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Title: AN ANALYSIS OF FACTORS AFFECTING RESOURCE USAGE IN THE PACIFIC COAST SALMON FISHERY

Abstract approved: ______________________
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An investigation of changes in resource allocation in the Pacific Coast salmon fishery was developed by combining fixed asset theory with the traditional models of resource allocation. Hypotheses were specified about factors determining the total amount of labor and vessels in the Pacific salmon fishery. These factors included landings in the previous year, the cyclical nature of the fishery, unemployment rates and distances from major labor markets. Statistical models were formulated for both time series and combined time series and cross section data. The latter were divided into separate data for periods with increased landings and periods with decreased landings. The data entering the models were collected primarily from publications of the Bureau of Commercial Fisheries.

Least-squares regression techniques were used to estimate

the parameters of the equations. The strongest results from the statistical investigation prevailed for the combined time series and cross section models, especially when the data were divided into periods of decreased landings and increased landings. It indicated that in the periods of increased landings, as a one percent increase in the index of landings occurred in year _t_, the number of fishermen and vessels increased by 0.35 and 0.34 percent, respectively, in the year _t+1_. The coefficients were significant at .01 probability level. In the years with reduced landings, the results indicated that as a one percent decrease occurred in the index of landings in year _t_, labor decreased by 0.0246 percent in year _t+1_ while the tonnage of vessels will be 0.0016 higher in the year _t+1_. The parameter estimates were not significantly different from zero at conventional levels of probability. The results signified that resources are highly immobile in periods of decreased landings. This implies that their salvage values are very low, and that the resources have little opportunity to transfer outside the fishery.

It is concluded from this study that to cause resources to be less "fixed" in the salmon fishery, society needs to improve the MVP of the factors. This would enable them to transfer to those industries where their MVP is greater. The development of education and training programs for fishermen is needed to acquire or improve skills that would increase mobility to other labor markets when periods of declining MVP occur in the fishery. Further, it is also concluded that society needs to improve the design of fishing vessels. The vessels should be designed not only for salmon fishing but also for other fisheries. This would increase the MVP of the vessels and narrow the gap between acquisition cost and salvage value in the salmon fishery.

An Analysis of Factors Affecting Resource Usage in the Pacific Coast Salmon Fishery

by

Peerarat Aungurarat

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

AN ANALYSIS OF FACTORS AFFECTING RESOURCE USAGE IN THE PACIFIC COAST SALMON FISHERY

I. INTRODUCTION

Statement of the Problem

Several popular reviews have been made pertaining to the trend in productivity of the salmon industry on the West Coast of the United States (Alaska, Washington, Oregon, and California). This trend has seriously declined since 30 years ago when the total salmon output reached its peak. Over the last few decades, the salmon industry has been using more and more fishing effort to catch a decreasing supply of fish. The pattern of production tends to be an inverse one, that is, as the output declines, the fishing effort continues to increase. This effect of overcapacity on earnings among salmon fishermen must be termed inefficient.

This actual phenomena brings about a serious problem in the excessive numbers in the fishing labor force and the amount of fishing gear used in salmon fishing. It is apparent that the tonnage of fishing vessels and the number of fishermen employed in the salmon industry increased rather steadily from 1947 to 1966 in Alaska, Washington, and Oregon (Table 1). As long as fishing is regarded as a common property resource, individuals freely enter

Table 1. The salmon fishing effort, quantity of landings (pounds and values) and average values per fishermen in Alaska, Washington, and Oregon, 1947-1966.

Year	Labor (No. of fishermen)	Vessels (net tonnage)	Landings (thousand pounds)	Value of landings (thousand dollars)	Average landings per fisherman (thousand pounds)	Average value per fisherman (thousand dollars)
1947	16, 249	44, 003	486, 560	36, 987	29.94	2.28
1948	19, 334	59, 443	395, 981	36, 220	20.48	1.87
1949	18, 451	59, 510	477, 074	45, 186	25.86	2.45
1950	19, 241	63, 156	321, 575	35, 585	16.71	1.85
1951	23, 589	70, 799	367, 030	50, 535	15.56	2.14
1952	22, 318	71, 842	344, 999	43, 438	15.46	1.95
1953	21, 889	69, 231	304, 945	35, 882	13.93	1.64
1954	20, 321	66, 742	315, 217	41, 114	15.51	2.02
1955	24, 608	69, 268	277, 900	36, 750	11.29	1.49
1956	19, 522	63, 869	312, 837	42, 285	16.02	2.17
1957	1/	1/	260, 125	37, 809	1/	1/
1958	1/	1/	303, 797	44, 284	1/	1/
1959	19, 990	58, 099	194, 915	32, 704	9.75	1.64
1960	21, 546	53, 285	229, 227	41, 391	10.64	1.92
1961	23, 206	63, 060	301, 760	47, 329	13.00	2.04
1962	21, 921	62, 767	307, 892	52, 330	14.04	2.39
1963	23, 689	66, 553	286, 316	45, 051	12.09	1.90
1964	22, 384	66, 057	342, 765	50, 945	15.31	2.28
1965	23, 486	65, 691	317, 068	60, 134	13.50	2.56
1966	24, 987	67, 314	378, 066	68, 619	15.13	2.75

1/ Data not available.

Source: Fishery Statistics of the United States, U.S. Dept. of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries.

in the typical competitive manner when cost and price are favorable. As a result, more and more entries have been engaged in the fishery.

Total salmon landings depend on two factors, namely, on the relative abundance of the respective salmon species, and on the fishing effort, that is to say, on the number of fishermen and the number and size of fishing vessels. The number of fishermen in the salmon industry in Alaska, Washington, and Oregon rose from 16, 249 in 1947 to 24, 987 in 1966. The total tonnage of fishing vessels increased during the same period for the three fishing states from 44, 003 net tons to 100, 486 gross tons.[1/] High prices of salmon products since 1956 have led to a large expansion in the number of fishing craft and the number of fishermen. At the same time, the abundance of some salmon species has been reduced. This gave prominence to the serious decline in the salmon production from the fishery, so that the same fishing effort has tended to yield smaller catches. The result is that the fishermen could not greatly increase their incomes from the salmon harvesting (data also included in Table 1).

An investigation of this situation would include an examination

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[1/] Tonnage data will be discussed in a later chapter.

of the efficiency of resource allocation in the salmon industry. In theory, rational resource usage in the purely competitive system involves setting the marginal value product (MVP) equal to factor price (P_x) to achieve equilibrium of the firm. It is often assumed that only one price is involved for each factor, but the actual resource allocation in the fishery industry as in the agricultural sector, suggests that this theory requires modification. Transfer costs of resources are not zero and all factors are not perfectly mobile. Once the fishermen and fishing vessels enter the salmon industry, they probably tend to remain since they may have little opportunity to be used outside the fishery. In other words, the salvage value of a resource is often lower than its acquisition price, causing "fixed assets" to result in the fishing industry. If the industry faced the situation of very low salvage values for fishermen and fishing vessels, the degree of asset fixity might be very high. Even if the MVP of factors would decline and shift downward to the left, it might be unable to lower resource use in periods of declining salmon stocks.

Faced with a declining productivity of salmon fishing effort because of the inefficient resource use, the problem for society is essentially to understand why some resources may be subject to fixity, or to understand the divergence between acquisition cost and salvage value of the fishing labor force and fishing vessels in the salmon industry of the Pacific West Coast.

Knowledge of these relationships in salmon production would be useful to the fishermen and to society in improving the quality of the resource use in the fishery so that society would be better off.

Objectives of the Study

The general objectives of the study will be to develop the fixed asset model, as combined with the traditional model, to provide a statement of certain hypotheses about resource usage. The latter are defined in terms of the fishing labor force and fishing vessels in the West Coast salmon fishery. In formulating such hypotheses, the objective is also to develop models which can be tested statistically. Finally, the results of testing hypotheses and estimating relationships among variables in the models will be presented.

Specific objectives are identified as follows: (1) to select the rational variables entering into the models in different time periods which will explain the movement of resource usage in salmon fishing by means of the fixed asset theory as combined with the traditional theory; (2) to estimate the parameters of the variables by using the method of least-squares regression; and (3) to specify what variables appear to be quantitatively significant in determining the change in labor resources and vessels resources in the salmon fishery.

II. THEORETICAL FRAMEWORK

Equilibrium Level of Fishing Effort in the Fishery

In this part of the research, an attempt is made to explain the theory for determination of fishing effort in the commercial salmon industry on the West Coast. The problems are investigated by study of the profit maximizing competitive firm. This firm has (1) a physical production function which states the technical relations between fishing effort and salmon product, (2) a factor price function (P_x), and (3) a product price function (P_y).

The examination of factor prices is made more relevant by considering the possibility of "fixed assets" in the fishery. Therefore, it appears desirable to investigate the relationships between acquisition costs, salvage values, and marginal value productivity of factors of production.

This analysis will lead to the important aspects of cost curves and supply curves for fishing firms, to the returns to factors of production, and to the firm and industry equilibrium. Following this, a statement of hypotheses about input usage in the salmon fishing will be presented.

In order to examine the equilibrium level of fishing effort in the fishery, an examination of the production function for the fishing firm is necessary to investigate the optimum combination of factors of production. It is necessary, therefore, to segregate the effects of changes in factor productivity (ΔMPP), changes in fishing efforts (ΔX_i), changes in price of salmon (ΔP_y), and changes in profit or rent from fishing. These changes may occur simultaneously. For example, the effect of a change in the fish density might be lower or higher operating costs. Salmon prices in the market may increase or decrease. Of course, the resource usage may be also changed by these factors. It will also be helpful to look at the characteristics of factor supply price (input price). It is an important criteria in guiding the efficiency in resource usage. The traditional theory and the theoretical concept of fixed assets will be used to explain the problems mentioned. The traditional concept of resource allocation theory does not include enough relevant information to explain the nature of factor price in the salmon fishery. We need to modify analysis of resource allocation more precisely to the characteristic situation of resource usage in the fishery. Perhaps, the explanation of fixed asset theory will be helpful in supplementing the traditional theory in the case of resource combinations in the fishery.

The Traditional Approach

This model presents a simple case which is based on the traditional approach to factor usage in the production process.

It does not consider the level of asset fixity. It is pointed out that the law of diminishing returns for the combination of certain fixed factors and certain variable factors determines the marginal cost (MC) and supply curve (SS) of the firm under perfect factor and product markets. That is, the traditional economic theory assumes that the firms can buy additional factors if it is profitable and that they can sell unprofitable factors at the same price. This means that all factors in the economy are perfectly mobile. The economic efficiency in resource usage derives from this. If salmon stocks decline, the lower the amount captured would be. This means that if a factor is lower in productivity (lower MPP), or if the price of salmon is low, some resources will move out of the salmon industry and move to those industries where they are more profitable. If larger salmon stocks result in a higher productivity, or if the price of salmon increases, the firm will acquire additional resources. The resources from less profitable industries would move to the salmon industry. In this manner, the factors freely enter and exit in order to balance the economic efficiency in the perfectly competitive system.

Assumptions. To examine factor usage by the firm in the traditional model, the following assumptions are listed to aid in the analysis.

1. Two time periods are assumed. The time period, $\underline{t_0}$, is a period of declining fish stocks or "fishing gets worse". Lower productivity (MPP) occurs in this period. The time period, $\underline{t_1}$, is a period of increasing fish stocks, or "fishing gets better". A higher MPP occurs in this period.

2. P_x, P_{acq}, and P_{salv} are constant and equal to each other, where

P_x = factor price.

P_{acq} = acquisition price of additional factor services.

P_{salv} = salvage value of existing factor services.

3. Fishing firms are competitive.

4. Salmon product (Y) is a function of fishing effort, i.e., number of fishermen and tonnage of fishing vessels.

5. Salmon price (P_y) is unaffected by the quantity of salmon landings of individual firms, but is affected by total landings.

6. Tastes and preferences remain unchanged throughout the period of analysis.

7. The production function of the individual firm is a continuous function which relates the flow of salmon landings to flows of fishing effort.

8. The technology of production is unchanged.

The Model. The purpose of the model is to specify the equilibrium level of fishing effort by a fishing firm in the salmon fishery by employing the traditional approach. Consider the fishing firm and industry to be in equilibrium. The production function of a single firm in any time period, t, is given by:

$$(1)\ Y_t = f\,(X_{1t},\ X_{2t},\ X_{3t})$$

where:

Y_t = quantity of salmon landings in year t.

X_{1t}, X_{2t} = number of fishermen and tonnage of fishing vessels, respectively, employed by the salmon fishing firm in year t.

X_{3t} = salmon stocks in year t.

The profit maximizing equation for the firm is defined by:

$$(2)\ \pi = TR - TC$$

$$(3)\ \pi = P_y \cdot Y - P_{x_1} \cdot X_1 - P_{x_2} \cdot X_2$$

$$(4)\ \pi = P_y\,[f\,(X_{1+},\ X_{2+},\ X_{3+})] - P_{x_1} \cdot X_1 - P_{x_2} \cdot X_2$$

Taking the partial deriviatives of equation (4) with respect to X_1, for example, yields:

$$(5)\ \frac{\partial \pi}{\partial X_1} = P_y \cdot \frac{\partial Y}{\partial X_{1t}} - P_{x_1}$$

Setting equation (5) = 0, the conditions for profit maximization can be shown as:

$$(6)\ P_y \cdot \frac{\partial Y}{\partial X_1} = P_{x_1}$$

$$(7)\ MVP = P_{x_1},\ \text{or}$$

$$(8)\ P_{x_1} \frac{\partial X_{1t}}{\partial Y} = P_y$$

$$(9)\ MC = P_y$$

When P_x is assumed to equal $P_{acq} = P_{salv}$, the situation is shown in Figure 1.

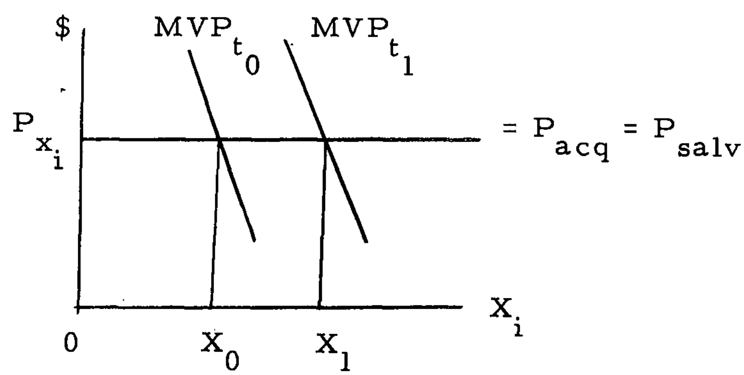

Figure 1. Quantity of an input used in the traditional approach.

In Figure 1, the individual firm should use different levels of inputs in the different situations to achieve equilibrium of the firm at MVP = P_x. In time t_0 (fishing gets worse), the MVP_{t_0} shifts downward and to the left, and MVP equals P_x at the X_0 level of input. In time t_1 (fishing gets better), the MVP shifts upward and to the right, and MVP equals P_x at the X_1 level of input ($X_1 > X_0$). Firms use more X_i because the factor is more productive and more valuable. The firm realizes more profits by increasing inputs in the time t_1 for the profitable production, and some of the inputs leave the firms in time t_0.

The firm's short-run cost curves can be shown in Figure 2.

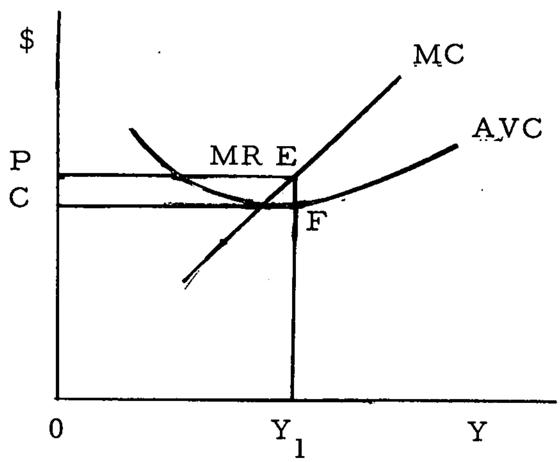

Figure 2. The short run cost curves of a firm.

The rent maximization of the firm is at the output Y_1, at which MC = MR = P. The area of rectangle PEFC comprises the profits for output Y_1 and price P. The firm is willing to produce as long as the product price is greater than the average variable cost (AVC) because the profits are still positive. The rational firm would stop producing where price is smaller than AVC because negative profits would occur. Therefore, the portion of the MC curve above AVC is the supply curve of the firm. It is the curve that reflects the quantities that the firm would produce at varying prices. The supply curve for the industry is the horizontal summation of each individual firm's supply curve.

The supply curve is determined not only by the costs of all factors of production but also by the density of salmon stocks. The costs of fishing depend partly on the size of the salmon run which affects the size of catch. This may be due to the cyclical nature of fish runs. For instance, the pink salmon in Puget Sound, Washington, have large runs in only odd-numbered years, while in even-numbered years very few of them are caught. The large runs for sockeye usually occur every fourth year. Higher fish stocks would reduce the operating costs for any given catch, and the effect would be reversed for the period of smaller fish stocks.

To make the analysis more clear, the production functions in time period $\underline{t_0}$ and $\underline{t_1}$ for the period of "fishing gets worse" and "fishing gets better" are shown in Figure 3.

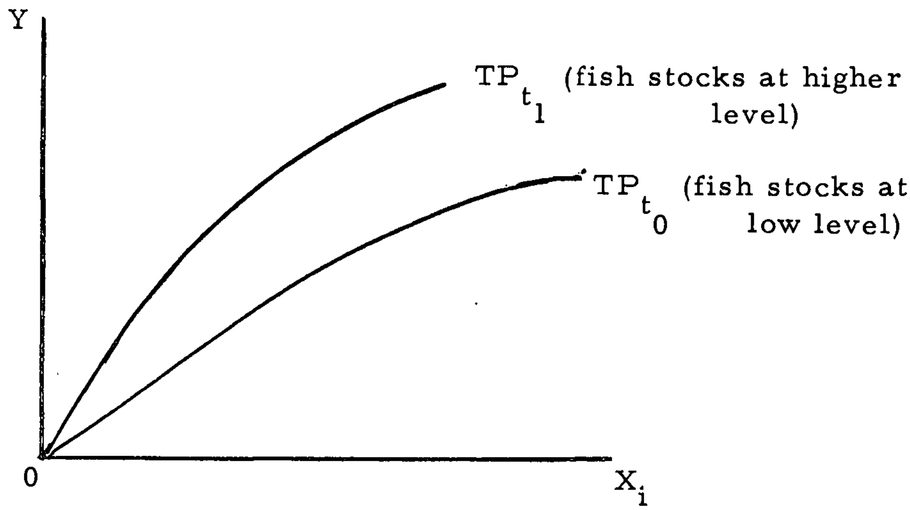

Figure 3. Two different assumptions about the production function.

Output levels increase for the lucky catch in time period $\underline{t_1}$, making it less costly to catch the fish. The cost curves then shift downward and to the right, to MC_{t_1} and SAC_{t_1} (Figure 4). In time period $\underline{t_0}$, the smaller salmon output would make it more costly to catch the fish. The cost curves then shift upward and to the left, to MC_{t_0} and SAC_{t_0}. It can be restated that the supply curve shifts downward and to the right to S_1S_1 in time period $\underline{t_1}$, and shifts upward and to the left to S_0S_0 in time period $\underline{t_0}$ (Figure 5).

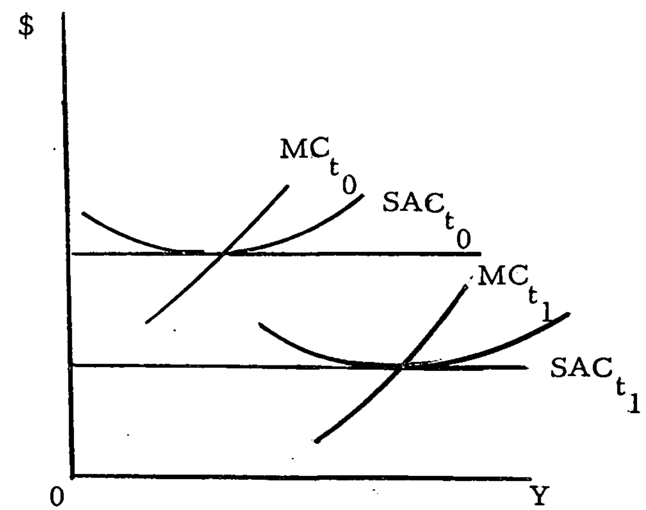

Figure 4. The effects on cost curves of changes in fish stocks.

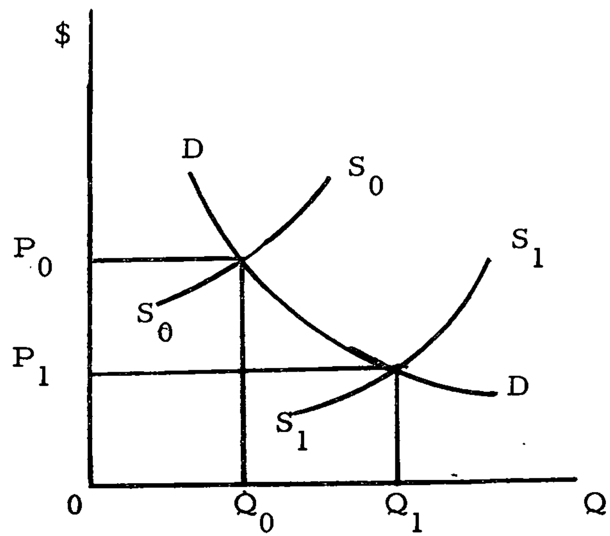

Figure 5. The effect on supply curves of changes in fish stocks.

Elasticity of Demand and Rent Maximization. Changes in cost curves due to the changes in salmon stocks will necessarily effect the profit or rent for fishing firms in each time period. In time period $\underline{t_0}$, the cost curves shift upward because the factors are less productive in that year due to the decline in fish stocks. An upward shift in the cost curves of firms must decrease industry output as fishing gets worse. The effect is reversed as fishing gets better. Downward shifts in the cost curves of firms occur in the time period $\underline{t_1}$.

Given the demand curve (DD) for salmon, the output level will drop to Q_0 from Q_1 (Figure 5) and the equilibrium price will increase from P_1 to P_0 in year year $\underline{t_0}$. In the same manner, the equilibrium price drops down from P_0 to P_1 in the year $\underline{t_1}$ and the quantity increases from Q_0 to Q_1.

It has been estimated in other studies that the demand for salmon is elastic. The analysis of Wood's thesis (1970) indicates that the price elasticity for canned salmon is -3.4. Another study by the Bureau of Commercial Fisheries (1970) supports the hypothesis that the demand for salmon is elastic. This study estimated that the price elasticity for salmon is -1.2971.

With these results, it is possible to examine the change in profit or rent for the fishing firm resulting from the change in salmon stocks in different time periods. To illustrate the behavior of these effects, the cost curves are examined in the period t_0 and t_1.

It has been suggested that as MVP increases in time t_1, to achieve the equilibrium of the firm at MVP = P_x, the firm requires more inputs, and the cost curves will shift down. In the same manner, in time t_0 the firm requires less inputs to maintain the equilibrium at the same price. This relationship, however, is set not only by the density of stocks but also by the different prices of fish. When fish stocks increase, resulting in an increase in supply, the demand for the product can also increase. As this occurs, the equilibrium price falls. Since the demand is elastic, it is signified that the salmon industry would benefit by increasing output. Increased supply will cause total revenue, at least in the short run, to increase because the salmon price will decline less than the quantity will increase. Consequently, in the period of declining fish stocks, the effects would be symmetric. Decreased supply will cause the price to go up, but less than the quantity offset, and total revenue will decline.

Under the conditions of declining and increasing total revenue in the fishery, the profits or rents per fishing firm will also be affected. Assuming that the number of firms remains constant, a condition of increased rents per firm will exist in the short time when supply shifts downward (S_1S_1). Consequently, decreased rents per firm will exist in the short time period with supply shifts upward (S_0S_0).

At each optimum position of the fishing firm in the periods described, the firm is producing the product in a quantity such that MC = price or MC = MR. The firm will profit by increasing its output as long as MC < MR, and it would increase production to the point at which MC = MR in order to maximize profits. As long as the profits are still to be shared among the firms, it would attract other firms to the salmon fishery. In other words, additional firms will increase the intensity of fishing effort. With these results, assuming a given stock of fish, there is a decrease in the average catch per unit of effort. This phenomenon seems to describe the situation of the salmon fishery in the Pacific West Coast up to the present. In this argument, it may simply reflect a large increase in the effort and a small sharing of the total catch by more fishing firms. In the traditional theory, firms would stop entering when TR = TC, or MC = AC, which is the point where sales or revenue equals all production costs. The profits are zero so that no entry or exit takes place in the industry. The equilibrium position of the industry has emerged. With this result, the industry must satisfy the identity, quantity demanded = quantity supplied.

<u>The Fixed Assets Approach</u>

The fixed assets model has been developed to better explain supply response and output behavior. It attempts to explain the input usage in the firm under the condition of imperfect factor markets which results in some degree of asset fixity.

As pointed out, the traditional resource allocation model explains the resource combination by treating the resources in the economy as perfectly mobile, and transfer cost as zero. If for some reason, transfer costs are not zero, and the resources are not perfectly mobile, the concepts of acquisition cost and salvage value are helpful in explaining the use of factors within firms or industries. As it is defined by Hathaway (7, p. 111), acquisition cost is what a farm operator (or the industry) has paid for a production asset or would have to pay in order to acquire more of a particular productive asset (input). Salvage value is what the farm operator (or the industry) could get for the asset (input) if it were sold rather than used in farm production.

If there is a large difference between acquisition cost and salvage value, there may be no incentive to change the quantity of input usage even though a change in physical productivity has occurred. The result would be the same in the case of a fishery as in agriculture. Once inputs such as fishing boats enter the fishery, they may tend to remain in use and have little opportunity to transfer outside the fishery. For the labor resource, especially in the remote fishing areas in Alaska, the characteristics of old age and low education may significantly cause the mobility of the resource to be low. Thus, the actual phenomenon of change in resource usage may be better explained by considering the conditions of imperfect factor markets, i.e., markets in which firms must buy and sell the inputs at different prices ($P_{acq} \neq P_{salv}$).

Assumptions. The assumptions used to develop the fixed asset model are similar to those in the traditional model except that we need to recognize the condition of imperfect factor markets. Therefore, assumption 2 of the traditional model should be changed to show that $P_{acq} > P_{salv}$.

The Model. Given the same production functions for a high level of fish stocks (time $\underline{t_1}$) and a low level of fish stocks (time $\underline{t_0}$) as shown in Figure 3, the problem of determining input usage in the different periods can be investigated as follows.

The model describing equilibrium levels of fishing effort in terms of MVP, acquisition cost, and salvage value is shown in Figure 6. In the theoretical concept of fixed asset theory, the MVP is bounded by acquisition cost and salvage value when the firm is in equilibrium. Shifting MVP upward or downward (as in the manner of changes in fish stocks) may not result in changes in

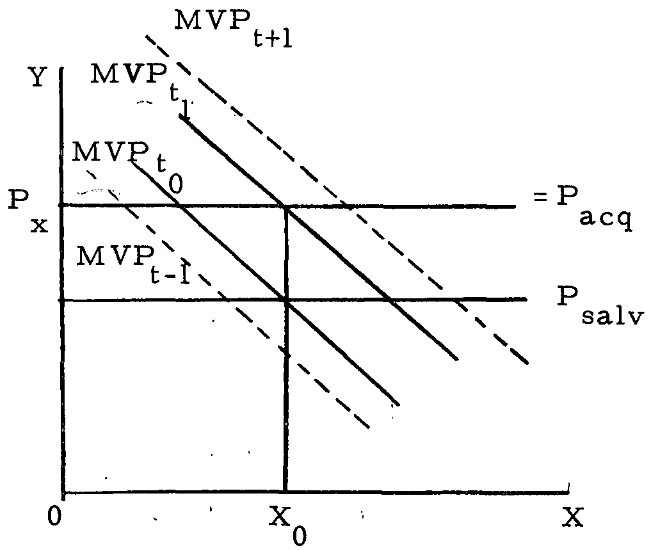

Figure 6. Input usage under the concept of fixed asset theory.

input usage.

For example, the realization of TP_1 in time period $\underline{t_1}$ guided the firm to produce at the level of inputs where $MVP_{t_1} = P_{acq}$ at the X_0 level of inputs to satisfy the equilibrium condition. But if the lower production function of TP_0 is expected in time period $\underline{t_0}$ (the period of unlucky catch), the MVP would shift downward and to the left (MVP_{t_0}). Here the firm would still use inputs at the level X_0 (where $MVP_{t_0} = P_{salv}$) to achieve the equilibrium of the firm. This would happen because the firm could not dispose of the less productive resource at a value equal to its acquisition cost. Thus the divergence of acquisition cost and salvage value will indicate the degree of asset fixity. The lower is the salvage value, the more highly fixed are the assets in the production process.

If the MVP shifts out of the bounded region of P_{acq} and P_{salv}, the input usage may increase or decrease (MVP_{t+1}, MVP_{t-1}). It is therefore possible to state that as fishing improves, the input usage could increase or remain constant, while as fishing gets worse, the input usage could decrease or remain constant. Although the change in fish stocks may cause the MVP to shift upward and downward, it is possible to show with the fixed asset theory that a firm could product different amounts of fish in time $\underline{t_1}$ and $\underline{t_0}$ by using the same amount of input.

Hypotheses

The purpose of the models described above has been to establish hypotheses about resource allocation in the salmon fishery on the Pacific West Coast. Various relationships among acquisition costs, salvage values, and marginal value productivities have been discussed. These elements influence resource employment under conditions of increasing and decreasing salmon stocks over time. Obviously, the results of the developed theories indicate that there are many variables which effect the change in resource usage in the salmon fishery. However, it may be desirable to consider some major variables which affect resource employment.

The following hypotheses are formulated about the effect on fishing effort of the more important variables.

Time Series Data

The statistical model is that the change in input usage for the salmon fishery between year t+1 and year t is dependent upon the change in the amount of salmon landings between year t-1 and year t, and upon the cyclical nature of the fishery in year t+1, or:

$$(10)\ X_{i_{(t+1)}} - X_{i_{(t)}} = f\,[L_{(t)} - L_{(t-1)},\ C_{(t+1)}]$$

where

X_i = fishing effort, measured in (a) number of fishermen and (b) tonnage of vessels.

L = salmon landings, measured in pounds.

C = cyclical nature of the fishery.

Time series data between 1947 and 1966 are available for seven Bureau of Commercial Fishery regions (Southeastern, Central, and Western in Alaska; Puget Sound and the Coastal District in Washington; the Coastal District in Oregon; and the Columbia River).

Assume we have estimated the linear relationships between fishing effort and quantity of salmon landings plus the cyclical nature of the fishery. The linear form is given by:

$$(11)\ X_{i_{(t+1)-(t)}} = \hat{\beta}_0 + \hat{\beta}_1 L_{(t)-(t-1)} + \hat{\beta}_2 C_{(t+1)}$$

where

$\hat{\beta}_0$ is the ordinate of the trend and $\hat{\beta}_1$ and $\hat{\beta}_2$ are the partial regression coefficients.

The coefficients or parameter estimates, $\hat{\beta}_1$ and $\hat{\beta}_2$, are expected to have positive signs. They would reflect the rate of change of X with respect to change in L, $(\frac{dX}{dL})$, holding constant the influence of C, and the rate of change in X with respect to change in C, $(\frac{dX}{dC})$, holding constant the influence of L.

The hypotheses that can be tested are that $\beta_1 = 0$ and $\beta_2 = 0$. These hypotheses can be tested for each of the seven regions.

As a matter of fact, the partial regression coefficients are not only dependent upon the variables L and C, but also on other variables. Unfortunately, some of the latter factors were not capable of measurement in this study and hence, they had to be disregarded. The major variables that we would like to measure, but cannot, are those which reflect the divergence between acquisition costs and salvage value of the resource, X. These factors not included directly in the statistical model would be quite relevant in understanding the conditions leading to changes in resource usage in the salmon fishery. The observed statistics, however, indirectly reflect the combined effect of a great variety of factors which may influence the change in resource usage. Since the salvage value of an input is generally smaller than its acquisition costs, and since acquisition costs (especially for vessels) may be fairly similar between regions, it might be possible to indirectly observe whether or not salvage values between the regions are equal. Since the slope of each regression line is also influenced by this unmeasured factor, differences in flatness or steepness of the curves may indicate the fixity or mobility of resources in the various regions.

Thus, a second hypothesis that can be tested with the time series data is:

$$(12)\ \hat{\beta}_{11} = \hat{\beta}_{12} \ldots = \hat{\beta}_{17}, \text{ and}$$

$$(13)\ \hat{\beta}_{21} = \hat{\beta}_{22} \ldots = \hat{\beta}_{27},$$

where

$\hat{\beta}_{ij}$ is the point estimate of the i^{th} parameter,

$\dfrac{dX_{i(t+1)-(t)}}{dL_{(t)-(t-1)}}$, in one of the seven fishing regions (j).

This is an attempt to consider indirectly the differences in salvage values between regions and the effect of these differences on the mobility of the resources.

Cross Section Data

Since data on unemployment rates and the distance of the salmon fishing regions to the major labor markets are capable of measurement and may differ between the regions at a given time and hence, may affect resource mobility, a more direct test of the hypothesis just discussed may be possible. The model for testing the hypothesis is:

$$(14)\quad \Delta X_{i_{(t+1)-(t)}} = f\,[\Delta L_{(t)-(t-1)},\ C_{(t+1)},\ U_{(t+1)},\ D]$$

where

X_i = fishing effort, i. e., the number of fishermen and tonnage of fishing vessels,

L = the total amount of salmon landings,

C = cyclical nature of the fishery,

U = unemployment rate of the civilian labor force in the major labor market,

D = distance from center of salmon fishing activity to the nearest major labor market.

The linear equation is formulated as:

$$(15)\quad \Delta X_{i_{(t+1)-(t)}} = \hat{\beta}_0 + \hat{\beta}_1 L_{(t)-(t-1)} + \hat{\beta}_2 C_{(t+1)} + \hat{\beta}_3 U_{(t+1)} + \hat{\beta}_4 D,$$

where

$\hat{\beta}_0$ is the ordinate of the trend and $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$ are the partial regression coefficients.

The coefficients or parameters estimates, $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$, all are expected to have positive signs. The hypotheses that can be tested directly with the cross section data are that $\beta_1 = 0$, $\beta_2 = 0$, $\beta_3 = 0$ and $\beta_4 = 0$.

III. SOURCES OF DATA AND MEASUREMENT OF VARIABLES

Statistical data were collected for each region to describe salmon landings, the cyclical nature of the fishery, unemployment rates, and the distance from the major fishing activity to major labor markets. These variables were expected to be helpful in explaining the determination of the size of the labor force and the tonnage of vessels in salmon fishing.

Labor

The number of commercial fishermen in the salmon fishery has been increasing over the past two decades. The total number of salmon fishermen in Alaska, Washington, Oregon, and California increased from 18, 058 to 29, 609 persons fishing by means of purse seines, gill nets, troll lines, and other small boats between 1947 and 1966.

"Fishermen" have been defined by the Bureau of Commercial Fisheries (11, 1964, p. 505) as all persons engaged in commercial fishing operations both on vessels and on-shore. Usually on-shore fishermen in most areas have been divided into "regular" and "casual". Regular fishermen are defined as those who receive more than one-half of their annual income from fishing, whereas casual fishermen are those who receive less than one-half their annual compensation from fishing. Unfortunately, this definition has not been used to separate regular from casual fishermen on the Pacific Coast. Therefore, the data on labor will be a weak point and a source of error in the statistical models.

Data series from the publications of the Bureau of Commercial Fisheries (11) were observed from 1947 through 1966, although the observations for 1957 and 1958 in southeastern and Central Alaska and some periods in California have been neglected because the statistics were not available.

Since there was some duplication in the number of fishermen in the various regions, the data have been deflated in order to reduce the duplication. For example, some fishermen fish in more than one region, so adding the number of fishermen in the Puget Sound and in the Coastal region of Washington results in a number that is larger than the actual total of fishermen in the two regions. These adjusted data were available for the troll fishery from 1960 through 1966, and for purse seiners for 1964 through 1966 (11). Averages for these periods were used to reduce the observed numbers of fishermen in each region in previous years.

Capital (net tonnage)

The other measure of inputs into the fishery is capital investment. This variable was also defined in terms of data from pubications by the Bureau of Commercial Fisheries (11). The variable was defined as tonnage of fishing vessels, which is the basic unit of the harvesting process. As in the labor force, the tonnage of fishing vessels in the salmon fishery has increased markedly. The data showed that in Alaska, Washington, Oregon, and California altogether, about 47, 264 net tons were devoted to salmon fishing in 1947. There were about 82, 663 net tons by 1966.

The data on vessels were also deflated in order to avoid the duplicated numbers in the regions. Observations for 1957 and 1958 in Southeastern and Central Alaska and for several years in California were not available.

For 1960-1966, the statistical format reported fishing vessels in gross tons instead of net tons as previously reported. To cause the units of tonnage to be the same for all years, a conversion factor for all salmon vessels was requested from the Bureau of Commercial Fisheries. The conversion equation which they estimated was: Net Tonnage = 0.592 + 0. 671 (Gross Tonnage). Therefore, the gross tonnage reported in 1960-1966 was made equivalent to the net tonnage data for previous years by using this equation.

In addition, an adjustment was made in the data on fishing boats. These are defined by the Bureau of Commercial Fisheries as craft having capacities of less than five net tons in the format reported in 1947-1959 or a capacity of less than five gross tons in

1960-1966. Fishing craft larger than this limit are defined by the Bureau of Commercial Fisheries as vessels. The data on number of fishing boats were converted to tonnage data as follows: the number of boats in the 1947-1959 period was multiplied by 2 tons, and the number of boats in the 1960-1966 period was multiplied by 2 tons. These were assumed to be average tonnages for salmon boats.

Landings (thousands of pounds)

The data on quantity of salmon landings on the Pacific Coast include the five major commercial species. These species range from Monterey Bay, California, to the Bering Sea. The five species of Pacific salmon which compose the commercial catch are chinook or king; red or sockeye; pink; coho or silver; and chum or keta.

The trend in production of salmon landings in the Pacific areas has seriously declined. Total catch decreased from 498.0 million pounds to 387.5 million pounds between 1947 and 1966. The quantity of salmon landings in the United States has varied between 201.7 million pounds and 498.0 million pounds over the 1947-1966 period.

The landing data series was available from the publications of the Bureau of Commercial Fisheries (11) between 1947 and 1966.

Cyclical Nature

In the attempt to explain changes in resource usage in the salmon fishery, observations on the cyclical nature of the fishery should be one helpful variable. For certain species, particularly salmon, the life cycle is of fundamental importance in determining the seasonal landings. Decisions by fishermen as to whether to enter or leave the fishery might be affected by this factor.

The various species differ notably in certain characteristics and natural habits: The timing of major runs of each species is subject to its life history which varies among species. The usual life period for king salmon is 4 to 6 years. The life cycle is 3 to 5 years for sockeye in the Puget Sound, but is 4 to 6 years in Alaska. The life period is usually 3 or 4 years for silver or coho, 3, 4 or 5 years for chum, but is invariably 2 years for pink salmon. Usually pinks are greatly abundant in odd years in the Puget Sound while in even years, very few are captured.

The cyclical nature was represented as a dummy variable in the models. It was a judgment variable which was made possible by the Bureau of Commercial Fisheries Yearbook (11) narrative descriptions of salmon runs in various regions in the preceding year. The dummy variable was introduced as <u>1</u> for all expected good runs, whether or not a good run actually occurred, and <u>0</u> for all expected bad runs. This variable was not measured in the coastal districts of Washington, Oregon, or California, or for the Columbia River because these are coho regions. Although this species has a three or four year life cycle, the runs in these regions did not vary as much from year to year as did some of the other species, notably pink salmon.

Unemployment Rate

One of major variables in explaining the degree of asset fixity in the salmon fishery is expected to be the unemployment rate. This belief is based on the possibility that more poverty and immobility exists in those areas where the unemployment rate is relatively high. Thus, this variable might be a reasonable one to enter the models in order to explain the behavior of resource use in terms of acquisition costs and salvage values.

The unemployment rate data were observed from publications of the U.S. Department of Labor (10). Data were available between 1957 and 1966 for the following principal cities in the salmon fishing states: Portland, Oregon; San Francisco, California; and Seattle, Washington. Data for Seattle were only available between 1958 and 1966. Also, the data source gave unemployment rates for "Alaska" rather than for any city in that state.

Distance

The distance from the center of the salmon fishing activity to the nearest major labor market was used as a possible explanation for resource fixity in the fishery. It would probably be that the greater the distance, like Alaska, the lower might be the resource mobility than for smaller distance areas like Washington, Oregon, and California. These areas are nearer major labor markets.

The distances from the center of salmon fishing activity in each region to the nearest major labor market were estimated by using maps. Distance was measured in air miles in Alaska, and in road mileage in other regions. The geographic centers of activity in the Alaska regions and in Puget Sound were estimated by weighting the salmon pack at various ports by the distance to the major labor market. The other centers were identified with the assistance of Marine Advisory Agents at Oregon State University.

All the data described above are measured to show how the movement of the independent variables such as landings, cycle, unemployment rate and distance influence the change in labor and capital investment (vessels) in the salmon fishery. These variables entering the equations in this study are hoped to explain resource behavior as mentioned in Chapter II. All the data cited are shown in the Appendix.

IV. ANALYSIS OF THE DATA

An investigation of the functional relationships for resource usage in the salmon fishery is implied by the statement of hypotheses. In this part, an attempt will be made to estimate the models in order to obtain a statistical explanation of the relationships between variables which directly and indirectly affect the fishing labor force and number of fishing vessels. The models are estimated by the method of step-wise linear regression. Models using time series data and combined cross section-time series data will be formulated and the selection of regions and time periods will be discussed. The results of the trial runs of each model are presented, and the conversions to index numbers for landings, labor force and vessels in the cross section models are explained. In addition, the interpretation of results is also described in more detail.

Time Series Models

Selection of Regions and Time Periods

The time series data entering into the models were gathered from seven salmon fishing areas: Southeastern, Central, and Western in Alaska, Puget Sound and Coastal in Washington, Columbia River in Washington and Oregon, and Coastal in Oregon. The reason for selecting these seven regions was because the regions are those which the Bureau of Commercial Fisheries has defined for data collection purposes.

It would pertain to the hypotheses to compare the relationships for the various regions. The purpose of this would be to measure the degree of consistency of the hypotheses and to observe the behavior of changes among the variables that would affect resource mobility in the salmon fishery. In other words, it is the desire to determine whether or not differences in change in resource use with respect to associated factors exist in various regions. Obviously, many variables may influence the change in resource use in the fishery. Some variables are not directly quantifiable through the period of analysis. There were some major quantifiable variables, however, for which data were reasonably available. These variables include the fishing labor force, net tonnage of vessels, quantity of salmon landings, and the cyclical nature of the fishery.

The selection of time periods was also considered. In the time series models, the yearly observations covered the period from 1947 through 1966. The reasons for selecting this time period are the adequacy of the statistics and the desire to obtain current data. Data from the World War II period were not used.

First Run

The first estimation of the relationships for the seven regions in the salmon fishery was in accordance with the hypotheses mentioned in Chapter II.

$$(16)\ \Delta X_{i_{(t+1)-(t)}} = f\ (\Delta L_{(t)-(t-1)},\ C_{(t+1)})$$

It was assumed that the functions represented by the equations were linear; thus the model was estimated in the following linear form:

$$(17)\ \Delta X_{i_{(t+1)-(t)}} = \hat{\beta}_0 + \hat{\beta}_1 \Delta L_{(t)-(t-1)} + \hat{\beta}_2\, C_{(t+1)}$$

The methodology employed a step-wise multiple regression technique, using the least squares method. The first run regression results, including parameter estimates and t-values (in parentheses), are shown in Table 2.

The results of the first computer run were very discouraging, since the prior expectation was that the partial regression coefficients would all be positive. That is, the signs of the estimated parameters were often inconsistent with the hypothesis. Most of the t-values and R^2 values were very low.

Table 2. First run regression results from time series data. 1/

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ $[L_{(t)-(t-1)}]$	$\hat{\beta}_2$ $[C_{(t+1)}]$	R^2	N
Alaska:						
Southeastern	X_1 2/	-67.582	-0.002	+34.395	0.028	15
			(-0.514)	(0.078)		
Central	X_1	340.325	+0.005	-138.475	0.067	15
			(0.711)	(-0.215)		
Western	X_1	30.919	+0.006	+438.367	0.341	18
			(1.713)	(1.673)		
Washington:						
Puget Sound	X_1	-863.018	-0.016	+1,214.041	0.598	18
			(-1.519)	(2.896)		
Coastal	X_1	7.361	-0.016	4/	0.023	18
			(-0.608)			
Columbia River:	X_1	-55.786	+0.008	4/	0.004	18
			(0.267)			
Oregon:						
Coastal	X_1	-9.989	+0.019	4/	0.052	18
			(0.933)			

Continued

Table 2--Continued.

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ $[L_{(t)-(t-1)}]$	$\hat{\beta}_2$ $[C_{(t+1)}]$	R^2	N
<u>Overall Region</u>:	X_1	-538.631	-0.004 (-0.596)	+756.194 (0.888)	0.080	
<u>Alaska</u>:						
Southeastern	X_2 3/	-128.167	-0.017 (-0.914)	+422.748 (0.203)	0.091	15
Central	X_2	523.889	+0.013 (0.634)	+52.875 (0.028)	0.038	15
Western	X_2	128.602	-0.002 (-0.279)	-31.859 (-0.055)	0.006	18
<u>Washington</u>:						
Puget Sound	X_2	-2,285.114	-0.039 (-1.573)	+3,364.873 (2.447)	0.549	18
Coastal	X_2	105.298	+0.053 (0.629)	4/	0.024	18
<u>Columbia River</u>	X_2	116.792	+0.116 (2.165)	4/	0.226	18

Continued

Table 2--Continued.

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ $[L_{(t)-(t-1)}]$	$\hat{\beta}_2$ $[C_{(t+1)}]$	R^2	N
Oregon:						
Coastal	X_2	112.924	+0.061 (0.663)	4/	0.027	18
Overall Region:	X_2	-2,475.171	-0.006 (-0.276)	+5,492.435 (1.909)	0.214	18

1/ The numbers in parentheses are t-values of the partial regression coefficients.
2/ Fishermen.
3/ Net tonnage of vessels.
4/ Not estimated because major cyclical runs are not important in these regions.

Second Run

In order to explore the relative effect on fishing effort of the independent variables, the definitions were changed slightly. The regressions were again determined by a step-wise procedure as in the other models. The model presented in the second run made some change in definition of the time periods. That is, the change in resource use between years t and t-1 was hypothesized to be dependent upon landings in year t-1 and the cyclical nature in year t, or

$$(18)\quad \Delta X_{i_{(t)-(t-1)}} = f\,(L_{(t-1)},\ C_{(t)}).$$

The linear functional form for the second computer run was formulated as:

$$(19)\quad \Delta X_{i_{(t)-(t-1)}} = \hat{\beta}_0 + \hat{\beta}_1 L_{(t-1)} + \hat{\beta}_2 C_{(t)}.$$

Detailed results of the step-wise regressions for the second run are given in Table 3. The numbers in parentheses are the "t-values" of the partial regression coefficients.

Interpretation of Results

Similar results were obtained for the two computer runs. However, generally, the results of the second computer run show a little greater explanatory power, especially about the consistency

Table 3. Second run regression results from time series data. 1/

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ (L_{t-1})	$\hat{\beta}_2$ (C_t)	R^2	N
Alaska:						
Southeastern	X_1 2/	-408.246	+0.005 (0.845)	+14.271 (0.031)	0.054	16
Central	X_1	-381.314	+0.006 (0.739)	-150.574 (-0.256)	0.061	16
Western	X_1	-292.189	+0.005 (0.982)	+597.348 (2.178)	0.233	19
Washington:						
Puget Sound	X_1	-736.998	-0.002 (-0.146)	+1,289.967 (2.789)	0.418	19
Coastal	X_1	8,642.460	+0.001 (0.063)	4/	0.0002	19
Columbia River:	X_1	56.803	-0.009 (0.605)	4/	0.021	19
Oregon:						
Coastal	X_1	56.478	-0.015 (-0.801)	4/	0.036	19

Continued

Table 3--Continued.

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ (L_{t-1})	$\hat{\beta}_2$ (C_t)	R^2	N
Overall Region:	X_1	-1,780.758	+0.006	+539.071	0.038	17
			(0.706)	(0.563)		
Alaska:						
Southeastern	X_2 3/	336.314	+0.002	+231.450	0.001	16
			(0.077)	(0.102)		
Central	X_2	-2,240.511	+0.028	-11.851	0.099	16
			(1.125)	(-0.007)		
Western	X_2	-160.228	+0.007	-111.476	0.037	19
			(0.668)	(-0.190)		
Washington:						
Puget Sound	X_2	-1,826.300	-0.010	+3,724.045	0.390	19
			(-0.271)	(2.552)		
Coastal	X_2	-329.274	+0.064	4/	0.082	19
			(1.232)			
Columbia River:	X_2	-147.879	+0.018	4/	0.021	19
			(0.603)			

Continued

Table 3--Continued.

Regions	Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ (L_{t-1})	$\hat{\beta}_2$ (C_t)	R^2	N
Oregon:						
Coastal	X_2	541.367	-0.105 (-1.308)	4/	0.091	19
Overall Region:	X_2	-11,458.184	+0.034 (1.498)	+4,750.358 (1.445)	0.212	17

1/ Numbers in parentheses are t-values of the partial regressions coefficients.
2/ Number of fishermen.
3/ Net tonnage of vessels.
4/ Not estimated because major cyclical runs are not important in these regions.

of signs and the size of t-values. The landings variable shows 11 positive and 5 negative signs in the second run, while it exhibited 8 positive and 8 negative signs in the first run. The cyclical nature variable obtained 7 positive and 3 negative signs in the second run and 8 positive and 2 negative signs in first run. Most of the t-values in the second run were improved over the first run, but the equations tend to have lower R^2 values in the second run than in the first run. In general, the comparison of these two runs indicates that the estimated parameters displayed a mixture of signs. Most of the coefficients are smaller than their standard errors. In both results, the t-values and also R^2 values were generally very low. The parameter estimates did not achieve the significant level of reliability. Therefore, very little can be concluded about the statistical significance of the parameters of the equations in time series models.

Combined Cross Section-Time Series Models

Selection of Regions and Time Periods

The time series models were not adequate for testing the hypotheses that the characteristics of the salmon fishery in one region are different from another region. The equations generally did not correspond to prior expectations. Most of the regression coefficients take on a mixture of signs and are not significant, and R^2 values were quite low. Therefore, cross section and time series data were combined to estimate the regression coefficients. An attempt was made to test the hypothesis of asset fixity more directly by adding the unemployment rate and distance variables. The data were gathered for the following regions: Southeastern, Central, and Western in Alaska; Puget Sound and Coastal in Washington; Columbia River in Washington and Oregon; Coastal in Oregon; and Northern, San Francisco, and Monterey in California. Yearly observations covering the period from 1957 to 1966 were used for each region. The reason for selecting this time period was because the unemployment data were available for all regions since 1957.

Conversion to Index Numbers

Some of the variables entering the cross sectional models were put on an index number basis because the fishing regions varied greatly in size of the fishery. To convert the variables to index indicators would reduce the dispersion due to size of the fishery, and would cause a clustering effect among the small and large values of the variables entering the models. Three variables (fishing labor force, vessel tonnages and quantity of landings) were placed on an index basis.

Third Run

To evaluate the effect on fishing effort of movements of the variables selected for the cross section analysis, the following model was formulated:

$$(20)\quad \Delta X_{i_{(t+1)-(t)}} = f\,(L_{(t)},\ C_{(t+1)},\ U_{(t+1)},\ D)\,.$$

The linear equation in the model was estimated in the form:

$$(21)\quad \Delta X_{i_{(t+1)-(t)}} = \hat{\beta}_0 + \hat{\beta}_1 L_{(t)} + \hat{\beta}_2 C_{(t+1)}$$

$$+ \hat{\beta}_3 U_{(t+1)} + \hat{\beta}_4 D\,.$$

The third run regression results, including parameter estimates and t-values, are presented in Table 4. The results of third computer run were still generally inconsistent with the hypotheses. Many wrong signs and very low R^2 and t-values were obtained. The estimated parameters remained incompatible and disagree in direction of signs.

Fourth Run

Hence, the equations were adapted to another form. The equation presented has made some change in the structure of time periods. The formulated model has been fitted with the implication

Table 4. Third run regression results from combined cross section and time series data. 1/

Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ (L_t)	$\hat{\beta}_2$ (C_{t+1})	$\hat{\beta}_3$ (U_{t+1})	$\hat{\beta}_4$ (D)	R^2	N
Fishermen (X_1)	15.41	-0.06 (-1.15)	+6.48 (1.19)	-1.56 (-1.09)	+0.01 (0.85)	0.05	80
Tonnage of vessels (X_2)	19.88	-0.11 (-2.29)	-0.71 (-0.14)	-1.12 (-0.87)	+0.01 (0.83)	0.08	80

1/ Numbers in parentheses are t-values of the partial regression coefficients.

of a hypothesis that:

$$(22)\ X_{i_{(t+1)}} = f\,(L_{(t)},\ C_{(t+1)},\ U_{(t+1)},\ D).$$

The following linear equation was used to estimate the parameters:

$$(23)\ X_{i_{(t+1)}} = \hat{\beta}_0 + \hat{\beta}_1\ L_t + \hat{\beta}_2\ C_{(t+1)} + \hat{\beta}_3\ U_{(t+1)} + \hat{\beta}_4\ D.$$

These are the regression models for the fourth computer run. The detailed results are given in Table 5.

The results of the adapted model in the fourth run were strengthened. That is, some estimated parameters agreed with prior expectation in direction of sign. The equations as a whole obtained higher R^2 values. The t-values on the coefficients for landings are reliable for statistical significance. Generally, the parameters seem to comply with the expected model.

In order to assist in a better understanding of the factors that affect the mobility of resources in the fishery in different situations of salmon stocks and landings, the observed variables were classified into two groups, that is, the years with landings increasing ($L_t > L_{t-1}$) and the years with landings decreasing ($L_t < L_{t-1}$). Thus, the 80 yearly observations were divided into 42 observations on increased landings and 35 observations on decreased landings. Three observations could not be used in this way. The computation of these regression results is also included in Table 5.

Table 5. Fourth run regression results from combined cross section and time series data. 1/

Regressor	$\hat{\beta}_0$	$\hat{\beta}_1$ (L_t)	$\hat{\beta}_2$ (C_{t+1})	$\hat{\beta}_3$ (U_{t+1})	$\hat{\beta}_4$ (D)	R^2	N
X_1 2/	85.88	+0.19 (3.40)	+6.48 (1.15)	-1.00 (-0.68)	+0.009 (0.51)	0.14	80
X_2 3/	89.95	+0.19 (3.25)	+6.25 (1.06)	-1.89 (-1.22)	+0.02 (0.93)	0.13	80
X_1 (Increased landings)	77.33	+0.31 (3.26)	-2.41 (-0.26)	-2.51 (-1.17)	+0.04 (1.24)	0.24	42
X_2 (Increased landings)	84.43	+0.32 (3.26)	-6.41 (-0.68)	-4.46 (-1.99)	+0.05 (1.95)	0.28	42
X_1 (Reduced landings)	102.90	+0.03 (-0.43)	+10.77 (1.62)	-1.37 (-0.64)	+0.005 (0.25)	0.08	35
X_2 (Reduced landings)	99.39	-0.002 (-0.003)	+1.15 (1.89)	-0.19 (-0.09)	-0.005 (-0.25)	0.13	35

1/ The numbers in parentheses are the "t-values" of the partial regression coefficients.
2/ Fishermen.
3/ Net tonnage of vessels.

Interpretation of Results

Landings. The test results in Table 5 for the 80 observations were that the slope of the regression line for the labor equation, $\frac{\partial X_{1(t+1)}}{\partial L_{(t)}} = 0.19$, and for the vessels equation, $\frac{\partial X_{2(t+1)}}{\partial L_{(t)}} = 0.19$. This means that the index value of X_i increases 0.19 units for each index unit increase in L. These can be converted into elasticities which indicate the percent change in the resources that can be expected as a result of a one percent index change in landings. The elasticities are derived from the regression coefficients, $\frac{\partial X_{i(t+1)}}{\partial L_{(t)}}$, multiplied by $\frac{\bar{L}}{\bar{X}_i}$ 1/. The elasticity results obtained were 0.1829 for labor and 0.1829 for vessels. The interpretation of the elasticities should be that, if a one percent increase in landings occurs in year t, other things remaining the same, labor and vessels would increase in the fishery by 0.18 percent in year t+1. The R^2 values of 0.14 and 0.13 were obtained for the labor and vessels equations, respectively, indicating that the independent variables explained 14 percent of the labor variation and 13 percent

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1/ $\bar{L}$ = average value of landings, and $\bar{X}_i$ = average value of the i^{th} resource.

of the vessel variation between 1957 and 1966. The landings coefficients yielded t-values of 3.40 for labor and 3.25 for vessels which are significant at the 0.01 probability level.

The above results are the average rates of change of resource use for each unit change in the index of landings in the salmon fishery, regardless of whether landings are increasing or decreasing. The rates of change in the periods where $L_t > L_{t-1}$ and $L_t < L_{t-1}$ are quite obviously different. The equations for the period $L_t > L_{t-1}$ obtained the landings coefficients of 0.31 for labor and 0.32 for vessels. The elasticities obtained were 0.35 for labor and 0.34 for vessels. The results indicate that, in the periods of "fishing gets better," if a one percent increase in landings occurs in year t, other things unchanged, labor and vessels would increase 0.35 and 0.34 percent, respectively, in year t+1. The regression equations obtained R^2 values of 0.24 for labor and 0.28 for vessels, indicating that the independent variables explained 24 percent of the labor variation and 28 percent of the vessels variation during the period of increased landings. The reliability of the coefficients are significant at the 0.01 probability level.

In the years with reduced landings ($L_t < L_{t-1}$), the equations obtained very small changes in resource use for each index unit change in landings. The elasticities obtained were 0.0246 for labor and -0.0016 for vessels, indicating that, in the periods of "fishing gets worse", if a one percent decrease in landings occurs in year t, other things unchanged, labor would decrease 0.0246 percent in year t+1 while vessel tonnage would be 0.0016 percent higher in the same period. The sign for the landings parameter remained negative for the vessel equation. The standard errors were much larger than the parameter estimates, so t-values were very low. Thus the landings variable is not satisfactory to explain the change in labor and vessels in the periods $L_t < L_{t-1}$. The regression equations explained only eight percent of the variation for labor and 13 percent for vessels.

In general, the landing variables agree in direction of sign with the statement of hypotheses. It indicated that a positive slope exists for changes in X with respect to change in L. The elasticities of the regression lines are smaller than one, telling that one percent changes in landings would result in changes in resource usage smaller than one. A difference prevailed between the landings coefficients in the time periods of "fishing gets better", $L_t > L_{t-1}$, and the time periods of "fishing gets worse", $L_t < L_{t-1}$. The importance of this difference can be related to the theory discussed in Chapter II. That is, the model seems to be consistent with the concept of fixed assets theory. The results point out that very little change occurs in resource use under the conditions of reduced landings. In the years with increased landings, the change in resource use is positive. We may say that labor and vessels have a high level of asset fixity in the periods of reduced landings. That indicates that the salvage value of the fishermen and fishing vessels may be low. This has brought about the situation that the resources in the salmon fishery are less mobile in periods of reduced landings than in the periods of increased landings.

Cyclical Nature. Result for the cyclical nature variable also tends to conform with the hypothesis that $\frac{\partial X_{i(t+1)}}{\partial C_{(t+1)}}$ would be positive. In general, the parameters estimated remain consistent and agree in direction of sign, indicating that an expected large run of salmon will tend to increase resource usage in the fishery. Adding the dummy variable, $C_{(t+1)}$, in the equations exhibited a negative sign only in the period of "fishing gets better", but the t-values in this period are very low and not significant. Hence, the dummy cyclical variable was not a significant factor in the period of "fishing gets better". The coefficients for the overall observations and periods of reduced landings are significantly different from zero, for both labor and vessels equations, at the 0.30 and 0.10 probability level, respectively.

Unemployment Rate. Results of the unemployment variable were unexpected because the parameters estimated are all negative. The t-values for the overall observations for the labor equation and for both equations in the period of reduced landings were very low and not significant, although the estimate was significantly different from zero at 0.30 probability level in the overall observations for the vessel equation. In the period of increased landings, the parameters estimated are significantly different from zero at the 0.30 and 0.10 probability levels for labor and vessels, respectively. Since the signs of the parameters remain inconsistent, little can be concluded about the statistical significance of this variable in the salmon fishery between 1957 and 1966.

<u>Distance.</u> Most of the positively signed distance parameters agree with prior expectations. They displayed the positive effect of $\frac{\partial X_{i(t+1)}}{\partial D}$. For the vessel equation in the period of fishing gets worse, the parameter estimate showed a negative sign which is inconsistent with the hypothesis. Considering the results of low t-values in most of the equations, except in the period of increased landings, the parameter estimates are not highly significant. The estimates are significantly different from zero only at the 0.30 and 0.10 probability level for the labor and vessels equations, respectively, in the years of increased landings. Thus, adding distance variables in the models did not add much to the statistical power of the model.

V. SUMMARY AND CONCLUSIONS

The main objectives of this study were to develop the fixed assets model as combined with traditional theory in order to lead to a statement of hypotheses about resource usage in the salmon fishery on the Pacific Coast. The objectives were also aimed at developing models which could be tested statistically and to present the results of such tests.

The models which were developed required both time series and cross section data. The time series variables which were thought to influence the change in resource use between years t+1 and t were the change in salmon landings between years t and t-1, and the cyclical nature of the fishery in the year t+1. This statistical model attempted to explain indirectly the differences in resource mobility among the seven Bureau of Commercial Fisheries regions in terms of differences between acquisition costs and salvage values of the resources. Since data on unemployment rates and distances from the center of salmon fishing activity to the major labor markets were available from 1957 through 1966, it was possible to investigate more directly whether the gap between acquisition costs and salvage values in the salmon fishery affected resource mobility. The change in resource usage between years t+1 and t in the cross section models was postulated to be a function of the change in landings between years t and t-1, the cyclical nature in year t+1, unemployment rates in year t+1, and distance to major labor markets. All the variables in the models were expected to have a positive relation to the change in resource usage.

The equations were solved using least-squares regression techniques. Parameter estimates were obtained for time series models for each of the seven regions and for a combined cross section and time series model which used 80 observations taken from 10 regions between 1957 and 1966. The latter were also divided into 35 observations on years of reduced landings and 42 increased landings observations.

The results of the time series models were generally weak, that is, the parameter estimates revealed a mixture of signs and the R^2 and t-values were very low. None of the parameter estimates reached significance levels. Very little could be concluded about the statistical significance of the parameters in these equations.

Parameters for the cross section models expressed stronger results, that is, the parameters seem to be consistent with the hypothesis, especially in the fourth run (Table 5).

Most of the coefficients for quantities landed displayed a positive effect on resource usage. Thus, it can be concluded that as the quantity of salmon landings increased in year t-1, the number of fishermen and vessels in the fishery will also increase in year _t_. Since most of landing coefficients were larger than their standard errors, the calculated t-values were large enough to reject the hypothesis that the landings coefficients were different from zero.

In general, it can be concluded that a weak positive relationship exists between the cyclical nature of the fishery (a dummy variable) and resource use. If good salmon runs are expected in year _t_, the number of fishermen and vessels will also increase in year _t_. Even though the coefficients were usually larger than their standard errors, the t-values were not large enough to reject the hypothesis that the cyclical coefficient is different from zero.

For all equations, unemployment rates displayed a negative effect on resource usage in the fishery. This was inconsistent with the hypothesis that as unemployment rates increase in year _t_, the number of fishermen and vessels will also tend to increase in year _t_. However, most of the t-values were low so the reliability of the estimated parameters was very weak.

The distance variable obtained a positive effect on resource usage for all equations except for the vessel equation under the conditions of "fishing gets worse". That is, as the distance from the center of the salmon fishing activity to major labor markets increases, the number of fishermen and fishing vessels will also increase. However, the reliability of the estimated parameters was again very weak and not significantly different from zero.

Results of test statistics indicate that the influence of the landings variable on resource mobility in the salmon fishery depends on the time period being considered. With the transformation of the landing coefficients to an elasticity basis, the high elasticities under the conditions of "fishing gets better" imply that resources are highly mobile in these periods. Some resources from outside the fishery will transfer to the fishery when their MVP is higher there in periods of increased fish landings. Firms would expect increased rents as a result of the downward shift in the cost curves in these periods. Since the demand elasticity for salmon is greater than one, it is possible to increase revenue to the fishermen under these conditions.

The very low elasticities under the periods of "fishing gets worse" indicate that very little change takes place in resource employment in the fishery in those periods. The estimated results for the salmon fishery are that only small changes occurred in the years 1957 through 1966. This simply means that salvage values are low in the fishery, especially in the periods of "fishing gets worse". If the resources were transferred to other industries, their MVP would be very low. Lower productivity and increased operating costs would result in periods of declining fish stocks. With the elastic demand for salmon, it signifies that the total revenue in the industry would decline. Of course, the fishermen might share a smaller revenue under these conditions.

The results of this study would indicate that in order to improve the productivity of resource usage in the salmon fishery, the resources must be less fixed. In doing so, consideration should be given to narrowing the gap between acquisition costs and salvage values of resources in the fishery. This gap may be narrowed by the following policies:

Education: One important factor which determines productivity is the existence of a skilled labor force. It is possible that the mobility of factors engaged in the salmon fishery is limited by their skills and ability to earn income outside the fishery. If the MVP of fishermen is lower in the fishery than elsewhere, they would be no better off if they transferred to other labor markets. Because their salvage values are smaller than their present earnings, the fishermen tend to remain "fixed" in the fishery even in the periods of declining MVP. In such situations, it means that the fishery is not operating at its optimum economic level. In order to improve the well being of the fishermen, development of education and training of the fishermen would be a major aid to labor mobility. This recommendation is based on the assumption that labor will be engaged in the occupation where the MVP is the greatest. Thus, training programs to develop a skilled labor force would increase their MVP and enable fishermen to transfer to those industries where their MVP is higher in the periods of "fishing gets worse".

Technological Advancement: The influence of technological advances might be needed in commercial fishing to increase the MVP of fishing vessels in order to narrow the gap between acquisition costs and salvage values. This could be done by introducing new technological changes into the design of salmon fishing vessels. The productivity of the vessels may be increased by new types of design. The vessels will be less "fixed" if the same vessel can be applied to not only salmon fishing but also to other fisheries.

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APPENDIX

Appendix Table 1. Number of fishermen, net tons of fishing vessels, quantity of landings, and expected cyclical nature of salmon runs in Alaska regions.

Year	Southeastern			
	Fishermen 1/ (X_1)	Net tons 1/ (X_2)	Landings 2/ (L)	Cycle (C)
1947	3, 201	11, 323	111, 362	0
1948	4, 998	19, 724	121, 508	0
1949	4, 026	16, 185	231, 897	0
1950	4, 565	19, 838	101, 679	0
1951	6, 151	29, 428	166, 026	1
1952	6, 164	24, 686	104, 501	0
1953	5, 828	20, 789	76, 952	1
1954	5, 277	19, 880	100, 710	1
1955	5, 738	20, 278	73, 135	0
1956	4, 471	20, 348	94, 502	1
1957	3/	3/	77, 487	1
1958	3/	3/	103, 765	1
1959	5, 461	17, 617	68, 710	0
1960	5, 536	14, 586	34, 239	0
1961	5, 133	18, 311	102, 565	0
1962	4, 555	18, 513	83, 426	1
1963	4, 322	17, 646	102, 412	0
1964	5, 206	17, 912	115, 948	1
1965	4, 920	19, 050	83, 139	0
1966	5, 332	19, 017	140, 729	1

Continued

Appendix Table 1--Continued.

Year	Central			
	Fishermen[1/] (X_1)	Net tons[1/] (X_2)	Landings[2/] (L)	Cycle (C)
1947	2, 641	9, 509	151, 090	0
1948	2, 479	12, 262	118, 580	0
1949	3, 090	14, 356	111, 652	0
1950	3, 552	16, 252	113, 304	0
1951	5, 627	22, 571	75, 941	0
1952	3, 452	15, 910	101, 641	0
1953	3, 870	15, 808	95, 777	0
1954	3, 737	14, 132	103, 831	0
1955	4, 127	15, 486	93, 831	0
1956	4, 793	15, 828	103, 847	1
1957	3/	3/	77, 813	0
1958	3/	3/	99, 910	0
1959	4, 240	9, 351	39, 972	0
1960	5, 447	10, 299	84, 158	0
1961	5, 005	11, 850	76, 955	0
1962	5, 078	12, 491	144, 842	1
1963	5, 937	13, 185	93, 255	0
1964	5, 520	12, 034	146, 389	1
1965	6, 286	12, 133	73, 228	0
1966	6, 051	12, 765	116, 645	1

Continued

Appendix Table 1--Continued.

Year	Western			
	Fishermen[1/] (X_1)	Net tons[1/] (X_2)	Landings[2/] (L)	Cycle (C)
1947	2, 339	5, 352	119, 355	1
1948	2, 808	7, 378	98, 282	0
1949	2, 140	6, 811	44, 706	0
1950	1, 829	6, 186	49, 936	0
1951	2, 501	6, 558	34, 622	0
1952	3, 306	7, 908	76, 826	1
1953	3, 048	5, 592	47, 547	1
1954	2, 162	5, 063	42, 492	0
1955	2, 520	4, 512	36, 709	0
1956	2, 402	4, 164	71, 549	1
1957	2, 656	3, 496	48, 137	0
1958	2, 426	4, 335	37, 581	0
1959	2, 063	4, 206	38, 596	0
1960	3, 304	5, 082	88, 704	1
1961	4, 598	4, 901	85, 294	1
1962	4, 869	7, 649	49, 580	0
1963	5, 137	7, 478	27, 369	0
1964	5, 301	8, 107	49, 286	1
1965	5, 958	8, 596	118, 477	1
1966	6, 445	9, 479	75, 951	0

1/ Bureau of Commercial Fisheries, Alaska Fishery and Fur-Seal Industry (Statistical Digest 1947-1956).
2/ Thousand pounds.
3/ Data not available.

Source: Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service (Statistical Digest 1947-1966).

Appendix Table 2. Number of fishermen, net tons of fishing vessels, quantity of landings, and expected cyclical nature of salmon runs in Puget Sound and Coastal districts of Washington.

Year	Puget Sound			
	Fishermen (X_1)	Net tons (X_2)	Landings 2/ (L)	Cycle (C)
1947	3, 281	9, 038	70, 400	1
1948	3, 883	10, 435	24, 546	0
1949	4, 693	12. 235	65, 646	1
1950	4, 618	11, 636	31, 483	0
1951	4, 881	12, 422	60, 847	1
1952	4, 541	11, 991	32, 781	0
1953	5, 277	15, 442	61, 416	1
1954	4, 806	14, 672	47, 471	1
1955	5, 612	16, 709	48, 703	1
1956	3, 753	12, 288	17, 591	0
1957	5, 468	18, 609	35, 435	1
1958	5, 434	18, 766	45, 591	1
1959	5, 196	17, 515	34, 624	1
1960	3, 837	13, 307	11, 387	0
1961	5, 117	15, 987	22, 213	1
1962	4, 127	14, 092	14, 408	0
1963	5, 097	17, 483	46, 537	1
1964	3, 337	11, 215	13, 313	0
1965	4, 127	14, 043	20, 070	1
1966	3, 502	11, 677	21, 982	1

Continued

Appendix Table 2--Continued.

Year	Coastal District 1/		
	Fishermen (X_1)	Net tons (X_2)	Landings 2/ (L)
1947	955	2,205	6,489
1948	1,096	2,581	7,517
1949	1,120	2,469	6,426
1950	1,184	2,994	8,142
1951	996	2,866	9,784
1952	1,346	4,087	11,568
1953	1,286	4,600	9,119
1954	1,408	4,926	8,524
1955	1,404	5,245	8,339
1956	1,187	4,555	7,054
1957	1,147	4,600	6,301
1958	1,131	3,975	5,640
1959	970	3,586	5,279
1960	1,107	3,668	3,253
1961	1,120	3,865	5,091
1962	1,084	3,936	5,614
1963	1,076	3,986	5,875
1964	926	3,747	4,910
1965	1,155	4,252	5,834
1966	1,193	4,332	6,769

1/ Cyclical nature not important.
2/ Thousands pounds.

Source: Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service (Statistical Digest 1947-1966).

Appendix Table 3. Number of fishermen, net tons of fishing vessels, and quantity of landings in Columbia River (Washington and Oregon) and Coastal district of Oregon.

Year	Columbia River		
	Fishermen (X_1)	Net tons (X_2)	Landings1/ (L)
1947	2, 529	3, 849	22, 554
1948	2, 734	4, 070	21, 367
1949	2, 249	4, 920	13, 670
1950	2, 478	3, 850	14, 315
1951	2, 400	3, 776	14, 458
1952	2, 409	3, 893	11, 909
1953	1, 509	3, 680	9, 784
1954	1, 861	4, 795	7, 973
1955	1, 843	3, 743	11, 574
1956	1, 772	3, 641	10, 944
1957	1, 309	2, 714	7, 945
1958	1, 238	2, 620	8, 284
1959	1, 319	2, 960	6, 398
1960	1, 414	2, 845	5, 412
1961	1, 234	2, 874	6, 424
1962	1, 469	3, 157	7, 639
1963	1, 278	3, 181	6, 898
1964	1, 215	3, 284	8, 699
1965	1, 555	3, 938	11, 830
1966	1, 643	4, 921	11, 080

Continued

Appendix Table 3--Continued.

Year	Coastal District		
	Fishermen (X_1)	Net tons 1/ (X_2)	Landings 1/ (L)
1947	1, 303	3, 026	5, 308
1948	1, 336	2, 988	4, 181
1949	1, 133	2, 532	3, 687
1950	1, 015	2, 400	2, 717
1951	1, 058	3, 231	5, 354
1952	1, 100	3, 377	5, 775
1953	1, 071	3, 320	4, 350
1954	1, 070	3, 274	4, 217
1955	1, 127	4, 014	5, 609
1956	1, 144	4, 045	7, 351
1957	1, 100	4, 508	6, 536
1958	973	3, 248	3, 026
1959	741	2, 846	1, 335
1960	901	3, 500	2, 074
1961	1, 004	3, 882	3, 219
1962	739	3, 273	2, 385
1963	842	3, 593	3, 944
1964	882	3, 759	4, 221
1965	1, 009	4, 120	4, 490
1966	1, 140	4, 971	4, 909

1/ Thousand pounds.
Source: Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service (Statistical Digest 1947-1966)

Appendix Table 4. Number of fishermen, net tons of fishing vessels, and quantity of landings in California.

Year	Fishermen (X_1)	Net tons (X_2)	Landings 1/ (L)
	Northern		
1958	847	2,916	1,599
1959	836	2,917	1,852
1960	887	3,017	2,437
1961	1,397	4,334	4,135
1962	1,488	4,499	4,194
1963	1,288	4,440	3,778
1964	1,472	4,968	5,423
1965	1,683	6,600	5,484
1966	2,644	9,045	6,936
	San Francisco		
1958	782	2,448	1,676
1959	1,070	3,474	4,583
1960	1,145	3,780	2,890
1961	1,334	4,295	3,702
1962	1,191	3,850	2,051
1963	1,242	4,356	3,494
1964	1,118	3,911	3,508
1965	1,159	4,761	3,652
1966	1,461	4,861	2,239
	Monterey		
1958	365	990	277
1959	335	1,057	270
1960	548	1,769	816
1961	564	1,583	655
1962	489	1,471	308
1963	445	1,483	512
1964	398	1,401	378
1965	379	1,342	492
1966	394	1,128	189

1/ Thousand pounds.

Source: Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service (Statistical Digest 1958-1966).

Appendix Table 5. Unemployment rates in major labor markets.

Year	Total unemployment rates (as percent of total work force)			
	Alaska	Seattle	Portland	San Francisco
1957	8.0	1/	5.2	4.2
1958	10.3	6.1	6.9	5.8
1959	9.5	5.1	4.7	4.6
1960	8.0	6.1	4.8	5.1
1961	9.9	6.5	6.5	5.9
1962	9.4	4.8	5.2	5.2
1963	9.4	6.0	4.8	5.3
1964	8.5	6.6	4.6	5.3
1965	8.6	4.8	4.0	5.0
1966	9.1	3.0	3.4	4.4

1/ Not available.

Source: Manpower Report to the President, U.S. Dept. of Labor. p. 285-289 (1959-1966); p. 281-282 (1957-1966).

Appendix Table 6. Distance from approximate center of salmon fishing activity to nearest major labor market.

Region	Geographic center of activity 1/	Labor market	Miles 2/
Alaska:			
1) Western	Bristol Bay	Anchorage	270
2) Central	Kodiak	Anchorage	280
3) Southeastern	Petersburg	Anchorage	610
Washington:			
4) Puget Sound	Puget Sound	Seattle	55
5) Coastal	Hoquiam	Seattle	170
Oregon:			
6) Coastal	Florence (coast midpoint)	Portland	170
7) Columbia River (Ore. and Wash.)	Astoria	Portland	100
California			
8) Northern	Eureka	San Francisco	280
9) San Francisco	Bodega Bay	San Francisco	50
10) Monterey	Monterey	San Francisco	110

1/ Geographic centers of activity in Alaska and Puget Sound were estimated by weighting the salmon pack at various ports by the distances to the major labor market. The other centers were identified with the assistance of Marine Advisory Agents.

2/ Air miles in Alaska, road mileage in other regions.