,044	97,406	no survey
1979	168,800	103,807	566	2,031	106,404	no survey
1980	168,800	112,997	1,136	904	115,037	no survey
1981	168,800	130,324	16,826	563	147,713	3,766,000
1982	168,800	92,612	73,918	2,217	168,747	no survey
1983	256,600	81,318	134,131	120	215,609	2,433,000
1984	416,600	99,212	207,115	329	306,656	1,838,000
1985	321,600	20,418	232,304	9,080	261,865	701,000
1986	116,600	114	62,587	10,088	72,789	623,000
1987	108,000	---	22,800	39,100	61,900	not available

OY = optimum yield

JV = joint venture fishery

Source: Pacific Marine Fisheries Commission Gulf of Alaska Plan Team Report 1985. PacFin Rep. 002. Available from 7600 Sand Point Way NE, Seattle, WA 98115

Table 2.--Actual walleye pollock adundance estimates (in millions of fish) used in calculating recruitment for model

Year/Year class	Abundance
Poor Recruitment	
1976/73	390.9
1977/74	324.4
1983/80	282.6
1984/81	241.3
Average	309.8
Average Recruitment	
1976/73	390.9
1977/74	324.3
1978/75	1274.6
1979/76	1778.9
1980/77	1608.2
1981/78	2111.7
1982/79	1255.2
1983/80	282.6
1984/81	241.3
1985/82	25.4
Average	929.3
Strong Recruitment	
1978/75	1274.6
1979/76	1778.9
1980/77	1608.2
1981/78	2111.7
1982/79	1255.2
Average	1605.7

Age 3 abundance estimates from 1976-85 all nation date set, Available from 7600 Sand Point Way NE, Seattle, WA 98115

CAGEAN model from results of the acoustic-trawl surveys for walleye pollock in the Gulf of Alaska in 1986. In R. L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1986, p 22. U.S. Dep. Commer., NOAA Tech Memo NMFS F/NWC-119.

Final numbers used in model:
Poor = 300 million
Average = 900 million
Strong = 1500 million

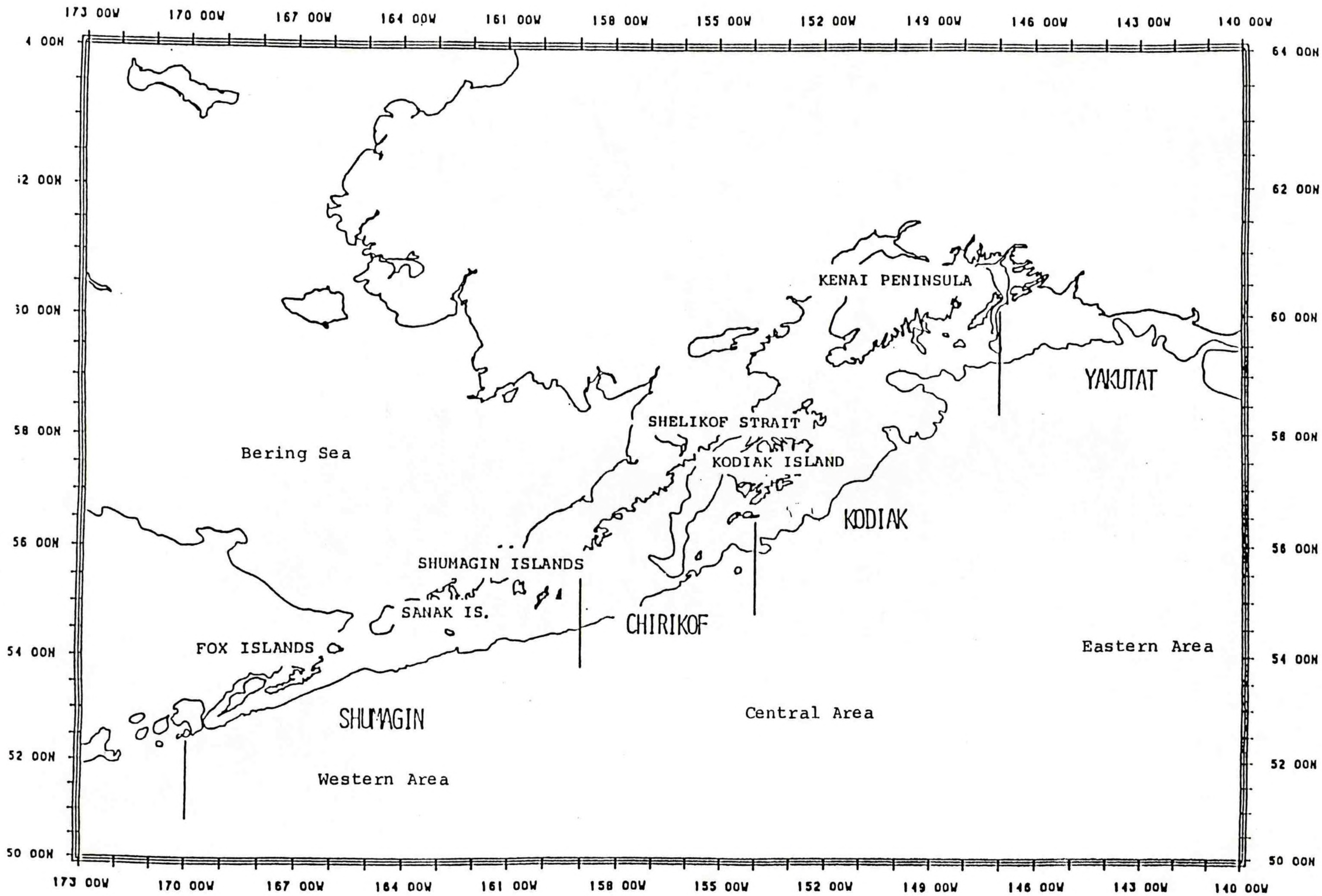
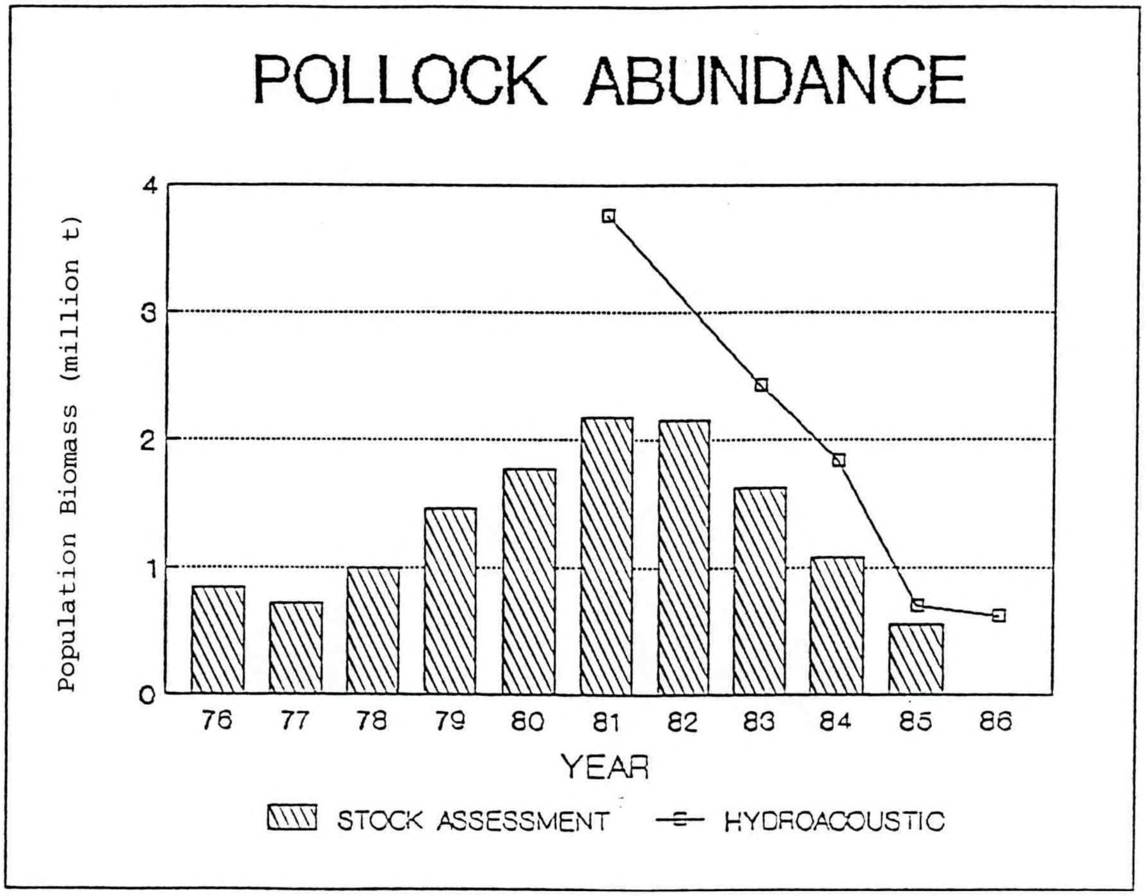


Figure 1.--Western Gulf of Alaska, showing locations and statistical areas referred to in text.



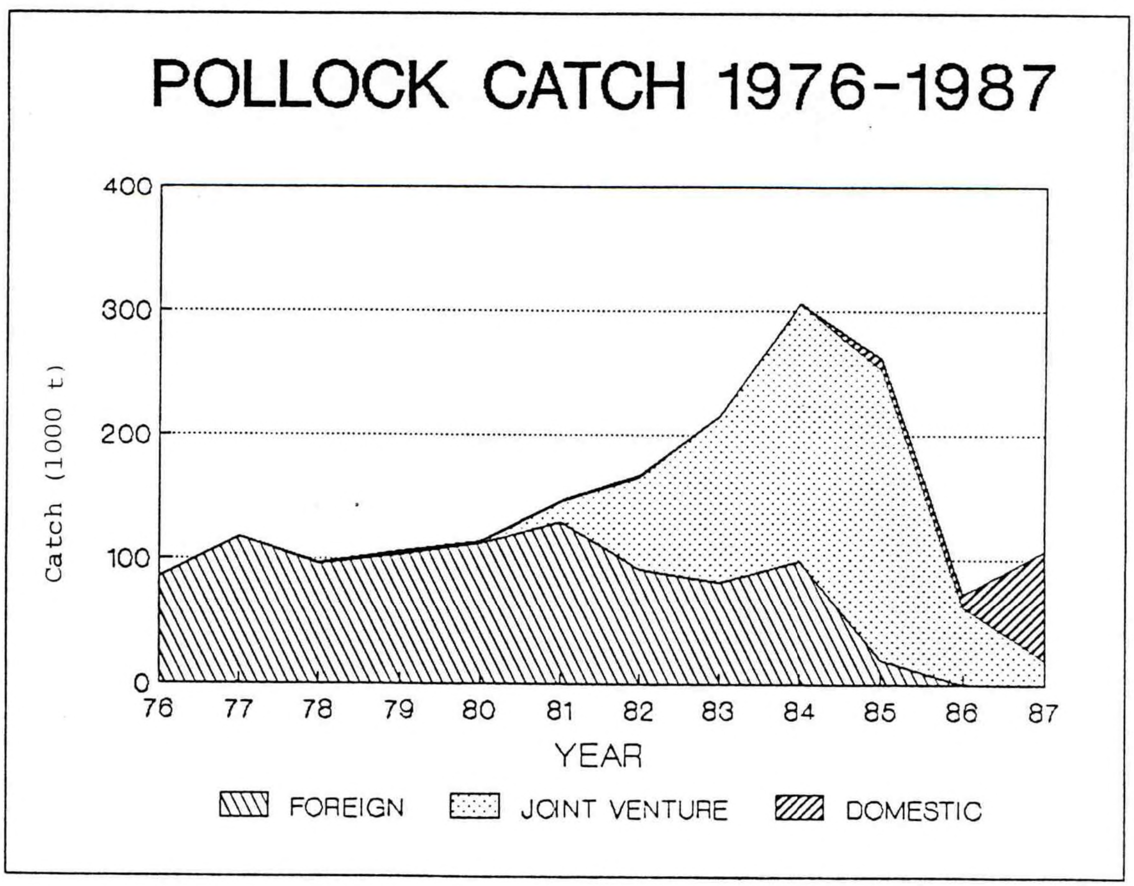
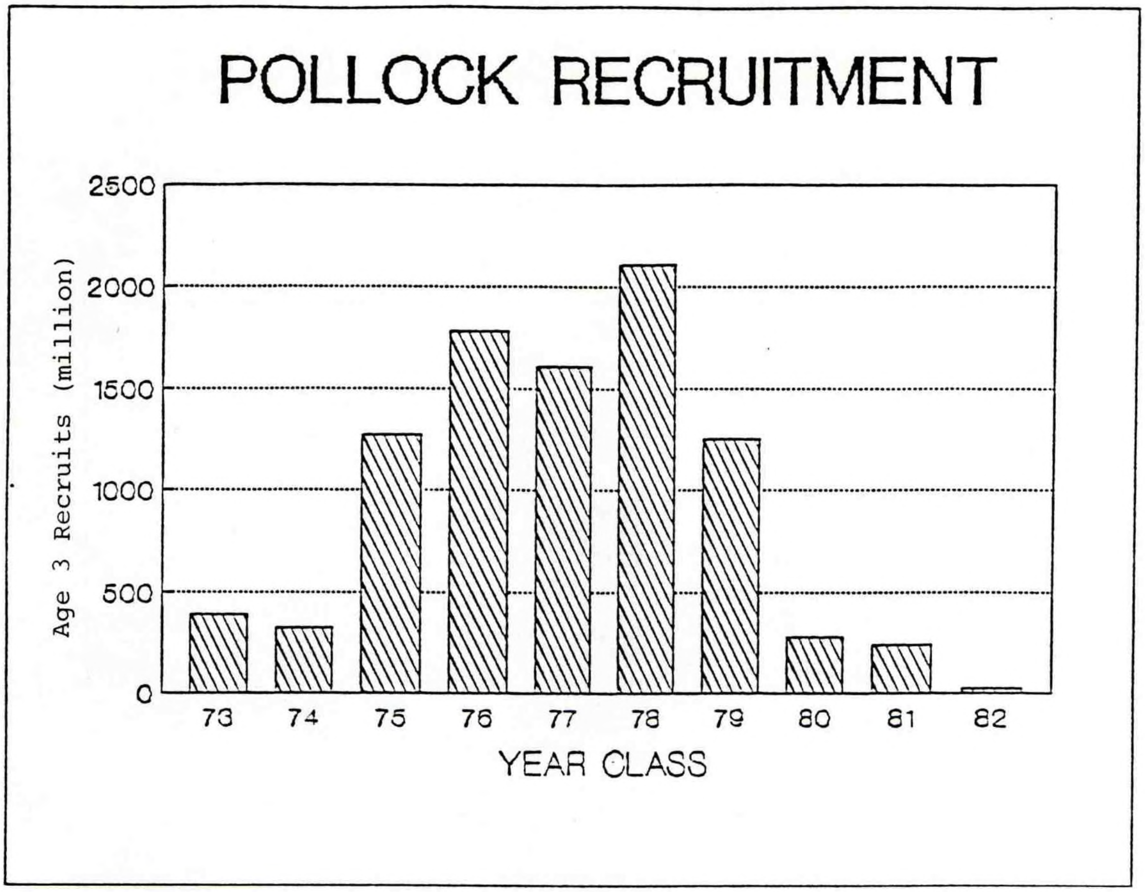


Figure 2.--Comparison of walleye pollock biomass and harvest 1976-87.



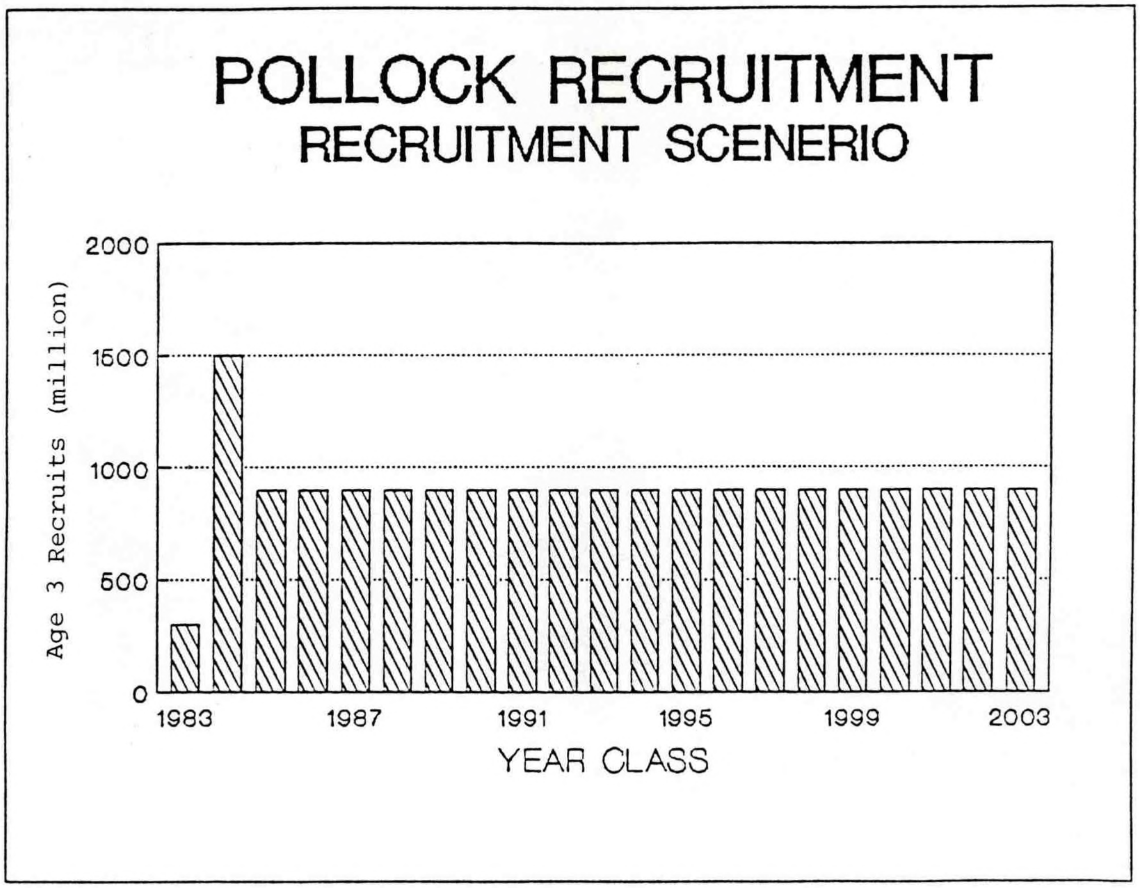


Figure 3.--Historic abundance of age 3 walleye pollock and projected abundance estimates for future year classes.

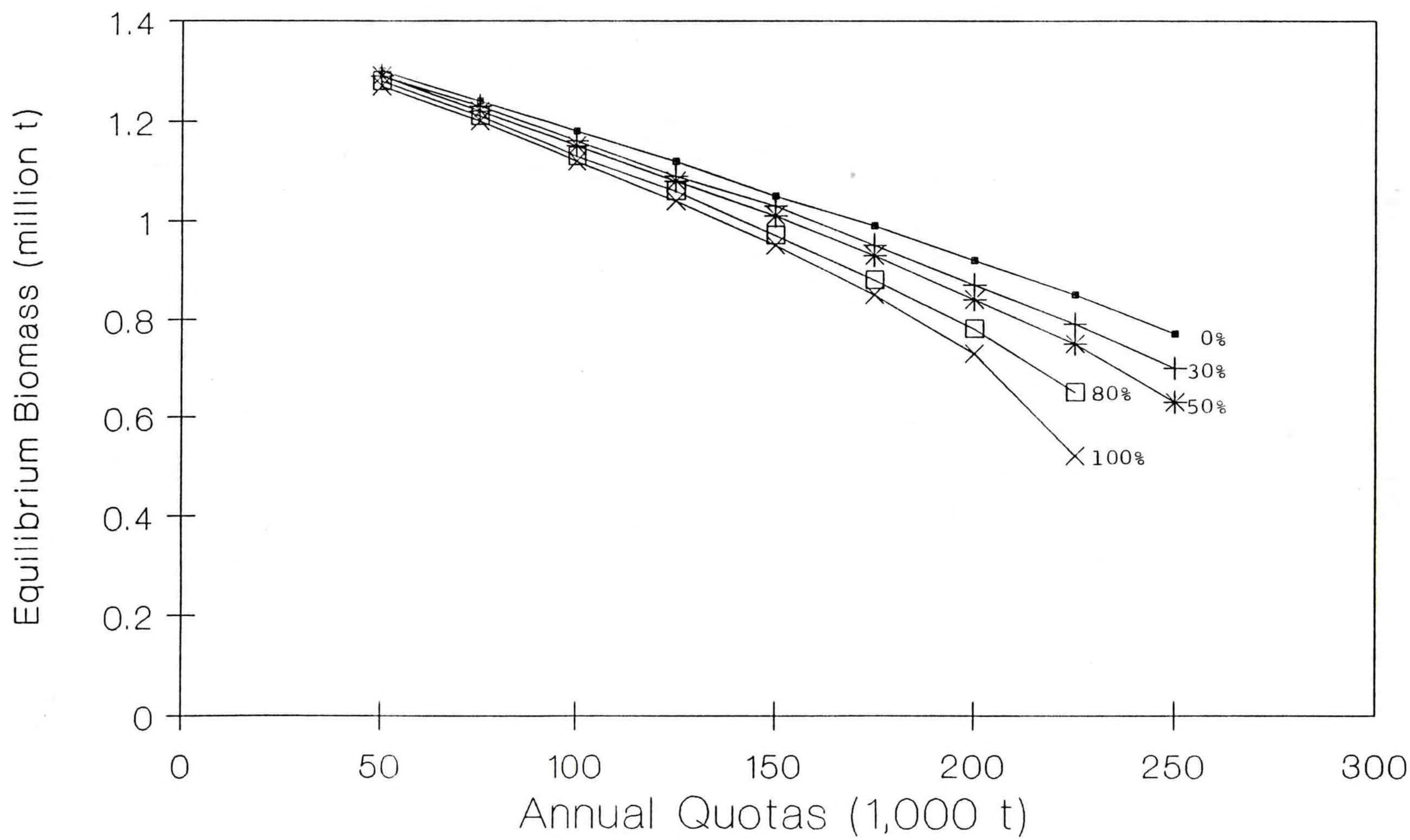


Figure 4.--Comparison of equilibrium biomass for the entire range of annual quotas for certain percentages of spring walleye pollock harvest.

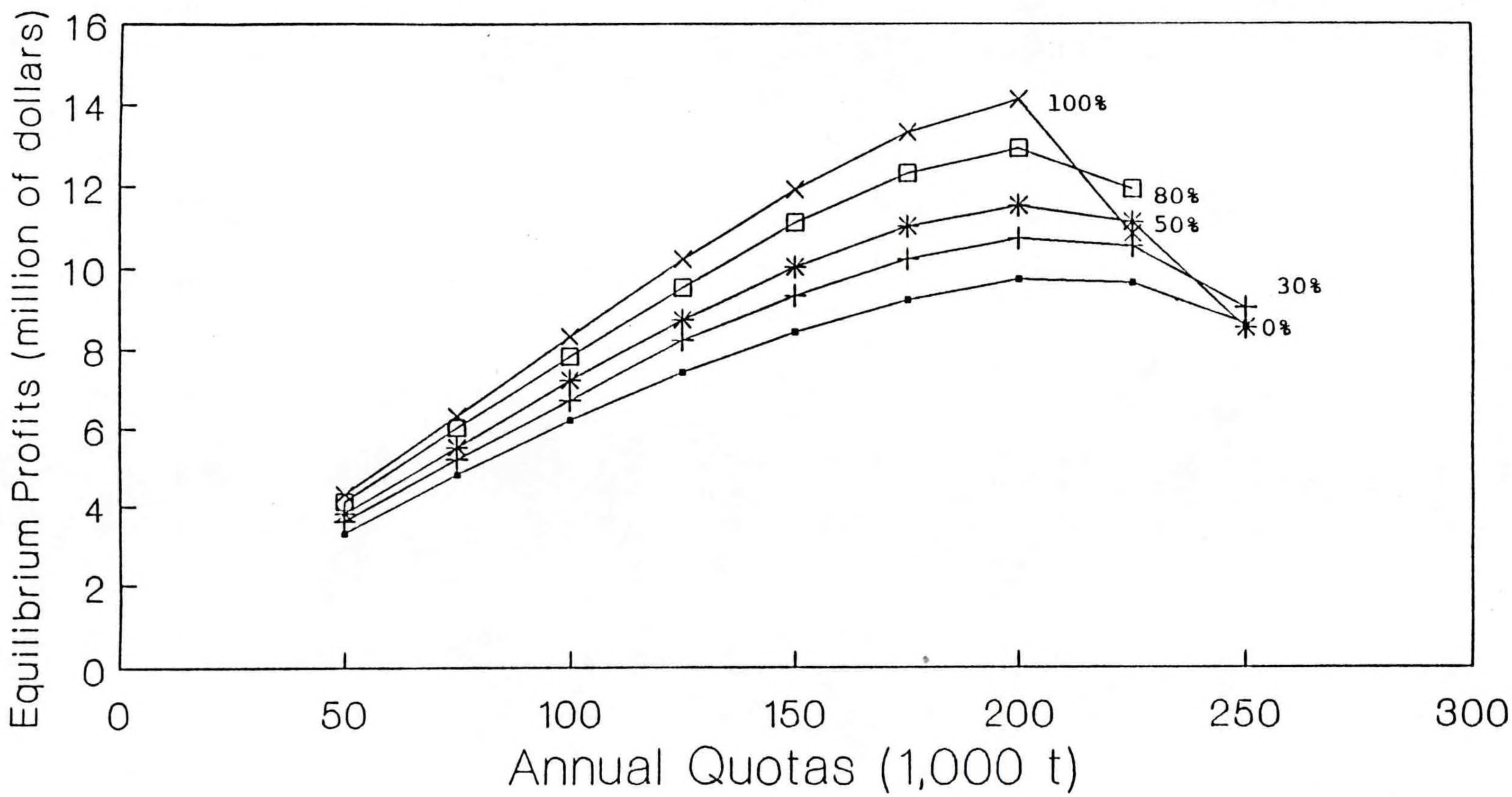


Figure 5.--Comparison of equilibium profits for the entire range of annual quotas for certain percentage of spring walleye pollock harvest.

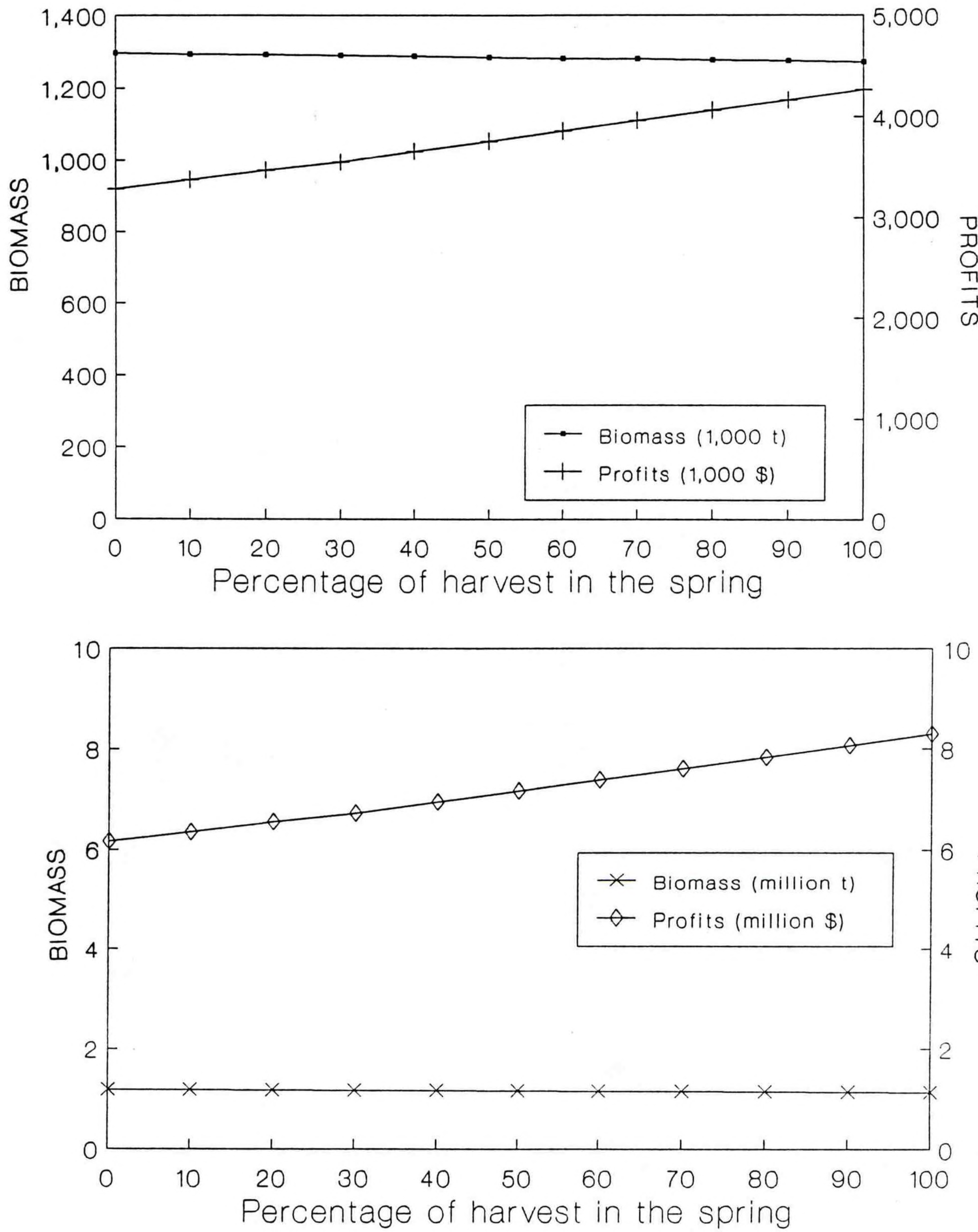


Figure 6.--Comparison of equilibrium biomass and equilibrium profits for an annual harvest of 50,000 t (upper panel) and 100,000 t (lower panel) as the percentage of spring harvest varies.

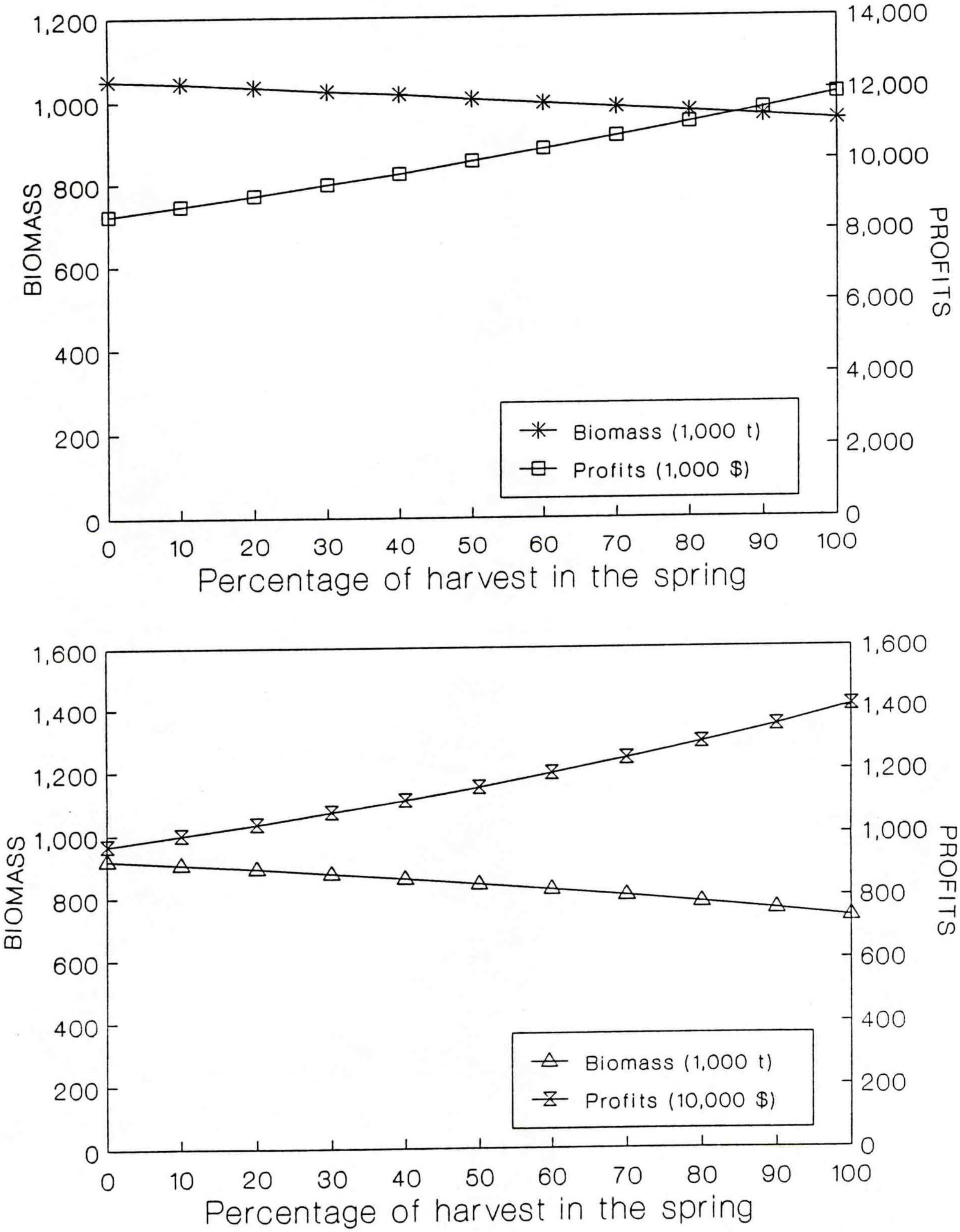
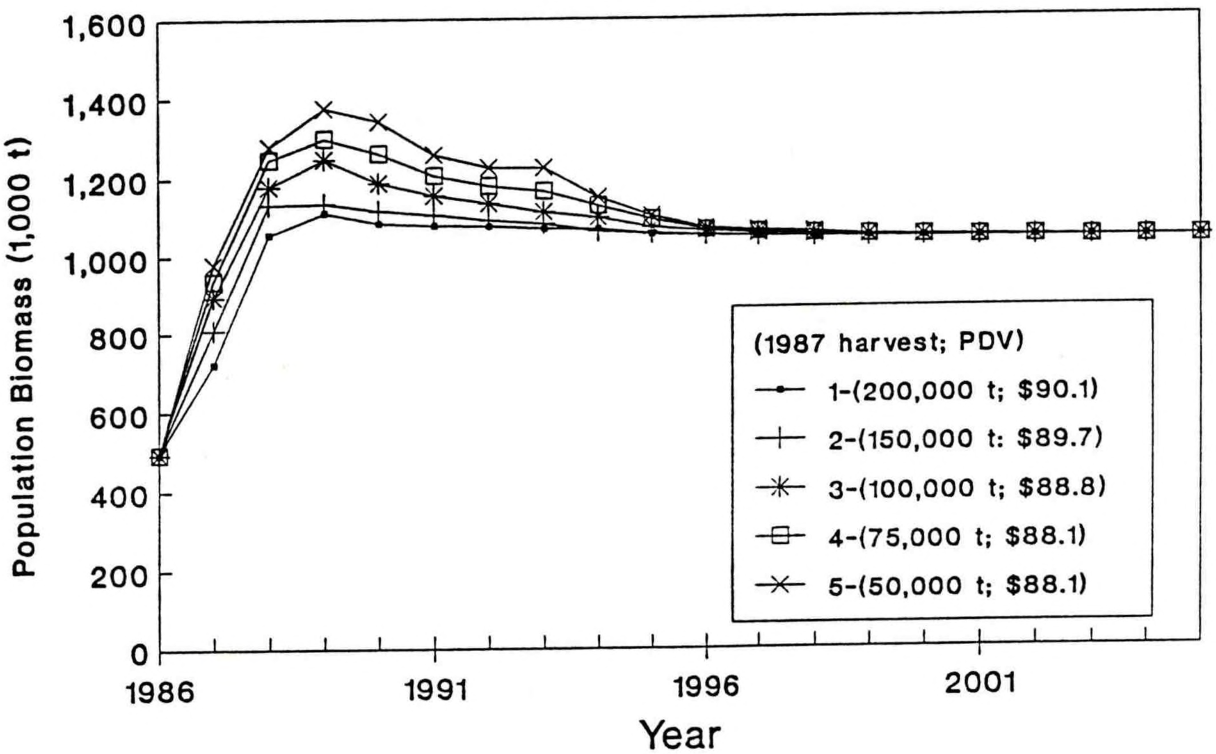


Figure 7.--Comparison of equilibrium biomass and equilibrium profits for an annual walleye pollock harvest of 150,000 t (upper panel) and 200,000 t (lower panel) as the percentage of spring harvest varies.



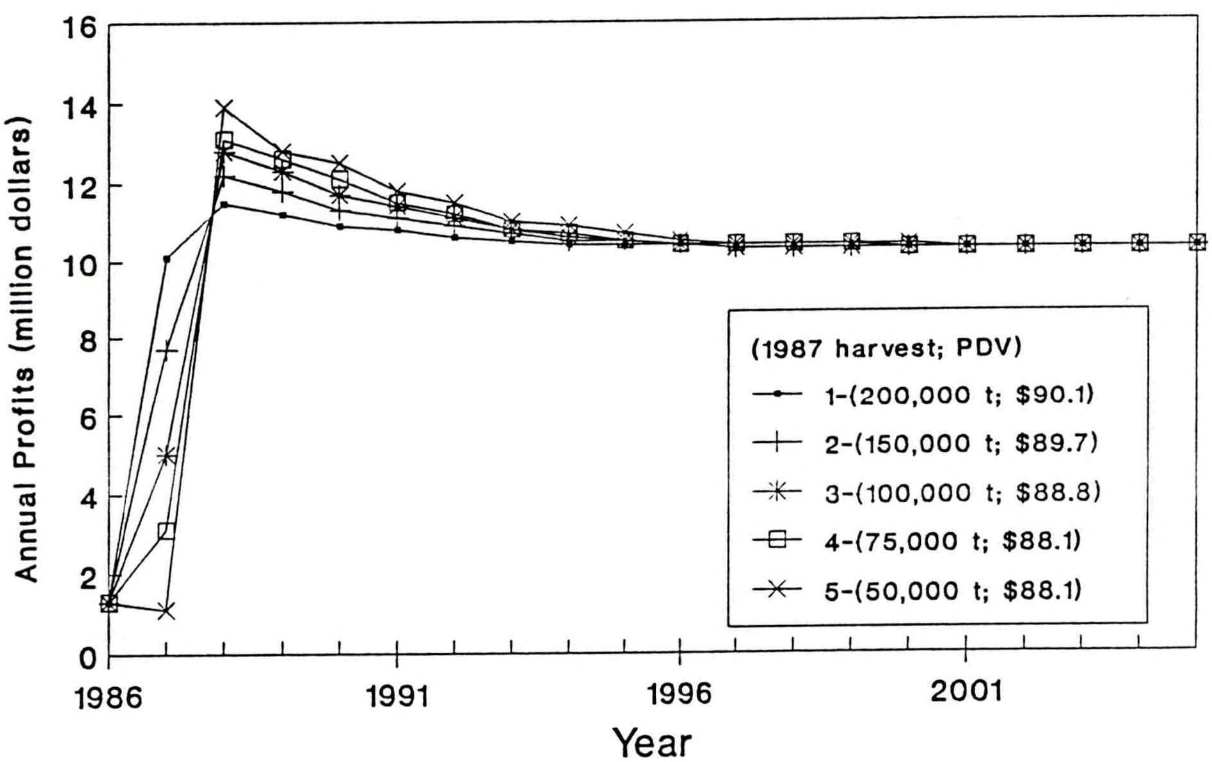


Figure 8.--Comparison of annual levels of walleye pollock biomass and profits for the five different 1987 harvest strategies, with the present discounted value (PDV) of profits for the 20 years in million of dollars.

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APPENDIX I

Summary of Actual Parameters Used to Initialize the Bioeconomic Projection Model

Biological Variables

Initial Population Vector (number (1,000's) of fish ages 3-10):
300,000; 44,300; 81,700; 52,300; 89,500; 151,300; 62,000; 11,700
(Nelson and Nunnallee 1987)

Average Weight at age in kilograms:
First season: 0.208, 0.421, 0.763, 0.857, 0.914, 0.981, 1.005, 1.145
Second season: 0.573, 0.729, 1.006, 1.011, 1.041, 1.182, 1.097, 1.243

Sexual Maturity at age: .03, .50, .84, .90, .95, .98, 1.00, 1.00
(E. P. Nunnallee, Northwest and Alaska Fish. Cent., 7600 Sand Point Way NE, Seattle, WA 98115 Pers. Commun., July 1986)

Age Three recruitment levels (Megrey and Alton 1987)
Poor = 300 million fish
Average = 900 million fish
Strong = 1,500 million fish

Recruitment scenario used in runs:
Poor 1986
Strong 1987
Average 1988-2005

Constant Natural Mortality: 0.4
Ratio of males to females: 1:1

Economic Variables

Base ex-vessel price (age 3-10) : $ 100.00/ton
Premium ex-vessel price: $ 120.00/ton
Duration of roe season: 90 days

APPENDIX II

Physical and Economic Characteristics of a Representative Vessel

Type of vessel	crabber/trawler
Length	37 m
Crew size (incl. captain)	five men
Market value	$2,000,000.
Operating days per year	240 at sea
Fishing days per year	190

Variable Costs

Food ($15/operating day/man X 240 X 5)	$18,000
Fuel & lubricants($850/operating day X 240)	204,000
Gear repair/replacement ($250/fishing day X 190)	47,500
*Opportunity cost of labor	489,600
Total variable cost to vessel:	759,100

Annual Fixed Costs

Maintenance	$80,000
Insurance	60,000
Depreciation (5% of market)	100,000
Opportunity cost of capital (10% of market value)	200,000
Other	30,000
Total fixed:	470,000

Total annual cost: $1,229,100

* Based on 34% share of gross revenue for an annual vessel's harvest of 14,400 t under a quota of 120,000 t.

Reference- Natural Resource Consultants 1984;
Captain Sewold, Skipper of Royal Baron, per. comm., 1987

Wespestad and Terry 1984;
Captain Sewold, Skipper of Royal Baron, per. comm., 1987