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In the formulation of fisheries management plans required under the Fisheries Conservation and Management Act of 1976 specific attention is paid to the "capacity" of domestic fishing vessels to harvest the predetermined optimum yield on an annual basis. Capacity is interpreted in this thesis as the technical harvesting potential of the fishing fleet over a specific period of time. In this context capacity reflects the size and composition of the fishing fleet of interest.

The primary emphasis of this thesis was to identify economic factors which affect harvesting capacity in the fishery. In this regard the long-run decision-making behavior of individual fishermen was of interest since the size and composition of the fleet, and hence harvesting capacity, is affected by specific choices made at the individual level. A theoretical analysis of the long-run decision making of individual fishermen was developed and was followed by an empirical application to a sample of fishermen who were active in the Oregon trawl fisheries during one or more of the years 1970-1975. The theoretical discussion initially centers upon those aspects of the fisherman's choices which detract from the application

of a contemporary flexible accelerator type model to the analysis of fisherman decision behavior. Instead the logit approach was chosen to analyze discrete choice decisions that occur at the individual level in the Oregon trawl fisheries. Logit analysis is specifically designed to handle qualitative dependent variables and theoretically allows for the differences in decision rules among members of the decision-making population. In addition, the results of the logit analysis at the individual level can be extended to the population level to examine aggregate behavior of interest to fishery policy makers.

The logit approach was applied to a number of individual decisions that affect technical capacity and the distribution of technical capacity in the Oregon trawl fisheries. The first logit model analyzed the decision of whether to leave or continue trawling. The next logit specification described the fisherman's choice of trawl fishery where the set of fishery alternatives in the Oregon case is comprised of the shrimp, groundfish and combination (groundfish and shrimp) fisheries. The last decision concerned the fisherman's choice of fishing vessel where vessels were classified according to gross tonnage and age.

In general the analytical results reflect the simplicity of the initial specifications. Nonetheless, the potential of the logit approach for analyzing fisherman decision-making behavior was reasonably well demonstrated. Finally, several modifications and extensions of the preliminary work were discussed which, in the light of more specific data, would lead to a more complete, predictive and policy-oriented analysis of harvesting capacity in the fishery.

An Economic Analysis Of The Long-Run Decision-Making Behavior of Oregon Otter Trawl Fishermen

by

Samuel F. Herrick Jr.

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Associate Professor of Agricultural and Resource Economics
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Head of Agricultural and Resource Economics

Dean of Graduate School

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CHAPTER I

INTRODUCTION

Historically, exploitation of the ocean's fishery resources has generally occurred under the doctrine of "freedom of the seas". As "freedom of the seas" precludes meaningful property or ownership rights, fishery resources are available to anyone who desires to fish and is willing to invest in the requisite vessel and gear; hence the designation of common property. In an era when fisheries resources were not being heavily utilized, this principle served reasonably well; fish were sufficiently abundant to satisfy the needs of all interested parties, and conflicts between nations were infrequent. Technological and economic growth has caused this situation to change in recent decades; in many areas of the world ocean, large numbers of fishing vessels have simultaneously concentrated on a particular fishery resource. This has led to serious depletion of certain valuable fisheries resources, with a threat of still further depletion, and to economic inefficiency from over-capitalization.

Following World War II there began a substantial build-up of foreign fishing off the continental United States and Alaska. A pronounced increase in foreign exploitation during the period 1965 to 1975 focused attention on a major United States problem: the nation's inability to effectively manage the fishery resources off its own coast, whether they were being exploited by American or foreign fishermen. The traditional laissez-faire attitude of the federal government with regard to the conservation and management of coastal fishery resources reflected in part its interest in maintaining the common property principle at the international level. This attitude is attributable to strong naval interests, the need to import large amount of energy and raw materials via ship, and distant water fishing interests notably tuna and shrimp. Strictly coastal fishing interests were to take a back seat to global concerns.

In an attempt to resolve the problems and issues confronting the world's fishing nations, the United States entered into several international fisheries arrangements. With but few exceptions, these institutions have not been particularly successful in reversing the declining trends in the fisheries of concern. Furthermore, in the future these arrangements would seemingly be less able to cope with increasing numbers of entrants and increased fishing pressure. This lack of success in the past which would be expected to continue in the future was primarily due to the absence of ownership rights in the resource(s) of interest. Thus, international fisheries arrangements have tended to be unable to: (1) insure the optimum harvest of the resource; (2) make timely management decisions; and (3) assure full compliance to these arrangements. They have been increasingly ineffective in allocating and controlling catch and fishing effort and incapable of resolving major disputes between user groups. These arrangements were not constituted to deal with other than conservation objectives.

The doctrine of freedom of access as applied to ocean resources became the dominant issue at the United Nations Third Law of the Sea Conference convened at Caracas, Venezuela, in 1974. At the Caracas session there evolved a general consensus among participant nations that some form of extended fisheries jurisdiction would become a part of the Law of the Sea fisheries convention. For the United States this meant altering its traditional position on Law of the Sea in recognition that a much higher degree of authority needed to be exercised over fisheries, and that this could be best achieved by granting the coastal states rights to and responsibilities for the resource. Thus, a national fishery management program--one that would mesh with state's rights within territorial waters, and international agreements--was seen to be an integral part of an extension of the United States fisheries jurisdiction. Such a program would represent a significant departure from current domestic fisheries practice and policy by placing fisheries resources under the federal government's authority.

The United States, in response to the 1974 session, conceded that a 200 mile fisheries limit would ultimately be accepted by the Law of the Sea conference. This concession along with popular political support for extending domestic fisheries jurisdiction prompted the United States to act unilaterally, but within the expected Law of the Sea fishery provisions, in establishing an interim 200 mile exclusive fisheries conservation zone. Extension of the United States' fisheries jurisdiction and the attendant conservation and management policies were promulgated in the Fisheries Conservation and Management Act of 1976 (FCMA).

The FCMA formally recognizes that a significant portion of the valuable fishery resources found in waters adjoining the continental United States were being exploited (by both domestic and foreign fishermen) to the extent that their viability was in jeopardy. The act further recognized that traditional conservation and management measures had been less than adequate in rectifying these circumstances. As a result, the contribution of fishery resources to the Nation's economic and social well-being with regard to both commercial and recreational use had been significantly affected. At the local and/or regional level the problem was particularly acute. The economies of many United States coastal communities, heavily dependent upon fishing and fishing-related activities, had been seriously eroded. Pockets of high unemployment and associated economic ills were attributed to stepped-up fishing activity mainly on the part of foreign fishermen over the past decade. International fishing agreements had proven relatively ineffective in terms of rehabilitating "over-fished" stocks sought by both domestic and foreign fishermen. Thus, the FCMA represented a national effort toward alleviating and preventing problems associated with the exploitation of fishery resources deemed vital to society's overall well-being.

The essence of the FCMA is the establishment of conservation and management programs dealing with the utilization of fairly well-defined fishery resources found in waters extending 200 miles seaward from the coastline of the United States. In addition, anadromous species that depend upon United States estuarine and inland water systems, but whose marine habitat ranges beyond the 200 mile limit, are included under the act. By appropriating these fishery resources under a policy of extended jurisdiction, the FCMA expresses a significant change both conceptually and operationally in terms of the conditions under which fishery resources had traditionally been exploited.

A major thrust of the FCMA is to provide for the preparation and implementation of fishery management plans that will achieve and maintain on a continuing basis the "optimum yield" (OY) from each fishery falling under the exclusive fishery management authority created under the act. Optimum yield is defined in the FCMA as:

> . . . The amount of fish . . . (A) which will provide the greatest overall benefit to the Nation with particular reference to food production and recreational opportunities; and (B) which is prescribed as such on the basis of the maximum sustainable yield from such fishery as modified by any relevant economic, social, or ecological factor.... [Sec. 3, (18)].

One of the significant departures of the FCMA from a traditional management approach is the explicit recognition under OY of resource uses and values other than those solely related to commercial fishing. In other words, under OY the fishery authority must deal with multiple objectives which, with respect to a particular fishery, take into consideration: (a) the condition of the fish stock; (b) the economic and social welfare of commercial fishermen participating in that fishery; (c) the interests of recreational fishermen; (d) the dependence of foreign fishermen upon that fish stock; (e) environmental relationships; and (f) the good of the Nation. To these ends, the management authority must explicitly acknowledge and account for the diverse and often times conflicting interests of distinct groups of fishery resource users and the consumers of fishery products when determining the OY from a particular fish stock.

While the FCMA addresses the general problems found in many of the Nation's coastal fisheries and provides the policy framework for their resolution, it stops short of providing specific solutions. Instead, the FCMA allows for the creation of fishery management councils on a regional basis which are charged with preparing a management plan for each fishery falling within its geographical area of authority. In its role as planning agent the management council deals with the problems besetting a particular fishery and charts a course of action aimed at their alleviation. Although extended jurisdiction offers a range of management alternatives governing the use of fishery resources, each management plan must address specific issues as discussed in the FCMA. In particular, the act requires that, in addition to OY, each management plan assess and specify:

> (A) the capacity and the extent to which fishing vessels of the United States, on an annual basis, will harvest the optimum yield specified under paragraph (3), and (B) the portion of such optimum yield which, on an annual basis, will not be harvested by fishing vessels of the United States and can be made available for foreign fishing... [Title III, Sec. 303, (a), (4)].

Popular support for extended jurisdiction among domestic fishermen was founded principally on the anticipated increase in benefits that would accrue to the United States fishing industry due to foreign exclusion. However, to the extent that the FCMA recognized interests other than those of domestic seafood producers, it mollified the prevalent belief that extended jurisdiction would result in windfall gains to the United States fishing industry. The fact that United States fishermen must demonstrate a capacity, and the intent to utilize this capacity, determines the extent to which these resources are redistributed in their favor. In other words, if after the OY is determined it is found that United States fishing vessels (fleets) lack the capacity to harvest the OY in excess of that which they have demonstrated an ability to harvest, then that portion of the OY can be allocated to foreign fishermen. Where traditional fisheries have excess fishing vessel capacity and other fishery resources are currently not utilized or under-utilized (opportunity fisheries), there may be some kind of transferable capacity. Thus, any windfall to the domestic fishing industry will reflect its ability to replace foreign fishermen and therefore not affect aggregate supply with regard to the quantity of fish that would be available under the specified OY. Put somewhat differently, the result will not be a windfall gain to the domestic fishing industry from a price increase attributable to a decreased foreign supply, but, rather, will be the more extensive and efficie use of existing fishery inputs, whereupon both producers and consumers stand to gain. Thus, the management council's assessment of domestic fishing vessel capacity and the extent to which OY will be harvested is crucial in terms of the distribution of fishery benefits among non-industry interest groups, as well as, between United States and foreign fishermen.

In addition to the importance of domestic "capacity and extent" from the standpoint of foreign exclusion, domestic fishing vessel capacity is also of interest in cases not involving allocations between United States and foreign fishermen. Indeed, there are fisheries that do not have a history of foreign exploitation, but are nonetheless subject to the same planning requirements concerning OY and "capacity and extent". However, while foreign exclusion may not be an issue in such fisheries, efficient harvest of the OY and its distribution among domestic user groups is still of concern, and relates to domestic harvesting capacity. That is, where estimates of domestic harvesting capacity exceed that which is deemed necessary to efficiently harvest an OY (which may also be the case where foreign fishing occurs as well), management measures aimed at altering or redirecting capacity may be desirable. Conversely, where capacity is less than OY and a fish stock is being harvested by foreigners or not harvested at all, management policies encouraging additional capacity have been pushed. Indeed, the domestic development of Alaskan groundfish resources is explicitly referred to in the FCMA.

In view of the United States interest in achieving satisfactory overall performance in the fisheries, the ability of policy makers to reasonably assess "capacity" and predict "extent" is vital to the successful realization of this goal and its attendant objectives. Not only would such estimates be extremely useful in their own right, they are specifically required under the guidelines of the FCMA. Thus, the fishery management councils are forced to address the questions of "capacity and extent". Without an understanding of the response of domestic fishermen to changes in their economic and political environments, answers to these questions will be arbitrary in nature, and then only by chance will the fishery management plans achieve the desired ends. What is needed then is a model capable of explaining the long- and short-run supply responses of United States fishermen with respect to changes in their planning and operating environments. A critical component in this model would yield information concerning the harvesting capacity of domestic fishing fleets. In an attempt to at least partially meet this need, the remainder of this study will focus on the capacity issue, viewing "capacity and extent" as respective long- and short-run decision variables of each individual fisherman.

A major concern of this study is to gain an appropriate conceptual and operational understanding of the term capacity as used in the FCMA with reference to domestic fishing vessels. From the context in which it is used, capacity seemingly relates to the harvesting potential of the particular fishing fleet under consideration at a particular point in time. It would follow then that predictions of capacity would take into account fleet structure--the size and composition of the fleet of interest. In this regard a predictive model could be constructed that would relate harvesting capacity to fleet structural changes as a consequence of changes in the fleet's operating environment.

The objective of this study, then, is to identify economic variables of interest to policy makers which affect harvesting capacity in the fishery. Specifically a theoretic model will be developed which describes the long-run decision making behavior of individual fishing firms. Following an examination of the theoretical issues, a logit specification of the model will be estimated using empirical observations on fishermen participating in the Oregon otter trawl fisheries.

The study initially takes up a general discussion of capacity, analyzing in particular the conceptual differences associated with this term. Attention is then focused on the development of a definition and measure of capacity suiting the unique needs of the harvesting sector of the fishing industry. The study then proceeds to a discussion of the peculiarities in the fishery with respect to the long-run decision making of the individual fisherman. Having discussed the nature of the fisherman's long-run decision making, alternative modeling approaches are examined and a theoretical justification for selecting the logit model is given. Next, a description of the Oregon otter trawl fleet is presented which consists of vessels that are able to engage in shrimp and/or groundfish trawling. The performance and structure of the fleet will be traced over the period 1970 to 1975, and the relative productivity of individual vessels investigated with regard to their unique physical characteristics. Logit models describing several of the fisherman's long-run decisions are then specified and estimated, followed by a discussion of the empirical results.

The results of the study are then summarized and the implications of the empirical analysis are examined with regard to their potential contribution to fisheries planning and policy making. The study concludes with a discussion concerning areas of additional research and the possible extensions of the analysis.

CHAPTER II

FISHING VESSEL CAPACITY

Production and Hold Capacity

The FCMA lends an intuitive, but inexact meaning to the word capacity. While a basic understanding of capacity is suggested by the syntax itself, the number of particular meanings that can be attached to this term is significant. Unless it is used and interpreted with the utmost of care, serious confusion of thought is likely to result.

To begin with, the fishing vessel embraces two widely accepted meanings of the term capacity. First, capacity represents a measure of content: the measured ability to contain. The fishing vessel is a container, for it is designed and constructed to hold a certain volume of fish. It is usual to accept this measure of volume as being fixed, and independent of the circumstances relating to the ability to capture or produce that which is to be held. For this reason hold space is intuitively appealing for specifying vessel capacity, and indeed, it is this correspondence which seems to prevail in the fishing industry. It then follows, that fleet capacity can be readily obtained by summing the hold spaces of the individual vessels comprising the fishing fleet. This measure of capacity will only be significant at that instant in time, and hence, fleet capacity measured in terms of collective hold space is inappropriate when attempting to estimate the quantity of fish that could be harvested during a one year period.

The second meaning of capacity which is also applicable to the fishing vessel designates the "maximum production or output". The creative aspect inherent in the second definition of capacity leads to a fundamental distinction: viz., the capacity to hold is a timeless or static notion, while the capacity to produce includes a time dimension. Since capacity in the latter sense is time dependent it is expressed and measured as a rate, i.e., the amount of output per unit of time, and as defined, represents the maximum output attainable for the unit of time under consideration. While these two definitions of capacity differ relative to what they actually measure, both are intrinsic to a fishing vessel and therefore to a fleet of fishing vessels.

Even though there is a significant difference between the capacity to hold and the capacity to produce, this does not mean that they can be evaluated independently when analyzing the capacity of a particular fishing vessel. Since fishing is both a capturing and holding process, a particular vessel will be designed and constructed according to a planned level of production capacity. That is, if it is planned that the vessel be capable of catching X tons of fish per fishing trip then it must be able to hold X tons of fish per fishing trip. In this sense, hold capacity becomes a constraint in terms of some integrated concept of fishing vessel capacity. If the interest is in what can be produced per unit of time, this can be no greater than that which can be held during that same time period. This suggests the interrelatedness between the two capacity concepts and the difficulties associated with deriving an operational measure of fishing vessel capacity from the popular definitions. The interdependence of these two vessel capacity factors during the actual fishing process is crucial; understanding this will aid in resolving the real issue underlying the determination of fishing vessel capacity.

This distinction between hold capacity and production capacity of a vessel becomes irrelevant when it is possible to express the latter in terms of the former. Suppose, for example, that each vessel comprising a particular fleet is able to fill its hold during a fishing trip (where the length of the fishing trip is a standardized unit of time). If each vessel makes the same number of fishing trips in a year the annual productive capacity of the fleet is given by the collective hold capacity times the expected number of fishing trips. Thus, in the case where hold space is the sole or limiting constraint on the fleet's maximum level of output, the two measures essentially reduce to one. That is, maximum annual output equals available hold space times the number of fishing trips. Suppose that hold space is not an active constraint on the vessel's maximum level of output. Instead, the vessel consistently fills a fixed proportion of the hold space. Annual output in the case of consistent excess hold capacity is given by landings per trip times expected trips. While the basic relationship remains intact (i.e., the hold capacity ultimately dictates the vessel's productive capacity), actual capacity in terms of the maximum possible output becomes a relative performance measure.

The fact that hold capacity may not be an active constraint introduces an additional consideration with regard to fish production capacity. Implicit in the concepts of capacity (those that have been discussed thus far) is the existence of some limitation. In the production concept it is the maximum output per unit of time, and in the hold concept it is a fixed volume. This implies the imposition of a constraint by at least one of the production factors. In the traditional production context this means that capacity is a short-run phenomenon, for the short-run is characterized by at least one of the productive inputs being fixed.

Furthermore, the input (or combination of inputs) that is not variable in the short-run is typically the capital stock. If the capital stock is represented by the fishing vessel and its concomitant gear, then fishing capacity should be analyzed in terms of the fishing vessel, and in view of the short-run variability of output the remaining fishing inputs must be available and utilizable in varying quantities. For this reason it is convenient and seems appropriate to define and measure the fishing fleet's capacity to harvest fish with relation to vessel hold space. Why then is it not unusual for fishing vessels to produce at less than hold capacity? This question raises additional capacity issues, one of which concerns the availability of other fishery inputs.

Capacity and the Availability of Productive Inputs

The hold capacity measure of what the fishing fleet is capable of harvesting assumes that the fish stock as an input is sufficiently available to fill the hold during the standard length fishing trip. If this were not the case then one would observe that it takes longer to fill the hold, or that standard trips result in holds being only partially filled. Under these circumstances the fish stock turns out to be a limitation on the vessel's maximum production level for a given time period. Hence, vessel and/or fleet capacity becomes a performance measure which is a function of fish availability.[1/] Thus, while the physical characteristics of the vessel ultimately determine what it is capable of producing per unit of time, what the vessel does produce will also depend upon the availability of the cooperating fishery inputs for the unit of time under

[1/] While a similar argument might be made with regard to the labor (captain and crew) input, it would be tenuous when vessel design which incorporates the labor component is taken into account.

consideration. With insufficient availability of cooperating inputs, hold capacity becomes superfluous. The concept of a production function is useful in clarifying this notion of capacity, where output is expressed as a function of factor inputs. For example:

$$Y = f(n, k) \tag{1}$$

where Y is output, n represents the non-capital inputs, and k is the capital stock input. In the short-run it is usual to combine different quantities of n with a flow of capital services from a fixed k to produce various quantities of the output. If in the fishery, the fishing vessel can be thought of as providing a flow of vessel hours and units of hold space, the production function for the short-run actual output is given by:

$$X = g(n, d) \tag{2}$$

where X is output flow, n is non-capital input flow, and d is capital services flow. At full capacity the relationship can be expressed as:

$$X_c = g(n_c, k) \tag{3}$$

where X_c is capacity output, n_c is the capacity non-capital input flow, and k is the fully utilized capital stock. At capacity the flow of capital services has been fully utilized. Additional units of n would be excessive since additional output can only be obtained by expanding the capital stock. In this sense, capacity output is the production flow, or sustainable output associated with the full utilization of the capital stock in conjunction with the other relevant production factors. Alternatively, conditions may warrant that the fish stock be limiting in the short-run production relationship. Under these circumstances capacity output will be expressed with respect to the full utilization of the fish stock in conjunction with the flow of services from the capital stock and non-capital inputs. The notion of fishing capacity is thus complicated by the presence of two stock inputs, capital and fish, and the determination of that which is binding in the short-run.

The complexity of this situation may be reduced by relating the harvest rate of an individual fishing unit to inputs of fishing effort and the fish stock; that is:

$$L = f(E, A) \qquad (4)$$

where L is pounds landed per unit of time, E is fishing effort, and A is a measure of the fish stock in units of availability. In equation (4) fishing effort is loosely defined as the fishery input reflecting the combined effect of the factors of production that are applied to the fish stock. Since the fishing vessel is a mechanism for collectively engaging the inputs in fishing, the amount of time a vessel spends at sea deploying these inputs is frequently taken as a measure of fishing effort. Thus, the level of fishing effort in equation (4) can be related to the ability of a fishing vessel to deploy fishing inputs, and is therefore expressible as a function of the vessel's design characteristics. That is:

$$E_c = g(V_c) \qquad (5)$$

where E_c is effort capacity, the maximum amount of time the vessel can engage in fishing activity during the year, ceteris paribus, and V_c denotes a flow of services from the vessel, a capital stock and fish container. By decomposing the fishery production function into separate harvesting and effort relationships, the distinction between fishery output and fishing activity becomes apparent. Furthermore, this decomposition provides a means of specifying fishing capacity independently of fishery output, in that a given fishing vessel possesses a fixed ability to generate a maximum amount of fishing effort per unit of time. That is, each vessel has an inherent effort capacity. Aggregating individual effort capacities will yield fleet effort capacity for the time period of interest. In turn, output capacity in the fishery will depend upon the availability of the fish stock to which the fleet effort capacity is put to use. In order to predict the maximum annual harvest, the capacity of the fish stock to assimilate this amount of effort must be determined. When the planning requirements set forth by the FCMA are considered, the OY, specified on an annual basis, would represent a limit on the harvest of a particular fish stock. Then, the ability to harvest the OY will depend upon the effort generating capacity of the fishing fleet, which in turn depends upon the design properties of the constituent vessels.

Viewing the fishing vessel as a producer of fishing effort introduces yet another consideration when attempting to define and measure fishing vessel capacity; i.e., the maximum amount of effort that can be produced during the time period of interest. Thus, in assessing the capacity of a fishing vessel, attention should be focused on all the inputs into the fishing activity in order to discover those which ultimately limit output. The discovery of the relevant input and the inclusion of the amount corresponding to the maximum level of its availability into the fishery production function will yield a measure of the physical output capacity.

So far relevant concepts of capacity both in a general and fishery context have been examined from a purely technological standpoint. Given this perspective, interest focuses primarily on the maximum sustainable physical output that can be obtained from a fixed input together with an uninterrupted supply of cooperating factors. If the fishing vessel is considered the fixed input in the fish harvesting process, the maximum output per unit of time would necessarily be defined according to some vessel characteristic and the complete utilization of the flow of services therefrom. Since fish production is both a catching and holding process, catching will not exceed the point where the ability of the vessel to hold the catch is being completely utilized. Hence the appeal of hold space to represent the fishing vessel's harvest capacity. However, the observance of partially filled fish holds for a standardized fishing period reveals the conditions under which this definition may be appropriate. The divergence between what could be held and what can actually be produced reflects the availability constraint imposed by the fish stock. The fact that enough fish may not be available during the fishing period, or that fish must also be considered as a finite input, suggests a relative performance measure of capacity in terms of the percentage of the hold space occupied. By investigating the fishery production function relating harvest to inputs of fishing effort and fish availability the interrelatedness of the stock inputs is shown to be recursive in nature. Decomposing the production function shows the distinction between effort production and fish production and directs attention to the vessel's capacity to generate fishing effort. Then by specifying the amount of fish that would be available, the relevant issue becomes the capacity, in terms of vessel effort production, that could be applied to the given fish stock.

Planned Capacity

The fact that capacity, be it hold or production, represents an extreme, suggests that there is some expected or normal level of fish availability that results in holds being filled to less than capacity. Put somewhat differently, capacity may be appropriately associated with some peak availability of fish, or unique environmental conditions which enhance effort production. That fish may exhibit a cyclical pattern of availability during the fishing season is acceptable in view of the annual spawning and migratory behavior of fish stocks, as well as seasonal fluctuations in climatic and environmental conditions which affect the ability to produce effort. Thus, if there is variation in availability of fish over the year there will be variation in the level of production. Hence, a fisherman that designs and constructs a vessel with a hold capacity capable of being filled under average conditions of availability over the year will experience insufficient capacity during periods of peak fishing or fish availability. For this reason it is not unusual to observe excess hold capacity with regard to the average annual catch of the fishing vessel. Given seasonal fluctuations in the availability of fish, the divergence between hold capacity and fish stock capacity becomes evident. This leads to a distinction between peak capacity, that associated with peak availability, and normal or intended capacity which is associated with the average availability of the fish stock. It is the upward departure from average conditions of fish availability and/or the ability to produce effort for which the excess hold capacity is intended.

According to Winston [58] there may be reasons for observing excess hold capacity, other than those attributable to a cyclical or stochastic pattern of fish availability. It is also reasonable to expect excess hold capacity when variations in the demand for the output are anticipated. When conditions of supply and demand are not completely predictable, it is often in the firm's interest to be able to produce more than that which average conditions dictate. In this regard the fisherman may possess some subjective temporal probability distribution of the factors influencing production and hence an intended pattern of capital utilization. Again recognizing that the maximum rate of output is ultimately determined by full utilization of the capital stock, it is that which is intended rather than that which can be or is actually produced that provides the basis for the capacity concepts offered by Winston. Winston gives the following definitions:

> Full capacity describes a firm's planned, intended (desired, optimal) level of utilization; the level that reflects satisfied expectations, is built into the capital stock and is embodied in the normal working schedule. Higher (sustained) utilization than this will induce new investment.
>
> Excess capacity describes unintended departures from--the failure to attain--that intended (desired, optimal) level of utilization.

Thus, two distinct concepts of fishing capacity emerge. First, there is that which appeals to the fixed design features of the fishing vessel and reflects that amount of output that could be produced and held by the completely utilized capital stock on a sustained basis; i.e., technical capacity. The second concept of capacity embraces the fisherman's expectations concerning variations in input supply and/or output demand and results in the introduction and utilization of a particular capital stock. The former concept is compatible with the technological limitations associated with a fixed capital stock, while the latter incorporates some additional considerations, including the appropriate technical form of the capital stock. In other words, "full" or planned capacity originates with all inputs being variable and proceeds to define a capital stock and hence a technical capacity consistent with the fisherman's expectations relating to variations in input supply and output demand. Thus, technical capacity is a product of planned capacity.

Planned capacity also brings an economic dimension into the analysis in that at some point additional output may not be unattainable, only uneconomical. In this context, the technical capacity of the fishing vessel is an economic variable *ex ante*, since it indirectly depends upon the fisherman's expectations of output and input prices. To the extent that anticipated factor and product prices affect intended output, planned capacity reflects a desire to produce the intended annual output at the lowest total cost. Thus the fishing vessel, a product of planned capacity, is expected to produce the annual output, consisting of the different levels of anticipated harvest over the year, at the lowest total cost. The average rate of output in this situation will not be coincident with that representing technical capacity, but rather that of Winston's "full capacity"; i.e., the normal operating schedule in terms of variable input and fish stock availability. If conditions change in favor of a higher degree of technical capacity utilization *ex post*, the built-in reserve representing idle capacity *ex ante* is then called upon. However, if these conditions prevail, expectations are revised, resulting in an upward adjustment of technical capacity. Similarly shortfalls in attaining the expected rates of production create "excess capacity" which, if persistent, will eventually lead to technical alterations in a downward direction.

Planned capacity as indicated is an element of the economic agent's planning horizon. The planning horizon in this case is synonomous with the long run - conventionally defined as a period of time over which all the inputs into the production process are variable. By its very nature the long run allows the economic agent to plan ahead and make decisions affecting the short run in which all production actually takes place. That is, the long run focuses upon all possible short-run situations among which the economic agent may choose and his actual selection which results in a particular technical capacity to produce. Once the technical capacity is operational the agent is in the short run. The fisherman, as an economic agent in the long run, is confronted with making a choice between many vessel alternatives each having a production range bounded at the upper end by technical capacity. Furthermore, each fishing vessel alternative can also be distinguished, economically, by its unique cost function, which defines its economic operation.[2/] Based upon the information and perceptions the fisherman has concerning stock availability and other factors which would affect input supply, he comes up with a distribution of expected harvest rates over the planning horizon. He then selects the vessel which enables him to produce the expected annual harvest most efficiently; i.e., at the lowest total cost. Thus, due to the stochastic rather than determinant nature of the annual output rates in the fishery, the notion of cost flexibility[3/] is implicitly incorporated into the fisherman's long-run decision making. To the extent that the annual utilization of the introduced vessel's technical capacity reflects satisfied expectations on the part of the fisherman, "full capacity" has been achieved in the Winstonian sense. This "full capacity" also has an economic

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2/ Economic operation implies the translation of the vessel's production function into a cost function.

3/ For a more complete discussion of cost flexibility see Stigler [48], [49 , pp. 129-130].

interpretation in the sense that prolonged deviations from the intended range of annual utilization will eventually lead to adjustments of the capital stock due to expected efficiency gains. This concept interprets full capacity in terms of an economic limit on the annual output that each alternative fishing vessel is capable of producing.

Economic Capacity

Once the fishing vessel is operational the fisherman has committed himself to a particular *modus operandi*, which can be usefully described by a short-run average cost curve (SAC) and time dimension. However, he is not locked into producing a fixed level of output and, as previously indicated, may experience fluctuations, anticipated or not, in the production circumstances which motivate him to adjust his rate of output. Thus, in the short run, capacity is more meaningfully related to the quantity of fish that will be caught in order to achieve the objectives of the fisherman during a specified time period. Assuming that the short-run objectives are not independent of economic considerations, the short-run average and marginal cost curves become the fisherman's relevant decision-making guides, and his concern with capacity *ex ante* is redirected toward the degree of capacity utilization *ex post*. To the extent that movement along the SAC curve takes place when the availability of fish and other inputs remain unchanged, vessel utilization, in terms of effort generation, is responsive to changes in the price of output. This behavior underlies the notion of short-run economic capacity which reflects a desire on the part of the fisherman to achieve some level of economic performance. In effect, economic capacity, other things remaining constant, moves with price. If output prices rise, *ceteris paribus*, short-run economic capacity will be expected to increase. If prices fall, it will fall. Conversely, if catch per unit of effort rises while prices remain constant, economic capacity or output will increase due to an increase in input availability.[4/]

The important aspect of economic capacity in the short run is that it is not necessarily the full utilization of the technical capacity of the fishing vessel. Rather, economic capacity reflects the extent to which the technical capacity will be utilized based upon cost and output market conditions and what can be produced with regard to existing environmental circumstances. If there are changes in any of these circumstances, then economic capacity output will likewise be expected to change.

Estimating Capacity

After distinguishing the three types of capacity discussed above - (1) planned; (2) technical; and (3) economic - the next step is to derive appropriate methodologies which will yield estimates of these capacity types. As previously interpreted, planned capacity represents an *ex ante* level of output reflecting each individual fisherman's harvest expectations. Therefore, a direct approach to the assessment of planned capacity would entail a survey of current and prospective fishermen with regard to their harvest expectations. With this information a harvest distribution for the fleet could be derived whose upper bound will represent the maximum output anticipated for the time period under consideration.

[4/] This change in economic capacity; i.e., utilization rate is not due to an increased utilization of the vessel per se, but an increase in the productivity of the inputs in the sense that they are more available. In terms of an increase in fish availability this corresponds to Smith's stock externality [46].

Technical capacity addresses the question: how much fish can be caught by a given vessel during each standard length trip when there are no limits on cooperative resource availability? Capacity in this context is associated with the vessel's physical hold space. Vessel technical capacity is thus measured in holdsful per unit of time. This allows technical capacity to be expressed as a maximum weight per unit of time which is consistent with the units of measure applied to harvest output in the fishery. In terms of effort generation, technical capacity might be expressed as the number of days (or hours) that the vessel could engage in fishing activity per unit of time. That is, the difference between the specified time period, and the amount of time that the vessel must necessarily cease fishing for maintenance and/or other reasons. Implicit in an effort generation measure of capacity is that effort potential is independent of fish availability.

On the other hand, it seems reasonable that fish availability will influence the amount of fishing effort actually generated by a particular vessel. To the extent that fish availability affects the proportion of effort capacity actually utilized, this variable enters the calculation of economic capacity as it is interpreted above. If this is the case, then both the economic capacity for effort and the economic capacity for output can only be estimated with reference to a particular level of fish availability. Given the level of fish availability, economic capacity will depend upon output price. Assuming that the fisherman's operating objective is to maximize profits for a given level of fish availability, he will generate effort to the point where the costs of generating the last unit of effort are equal to the returns forthcoming from its generation. This is the economist's familiar first order equi-marginal rule for profit maximization which in this case is applied to effort in order to obtain economic capacity in terms of optimum effort generation. Since the availability of fish interposes between effort generation and harvest, economic capacity with regard to harvest is determined by inserting the optimal level of effort into the fishery harvest function. This approach reflects the individual fisherman's lack of control over fish availability by treating effort as an intermediate output. In other words it is impossible for the individual fisherman to vary the harvest rate by adjusting fish availability. Rather, given fish availability he adjusts his level of fishing effort to attain the desired level of harvest.

The optimum level of effort production will be attained when the marginal cost of producing effort is equal to the value of its marginal yield. The marginal yield of effort will correspond to the price of effort in the sense that it represents the value of effort as an input, i.e., what the fisherman would be willing to pay for an additional unit of effort. The marginal cost of effort for a given vessel is obtained from the vessel's cost function. The perceived price of effort on the other hand is equal to the average return per unit of effort. Effort is paid an average rather than a marginal return because the cooperating input fish is zero priced. Furthermore, since the individual fisherman is unable to control the success of a given unit of effort, catch per unit of effort is a fishery wide phenomenon, catch and hence average return per unit of effort is exogenous to the individual fisherman. In this sense, the average return per unit effort corresponds to the price or marginal revenue received by the fisherman, since this is what he will earn from an additional unit of effort. Under these circumstances the profit equation for the individual vessel is given by:

$$\Pi_i = P_F \cdot \overline{F} \cdot E_i - C_i \qquad (6)$$

where Π_i is profit for the i^{th} vessel, P_F is the price of fish, $\overline{F}$ is the fishery wide catch per unit effort, E_i denotes the effort generated by the i^{th} vessel, and C_i, vessel cost, is a function of effort produced.[5/] The i^{th} vessel will be producing the optimum level of effort when the perceived price of effort is equal to its marginal cost, or:

$$\frac{\partial C_i}{\partial E_i} = P_F \cdot \overline{F} \qquad (7)$$

Solving equation (7) for the equilibrium level of effort and multiplying this amount by the fishery wide catch per unit of effort will yield the vessel's instantaneous economic capacity in terms of pounds of fish landed. In this case, the vessel's economic capacity is a consequence of the extent to which its technical capacity will be utilized at a specific point in time and under very specific conditions. Here, "will" implies a predictable type of behavior on the part of the fisherman in response to a variety of economic and environmental conditions affecting input and output prices and the availability of fish.

Economic theory provides useful insights into the concepts of production capacity and capital utilization in the fishery. Many of the issues treated herein will in reality be much more complex and require a greater degree of sophistication in their treatment and resolution. The attempt here is to provide a framework for analysis by appealing to the traditional economic theory of the firm while simultaneously recognizing the peculiarities of the fishery. The inability of the fishing firm to

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5/ In the most general case, costs are also a function of the number of vessels in the fishery, the crowding externality proposed by Smith [46].

control all of the productive resources is an unusual and complicating factor deserving special attention when adapting popular definitions and measures of capacity to the fishery.

The FCMA requirement that "capacity and extent" be specified for the domestic fleet presents difficulties of conceptualization and measurement, since a precise functional definition is conspicuously lacking in the language of the act. The preceding discussion considered some of the problems of defining capacity in the fish harvesting sector of the industry and suggested possible estimation procedures. In this regard several aspects of the capacity issue were examined which resulted in a distinction between technical and economic capacity. Technical capacity was shown to be a consequence of the fisherman's expectations concerning future conditions in the fishery. Technical capacity is manifested in the form of a particular vessel becoming operational in the fishery and represents the amount of fish that vessel could catch per unit time when there are no constraints on the availability of the resource. Capacity in this context is associated with the design characteristics of the vessel which reflects its ability to capture and hold fish. Thus, a production capacity measure is provided which would ascertain whether or not the fleet is capable of harvesting the optimum yield.

The "extent" issue, on the other hand, is concerned with the degree to which the technical capacity will be utilized. Utilization is the essence of economic capacity and therefore "extent" entails a more detailed analysis of the economic and environmental factors influencing the fisherman's production decision making. Thus, while the technical measure relates to "assess the capacity", it does not provide much guidance as to the "extent to which" this capacity will be utilized. This is not to say, however, that economic capacity is independent of technical capacity. Recognition that each distinct vessel produces a given output at a unique cost makes economic capacity a function of the vessel's design properties. That is, the degree of capacity utilization will depend upon the cost of the output produced by each particular vessel. In turn, the extent to which the OY will be harvested will depend upon the size and composition of the fleet.

It would seem then that the structure of the fishing fleet is of critical concern to those attempting to predict "capacity and extent". Furthermore, since the composition of the fleet is a consequence of individual investment decision making, "capacity and extent" will be founded upon the expectations of existing and potential fishermen which guide their long-run decision making concerning the size of the vessel they will operate in the fishery. Thus, it is the investment behavior of individual fishermen that ultimately reflects what can and hence what is expected to be caught. In view of the significance of fisherman investment behavior, it is the investment and related decisions on the part of individual fishermen that will be the principal focus of the remainder of this study.

CHAPTER III

METHODOLOGY

Investment Issues in the Fishery

Since assessment of the harvesting capacity in the fishery is a major issue confronting regional fishery management councils, they should be especially interested in the flow of capital into and out of the fishery. While aggregate data have been analyzed with regard to the size and structure of fishing fleets, an understanding of what stimulates investment in the fisheries has been limited by a paucity of disaggregated data.

In order to estimate the harvesting capacity in a fishery it is the aggregate capital stock which is of primary concern. However, the aggregate capital stock, and hence harvesting capacity, is affected by various decisions that are made at the individual fisherman level, i.e. decisions relating to net changes in the fisherman's capital stock will certainly alter the harvesting capacity of the fleet. But, aggregation may obscure the phenomena of interest by suppressing variations in the decision-making behavior of individual fishermen. In this sense individual level data can be more fruitful than aggregate data in analyzing fishery harvesting capacity.

At any point in time the fisherman's principal capital stock is his fishing vessel(s) which is characterized by a number of intrinsic physical features. Fishing gear (e.g., nets, lines, hydraulics, electronics) is also an item of capital stock. However, in accordance with the concept of technical capacity presented earlier, the limiting factor in terms of the capital stock is the fishing vessel itself. That is, while additional units of gear may enhance vessel performance, gear combinations are ultimately determined by vessel design. In this context, technical capacity refers to the maximum harvest rate of a particular vessel employing the optimal gear technology for the fishery in which it is engaged. At a subsequent point in time the fisherman may decide to sell or scrap his vessel, and replace it with another, or not replace it at all. The fisherman can replace his capital stock by constructing a new vessel or by purchasing one that has been previously owned. No replacement implies exit from the fishery. Decisions such as these by existing fishermen will result in expansion or contraction of the fleet technical capacity. Equally important in this regard is the issue of entry by potential fishermen, i.e. changes in the fishery capital stock due to the entry -- including the transfer of fishermen from adjacent fisheries -- of new fishermen. Thus, in order to comprehend what affects change in the fishery capital stock one must understand what moves individual fishermen to make these types of decisions which concern their level of participation in the fishery. Since these decisions entail capital flows, attention will be directed to the individual fisherman's investment behavior.

A Modern Theory of Investment Behavior: An Overview

Modern theories of investment behavior address two interrelated issues: how the optimal or desired level of capital stock is determined and the process by which the capital stock is adjusted when it differs from the desired level. Most recent theories on the desired level of capital stock have evolved from the accelerator model of J.M. Clark [11]. Rigidly construed, the accelerator principle asserts that net investment is proportional to the rate of change in output. Because of its simplicity, the "rigid" accelerator theory has had a controversial existance that has led to numerous additions and revisions, the more significant of which are touched upon here.

One of the basic assumptions of the rigid accelerator model is that the firm prior to an increase in the rate of output must have no excess capacity. Since excess capacity was frequently observed in reality, attempts were made to adjust the accelerator to these facts. Given secular excess capacity a capacity utilization theory emerged which included the firm's level of output and its capital stock as well as change in output as determinants of the desired capital stock.[1/] Another difficulty with the simple accelerator model relates to its assumption that firms can obtain capital funds with little or no difficulty so that the desired rate of investment stimulated by changes in output will not be constrained by inadequate finance. Since unlimited availability of financing does not exist in actuality -- capital markets are not perfectly competitive -- it was postulated that the firm's desired rate of investment also depended upon the supply of investment funds, along with the internal resources of the firm. Hence, profits and the cost of external financing became determinants in a liquidity theory of investment behavior.[2/] Current profits were also considered a measure of expected profits and therefore were viewed as directly influencing the firm's desired capital in yet another variation of the accelerator model.[3/]

1/ The capacity utilization theory is presented in H.B. Chenery [10] and is readdressed in B. Hickman [18].

2/ For a discussion of liquidity and the role of profits with regard to desired capital stock see Meyer and Kuh [34].

3/ The dependency of investment on the level of profits is discussed in Tinbergen [52].

The simple accelerator model, and the subsequent revisions thereof, while readily subject to empirical testing, received criticism for lacking motivational substance. That is, their dominant descriptive nature portrayed the firm as little more than a simple respondent, merely reacting to overtaxed technical capacity and taking steps to remedy this deficiency. Little attention was given to theoretical rationale until more current syntheses of the above approaches focused on the long-run objectives of the firm.

Perhaps one of the most satisfactory of the later developments in studies of producer investment behavior is that of Jorgenson and others (Jorgenson [22], Jorgenson [23], Jorgenson and Siebert [24], and Jorgenson, Hunter, and Nadiri [25]). The Jorgenson approach employs maximization of net worth as the theoretical underpinning in a "flexible accelerator" model of investment behavior. In the Jorgenson model, demand for capital stock is determined to maximize net worth, where net worth is the integral of discounted net revenues. Net revenue is defined as the difference between current revenue and expenditures on both current and capital account including taxes. Jorgenson deduces the necessary conditions for maximization of net worth for the case of two inputs -- one current and one capital -- and one output, noting that the approach is easily extended for any number of inputs and outputs. This case is stated as:

$$\text{Max NW} = \text{Max} \int_0^\infty e^{-rt}[pQ - sL - qI - D(t)]dt,$$

where

NW = net worth

t = time

r = interest rate

p = output price

Q = output

s = wage rate

L = labor input

q = cost of capital

I = investment

$D(t)$ = direct taxes.

Maximizing net worth subject to:

$$Q = Q(L,K)$$

a production function relating output to inputs of labor and capital (K) and $\partial K/\partial t = I - \delta K$ a constraint stating that the rate of growth of capital stock ($\partial K/\partial t$) relating investment to desired capital (K^*) is investment less replacement capital (δK), yields the marginal decision criterion

$$\frac{\partial Q}{\partial K} = \frac{c}{p} .$$

Here, $\frac{\partial Q}{\partial K}$ denotes the marginal product of capital and c represents the implicit rental value of capital. In order to determine the desired capital stock the form of the production function must be specified. If the production function is of the Cobb-Douglas form $Q = AL^{\alpha}K^{\beta}$ the desired, or equilibrium, capital stock is

$$K^* = p\frac{\beta Q}{c} .$$

Another consideration is the time structure of the investment process. Jorgenson recognizes that the introduction of the desired capital stock does not occur instantaneously -- investment projects require time to complete. Hence, an adjustment process is incorporated in this type of model to account for the lagged response to changes in the demand for capital. The adjustment process also implicitly introduces uncertainty into the model in that the more variable expectations are, the more hesitant the response of optimal capital stock will be. Since investment decisions are long-run in nature uncertainty is an unavoidable fact.[4/]

With the Jorgenson flexible accelerator (FA) model serving as a point of departure, investment in the fisheries will now be discussed. In particular, the fisherman's vessel investment decision, and the peculiarities surrounding this issue will be examined. This investigation will reveal, that while the FA model is directly applicable, or adaptable, to many producer investment situations, it displays inherent shortcomings when applied to the problem at hand.

Application of the FA Model to the Fishery Investment Problem

Bockstael [6] in a study of investment behavior in the New England groundfish fishery discusses the difficulties encountered in the application of the FA model to this investment issue.

First there is the question of continuous investment. The FA decision rule states that net adjustments to the capital stock take place up to the point where the value of the marginal product of capital is equal to its marginal user cost. Consequently, the FA model requires that capital be perfectly divisible in order that incremental adjustments can be made in response to shifting equilibria. However, the fisherman's capital stock is measured as an indivisible[5/] unit of length, tonnage, age, and hull

4/ Explicit treatment of uncertainty in a subsequent development of the flexible accelerator theory is given by Birch and Siebert [5].

5/ While it is technically possible to modify an existing vessel's length, tonnage, etc. to create a "different" vessel, it is more common to observe one vessel being replaced by another.

material. In this context, an adjustment to the fisherman's capital stock takes place through a distinct change in his vessel holdings. Furthermore, exit and entry were also recognized as being significant concerns of fishery policy makers. But the FA model explains capital stock adjustments solely in terms of the maximization behavior of the typical firm already in the industry. Thus, an empirical analysis of fisherman investment decision making would want to address entry with regard to both the entry and the corresponding choice of capital stock decision, as well as exit.

The FA model also requires the specification of a production function. This requirement poses a particularly difficult problem where fish, an input as well as an output, are beyond the direct control of the fisherman. In general, a production function is a schedule showing the maximum amount of output that can be produced from a specified set of inputs given the existing technology. Inherent in this relationship is that output is determinant. On the other hand, fishing, even when the most sophisticated technologies are employed under optimal conditions, still remains a hunting process. Therefore, when a specific set of technical inputs is applied to a particular fishing ground, it is more appropriate to consider an expected, rather than a certain amount of product forthcoming.[6/]

Another issue is the normative nature of the FA model. The FA model establishes net worth maximization as the investment objectives of the firm. Therefore, only those variables which affect economic performance will be

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6/ This is not to say that a fisherman's production function cannot be specified and estimated, but that one would expect the estimated marginal products to have relatively high variances.

explicitly included in determining the investment decision the firm makes in order to achieve this objective. However, it is often argued that the fisherman, due to the technological and psychological character of fishing, is strongly influenced in his decision making by a number of non-economic factors (e.g., tradition, preferences, personal welfare) as well as expected costs and returns. Unlike the values of market variables which under conditions of perfect competition are independent of the actions of the individual fisherman, non-pecuniary factors are frequently fisherman specific and may have a significant, but different, effect upon each fisherman's decision making. Thus, when explaining investment behavior, it is well to keep in mind that the fisherman may seek to satisfy multiple objectives and that the satisfaction of these objectives will in turn depend upon other than economic variables.

Several reasons are found then for not directly applying the FA model in an empirical analysis of investment decision making in the fishery. The FA model requires that adjustments in the level of capital stock be continous which does not approximate investment conditions in the fishery. Exit and entry, important issues for policy makers, are not treated by the FA model. The need for a specific production function is a difficult requirement to satisfy when dealing with the biological uncertainties inherent in fishing. Finally, the possibility of investment in fish harvesting being undertaken for non-economic reasons exists. It is on these grounds that attention is turned to an alternative approach to modeling investment behavior in the fishery. This inquiry leads to an examination of logit analysis and its properties that overcome the deficiencies encountered when attempting to apply the FA model to the problem at hand.

A Behavioral Model of Fishery Investment Decision Making

In the long-run fisheries supply response situation a fundamental concern regards the explanation of investment decision making on the part of primary producers. A behavioral (positive) model of the investment decision making process relates observations of actual choice to a theory of rational choice among competing alternatives. In this sense, the positive model specifies the manner in which the choice of a particular investment alternative responds to changes in the variables deemed influential in the choice decision. In developing a disaggregated behavioral model of fisheries investment the attempt is to explicate the causal relationships between the alternative the fisherman chooses, the attendant circumstances unique unto the fisherman and the terms under which the different alternatives are offered. If these causal relationships can be defined, then the model is capable of explaining how investment choice decisions vary as fishery conditions change. Furthermore, by establishing the causal relationships of investment choice the effects of proposed and/or anticipated changes in the fishery on the fisherman's investment choice can be predicted. If the model is truly behavioral its parameters should represent the causal relationships in general rather than reflect the circumstances surrounding a distinct situation. This flexibility minimizes the need to restructure the model when it is applied under dissimilar conditions.

In the discussion of the previous section the discontinuity problem in terms of the fisherman's investment decision variable was noted. In general, the reliability of the behavioral model reflects the extent to which the factors affecting behavior can be observed and measured.

Thus, a problem arises when the decision variable itself is unmeasurable or discontinuous. In the case where one attempts to explain the choice among discrete alternatives (e.g., maintaining one's present position or switching to another position) vis-a-vis the quantity chosen of a continuous decision variable, the traditional marginal orientation is no longer appropriate. Traditional econometric techniques are deficient when attempting to explain the variation in a dependent variable which takes on discrete values.

In a binary choice situation the occurrence or non-occurrence of an event (E) is observed. Let X denote a vector of variables (which may be categorical and/or continuous themselves) which are explanatory or predictor variables for E. If theory demands that the greater the values of X, the greater the chance that a particular outcome will occur, one can think in terms of a monotonic relationship between X and the probability of event E, P(E). That is:

$$P(E) = f(X) \tag{1}$$

In reality P(E) cannot be observed. Instead the occurrence or non-occurrence of the event is observed. Thus, the relationship in equation (1) is transformed into:

$$Y = Y(X) \tag{2}$$

where Y is the dichotomous variable taking the value of one or zero with the respective occurrence or non-occurrence of E.

The simplest formulation of the model is the linear probability function:

$$Y = X\beta + \varepsilon \tag{3}$$

where Y is a linear combination of X, and least squares estimates are computed for the β. Since the zero/one values of the $X\beta$ represent the certainty of the event not occurring or occurring, the conditional expectations of Y may be interpreted as the conditional probability of the event:

$$P(E) = P(Y = 1 | X\beta).$$

There are a number of problems associated with estimating the β in equation (3) using least squares. First, the limitations on the values of the dependent variable lead to restrictions on the values which can be taken by the disturbance term ε (i.e., $\varepsilon = 1 - X\beta$ when $Y = 1$ and $\varepsilon = -X\beta$ when $Y = 0$). Under the assumptions of the model in equation (2) for fixed X, x_j, y_j is a Bernoulli random variable so that $E(y_j | x_j) = x_j\beta$ and $Var(y_j | x_j) = Var(\varepsilon_j)$. The restrictions on ε will result in the $Var(\varepsilon_j) = x_j\beta(1 - x_j\beta)$. Since the variance of ε depends upon the value of the X's the model is intrinsically heteroscedastic. The heteroscedasticity means that ordinary least squares estimation will yield inefficient estimates of β. Another problem involves the probability interpretation of Y, that

$$0 \leq P(Y | x) \leq 1.$$

However, the prediction of Y, $\hat{Y}$, does not satisfy this requirement since the $X\beta$ can take on any real value. In the case where predictions are a vital part of the analysis the potential inconsistency of the predictions with respect to the probability interpretation of the dependent variable raises another objection to the use of least squares estimation. Finally, since the ε is not normally distributed, the estimates of β are likewise not normally distributed. Thus, in order to derive approximately correct significance tests for the estimators, an appeal must be made to the central limit theorem.

While the technical difficulties associated with the linear probability model can be overcome, there are other reasons to suspect that $F(X\beta)$ is a non-linear function. First, the range of $F(X\beta)$ is zero to one which implies that the relationship must be non-linear, at least at the boundaries. Secondly, the general sigmoidal curves have theoretic appeal due to their marginal properties, particularly as the probability limits are approached. Finally, in the case of several exogenous variables the additive form obscures the interaction effects that might rightly be expected among these variables. That is, the marginal change in probability with respect to the change in one of the exogenous variables would almost certainly depend upon the values of the other exogenous variables. Thus, the problem resolves itself to one of finding a suitable probability transformation such that as the probability increases over the range zero to one the transform increases over the domain $-\infty$ to ∞.

The modeling problem with discrete dependent variables can now be addressed with respect to the fundamental form of the underlying probabilities and the appropriate estimation techniques for alternative specifications and data sets. Summarizing, the model under consideration can be written as:

$$P(E) = \text{Prob}(Y=1) = F(X\beta) \tag{4}$$

and

$$1 - P(E) = \text{Prob}(Y = 0) = 1 - F(X\beta),$$

where $F(X\beta)$ is simply the cumulative distribution function that describes how the probabilities are related to the explanatory variables.

One of the earliest methods employed in the analysis of binary response was probit analysis [Finney (14)]. The probit model assumes that the underlying probability distribution in equation (4) is normal. Using the normal distribution leads to

$$P(y_t = 1) = \text{Prob}(x_t\beta > u_t) = F(x_t\beta) = \frac{1}{\sqrt{2\Pi}} \int_{-\infty}^{x_t\beta} \exp - \frac{U^2}{2}\, du$$

and

$$P(y_t = 0) = \text{Prob}(x_t\beta < u_t) = 1 - F(x_t\beta) = \frac{1}{\sqrt{2\Pi}} \int_{x_t\beta}^{\infty} \exp - \frac{U^2}{2}\, du$$

where u_t represents a threshold that is specific to the individual such that

$$Y_t = 1 \text{ if } x_t\beta \geq u_t$$

$$= 0 \text{ if } x_t\beta < u_t,$$

and the probit of $P(Y_t) = x_t\beta$.

The maximum likelihood procedure can be employed to estimate β in the above relationship where observations are made on X and on the binomially distributed alternative outcomes.

Interpretation of the probit β is not as straightforward as that in the linear probability model where the coefficients indicate the marginal change in probability associated with a unit change in the corresponding explanatory variable. In the probit relationship the dependent variable is not the linear combination of the independent variables, but its unit cumulative normal transformation. Therefore, in the probit model the coefficient represents the change in standard deviations of the normally distributed dependent variable with respect to a change in the associated independent variable. That is, a one unit change in x_i will produce a change of β_i standard deviation units on the probability. This can be shown to equal

$$\frac{\partial P}{\partial x_i} = \beta_i f(x\beta)$$

where $f(x\beta)$ is the normal density function evaluated at $x\beta$.

Logit analysis also seeks a solution to the problem of the infinite probability range. Like probit, the basic approach is to find a transformation of the probability which can take on the values $-\infty$ to ∞ while constraining the probability itself to the zero to one interval. Starting with the relationship in equation (4) consider the ratio $\frac{P(E)}{1-P(E)}$ which translates into the odds in favor of the event occurring. As the probability of the event occurring increases from zero to one, the odds increase from zero to infinity. Taking the natural log of the odds, $\log \frac{P(E)}{1-P(E)}$, the ratio ranges from $-\infty$ to ∞ as the probability increases from zero to one. The log of the odds ratio is known as the logit of a positive response. It is then postulated that the logit is a linear function of the exogenous variables,

$$\log \frac{P}{1-P} = X\beta. \tag{5}$$

Rearranging the terms in equation (5) yields:

$$P = \frac{1}{(1+e^{-X\beta})} \quad \text{and } 1-P = e^{-X\beta}/(1+e^{-X\beta}) \tag{6}$$

which is the logistic distribution and ranges from zero to one as $X\beta$ goes from $-\infty$ to ∞.

For large samples where observations can be grouped on the basis of explanatory variables, probabilities for the occurrence of the event within each group can be estimated. The log of the odds transformation converts the probability estimates to a continuous unbounded variable which becomes the dependent variable in equation (5), with the categorical definitions as explanatory variables. The linear relationship can then be estimated using least squares techniques. The key to a linear estimation of equation (5) is the derivation of a contingency table for the explanatory and dependent variables.

In cases which preclude the calculation of contingency tables (e.g., continuous exogenous variables or small samples) the method of maximum likelihood can be used to estimate the parameters of the distribution. In these cases instead of estimating the linear log of the odds function, the procedure deals directly with the probability function. The maximum likelihood procedure allows each independent sample observation to be treated distinctly, thereby extending the range of application of the logit model.

While the logits are a linear function of the explanatory variables, the probabilities are not. In the linear form the β shows the change in the logit for a unit change in the corresponding explanatory variable. The relationship between the change in probabilities and a change in one of the explanatory variables is given by:

$$\frac{\partial P}{\partial x_i} = \frac{\partial [1/1+e^{-X\beta}]}{\partial x_i} \tag{7}$$

which yields

$$\frac{\partial P}{\partial x_i} = \beta_i P(1 - P) \tag{8}$$

Both the probit and logit models have more desirable properties than the linear probability model when modeling dichotomous dependent variables. Structurally the logit and probit models have the desired shape and illuminate the interactions between exogenous variables. Furthermore, while some of the technical problems inherent in the least squares estimation of the linear probability model can be overcome, estimations which are linear in the dependent probability will in general be inefficient since the dependent variables are not normally distributed. However, the specific non-linear probability distributions underlying the logit and probit models obviate these problems by allowing for alternative estimation procedures. Finally, it can be shown for the logit model that, by extending the simple dochotomy, a general model treating the unordered polytomous case can be derived and estimated. In the polytomous case the logit model is favored over the probit model because of its computational tractability.

A Theoretical Basis for Logit Analysis

McFadden's (McFadden [33]; Domencich and McFadden [13]) interest in human choice behavior has led to perhaps the most satisfactory development and application of the logit model to the general decision making process. His efforts have resulted in a theory of individual choice among discrete alternatives which is rooted in the individual utility maximization premise of microeconomic theory.

As recognized above, the discrete case is not concerned with the relationship between exogenous factors and an individuals decision to alter his position at the margin, but with the individual's decision to move to an entirely different position or not to move at all. In the earlier discussion of the logit model it was assumed that each individual's probability of attaining a certain outcome is the same for a given combination of exogenous variables. There was no allowance for the fact that actual probabilities may fluctuate randomly about some expected value due to unmeasurable or unobserved factors affecting the individual outcomes. In a decision making context this would imply that where the alternative set consists of discrete decisions and the factors affecting choice are the same for all individuals the identical decision will be made by all. Discrepancies in observed choice must then be attributed to measurement error or irrationality on behalf of the decision maker. In contrast, where individuals are faced with a continuum of choice, the assumption is made that individuals in the population may indeed be influenced by unobserved factors, but that these factors vary randomly about zero. It is implied, then, that there is some common behavioral rule and that variations in aggregate choice can be explained by variation in individual choice at the intensive margin (i.e., to choose more or less) due to fluctuations in exogenous variables common to all individuals in the population.

McFadden addresses the problem of individual discrepancies at the extensive margin (i.e., a choice among discrete alternatives) by explicitly accounting for unobservable influences which lead to a distribution of decision rules over the population. He proceeds as follows.

In analyzing a particular choice situation data are obtained by randomly drawing an individual from the population and noting the set of alternatives (J) available to him the individual's vector of personal relevant measurable attributes (s) and his actual choice (i). The probability of observing just such an outcome is likened to drawing from a multinomial distribution with selection (conditional) probabilities $P(i|s, J)$ for $i \varepsilon J$. An individual decision rule is a function (h) which relates the vector s and the alternative set J to one member of the alternative set. If there is a distribution of individual decision rules over the population, then the probability that a randomly drawn individual having attributes s and facing alternative set J chooses alternative i is equivalent to the probability Π of the decision rule occurring which yields choice i. That is:

$$P(i|s, J) = \Pi(h|h(s, J) = i). \tag{9}$$

Now, suppose that the individual's decision rule reflects the utility he expects to derive from each of the alternatives in the set J, indexed $j = 1, \ldots, J$, where each alternative is described by a vector of attributes x. The individual's choice function in terms of utility can then be written as:

$$U = U(x, s), \tag{10}$$

which relates the desirability of an alternative to its vector of attributes x. The individual would choose alternative i over alternative j if the satisfaction derived from alternative i exceeded that of alternative j or

$$U(x_i, s) > U(x_j, s). \tag{11}$$

If the attribute vectors x_i, x_j and s identified all the factors influencing the individual's choice then it would be possible to predict this individual's choice behavior. However, the fact that the vectors s and x omit unmeasurable factors is the essence of the problem.

To overcome this limitation the choice function can be expanded to:

$$U = U(x, s, \varepsilon) \qquad (12)$$

where ε is a vector capturing all the unmeasurable and/or unobservable factors influencing the decision maker in his choice of alternative. If sample observations are then randomly drawn from a population of decision makers facing the same alternative set and having the same observable personal attributes, the vector ε will be random and the resulting choices will be stochastic. The expression (12) can be restated as the sum of a non-stochastic function $V(x, s)$ and a stochastic term ε, that is

$$U = U(x, s, \varepsilon) = V(x, s) + \varepsilon(x, s) \qquad (13)$$

From equation (13) the function $V(x_j, s)$ will represent the utility that an individual with observed characteristics s derives from alternative j with observed attributes x_j. The stochastic influence from unobserved choice factors will be accounted for by the stochastic term $\varepsilon_j = \varepsilon(x_j, s)$ for $j=1, \ldots, J$. The prbability that a randomly drawn individual with utility maximiation rule h_ε, attributes s and alternative set J will choose alternative i represented by x_i as given by:

$$P_i \equiv P(x_i | s, J) = \Pi[h_\varepsilon | h_\varepsilon(s, J) = x_i]$$

$$= \text{Prob}[V(x_i, s) + \varepsilon_i > V(x_j, s) + \varepsilon_j \text{ for all } j \neq i]$$

$$= \text{Prob}[\varepsilon_j - \varepsilon_i < V(x_i, s) - V(x_j, s) \text{ for all } j \neq i] \qquad (14)$$

Thus, the event will occur with some probability which can be denoted by

$$H_i = h(x_1, 111, x_J; s; \varepsilon_1, \ldots, \varepsilon_J). \qquad (15)$$

If the stochastic term $W = \varepsilon_j - \varepsilon_i$ has a cumulative distribution function $g(\quad)$ and by letting $V(X, s) = V(x_i, s) - V(x_j, s)$ then

$$H_i = g[V(X, s)] \ . \tag{16}$$

In order to estimate the probability of choosing alternative i it is necessary to know the form of the non-stochastic (choice) function $V(X, s)$ and the form of the cumulative distribution function $g(\quad)$. It is assumed that the choice function is linear in the parameters. This assumption is not that limiting since more complex relationships can be reduced to the linear form by the appropriate transformation of the variables. Turning to the form of the cumulative distribution function $g(\quad)$ the probability Π induces a joint cumulative distribution function $F(\varepsilon_1, \ldots, \varepsilon_j)$. The joint cumulative distribution of the stochastic terms $\varepsilon_1, \ldots, \varepsilon_j$ given a specific value for ε_1, say $\varepsilon_1 = t$, is given by

$$F_1(t, \varepsilon_2, \varepsilon_3, \ldots, \varepsilon_j), \tag{17}$$

where

$$F_1 = \frac{\partial F}{\partial \varepsilon_1} = \text{Prob}(\varepsilon_1 = t).$$

Now, if ε_1 assumes a certain value t, alternative 1 will be chosen only if

$$\varepsilon_j < t + v_1 - v_j \qquad j = 2, \ldots, J \tag{18}$$

where $v_i = V(x_i, s)$. The probability that alternative 1 will be chosen for a specific value of $\varepsilon_1 = t$ is

$$P(x_1|\varepsilon_1 = t) = F_1(t, (t+v_1-v_2), (t+v_1-v_3),\ldots, (t+v_1-v_j)) \quad (19)$$

Thus, the probability of choosing alternative 1 is the integral of equation (19) for all possible t:

$$H_1 = \int_{t=-\infty}^{\infty} F_1(t,(t+v_1-v_2), \ldots, (t+v_1-v_j))\,dt. \quad (20)$$

By replacing F_1 and v_1 by F_i and v_i, a similar equation holds for the probability of selecting alternative i and so on.

McFadden points out that it is difficult in practice to define joint distributions F( ) which allow the computation of econometrically useful formulas for the H_i in equation (20). Instead he resorts to a sequence of probability axioms[7/] which lead to the specification of the selection probability. Given the selection probability specification, the question is examined as to whether this formula could be obtained via equation (20) from some distribution of utility-maximizing decision makers.

Starting with the axiom which states that the relative odds of one alternative being chosen over a second alternative should be independent of the presence or absence of an unchosen third alternative, the selection probability for alternative i is derived as:

$$P(x_i|s, J) = e^{v_i}/\sum_{j=1}^{J} e^{v_j}. \quad (21)$$

7/ These axioms and the derived selection probability are found in McFadden [33], pp. 109-110.

If it is assumed that the distribution of utility-maximizing decision makers is defined such that the stochastic terms $\varepsilon_j (j = 1, \ldots, J)$ are independently and identically distributed according to the extreme value distribution[8/]

$$\text{Prob}(\varepsilon(x_j, s) \leq \varepsilon) = e^{-e^{-\varepsilon}} \qquad (22)$$

It can be shown that the selection probability given by equation (20) yields the specification given in equation (21). From equation (19)

$$P(x_i | \varepsilon_i = t) = F_i[t, (t + v_i - v_2), \ldots, (t + v_i - v_j)].$$

Inserting the extreme value distribution leads to

$$e^{-t} \prod_{j=1}^{J} e^{-e^{-(t+v_i-v_j)}} = e^{-t} e^{-e^{-t} \sum_{j=1}^{J} e^{v_j - v_i}} . \qquad (23)$$

Substituting equation (23) into equation (20)

$$H_i = \int_{t=-\infty}^{\infty} e^{-t} e^{-e^{-t} \sum_{j=1}^{J} e^{v_j-v_i}} dt$$

$$= \int_{t=-\infty}^{\infty} e^{-t} \frac{\sum_j e^{v_j-v_i}}{\sum_j e^{v_j-v_i}} e^{-e^{-t} \sum_j e^{v_j-v_i}} dt$$

8/ For a discussion justifying selection of the extreme value distribution see Domencich and McFadden [13] pp. 61-65.

$$= \frac{1}{\sum_j e^{v_j - v_i}} \int_{t=-\infty}^{\infty} e^{-t} \sum_j e^{v_j - v_i} e^{-e^{-t} \sum_j e^{v_j - v_i}} dt$$

$$= \frac{1}{\sum_j e^{v_j - v_i}} \left[e^{-e^{-t\sum_j e^{v_j - v_i}}} \right]_{-\infty}^{\infty}$$

which produces

$$H_i = 1 / \sum_{j=1}^{J} e^{v_j - v_i}. \qquad (24)$$

Rearranging the terms in equation (24) yields the selection probability given by equation (21), i.e.

$$H_i = e^{v_i} / \sum_{j=1}^{J} e^{v_j}. \qquad (25)$$

The odds of choosing alternative i over alternative j is given by:

$$H_i / H_j = e^{v_i} / e^{v_j} \qquad (26)$$

and the log of the odds in favor of alternative i can be expressed as

$$\log(H_i / H_j) = v_i - v_j. \qquad (27)$$

The model given by equation (27) is known as the conditional or multinomial logit model.

Equation (21) specifies the selection probability and is obtained from equation (20) using the extreme value distribution $e^{-e^{-\varepsilon}}$ to describe the random variation attributable to individual behavioral characteristics where each individual has a utility function of the form $V(s, x) + \varepsilon(s, x)$

and ε varies randomly over the population. Thus, the selection probability accounts for stochastic variation across the population, but can be expressed solely in terms of observable, "representative" utility $V(x, s)$. In this case $\varepsilon(x, s)$ represents the independent weight each individual decision maker in the population personally ascribes to the alternatives in a particular set.

Earlier it was assumed that the "representative" component of the utility function $V(x, s)$ was linear in the parameters, i.e.

$$V(x, s) = Z^1(x, s)\,\Theta_1 + \ldots + Z^k(x, s)\Theta_k = Z(x, s)'\Theta. \qquad (28)$$

The $Z^k(x, s)$ are specified numerical functions with no unknown parameters, $Z' = (Z^1, \ldots, Z^k)$ is a row vector of these functions and $\Theta = (\Theta_1, \ldots, \Theta_k)'$ is a column vector of unknown parameters. Then

$$P_{in} = P(x_{in}|s_n, J_n) = e^{Z_{in}\Theta} / \sum_{j=1}^{Jn} e^{Z_{jn}\Theta} \qquad (29)$$

is the probability that an individual n, with measurable attributes S_n and alternative set J_n (with members j=1, ..., J) chooses alternative i represented by the vector of alternative attributes x_i. Next consider a choice experiment where there are N groups of individuals (therefore N distinct trials) and individual attributes and alternative sets differ among groups but not within. The experiment provides R_n repetitions of trial n and the alternative j is chosen S_{jn} times, then

$$R_n = \sum_{j=1}^{J_n} S_{jn}. \qquad (30)$$

In this case the vector $(S_{in}, \ldots, S_{J_n n})$ represents the results of R_n independent drawings from a multinomial distribution with probabilities given by equation (29) for i = 1, ..., J_n. From the multinomial the probability of a particular sample is given by:

$$\text{Prob}(S_{1n}, \ldots, S_{J_n n}) = R_n! \prod_{i=1}^{Jn} \frac{P_{in}^{S_{in}}}{S_{in}!} . \qquad (31)$$

The likelihood (L) of a particular sample is a function

$$L = \prod_{n=1}^{N} \frac{R_n!}{S_{1n}! \cdots S_{J_n n}!} \prod_{i=1}^{Jn} P_{in}^{S_{in}}. \qquad (32)$$

Of particular interest is the case without repetition, i.e. where individual attributes and alternatives vary over all individuals. In this case

$$R_n = \sum_{j=1}^{Jn} S_{jn} = 1, \qquad (33)$$

where S_{jn} = 0 or 1 and the likelihood function reduces to

$$L = \prod_{n=1}^{N} \prod_{i=1}^{Jn} P_{in}^{S_{in}}. \qquad (34)$$

Making the log transformation and substituting for P_{in} yields the log-likelihood function

$$\log L = \sum_{n=1}^{N} \sum_{i=1}^{Jn} S_{in} \log \left[\sum_{j=1}^{Jn} e^{(Z_{jn} - Z_{in})\Theta} \right]. \qquad (35)$$

Because the choice observations represent random samples from a population with a known statistical distribution, maximizing equation (35) with respect to Θ will yield maximum likelihood estimators $\hat{\Theta}$ which under very general conditions possess good large sample properties. Thus, the multinomial logit model makes it possible to functionally relate the probability of an event occurring to variables which are believed to influence its occurrence.

McFadden emphasizes the generality and limitations of the multinomial logit model. Explanatory variables can include attributes of the alternatives and/or interactions between alternative and individual attributes. Attributes which are invariant over the range of alternatives are excluded since the associated coefficient would be unidentified. In general the alternatives are unranked so that the indexing j is arbitrary. Under these conditions, the alternative attributes are generic in nature, i.e. common to each alternative in the set. However, there may be situations where the alternatives are ranked and the rank j is a component of the vector of attributes x_j which distinguishes the unique character of the j^{th} alternative. In this case, an alternative speciific dummy variable is intr duced which would indicate the observed preference for that particular alternative. In addition, there might arise alternative specific interaction effects.

If the alternatives are unranked (only generic variables enter the formulation) then the alternatives facing different individuals need not correspond. This holds because the $\hat{\Theta}$ will be the same for estimating each of the selection probabilities. In other words, as long as the same variables can be measured for each alternative, it does not matter which of the alternatives in the set the individual actually faces.

The axiom on the "independence of irrelevant alternatives" underlies one of the strongest properties of the multinomial logit formulation.

Once the coefficients for the generic variables have been estimated, introducing a new alternative into the alternative set does not necessitate a re-estimation of the model. As long as the values of the generic variables associated with the new alternative can be measured, the alternative can be readily incorporated into the model and its selection probability obtained. If the alternatives are independent, selection probabilities of the original alternatives will decrease proportionally (odds ratios will remain the same) to accommodate the new alternative. The proportional decrease in the selection probability of each old alternative is equal to the selection probability of the new alternative. This property also reveals a weakness in the model, in that one cannot postulate a pattern of differential substitutability and complementarity between alternatives. For this reason application of the model should be limited to situations where alternatives can reasonably be assumed to be distinct and weighed independently in the eyes of each decision maker. Thus, the multinomial logit model, which relates discrete choice to a theory of utility maximization, appears particularly well suited for the analysis of investment and investment related decision-making behavior in the harvesting sector of the fishery.

CHAPTER IV

DESCRIPTION OF THE DATA AND THE EMPIRICAL ANALYSIS

Introduction and Scope

The behavioral analysis of the long-run decision making by Oregon trawl fishermen incorporates the multinomial logit model as developed by McFadden. The derivation of this model is founded upon a theory of rational choice behavior which asserts that a decision maker can rank possible alternatives in order of preference and will always select from available alternatives the option he perceives to yield the greatest level of satisfaction, given the common and alternative specific attributes for each option and the choice circumstances unique to the individual. In the case of a compound decision, the model is most successfully applied when the observed behavior can be factored into component decisions and choice alternatives can be assumed to be distinct and independent in the eyes of the decision maker. A sufficient condition for factorization is that the individual's utility function has an additively separable form with regard to the attributes of the mutually exclusive alternatives in the multiple decision set. Independence of alternatives implies that the odds of one alternative being chosen over another be independent of the presence or absence of non-chosen third alternatives. This independence of irrelevant alternatives property is consistent with the separability of decisions characteristic under the assumption of additive separability of utility.

Using the logit approach the long-run supply response behavior of Oregon otter trawl fishermen will be examined over the time period 1970-75.

Typically, an Oregon otter trawl fisherman owns and operates a single vessel which is designed to tow a net (trawl gear) through the water specializing in the capture of a mixture of species of bottom and near bottom fish referred to collectively as groundfish or in the capture of shrimp. Alternatively, the vessel may be of a more flexible design, allowing a relatively quick change over from groundfish to shrimp and vice versa. Thus, Oregon otter trawl fishermen can participate in three distinct fisheries: (1) groundfish; (2) shrimp; and (3) shrimp and groundfish (which will be referred to in this thesis as "combination"). Furthermore, these fisheries are characterized by heterogeneous fleets, where each vessel's relative productivity (fishing power) is to some extent determined by its physical properties (a gross revenue function estimated for Oregon trawl vessels is discussed in the following section).

Of interest in this study is the change in the structure (or size and composition) of the trawl fleet over the time period 1970-75 with regard to the number and types of vessels participating in each fishery. To better understand these structural changes the decision making of individual fishermen will be examined in terms of their observed behavior when moving from one time period to a future time period. Specifically, an attempt will be made to relate the probability of a particular outcome occurring to measurable economic factors deemed to influence that outcome.

When one considers the full range of decisions involved and allows for the wide range of substitutes and complements, it is clear that there are an enormous number of potential variables in the decision process. Substitutes in this context may be viewed as competing alternatives (e.g., the alternative fisheries). A complement to a particular choice is a second choice that tends to be tied to or induced by the first choice (e.g., given choice of a particular fishery may preclude certain types of vessels). To reduce the complexity of the analysis, it would be desirable to separate the observed outcome into its constituent decisions. In order to accomplish this the assumption of additively separable utility will be invoked, allowing the specification of a distinct choice model for each component decision leading to the observed behavior on the part of a trawl fisherman in a subsequent time period.

Using this framework, one can view the fisherman as periodically being faced with a sequence of discrete decisions concerning his activity in the Oregon trawl fisheries. First, if the fisherman has a history of participation in the trawl fishery, he will upon occasion decide whether or not to remain in trawling. Second, if the fisherman decides to stay in trawling he may then review his trawling opportunities. The opportunity set facing the fisherman at this juncture is comprised of the shrimp and/or groundfish alternatives. In other words, if the fisherman decides to continue trawling he may consider it worthwhile to switch to another type of species or fishery. Finally, he will judge the adequacy of the vessel currently held for the particular fishery chosen and decide whether to replace or maintain it. Assuming for the moment that there are three classes (the vessel classification scheme is developed in the next section) into which a given trawl vessel will fall, the options outlined are shown in Figure 1.

As indicated in Figure 1, the exit decision is terminal. If the fisherman decides to stay in trawling he then faces the fishery decision which includes the status quo and maintenance alternative. Similarly, with regard to vessel class choice he can opt for a new vessel or maintain the current vessel, modifying it if necessary to suit a new fishery.

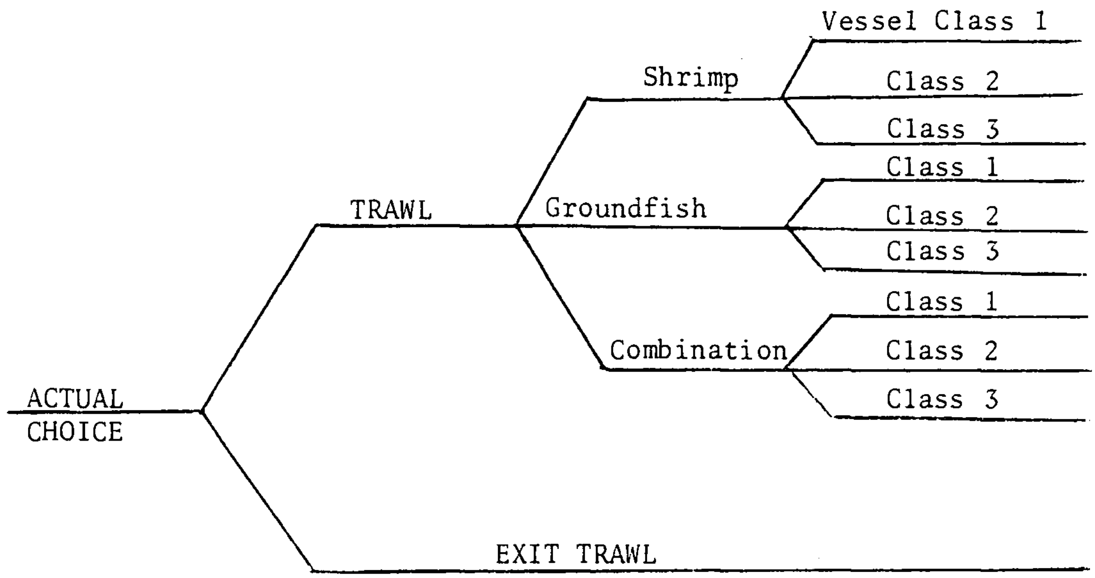

Figure 1. The Sequence of Decisions Facing the Trawl Fisherman.

Instead of the sequence in Figure 1, it might be argued that the fisherman, given the decision to stay in trawling, first considers the vessel alternatives, then for a particular vessel chosen (including the choice to maintain) decides upon which of the alternative fisheries to pursue. In this case the decision "tree" of Figure 1 is redrawn in Figure 2. In contrast to Figure 1, the "tree" in Figure 2 interchanges the fishery and vessel class decisions. However, given that the assumption of additively separable utility is valid, the independence of irrelevant alternatives can be exploited to show that the ordering of component decisions is inconsequential to the analysis. Referring specifically to the compound decision of what fishery to participate in and what vessel class to use; by the laws of conditional probability one can state:

[Probability of choosing fishery GF, vessel class 1]	=	[Probability of choosing vessel class 1 conditioned on the event that fishery GF is chosen]	x	[Probability of choosing fishery GF, any vessel class]

Under the independence of irrelevant alternatives assumption, the conditional probability will not depend on whether or not the individual has the option of fisheries other than groundfish, and hence:

[Probability of choosing vessel Class 1, conditioned on the event that fishery GF is chosen]	=	[Probability of choosing vessel Class 1 when the set of alternatives is the set of vessel classes available under fishery GF]

Thus, when the powerful assumptions of additive separability of utility and the independence of irrelevant alternatives are met, the

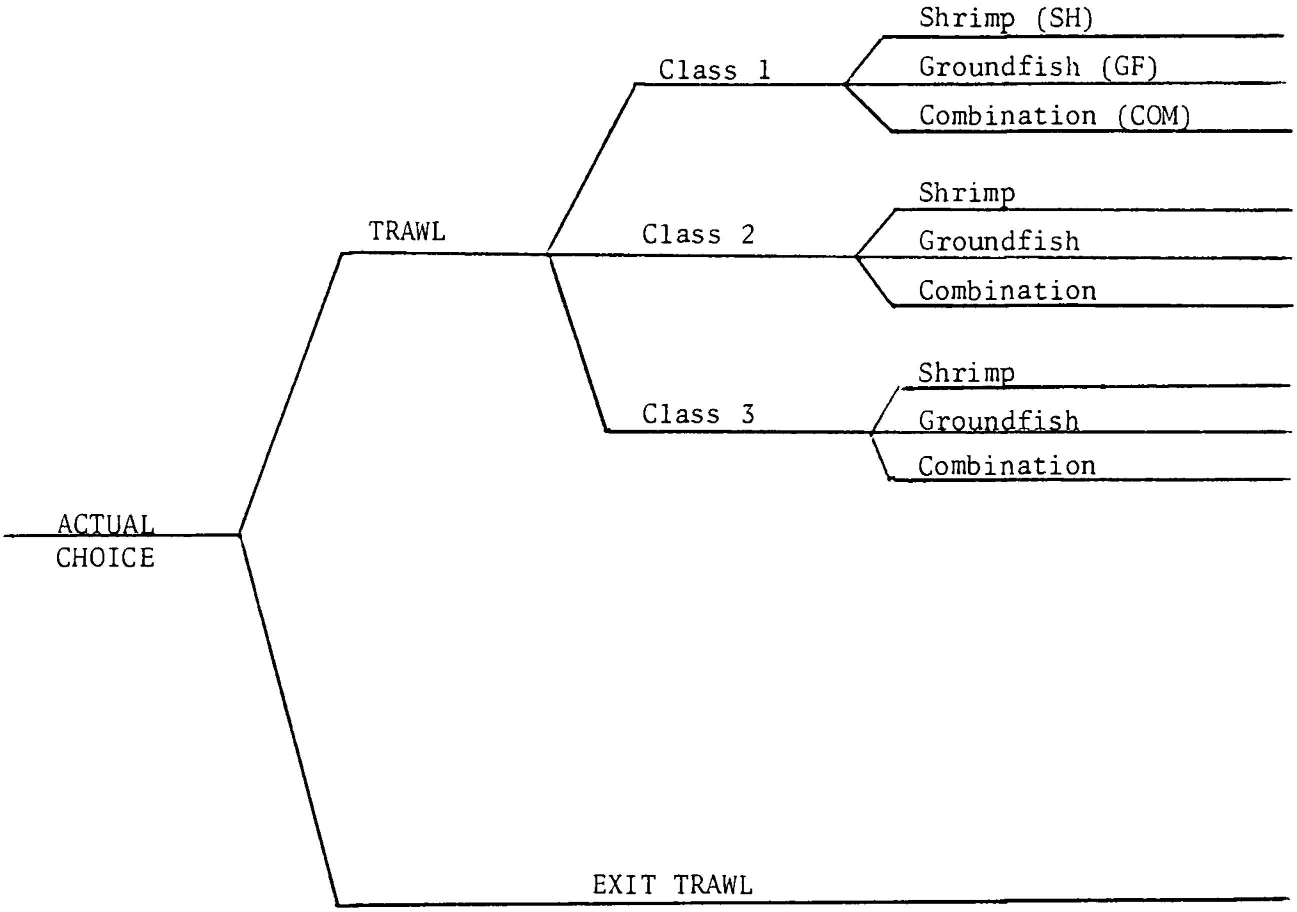

Figure 2. An Alternative Specification of the Sequence of Decisions Facing the Trawl Fisherman.

overall task can be greatly simplified by decomposing the simultaneous fishing decisions of an individual trawl fisherman into a series of separate choice models. The data available to analyze these distinct decisions is described in the next section.

The Data

The data consist of observations on the behavior of fishermen that had recorded landings in any of the Oregon trawl fisheries in one or more of the years 1970-75. Typically, the Oregon trawl fisherman is the owner/operator of a single vessel which is identified by an Oregon state boat plate number. Virtually 100 percent of the Oregon trawl vessels are in excess of the five gross tons and therefore have a federal documentation. Given the boat plate number, it is possible, in most cases, to determine the vessel's relevant physical characteristics from federal documentation lists. In some cases it was not possible to ascertain the vessel's physical characteristics. These vessels were then dropped from the population. Furthermore, the few fishermen owning and operating more than one vessel were also removed from the population, since the multiple ownership decision is beyond the scope of this study. Vessel landings information was reported on a per trip basis and consisted of: (a) total pounds of each species delivered to an Oregon dealer; (b) the type of gear (shrimp or groundfish) used;[1/] and (c) the number of hours the gear was in the water for that trip (the hours information was not always available for each trip). These data were supplemented with corresponding data on Oregon ex-vessel prices for the range of species landed. Cost

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[1/] While a combination vessel is geared to catch both shrimp and groundfish, the change over is not made at sea. Thus for a particular trip the vessel fished one gear or the other.

data were not directly available. However, a pooled sample of trawl vessels was obtained for which total variable costs (operating costs), total landings, and vessel length was reported. Furthermore, the vessels were distinguishable by the fishery in which they participated. This sample was used to generate an operating cost estimating equation which in turn was applied to the Oregon trawl vessel sample. For estimation purposes it is desirable that operating cost function have a high overall explanatory and predictive power. The most satisfactory relationship in this regard is given as:

$$TVC = e^{\alpha} TONS^{(\beta_1+\delta_1 GF+\delta_2 SH)} LEN^{(\beta_2+\delta_3 GF+\delta_4 SH)} TIME^{(\beta_2+\delta_5 GF+\delta_6 SH)} \qquad (1)$$

where

TVC = vessel's annual total variable costs (includes crew share, fuel, gear, supplies, repairs, unloading)

TONS = tons of fish landed

LEN = vessel length

TIME = the year of the particular observation (a trend variable capturing inflationary and technological influences).

The variables GF and SH are fishery dummys which enter according to the scheme:

Fishery participated in	GF	SH
Groundfish	1	0
Shrimp	0	1
Combination	0	0

The fishery dummies interact with the main explanatory variables to indicate that a change in operating costs due to a change in one of the explanatory variables will depend upon the fishery in which the vessel is operating. The results of the log linear estimation of equation (1) are reported in Table 1.

In addition to estimating a vessel's annual operating expenditures, vessel market values were predicted for each of the years a particular vessel appeared in the Oregon trawl sample. The market value estimating equation was obtained from Bell et. al. [3] and is shown as:

$$y = 3492.97x_1 + .236\ x_2^3 - 495.06\ x_3 + 11864.50 \qquad (2)$$

where y = market value

x_1 = net tons

x_2 = length

x_3 = age.

This market value function was estimated using 1976-77 Oregon data.[2/] Since 1970-1975 is the time period covered in this study, market values for vessels in each of those years would have to be adjusted when employing equation (2) to reflect net appreciation, or depreciation. An analysis of vessel market values over the period 1970-1976 revealed that market values had been increasing at an annual average rate of 14 percent.[3/] Thus, the market values predicted for the 1970-1975 sample of vessels using equation (2) were adjusted accordingly.

Since one of the investment decisions to be examined in the empirical analysis involves the fisherman's choice of a particular type of fishing

2/ Frederick Smith, personal correspondence.

3/ Ibid.

Table 1. Fishing Vessel Total Variable Costs (TCV): Results From Log Linear Estimation (t-values in parentheses)

Dependent Variable	Constant	ℓn(TONS)	ℓn(LEN)	ℓn(TIME)	GFℓn(TONS)	SHℓn(TONS)	GFℓn(LEN)	SHℓn(LEN)	GFℓn(TIME)	SHℓn(TIME)
ℓn(TVC)	-33.942	.8163	-.6956	9.9386	.1053	-.2796	1.1244	.6514	-1.1949	-.1826
R^2 = .9518	(-9.742)	(5.788)	(-1.431)	(11.993)	(.638)	(-.712)	(1.883)	(.646)	(-2.188)	(-.231)

vessel, some means of classifying vessels is necessary in order to conduct the analysis. If vessel investment choice is sensitive to the fisherman's expectations concerning environmental and economic factors, one would want to focus on those vessel characteristics that best reflect productive capability in devising a classification scheme. To this end functions relating gross revenues to various physical characteristics of the vessel were specified and estimated using the Oregon trawl sample to indicate which of the vessel properties would be most useful in establishing a vessel classification system. The following relationship produced the best statistics:

$$GR = e^{\alpha_1} AGE^{\beta_1} HP^{\beta_2} TRIPS^{\beta_3} GT^{\beta_4}, \quad (3)$$

where GR = annual gross revenues

AGE = age of the vessel

HP = vessel horsepower

TRIPS = number of trips the vessel made during the year

GT = vessel gross tonnage.

Results of the log linear estimation of equation (3) are presented in Table 2.

Of the vessel physical characteristics age and gross tonnage were selected as classification variables. Vessel horsepower was omitted from the classification scheme because of the questionable reliability of horsepower in terms of its timely inclusion in vessel documentation lists. Age was included because it would seem to share in the explanatory role of vessel hull material and other vessel physical properties not explicitly included in the classification scheme. That is, the vast majority of vessels constructed prior to 1950 had wooden hulls, while those built

Table 2. Fishing Vessel Gross Revenues (GR): Results From Log Linear Estimation (t-values in parentheses)

Dependent Variable	Constant	ℓn(AGE)	ℓn(HP)	ℓn(TRIPS)	ℓn(GT)
ℓn(GR)	3.4382	.0276	.1481	.9992	.7337
R^2 = .7602	(3.8790)	(.4900)	(.9040)	(17.6260)	(5.6280)

after 1950 were of steel. Finally the distribution of the vessels according to age (denoted by the year the vessel was built) and gross tonnage made it convenient to use these variables as vessel classifiers (see Table 3 and Table 4). The resulting vessel classification scheme is shown in Table 5. Thus, a specific vessel in the Oregon trawl sample will fall into one of these classes. Then, for a particular vessel class, it is possible to estimate average earnings, average operating expenditures, and average market value for a given year by summing the respective values estimated for each of the vessels in that class for that year and dividing by the number of vessels in the class.

The decision variables incorporated in the analysis reflect changes that occurred in the Oregon trawl fleet from 1970 to 1975. The structure of the trawl fleet (see Tables 6 through 8) is affected by the decision-making behavior of individual fishermen choosing to stay in trawling or to leave trawling and the choices of fishermen entering trawling. The decision to exit the trawl fleet changes the structure of the overall fleet (see Table 9) as well as the number of vessels in a particular trawl fishery (see Table 10). The decision to enter trawling likewise affects the structure of the fleet (see Table 11) and the number of vessels in a particular trawl fishery (see Table 12). In addition, the structure of the trawl fleet and the number of participants in each trawl fishery is altered by the decisions of fishermen remaining in trawling. Existing trawl fishermen can change or maintain their current vessel (see Table 13) as well as remain in the current trawl fishery or switch to another trawl fishery (see Table 14). Collectively, these decisions produce a net change in the structure of the trawl fleet (see Table 15 and Table 16). Changes in the fleet's structure, in turn, affect "capacity and extent".

Table 3. Frequencies and Measures of Central Tendency for Age (all vessels 1970-1975).

Interval	Frequency	Percent Frequency
1900 - 1909	13	2.21
1910 - 1919	48	8.16
1920 - 1929	77	13.10
1930 - 1939	60	10.20
1940 - 1949	144	24.49
1950 - 1959	36	6.12
1960 - 1969	132	22.45
1970 - 1979	78	13.26

Mean	1947
First Quartile	1934
Median	1945
Third Quartile	1967
Maximum Value	1975
Minimum Value	1900

Table 4. Frequencies and Measure of Central Tendency for Gross Tonnage (all vessels 1970-1975).

Interval	Frequency	Percent Frequency
0 - 29	130	22.11
30 - 59	300	51.02
60 - 89	88	14.97
90 - 119	58	9.86
120 - 149	3	.51
150 - 179	0	0
180 - 209	8	1.361
210 - 239	0	0
240 - 269	0	0
270 - 299	0	0
300 -	1	0

Mean	53
First Quartile	31
Median	44
Third Quartile	62
Maximum Value	927
Minimum Value	7

Table 5. Classification of Vessels According to Gross Tonnage and the Year Built.

Gross Tons	1900-1950	1951-1975
0 - 30	Class 1	Class 4
31 - 60	Class 2	Class 5
61 -	Class 3	Class 6

Table 6. Distribution of Vessels in the Oregon Shrimp Fishery Sample 1970-1975.

Year	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1970	9	6	0	1	6	5	27
1971	7	3	0	1	5	3	19
1972	12	4	0	1	10	3	30
1973	7	4	1	0	12	4	28
1974	4	5	0	0	20	19	48
1975	2	5	1	0	12	14	34
Total	41	27	2	3	65	48	186

Table 7. Distribution of Vessels in the Oregon Groundfish Fishery Sample 1970-1975.

Year	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1970	4	16	7	0	1	4	32
1971	4	19	9	1	0	4	37
1972	4	7	3	0	1	1	16
1973	3	14	5	1	1	1	25
1974	3	12	2	0	2	0	19
1975	4	6	1	0	2	0	13
Total	22	74	27	2	7	10	142

Table 8. Distribution of Vessels in the Oregon Combination Fishery Sample 1970-1975.

Year	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1970	4	9	3	1	1	0	18
1971	6	8	5	1	3	3	26
1972	7	13	3	2	2	3	30
1973	15	14	3	3	11	8	54
1974	12	17	7	5	10	11	62
1975	10	19	5	2	17	17	70
Total	54	80	26	14	44	42	260

Table 9. Exit from Trawling by Vessel Class 1970-1974.

Year	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1970	5	11	1	0	3	4	24
1971	3	9	8	1	0	8	29
1972	4	5	2	1	1	2	15
1973	9	7	2	0	10	3	31
1974	4	10	2	1	6	11	34
Total	25	42	15	3	20	28	133

Table 10. Exit from Each Trawl Fishery 1970-1974.

Year	Shrimp	Groundfish	Combination	Total
1970	11	9	4	24
1971	4	19	6	29
1972	5	5	5	15
1973	12	3	16	31
1974	18	4	12	34
Total	50	40	43	133

Table 11. Entering Trawling by Vessel Class 1971-1975.

Year	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1971	6	9	4	1	6	3	29
1972	5	6	2	1	7	2	23
1973	9	12	5	0	14	6	46
1974	5	12	1	2	18	15	53
1975	1	3	0	1	4	13	22
Total	26	42	12	5	49	39	173

Table 12. Entry Into Each Trawl Fishery 1971-1975.

Year	Shrimp	Groundfish	Combination	Total
1971	8	10	11	29
1972	10	3	10	23
1973	12	13	21	46
1974	23	5	25	53
1975	8	2	12	22
Total	61	33	79	173

Table 13. The Number of Fishermen Maintaining and Changing Vessels by Vessel Class 1970-1975.

From Class	To Class 1	2	3	4	5	6
1	55	1	1	0	3	2
2	0	80	0	0	0	0
3	0	0	21	0	0	0
4	0	1	0	9	1	0
5	1	0	0	0	40	0
6	0	0	0	0	0	30

Table 14. The Number of Fishermen Remaining In or Switching To Another Trawl Fishery 1970-1975.

From Fishery	To Fishery: Shrimp	Groundfish	Combination
Shrimp	35	2	17
Groundfish	4	45	16
Combination	14	12	74

Table 15. Net Changes in the Distribution of Oregon Trawl Vessels 1970-1975.

Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
-5	2	-2	0	32	13

Table 16. Net Changes in the Distribution of Oregon Trawl Fishermen by Fishery 1970-1975.

Shrimp	Groundfish	Combination
10	-13	40

Thus, there will be an interest on the part of fishery policy makers as to what influences individual fishermen in making these types of decisions. This interest is pursued in the following section where the role of economic variables in each type of decision is examined.

Specification of the Logit Choice Models

For a fisherman active in Oregon trawling in any of the years 1970-75, one would observe the following:

(a) vessel owned;

(b) vessel gross tonnage;

(c) vessel net tonnage;

(d) vessel length

(e) year vessel was built;

(f) fishery participated in;

(g) total revenues for the year (f(price, landings));

(h) total operating costs of the year (f(tons landed, length, time, SH, GF)); and

(i) vessel market value in that year (f(net tons, length, age)).

In a subsequent year the same fisherman's presence or absence is noted. If he is present his decisions concerning fishery and vessel choice are observed. This in general describes the variables and observational format employed in the discrete decision models of trawl fisherman behavior postulated below.

In order to specify a multinomial or binomial logit model for each of the fisherman's decisions identified above, it is necessary to examine the objectives under which the fisherman operates. Traditional economic theorists state that the long-run decision making of the firm is guided by a net worth maximization objective. While the explicit objective in this situation may be one step removed, this does not detract from the theory of rational choice underlying the multinomial logit model. In this regard, the maximization of net worth is viewed as contributing to the overall satisfaction the fisherman derives from the fishing activity. In other words, the fisherman's objective function can include consumption as well as production-oriented components. Therefore, his decision making may be strongly influenced by a number of non-economic factors (tradition, preferences, etc.) as well as expected costs and returns. However, as noted earlier, while the values of market variables which, under conditions of perfect competition, are independent of the actions of the individual fisherman, non-pecuniary factors are often fisherman specific, and may have a significant but different effect upon each fisherman's decision making.[4/] Thus, examining the fisherman's decision behavior within a production context does not appear to violate the conditions under which the logit model works best. Furthermore, inasmuch as a net worth maximization approach will reveal the strength of economic variables in the fisherman's decision making, some inferences may be drawn concerning the argument that "fishermen fish for the sake of fishing".

The choice between exiting and continuing trawling is examined for an existing fisherman proceeding from the time period t into the time period t+1. In between these periods the fisherman is assumed to

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[4/] As shown above, a highly desirable feature of the logit model developed by McFadden [see [13] pp. 51-65, and [33] pp. 105-113] is its ability to deal with individual discrepancies at the extensive margin by explicitly accounting for unobserved and/or unmeasurable influences which lead to a distribution of decision rules over the population.

pause and evaluate his trawl fishing preference vis-a-vis perceived alternative opportunities available to him. As long as trawling affords him at least as much satisfaction as he would expect to derive from the next best alternative, he will choose to remain in trawling. The economic theory of the firm puts this in a somewhat different perspective. Firms will enter an industry when the perceived rate of return on invested resources is greater than that which could be realized in the next best alternative. Conversely, firms will exit an industry if more promising opportunities, in terms of rate of return, are available elsewhere. Thus, the fisherman would exit trawling if the rate of return on his invested capital (including human) could be increased in the pursuit of some alternative activity.

Suppose that prior to period t the potential fisherman observes that he has the financial resources to invest in a vessel that is capable of generating a discounted rate of return in excess of that which he is realizing in his current occupation. These circumstances attract him into trawling. Then, once he is trawling, his exit/remain decision is dependent upon not only his fishery rate of return relative to the rate of return outside of trawling, but his trawling rate of return relative to the average rate of return within the trawl fisheries. That is, a preference for fishing is bolstered not only by extra fishery comparisons, but also by intra fishery comparisons: the fisherman will stay in trawling if he is doing as well as or better than other trawlers. This argument suggests that the average rate of return in trawling represents the opportunity cost of capital to the fisherman. In other words, the fisherman perceives that the average rate of return in trawling is at least as great as the rate of return in his next best alternative. If the fisherman is relatively unsuccessful in trawling he will try his next best alternative. In this sense, the individual fisherman compares his economic performance with some trawl-fisheries-wide standard in making the decision to exit or remain in trawling.

Using rate of return on invested capital as a performance measure, one might then view the individual fisherman's rate of return vis-a-vis the trawl-fisheries-wide average at a particular point in time as influencing his exit/remain decision. In this context, the observed presence or absence of a fisherman in some subsequent time period t+1 is related to his own rate of return in period t and the trawl-fisheries-wide average rate of return in periods t and t-1. Specifically, it is postulated that the fisherman leaves the fishery after a relatively bad year which is reflected by a return on his invested capital in t that is significantly less than the trawl-fisheries-wide average rate of return in t-1 and t. The focus is not on the change in the fisherman's internal rate of return from one period to another, but his rate of return at any point in time relative to the average trawling rate of return in the previous period and whether this relative position is maintained in the present period. Conversely, the fisherman is encouraged to remain in trawling when his rate of return at any point in time t, is at least as great as the trawl-fisheries-wide average rate of return in the previous time period, t-1 and at least as great as that in the current time period t.

A logit specification of the binary choice model relating the fisherman's choice of exiting and remaining in trawling to his own, relative to the fisheries wide average, rate of return is given by,

$$P_{in} = 1/1+e^{-L} \qquad (4)$$

In equation (4), P_{in} is the probability that fisherman n will stay in trawling (alternative i);

$$L = \log P_{in}/1\text{-}P_{in} = \alpha + \beta_1 x_{1n} + \beta_2 x_{2n} \tag{5}$$

where L is the log of the odds in favor of fisherman n remaining in trawling.

$$x_{1n} = \left(\frac{\text{net operating revenue for fisherman n}}{\text{market value of fisherman n's vessel}}\right)_t - \left(\frac{\text{fisheries wide average net operating revenue}}{\text{fisheries wide average vessel market value}}\right)_{t-1}$$

$$x_{2n} = \left(\frac{\text{net operating revenue for fisherman n}}{\text{market value of fisherman n's vessel}}\right)_t - \left(\frac{\text{fisheries wide average net operating revenue}}{\text{fisheries wide average vessel market value}}\right)_t;$$

β_1, β_2 are parameters measuring the effects of the respective variables on the response, and α denotes the "pure preference" for remaining in trawling. In general "pure preference" effects enter the model as alternative specific dummy variables reflecting a preference for a specific alternative. In this particular case α is attached to a dummy variable (D_1) of the form:

Alternative	D_1
Remain	1
Exit	0

The ratio of net operating revenue to vessel market value represents the rate of return on investment in this case.

The second decision model of interest explains the fisherman's choice of fishery. In choosing among fisheries a trawl fisherman will weigh the benefits (pecuniary and non-pecuniary) and costs associated with each alternative. The fisherman will engage in a particular fishery if the expected returns are sufficiently large to make that choice the most profitable use of his limited resources.

In this simplest formulation, one would always expect to find fishermen in the fishery with the highest potential net earnings. However, given differentials in human capital, access to information, and the assessment of risk (or differences in risk preference), the pure economic choice will be modified by non-economic considerations. All other things being equal fishery choice will be governed by the expected returns and expected costs - primarily annual operating expenditures[5/] - associated with each alternative relative to the earnings/expenditure position of the fisherman in his current situation. That is, the probability that a fisherman n will enter fishery i will be a function of the relative difference in earnings between fishery i and his current earnings and the relative difference in operating costs between fishery i and his current expenditures.[6/] Insofar as there are two distinct sub-populations faced with this decision additional considerations are introduced.

One sub-population consists of existing fishermen (those already in a fishery) who will compare their performance in the current fishery with their expected performance in the alternative fisheries. In this regard,

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5/ Annual fixed costs are assumed to be the same for all fisheries.

6/ A present value approach to this decision is not undertaken since the commitment to a particular fishery does not usually involve major long-term capital investment, i.e., it is primarily a gearing consideration. Thus the fishery decision is assumed to be made on an annual basis. It is further assumed that the fisherman expects current economic conditions to carry over into the next period.

the existing fisherman will compare his current operating revenues and operating costs with the operating revenues and costs from each fishery alternative generated by the same capital stock. He will then choose, ceteris paribus, the fishery that yields the greatest increase in net operating revenues over current net operating revenues. In addition, existing fishermen will already have experience in at least one of the trawl fisheries. This will also influence their choice of future fishery. That is, a shrimp fisherman, ceteris paribus, is likely to stay in the shrimp fishery. The other sub-population is comprised of entering fishermen, i.e., those fishermen who did not record Oregon landings in 1970, but did in any one or more of the years 1971-1975. Thus, the new fisherman's decision will be based upon the relative expected net operating revenues from each alternative fishery.

For the overall population, the probability that fisherman n will choose fishery i in period t+1, P_{in}, will be a function of the relative increase in expected operating revenues and operating costs for the fisherman's capital stock over the operating revenues and costs from his current fishery and the particular fishery in which the fisherman is engaged in period t. That is, for the three fisheries of interest (i = 1, 2, 3):

$$P_{in} = f(FDTR_{1n}, FDTR_{2n}, FDTR_{3n}, FDOC_{1n}, FDOC_{2n}, FDOC_{3n}; F_n),$$

where

$FDTR_{in}$ = average total revenue from fishery i for the class of vessel fisherman n holds in t minus the actual total revenue from fishing for the fisherman in period t (which will be equal to zero for new fishermen);

$FDOC_{in}$ = average operating costs for fishery i for the class of vessel fisherman n holds in t minus the actual operating costs for fishing for the fisherman in period t (which will be equal to zero for new fishermen); and

F_n = the fishery in which fisherman n participated in period t.

In this case the variable F_n represents a "pure preference" for the fishery in which the fisherman is already participating. Thus, it enters the formulation as an alternative specific dummy variable.

A multinomial logit specification of the fishery choice model for fisherman participating in a particular fishery in period t can be written in the form:

$$P_{in} = \left[\sum_{j=1}^{3} \exp \left[(DTR_{jn} - DTR_{in})\beta_1 + (DOC_{jn} - DOC_{ij})\beta_2 \right] + \alpha_1 FD_1 + \alpha_2 FD_2 + \alpha_3 FD_3 \right]^{-1} \qquad (6)$$

where FD_i (i = 1, 2, 3) is the "pure preference" dummy whose coefficient α reflects the additional weight given to staying in that particular fishery. That is, when explaining the "no change" choice, the probability of no change will be incremented by α. When evaluating a choice representing a change in fisheries, D_i will equal zero indicating a lower preference, ceteris paribus, for that alternative. Entering fishermen are not depicted by "pure preferences". The scheme for fishery alternative specific dummy variables is shown as:

Fishery Alternative	FD_1	FD_2	FD_3
Shrimp	1	0	0
Groundfish	0	1	0
Combination	0	0	1

where FD_1 through FD_3 equal zero for entering fishermen. The β_1 and β_2 in equation (6) denote the effect of the difference in total revenue, and the difference in operating cost respectively on fishery choice.

The last decision to be analyzed is that of vessel choice: the choice of vessel in period t+1 given the vessel held in period t (the entering fisherman is assumed not to have a vessel in t). In this case, the fisherman maintains, switches to, or enters a vessel which will fall into one of the six vessel classes defined above. Thus, the decision model will explain why a particular vessel class is chosen in terms of the probability of that choice being made. As in the fishery case, the fisherman will compare the costs and benefits of each alternative and select a particular vessel which he expects to be most profitable over the relevant time horizon. Under this criterion one would expect to observe a fairly homogeneous fleet, represented by the vessel class with the greatest net earnings potential. However, owing to imperfect capital markets, the resources required to introduce a vessel of a different class will not be equally accessible to all fishermen and again non-pecuniary considerations will qualify the fisherman's pure economic choice. But economic factors will play a role in determining vessel choice. In this regard the fisherman's vessel choice will be a function of vessel cost and the discounted net return that the vessel is expected to generate.

Existing fishermen will relate the economic performance of their current vessel to the average performance of vessels in each alternative class when choosing among the alternatives. Since gross revenues, operating costs,[7/] and market values can be measured for each vessel class, it is possible for the fisherman to evaluate the vessel choice alternatives using the present value framework. For the i^{th} alternative in the set of vessel classes,

$$NPV_i = \sum_{t=0}^{T} \frac{NOR_{i,t}}{(1+r)^t} + S_i - K_i, \tag{7}$$

where

NPV_i = the net present value for the average vessel in class i;

K_i = the initial outlay for the average vessel in class i;

$NOR_{i,t}$ = the expected net operating revenue for the average vessel in class i for the t^{th} period;

r = the discount rate;

S_i = the salvage value of the average vessel in class i.

The net present value criterion states that the fisherman will select the alternative yielding the greatest net present value. The fisherman then chooses a vessel from class i over a vessel from class j if

$$NPV_i > NPV_j.$$

Substituting from equation (7) yields

$$\underbrace{\sum_{t=0}^{T} NOR_{i,t}/(1+r)^t}_{X_i} - K_i > \underbrace{\sum_{t=0}^{T} NOR_{j,t}/(1+r)^t}_{X_j} - K_j$$

7/ Again annual fixed costs (insurance, moorage, etc.) are assumed constant for each vessel class.

where salvage values are assumed to be equal. Rearranging leads to

$$x_i - x_j > K_i - K_j \tag{8}$$

Inequality (8) states that alternative i will be chosen over alternative j when the difference in respective discounted revenues is greater than the difference in respective capital outlays.

Under this present value approach, the fisherman's decision regarding vessel choice is guided by his expectations concerning future net revenue streams. Since it is impossible for the fisherman to know exactly what will happen over the relevant time frame, uncertainty enters the decision process. Hence, knowledge of the fisherman's expectations of prices and yields is crucial to the analysis. The essence of these estimates would be the fisherman's subjective probability distribution for the stochastic variables under consideration. However, inasmuch as the formation of the fisherman's expectations is beyond the immediate scope of this study the simplifying assumption is introduced that the fisherman expects the prices and yields at the time the investment decision is made to prevail over the planning period. That is, the operating performance for each of the vessel alternatives at the time the selection decision is made weighs most heavily upon the fisherman's choice of vessel.[8/] It is also assumed that the occurrence of a particular vessel in the time period t+1 results from the fisherman's perceptions of price and yield in period t.

8/ If the decision year's prices and yields are expected to continue into the future, then for a given discount rate differences in discounted future net returns beyond the decision year will be of the same magnitude as the differences in net returns of the present year.

In addition to the cost and revenue factors influencing vessel choice, the class of vessel that the fisherman operates currently will also be taken into consideration. An alternative specific dummy variable denoting the class of vessel presently held is included to reveal a preference to maintain the same vessel or his unwillingness to change, ceteris paribus.

Corresponding to the fishery choice case, the fisherman's vessel choice is directed by the difference between the net operating revenue (the difference between total revenues and operating costs) for the vessel currently held and the average net operating revenue for each of the alternative classes. Similarly it is the net capital outlay (expressed as the difference between the market values of the vessel currently held[9/] and the average market value for each of the alternative classes) that enter as an explanatory variable in the model.

The general form of the logit vessel choice model is given by:

$$P_{in} = \left[\sum_{j=1}^{6} \exp[(DTR_{jn} - DTR_{in})\beta_1 + (DOC_{jn} - DOC_{in})\beta_2 + (DK_{jn} - DK_{in})\beta_3] + \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + \alpha_5 D_5 + \alpha_6 D_6 \right]^{-1}, \quad (9)$$

where

P_{in} = probability of alternative i being chosen by fisherman n;

DTR_{jn} = annual relative total revenues fisherman n associated with alternative j;

9/ The net operating revenue for the vessel currently held as well as its market value will be equal to zero for the entering fisherman.

DOC_{jn} = annual relative operating costs fisherman n associated with alternative j;

DK_{jn} = net capital outlay fisherman n associates with alternative j;

and the β's and the α's are the parameters to be estimated. The alternative specific dummy variables enter according to the scheme:

Vessel Class Alternative	D_1	D_2	D_3	D_4	D_5	D_6
1	1	0	0	0	0	0
2	0	1	0	0	0	0
3	0	0	1	0	0	0
4	0	0	0	1	0	0
5	0	0	0	0	1	0
6	0	0	0	0	0	1

and the values of D_1 - D_6 will be zero for entering fishermen.

Empirical Analysis

The method used to estimate the three decision models described above is the maximum likelihood procedure. This procedure is employed in view of the continuous nature of the economic explanatory variables included in each of the decision models. Provided the data are not multicollinear the vector $\hat{\beta}$, satisfying the first order conditions for maximization, is a unique maximizer for the likelihood function (equation (35) p. 54). Hence, there is a unique maximum likelihood estimator.[10/]

10/ The conditions for the existence of the maximum likelihood estimator are given in McFadden [33].

Since standard errors for the elements in the maximum likelihood estimator $\hat{\beta}$ can be derived, tests of significance and measures of goodness of fit can be applied to the estimation results. Thus, t-statistics can be computed for each of the estimated parameters to test whether it is significantly different from zero.

A goodness of fit measure indicates the degree to which the model approximates the observed data and therefore its predictive power. The likelihood ratio statistic can be used to test the overall explanatory power of the model. In general, the likelihood ratio, λ, is the ratio of the value of the likelihood function maximized under whatever constraints are embodied in the hypothesis being tested to the value maximized under no constraints except those implicit in the model. The quantity $-2 \log \lambda$ is distributed as a chi-square statistic with as many degrees of freedom as there are independent restrictions in the hypothesis being tested. If, for example, the null hypothesis states that the true parameter vector, β, is zero or that it is zero except for pure alternative effects, (a preference for a particular alternative) then this statistic provides a test of the significance of the estimation, indicating the "variance" explained. McFadden [33, p. 121] defines a coefficient of determination analogous to the multiple-correlation coefficient in the lienar statistical model as

$$p^2 = 1 - \frac{L(\hat{\Theta})}{L(\hat{\Theta}^H)}$$

where $L(\hat{\Theta})$ denotes the unconstrained maximization of the log-likelihood function and $L(\hat{\Theta}^H)$ maximization under the null hypothesis.

The parameter estimates generated by the logit analysis are related to the difference in value between the generic explanatory variables associated with the chosen and non-chosen alternatives respectively. Furthermore, the magnitude of the estimated parameters, $\hat{\beta}$, reflect that it is the natural log of the values of the exogenous variables which enter the estimation (total revenues, operating costs, and capital outlays are measured in thousands of dollars per year; the dummy variables take the value zero or one). Using the vessel choice specification as an example, it is hypothesized that alternative i will be chosen over alternative j if $DTR_{in} > DTR_{jn}$ or $(DTR_{jn} - DTR_{in}) < 0$, ceteris paribus. It follows that the greater the difference $(DTR_{in} - DTR_{jn})$, ceteris paribus the greater P_{in}. Thus, β_1 in the vessel choice model is expected to be positive. Similar reasoning would make β_2 and β_3 negative. Since the complete term $(DTR_{jn} - DTR_{in})\beta_1$ is an exponent in the denominator of the probability function, this qualitative relationship is expected to hold.[11/] In general a positive and significant coefficient would be expected for the variables hypothesized to increase the probability of an alternative being chosen. Conversely, a negative coefficient would be anticipated for those variables which are expected to detract from a particular choice.

[11/] The choice probability solely in terms of gross revenues is

$$P_{in} = 1/\sum_j e^{(DTR_{jn} - DTR_{in})\beta_1}$$

where $(DTR_{jn} - DTR_{in})$ is expected to be < 0. For a $\hat{\beta}_1 > 0$, P_{in} will increase as the difference $(DTR_{jn} - DTR_{in})$ increases since the denominator will be decreasing.

The exit-continue specification was estimated[12/] for all fishermen that could have left trawling in any one of the years 1972-1975 (see Table 17). The estimation results indicate that the relative rate of return variables do not significantly influence this choice. The dummy variable associated with remaining in trawling is highly significant indicating a strong desire to continue trawling. That Oregon trawl fishermen choose to remain in trawling in spite of their economic performance vis-a-vis the remainder of the fleet may reflect the fact that many Oregon trawl vessels fish for other species during the year (e.g., crab). In this case trawling might be considered a secondary pursuit, i.e., one that contributes to overhead, but is not as lucrative as some of the alternative fisheries. On the other hand full-time trawlers may lack experience and/or the skills to engage in alternative activities, including alternative fisheries. In addition, the consumptive elements of fishing cannot be overlooked. To the extent that some satisfaction or pleasure is derived from "catching" fish, there are the leisurely aspects to consider. Also, Oregon trawl fishermen may be highly tradition bound. They may not be given to the relatively quick response suggested in the model. Furthermore, exit in terms of economic considerations may be a much more cumulative process. These factors, taken collectively or individually, may partially account for the insensitivity of Oregon trawl fishermen to changes in the economic variables of the magnitude observed over the time period. However, while the economic variables are not

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[12/] The Quail 3.0 logit computer algorithm was used to obtain estimates of the logit parameters. Procedures for assembling the data and a discussion of the output are found in Berkman _et. al._ [4].

Table 17. Results of Logit Exit/Continue Fisherman Choice Model -- All Fishermen (t-statistics in parentheses).

Variable	Coefficient
Difference between fisherman's rate of return in t and average trawl rate of return t-1(X_1).	.02230 (1.064)
Difference between fisherman's rate of return in t and average trawl rate of return in t(X_2).	.02236 (1.021)
Pure preference for remaining in trawling (D_1).	1.121 (7.812)*

Log likelihood = 51.7*

Percent correctly predicted = 76.36

Likelihood ratio index (p^2) = .2257

* significant at the 99 percent level.

significant individually, they do act in the expected direction. This is satisfying since the overall power of the specification is encouraging.

The next choice of interest was that of the fishery in which the fisherman will engage. The fishery choice specification was initially estimated combining all the observations over the 1970-1975 time period. Thus, the results (see Table 18) show the influence of potential net gains (losses) on the active and entering fisherman's fishery choice. The most disturbing thing about these results is the unexpected sign of the operating cost coefficient. The fact that an increase in relative operating costs significantly increases the probability of that alternative behing chosen sharply contradicts the expected behavior. One anticipates costs to be significant since this is an economic variable over which the fisherman has relatively greater control in the sense that the production of fishing effort is deterministic while the harvest of fish is not. However, the qualitative relationship is unacceptable which in light of the dominant pure preference effects suggests an error in specification.

Because of the disappointing results when analyzing fishery choice for all fishermen (entering and current) taken together, the population was partitioned to examine the behavior of active and entering fisherman separately. The sub-population of active fishermen was further divided into active shrimp, groundfish, and combination fishermen. For each type of fishermen a specification relating the probability of a particular fishery choice to the expected increase in total revenues and the expected increase in operating costs as well as a pure preference for the fishery in which the fisherman was operating in period t was estimated (see Tables 19-21).

Table 18. Results of the Logit Fishery Choice Model -- All Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
Expected increase in total revenues (FDTR)	-.0000027 (-.4489)
Expected increase in operating costs (FDOC)	.0000251 (2.038)*
Preference of shrimp fishermen to remain (FD_1)	1.3310 (4.516)*
Preference of groundfish fishermen to remain (FD_2)	1.338 (4.807)*
Preference of combination fishermen to remain (FD_3)	1.818 (7.596)*

Log likelihood = 66.20*

Percent correctly predicted = 55.11

Likelihood ratio index = .1431

* significant at the 99 percent level.

Table 19. Results of the Logit Fishery Choice Model - Shrimp Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
FDTR	.0000246 (.9725)
FDOC	-.0000405 (-.7119)
FD_1	1.508 (3.436)*

Log likelihood = 11.77*

Percent correctly predicted = 64.81

Likelihood ratio index = .1983

* significant at the 99 percent level.

Table 20. Results of the Logit Fishery Choice Model - Groundfish Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
FDTR	.0000229 (1.521)
FDOC	.0000068 (.2710)
FD_2	1.375 (4.344)*

Log likelihood = 19.80*

Percent correctly predicted = 70.77

Likelihood ratio index = .2773

* significant at the 99 percent level.

Table 21. Results of the Logit Fishery Choice Model - Combination Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
FDTR	.0000096 (.8190)
FDOC	-.0000046 (-.2072)
FD_3	1.630 (6.316)*

Log likelihood = 35.03*

Percent correctly predicted = 74.00

Likelihood ratio index = .3185

* significant at the 99 percent level.

Results of the separate fishery choice estimations for shrimp, groundfish, and combination fishermen, indicate that the economic variables specified are not significant in the fishery choice by active fishermen. All the types of fishermen showed a strong preference for staying in their current fishery. That this preference is strongest among combination fishermen is not surprising since they participate in both shrimping and groundfishing over the year. It also stands to reason that economic factors would be least significant for this type of fishermen in terms of an outright change of fishery. Rather than switch over to one type of fishery completely, the combination fishermen may simply adjust the amount of time he spends in shrimping vis-a-vis groundfishing in response to relative economic conditions. The flexibility that the combination fishery offers would better enable its participants to sustain operations under adverse economic conditions. This also brings into consideration the seasonal aspects of trawl fishing. Groundfish fishing is year round, while shrimping is limited by a seasonal constraint. Instead of combining groundfishing and shrimping, the shrimper may find it more rewarding to fish crab or engage in some non-fishing activity during the off season. Similarly for the groundfish fisherman bad weather may replace the seasonal constraint and force him into crabbing or some alternative non-fishery pursuit. In either case these choices would be represented by economic variables not contained in this analysis.

Since all the fishery choice specifications discussed so far included the status quo alternative for current fishermen, a specification, solely in terms of the economic variables was estimated only for those active fishermen who changed fisheries (see Table 22). The estimated results for the "change fishery" model indicate that the decision to switch fisheries

Table 22. Results of the Logit Fishery Choice Model - Active Fishermen Who Changed Fishery 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
FDTR	-.0000055 (-.4853)
FDOC	.0000405 (1.762)

Log likelihood = 2.47

Percent correctly predicted = 47.69

Likelihood ratio index = .0346

for any type of active fishermen, is seemingly unrelated to the economic considerations specified.

The final fishery choice specification relates the choice of entering fishermen to the economic variables representing expected total revenues and expected operating costs. The estimation results (see Table 23) indicate that these variables are important in the incoming fisherman's decision making and the signs are as expected. While the variables included are individually significant, the specification is lacking in its overall predictive ability. This suggests that the fishery choice decision of entering fishermen involves more than net revenue comparisons of the alternatives involved. Indeed, this decision becomes much more complex when examined in the context of occupational choice.

The last decision model deals with vessel choice. The general specification of this model relates the fisherman's choice of a particular class of vessel to economic variables representing the expected increase in total revenues, DTR, the expected increase in operating costs, DOC, and the net capital outlay, DK, for a vessel in any given class over that which is currently held. In addition a preference for the status quo is reflected by the alternative specific dummy variable, D_i ($i = 1, \ldots, 6$). The initial specification describes the vessel choice behavior of all fishermen: those currently in trawling and those entering trawling. The estimation results (see Table 24) for this specification reveal that none of the economic variables included to explain vessel choice are significant. The dummy variables indicating a preference to maintain class one and class four vessels are significant while the remainder are not. One suspects some collinearity problems among the explanatory variables in view of their relative size and significance and the over-

Table 23. Results of the Logit Fishery Choice Model - Entering Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
FDTR	.0000480 (4.158)*
FDOC	-.0001096 (-3.857)*

Log likelihood = 19.00*

Percent correctly predicted = 46.53

Likelihood ratio index = .0431

* significant at the 99 percent level.

Table 24. Results of the Logit Vessel Choice Model - All Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
DTR	.0000322 (1.123)
DOC	-.0000836 (-.9970)
DK	-.0000006 (-.2644)
D_1	4.291 (5.208)*
D_2	30.87 (.0001278)
D_3	30.74 (.0000618)
D_4	2.997 (2.436)*
D_5	30.77 (.0001009)
D_6	30.62 (.0000862)

Log likelihood = 189.10*

Percent correctly predicted = 72.73

Likelihood ratio index = .6398

* significant at the 99 percent level.

all predictive power of the model.[13/] Since these results are less than satisfactory, the population was again partitioned to see if there are behavioral differences for active and incoming fishermen.

Active fishermen were further divided according to the fishery in which they operated in the decision year, i.e., the vessel choice in t+1 of shrimpers, groundfish fishermen and combination fishermen in period t. The general vessel choice specification was estimated for all fishermen in each of these groups. Results were obtained for shrimp and combination fishermen (see Tables 25 and 26) while maximum likelihood estimators for the model specified were unobtainable for groundfish fishermen. Neither the shrimp nor the combination estimation yielded satisfactory results with regard to the role of individual variables. The failure of the groundfish specification to converge is likely due to the fact that none of the existing groundfish fishermen changed vessel class over the time period of interest. Furthermore, only three shrimp fishermen changed vessels, while seven combination fishermen shifted from one vessel class to another. Thus, the poor results in general and the pecularities in the dummy variables specifically can be partially attributed to the lack of vessel class changing by existing fishermen.

A specification which excluded the status quo alternative was estimated for the relative few (10 out of 245) existing fishermen who changed vessel class. The estimation results (see Table 27) were far from satisfactory. An examination of the actual change these ten fishermen made revealed that in nine out of the ten cases, the fisherman shifted from a

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[13/] However, simple correlations between the independent variables did not bear this out. Furthermore, respecifying the model by combining total revenues and operating costs into a net operating revenue variable did not improve the results.

Table 25. Results of the Logit Vessel Choice Model - Shrimp Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
DTR	-.0000305 (-.4141)
DOC	.00009463 (.6056)
DK	-.0000017 (-.1400)
D_1	3.684 (4.173)*
D_2	33.24 (.0000593)
D_3	0 (0)
D_4	33.43 (.0000856)
D_5	4.627 (4.396)*
D_6	33.20 (.0000838)

Log likelihood = 210*

Percent correctly predicted = 95.52

Likelihood ratio index = .8751

* significant at the 99 percent level.

Table 26. Results of the Logit Vessel Choice Model - Combination Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
DTR	.0000045 (.0892)
DOC	-.0001123 (-.7348)
DK	.0000015 (.3585)
D_1	2.912 (4.475)*
D_2	37.99 (.0001503)
D_3	38.28 (.0000861)
D_4	2.911 (2.868)*
D_5	37.87 (.0000926)
D_6	42.33 (.0000995)

Log likelihood = 165.77

Percent correctly predicted = 93.52

Likelihood ratio index = .8567

* significant at the 99 percent level.

Table 27. Results of the Logit Vessel Choice Model - All Fishermen Who Changed Vessel Class 1970-1975 (t-statistics in parentheses)

Variable	Coefficient
DTR	.0000017 (.0450)
DVC	-.0000298 (-.4758)
DK	.0000021 (.5234)

Log likelihood = 1.06

Percent correctly predicted = 10.00

Likelihood ratio index = .0293

relatively small (the largest being 29 gross tons) vessel to a significantly larger vessel. Thus the size of the vessel held would appear to be a significant factor in the decision to change vessel class.

The last vessel class choice specification describes the behavior of entering fishermen. Entering fishermen appear to be significantly affected by the total revenues associated with each vessel class, as well as the capital outlay (see Table 28). The total revenue and capital outlay variables are significant at the 95 percent level and all of the variables act in the "exected" or "anticipated" direction. Since entering fishermen would come by total revenue information most easily, it is reasonable that this variable is the most significant of those specified. Vessel cost estimates are usually not that difficult to obtain and hence the relative significance of this variable. On the other hand, the entering fisherman may not possess good information concerning vessel operating costs and this may help explain its insignificance. As in the fishery choice decision for entering fishermen, the vessel class decision is much more complex then the specification allows and this would contribute to the poor overall power of the model.

Extending the Logit Results

In general, once the parameters of a specified behavioral choice model have been estimated, it is possible to predict the behavior of an individual selected randomly from the population. To proceed beyond the individual level (i.e., to forecast population decisions of interest to policy makers) it is necessary to consider the process of aggregation.

A given population will contain a larger number of individuals with diverse socioeconomic backgrounds and differences in the set of

Table 28. Results of the Logit Vessel Choice Model - All Entering Fishermen 1970-1975 (t-statistics in parentheses).

Variable	Coefficient
DTR	.0000240 (2.012)
DVC	-.0000219 (-1.001)
DK	-.0000029 (-1.899)

Log likelihood = 4.30

Percent correctly predicted = 22.61

Likelihood ratio index = .0119

choice alternatives to which they have access. By identifying a sub-population i with common socioeconomic characteristics, S^i, and a common set of alternative attributes $(x_1^i, \ldots, x_J^i)$, the behavioral model estimated for this group yields probabilities P_j^i that an individual drawn at random from sub-population i will choose alternatives $j = 1, \ldots, J_i$. These probabilities give the expected distribution of the sub-population over the set of alternatives. If $i = 1, \ldots, I$ indexes the population by socioeconomic characteristics and alternatives available and N_i denotes the size of sub-population i, the expected population demand for alternative j is given by

$$D_j = \sum_{i=1}^{I} N_i P_j^i, \tag{10}$$

where D_j represents the total number of individuals choosing alternative j. In reality, the size of each sub-population may not be known. In such a case, if Θ_i is the probability that an individual belonging to sub-population i will be randomly drawn from the population containing N individuals, then

$$D_j = \sum_{i=1}^{I} P_j^i N \Theta_i . \tag{11}$$

Given the aggregate demand for the various alternatives one can then analyze policy effects. For an individual of "type" i the probability of choosing alternative j is given by the multinomial logit model

$$P_j^i = e^{\beta' Z_j^i} \Big/ \sum_{\ell=1}^{J_i} e^{\beta' Z_\ell^i} \tag{12}$$

where $Z_j^i = Z(X_j^i, S^i)$ is a K-vector of numerical functions of the observations and β is a corresponding vector of parameters. The expected demand for alternative j by the N_i members of sub-population i is $N_i P_j^i$. Multiplying both sides by N_i and then differentiating equation (12) with respect to component k in the vector of independent variables yields

$$\frac{\partial(N_i P_j^i)}{\partial Z_{jk}^i} = \beta_k N_i P_j^i (1 - P_j^i), \tag{13}$$

the change in aggregate demand of group i given a one unit change in component k. Correspondingly, the change in the demand $N_i P_j^i$ caused by a one-unit change in component k in the vector of independent variables for alternative $\ell \neq j$ is given by

$$\frac{\partial(N_i P_j^i)}{\partial Z_{\ell k}^i} = -\beta_k N_i P_j^i P_\ell^i, \quad \ell \neq i. \tag{14}$$

The next step is to convert these expressions to elasticity terms. In general, the elasticity of demand is defined as the ratio of the proportionate rate of change in the quantity (Q) of a good demanded to the proportionate rate of change in its i^{th} determinant (x_i) expressed as

$$\frac{dQ}{dx_i} \cdot \frac{x_i}{Q} .$$

Thus, the type i elasticity of demand for alternative j with respect to its own variable Z_{jk}^i is

$$E_j^i(j,k) = \frac{\partial(N_i P_j^i)}{\partial Z_{jk}^i} \cdot \frac{Z_{jk}^i}{N_i P_j^i} = \beta_k Z_{jk}^i (1 - P_j^i). \tag{15}$$

Similarly, the type i cross elasticity of demand for alternative j with respect to a change in the variable $Z_{\ell k}^i$ can be stated as

$$E_j^i(\ell,k) = \frac{\partial(N_i P_j^i)}{\partial Z_{\ell k}^i} \cdot \frac{Z_{\ell k}^i}{N_i P_j^i} = -\beta_k Z_{\ell k}^i P_\ell^i. \tag{16}$$

Using the proportion of total demand for alternative j originating from individual's in each sub-population (i = 1, ..., I) a weighting scheme

$$W_i = N_i P_j^i / \sum_\ell N_\ell P_j^\ell,$$

can be derived where W_i is a weight giving the proportion of total demand for alternative j originating from type i individuals. These weights can then be used to compute the demand elasticities for the population. The population elasticity of demand for alternative j with respect to a one-unit change in its own variable Z_{jk} is

$$E_j(j,k) = \sum_i W_i E_j^i(j,k) \tag{17}$$

and the population cross elasticity becomes

$$E_j(\ell,k) = \sum_i W_i E_j^i(\ell,k). \tag{18}$$

The key to analyzing policy effects is the ability to distinguish individual types at the estimation stage. One way this may be accomplished is by incorporating variables representing the interaction between alternative attributes and individual attributes (socioeconomic variables) in the model. These variables act as shift parameters for differing socioeconomic characteristics. Alternatively, the data may be partitionable by socioeconomic characteristics in which case separate estimations can be performed for each data subset. This latter alternative is to some extent represented herein by partitioning the sample according to the "type" of fishermen.

Based upon the preliminary results reported here, the logit approach appears promising in the analysis of fisheries decision making at the micro level. The estimations yield some interesting implications, indicating the direction of future work. The findings sharply distinguish incoming from existing Oregon trawl fishermen. Those entering trawling are significantly influenced in their fishery and vessel choice by recent relative earnings and costs. Existing fishermen, on the other hand, are decidedly unresponsive to changes in these economic factors under the adjustment processes specified. They display a pronounced conservatism with regard to making major fishery and capital stock adjustments on a year-to-year basis. Thus, in the process of refining the analysis, one would want to focus on the transition into trawling and the subsequent adjustment mechanisms. These issues, as well as other important implications are discussed in Chapter V.

CHAPTER V

SUMMARY, IMPLICATIONS AND CONCLUSIONS

A Summary of the Approach and Results

The enactment of the Fisheries Conservation and Management Act of 1976 signified a major change in United States ocean fisheries policy. The FCMA placed the formerly common property resources found in the newly created 200 mile exclusive fisheries zone under a central fisheries management authority. The central authority was to rely upon regional fishery management councils to devise plans providing for the optimal utilization of the fishery resources falling within their specific locale. In the planning process, the FCMA required the regional council to assess, on an annual basis, domestic harvesting "capacity" in each of the fisheries under its purview. Since a precise definition of capacity is missing from the FCMA it was interpreted in this study as a technical measure, representing the maximum amount of fish that a particular vessel could catch per unit of time under optimal environmental and fish availability conditions. Capacity in this sense is largely determined by the physical properties of the fishing vessel, which in turn reflect the harvesting expectations of its owner.

Knowledge concerning domestic capacity in a particular fishery is not only of specific interest with regard to foreign allocations, but is more generally useful in terms of domestic fisheries conservation and development policies. In this latter context it may be desirable to redistribute existing capacity and simultaneously direct new capacity into more appropriate fisheries. In either situation information regarding structural changes in the domestic fishing fleet would be necessary for policy makers. The size and composition of the fishing fleet directly relates to the investment decision making of individual fishermen. Thus, the goal of the study was to gain a greater understanding of the fisherman's long-run decision making behavior which would provide beneficial input to policy decisions.

A contemporary model of firm investment behavior, the flexible accelerator, was examined in terms of its applicability to the fisheries issues of interest. Its inability to approximate the micro conditions in the fishery, particularly with regard to discrete investment options, focused attention on alternative approaches. The alternative that appeared most promising both from a theoretical and computational standpoint was the logit qualitative choice model. The strength of the logit formulation over other, more traditional, econometric techniques (e.g., multiple regression analysis) lies in its ability to describe the choice behavior of individuals confronted with many discrete alternatives. This is especially important in the analysis of individual decision making in the Oregon trawl fisheries which involves both a choice of fishery and choosing from among non-homogeneous, indivisible units of capital. A regression approach could only deal with these issues at a highly aggregated level, where the dependent variables might denote the number of fishermen in a specific trawl fishery, and the number of vessels or dollars of capital stock respectively. Other desirable features of the logit analysis include: the explicit recognition that individual decision rules may be distributed across the population according to unobservable factors such as experience, tradition, etc., which would seemingly account for "irrational" behavior; a high degree of flexibility in the types of explanatory variables admissible (e.g., attributes of alternatives, alternative specific shift variables, and interactions between alternative and individual attributes); incommensurate individual alternative sets in the case of unranked alternatives (i.e., those models specified solely in terms of unweighted generic variables); and again in the case of unranked alternatives the ability to introduce a new alternative without re-estimating the model. In addition, the estimation results can be extended beyond the individual level to forecast population decisions of interest to policy makers. For these reasons the decisions affecting capacity in the Oregon trawl fisheries were analyzed using the logit approach.

One of the concerns of the study was the value of available microdata in analyzing the long-run decision making behavior of Oregon trawl fishermen. The state of Oregon requires that landings transactions between trawl fishermen and fish dealers be recorded and reported to the Oregon Department of Fish and Wildlife. These data were made available for this study under an agreement of confidentiality and presumably would be available to fisheries policy makers under like arrangements. The raw data revealed patterns of fishery participation and vessel ownership for fishermen recording Oregon trawl landings during the period 1970-1975. Values for the dependent variables used in the empirical analysis were derived by observing a particular fisherman's fishery and vessel choices over the time period. In order to obtain corresponding observations on the costs and revenues hypothesized to effect a given choice, independent operating cost and vessel market value estimating equations were employed. Likewise average ex-vessel landings prices were used to produce estimates of gross revenues. Thus, with the aid of some supplemental information, a microdata set was generated which would serve to test the hypotheses concerning the influence of specific economic variables on the individual fisherman's long-run decision making.

Three logit models were specified to analyze the decision of whether to leave or continue trawling, the choice of trawl fishery, and the choice of vessel class. The estimation results for the exit/remain decision indicated that the fisherman's choice in period t+1 was not significantly influenced by his own rate of return in period t relative to the fleet-wide average rate of return in periods t-1 and t; a "pure" preference for trawling dominated the results. Several possible explanations were offered as to why the preliminary specification failed to perform as expected; most imply a more sophisticated adjustment mechanism than the simple one specified (i.e., choice in t is related to relative performance in t and t-1). By incorporating a cumulative adjustment process the model would indicate whether a history of relatively poor performance leads to the exit choice. Conversely, a history of reasonably consistent "good" years would justify continuing. Some inconsistency in an individual's performance would be expected simply due to the uncertainties and risks involved in fishing. Thus, extending the adjustment process would introduce the framework of uncertainty within which the fisherman operates. To the extent that he anticipates permanent and transitory phenomena in the fishery the prudent fisherman will be prepared to hold over. Stretching out the adjustment process would illuminate the fisherman's expectations. A longer history of the fisherman's trawling activity would be useful input; years of experience would account for net worth and human capital accumulation. With respect to human capital accumulation, there would be some initial adjustment period during which pure economic variables would seemingly play a secondary role in the exit/remain decision.

A consideration related to the development of fishery skills is the access the trawl fisherman has to non-trawling alternatives. The temporary or permanent exit from trawling may be partially explained by relatively high expectations from some non-trawling opportunity. This suggests that the expected rate of return in the non-trawling alternative represents the opportunity cost of capital to the fisherman. Expanding the exit/remain choice specification to include the average rate(s) of return in the most accessible non-trawling fishery alternative(s) would be a step consistent with the theory of exit and entry presented above. A model of exit/remain incorporating the refinements suggested would probably improve the analysis.

The next issue examined was that of fishery choice, where the fisherman, either continuing or entering trawling, chooses between the shrimp, groundfish, or combination fisheries. For his given capital stock, the fisherman's fishery choice was related to the increase in net revenue each alternative was expected to yield in excess of his current net earnings. He would be expected to select the alternative that represented the greatest gain in net revenue. Several specifications of this decision were estimated in an attempt to distinguish between the "types"of fishermen already active in trawling, and those entering trawling. The general model of trawl fishery choice was most successful in describing the behavior of incoming fishermen. Separate estimations for active shrimp, groundfish, and combination fishermen indicated that fishery choice was governed by a preference for the status quo. The decision to switch fisheries by any of these types of fishermen was not significantly influenced by the economic variables specified. Again the simple adjustment process (the value of the economic variables in t determine choice in t+1) in the case of existing fishermen is dubitable. That is, future expectations appear to be founded upon more than the fisherman's most recent experience. Specifying a longer adjustment process would contribute in this regard. Furthermore, it may not be possible to switch fisheries as rapidly as specified; the technological aspects may entail more than simple re-gearing.

As in the exit/remain model, lengthening the adjustment process would tend to capture the role of human capital formation in the fishery choice decision. The new, inexperienced trawl fishermen would be inclined to enter the trawl fishery requiring the least amount of trawling skills ceteris paribus. Immediately thereafter a period of learning and confidence building takes place after which the potential for greater earnings in an alternative trawl fishery becomes a more justifiable attraction. To incorporate this psychology into the explanation of fishery choice the model for entering fishermen could be revised to include explanatory variables which reflect the elements of human capital required in each of the trawl fisheries. This might be most easily accomplished by ranking the alternatives according to an ordinal weighting scheme with the highest (or lowest) weight being attached to the fishery meriting the highest acquired ability.

Another factor which is unaccounted for in any of the trawl fishery choice specifications is the seasonal limitation imposed on the shrimp fishery. Shrimp are harvested only part of the year, while the groundfish fishery due to its multi-species nature continues year round. Thus, there are some seasonal considerations which may affect fisheries choice. In this regard the decision to trawl for shrimp may be linked to non-trawling opportunities. Selecting the shrimp alternative would allow, if not by choice then circumstance, the fishermen time to pursue some alternative non-trawling activity (assuming that he would choose the combination option if he wanted to engage in the trawling alternative). In either case, the model could be restructured, perhaps by including an alternative specific shift variable, to reflect the seasonal constraint in the shrimp fishery.

The last issue analyzed concerned the trawl fisherman's choice of vessel, where his choice fell within a specified vessel class. The economic factors hypothesized to influence this choice express the fisherman's performance expectations of vessels in each alternative class relative to the performance of the vessel he currently holds. The performance differential was considered in light of the net capital outlay associated with each alternative. In addition, an alternative specific dummy variable was included to indicate a preference for one's current vessel; i.e., when there are no perceptual differences among vessel classes in terms of performance and capital outlay attributes, the fisherman will maintain his present vessel.

As in the fishery choice case the most satisfactory results were obtained for incoming fishermen. The poor performance of the specifications describing the decision behavior of existing fishermen in each type of trawl fishery was primarily ascribed to the fact that existing fishermen exhibited an extreme propensity to maintain the current class of vessel; net growth in trawl capacity over the time period considered was predominately through the entry of new fishermen. For the few (10) fishermen who actually shifted to a different vessel class, all but one of these changes was a movement from a relatively small to a significantly larger vessel. Since a movement in this direction was expected, a vessel choice model including a dummy variable to denote the class of vessel currently held was estimated. The results showed that the size of the vessel currently held had no effect on choice; all the dummy coefficients were equal to zero. Again the overwhelming choice to maintain one's current vessel on the part of fishermen in the sample would contribute to this occurrence. A major implication of the vessel choice estimations for existing fishermen points toward a finer partitioning of this group based upon personal attributes. Dividing the sample of existing fishermen into fishery type was a gross attempt in this direction. These subsets could be broken down further by years of experience, net worth or by other socio-economic characteristics that distinguish individuals. The specification, solely in terms of vessel class attributes, could then be estimated for each of these groups to indicate the effect of differing personal characteristics. Alternatively, given a vector of individual characteristics, interaction terms between socioeconomic and vessel class attributes would affect the probability of a particular choice for "different" individuals. For example, vessel performance is also dependent on operator skills; therefore operating costs might be deflated by years of experience (or revenues correspondingly adjusted in the opposite direction). Similarly capital accumulation would depress the influence of the net capital outlay factor.

Again, the appropriateness of a more extensive adjustment process is implied. Fishermen may not be able to change vessels as quickly as specified because of technologically induced lags, financial constraints, etc. The one year lag incorporated in the vessel class choice model may inadequately reflect the durable nature of the physical asset under consideration, and therefore the longer process of accumulation or decummulation involved. A hesitancy towards changing vessel class on the part of existing fishermen is also linked to the uncertainty surrounding decisions of this magnitude. Expectations may be formed on the basis of experience preceding the most recent period in time; a sluggish response to change might relate to the variability in the fisherman's performance in the more distant past. In view of the realities and uncertainties affecting vessel choice it would seem reasonable to associate the fisherman's choice of vessel class in period t+1 with the values of the explanatory variables extending backward beyond period t.

Another aspect of the vessel class choice decision for both existing and entering fishermen concerns the non-trawling utilization of the fisherman's capital stock. The possibility of the fisherman engaging his vessel in non-trawl fisheries exists, as discussed above. The analysis of vessel choice might then want to incorporate these possibilities. In this case the vessel choice decision could be viewed as a conditional choice, i.e., the probability of a particular vessel being chosen when the fisheries (trawling and non-trawling) in which the fisherman plans to participate are given.[1/] This approach is similar to that already taken for incoming fishermen in that their vessel class choice is conditioned on their entry into one of the trawl fisheries. By further conditioning vessel class choice on the type of fishery(s) selected, individual fisherman characteristics, which differentiate behavior between groups, are implicitly introduced into the analysis.

[1/] Trade articles on vessel construction discuss the fisherman's choice of vessel in this context (see for example various issues of The Fisherman's News [49]). However, in line with the earlier discussion of decision sequences one might argue that fishery choice is conditioned on vessel choice; the assumption of "independence" implies no practical significance.

While the vessel class choice specification for incoming fishermen produced more satisfactory results, its simplicity was revealed in its overall explanatory power. Improvements in the specification for incoming fishermen would include those suggested for existing fishermen. It would seem that entering fishermen would base their vessel class (as well as fishery choice) decision on information accumulated over a longer period of time than that specified in the model. In addition, more background on the entering population would provide information concerning individual attributes - valuable input to the analysis. By identifying potential entrants the entry decision could be treated similarly to the exit decision and would allow the computation of conditional probabilities. One group of entrants that has already been identified consists of fishermen transferring from non-trawl fisheries. Current crew members might also be considered as potential entrepreneurs since they would already have acquired some of the skills necessary to undertake this step. Backward integration by the processing sector would result in additional entrants. While processor owned and operated vessels have not been prevalent in the Oregon trawl fisheries, opportunities created under the FCMA may make this an attractive option for this particular group. A somewhat related issue addresses multiple vessel ownership, the case where a single entrepreneur holds more than one vessel. If multiple ownership involves the introduction of an additional vessel, in perhaps an unaccustomed fishery, then the individual's choice behavior should be differentiated from his choice behavior as an existing fisherman. In other words, he is distinguished from an existing fisherman when he adds to his vessel holdings. Instead of the existing fisherman adding to his vessel holdings, the entering fisherman could simultaneously introduce two or more vessels, a more complicated situation but within the framework of the analysis. This situation as well as the former could be treated through a separate choice specification where the multiple vessel choice is determined by expected gains in net earnings in addition to accumulated experience and net worth.

Future Directions

Overall several potential improvements to the analysis emerge. More appropriate specifications would explicitly address the time structure of the decision processes and the formation of the individual's expectations. The time structure of long-run individual decision processes has frequently been approximated through some form of distributed lag function. In situations where uncertainty is not considered explicitly or assumed away, lags in the adjustment process are primarily attributed to friction; i.e., the movement from one state to another is not instantaneous but a gradual process impeded by technological, financial and/or other relevant factors. Thus, the observed state is linked to conditions in some earlier time period. In this sense, the distributed lag model attempts to describe the dynamic technical process involved in shifting equilibrium positions. In the "frictional" situation the form of the distributed lag is usually assumed *a priori* rather than derived as an implication of a particular behavioral hypothesis. However, due to the nature of long-run decision making in the fishery, the lag formulation should be conceptually expanded to explicitly incorporate behavior under uncertainty.[2/]

2/ Uncertainty as used here is associated with the fisherman's subjective expectations regarding future outcomes.

To explicitly account for the decision maker's expectations and changes in his expectations a class of adaptive expectations models has evolved that employ an adjustment process which ascribes response lags to uncertainty and the discounting of current information. In general these models share the presumption that the response (or dependent) variable is autoregressively related to prior and present values of the explanatory variables which are "expectational" in nature. That is,

$$y_t = f(x_t^*)$$

where y_t is the response variable in period t and

$$x_t^* = \sum_{k=1}^{\infty} \alpha_k x_{t-k}.$$

Here, x_t^* represents the "subjective" expectation for the explanatory variable x_t. Thus, while the adaptive expectations model may be indistinguishable from the frictional model in its estimating form, the two models are not conceptually equivalent. The problem lies in restructuring the analysis of fisherman decision making to explicitly integrate the time structure of the decision processes and the formation of individual expectations. To this end, the specification should incorporate expectational variables that enter through a distributed lag formulation.

One approach toward resolving this problem follows from the work of Behrman [2] and Just [26] and concerns a modification of the general adaptive expectations model to include the subjective expectations for the mean squared error of the prediction terms. If x_t^* represents the subjective expectations on the mean of the explanatory variable x_t then $(x_t - x_t^*)^2$, the mean squared error, expresses the uncertainty surrounding that variable. This approach appears particularly well suited for the fisheries problem where, as discussed in Chapter II, interest is not so much with the expected output, but with the variation in output over the relevant time period. By introducing the mean squared error for each of the expectational variables deemed to influence the fisherman's exit, fishery, and vessel class choice, via a distributed lag formulation, these decisions will then depend upon the subjective distributions of the explanatory variables and the way in which they are altered over time. Furthermore, such a specification would not appear to pose any problems with respect to the frictional aspects of the adjustment process. For example, a change to a larger vessel class would usually be associated with expectations that have been revised upwards over time. The lag between the observed choice and the significant expectational variables implicitly reflects the technological, financial, and/or other frictional constraints that also characterize the adjustment process.

The theoretical revision outlined above is particularly appealing because harvesting conditions in the fishery are characterized by a high degree of risk and uncertainty. From a practical standpoint, such a modification can be readily adapted to the logit form. Entering expectational variables through a distributed lag formulation conceptually and operationally relates the fisherman's response to elements of uncertainty and changing uncertainty. This is especially significant with regard to fishery management options since the policy directives declared in the FCMA are aimed at achieving stability in the fisheries.

Another modification of the analysis entails the refinement of capital stock alternatives. The initial specification describing the choice of capital stock limited this choice to one of six vessel class alternatives which were defined in terms of age and gross tonnage. The vessel classification scheme could readily be extended through a further division by the age and gross tonnage descriptors. An alternative approach would add more dimensions to the existing scheme. Expanding the alternative set according to the latter scheme would relax the assumption that limited capital adjustment to a discrete vessel change. One could go so far as to include modifications that the fisherman can make to his existing vessel. Such modifications would represent capital substitutability, i.e., adding to capacity by upgrading one's current vessel in lieu of moving to another vessel class. Altering the physical characteristics of an existing vessel (e.g., constructing a stern ramp, installing a more powerful engine, or adding more sophisticated electronics) could shift the vessel into a higher class with respect to fishing power. That is, the same vessel outwardly becomes more effort efficient. However, as noted earlier, the extent of such alterations are limited by the intrinsic design properties of the fishing vessel.

Vessel modification alternatives might be added to the initial alternative set to represent the shift from one class of vessel to another as a transitory process. In other words the fisherman initially enters a vessel which then undergoes a series of discrete modifications which culminates when the original vessel's modification threshold is reached.[3/] This modification threshold would be associated with the full utilization of the vessel's technical capacity.

[3/] Bockstael [6] has suggested that a more discrete transition process (moving from one vessel class to another) can be conceptualized as a Markov process, where the predicted values of the logit dependent variables may be viewed as the transition probabilities of the Markov matrix. Since these transition probabilities will change as the values of the explanatory variables change, the Markov process described is nonstationary.

Performance and capital outlay attributes describing the vessel classes in the preliminary vessel class choice model would also describe the set of modification alternatives. If not for the presence of alternative specific shift variables in the preliminary model, the modification alternatives could readily be entered without re-estimating the specification (this follows from the axiom on the independence of irrelevant alternatives). The notion of a modification threshold and its correspondence to technical capacity suggest altering the initial vessel class specification to account for capital utilization. As the flow of services from the existing capital stock becomes fully utilized, modifications will occur. The actual output level could serve as a proxy for capital utilization in such a revision. In this instance output would be an alternative specific shift variable representing the utilization rate of the alternative currently held by the fisherman. Furthermore, to capture the dynamic process involved, output would be introduced through a distributed lag formulation. The revisions suggested here would then associate the fisherman's movement from one alternative to another with the utilization rate of the capital stock he currently holds. It should also be noted that this modification is compatible with that suggested in the discussion of uncertainty. Combining these two modifications would lead to a more complete specification relating the fisherman's choice of capital stock to his expectations regarding the relative net worth of each alternative, as well as to changes in these expectations, and to changes in the actual utilization rate of his current capital stock.

A further extension of the preliminary analysis deals with the development of opportunity trawl fisheries. Of particular interest to Oregon fishermen is the potential for Pacific hake (*Merluccius productus*) a species heretofore underutilized by domestic west coast fishermen. Historically, Pacific hake have been of foreign interest only as a food fish. A lack of consumer acceptance in the fresh fish markets together with the special requirements for harvesting and handling this species discouraged domestic exploitation. However, with the tremendous growth in the domestic consumption of prepared fishery products (fish sticks, fish portions, etc.) coupled with the enactment of the FCMA, Pacific hake are currently attracting considerable interest from domestic fishermen and fish processors. This interest is, and will be, manifested through the introduction of domestic harvesting and processing technical capacity. Since Pacific hake are a species subject to the provisions of the FCMA, fishery policy makers are mindful of the attraction hake have for current and potential domestic utilization. Their immediate concern focuses primarily on the "capacity and extent" issue which is the basis for determining what portion of the optimum yield can be allocated to foreign fishing interests. Thus, they need to be particularly aware of the decision-making behavior of the interested parties. In this regard the analysis of trawl fishery choice should allow for the hake alternative and any other relevant opportunity fisheries.

The hake alternative can be easily introduced into the general fishery choice model since this alternative is describable by the generic variables already contained in the specification. The inclusion of a hake alternative does not disturb the model as it stands conceptually. However, the general form of the capital stock model may need to be estimated for the subset of hake fishermen in the population. The point of interest here is in hc the choice behavior of hake fishermen differs from other types of trawl fishermen.

The analysis of harvesting capacity is incomplete without taking into account the interrelatedness of the vertically aligned sectors comprising the fishing industry. The analysis is inherently holistic since constraints at one level in the industry will inevitably be felt throughout. Thus, the complete analysis of capacity and capacity utilization would necessarily entail a systems approach.

The fisherman's perceptions of ex-vessel prices were expected to bear on capital formation in the fishery and therefore on technical capacity. The demand for fish at dockside is a derived demand. Thus, ex-vessel prices link the harvesting sector to the processing sector and this linkage continues on up the line until it terminates at the retail market level. Demand signals filtering back down through the industry reflect the ability to absorb various quantities of fish and fishery products. Eventually these signals reach the fisherman and enter his planning process. Hence, demand at the retail level affects planned capacity and the rate of capacity utilization at the processing level. Processing capacity will be allocated on the basis of the relative profitability of alternative fishery products. This affects the processor's ability to handle lesser valued species, shifting demand at the harvesting level. In extreme cases, where the availability of cooperating inputs imposes an absolute limit on the processing sector, landings quotas may be placed on the harvesting sector. These quotas, when they are met, effectively reduce the marginal ex-vessel price of the subjected species to zero. In this manner capacity in the processing sector influences long- and short-run decision making in the harvesting sector. A thorough analysis of the fish harvesting capacity will require fitting together the vertical elements that affect decision making at the fisherman level.

A broader systems approach towards analyzing capacity appears appropriate in view of these theoretical concerns and the policy implications. Adding a vertical dimension would enrich the analysis by explicitly introducing theoretical components such as price levels throughout the system, prices and quantities of substitutable species, and harvest quotas.

Prices and quantities of substitutable species deserve attention especially with regard to the increasing popularity of prepared fishery products. In the processing/production of prepared fishery products, where specific species of fish are often indistinguishable by the consumer, substitution among inputs may occur to a much greater extent than in the marketing of fresh fish. Under these circumstances the supply and demand for substitute species affects individual decision making at the harvesting level. Substitutability in the prepared fishery products market presents some interesting policy implications for the trawl fisheries, particularly the multi-species groundfish fishery. Harvesting capacity might be channeled into more appropriate areas through finely tuned policies implemented at the successive industry levels. The implications seem particularly significant in the case of opportunity trawl fisheries.

Conclusions

This study examined several issues which affect aggregate harvesting capacity in the Oregon trawl fisheries. Regional fishery councils are required under the FCMA to assess capacity and the extent to which this capacity will be utilized in order to estimate the annual domestic harvest and the allowable level of foreign catch. While a number of definitions for capacity exist, the peculiarities of fish harvesting necessitated a conceptual blending of these in order to derive a fish harvesting interpretation of capacity. Two notions of capacity emerged: technical and economic capacity. Technical capacity is associated with the design properties of the fishing vessel which reflect to a large extent its ability to catch fish. In this sense technical capacity represents a limit on the amount of fish that can be harvested over a given period of time. The important aspect of technical capacity in this study is that it depends upon the individual fisherman's expectations concerning future conditions in the fishery. Technical capacity is demonstrated when the fisherman's long-run planning process culminates with the introduction of a unique fishing vessel into a specific fishery. Once the fishing vessel is operational the notion of economic capacity, which concerns the extent to which technical capacity is utilized in the short-run, is meaningful.

Technical capacity is affected by any decision that alters the gross capital stock in the fishery. These decisions originate at the individual level in the form of discrete vessel adjustments. Logit analysis was employed to analyze these types of decisions on the basis of its theoretical and computational attractiveness. Despite the simplicity of the models specified the analytical results indicated the potential of the logit approach for examining the decision behavior of individual fishermen participating in the Oregon trawl fisheries.

Perhaps the most significant contribution of any study that is so preliminary in nature is in pointing out the number of interesting paths that subsequent investigations might follow. The initial findings are indeed useful in this regard. Future work would be enhanced by incorporating any one or more of the revisions touched upon above. Extending the analysis in any of these directions would require more specific data. However, the benefits, in terms of being able to evaluate and predict changes in fish harvesting capacity and the effects of alternative fishery policies, may more than offset the costs. Finally, the form and comprehensiveness of the complete integrated analysis would permit its application to any number of problems within a particular fishery as well as to other fisheries of interest.

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