DETERMINANTS OF FISHING PERFORMANCE:

THE WASHINGTON STATE SALMON FISHERY

by

Cory Scott Finnell

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Applied Economics

MONTANA STATE UNIVERSITY
Bozeman, Montana

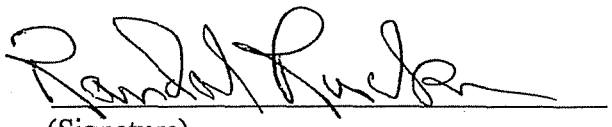
December 1995

APPROVAL

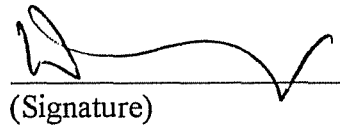
of a thesis submitted by

Cory Scott Finnell

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Randal Rucker  9/5/95
(Signature) Date

Approved for the Department of Agricultural Economics/Economics

Douglas Young  9-5-95
(Signature) Date

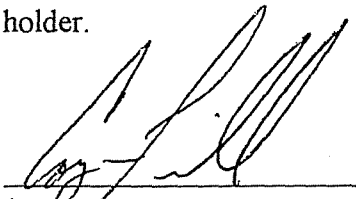
Approved for the College of Graduate Studies

Robert Brown _____ _____
(Signature) Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University-Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature 

Date 9/5/95

ACKNOWLEDGMENTS

I am indebted to Dr. Randal Rucker for his tireless guidance and encouragement. He spent many hours discussing and reviewing my thesis work and provided occasional prodding when I needed it. Without his help I could not have finished the program in one year. Professor Rucker's commitment to the graduate program is truly incredible. Thanks also go to my two other committee members, Professors Ron Johnson and Terry Anderson, who always made time to discuss my thesis. I would also like to thank my parents and Tracy Forin for their continued support and understanding.

TABLE OF CONTENTS

Page

LIST OF TABLES vii

LIST OF FIGURES viii

ABSTRACT ix

1. INTRODUCTION 1

2. LITERATURE REVIEW 5

3. THEORETICAL MODELS OF THE FISHERY 22

    The Gordon Fishery Model Expanded 22
    Heterogeneity Introduced into the Gordon Fishery Model 24

4. THE WASHINGTON STATE SALMON FISHERY 29

    Historical Development 30
    Current Regulation 33
    Species and Harvest Methods 34

5. DATA SET CONSTRUCTION 38

    Washington Department of Fish and Wildlife Data Bases 38
    Performance Measure Calculation 41
    Construction of Performance Measure Data Sets 46

6. EMPIRICAL ESTIMATION AND RESULTS 50

    Explanatory Power of Vessel Characteristics 51
    Tests for Systematic Differences across Vessels 63
    Daily and Weekly Performance versus Annual Performance 66
    Test for Systematic Differences in Annual Performance 71

7. SUMMARY AND CONCLUSIONS 73

LITERATURE CITED 76

APPENDICES 80

Appendix A—Seine Vessel Correlation Coefficients 81
Appendix B—Gill Net Vessel Correlation Coefficients 82
Appendix C—Troll Vessel Correlation Coefficients 83
Appendix D—Seine Fishermen Dummy Regression Coefficients 84
Appendix E—Gill Net Fishermen Dummy Regression Coefficients 86
Appendix F—Troll Fishermen Dummy Regression Coefficients 89

LIST OF TABLES

Table Page

1. 1991 Average Price and Pounds, by Species 35
2. 1991 Pounds Harvested by Species and Gear Type 36
3. Number of Days Fished per Trip for the Troll Fleet 42
4. Attributes of Performance Measure Data Sets 48
5. Summary Statistics of Vessel Characteristics 52
6. Seine Vessel Coefficients 55
7. Seine Vessel Coefficients, Vessels over 58 Feet Excluded 56
8. Gill Net and Troll Vessel Coefficients 58
9. Summary of Vessel Coefficients from Performance Measure Regressions 60
10. Summary Statistics for Fisherman Dummy Variable Regressions 65
11. Summary of Vessel and Operator Effects 66
12. OLS Estimates for Daycoefficient and Weekcoefficient Variables 69
13. OLS Estimates of First Order Lag of Annual Performance Measure 71

LIST OF FIGURES

Figure Page

1. Individual and Fishery Cost Curves 23

2. Cost Curves for Heterogeneous Fishermen 26

ABSTRACT

Very different economic implications come out of fishery models depending on whether fishermen are assumed homogeneous or heterogeneous in fishing skill. It is, however, common for economists to assume that fishermen are homogeneous in fishing skill. If fishermen are systematically different in fishing ability, any analyses of the political economy of private and public regulations that were based on an assumption of homogeneous fishermen, must be reconsidered.

To test for systematic differences in fishing ability, cross-section time-series data sets were constructed from data bases maintained by the Washington Department of Fish and Wildlife. Performance measures were calculated for all fishermen in the non-Indian salmon purse seine, gill net, and troll fleets. Statistical analyses were performed on the performance measures for a sample of fishermen.

Vessel characteristics account for approximately 1 percent to 20 percent of the variation in the performance measures. A composite operator effect accounts for 8.2 percent to 28.5 percent of the variation in the performance measures. Heterogeneity in fishing skill exists within the Washington salmon purse seine, gill net and troll fleets.

CHAPTER 1

INTRODUCTION

There is a substantial economic literature arguing that open access fisheries attract a suboptimal allocation of resources. Aggregate social welfare is reduced because resources are diverted from higher valued uses to the production of fishing effort. This diversion occurs because new entrants impose costs on existing fishermen that are not taken into account by entering fishermen. The persistence of this misallocation and various proposals to mitigate the resulting rent dissipation are the motivators of the extensive literature on the economics of fisheries. In this literature a common simplifying assumption is that of a constant rate of catch per unit of effort across fishermen. Any variation in catch across individuals is assumed to be random and unrelated to differences in fishing skill. If variations in catch across fishermen are systematic rather than random the assumption of homogeneous fishermen is invalid. Any gains in clarity of exposition from this assumption come at the expense of imposing an unrealistic framework for the analysis.

From the perspective of the economist a critical determinant of the optimal harvest rate of a fishery is the cost of fishing. The dollar value of fish produced does not account for the resources used up in the production of fish. Maximizing the difference between the total revenue generated and the total costs allocated ensures that the value placed on the

last fish harvested is not less than the cost of harvesting. If the cost of harvesting the last fish exceeds the marginal benefit consumers place on the last fish, society's resources are being diverted from higher valued uses. Optimality requires allocation of effort to the point where the marginal cost of fishing effort is equal to the marginal value of landed fish. The optimality condition is violated when property rights to the fishery are not defined and access to the fishery is privately or publicly unregulated. Under conditions of open access over production results.

Fishery models require a linkage between effort, fish production, and costs. The integration of economic costs into the biological model of a fishery was formally presented by the economist H. Scott Gordon in 1954. Today the biological literature routinely incorporates economic costs into fishery models (Beddington et al. 1993). Because fishermen cannot directly control the number of fish caught per unit of time spent fishing, the relevant choice variable of production is effort rather than quantity of fish produced. Hours or days spent fishing are sometimes proposed as proxies of effort (Anderson 1977, Tietenberg 1992), but, these are only appropriate if fishermen are homogeneous. If fishermen are heterogeneous, one fisherman's hour of fishing produces a different effective level of effort than another fisherman's hour. If the quantity of fish produced per unit of time varies systematically across fishermen it may be important to account for skill when designing and analyzing regulatory proposals to correct for the suboptimal allocation of effort to the fishery.

Increasing the net economic value of fish resources requires the establishment of property rights to the production of fishing effort. Whether property rights are publicly or

privately regulated, the standard Gordon fishery model, which assumes homogeneous fishermen, predicts gains to those fishermen who are included in the regulated fishery. With lower levels of aggregate effort applied to the fishery, the remaining units of effort receive a higher return per unit of effort. The Gordon model, therefore, predicts support for effort-reducing regulations from fishermen who expect to be included in the regulated fishery. It also predicts that fishermen will support regulations that reduce their costs of fishing. If the return per unit of effort remains constant, a reduction in the cost per unit of effort translates into higher profits. Unfortunately these predictions frequently are violated in regulated fisheries. Assuming fishermen can influence the structure of regulations, the regulations predicted from models assuming homogeneous fishermen are in conflict with observed regulations. It is necessary to construct theoretical models that incorporate heterogeneous fishermen in order to predict observed regulations.

Discussed at length in the literature review section of this thesis are examples of fisheries characterized by cost-increasing regulations. Also reviewed are examples of firms unwilling to reduce individual effort or quantity produced in order to receive the benefits of a cartel like arrangement. If fishermen are heterogeneous, effort-reducing regulations such as allocating poundage quota, taxing fishing effort or instituting limited entry programs may be opposed by included fishermen depending on the provisions of the regulations (Johnson and Libecap 1982). Furthermore, if fishermen are heterogeneous, one group may benefit from regulations that raise the costs of fishing for another group. These regulations might take the form of gear restrictions or season and area closures (Karpoff 1987). Because very different implications come out of models depending on

whether the fishermen are assumed homogeneous or heterogeneous, empirical investigations of the degree of heterogeneity are important.

The purpose of this thesis is to determine to what extent variations in catch across fishermen are due to differences in fishing skill. Pooled cross-section time-series data from the Washington state salmon purse seine, gill net and troll fisheries are used in the analysis. Variations in catch across a cross-section of fishermen could be due to random chance but pooled cross-section time-series data allow for tests of systematic differences over time.

This thesis proceeds as follows. Chapter two presents a literature review. In chapter three, heterogeneity is introduced into the standard Gordon fishery model. Chapter four describes the Washington salmon fishery and chapter five explains the construction of the data sets used in the analyses. Chapter six presents the statistical analysis, and chapter seven contains conclusions and possible extensions.

CHAPTER 2

LITERATURE REVIEW

The purpose of this literature review is to discuss relevant aspects of the relationship between the characteristics of the firms in an industry and the regulations in effect for that industry. In particular, if firms are heterogeneous how does this affect an industry's response to (or proposal for) regulations? This thesis is an empirical investigation of heterogeneous skill in the Washington state salmon fishery, therefore, the journal articles reviewed are pertinent to fishery regulations. Gordon (1954), Bell (1972), Johnson and Libecap (1982), Kincaid (1995), Anderson (1985), Karpoff (1987), Salvanes and Steen (1994) and Higgs (1982) deal explicitly with the political economy issues of fisheries. Hallagan (1985) is an extension of Johnson and Libecap to the hop industry and Hilborn and Ledbetter (1985) is an empirical investigation of the determinants of fishing ability in the British Columbia salmon purse seine fishery.

Scott Gordon (1954) concluded that resources owned in common yield zero economic rent at the margin and in total. Gordon's analysis dealt primarily with fishery resources and introduced the application of economic analysis to the exploitation of the fishery. The zero rent conclusion results from the assumption of homogeneous fishermen operating in an environment where input prices (the wage and rental rates of the labor and capital used in fish production) are not bid up by increased levels of fishing effort. His

work demonstrates that the value of the resource can only be maximized when the costs of fishing are explicitly accounted for in the analysis. Gordon's fishery model contained four equations and four variables:

$$P=P(L)$$

$$L=L(P,E)$$

$$C=C(E)$$

$$C=L$$

where P is the population of the fish stock, L is the total value landed, E the quantity of effort applied to the fishery and C the total cost of producing effort level E. Gordon assumes total costs to be a linear function of effort. This assumption of a constant cost of effort produces horizontal and equal average and marginal cost curves for the fishery. The production function L(P,E) is assumed to be concave in effort, holding fish population constant, because, at increased levels of effort the fish population declines and catch increases at a decreasing rate. The average product and marginal products of effort are assumed to be linear functions of effort. Each individual fisherman's production of effort is assumed small relative to total production for the fishery. The individual fisherman cannot control the aggregate level of effort applied to the fishery and, therefore, cannot control his level of catch per unit of effort. The individual fisherman bases his production decisions on what he expects to receive, the fishery wide average product per unit of effort and is unconcerned with the marginal product of the fishery. Effort is expanded until the marginal cost of increasing effort is equal to the average product of the fishery. Total value landed is equal to the total costs of fishing; C=L. All rents are dissipated and

the aggregate value of the fishery is equal to zero. The individual fisherman receives an opportunity cost income but no more, and in Gordon's words: "By and large, the only fishermen who becomes rich is one who makes a lucky catch or one who participates in a fishery that is put under a form of social control that turns the open resource into property rights."

Net social benefits are maximized when the difference between the value of landed fish and the costs of extraction is maximized. This occurs at a level of effort that equates the marginal cost of effort to the marginal product for the fishery. The optimal solution is not, however, a competitive equilibrium because the average product of the fishery exceeds the marginal cost of producing effort. In the absence of private property rights or public (government) property rights, all rental value from the fishery will be dissipated through the over production of effort.

Gordon describes decreases in catch per unit of effort as the law of diminishing returns asserting itself in the fishery but does not discuss the possibility of systematic differences in catch per unit of effort across fishermen. A horizontal supply curve of effort results from the assumption of constant marginal cost of effort. The linear average product and marginal product curves for the fishery are results of the assumption of a constant rate of decrease in these two measures per unit increase in effort. If systematic differences exist across fishermen in their ability to catch fish per unit of effort or in their costs of producing a unit of effort, Gordon's zero rent conclusion for the open access fishery does not hold.

Bell (1972) empirically estimated the over production externality that existed in the 1966 New England lobster fishery. Increasing the number of lobster traps reduced the average catch from existing lobster traps, a decrease Bell referred to as a technological externality. The relevant portion of his analysis is the generation of upward sloping average and marginal cost curves as functions of quantity of lobster produced. These costs curves were generated while maintaining Gordon's assumption of a linear total cost curve for effort. Therefore, even in the presence of constant and equal average and marginal costs of effort, upward sloping average and marginal cost curves result as functions of quantity produced. The marginal and average costs per unit of effort are constant, as in Gordon's analysis, but the average and marginal costs as functions of quantity produced are upward sloping.

Bell estimated the average productivity of a lobster trap as a function of the number of lobster traps used and the mean annual seawater temperature. The OLS regression took the following form:

$$(\frac{Q}{E})_t=\beta_0+\beta_1 E_t+\beta_2 F_t+\upsilon_t$$

where Q is the annual landings of northern lobster, E the annual number of lobster pots fished and F the mean annual seawater temperature with all variables subscripted to year t. After estimating the parameters, B_0, B_1 and B_2 the average water temperature for 1966 was inserted and the equation multiplied through by E. The result is the quantity of lobster produced as a function of effort alone. Combining this with Gordon's assumption of a linear total cost function for effort, $TC_t=cE_t$, where TC_t equals total cost in year t, E_t

equals the number of pots fished in year t and c equals the constant marginal cost of effort, the average cost as a function of quantity of lobsters produced is calculated. The marginal cost curve is calculated by multiplying the average cost curve by Q and differentiating the result. The resulting average and marginal cost curves as functions of quantity of lobster produced are upward sloping. Bell empirically estimated the number of lobster traps that would maximize the difference between total revenue produced and the total costs of production. The number estimated was well below the actual number of traps fished and Bell's analysis reinforced the hypothesis that all rents are dissipated in an open access fishery.

Johnson and Libecap (1982) found significant heterogeneity in terms of catch per unit of effort in the Texas bay shrimp fishery. Differential fishing abilities generate different cost curves across fishermen. The industry supply curve of effort is therefore upward sloping. This result, according to Johnson and Libecap, explains the absence of informal contracts among fishermen as well as their resistance to various regulatory schemes that would improve the economic efficiency of the fishery. The individual fisherman's production function or catch function is a function of effort, e and the level of the stock of fish X:

$$h_i=f(e_i,X);\ i=1,2,3,..N$$

The catch function, h, and the level of effort, e, are subscripted to denote fishermen i with i ranging over the total number of fishermen N. The individuals effort level e_i is a function

of capital, labor, and fishing ability. The change in the value of catch with respect to a change in the level of effort is assumed constant and equal across all N fishermen. Costs, however, vary over the N fishermen due to differences in fishing ability. The economic profits or rents accruing to the individual fisherman take the form:

$$rents_i = Pf(e_i, X) - C_i(e_i)$$

where P represents the exogenously determined price of landed fish and $C_i(e_i)$ the costs to fisherman i of producing e_i units of effort. Because the costs associated with producing effort are not constant across fishermen, inframarginal fishermen earn economic profits in open access equilibrium. Entry into the fishery persists until the marginal fisherman's return per unit of effort is equal to his average cost of producing effort.

Three commonly proposed regulations to move open access fisheries towards economic efficiency are fishing quota allocations, taxes on fishing effort, or catch and limits to entry into the fishery. Johnson and Libecap attribute the absence of these measures in the Texas shrimp fishery to the heterogeneity of skill of the participants. With an upward sloping supply schedule of effort, if quota is allocated equally across fishermen, it is possible that the net change in rents for more productive fishermen will be negative. Quota allocations may increase the economic efficiency of the fishery but if the quota is allocated without regard to differences in fishing skill it is possible that wealth will be transferred from more to less productive fishermen. More productive fishermen will oppose this type of allocation. The costs of allocating quota based on fishing ability,

however, may be prohibitively expensive. Taxes on fishing effort reduce the rent received by the individual fisherman but can increase the rental value of the fishery through a reduction in aggregate effort. If the increased rents captured in tax revenue are not distributed back to the fishermen, they are made worse off and will oppose this type of regulation. Skill heterogeneity can also generate resistance to limited entry programs. Johnson and Libecap show that transferable limited entry permits affect different groups of fishermen unequally. The unequal distribution of gains creates resistance to this type of regulation and drives up the costs of implementation. Because of the differential wealth distribution of efficient allocative schemes, heterogeneous fishermen favor regulatory policies that do not change their relative ranking in the fishery and policies that enhance their individual net revenues.

Limits on individual fishing effort did not exist in the Texas shrimp fishery between 1953 to 1958 but did exist in various New England fisheries. Kincaid (1995) finds significant heterogeneous fishing skill in the various New England fisheries and attributes the limitation on individual effort to lower enforcement and monitoring costs than in the Texas shrimp fishery.

Fish buyers and processors were spread out over a large geographical area in the Texas shrimp fishery. This made the monitoring of individual fishing effort prohibitively costly. Fishermen could land one day's catch in one port and another day's catch in a different port. In contrast, the New England fisheries were more concentrated. Different species were targeted in different areas and ports specialized in buying and processing

particular species. Individual fishing effort could be monitored in the specialized ports and circumventing this monitoring by transporting fish to a different port was not feasible.

The geographical dispersion of shrimp buyers in Texas and the relatively low cost involved in landing shrimp in different ports created higher effort limitation costs in this fishery. Kincaid admits, however, that he can say nothing regarding the heterogeneity of fishermen skill in the New England fisheries relative to the Texas shrimp fishery. In essence what he did show is that the New England fisheries were more homogeneous along certain margins such as the concentration of fish buyers and fish stocks. His point is, however, well taken. Fishermen are interested in increasing their individual profits and heterogeneity in itself does not preclude them from benefiting through collective action. Transaction costs are an important factor in determining fishermen responses to proposed limitations on individual effort.

The economic analysis of regulatory responses from heterogeneous firms was extended to the United States hop industry by Hallagan (1985). Hallagan examined United States hop grower responses to a USDA quantity limitation marketing order. The marketing order, which would have allocated production rights to hop growers, required two thirds majority support from the growers. The order limited hop production and required new entrants to purchase production allotments from existing growers. The order would in effect create a hop grower cartel with the United States government providing enforcement and insulation from anti-trust regulation. The fact that the growers voted against the order in 1965 but adopted the order in 1966 motivated Hallagan's study.

The cartel like arrangement of the marketing order would seem to benefit all current hop producers. Decreased aggregate production would artificially induce scarcity, increase the price per pound of hops produced, and raise industry profits. If growers are heterogeneous, however, the increase in profits may be unequally distributed across growers. Empirical analysis performed by Hallagan supports Johnson and Libecap's hypothesis that low cost or more productive firms will resist quotas allocated on an egalitarian basis. Hallagan does not find, however, a theoretical basis for opposition to quota allocated proportional to production.

The 1965 marketing order if adopted would have allocated production quota based on historical production levels. Hop plants do not produce salable yields for two years after they are planted and, therefore, a grower who had planted hops in 1964 or 1965 would have higher expected future production relative to historical production. Growers who are in the process of expanding production will resist quotas allocated on a historical basis and growers who are contracting production will support this type of allocation. In 1965 opposition from the former stalled the legislation. Because there is a lag between hop planting and harvest, growers contract forward to ensure demand for their product at time of harvest. The 1966 legislation differed from the 1965 legislation because it incorporated information from forward contracts into the initial allocation scheme. Growers who were expanding production would be allocated quota in proportion to their planned future production. Changing the initial allocation scheme to include information from forward contracts, the 1966 marketing order was supported by enough growers to pass the two-thirds majority threshold.

Hallagan found that low cost hop growers opposed the 1965 marketing order because they could remain in business when hop prices were low and be better off after the low prices had driven high cost growers out of business. Hallagan's analysis reinforces the hypothesis that regulations, in this case the marketing order, that seem to benefit an industry in the aggregate, will be opposed by low cost producers if benefits are transferred from low cost producers to high cost producers.

Anderson (1985) compares the economic efficiency gains of gear restrictions and license limitation programs under two assumptions of a fishery's supply schedule of effort. The gains, assuming identical vessels and constant input costs and the resulting horizontal supply curve of effort are compared to the gains under an upward sloping supply schedule. Possibilities discussed for the generation of an upward sloping supply schedule are heterogeneous fishing skill and/or heterogeneous opportunity costs of labor and vessels.

Gear restrictions are modeled as an increase in the cost of supplying effort. For a constant cost fishery, characterized by constant input prices independent of output level, the horizontal supply schedule shifts up and the equilibrium level of effort decreases. The decrease in effort is a move towards economic efficiency in terms of effort expended, but all rental gains are dissipated by the increase in costs imposed by the gear restrictions. The net rental value of the fishery remains at zero. With an upward sloping supply schedule, however, all rents gained by the reduction in effort are not necessarily dissipated through increased costs. The removal of less productive fishermen by means of a cost-increasing regulation may actually produce net economic gains.

Anderson also argues that license limitation programs will always generate net economic gains for a constant cost industry. If the number of vessels or fishermen is limited the resulting increase in rents is not entirely dissipated. For the increasing cost industry, a limitation on entry can produce positive, negative or zero net economic gains. The limitation of effort increases the average return per unit of effort and induces remaining vessels to increase their level of effort production. This expansion of effort comes at a higher cost than that which could be produced by the excluded vessels. If the increased rents are greater than (less than) the increase in costs the net economic gain will be positive (negative). The assumed shape of the industry's supply curve of effort, therefore, determines the economic efficiency gains from reductions in effort.

Karpoff (1987) is an extension of Johnson and Libecap applied to gear restrictions, season, and time closures (the regulatory controls discussed in Anderson). The self interest hypothesis—observed regulations are in place because they serve the interests of the fishermen—is assumed to apply to fishery regulations. If the fishing community has captured the political process of designing fishing regulations, then it follows that observed regulations are preferred by fishermen. Under the assumption of homogeneous fishermen, it is not possible to explain the existence of gear restrictions and season closures using the self interest hypothesis. The assumption of heterogeneity in fishing skill is required to explain the persistence and widespread use of these types of regulations.

If fishermen are homogeneous, regulations will be adopted only if they are favored by all fishermen. Since homogeneity assumes that fishermen currently not fishing are identical to those who are, the self-interest hypothesis implies that only regulations that

increase the number of fishermen would be favored. A model of the effect of gear restrictions and season and time closures on the cost curves of homogeneous fishermen, however, predicts a reduction in the number of people participating in the fishery. This conclusion is identical to Anderson's. The self interest hypothesis is therefore in conflict with the existence of gear restrictions and season closures, given the assumption of homogeneous fishermen.

Karpoff introduces heterogeneity into the model to explain the regulatory use of gear restrictions and season closures. The heterogeneity comes in the form of differential capital and political clout across two groups of fishermen. The first group uses fewer units of capital in the fishery and has more political clout than the second group. An example of such a situation given by Karpoff is a group of capital-constrained indigenous fishermen competing with a non-indigenous group of highly capitalized fishermen. The indigenous fishermen, by definition, control the political process and institute regulations that favor them over the outsiders. A gear restriction that is binding on the more capitalized group will allow the entrance of a greater number of less efficient indigenous fishermen. Season and time restrictions have a similar effect. The group of fishermen employing more capital per unit of time are negatively impacted by season and time closures to a greater extent than the less capitalized group. The existence of these types of regulations are therefore consistent with the self interest hypothesis. The necessary assumption, however, is that of heterogeneous fishermen.

Hilborn and Ledbetter (1985) estimated that 30 to 34 percent of the variability in catch between vessels in the British Columbia salmon purse seine fleet is systematic. Of

this 30 to 34 percent, vessel attributes accounted for less than 10 percent of the variability. The remaining 20 to 24 percent was attributed to combined skipper, crew and net effects.

Hilborn and Ledbetter calculated a performance measure from the fish ticket data base maintained by the British Columbia Department of Fisheries and Oceans. The fish tickets contain weight and number of species caught, the value of landed fish, and the area fished and are filled out when fish are transferred from the vessel to the buyer. This daily information was used to obtain the value of landed fish by vessel, week, and area. The performance measure took the following form:

$$P_{ij}=\frac{1}{n}\sum_{i=1}^{n}(C_{ijk}-\bar{C}_{jk})$$

P_{ij} is the annual performance measure for the ith vessel in year j. C_{ijk} is the value of fish landed by vessel i in area j in week k, and C_{jk} is the average value of fish landed in area j for week k. Vessels were included in the analysis if they fished in both Johnstone Strait and the Strait of Juan de Fuca in each year 1973 to 1977.

Skipper, crew and net effects are inferred from the results of two separate data analyses. First the annual performance measure for each vessel was regressed on vessel attributes. The attributes included were the year the vessel was built, the estimated value of the vessel, and the horsepower, length and gross tonnage of the vessel. An analysis of variance was applied to the performance measure using the vessel as the treatment. The difference between the explanatory power of the two tests was attributed to skipper, crew and net effects.

The R^2 from the regression of the annual performance measure on the vessel characteristics equaled 0.04 and 0.12 for Johnstone Strait and the Strait of Juan de Fuca, respectively. The analysis of variance test explained 34 percent of the variation in the Johnstone Strait and 29 percent in the Strait of Juan de Fuca. Hilborn and Ledbetter attribute the difference between these two measures to the skipper, crew and net effects. They conclude 20 to 24 percent of the variance in catch between vessels in the British Columbia salmon purse seine fleet is explained by the effect of skipper, crew and nets. A more careful calculation would result in the inference that 30 percent (34 percent-.04 percent) of the variation in the Johnstone Strait fishery is attributable to this effect and 17 percent (29 percent-12 percent) in the Strait of Juan de Fuca.

Salvanes and Steen (1994) test for systematic year to year movements in vessel efficiency scores for vessels participating in the Norwegian seal fishery during 1937 to 1970. An efficiency score is calculated for each vessel:

$$ES=\frac{AR}{PR}$$

The efficiency score ES is equal to the vessel's actual revenue, AR, divided by a measure of predicted revenue, PR. A revenue to effort ratio is calculated for each vessel using a revenue model generated by the authors. The vessels are ranked according to this ratio and the upper quartile is selected to compute a "thick" revenue frontier, represented by PR.

To test for systematic differences in a vessel's ES through time, eleven vessels were identified that fished for seals between 10 and 25 consecutive seasons from 1937 to

1970. The ES measure for each was tested for stationarity assuming year to year movements followed the autoregressive process:

$$ES_t = \rho ES_{t-1} + \upsilon_t$$

If the error term is well behaved, a value of ρ equal to 1 indicates a random walk process. If $|\rho|<1$, the process follows a systematic pattern. For 8 of the 11 vessels, the random walk hypothesis could not be rejected meaning that fishing luck plays a dominate role in determining the movement of a vessel's efficiency score through time. This is significant, they conclude, because if a fishery is regulated using a quota share per vessel, and catch per vessel is dependent on fishing luck, some vessels will not be able to catch their share of the harvest. Also, if catch is determined stochastically, the individual fisherman's supply function of effort may not be well defined.

The authors do find that vessel specific characteristics are significant in explaining vessel revenue. Two regressions were performed to estimate the determinants of revenue. One regression with $R^2 = 0.73$ included vessel dummy variables, and the other regression with $R^2 = 0.46$ did not. The difference in the R^2's (.73 vs .46) suggests that vessel specific effects, independent of the physical characteristics of the vessel, explain substantial variation in revenue across vessels.

Higgs (1982) recounted the historical development of the Washington salmon industry. When non-Indians arrived to the Washington territories in the 1850's they found area Indian tribes participating in riparian fisheries. The Indians harvested salmon when the salmon returned to spawn in rivers and streams. Non-Indians soon set up their own

riparian fishing operations using stationary fish traps and fish wheels along the Columbia river. Only a limited number of suitable fish trap and fish wheel sites existed along the Columbia and once these sites were taken, other forms of fishing gear developed to harvest fish before they made it into the traps. Higgs details the development of the conflicts that resulted between fishermen utilizing stationary gear and fishermen using mobile gear and the conflicts that later arose between commercial fishermen and sport fishermen.

Gill net fishermen harvested fish before they made their way up river to the fish traps. The resulting reduction in harvest for the fish wheel operators was not taken into account by the gill net operators and the operators of fish wheels had little recourse because property rights to fish stocks were not defined. Mixed gear fisheries , according to Higgs, are socially inefficient because intercepting gears raise the costs of fishing and the existence of mixed gear fisheries are the result of fishery managers that are either completely unconcerned with social efficiency or are more concerned with objectives that conflict with social efficiency.

The political and judicial process ignored the increase in costs generated by mobile gear types and ultimately outlawed all stationary gear on the Columbia river and in Puget Sound. Higgs argued that the stationary fish traps and fish wheels were outlawed because they were too efficient. Abundant harvests and profits accrued to the owners of fish wheels who exerted little effort in the fishing operation. In contrast, the gill net fishermen were considered hard working, daring men who risked their lives to earn a modest living. The gill net operators won the political battle through legislation that banned the

stationary gear. Higgs does not present a hypothesis, however, detailing the inability of the stationary gear owners inability to capture the political process. He argued that regulations that favored equity won out over regulations that favored economic efficiency. In light of the above reviews it seems useful to incorporate distributional gains in the analysis of political outcomes. In this case it might be argued that the gains to gill net fishermen outweighed the losses to fish wheel operators and the gill net operators communicated this to the political process.

In summary, academic research provides useful insights into the relationship between industry regulations and firm characteristics. Regulations that appear to improve economic efficiency or provide insulation from the rigors of economic competition are not always supported by all members of the industry. If firms are heterogeneous in ability, and therefore in their costs of production, regulations may protect high cost producers at the expense of low cost producers. If we assume industry participants affect the political process, analyses of observed regulations must incorporate the degree of heterogeneity in the industry. The remainder of this thesis focuses on identifying if heterogeneity in fishing skill characterizes the Washington state salmon fishery.

CHAPTER 3

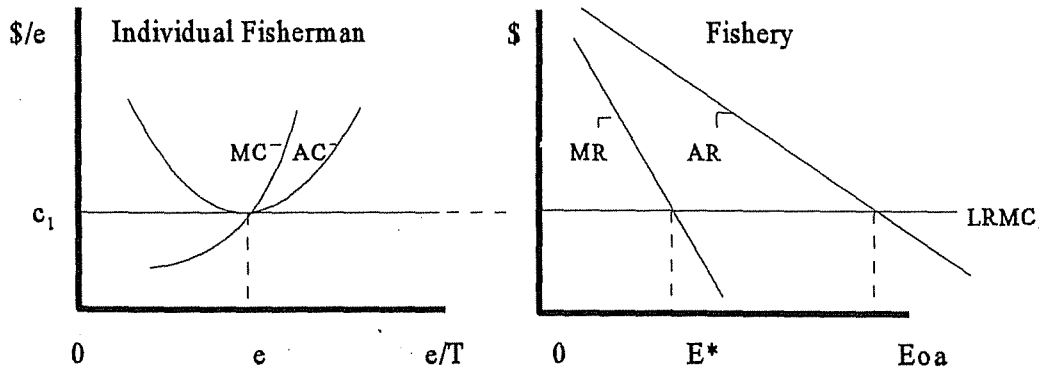
THEORETICAL MODELS OF THE FISHERY

In the fishery model developed by Gordon total costs and total fish production are linear functions of fishing intensity. Gordon does not explicitly define fishing intensity but compares it to the phrase "fishing effort" used throughout the biology literature. The difficulties in defining fishing intensity or fishing effort are discussed later. Fishermen's opportunity costs and effort production costs are explicitly assumed equal. Fishing ability is implicitly assumed equal across fishermen and Gordon also assumes that output and input prices are exogenously determined and unaffected by aggregate levels of effort.

The Gordon Fishery Model Expanded

Gordon's result is presented graphically in figure 1 under the label Fishery. Aggregate effort in the competitive equilibrium is Eoa and industry rents are zero.

Figure 1. Individual and Fishery Cost Curves



A possible representation of the long run average cost (AC) and marginal cost (MC) curves for a representative fisherman that would motivate Gordon's result are presented in figure 1 under the label Individual Fisherman. The cost curves for the representative fisherman presented in figure 1 are similar to those in Anderson (1977). In equilibrium for the fishery, Eoa units of effort are produced. Each additional unit of effort is added to the fishery at minimum long run average cost. The individual fisherman produces e units of effort at cost c_1. Summing the individual levels of effort, e, produced at marginal cost c_1, produces the fishery long run supply curve labeled LRMC. At E* units of effort the difference between the total costs of effort production and the total revenue generated are at a maximum. This is not, however, a competitive equilibrium. For levels of effort less than Eoa the average return per unit of effort, AR, is greater than the minimum average cost of producing a unit of effort and fishermen earn economic

profits. Available profits induce entry of more fishermen until the average return per unit of effort is equal to the minimum average cost per unit of effort. Eoa is the open access equilibrium, total costs are equal to total revenue, each fisherman earns an opportunity income but zero economic profits, and all resource rental value is dissipated.

Gordon's zero rent equilibrium conclusion for the open access fishery rests on the assumption of an infinitely elastic (horizontal) supply schedule of effort. If skill and/or opportunity costs vary across fishermen, however, the result is an upward sloping supply schedule (Johnson and Libecap 1982, Anderson 1985). The intention here is to introduce heterogeneity in fishing skill into the Gordon model.

Heterogeneity Introduced into the Gordon Fishery Model

The form heterogeneity might take deserves special attention. The unit of measurement on the horizontal axis in graph 1 is a standardized unit of effort. Gordon modeled total costs and total production as a function of fishing effort without explicitly defining a unit of effort. Wilen (1979) discusses the difficulty of defining a standard unit of effort because of the multidimensional nature of the term. Vessel length, engine horsepower and vessel tonnage are examples of inputs used in the production of effort and are examples of the types of capital dimensions commonly identified and targeted for regulatory programs (Frazer 1979, Wilen 1979, Crutchfield 1979). The empirical literature uses such proxies for effort as the number of lobster pots fished (Bell 1972) or the number of vessels used in fishing (Meany 1979). Using physical measures of the

capital employed in fishing , however, does not approximate the effective effort of the fishery if fisherman are different in their abilities to combine physical capital with labor to produce harvested fish.

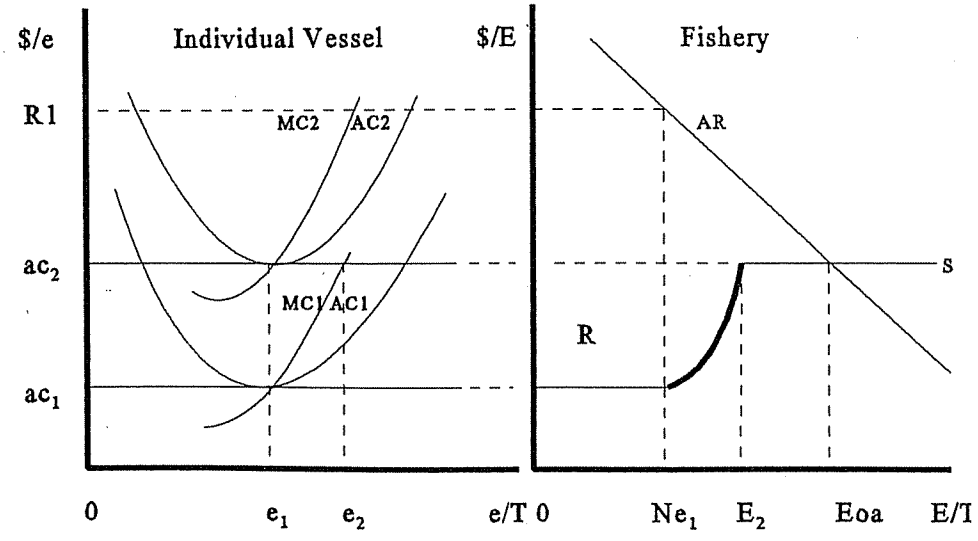
Differential ability can be viewed in two ways. First, if a standard unit of effort is defined as a common fishing operation, such as deploying and retrieving a purse seine net, differences in ability could take the form of identifying areas to deploy the net, amount of time required to deploy the net, time required to retrieve the net, and the amount of time required to process the fish landed in order to make the net available for another deployment. This definition requires the assumption that the value of the fish caught with each standard fishing operation is equal across fishermen. This is the approach adopted by Johnson and Libecap (1982). A second possible definition of effort is the production of a standard amount of fish, say, a given dollar amount of fish landed. This definition requires a control for the amount of capital and labor employed in producing the standard unit of fish. In this context fishermen vary in their ability to locate fish and to land located fish. Incorporating either measure into fishermen's cost curves yields a similar result. The high skill fisherman will have lower unit costs relative to a low skill fisherman.

To illustrate, let the deployment and retrieval of a purse seine net of given dimensions represent a standard unit of effort. Each deployment returns an equal number of fish across fishermen, and the price per pound is constant. Assume, also, that equal amounts of capital and labor are employed by all fishermen and that these inputs are paid on an hourly basis. Finally, assume that the rental and wage rates paid are equal across fishermen. If fisherman 1 can produce two hauls of the net in the same time as fisherman

2's one haul, fisherman 1's average and marginal cost of effort are half that of fisherman 2's. Therefore, maintaining all the assumptions of the Gordon model but introducing a new dimension, skill, average costs and marginal costs vary across individuals.

In figure 2, cost curves for two representative fishermen are graphed. MC1 and AC1 are the long run marginal cost and average cost curves of a high skill fisherman. MC2 and AC2 are the long run marginal and average cost curves of a low skill fisherman. The unit of effort, e, is defined as the performance of one fishing operation.

Figure 2. Cost Curves for Heterogeneous Fishermen



To generate the industry supply curve, assume a limited number of high skill fishermen equal to N. The N high skill fishermen will each produce e_1 units of effort at minimum average cost ac_1. The industry supply curve is horizontal up to point Ne_1.

Beyond Ne_1 the marginal cost of producing additional units of effort is greater than ac_1. At aggregate effort level Ne_1 and individual effort level e_1 each fisherman in group 1 earns rents equal to $(R1\text{-}ac_1) * e_1$. The marginal revenue from additional production is greater than the marginal cost of production so each fisherman in group 1 expands output along the marginal cost curve MC1 up to effort level e_2. At effort levels per high skill fisherman greater than e_2, the marginal cost of additional effort is greater than the minimum average cost from group 2 fishermen, ac_2. Group 2 fishermen will enter with each fisherman producing e_1 units of effort. Assuming an infinite number of group 2 fishermen the industry supply curve again becomes horizontal and the equilibrium level of effort is at Eoa. In equilibrium the high skill fishermen earn profits equal to area R. Dropping the assumption of homogeneous fishermen results in economic profits in open access equilibrium.

The coincidence of minimum average cost at effort level e_1 across the two groups in figure 2 is arbitrary. There are no predictions made regarding the effort level that minimizes long run average cost across the two groups. Group 2 could possibly achieve minimum long run average cost at a higher level of effort or at a lower level of effort than group 1.

The purpose of this study is to empirically test for systematic differences in fishing ability across fishermen. Measurements of standardized fishing operations, such as the deployment and retrieval of a purse seine net, however, are not available. What is available are daily catch records by vessel and the physical characteristics of the vessels used in fish production. If systematic differences in the ability to produce fish during a

given time period exist, controlling for vessel characteristics, more productive fishermen produce fish at lower cost than less productive fishermen. If systematic differences exist, the above cost curve analysis applies. Good fishermen earn rents in open access equilibrium and any analyses of the political economy of private and public regulations that were based on an assumption of homogeneous fishermen, must be reconsidered.

CHAPTER 4

THE WASHINGTON STATE SALMON FISHERY

Today the Washington state salmon fishery is managed by a complex conglomeration of regulatory agencies. Numerous agencies have been established to deal with the competition for salmon across states, between the United States and Canada, and between Indians and non-Indians within Washington. Property rights to salmon stocks are difficult to establish and enforce because of the migratory nature of the species. Salmon genetically linked to the Fraser river system in British Columbia Canada have been identified as far away as Alaska and Oregon. Another complication is the substantial year-to-year variation in salmon harvest between areas and within areas. Between 1976 and 1991, the commercial pounds landed in Washington ranged from a low of 26.3 million pounds in 1983 to a high of 65.6 million in 1985. The 16 year low and high are only two years apart. The large year-to-year variation in salmon harvest combined with the allocation constraints across Indians and non-Indians and between other states and countries make the Washington salmon fishery a regulatory nightmare.

Historical Development

The historical development of the Washington salmon fishery is quite colorful. The following historical description of the Washington salmon fishery draws heavily from the analysis of Nickerson and Rucker (1994). Before non-Indians arrived, the Indians had established a system of property rights to the fishery (Higgs 1982). These rights were both inter-tribal and intra-tribal in nature. Salmon were harvested on rivers and streams using various types of nets, traps and other gear. Because the offspring of spawning salmon would return to the river, the Indians allowed adequate numbers of salmon to escape harvest and spawn, thus, ensuring future harvests. Non-Indians introduced salmon fishing gear that allowed salmon to be harvested further and further away from the rivers and streams where they spawned. This made the relationship between escapement on a given river and future harvests tenuous. Allocation between Indians and non-Indians and across gear types for the non-Indians became a source of great conflict and at times violence (Higgs 1982)

The most visible manifestation of the conflicts between non-Indian fishermen utilizing different gear types and between commercial fishermen and sport fishermen was the passage of Initiative 77 in 1934. This initiative outlawed the use of fixed gear such as fish wheels and set nets and divided the Puget Sound fishery into an outside area and an inside area. The division of the Puget Sound fishery was the result of the increasing influence of the sport fishery (Higgs 1982, Crutchfield and Pontecorvo 1969). The inside area included the waters of Puget Sound, Bellingham Bay, and Deception Pass. Purse

seine vessels were restricted to fishing in this area from October 5 to November 20 and gill net licenses were only available to those who held licenses in 1932 or 1933 (Higgs, Crutchfield). These restrictions were later altered but the adoption of the legislation points to the increasing political struggles taking place between gear groups and between commercial fishermen and sport fishermen.

Before 1974, with the exception of the mandates of Initiative 77, the Washington state salmon fishery was essentially an open access fishery. Fishermen were required to purchase a license from the Department of Fish but license fees were nominal and the sale of licenses was not restricted. Major changes occurred in 1974 when Judge Boldt ruled that treaties signed in the mid-1850s between the United States and Washington area Indian tribes granted to the Indians 50 percent of the yearly salmon harvest. In the mid-1850s Issac Stevens, the Governor and Superintendent of Indian Affairs of the Washington Territories, was given authority by the federal government to negotiate treaties with area Indian tribes. The purpose of the treaties was to negotiate peaceful land settlements between the Indians and non-Indians. The treaties that were negotiated granted Indians the exclusive use of parcels of land, reservations, and the retention of the right to gather food at their usual and accustomed fishing places: "The right of taking fish, at all usual and accustomed grounds and stations, is further secured to said Indians in common with the citizens of the territory....together with the privilege of hunting, gathering roots and berries, and pasturing their horses on open and unclaimed lands."[1]

---

[1]Treaty of Medicine Creek, Art. 3,10 Stat. 1132 (1855) Source: Washington Salmon: Understanding ion, Washington State House of Representatives, 1988.

When confrontations between Indian and non-Indian fishermen escalated in the 1970s U.S. District Attorney Stan Pitkin brought suit against the state of Washington. The suit was brought by the United States on behalf of local Indian tribes. In 1974 Judge Boldt ruled in *U.S. v. Washington*, 384 F.Supp. 312 (1974) that

> Nontreaty fishermen shall have the opportunity to take up to 50% of the harvestable number of fish that may be taken by all fishermen at usual and accustomed grounds and stations, and treaty right fishermen shall have the opportunity to take up to the same percentage of harvestable fish.

As of June 1, 1974, Indian fishermen exercising fishing rights were required to specify the areas opened to fishing. Biologists working for the Indian tribes and biologists working for the state were instructed to meet and formulate guidelines and regulations for the salmon fishery. In 1974 the Northwest Indian Fisheries Commission was established by the Indian tribes named in *U.S. v. Washington* and became the regulatory body for Indians exercising treaty fishing rights. The Boldt decision had, in effect, split the management of the commercial salmon fishery between the Washington Department of Fish and the Northwest Indian Fisheries Commission.

Concurrent to the Boldt decision, the legislature of the State of Washington adopted Third Substitute Senate Bill No. 2940. This bill froze the number of non-treaty commercial salmon vessel licenses available. Only those license holders of record between January 1, 1970 and May 6, 1974 were eligible to renew their license.[2] The Bill passed in 1974 was temporary and was set to expire on December 31, 1977. In 1977 the license

---

[2] In 1972 1,729 gill net, 275 purse seine, 61 reef net, and 3,753 troll licenses were sold from the state to men. Source: Salmon Limited-Entry Program Development, Interim Progress Report. Washington Department of ies, May 1976.

moratorium was extended to 1980 and in 1979 the legislature made the moratorium permanent (Benson and Longman, 1978). Amendments were added to the bill in 1977 requiring at least one food fish landing per license and a federally funded vessel buy back program was implemented. Interested vessel license holders could receive, in payment from the state, the average of two independent valuation surveys for their vessel. The vessels purchased by the state were then auctioned off to the public under the stipulation that the buyer not use the vessel in the Washington State salmon fishery (Bell 1978). The number of licenses for each gear type were therefore frozen at the 1974 open access equilibrium, with downward fluctuations possible through ineligibility (did not land a food fish) and the buy back program.

Current Regulation

The duties of the numerous agencies currently involved in regulating the fishery are roughly delineated by area. The Pacific Salmon Commission (PSC) establishes catch parameters for stocks in the Pacific Northwest. The commission was created in 1985 under the U.S.-Canada Salmon Interception Treaty. This treaty was formed to establish harvest guidelines for each country in proportion to the number of salmon originating in each country. The PSC was established to oversee the implementation of the provisions of the treaty and consists of eight individuals, four each from the U.S. and Canada. The American members are appointed by the President and include a representative from the Federal government, the State of Washington, the State of Oregon, and a representative of

the treaty tribes covered under the Boldt decision. The catch guidelines established by the PSC are considered by the states (U.S.) or provinces (Canada) affected.

The catch guidelines established by the PSC are passed along to The Pacific Fishery Management Council (PFMC). The PFMC was created in 1976, under the Magnuson Fishery Conservation and Management Act, to monitor fisheries management plans for U.S. coastal waters. In February of each year the PFMC determines the allocation of the PSC parameters between the states of Washington, Oregon, and California. In March the various fishing groups meet with the PFMC to discuss and negotiate allocation across gear types, allocation between Indians and non-Indians, escapement goals and gear restrictions. Once the PFMC guidelines are established for the ocean fishery, the Washington Department of Fish and Wildlife (WDOFW) and The Northwest Indian Fisheries Commission (NWIFC) establish guidelines for Puget Sound and the Columbia River.[3] The WDOFW enforces the regulations that are established for non-treaty commercial fishermen operating in Washington. The WDOFW manages non-treaty commercial catch using combinations of season, area and gear restrictions.

Species and Harvest Methods

Chinook, chum, pink, coho and sockeye salmon are harvested in Washington. Chinook salmon are the largest and along with sockeye command the highest price. Most of the sockeye salmon harvested in Washington are on their way to spawn in the Fraser

[3] The Washington Department of Fish recently merged with the Washington Department of Wildlife to form ashington Department of Fish and Wildlife.

River system in British Columbia. Pink salmon are the smallest on average and along with chum salmon command the lowest price. Puget Sound pink salmon spawn only in odd numbered years. Table 1 presents the average price per pound and average pounds per landed fish, by species, for 1991. 1991 is the latest year published data are available from the WDOFW.

Table 1. 1991 Average Price and Pounds, by Species

Species	Average Price/Pound	Average Pounds/Fish landed
Chinook	$1.22	14.50
Chum	$0.54	9.25
Pink	$0.20	4.00
Coho	$0.86	6.39
Sockeye	$1.21	5.32

Source: Washington Department of Fish and Wildlife, 1991 Fisheries Statistical Report

Troll fishermen operate off the coast of Washington and in the Strait of Juan de Fuca and catch large numbers of chinook, coho and pink salmon. They catch virtually no chum or sockeye salmon. Gill net fishermen catch all five species and purse seine fishing is amenable to coho, chum, pink and sockeye fishing. Chinook stocks are less concentrated relative to the other species and are, therefore, only landed incidentally by purse seine fishermen. Table 2 presents the 1991 combined Indian and non-Indian pounds harvested by species and gear type.

Table 2. 1991 Pounds Harvested by Species and Gear Type

Gear	Chinook	Chum	Pink	Coho	Sockeye	Total
Purse Seine	271	2,775	10,183	1,023	4,147	18,399
Gill net	3,259	7,307	2,234	5,221	5,313	23,334
Troll	762	0	189	766	1	1,718
Reef net	3	24	788	10	306	1,131
Other Gear	198	17	108	310	13	646
Total	4,493	10,123	13,502	7,330	9,780	45,228

Source: Washington Department of Fish and Wildlife, 1991 Fisheries Statistical Report

Four gear types are licensed for use by non-Indian commercial fishermen. In 1991, 327 purse seine, 50 reef net, 979 troll and 1,644 gill net commercial salmon licenses were issued. The purse seine vessels only fish in Puget Sound. Reef nets are fished in the San Juan Islands and the troll vessels are restricted to coastal waters and the Strait of Juan de Fuca. There are three distinct gill net licenses. These are the Puget Sound, Gray's Harbor, and Willapa Harbor licenses. The scope of this thesis is limited to the non-treaty commercial purse seine, troll and Puget Sound gill net fisheries.

Higgs (1982) includes an appendix with detailed descriptions of the gear types used in the Washington salmon fishery. Purse seine vessels encircle schools of fish with 200-300 fathom long nets that extend 20-25 fathoms deep. One edge of the net is attached to the vessel and the other to a skiff. Once the fish are encircled the net is brought on board by drawing in a rope running through the bottom rungs of the net at a faster rate than the top edge of the net. Because the bottom edge is pulled in faster than

the top, the bottom of the net is drawn together forming a purse, trapping the fish. Juvenile fish are able to escape through the holes in the net, while larger fish cannot.

Troll fishermen attract salmon by pulling baited hooks or lures through the water. The hooks are attached to long poles that extend perpendicular to the side of the vessel and are fished at varying depths by using appropriate sinkers. When a fish strikes, the line is reeled in and the fish is removed, cleaned, and stored. In Washington there are typically two distinct troll fishing seasons, one in early summer and the other in mid to late summer. During this time, troll fishermen occasionally stay out for weeks at a time before returning to port.

Gill net fishermen in Puget Sound operate at night when the fish cannot see the drift net. Corks or some other type of floatation device are set atop one edge of the net and weights are set along the other. The nets are floated through the water across the path of salmon who become entangled in the web of material. The opening between strands of material (the mesh size) of the net is varied to target certain species or certain age classes within species. Small juvenile fish are able to pass through the net and larger fish do not become entangled if the mesh size is too small.

CHAPTER 5

DATA SET CONSTRUCTION

This chapter describes the construction of the data sets used in the empirical analyses to follow. Cross-section time-series data sets are created that are used to test for heterogeneous fishermen in the Washington commercial salmon purse seine, Puget Sound gill net and troll fisheries. The time series spans 1981 to 1986 and a sample of fishermen is chosen from among the thousands that fish each year.

Washington Department of Fish and Wildlife Data Bases

The Washington Department of Fish and Wildlife (WDOFW) maintains an annual fish ticket data base and an annual commercial license data base. Both were provided by the WDOFW and all of the following analyses were performed on data sets created using this information. The fish ticket file contains information recorded from transactions between fishermen and fish buyers. The commercial license file, hereafter referred to as the vessel file, contains annual registration information and information on the physical characteristics of the vessels licensed to fish in Washington. Both files identify vessels by a state issued vessel registration number that can be used to link the fish landings information to the vessel license information.

When a fisherman sells his catch to a dealer in a port within the boundaries of the state of Washington, the transaction is recorded on a fish ticket. Fish buyers are licensed and bonded by the state and are required to fill out a fish ticket at the time of each purchase. The tickets have multiple copies, one of which must be received by the WDOFW within four days of the landing. Two copies are retained by the buyer and one copy is for the fisherman. The ticket heading contains the type of gear used, vessel registration number, fish buyer identification number, date of the landing, catch area and fish ticket number. Codes are used to simplify and standardize the process. For example, the gear codes for gill net, purse seine and troll are 14, 19, and 41. The body of the fish ticket contains the species landed, number of fish, pounds, type of pounds, price paid per pound and grade of the species. Again, codes are used where the information is not numerical. The type of pounds code indicates whether the fish were landed whole (round pounds), or with the head removed (dressed pounds). The grade code is a two digit numerical code representing the size of the fish. Each species/grade/price combination is listed on a separate line of the fish ticket. For example, if a fisherman lands 5 sockeye and 10 chinook and two of the chinook command a higher price there will be three separate entries on the fish ticket, one for the five sockeye, one for the two high quality chinook and one for the eight lower quality chinook. Each separate entry on the fish ticket becomes an observation in the fish ticket data base.

Once the fish ticket is received by the WDOFW the heading information is checked by computer input schedulers. Research analysts check the species and catch area information for accuracy and reasonableness. If there are consistent errors from a certain

dealer the dealer is liable to pay civil penalties of ten to fifty dollars per inaccurate fish ticket, therefore, a monetary incentive exists for the dealers to provide accurate and complete information. When the review process is complete the fish tickets are sent to the data entry division where they are entered into the annual fish ticket data base. Once entered into the data base the data base itself is reviewed by biologists and fishery managers. Once all the reviewers are satisfied with the accuracy of the data base it is labeled "final". All of the annual files used in the present analysis are "final" versions. The typical annual file contains 300,000 observations.

The fish ticket data base contains information on all species landed by all gear types. The first step was to identify all salmon landings made by commercial fishermen. Indian fishermen exercising treaty fishing rights are excluded from the analysis. All data base construction and analysis steps were performed using the SAS software package. From each annual fish ticket file, 1981 to 1986, all salmon landed by commercial fishermen were exported to six separate annual salmon files. Observations that had missing vessel registration numbers were deleted.[4] The round pounds landed were multiplied by the dealer reported price to arrive at the money paid to the fishermen. If the price reported by the dealer was missing, the missing value was replaced by the annual average value from all non-missing observations for that species and grade. Next, each individual salmon file was sorted into three separate files, one for each of the gear types.

---

[4]The percentage of vessel registration numbers missing ranged from a low of 2.2 percent in 1982 to 5.0 in 1986.

The result was 18 files, 6 annual files for each of the three gear types. These 18 files were used to calculate the performance measures discussed below.

Performance Measure Calculation

Similar to Hilborn and Ledbetter a performance measure was calculated for each vessel that had a landing observation in the fish ticket file. Performance measures for each gear type and year were calculated separately. The first measure took the following form:

$$P_{ijt} = \frac{\frac{V_{ijt}}{m_{ijt}}}{\frac{1}{n}\sum_{i=1}^{n}\frac{V_{ijt}}{m_{ijt}}}$$

Where:

P_{ijt} = Performance measure for vessel i for day j in year t
V_{ijt} = Value of catch for vessel i for day j in year t
m_{ijt} = Number of days fished by vessel i to produce value landed on day j in year t
n = Number of vessels fishing on day j in year t

Because this performance measure is calculated relative to other vessels landing fish on the same day, the daily performance measure controls for weather and stock size variability. A measure above (below) one indicates the above (below) average catch for the vessel for the day fished. The value landed by vessel i on day j in year t is divided by m_{ijt}, the number of days fished, to produce an average daily value for the trip. For instance, if a vessel landed $1,000 of fish on July 1 and had been fishing for two days, the

performance measure would be calculated for July 1 and the numerator would equal $500. A more robust measure would compare the actual value of catch for each day to the average catch for each day. If a vessel fishes for more than one day before landing the fish caught, however, it is impossible to determine from the fish ticket data base the value of fish caught on each day. For the purse seine and gill net fisheries this complication is mitigated by the fact that during 1981 to 1986 between 97.5 percent and 99.7 percent of the fishing trips lasted one day. This is not the case in the troll fishery. Table 3 presents the number of days fished per trip for the troll fleet.

Table 3. Number of Days Fished per Trip for the Troll Fleet.

Year	Number of Days Fished	Frequency	Percent
1981	1	14,157	81.3
	2	1,173	6.7
	3-35	2,085	12.0
1982	1	8,608	80.0
	2	750	7.0
	3-21	1,405	13.0
1983	1	4,662	74.9
	2	595	9.6
	3-15	970	15.5
1984	1	420	65.6
	2	91	14.2
	3-8	129	20.2
1985	1	3,497	78.5
	2	405	9.1

Table 3, cont.

	3-10	554	12.4
1986	1	2,508	79.4
	2	376	11.9
	3-8	276	8.7

It is common for troll fishermen to fish for more than one day before landing their fish. In some cases discussed below the performance measure used for the troll fishery is an average value landed calculated over a period of three weeks or more. Problems with the daily measure also exist for the gill net and seine gear types.

Gill net fishermen fish at night. Regulations for 1981 to 1986 restricted fishing hours to begin between 3 to 7 p.m. and end between 8 to 9 a.m. depending on the area and date of opening. This presents complications in the interpretation of the daily performance measure. If only one vessel makes a landing before midnight on day 1 that vessel receives a performance measure equal to one. If all the other vessels land their fish in the morning they are included in the performance measure for day 2. Similar problems exist in the purse seine fishery. When an area is opened to purse seine fishing, vessels can typically fish between 5 a.m. and 8 or 9 p.m. If a vessel were to land fish after midnight it would be included in a different performance measure calculation than the other vessels even though all vessels were fishing during the same hours on the same day. A daily performance measure is desirable because it accounts for weather and stock size variations but it is impossible using available data to be certain which day fish landed were actually

caught. Alternative , broader, measures are calculated to mitigate these complications and to provide a measure against which the robustness of the statistical analyses performed on the daily measures can be compared. A second performance measure for the purse seine and gill net fisheries takes the form:

$$WP_{ikt} = \frac{V_{ikt}}{\frac{1}{n}\sum_{i=1}^{n} V_{ikt}}$$

Where:

WP_{ikt} = Performance measure for vessel i in week k in year t

V_{ikt} = Value of catch for vessel i for week k in year t

n = Number of vessels fishing in week k

And for the troll fishery:

$$OP_{iot} = \frac{V_{iot}}{\frac{1}{n}\sum_{i=1}^{n} V_{iot}}$$

Where:

OP_{iot} = Opening performance measure for vessel i during opening o in year t

V_{iot} = Value of catch for vessel i during opening o in year t

n = Number of vessels fishing during opening o

The second measure is a weekly performance measure for the purse seine and gill net fleets and an opening performance measure for the troll fishery. The first day an area is opened for purse seine and gill net fishing is typically between Monday and Friday and the openings usually do not extend into the following week. A week is therefore defined as the seven days starting on Monday and ending on Sunday. For the troll fleet there are typically two distinct openings each year. The first is in the early summer and the second in mid to late summer. Because troll vessels commonly fish for more than 7 days at a time an opening measure seemed more appropriate than a weekly measure . These alternative performance measures will be used as a check on the sensitivity of the analyses performed on the daily measures.

Finally an annual performance measure is calculated for each fishery and each year:

$$AP_{it} = \frac{V_{it}}{\frac{1}{n}\sum_{i=1}^{n} V_{it}}$$

Where:

AP_{it} = Annual performance measure for vessel i in year t

V_{it} = Value of catch for vessel i in year t

n = Number of vessels fishing in year t

Dividing the total value of the fishery by the number of vessels fishing in year t is necessary to correct for changes through time in the number of vessels fishing.

Construction of Performance Measure Data Sets

The vessel file contains an observation for each unique occurrence of vessel registration number/gear type/owner/operator. It is possible and common for vessels to have licenses for multiple gear types and a license fee is required for each. The owner field lists the name of the vessel title holder but this is not necessarily the person who operates the vessel during the fishing season. A separate operator field lists the name of the person who will operate the vessel using the indicated gear type. It is costless to list additional operators. An owner can for instance, list himself his brother and his next door neighbor at zero marginal cost. The person who actually lands fish using the vessel must, however, be listed in the commercial license file as an operator for that particular vessel. A record type field flags observations that list multiple operators. The first owner operator combination is set to 0, all others are set equal to 1. If a vessel did not change ownership in 1987, had only one registered operator and had a purse seine license, trawl license and crab license, three observations would exist for this vessel in year 1987. If two operators were listed for the purse seine license an additional observation would exist, record type 1, for the additional operator. In addition to owner and operator information the data base contains information on the physical attributes of the vessel. The length, beam, horsepower, type of engine, net tonnage, gross tonnage, year built, year purchased,

purchase price, number of crew and electronic equipment on the vessel are all fields in the data base. Fishermen are encouraged, but not required, to fill out vessel information forms detailing the physical attributes of their vessel. There is no incentive to provide accurate and complete information, but misleading and inaccurate information comes without reward as well.

The purpose of the analyses is to determine to what extent heterogeneity in skill determines the value of landed fish. Each performance measure calculated above must be linked to a particular operator, but, since multiple operators can be listed in the vessel file, this is impossible. It is possible ,however, to identify the vessels that only have one operator listed. For each of the three fisheries the vessels that had a constant and unique owner/operator combination during the period 1981 to 1986 were identified. From this sample, vessels were identified that had complete physical characteristic information in the vessel file. If the information was missing but obvious, the missing information was replaced. For example, if the length of a vessel listed for 1981 to 1984 and 1986 was 55 feet but the information was missing in 1985 , the missing information for 1985 was replaced with 55 feet. Combining the performance measures with the sample of vessels identified in the vessel file resulted in a sample of 74 fishermen for the purse seine fleet, 149 for the gill net fleet and 81 for the troll fleet. Table 4 presents the number of vessels that landed fish (Participants) for each fishery and year. The percentage of total participants sampled (Pct. of Total) is listed in the table as well as the mean value of the annual performance measure for the vessels sampled.

Table 4. Attributes of Performance Measure Data Sets

Fishery	Year	Participants	Sample Size	Pct. of Total	AP_{ijt} Avg.(Sample)
Seine	1981	385	74	19.2%	1.33
	1982	362	74	20.4%	1.33
	1983	354	74	20.9%	1.34
	1984	330	74	22.4%	1.54
	1985	353	74	20.9%	1.44
	1986	324	74	22.8%	1.17
Gill Net	1981	1,439	149	10.4%	1.52
	1982	1,402	149	10.6%	1.67
	1983	1,323	149	11.3%	1.65
	1984	1,200	149	12.4%	1.72
	1985	1,249	149	11.9%	1.64
	1986	1,174	149	12.7%	1.31
Troll	1981	2,435	81	3.3%	3.29
	1982	2,247	81	3.6%	4.17
	1983	2,048	81	4.0%	4.71
	1984	378	81	21.4%	1.47
	1985	1,143	81	7.1%	3.52
	1986	1,248	81	6.5%	3.58

By construction, the annual performance measure equals one for each gear type in each year. The samples, however, are above the mean value for each fishery and each year. The vessels sampled are ,therefore, operated by fishermen that land more value than those vessels that were not sampled. The sample mean is particularly high for the 81 troll

vessels sampled. A smaller percentage of the total number of vessels fishing in the troll fleet were sampled because troll boats tend to change owners more often and/or more than one operator for each season is listed more often than in the purse seine and gill net fleets. In 1984 the salmon troll season was considerably shorter than in the other 5 years. Fewer vessels fished in 1984 and this introduced a discontinuity into the fishing history of many vessels in the troll fleet. The sample of 81 vessels all fished in 1984 and provides a possible explanation for the above average mean value of the annual performance measure—only good fishermen fished in 1984.

CHAPTER 6

EMPIRICAL ESTIMATION AND RESULTS

Fishing operations basically combine two composite inputs, capital and labor, to produce fishing effort. Of interest in this chapter is the problem of how to isolate systematic differences across fishermen in their ability to find, harvest and land fish. If systematic differences exist we can infer that the average cost of producing fishing effort is different across fishermen.

To isolate the differences in fishing skill, it is necessary to control for differences in vessel characteristics across fishermen. Two equally skillful fishermen might systematically produce different levels of catch if one has a better boat than the other. Hilborn and Ledbetter (1985) isolated fishermen skill using two separate data analyses. As discussed in chapter 2 their performance measure first was regressed on the vessel characteristics of the vessels used in the fishing operation. Next, an analysis of variance technique was employed to determine the extent to which the vessel, in a composite sense, explained differences in landed catch. The difference in explanatory power of the two analyses was attributed to skipper, crew and net effects.

The analysis of variance technique used by Hilborn and Ledbetter is equivalent to an OLS regression of the performance measure on qualitative dummy variables for each of the vessels. At first blush it would appear that an improved analysis would include the

vessel characteristics and dummy variables in a single regression. However, this is in some cases impossible and in others unwise. For a given vessel and, therefore, in this analysis a given fisherman, some of the vessel characteristics measured are unlikely to change through time. For instance, it is uncommon for fishermen to change the length of their vessel. If a vessel characteristic does not change, the intercept is a linear combination of the characteristic and the qualitative vessel dummy variable. The data matrix is not invertible and the coefficients cannot be estimated using OLS. If only very small changes occur, the matrix is invertible. If the characteristics and the dummy variables are highly correlated, however, the standard errors of the regression coefficients are increased and coefficients may appear insignificant.

Explanatory Power of Vessel Characteristics

The first step, then, in identifying heterogeneity in skill is to determine the explanatory power of vessel characteristics in explaining differences in the performance measures. If vessels were homogeneous this step could be ignored. The differences across fishermen would implicitly account for differences in vessel characteristics. Unfortunately, vessels in the Washington salmon fishery are not homogeneous. For the vessels sampled the range in vessel length alone exceeds 20 feet in all three fisheries. Table 5 presents summary statistics for the vessels used in the following analyses.

Table 5. Summary Statistics of Vessel Characteristics

Seine				
	Minimum	Maximum	Mean	Std. Deviation
Length	42.0	68.0	55.3	6.2
Beam	12.0	20.0	15.8	2.0
Horsepower	110.0	455.0	243.6	82.9
Net Tons	1300.0	5400.0	2921.1	991.6
Year Built	1911	1980	1943	23
Gill Net				
	Minimum	Maximum	Mean	Std. Deviation
Length	16.0	41.0	31.6	4.0
Beam	8	14	10.7	1.2
Horsepower	25.0	660.0	242.7	120.8
Net Tons	100.0	1700.0	769.5	333.9
Year Built	1915	1981	1969	11.8
Troll				
	Minimum	Maximum	Mean	Std. Deviation
Length	19.0	48.0	36.0	7.7
Beam	7.0	105.0	11.3	6.3
Horsepower	16.0	550.0	163.0	95.6
Net Tons	75.0	3100.0	1034.7	718.9
Year Built	1917	1979	1957	17.8

To determine to what extent vessel characteristics determine performance in the purse seine fleet the following regression was performed:

For the purse seine fishery:

$$P_{ijt} = \beta_0 + \beta_1 Length_{it} + \beta_2 Horsepower_{it} + \beta_3 Nettons_{it} + \beta_4 Yearbuilt_i + \beta_5 Lengthover58_i + \beta_6 Loran_i + \beta_7 Radar_i + \beta_8 Fathometer_i + \upsilon_{ijt}$$

Where:

P_{ijt} = Daily performance measure for vessel i on day j in year t

Length = Length of vessel i in year t

Horsepower = Engine horsepower of vessel i in year t

Nettons = Net tons of vessel i in year t

Yearbuilt = Year vessel i was built

Lengthover58 = Qualitative dummy variable set equal to one if the vessel length exceeds 58 feet

Loran = Qualitative dummy variable set equal to one if the vessel has Loran equipment

Radar = Qualitative dummy variable set equal to one if the vessel has Radar equipment

Fathometer = Qualitative dummy variable set equal to one if the vessel has a Fathometer

The beam measurement of the vessel is not included in the seine regression because it is highly correlated ,ρ= 0.89, with the net ton measurement. Correlation coefficients for all of the purse seine vessel characteristics are presented in Appendix A. The gill net and troll vessel characteristic correlation coefficients are presented in Appendices B and C. The type of engine used, gasoline or diesel, is known, but, a dummy

variable for the engine type is not included in the seine regression because all of the vessels in the sample used diesel engines.

In general larger boats are expected to catch more fish. The expected sign for Length, Horsepower and Nettons is therefore positive. It is also expected that newer boats will harvest more fish, therefore, the expected sign for Yearbuilt is positive. There is not a length restriction on purse seine vessels used in the Washington salmon fishery but there is a 58 foot restriction for the Alaskan salmon purse seine fisheries. Although impossible to tell from the vessel license registration file, the WDOFW asserts that a significant number of Washington purse seine owner-operator combinations also fish in Alaska. The Lengthover58 variable is included in the seine regression to control for differences that might exist across fishing units that only fish in Washington. To the extent that the 58 foot limit in Alaska is binding and larger vessels are better suited to catching more fish a positive effect is expected for vessels over 58 feet. An opposing effect is also possible; vessels under 58 feet are operated by better fishermen who fish more often, in both Washington and Alaska, relative to those with vessels over 58 feet. An *a priori* prediction on the sign for the Lengthover58 variable is therefore not possible. Loran, radar and fathometer equipment is expected to positively affect value landed so the expected signs are all positive. Table 6 presents the regression results for the purse seine fishery.

Table 6. Seine Vessel Coefficients

Seine		
Number of Observations	R^2	F Statistic
5,679	0.0516	38.5
Variable	Parameter Estimate	t statistic
Intercept	-0.679917	-2.71
Length	0.026617	7.32
Horsepower	0.000920	4.23
Net Tons	0.000055	2.30
Year Built	-0.000303	-0.31
Length Over 58	-0.463878	-10.94
Loran	0.003687	0.11
Radar	-0.014741	-0.22
Fathometer	0.001182	0.01

For the seine fishery the coefficients for length, horsepower and net tons have the expected sign. All three are significant at the 5 percent confidence level for a one tailed t-test. The negative sign on the year built coefficient is counter-intuitive but is not significantly different from zero. The coefficient for the dummy variable set equal to one if the vessel is over 58 feet is negative and significantly different from zero. The magnitude of the coefficient is surprisingly large. The interpretation of the change in the performance measure with respect to a 1 foot change in length holding everything else constant is:

$$\frac{\partial P_{ijt}}{\partial Length} = 0.026(1) - 0.46(L58)$$

$$L58 = \begin{cases} 1 \, if \, length > 58 \, feet \\ 0 \, otherwise \end{cases}$$

Therefore a one foot change in length from 57 feet to 58 feet adds 0.026 units to the performance measure. A movement from 58 feet to 59 feet reduces the performance measure by 0.464-0.26=0.43 points. The results of excluding the vessels that are over 58 feet in length and running the regression without the length over 58 feet dummy variable are presented in table 7.

Table 7. Seine Vessel Coefficients, Vessels over 58 Feet Excluded

Seine		
Number of Observations	R^2	F Statistic
4,277	0.0670	43.8
Variable	Parameter Estimate	t Statistic
Intercept	-0.589182	-2.15
Length	0.020723	4.96
Horse power	0.000843	3.02
Net Tons	0.000151	4.60
Year Built	-0.000836	-0.77
Loran	-0.104805	-2.67
Radar	0.138050	0.91
Fathometer	-0.128199	-0.55

The R^2 increases slightly when the Lengthover58 variable and the corresponding observations are excluded. The Loran coefficient switches sign becoming negative and significant. There is no reason to believe Loran equipment lowers performance. Approximately 5 to 6 percent of the variation in the performance measures across fishermen in the purse seine fleet is explained by vessel characteristics. Performing an F test, the hypothesis that vessel characteristics are jointly insignificant in explaining performance can be rejected at the 1 percent confidence level for both regressions. Vessel characteristics are significant in explaining performance but their explanatory power is small relative to the total variability in performance.

A similar regression is performed using the data from the gill net and troll fleets.

$$P_{ijt}=\beta_0+\beta_1 Length_{it}+\beta_2 Beam_{it}+\beta_3 Horsepower_{it}+\beta_4 Nettons_{it}+\beta_5 Yrbuilt_i$$
$$+\beta_6 Engine\,type_{it}+\beta_7 Loran_{it}+\beta_8 Radar_{it}+\beta_9 Fathometer_{it}+\upsilon_{ijt}$$

The regression takes the following form:

Where:

P_{ijt} = Daily performance measure for vessel i on day j in year t

Length = Length of vessel i in year t

Beam = Beam of vessel i in year t

Horsepower = Engine horsepower of vessel i in year t

Nettons = Net tons of vessel i in year t

Yearbuilt = Year vessel i was built

Enginetype = Qualitative dummy variable set equal to one if the engine is a diesel engine

Loran = Qualitative variable set equal to one if the vessel has Loran equipment

Radar = Qualitative variable set equal to one if the vessel has Radar equipment

Fathometer = Qualitative variable set equal to one if the vessel has a Fathometer

The regression results for the gill net and troll fleets are presented in table 8. Similar to the purse seine fleet, larger, faster vessels are predicted to land more fish and electronic equipment is predicted to positively affect performance.

Table 8.Gill Net and Troll Vessel Coefficients

Gill Net		
Number of Observations	R^2	F Statistic
12,217	0.0116	16.0
Variable	Parameter Estimate	t Statistic
Intercept	0.477406	3.83
Length	0.007894	2.24
Beam	0.008159	0.79
Horsepower	0.000189	1.97
Net Tons	0.000100	2.84
Year Built	0.003038	3.68
Engine Type	-0.052850	-1.97
Loran	0.059623	1.79
Radar	0.012091	0.60
Fathometer	-0.062582	-1.04
Troll		
Number of Observations	R^2	F Statistic
3,065	0.0951	35.7
Variable	Parameter Estimate	t Statistic

Table 8, cont.

Intercept	-0.508308	-1.53
Length	0.023893	2.71
Beam	0.005334	1.04
Horsepower	0.000407	1.09
Net Tons	-0.000032	-0.44
Year Built	0.003710	1.84
Engine Type	0.617000	4.45
Loran	-0.134295	-1.10
Radar	0.284206	5.34
Fathometer	0.310101	1.82

For the gill net fleet all quantitative variables have the expected positive sign and all but the coefficient for beam are significantly different from zero at the 5 percent level of confidence. The coefficient for engine type indicates that vessels using diesel engines have a lower performance measure than vessels with a gas engine. The coefficient is significant at the 5 percent confidence level. The negative coefficient for the fathometer dummy is counter-intuitive but not significantly different from zero.

For the troll fleet, length, beam, horsepower, and year built all have the expected positive sign. The coefficient for net tons is negative but insignificant. The coefficients for the qualitative variables indicate diesel engines and radar significantly improve performance. The Loran dummy is negative but insignificant and the Fathometer dummy is positive and significant at the 10 percent confidence level for a one tail t-test.

Vessel characteristics are jointly significant in explaining performance in both fleets. An F test rejects the hypothesis that vessel characteristics are jointly insignificant at the 1 percent confidence level. Vessel characteristics explain approximately 1 percent of the variation in the daily performance measure in the gill net fleet and 9 percent in the troll fleet.

The above regressions, for all three fleets, were repeated using the weekly (the opening performance measure is used for the troll fleet) and annual performance measures in place of the daily performance measure. Table 9 repeats the results from the regression using the daily performance measure and also presents the results from the regressions using the weekly and annual performance measures.

Table 9. Summary of Vessel Coefficients from Performance Measure Regressions

Fishery	Variable	P_{iit}	t	WP_{ikt}	t	AP_{it}	t
Purse Seine	Length	0.026	7.3	0.023	5.0	0.0047	0.29
	Horsepower	0.0009	4.2	0.0005	2.0	0.00003	0.03
	Net tons	0.00005	2.2	0.00006	2.0	0.0001	1.5
	Year built	-0.0003	-0.30	-0.0003	-0.2	-0.012	-3.1
	L. over 58	-0.46	-10.9	-0.41	-7.5	-0.019	-0.1
	Loran	0.0036	0.1	0.049	1.1	-0.083	-0.6
	Radar	-0.014	-0.2	-0.031	-0.3	0.278	0.8
	Fathometer	0.0011	0.0	-0.349	-1.5	0.320	0.3
R^2		0.051		0.045		0.048	
F Statistic		38.5		19.8		4.4	
Gill Net	Length	0.007	2.2	0.0003	0.05	0.0025	0.1
	Beam	0.008	0.7	0.05	3.3	0.12	2.5
	Horse power	0.0001	1.9	0.0004	3.1	0.0003	0.7

Table 9, cont.

	Net tons	0.00009	2.8	0.00008	1.5	0.0001	0.9
	Year built	0.003	3.6	0.002	1.8	0.006	1.3
	Engine type	-0.052	-1.9	-0.050	-1.2	-0.339	-2.5
	Loran	0.059	0.059	-0.052	-1.0	-0.417	-2.5
	Radar	0.012	0.6	0.043	1.4	0.237	2.2
	Fathometer	-0.062	-1.0	-0.10	-1.1	-0.173	-0.5
R^2 F Statistic		0.011 15.9		0.021 14.7		0.064 6.7	
Troll	Length	0.023	2.7	0.066	1.9	0.11	1.8
	Beam	0.0053	1.0	-0.0082	-0.4	-0.025	-0.9
	Horse power	0.00040	1.0	-0.00034	-0.2	-0.001	-0.6
	Net tons	-0.000031	-0.4	-0.00027	-0.9	-0.0005	-1.1
	Year built	0.0037	1.8	0.0182	2.2	0.028	2.0
	Engine type	0.617	4.4	1.934	3.4	3.04	3.3
	Loran	-0.134	-1.1	-0.352	-0.7	-0.326	-0.4
	Radar	0.284	5.3	0.683	3.1	0.629	1.7
	Fathometer	0.31	1.8	-0.259	-0.3	-0.514	-0.4
R^2 F Statistic		0.095 35.6		0.146 14.0		0.199 13.1	

The coefficients are for the most part stable across the three performance measures. The negative and significant coefficient for year built in the annual regression for the purse seine fishery is, however, unexpected. The mean year built for vessels 58 feet and under is 1946. For vessels over 58 feet the mean year built is 1928. If a substantial number of the smaller vessels (and newer vessels) exit the Washington fishery to fish in Alaska, the proportion of annual catch harvested by this group of vessels will

decrease. This is a possible explanation of the negative and significant coefficient on the year built variable. Unfortunately it is impossible, using publicly available information, to determine which vessels fish in both areas.

For the purpose of this study the most important question is the overall explanatory power of the vessel characteristics. The explanatory power of vessel characteristics is consistent across performance measures in the seine fishery ranging from 4.5 percent to 5.1 percent. The largest difference across measures occurs in the troll fleet. The vessel characteristics explain 9.5 percent of the variation in the daily measure and 19.9 percent of the variation in the annual performance measure. The substantial difference between the R^2 measure in the daily regression and annual regression is not entirely surprising. Troll fishermen fish for extended periods of time and it is impossible to match their landed fish to the actual day the fish were caught. The daily measure for the troll fleet, therefore, averages weather and stock size variability over many days. Also, if only a few troll vessels return to port on a given day, their performance measure may not reflect their true performance relative to other fishermen. Because the fishing hours for the seine fishery extend no later than 8 or 9 p.m., this fleet is the least likely to have vessels landing fish on any other day than when they were caught. Therefore we would expect the least improvement in the weekly measure over the daily measure.

Tests for Systematic Differences across Vessels

Vessel characteristics, although statistically significant determinants of performance, account for a small percentage of the variation in performance across fishermen. The next step then is to determine to what extent vessels in a composite sense, the physical characteristics of the vessel combined with the operator, crew and other unmeasured effects, account for variations in the daily and weekly performance measures. Once the composite effect is measured, an operator effect can be inferred by subtracting off the vessel characteristic effect calculated in the previous regressions. The operator effect is actually an aggregate measure of the explainability of all vessel specific effects unaccounted for in the vessel characteristic regressions. These could include skipper effects, crew effects, and physical vessel attribute effects not measured in the characteristics used above. The following regressions were performed to identify systematic differences in catch across vessels:

For the purse seine fishery:

$$P_{ijt}=\beta_0+\sum_{i=1}^{73}\beta_i Fisherman_i+\upsilon_{ijt}$$

$$WP_{ijt}=\beta_0+\sum_{i=1}^{73}\beta_i Fisherman_i+\upsilon_{ijt}$$

For the gill net fishery

$$P_{ijt}=\beta_0+\sum_{i=1}^{148}\beta_i Fisherman_i+\upsilon_{ijt}$$

$$WP_{ijt}=\beta_0+\sum_{i=1}^{148}\beta_i Fisherman_i+\upsilon_{ijt}$$

For the troll fishery:

$$P_{ijt}=\beta_0+\sum_{i=1}^{80}\beta_i Fisherman_i+\upsilon_{ijt}$$

$$OP_{ijt}=\beta_0+\sum_{i=1}^{80}\beta_i Fisherman_i+\upsilon_{ijt}$$

$Fisherman_i$ is a qualitative dummy variable set equal to one for fisherman i. The above regressions capture the systematic differences across fishermen without controlling for vessel characteristics. The net operator effect, as it has been broadly defined, is calculated by subtracting the explanatory power of the vessel characteristics from the

explanatory power of the regressions using fishermen dummies. For each gear type, one fisherman dummy is excluded and the excluded fisherman's coefficient is captured in the intercept term. Summary statistics for the six regressions are presented in Table 10. The estimated coefficients for the purse seine regressions are presented in Appendix D, for the gill net fishery in Appendix E and the troll fishery in Appendix F.[5] Table 11 summarizes the explanatory power of the vessel characteristics and fishermen dummies and presents the calculated operator effect.

Table 10. Summary Statistics for Fisherman Dummy Variable Regressions

Seine			
Dependent Variable	Number of Observations	R^2	F Statistic
P_{ijt}	5,679	0.166	15.3
WP_{ikt}	3,191	0.192	10.1
Gill Net			
Dependent Variable	Number of Observations	R^2	F Statistic
P_{ijt}	12,236	0..093	8.4
WP_{ikt}	6,061	0.157	7.5
Troll			
Dependent Variable	Number of Observations	R^2	F Statistic
P_{ijt}	3,065	0.231	11.2
OP_{ijt}	746	0.431	6.3

[5] Because vessel characteristics are unaccounted for, the estimated coefficients do not represent a ranking of level for the sampled fishermen. The important result is the explanatory power of the coefficients.

Table 11. Summary of Vessel and Operator Effects

Purse Seine					
Day			Week		
Vessel Characteristics	Composite	Operator	Vessel Characteristics	Composite	Operator
5.1%	16.6%	11.5%	4.5%	19.2%	14.7%
Gill Net					
Day			Week		
Vessel Characteristics	Composite	Operator	Vessel Characteristics	Composite	Operator
1.1%	9.3%	8.2%	2.1%	15.7%	13.6%
Troll					
Day			Week		
Vessel Characteristics	Composite	Operator	Vessel Characteristics	Composite	Operator
9.5%	23.0%	13.5%	14.6%	43.1%	28.5%

The operator effect explains 11.5 percent of the purse seine daily performance measure and 14.7 percent of the weekly measure. For the gill net fishery the percentages are 8.2 percent and 13.6 percent and for the troll fishery 13.5 percent and 28.5 percent. Systematic heterogeneity unaccounted for by vessel characteristics is present. The null hypothesis that the coeffecients on the fishermen dummies are jointly insignificant can be rejected at the 1 percent confidence level for all six regressions.

Daily and Weekly Performance versus Annual Performance

Johnson and Libecap argued that more productive fishermen would resist regulations that allocated poundage quota equally across fishermen. Hallagan argued that quota allocated proportional to planned production would be supported by more

productive hop growers. The state of Alaska recently allocated halibut poundage quota to fishermen based on historical production. Recalling the important role costs play in the maximization of fishery resources an interesting question to ask is, do high skill fishermen produce large shares of annual catch? If they do not, quota allocated on a historical basis is not allocated to the best fishermen and therefore is not allocated to low cost fishermen. The following regression tests the hypothesis that "good" fishermen on a daily basis also produce large shares of the annual total catch.

$$YP_{it}=\tau_0+\tau_1 Daycoefficient_i+\upsilon_{it}$$

Where:

YP_{it} = Annual performance measure for vessel i in year t

$Daycoefficient_i$ = Regression coefficient for fisherman i from the daily performance measure regression (the coefficients for each fisherman are presented in Appendices D through F).

And the following regression tests the hypothesis that "good" fishermen on a weekly basis (opening basis for the troll fleet) produce large shares of the annual total catch.

$$YP_{it}=\tau_0+\tau_1 Weekcoefficient_i+\upsilon_{it}$$

Where:

YP_{it} = Annual performance measure for vessel i in year t

$Weekcoefficient_t$ = Regression coefficient for fisherman i from the daily performance measure regression (the coefficients for each fisherman are presented in Appendices D through F)

The Daycoefficient variable is obtained from the regression of the daily performance measure on the fishermen dummies. The Weekcoefficient is from the regression of the weekly performance measure (the opening performance measure for the troll fleet) on the fishermen dummies. To include the fishermen omitted from the dummy variable regressions the intercept is added to all of the other coefficients. The omitted fisherman's coefficient then becomes the intercept from the fishermen dummy regression. This is equivalent to running the regressions including all of the dummy variables and suppressing the intercept. The above regression uses regression coefficients as an independent variable. Because these coefficients are stochastic, the regressor and the error term may be contemporaneously correlated. If this is the case, OLS estimates are biased. No attempt is made here to correct for these complications. A positive coefficient on the Daycoefficient or Weekcoefficient variable indicates that good fishermen on a daily or weekly basis produce large shares of the annual total catch. The regression results are presented in Table 12.

Table 12. OLS Estimates for Daycoefficient and Weekcoefficient Variables

Seine

Day Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-0.059779	-0.46
	Day Coefficient	1.433714	11.80
Number of Observations	= 444		
R^2	= 0.240		
F Statistic	= 139.3		
Week Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-0.089086	-0.73
	Week Coefficient	1.490800	12.82
Number of Observations	= 444		
R^2	= 0.271		
F Statistic	= 164.3		

Gill Net

Day Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-0.287046	-2.08
	Day Coefficient	1.816186	14.10
Number of Observations	= 894		
R^2	= 0.182		
F Statistic	= 198.9		
Week Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-0.660158	-6.95
	Week Coefficient	2.146662	25.15
Number of Observations	= 894		
R^2	= 0.415		
F Statistic	= 632.5		

Table 12, cont.

Troll

Day Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-1.854360	-5.85
	Day Coefficient	3.491440	18.47
Number of Observations	= 486		
R^2	= 0.413		
F Statistic	= 341.0		
Season Regression	Variable	Parameter Estimate	t Statistic
	Intercept	-0.232427	-1.17
	Opening Coefficient	1.550610	23.32
Number of Observations	= 486		
R^2	= 0.529		
F Statistic	= 544.0		

The coefficients on the Daycoefficient and Weekcoefficient variables (Opening coefficient for the troll fleet) are all significantly positive. Fishermen in the Washington salmon fishery that perform well on a daily or weekly basis produce large shares of the total value landed for the year. Regulations targeted to fishermen who produce a small proportion of annual catch, target low skill fishermen. For instance, the food fish landing requirement in order to renew a fishing license targets low skill fishermen. If it were the case that high skill fishermen only fished for a few days a year, regulations aimed at low annual producers might target more productive fishermen.

Test for Systematic Differences in Annual Performance

An alternative test (similar to Salvanes and Steen) for systematic differences in fishing ability is to regress the annual performance measure on a first order lag of the annual performance measure (APLAG). A modified Cocharane-Orcutt procedure is performed to recover unbiased and consistent estimates (Ramanathan, 1989). The results are presented in Table 13:

Table 13. OLS Estimates of First Order Lag of Annual Performance Measure

Seine		
Number of Observations	R^2	F Statistic
296	0.614	468.1
Variable	Parameter Estimate	t Statistic
Intercept	0.305383	3.87
Year Performance Lag	0.794682	14.15
Gill Net		
Number of Observations	R^2	F Statistic
596	0.628	1,001.0
Variable	Parameter Estimate	t Statistic
Intercept	0.403089	6.37
Year Performance Lag	0.766247	27.82
Troll		
Number of Observations	R2	F Statistic
324	0.381	198.1

Table 13, cont.

Variable	Parameter Estimate	t Statistic
Intercept	1.475918	5.68
Year Performance Lag	0.604932	14.07

Salvanes and Steen concluded that if a nonstationary process generated a vessel's efficiency score, then fishing luck dominated the determination of the efficiency score. To test for nonstationarity they performed Dickey Fuller unit-root tests on the hypothesis that the coefficient on the first order lag of the efficiency score, ρ, was equal to one. For 8 of the 11 vessels tested, the hypothesis $\rho=1$ could not be rejected. Salvanes and Steen concluded that luck dominated the performance of these 8 vessels.

In Table 13, the null hypothesis that the coeffecient on APLAG is equal to one can be rejected at the 1 percent level for all three gear types. Even if the hypothesis that the coefficient on APLAG is equal to 1 could not be rejected a different interpretation than Salvanes and Steen's is offered in the present context. The coefficient on APLAG is positive and significantly different from zero. The current year's performance is positively affected by the previous year's performance. Fishermen who do well (poorly) one year, on average do well (poorly) the next year. It is the ranking of the fishermen that is important. If the ranking, in terms of the value of fish landed, is consistent through time, fishing skill is an important determinant of landed value. The above regression results add to the earlier evidence that the annual performance measure follows a systematic pattern through time. Heterogeneity exists and persists in the Washington salmon fishery.

CHAPTER 7

SUMMARY AND CONCLUSIONS

Fishermen in the Washington state salmon purse seine, gill net and troll fisheries are heterogeneous in their ability to produce fish. Vessel characteristics account for 1 percent to 20 percent of the variation in the landed value of catch depending on the gear type and performance measure used. The operator effect accounts for 8.2 percent to 28.5 percent of the variation, again, depending on the gear type and performance measure used. These results are similar in magnitude to those found in the British Columbia salmon purse seine fleet by Hilborn and Ledbetter.

Fishermen who perform well on a daily or weekly basis also produce large shares of the annual total value landed. If this result is consistent in other fisheries, quota or limited entry permits allocated to fishermen based on historical catch will go to more productive fishermen. If the goal is to reduce aggregate effort, it is desirable to do so by eliminating high cost producers of effort. The net gain from a reduction in effort is higher from the elimination of a high cost producer relative to a low cost producer. Because high cost producers produce a smaller proportion of the annual total catch, regulations aimed at restricting fishermen, based on low historical catch rates, will restrict high cost fishermen.

If fishermen are heterogeneous, Gordon's zero rent open access equilibrium condition does not hold. High skill fishermen earn rents and may be made worse off by

regulations that reduce aggregate effort towards economic efficiency (Johnson and Libecap, 1982). If the benefits of effort reduction impact fishermen unequally, it is more costly for them to reach agreement on how to limit effort among themselves. Homogeneous fishermen would be better able to contract among themselves to adopt regulations that would increase their individual rents.

Fishery regulation is commonly accomplished through public intervention. If the fishery is characterized by an upward sloping supply schedule of effort some rental value is given up when effort is reduced from the open access equilibrium. If public regulation of the fishery ignores the existence of open access rents, the benefits of regulation are overestimated. If the costs of regulating effort, combined with the open access rents lost to regulation, exceed the net gains in rental value from reductions in effort, society is better off with an unregulated fishery.

If we assume fishermen influence the regulatory process, it follows that established regulations benefit the most politically powerful group of fishermen. Homogeneity would imply that groups of fishermen could get together and lobby the regulatory process for regulations that would increase their individual wealth. The more homogeneous the gear type the less likely fishermen are willing to adopt cost increasing regulations (Anderson 1985) and the more likely they are to limit entry among themselves (Johnson and Libecap 1982). This implies that the more homogeneous the gear type, the less likely it is for regulations to be cost increasing in nature.

An interesting extension of the current analysis would be to compare the extent of gear, area and time restrictions to the heterogeneity of the gear types in the Washington

salmon fishery. Comparing the degree of heterogeneity across gear types is difficult. A possible procedure would be first, to identify a group from each fishery, roughly equal in number, whose members within each group use vessels whose characteristics are very near the mean for that gear type. Next, for each gear type separately, the daily or weekly performance measure could be regressed on dummy variables, one for each fishermen in the group. The variance of the estimated coefficients from each of these regressions would represent the degree of heterogeneity in skill across the three gear types. Based on the previous discussion, it is predicted that the more homogeneous the group, the more likely regulations are going to be rent generating in nature. A difficulty in this approach, of course, is how regulations could be ranked across gear types in terms of their rent-generating capabilities.

LITERATURE CITED

Anderson, Lee G., The Economics of Fishery Management. Baltimore: Johns Hopkins University Press, 1977.

Anderson, Lee G., "Potential Economic Benefits from Gear Restrictions and License Limitation in Fisheries Regulation." Land Economics. (61) 1985: 409-18.

Beddington, J. R., Fogarty, M. J., Rosenberg, A. A., Shepherd, J. G., and Sissenwine, M. P., "Achieving Sustainable Use of Renewable Resources." Science. (262) 1993: 828-29.

Bell, Douglas M., "Gear Reduction/Buyback Programs in British Columbia and Washington State." in Limited Entry as a Fishery Management Tool. Seattle: University of Washington Press, 1978: 353-57.

Bell, Frederick W., "Technological Externalities and Common-Property Resources: An Empirical Study of the U.S. Northern Lobster Fishery." Journal of Political Economy. (80) 1972: 148-58.

Benson, Gary, and Longman, Robert, "The Washington Experience with Limited Entry." in Limited Entry as a Fishery Management Tool. Seattle: University of Washington Press, 1978: 333-37.

Crutchfield, James A., "Economic and Social Implications of the Main Policy Alternatives for Controlling Fishing Effort." Journal of the Fishery Research Board of Canada. (36) 1979: 742-52.

Crutchfield, James A., and Pontecorvo, Giulio, The Pacific Salmon Fisheries. Baltimore: John Hopkins Press, 1969.

Fraser, Alex G., "Limited Entry: Experience of the British Columbia Salmon Fishery." Journal of the Fishery Research Board of Canada. (36) 1979: 754-63.

Gordon, H. Scott, "The Economic Theory of a Common Property Resource: The Fishery." Journal of Political Economy. (62) 1954: 124-42.

Hallagan, William S., "Contracting Problems and the Adoption of Regulatory Cartels." Economic Inquiry. (25) 1985: 37-56.

Higgs, Robert, "Legally Induced Technical Regress in the Washington Salmon Fishery." in Research in Economic History. (7) 1982: 55-86.

Hilborn, Ray, and Ledbetter, Max, "Determinants of Catching Power in the British Columbia Salmon Purse Seine Fleet." Canadian Journal of Fisheries and Aquatic Sciences. (42) 1985: 51-56.

Johnson, Ronald N., and Libecap, Gary D., "Contracting Problems and Regulation: The Case of the Fishery." The American Economic Review. (72) 1982: 1005-22.

Karpoff, Jonathan M., "Suboptimal Controls in Common Resource Management: The Case of the Fishery." Journal of Political Economy. (95) 1987: 179-94.

Kincaid, Joel, "Production Controls, Transaction Costs, and Common Property: The Case of the Fishery." Unpublished manuscript, North Carolina State University, Department of Economics, Raleigh, NC, August 1995.

Meany, T.F., "Limited Entry in the Western Australian Rock Lobster and Prawn Fisheries: An Economic Evaluation." Journal of the Fishery Research Board of Canada. (36) 1979: 859-66.

Nickerson, Peter H., and Rucker, Randal R., "Indian and Non-Indian Salmon Fisheries: The Economic Effects of *U.S. v. Washington*." Unpublished manuscript, Seattle University, Department of Economics, Seattle, WA, and Montana State University, Bozeman, MT, December 1994.

Ramanathan, Ramu, Introductory Econometrics. Harcourt Brace Jovanovich, 1989.

Salvanes, Kjell G., and Steen, Frode, "Testing for Relative Performance between Seasons in a Fishery." Land Economics. (70) 1994: 431-47.

Tietenberg, Tom, Environmental and Natural Resource Economics. Harper Collins, 1992.

Washington Department of Fisheries, Salmon Limited-Entry Program Development. Interim Progress Report, Olympia, WA, 1976.

Washington Department of Fish and Wildlife, 1991 Fisheries Statistical Report. Olympia, WA, 1994.

Washington State House of Representatives, Washington Salmon: Understanding Allocation. Olympia, WA, 1988.

Wilen, James E., "Fishermen Behavior and the Design of Efficient Fisheries Regulation Programs." Journal of the Fishery Research Board of Canada. (36) 1979: 855-58.

APPENDICES

Appendix A - Seine Vessel Correlation Coefficients

Correlation Analysis

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 444

	LENGTH	BEAM	HORSEPOWER	NET TONS	YEAR BUILT
LENGTH	1.00000 0.0	0.52850 0.0001	0.25144 0.0001	0.52186 0.0001	-0.11231 0.0179
BEAM	0.52850 0.0001	1.00000 0.0	0.62004 0.0001	0.89174 0.0001	0.57053 0.0001
HORSEPOWER	0.25144 0.0001	0.62004 0.0001	1.00000 0.0	0.65200 0.0001	0.58877 0.0001
NET TONS	0.52186 0.0001	0.89174 0.0001	0.65200 0.0001	1.00000 0.0	0.60445 0.0001
YEAR BUILT	-0.11231 0.0179	0.57053 0.0001	0.58877 0.0001	0.60445 0.0001	1.00000 0.0
LENGTHOVER58	0.68409 0.0001	0.14288 0.0025	0.01547 0.7451	0.13473 0.0045	-0.31064 0.0001
LORAN	-0.04931 0.2999	0.26720 0.0001	0.35735 0.0001	0.26543 0.0001	0.44619 0.0001
RADAR	-0.17912 0.0001	0.06364 0.1807	0.21788 0.0001	0.08602 0.0702	0.18991 0.0001
FATHOMETER	-0.02826 0.5525	-0.03763 0.4290	-0.09864 0.0377	-0.01894 0.6906	-0.01680 0.7240

	LENGTHOVER58	LORAN	RADAR	FATHOMETER
LENGTH	0.68409 0.0001	-0.04931 0.2999	-0.17912 0.0001	-0.02826 0.5525
BEAM	0.14288 0.0025	0.26720 0.0001	0.06364 0.1807	-0.03763 0.4290
HORSEPOWER	0.01547 0.7451	0.35735 0.0001	0.21788 0.0001	-0.09864 0.0377
NET TONS	0.13473 0.0045	0.26543 0.0001	0.08602 0.0702	-0.01894 0.6906
YEAR BUILT	-0.31064 0.0001	0.44619 0.0001	0.18991 0.0001	-0.01680 0.7240
LENGTHOVER58	1.00000 0.0	-0.13975 0.0032	-0.25191 0.0001	0.03368 0.4790
LORAND	-0.13975 0.0032	1.00000 0.0	0.11728 0.0134	0.03954 0.4059
RADARD	-0.25191 0.0001	0.11728 0.0134	1.00000 0.0	0.33713 0.0001
FATHD	0.03368 0.4790	0.03954 0.4059	0.33713 0.0001	1.00000 0.0

Appendix B - Gill Net Vessel Correlation Coefficients

Correlation Analysis

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0

	LENGTH	BEAM	HORSEPOWER	NET TONS	YEAR BUILT
LENGTH	1.00000 0.0	0.55431 0.0001	-0.16344 0.0001	0.66423 0.0001	-0.14055 0.0001
BEAM	0.55431 0.0001	1.00000 0.0	0.24280 0.0001	0.65007 0.0001	0.41527 0.0001
HORSEPOWER	-0.16344 0.0001	0.24280 0.0001	1.00000 0.0	0.04795 0.0001	0.49840 0.0001
NET TONS	0.66423 0.0001	0.65007 0.0001	0.04795 0.0001	1.00000 0.0	0.18603 0.0001
YEAR BUILT	-0.14055 0.0001	0.41527 0.0001	0.49840 0.0001	0.18603 0.0001	1.00000 0.0
ENGINE TYPE	0.64382 0.0001	0.31200 0.0001	-0.57475 0.0001	0.40365 0.0001	-0.29564 0.0001
LORAN	0.18819 0.0001	0.19390 0.0001	-0.00677 0.4541	0.19394 0.0001	0.05647 0.0001
RADAR	0.31001 0.0001	0.23641 0.0001	0.04429 0.0001	0.17291 0.0001	-0.04126 0.0001
FATHOMETER	0.03169 0.0005	0.01540 0.0885	-0.07681 0.0001	0.05691 0.0001	-0.03327 0.0002

	ENGINE TYPE	LORAN	RADAR	FATHOMETER
LENGTH	0.64382 0.0001	0.18819 0.0001	0.31001 0.0001	0.03169 0.0005
BEAM	0.31200 0.0001	0.19390 0.0001	0.23641 0.0001	0.01540 0.0885
HORSEPOWER	-0.57475 0.0001	-0.00677 0.4541	0.04429 0.0001	-0.07681 0.0001
NET TONS	0.40365 0.0001	0.19394 0.0001	0.17291 0.0001	0.05691 0.0001
YEAR BUILT	-0.29564 0.0001	0.05647 0.0001	-0.04126 0.0001	-0.03327 0.0002
ENGINE TYPE	1.00000 0.0	0.09998 0.0001	0.17638 0.0001	-0.02779 0.0021
LORAN	0.09998 0.0001	1.00000 0.0	0.02630 0.0036	0.03569 0.0001
RADAR	0.17638 0.0001	0.02630 0.0036	1.00000 0.0	0.25768 0.0001
FATHOMETER	-0.02779 0.0021	0.03569 0.0001	0.25768 0.0001	1.00000 0.0

Appendix C - Troll Vessel Correlation Coefficients

Correlation Analysis

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0

	LENGTH	BEAM	HORSEPOWER	NET TONS	YEAR BUILT
LENGTH	1.00000 0.0	0.26221 0.0001	-0.23847 0.0001	0.73109 0.0001	-0.40230 0.0001
BEAM	0.26221 0.0001	1.00000 0.0	0.03011 0.0956	0.30916 0.0001	-0.02264 0.2103
HORSEPOWER	-0.23847 0.0001	0.03011 0.0956	1.00000 0.0	-0.04035 0.0255	0.48247 0.0001
NET TONS	0.73109 0.0001	0.30916 0.0001	-0.04035 0.0255	1.00000 0.0	0.10449 0.0001
YEAR BUILT	-0.40230 0.0001	-0.02264 0.2103	0.48247 0.0001	0.10449 0.0001	1.00000 0.0
ENGINE TYPE	0.83987 0.0001	0.21807 0.0001	-0.45094 0.0001	0.52044 0.0001	-0.52609 0.0001
LORAN	0.72078 0.0001	0.11921 0.0001	-0.18151 0.0001	0.44811 0.0001	-0.36737 0.0001
RADAR	0.43861 0.0001	0.12372 0.0001	-0.18081 0.0001	0.32553 0.0001	-0.14955 0.0001
FATHOMETER	0.05653 0.0017	-0.16438 0.0001	-0.12614 0.0001	0.09013 0.0001	0.00628 0.7283

	ENGINE TYPE	LORAN	RADAR	FATHOMETER
LENGTH	0.83987 0.0001	0.72078 0.0001	0.43861 0.0001	0.05653 0.0017
BEAM	0.21807 0.0001	0.11921 0.0001	0.12372 0.0001	-0.16438 0.0001
HORSEPOWER	-0.45094 0.0001	-0.18151 0.0001	-0.18081 0.0001	-0.12614 0.0001
NET TONS	0.52044 0.0001	0.44811 0.0001	0.32553 0.0001	0.09013 0.0001
YEAR BUILT	-0.52609 0.0001	-0.36737 0.0001	-0.14955 0.0001	0.00628 0.7283
ENGINE TYPE	1.00000 0.0	0.72496 0.0001	0.37399 0.0001	0.02183 0.2270
LORAN	0.72496 0.0001	1.00000 0.0	0.39978 0.0001	0.40608 0.0001
RADAR	0.37399 0.0001	0.39978 0.0001	1.00000 0.0	0.18933 0.0001
FATHOMETER	0.02183 0.2270	0.40608 0.0001	0.18933 0.0001	1.00000 0.0

Appendix D - Seine Fishermen Dummy Regression Coefficients

OLS Estimates

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	73	805.29488	11.03144	15.287	0.0001
Error	5605	4044.61558	0.72161		
C Total	5678	4849.91046			

Root MSE	0.84948	R-square	0.1660
Dep Mean	1.04421	Adj R-sq	0.1552
C.V.	81.35118		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.055821	0.10456320	10.097	0.0001
FSHRMN1	1	0.142531	0.15360098	0.928	0.3535
FSHRMN2	1	0.688434	0.12372084	5.564	0.0001
FSHRMN3	1	0.116821	0.12890081	0.906	0.3648
FSHRMN4	1	-0.088588	0.15509228	-0.571	0.5679
FSHRMN5	1	-0.223614	0.13526572	-1.653	0.0984
FSHRMN6	1	-0.292478	0.17156994	-1.705	0.0883
FSHRMN7	1	-0.241732	0.13583158	-1.780	0.0752
FSHRMN8	1	0.122121	0.14336983	0.852	0.3944
FSHRMN9	1	-0.472295	0.14428621	-3.273	0.0011
FSHRMN10	1	0.483857	0.12309913	3.931	0.0001
FSHRMN11	1	-0.028726	0.14336983	-0.200	0.8412
FSHRMN12	1	0.290480	0.17298312	1.679	0.0932
FSHRMN13	1	-0.184201	0.13972845	-1.318	0.1875
FSHRMN14	1	-0.446847	0.17298312	-2.583	0.0098
FSHRMN15	1	-0.420612	0.12586645	-3.342	0.0008
FSHRMN16	1	0.259982	0.12655122	2.054	0.0400
FSHRMN17	1	-0.019900	0.14524793	-0.137	0.8910
FSHRMN18	1	-0.167615	0.13583158	-1.234	0.2173
FSHRMN19	1	-0.021400	0.14844235	-0.144	0.8854
FSHRMN20	1	0.473720	0.15837502	2.991	0.0028
FSHRMN21	1	-0.183976	0.15087448	-1.219	0.2227
FSHRMN22	1	-0.435453	0.16114271	-2.702	0.0069
FSHRMN23	1	-0.006626	0.13445483	-0.049	0.9607
FSHRMN24	1	-0.030316	0.21282803	-0.142	0.8867
FSHRMN25	1	0.110699	0.13226314	0.837	0.4026
FSHRMN26	1	-0.475224	0.17932440	-2.650	0.0081
FSHRMN27	1	-0.156602	0.13181955	-1.188	0.2349
FSHRMN28	1	0.169906	0.12509939	1.358	0.1745
FSHRMN29	1	-0.211248	0.13936633	-1.516	0.1296
FSHRMN30	1	-0.288241	0.13734346	-2.099	0.0359
FSHRMN31	1	-0.441387	0.14732189	-2.996	0.0027
FSHRMN32	1	0.159873	0.13077101	1.223	0.2216
FSHRMN33	1	-0.045447	0.13077101	-0.348	0.7282
FSHRMN34	1	-0.235070	0.14678335	-1.601	0.1093
FSHRMN35	1	-0.091969	0.15024084	-0.612	0.5405
FSHRMN36	1	0.271245	0.13445483	2.017	0.0437
FSHRMN37	1	-0.078337	0.16422304	-0.477	0.6334
FSHRMN38	1	0.457096	0.15433512	2.962	0.0031
FSHRMN39	1	-0.773475	0.15024084	-5.148	0.0001
FSHRMN40	1	0.111908	0.14962475	0.748	0.4545
FSHRMN41	1	-0.366855	0.12547584	-2.924	0.0035
FSHRMN42	1	-0.348906	0.14844235	-2.350	0.0188
FSHRMN43	1	-0.361832	0.31801655	-1.138	0.2553
FSHRMN44	1	-0.284269	0.14476119	-1.964	0.0496
FSHRMN45	1	-0.223362	0.14574689	-1.533	0.1254
FSHRMN46	1	-0.297209	0.15024084	-1.978	0.0480
FSHRMN47	1	-0.214766	0.14336983	-1.498	0.1342
FSHRMN48	1	-0.521130	0.16647839	-3.130	0.0018

FSHRMN49	1	-0.119048	0.15668030	-0.760	0.4474
FSHRMN50	1	0.041103	0.13866439	0.296	0.7669
FSHRMN51	1	-0.573261	0.14678335	-3.905	0.0001
FSHRMN52	1	-0.154952	0.13972845	-1.109	0.2675
FSHRMN53	1	-0.486523	0.18110877	-2.686	0.0072
FSHRMN54	1	-0.323530	0.13249046	-2.442	0.0146
FSHRMN55	1	-0.155201	0.16018791	-0.969	0.3327
FSHRMN56	1	-0.618325	0.15509228	-3.987	0.0001
FSHRMN57	1	0.187598	0.13672122	1.372	0.1701
FSHRMN58	1	-0.373313	0.14902548	-2.505	0.0123
FSHRMN59	1	-0.026667	0.15219762	-0.175	0.8609
FSHRMN60	1	0.053176	0.13612252	0.391	0.6961
FSHRMN61	1	0.346629	0.14574689	2.378	0.0174
FSHRMN62	1	-0.020036	0.13118048	-0.153	0.8786
FSHRMN63	1	-0.646975	0.18110877	-3.572	0.0004
FSHRMN64	1	0.021221	0.14382256	0.148	0.8827
FSHRMN65	1	-0.548130	0.18704833	-2.930	0.0034
FSHRMN66	1	0.474513	0.13936633	3.405	0.0007
FSHRMN67	1	-0.683513	0.30184795	-2.264	0.0236
FSHRMN68	1	0.495236	0.13319568	3.718	0.0002
FSHRMN69	1	0.343320	0.14009832	2.451	0.0143
FSHRMN70	1	-0.081319	0.16647839	-0.488	0.6252
FSHRMN71	1	1.162608	0.14476119	8.031	0.0001
FSHRMN72	1	1.500299	0.14844235	10.107	0.0001
FSHRMN73	1	-0.074431	0.13554602	-0.549	0.5829

Appendix E - Gill Net Fishermen Dummy Regression Coefficients

OLS Estimates

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	148	817.12805	5.52114	8.370	0.0001
Error	12087	7973.11371	0.65964		
C Total	12235	8790.24176			

Root MSE	0.81218	R-square	0.0930
Dep Mean	1.07696	Adj R-sq	0.0819
C.V.	75.41438		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.304507	0.07926110	16.458	0.0001
FSHR1	1	0.084302	0.17274555	0.488	0.6256
FSHR2	1	-0.224177	0.12096380	-1.853	0.0639
FSHR3	1	-0.019547	0.12053160	-0.162	0.8712
FSHR4	1	-0.309218	0.20719362	-1.492	0.1356
FSHR5	1	-0.517727	0.18375929	-2.817	0.0048
FSHR6	1	-0.515542	0.11263494	-4.577	0.0001
FSHR7	1	0.026980	0.15852219	0.170	0.8649
FSHR8	1	-0.133779	0.14360502	-0.932	0.3516
FSHR9	1	-0.051829	0.10334382	-0.502	0.6160
FSHR10	1	-0.546132	0.19414924	-2.813	0.0049
FSHR11	1	-0.414356	0.09605810	-4.314	0.0001
FSHR12	1	-0.610393	0.11377781	-5.365	0.0001
FSHR13	1	-0.575077	0.13075226	-4.398	0.0001
FSHR14	1	-0.104157	0.16601551	-0.627	0.5304
FSHR15	1	-0.131041	0.13600715	-0.963	0.3353
FSHR16	1	-0.425714	0.12279076	-3.467	0.0005
FSHR17	1	-0.094072	0.16026106	-0.587	0.5572
FSHR18	1	-0.421954	0.11131098	-3.791	0.0002
FSHR19	1	-0.016984	0.13955356	-0.122	0.9031
FSHR20	1	-0.395865	0.18698257	-2.117	0.0343
FSHR21	1	-0.048020	0.12479214	-0.385	0.7004
FSHR22	1	-0.764653	0.14828393	-5.157	0.0001
FSHR23	1	-0.284358	0.18375929	-1.547	0.1218
FSHR24	1	-0.542719	0.12699508	-4.274	0.0001
FSHR25	1	-0.547078	0.18698257	-2.926	0.0034
FSHR26	1	-0.318581	0.10200536	-3.123	0.0018
FSHR27	1	-0.174644	0.12327378	-1.417	0.1566
FSHR28	1	-0.427891	0.10320282	-4.146	0.0001
FSHR29	1	-0.878322	0.16400057	-5.356	0.0001
FSHR30	1	-0.151663	0.10517770	-1.442	0.1493
FSHR31	1	-0.185047	0.11182743	-1.655	0.0980
FSHR32	1	-0.806757	0.13143966	-6.138	0.0001
FSHR33	1	-0.563066	0.12699508	-4.434	0.0001
FSHR34	1	-0.600319	0.13772355	-4.359	0.0001
FSHR35	1	-0.231486	0.17037798	-1.359	0.1743
FSHR36	1	-0.359296	0.12096380	-2.970	0.0030
FSHR37	1	-0.201664	0.21233204	-0.950	0.3423
FSHR38	1	-0.401805	0.13287396	-3.024	0.0025
FSHR39	1	-0.179237	0.12327378	-1.454	0.1460
FSHR40	1	-0.614752	0.22418423	-2.742	0.0061
FSHR41	1	0.199950	0.12231862	1.635	0.1021
FSHR42	1	-0.694758	0.18074311	-3.844	0.0001
FSHR43	1	-0.779028	0.17037798	-4.572	0.0001
FSHR44	1	-0.511791	0.12943283	-3.954	0.0001
FSHR45	1	-0.096325	0.10620557	-0.907	0.3644
FSHR46	1	-0.186922	0.11056698	-1.691	0.0909
FSHR47	1	0.200071	0.11928888	1.677	0.0935

FSHR48	1	-0.107347	0.11774733	-0.912	0.3620
FSHR49	1	-0.567493	0.14957003	-3.794	0.0001
FSHR50	1	-0.029352	0.11105899	-0.264	0.7916
FSHR51	1	-0.366631	0.09983728	-3.672	0.0002
FSHR52	1	-0.710184	0.15852219	-4.480	0.0001
FSHR53	1	-0.323233	0.12532280	-2.579	0.0099
FSHR54	1	-0.248078	0.13287396	-1.867	0.0619
FSHR55	1	-0.308023	0.10092343	-3.052	0.0023
FSHR56	1	0.005417	0.13143966	0.041	0.9671
FSHR57	1	-0.695527	0.23108382	-3.010	0.0026
FSHR58	1	-0.279891	0.26878745	-1.041	0.2978
FSHR59	1	-0.128413	0.12140549	-1.058	0.2902
FSHR60	1	-0.486010	0.12943283	-3.755	0.0002
FSHR61	1	-0.767068	0.14360502	-5.342	0.0001
FSHR62	1	-0.115079	0.11182743	-1.029	0.3035
FSHR63	1	-0.641125	0.13214660	-4.852	0.0001
FSHR64	1	-0.528041	0.10438014	-5.059	0.0001
FSHR65	1	-0.361754	0.11500408	-3.146	0.0017
FSHR66	1	-0.493930	0.11598432	-4.259	0.0001
FSHR67	1	-0.526212	0.19414924	-2.710	0.0067
FSHR68	1	-0.329044	0.11407620	-2.884	0.0039
FSHR69	1	-0.762030	0.14471030	-5.266	0.0001
FSHR70	1	-0.525693	0.20719362	-2.537	0.0112
FSHR71	1	-0.319680	0.20719362	-1.543	0.1229
FSHR72	1	-0.099377	0.10306349	-0.964	0.3349
FSHR73	1	-0.258891	0.16601551	-1.559	0.1189
FSHR74	1	0.357589	0.12699508	2.816	0.0049
FSHR75	1	-0.401950	0.12053160	-3.335	0.0009
FSHR76	1	-0.074660	0.10751498	-0.694	0.4874
FSHR77	1	-0.535678	0.12879928	-4.159	0.0001
FSHR78	1	0.004609	0.09605810	0.048	0.9617
FSHR79	1	-0.333327	0.10918013	-3.053	0.0023
FSHR80	1	-0.304402	0.14253875	-2.136	0.0327
FSHR81	1	0.521529	0.15375749	3.392	0.0007
FSHR82	1	-0.605982	0.12327378	-4.916	0.0001
FSHR83	1	-0.463899	0.12185698	-3.807	0.0001
FSHR84	1	-0.328731	0.11105899	-2.960	0.0031
FSHR85	1	-0.261366	0.10585384	-2.469	0.0136
FSHR86	1	0.053652	0.12096380	0.444	0.6574
FSHR87	1	-0.205717	0.12096380	-1.701	0.0890
FSHR88	1	0.020126	0.15527566	0.130	0.8969
FSHR89	1	-0.364316	0.11738089	-3.104	0.0019
FSHR90	1	-0.353002	0.12586650	-2.805	0.0050
FSHR91	1	-0.465916	0.15375749	-3.030	0.0024
FSHR92	1	-0.291728	0.11437995	-2.551	0.0108
FSHR93	1	-0.214646	0.12279076	-1.748	0.0805
FSHR94	1	-0.017943	0.11156709	-0.161	0.8722
FSHR95	1	-0.417379	0.15852219	-2.633	0.0085
FSHR96	1	-0.489069	0.13214660	-3.701	0.0002
FSHR97	1	-0.124574	0.10940249	-1.139	0.2549
FSHR98	1	-0.101479	0.09914027	-1.024	0.3061
FSHR99	1	0.397018	0.11969443	3.317	0.0009
FSHR100	1	-0.181649	0.10453564	-1.738	0.0823
FSHR101	1	0.210962	0.10422658	2.024	0.0430
FSHR102	1	-0.280674	0.10226085	-2.745	0.0061
FSHR103	1	-0.312124	0.16601551	-1.880	0.0601
FSHR104	1	-0.322444	0.15375749	-2.097	0.0360
FSHR105	1	-0.253522	0.10069701	-2.518	0.0118
FSHR106	1	-0.149946	0.14704718	-1.020	0.3079
FSHR107	1	-0.160947	0.13008357	-1.237	0.2160
FSHR108	1	-0.004341	0.12053160	-0.036	0.9713
FSHR109	1	-0.404357	0.11468919	-3.526	0.0004
FSHR110	1	-0.638751	0.12818224	-4.983	0.0001
FSHR111	1	-0.107351	0.10377713	-1.034	0.3010
FSHR112	1	-0.809434	0.15375749	-5.264	0.0001
FSHR113	1	1.133698	0.20719362	5.472	0.0001
FSHR114	1	-0.401470	0.22418423	-1.791	0.0733
FSHR115	1	-0.249137	0.10771271	-2.313	0.0207
FSHR116	1	-0.409964	0.12010858	-3.413	0.0006
FSHR117	1	0.006187	0.09738827	0.064	0.9493

FSHR118	1	-0.202707	0.10348652	-1.959	0.0502
FSHR119	1	-0.173710	0.11500408	-1.510	0.1309
FSHR120	1	-0.324555	0.09417621	-3.446	0.0006
FSHR121	1	-0.084736	0.11738089	-0.722	0.4704
FSHR122	1	0.243214	0.11182743	2.175	0.0297
FSHR123	1	-0.204570	0.14051490	-1.456	0.1455
FSHR124	1	-0.160396	0.10025824	-1.600	0.1097
FSHR125	1	0.120555	0.12376808	0.974	0.3301
FSHR126	1	-0.521453	0.09788023	-5.327	0.0001
FSHR127	1	-0.766127	0.15852219	-4.833	0.0001
FSHR128	1	-0.136816	0.09933449	-1.377	0.1684
FSHR129	1	-0.475104	0.13075226	-3.634	0.0003
FSHR130	1	-0.262785	0.13518818	-1.944	0.0519
FSHR131	1	-0.542253	0.14957003	-3.625	0.0003
FSHR132	1	-0.050863	0.12642375	-0.402	0.6875
FSHR133	1	-0.740704	0.10853272	-6.825	0.0001
FSHR134	1	0.226148	0.10239079	2.209	0.0272
FSHR135	1	0.040481	0.09365651	0.432	0.6656
FSHR136	1	0.549670	0.11437995	4.806	0.0001
FSHR137	1	-0.266903	0.10853272	-2.459	0.0139
FSHR138	1	-0.474410	0.18074311	-2.625	0.0087
FSHR139	1	-0.158951	0.18698257	-0.850	0.3953
FSHR140	1	-0.737599	0.28209230	-2.615	0.0089
FSHR141	1	-0.206144	0.11105899	-1.856	0.0635
FSHR142	1	0.006372	0.09771328	0.065	0.9480
FSHR143	1	-0.151545	0.19815274	-0.765	0.4444
FSHR144	1	-0.027388	0.11263494	-0.243	0.8079
FSHR145	1	-0.528563	0.13518818	-3.910	0.0001
FSHR146	1	0.011703	0.11738089	0.100	0.9206
FSHR147	1	-0.524486	0.24749269	-2.119	0.0341
FSHR148	1	-0.445362	0.16400057	-2.716	0.0066

›endix F - Troll Fishermen Dummy Regression Coefficients

OLS Estimates

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	80	1295.79037	16.19738	11.170	0.0001
Error	2984	4326.99674	1.45007		
C Total	3064	5622.78712			

Root MSE	1.20419	R-square	0.2305
Dep Mean	1.44546	Adj R-sq	0.2098
C.V.	83.30823		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.497974	0.19534490	2.549	0.0108
FSHRMN1	1	1.224446	0.26667522	4.592	0.0001
FSHRMN2	1	0.304931	0.23924766	1.275	0.2026
FSHRMN3	1	1.891538	0.30648229	6.172	0.0001
FSHRMN4	1	0.554457	0.32742997	1.693	0.0905
FSHRMN5	1	0.759846	0.21854683	3.477	0.0005
FSHRMN6	1	0.630297	0.35887150	1.756	0.0791
FSHRMN7	1	2.364691	0.31010041	7.626	0.0001
FSHRMN8	1	0.619076	0.26960157	2.296	0.0217
FSHRMN9	1	1.120452	0.28891900	3.878	0.0001
FSHRMN10	1	0.909535	0.24965455	3.643	0.0003
FSHRMN11	1	1.071775	0.28007006	3.827	0.0001
FSHRMN12	1	1.021954	0.34455602	2.966	0.0030
FSHRMN13	1	1.131838	0.28426858	3.982	0.0001
FSHRMN14	1	0.541402	0.22226212	2.436	0.0149
FSHRMN15	1	0.911420	0.26147531	3.486	0.0005
FSHRMN16	1	0.635325	0.35887150	1.770	0.0768
FSHRMN17	1	1.489178	0.26667522	5.584	0.0001
FSHRMN18	1	1.241792	0.36719299	3.382	0.0007
FSHRMN19	1	1.199065	0.24965455	4.803	0.0001
FSHRMN20	1	1.334173	0.26270153	5.079	0.0001
FSHRMN21	1	1.794514	0.31812886	5.641	0.0001
FSHRMN22	1	0.924276	0.24885980	3.714	0.0002
FSHRMN23	1	1.520614	0.35887150	4.237	0.0001
FSHRMN24	1	1.587879	0.29410060	5.399	0.0001
FSHRMN25	1	1.308172	0.29991282	4.362	0.0001
FSHRMN26	1	2.492032	0.34455602	7.233	0.0001
FSHRMN27	1	1.242734	0.24389368	5.095	0.0001
FSHRMN28	1	1.220954	0.29143773	4.189	0.0001
FSHRMN29	1	1.295766	0.26529854	4.884	0.0001
FSHRMN30	1	2.448076	0.28211715	8.678	0.0001
FSHRMN31	1	0.882179	0.22979722	3.839	0.0001
FSHRMN32	1	0.453250	0.30309367	1.495	0.1349
FSHRMN33	1	1.923506	0.27625941	6.963	0.0001
FSHRMN34	1	0.322310	0.32742997	0.984	0.3250
FSHRMN35	1	0.215006	0.24590310	0.874	0.3820
FSHRMN36	1	1.689546	0.28891900	5.848	0.0001
FSHRMN37	1	0.735837	0.28426858	2.589	0.0097
FSHRMN38	1	1.450721	0.26397500	5.496	0.0001
FSHRMN39	1	1.860411	0.33266038	5.593	0.0001
FSHRMN40	1	1.094062	0.32260148	3.391	0.0007
FSHRMN41	1	0.152367	0.26397500	0.577	0.5638
FSHRMN42	1	0.851976	0.23724556	3.591	0.0003
FSHRMN43	1	1.267314	0.32742997	3.870	0.0001
FSHRMN44	1	0.468811	0.35887150	1.306	0.1915
FSHRMN45	1	1.329288	0.29143773	4.561	0.0001
FSHRMN46	1	0.070071	0.26397500	0.265	0.7907
FSHRMN47	1	3.108493	0.30309367	10.256	0.0001
FSHRMN48	1	1.857772	0.25218918	7.367	0.0001

FSHRMN49	1	1.281649	0.28891900	4.436	0.0001
FSHRMN50	1	0.013260	0.29991282	0.044	0.9647
FSHRMN51	1	0.866340	0.27278431	3.176	0.0015
FSHRMN52	1	1.796920	0.31010041	5.795	0.0001
FSHRMN53	1	1.458896	0.28426858	5.132	0.0001
FSHRMN54	1	0.661856	0.26397500	2.507	0.0122
FSHRMN55	1	2.422301	0.31812886	7.614	0.0001
FSHRMN56	1	0.208939	0.25699322	0.813	0.4163
FSHRMN57	1	0.459208	0.35887150	1.280	0.2008
FSHRMN58	1	1.711795	0.27448280	6.236	0.0001
FSHRMN59	1	-0.074782	0.31010041	-0.241	0.8095
FSHRMN60	1	1.478115	0.33834729	4.369	0.0001
FSHRMN61	1	0.634647	0.31010041	2.047	0.0408
FSHRMN62	1	-0.034549	0.28891900	-0.120	0.9048
FSHRMN63	1	0.186555	0.28007006	0.666	0.5054
FSHRMN64	1	0.477033	0.25131806	1.898	0.0578
FSHRMN65	1	1.523494	0.35136537	4.336	0.0001
FSHRMN66	1	0.278080	0.27278431	1.019	0.3081
FSHRMN67	1	0.430197	0.32260148	1.334	0.1825
FSHRMN68	1	1.020467	0.25699322	3.971	0.0001
FSHRMN69	1	0.267504	0.33834729	0.791	0.4292
FSHRMN70	1	0.404586	0.25497589	1.587	0.1127
FSHRMN71	1	1.487471	0.41229092	3.608	0.0003
FSHRMN72	1	0.750173	0.28007006	2.679	0.0074
FSHRMN73	1	1.398000	0.32742997	4.270	0.0001
FSHRMN74	1	1.420204	0.32260148	4.402	0.0001
FSHRMN75	1	1.084062	0.35887150	3.021	0.0025
FSHRMN76	1	0.003195	0.29991282	0.011	0.9915
FSHRMN77	1	2.538657	0.27625941	9.189	0.0001
FSHRMN78	1	0.224434	0.35136537	0.639	0.5230
FSHRMN79	1	-0.009302	0.26397500	-0.035	0.9719
FSHRMN80	1	0.042751	0.28211715	0.152	0.8796