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Despite the fact that fishing is an inherently uncertain business, risk has rarely been formally recognized in fisheries science or management. Few fishery management plans include any form of risk assessment and those that do focus on minimizing risk caused by uncertainty associated with markets and environmental conditions. Fishermen's attitudes towards risk, whether they are risk-neutral, risk-averse, or risk-prone, have rarely been considered. Although fishermen's attitudes towards risk have been shown in theory to have an impact on fish populations, none of the previous investigations precisely identified whether fishermen are risk-neutral, risk-averse, or risk-prone.

This research attempted to identify fishermen's attitudes towards risk from an analysis of their decisions about where to fish. The research applied risk-sensitive foraging theory to an analysis of data from the Oregon trawl fishery for 1991. The data were provided by the Oregon Department of Fisheries and Wildlife. One file contained tow-by-tow information for each fishing trip on landings by species, time

spent fishing, type of gear, and fishing locations. A corresponding file contained trip-by-trip information on landings and price by species. The two data files were screened for inconsistencies and then classified into small homogeneous categories based on port, fishing gear, fishing area, and boat size.

Various variance-discounting models were fitted to each category to determine fishermen's attitudes toward risk. The models describe the expected utility of fishing at a given distance from port as a linear function of the mean, variance, and third moment of the dollar value per hour of the retained catch. The unknown parameters were estimated from the data using logistic regression techniques.

The results of the analysis indicated that in two of fifteen categories the fishermen were risk-averse, and in four categories they were risk-neutral. However, for the remaining nine categories the results were inconclusive and in some cases the fishermen's choice of fishing locations appeared illogical. Instead of preferring fishing grounds that generated higher profits, it appeared that fishermen actively avoided such grounds. The inconclusive and sometimes illogical results may have been due to inappropriate assumptions about the data and about the factors motivating fishermen's decisions. Additionally, there might have been some factors that could have affected the analysis which this research overlooked. For example, this research only accounted for monetary rewards, but fishermen may have preferences other than revenues and costs that influence their choice of fishing grounds.

Fishing Location Choices in Oregon Trawl Fisheries: Are Fishermen Risk-averse or Risk-prone ?

By

Jiraporn Trisak

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Jiraporn Trisak, Author

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

Table | Page

LIST OF TABLES (Continued)

LIST OF APPENDIX TABLES

LIST OF APPENDIX TABLE (Continued)

Fishing Location Choices in Oregon Trawl Fisheries: Are Fishermen Risk-averse or Risk-prone ?

I. INTRODUCTION

Fisheries management has traditionally focused on managing fish populations. Recently, more emphasis has been placed on managing the people involved in fisheries, particularly the fishermen (Barber and Taylor, 1990). In order to successfully manage fishermen, managers must understand and anticipate their behavior. This is very important to the success or failure of any fishery management plan because fishermen will respond to changes in fishing regulations. Unfortunately, fishermen's behavior, especially their attitude towards risk, has not been anticipated by fishery managers or regulators (Mendelssohn, 1982; Rettig, 1981). Fishermen must routinely make decisions in spite of great uncertainty. How fishermen make decisions depends on their attitudes towards risk. Better understanding of how fishermen respond to uncertainty should improve management policies.

There have been few previous investigations of fishermen's attitudes towards risk. But there have been many studies of behavior with respect to risk in fields such as agriculture and insurance. Most studies which deal with risk in fisheries focus on minimizing the risk caused by uncertain events, such as volatile fisheries markets or changing environmental conditions. Mendelssohn (1982) and Rettig (1981), two studies concerned with fishermen's attitudes towards risk, do not identify precisely whether fishermen are risk-averse and prefer rewards with low variability, or risk-variability in reward. Mendelssohn (1982) concludes that changes in the degree of risk-aversion could have an impact on the dynamics of a fish population. In a situation with high risk, as would likely occur when there were low densities of fish, the price for the fish tends to be high. Because a fishermen has less chance of catching fish, demand is likely to be greater than supply. As a consequence, fishermen who are risk-prone may be enticed by the high prices to continue fishing, which would cause the fish population to be further over-exploited. Rettig (1981) hypothesizes that fishermen are likely to be risk-prone and fishery managers risk-averse. Both Mendelssohn and Rettig strongly suggest that fishermen's attitudes towards risk have an impact on fish populations and that fishery managers should consider fishermen's attitudes towards risk when developing fisheries management plans.

STATEMENT OF THE PROBLEM

In contrast to fisheries management, risk is usually considered explicitly in agricultural policy (Hanna, 1983). For example, federal crop insurance protects agricultural producers from uncertainties such as crop failure due to chance weather events, disease, insect infestation, or general economic conditions. The goal is to promote more stable production. Mapp et al. (1979) found that participation by farmers in risk management programs depends partly on the farmers' attitude towards risk. Most models of decision making under risk assume knowledge about the decision-makers' risk preferences (Young, 1979). If the decision-makers' risk preferences are known, the models can be applied to evaluate policy and recommend appropriate actions.

The few fishery management plans that include some form of risk assessment consider only the variability associated with catch rates, fish prices, or biological productivity. As a result, those management plans attempt to identify ways of reducing risk in harvest and fish markets. The Pacific Fishery Management Council (PFMC) promotes risk-averse strategies to protect and conserve resources (Rettig, 1981). Unfortunately, its management plans fail to identify the different risk preferences of the persons involved in the fisheries: fishermen, managers, and scientists. As a consequence, there may be conflict between the commercial fishermen and scientists involved in designing the management plans. Rettig hypothesizes that this inconsistency results from a basic difference between fishermen and scientists in their attitudes towards risk; fishermen are more risk-prone than scientists. Identifying whether fishermen are risk-neutral, risk-averse, or risk-prone, can help reduce conflict if management objectives take into account attitudes towards risk.

Although commercial fishermen use sophisticated electronics and advanced technology when they go fishing, many aspects of fishing are similar to the foraging activities of natural predators. It seems reasonable that ideas and techniques developed for studying natural foragers could be applied to an investigation of fishing behavior. However, because of some inherent differences between natural foragers and fishermen, it is not appropriate to analyze fishermen's behavior by directly using the models of foraging theory. One could argue that a natural forager maximizes its energy intake based primarily on instincts and that genetics largely control how a natural forager determines the costs and benefits of various choices (Stephens and Krebs, 1986). But fishermen determine the best way to fish through skills learned by study or experience. In addition, fishermen are not faced with the problem of avoiding predators. In contrast, many animal predators must balance the benefits of feeding against the risk of being caught by some other predators. Herbivores may face an additional complication due to the presence of poisonous plants distributed in foraging patches (Stephens and Krebs, 1986). The concepts and techniques of foraging theory need some modifications to make them appropriate for a study of fishermen.

OBJECTIVES

The overall goal of this research is to identify fishermen's attitudes towards risk; whether they are risk-neutral, risk-averse, or risk-prone. The approach in this study was to apply a special branch of foraging theory called "risk-sensitive foraging theory" to the analysis of data on fishing locations from the logbooks of commercial trawl fishermen in Oregon.

II. LITERATURE REVIEW

FISHERMEN AS FORAGERS

Optimal foraging theory attempts to explain the behavior of natural predators, and has been applied in numerous disciplines including psychology, ecology, ethology, and anthropology (Kamil, Krebs, and Pulliam, 1987). However, this theory has not been widely applied in fisheries. A fisherman can be viewed as a forager whose prey is fish. The fishermen's behavior--what kind of fish they catch, where they go fishing, what gear they use--is analogous to the behavior of natural foragers. However, fishermen go fishing with the aim of making profits, whereas animals hunt particular prey to maximize their energy intake or their reproductive success.

In fisheries, we can apply foraging theory to the question of where fishermen choose to go fishing. Fishing grounds are analogous to foraging patches. Each fishing ground has a different abundance of fish and different environmental conditions, which results in differing degrees of certainty with regard to catch rates. A fisherman who is "risk-prone" will select fishing grounds that produce highly variable catch rates, even though the average catch is lower. A "risk-averse" fisherman, however, will select fishing grounds that provide relatively certain catches, even though these grounds do not necessarily produce the greatest catch on average.

In a commercial fishery, fishermen may seek to maximize their "utility" rather than simply their profits. Utility measures the level of satisfaction an individual derives from receiving some amount of goods. How fishermen maximize their utility depends in part on how they react to alternative choices in uncertain or risky situations. Some fishermen may derive more utility from choices with highly variable rewards, but others may prefer choices with less variable rewards. Fishing involves many uncertain factors that must be considered in the decision-making process, including catch rates, operating costs, and market prices for fish.

Uncertainty in Fisheries

Gates (1984) identified numerous sources of uncertainty in fishing operations including catch rates, equipment failure, prices, weather, quality of inputs, and fisheries management policies. Problems with data quality and ignorance by fisheries economists of how to apply decision analysis are the main reason why there have been few studies of fishermen's behavior under uncertainty. Additionally, the concept of utility theory under uncertainty is hard to apply empirically. For example, failure of fish finding equipment would likely result in reduced catch rates, but empirical data sets, such as those maintained by the National Marine Fisheries Service (NMFS) for New England vessels, would rarely record this sort of problem. The lack of this kind of information makes it difficult to analyze uncertainty in fishing operations because averaging procedures mask the variability experienced by individual fishermen.

Choice of Fishing Location

Rothschild (1972) discussed the idea that under perfect certainty skippers would tend to fish in areas where the expected catch is the highest. Unfortunately, the real world is uncertain. Those areas that can provide the highest average catches might also produce highly variable catches. In contrast, some areas might provide smaller average catches of fish, but with greater reliability. The fishermen know that if they fish in these areas they will get fewer fish, but they are more certain of what they will catch. A fishermen will choose between these two kinds of fishing areas based on his attitude toward risk. Risk-prone fishermen will prefer the areas with higher average catches even though the catches are more variable, while risk-averse fishermen will prefer the areas with lower but more stable catches. The preferences could depend on fishermen's skill and their knowledge. Rothschild does not discuss any strategies related to fishermen's decisions about where to go fishing, nor does he examine empirically whether fishermen are risk-prone or risk-averse.

Hilborn and Ledbetter (1979) examined fishermen's behavior regarding the weekly movements of the British Columbia salmon fleet. They found that fishermen were likely to move their boats to areas where catch per hour was high. However, in some areas where catch per hour was high, fewer boats aggregated, presumably because travel costs to those fishing grounds were high. Hilborn and Ledbetter did not examine the question of fishermen's response to uncertainty and their attitude towards risk.

Eales and Wilen (1986) empirically examined fishing location choices by fishermen. In any seasonal fishery, such as the fishery for pink shrimp (*Pandalus jordani*), short-run decisions such as choice of fishing grounds are very important. Because fishermen cannot easily change their gear or move to other locations once they have made their decisions, the short fishing period limits the fishing operations. The results from the study support the hypothesis that fishermen do not choose fishing locations randomly, but instead seek to maximize their expected profits. Fishermen apparently consider two factors when choosing where to fish: fish abundance and distance to the fishing grounds. Fishermen update their knowledge based on information from the previous day and then use it in the decision-making process. Today's decision is influenced by the information about relative abundance yesterday. Fishermen will not move to a new location where high shrimp abundance has been reported unless they are sure that the new location will provide them better expected profits than the present location. This result, however, does not apply in all situations. For instance, if fish or shrimp aggregate and then dissipate over very short time spans at a particular fishing ground, then yesterday's catch records will not provide accurate predictions about today's catches. In addition, the Eales and Wilen study does not provide information about the details of the decision-making process for choosing a location or about fishermen's attitudes towards risk.

Sampson (1991) developed two models to examine fishermen's choice of fishing location in the short-run. Fishermen's decisions about where to go fishing are influenced by the costs of fishing at various fishing grounds as well as by the abundance of fish in those areas. The economic factors that have an effect on the fishermen's decisions are fish prices, fuel costs, and wage rates. The models assume that fish density is a simple linear function of distance from port, and also assume that skippers choose between alternative fishing locations to maximize their profits. In the first model the choice of fishing location is constrained by the capacity of the fish hold. Skippers spend as much time fishing as they need to fill the hold. In the second model, the available time for fishing is fixed. In either model, the fishing location for maximum profit occurs a particular distance from port. It should be noted that these models are theoretical and make some unrealistic assumptions. Of particular concern is the assumption that fishermen have perfect knowledge about the spatial distribution of the fish.

Sampson (1992) developed short-run and long-run models of optimal fishing location based on the assumption that fishing trips are of a fixed duration. In both models, given a particular level of fish price and fish stock abundance, the optimal locations depend on a fishing vessel's technical and economic characteristics. Technical characteristics include fuel consumption, catch rate and vessel speed, while the economic characteristics are wage rates and fuel prices. Sampson did not examine how fishermen's attitudes towards risk would influence their choice of fishing location but instead assumed that fishermen have perfect knowledge about relative catch rates at all fishing locations.

Healey and Morris (1992) investigated the relationship between catches and the dispersion of salmon fishing vessels operating off southwestern Vancouver Island. They concluded that fishermen behave like predators that conform to the "ideal free distribution" model of foraging theory. The way the fishing fleet distributes itself relative to the distribution of fish is identical to the way predators distribute themselves relative to their prey so that each predator gets the same foraging payoff.

Under this model, fishermen behave as if they have perfect information on the distribution of the fish.

Gillis, Peterman, and Tyler (1993) applied the ideal free distribution model to investigate the spatial allocation of effort and interactions between fishing vessels of the bottom trawl fishery in the Hecate Strait, British Columbia, Canada. They found that competition between fishing vessels resulted in the vessels conforming to an ideal free distribution. The vessels moved between fishing areas so that catch per unit effort (CPUE) was equalized between fishing areas. They therefore suggested that instead of using the CPUE of a particular area as an index of fish abundance, it would be better to use relative fishing effort. This is because CPUE is not only influenced by fish abundance but also by the behavior of fishermen in moving their fishing vessels. Aggregated CPUE for the study area may not accurately reflect the fish abundance, but instead may be influenced by the interaction and competition between fishing vessels.

FORAGING THEORY

Optimal foraging theory developed from studies of animal feeding behavior. The questions of how and why a forager selects particular prey induced an interest in studies of feeding behavior. Most studies that have tried to explain and predict feeding behavior have been based on the idea that foragers selectively feed on prey in order to maximize their net energy intake (Stephens and Krebs, 1986; Schoener, 1987).

In some of the models of optimal foraging theory, foragers actions are based primarily on the long-term average food reward. In these model the probability that foragers will get a certain amount of reward are the same for every visit to a feeding patch (Stephens and Krebs, 1986; Lendrem, 1986). In the face of uncertainty, however, foragers must not only deal with the mean food reward but also the probability of getting the food. Some foragers will select their prey based solely upon the expected food reward. Others will base their choice of prey on both the mean and the variability of the food reward. Theorists have noted that how the foragers make decisions is analogous to how consumers select goods when offered alternative choices of goods. Various researchers in foraging theory have borrowed from economics the idea of utility theory to describe foragers' behavior under uncertainty. This special branch of foraging theory is sometimes described as "risk-sensitive foraging theory" (Lendrem, 1986).

Maximizing Energy Intake: Prey and Patch Models

Many mathematical models have been developed to explain the feeding behavior of foragers. Some are average-rate maximizing models, which describe how animals maximize their long term average rate of energy intake. The original models are from the studies of MacArthur and Pianka (1966) (Cited from Stephens and Krebs, 1986; Schoener, 1987). These fundamental models in foraging theory take two perspectives, prey and patch models. The prey models, also known as the optimal diet theory (Schoener, 1987), describe the predator's decision to choose a certain kind of prey (Stephens and Krebs, 1986); the forager will select prey to maximize its energy intake. The patch models examine how long the forager should stay in a patch to maximize its energy intake (Stephens and Krebs, 1986). Which perspective is appropriate depends on how the foragers' problems or choices will be analyzed. Stephens and Krebs (1986) point out that the different analyses of the prey and patch models are distinguished by the fact that foraging theorists usually think of prey and patch in different ways. Using the definitions of MacArthur and Pianka, Stephens and Krebs distinguish between the prey and patch models as follows:

> "Foraging theorists usually think of prey as discrete items that a forager captures and completely consumes, but they think of patches as clumps of food or simply heterogeneities in the prey distribution".

FORAGING THEORY AND ECONOMICS

Economic concepts seem to have had less influence on studies of foraging than ecological concepts have had (Schoener, 1987). However, in some foraging studies, mostly those concerned with constraints on foraging or with environmental uncertainty, some techniques from economics have been applied. Utility theory, for example, is one idea from economics that has been applied in many foraging studies. The theory has been used as a tool to describe and predict a forager's behavior under uncertainty.

Decision Making Under Risk and Uncertainty

Frank H. Knight, an economist, distinguished between risk and uncertainty 60 years ago (Doll and Orazem, 1978; Pindyck and Rubinfeld, 1992; Schoemaker, 1980).

Risk refers to situations in which all possible outcomes and their relative likelihoods are known. Uncertainty refers to situations in which only the possible outcomes are known. However, in modern decision theory, either term is used to refer situations in which the decision-maker does not have complete information. Either the possible outcomes or the likelihood of the outcomes are unknown (Doll and Orazem, 1978). I will use the terms risk and uncertainty interchangeably to refer to situations where complete information is lacking.

Utility Function Analysis

One theory that has been used to describe or study the behavior of decision-making under uncertainty is the expected utility theory (Fishburn, 1988; Schoenmaker, 1980; Stephens and Krebs, 1986), also known as the Von Neumann-Morgenstern utility theory. Utility measures the level of satisfaction that a consumer obtains from consuming a good (Pindyck and Rubinfeld, 1992; Stephens and Krebs, 1986). A consumer's preference can be explained under the assumption that the consumer chooses goods to maximize his satisfaction or his utility, given a limited budget available to him. Presumably, a consumer always prefers a choice that gives the highest utility (Doll and Orazem, 1978; Schoemaker, 1980). In addition, consumers must have a consistent set of preferences (Friedman and Savage, 1948; Stephens and Krebs, 1986). If they prefer choice I to choice II, and prefer choice II to choice III, they, therefore, should prefer choice I to choice III. Generally, economists measure a consumer's utility as a function of different variables of interest. For example, the utility of a combination of two goods, A and B, might be proportional to the product of the quantity of A times the quantity of B.

Utility Functions and Risk

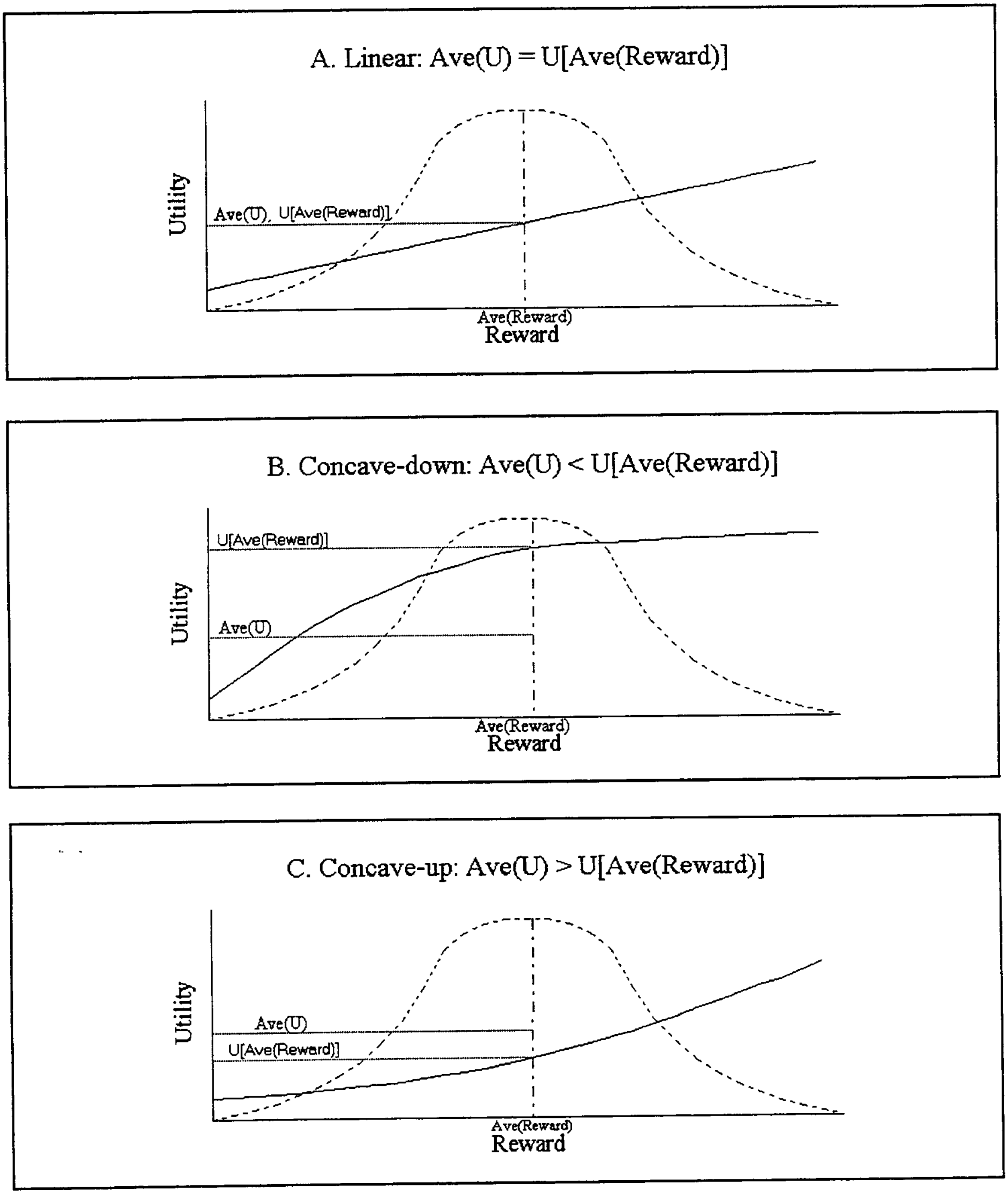
Based on the fact that consumers or foragers have varying preferences, their decisions will not be the same when faced with situations of differing uncertainty. Hence, three types of utility functions are used to identify types of attitudes towards risk (Doll and Orazem, 1978; Stephens and Krebs, 1986; Pindyck and Rubinfeld, 1992).

Risk Neutral A person whose preference is unaffected by the degree of risk has a linear utility function. An increase of one unit of reward also produces an increase of one unit of utility (Figure 1 A).

Risk Aversion A person who is risk-averse has a utility function that is concave down (Figure 1 B). A risk-averse person derives greater satisfaction from less variable rewards. He would prefer to invest his money in a stable bank account rather than gamble on the stock market, even though he might obtain a higher rate of return from the stocks.

Risk-proneness A person who is risk-prone has a utility function that is concave up (Figure 1 C). A risk taker is a person who prefers risk. Even a small increase in mean reward will produce a disproportionately large increase in utility.

Figure 1 (A) A linear utility function; risk-neutral foragers. (B) A concave-down utility function; risk-averse foragers. (C) A concave-up utility function; risk-prone foragers. (Applied from Stephens and Krebs, 1986). Solid line represents the utility curve; dashed curve represents the reward distribution.



One application of utility theory in economics, which has nothing to do with risk or uncertainty, is in the development of the analysis of consumer behavior and the derivation of demand functions. Utility is postulated to be a function of a consumer's fixed income and the quantities and prices of goods available to be purchased and consumed. Suppose that a consumer is indifferent between purchasing 5 units of good A (at a particular price) and 2 units of good B, versus 3 units of A and 4 units of B. In this case, the consumer derives the same utility from either combination. If the utility function is known, then it is possible to derive a demand curve that relates the price for that good to the quantity of the good consumed.

The application of utility theory relevant to this research is the study of individual behavior under uncertainty. For example, farmers may have different efficiencies and variable willingness to bear risk. If farmers can be grouped by their attitudes towards risk, managers may be able to develop more appropriate policies which directly accommodate the farmers' risk preferences (Young, 1979).

III. METHODS: DATA PREPARATION

In this study I applied risk-sensitive foraging theory to data on the choice of fishing location by commercial trawl fishermen in Oregon. In the Oregon trawl fishery, a fishing trip typically lasts from one to five days, and during a single trip the trawl gear will be fished at several different locations. A trip with well chosen fishing locations can produce large and valuable catches. One with poor locations can lead to bankruptcy or even a fatal accident.

THE COMMERCIAL TRAWL LOGBOOK DATA

This research used data, collected by the Oregon Department of Fisheries and Wildlife (ODFW), on the landings by species, fish prices, fishing locations, and time spent fishing at each location for the commercial trawl fishery for 1991. I organized the data into two files, Logbooks and Landings. The Logbooks file contained tow-by-tow information for individual trips as recorded by trawl fishermen operating from ports along the Oregon coast. The Landings file contained trip-by-trip information on landings and price by species.

Any fish dealer who purchases fish in Oregon is required to complete an official "ticket" indicating the weight and, optionally, the value of the fish purchased. The tickets are pre-printed with unique identifying numbers. Dealers send one copy of each ticket to the ODFW office in Portland and another copy of the ticket is collected routinely by local ODFW port biologists. Data from the two copies are keypunched separately, once in Newport and again in Portland, and the results from the two data sets are compared and any existing discrepancies are resolved (Sampson, Crone, & Saelens, 1992).

The commercial trawl logbook, which fishermen are legally required to fill out, contains detailed information about the fishing activities of the trawl fleet. Despite the legal requirement, in practice not all fishermen filled out their logbooks. From the three ports, Astoria, Newport, and Coos Bay, there were a total of 4335 fishing trips in 1991 but only 3388 of these trips had logbooks. The information for each fishing trip includes the fishing gear, departure and return times, departure and return ports, fishing locations, tow durations, and the skippers' estimates of the species caught and their quantities. The local biologists at each port collect the logbooks routinely. They examine, correct obvious errors, code every logbook, and fill in missing items such as target species or tow depths. When screening the data prior to data entry, they match up the logbooks with the landing tickets on which the dealers record the weight and value of the fish purchases. The biologists then assign the ticket numbers corresponding to each trip on the logbooks during the data entry (Sampson, Crone, and Saelens, 1992). Data from the logbooks are entered onto computers at the ODFW office in Newport and are transmitted to the mainframe computer in Portland. Further data processing is done in the ODFW Portland office to adjust the logbook hail weights, which are landings estimated by skippers, so they correspond with the landings reported on the fish tickets.

STUDY AREAS AND FISHING LOCATIONS

This project focused on the data in the Logbooks and Landings files for fishing locations in the vicinity of Oregon's three major fishing ports, Astoria, Newport, and Coos Bay (Figure 2). I defined fishing locations by using the following scheme. At each port, I designated a buoy at the entrance to the port as the starting point for fishing trips from that port, and measured the distances to the fishing grounds from this reference point. I assigned arcs marking off areas equidistant from the reference point for each port (Figure 3). The distance between adjacent arcs was 10 nautical miles (1853.2 meters). I subdivided each fishing area into fishing locations by rays originating from the reference point for each port. The angle between adjacent rays was 15 degrees. All fishing locations in a given fishing area had approximately the same surface area. For example, off Astoria there were five fishing areas, each of them covering a particular range of distances from the buoy. The area closest to the reference point was designated as area 1. The next closest area was area 2, etcetera. Each area was divided by rays into eleven fishing locations. The fishing locations in each area were numbered from 1 to 11 for Astoria and Newport, and from 1 to 10 for Coos Bay, with fishing location 1 located furthest south.

For Newport, there were eleven fishing locations in area 1 and 2, but only ten, nine, and eight in areas 3-5. This avoided overlap with fishing locations associated with Coos Bay.

Figure 2 Areas of study.

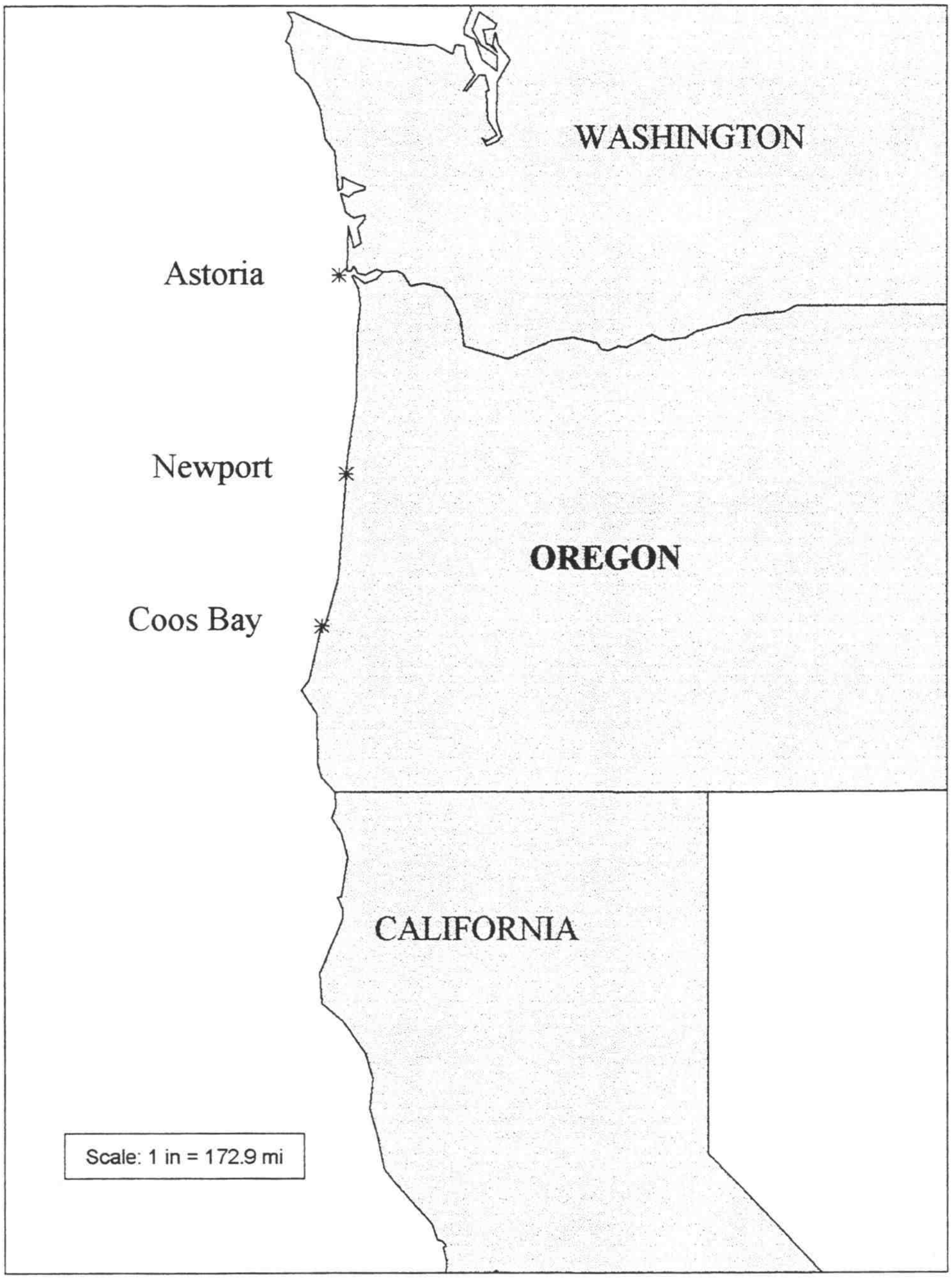
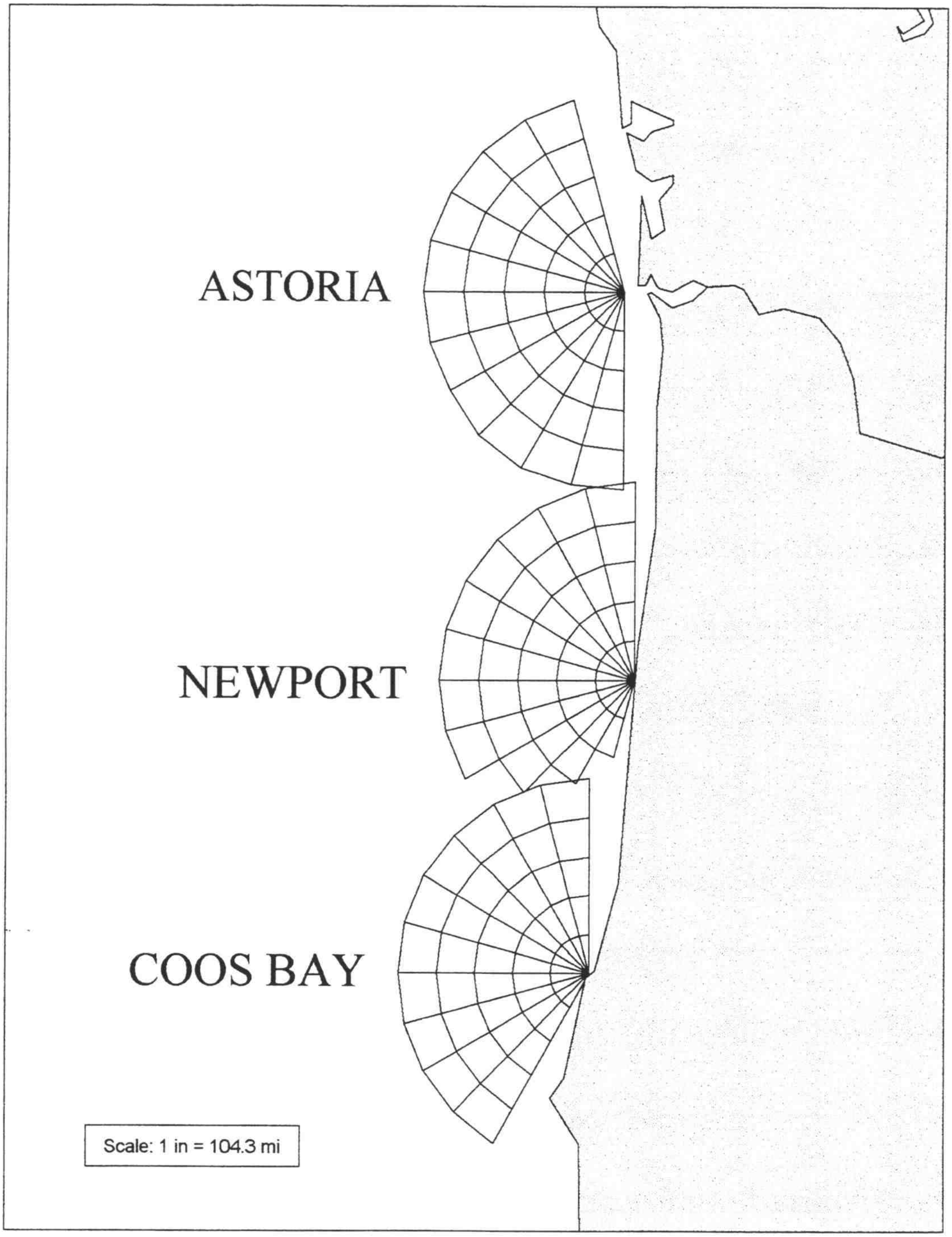


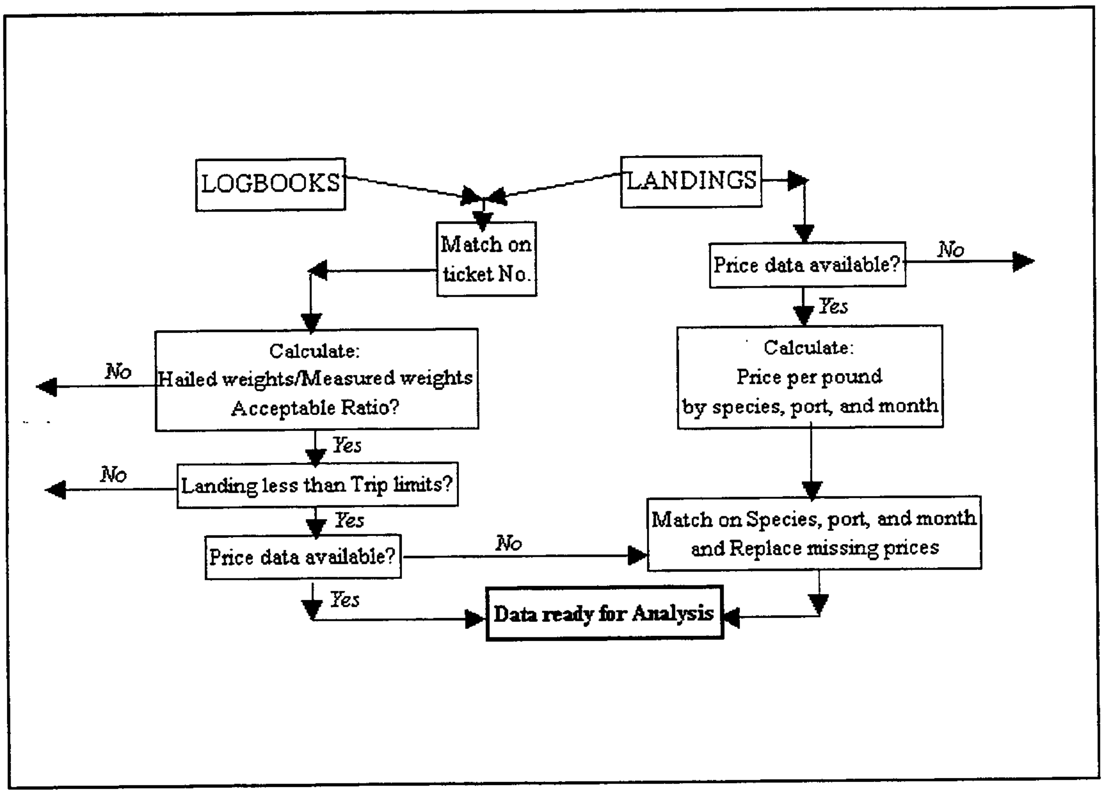
Figure 3 Fishing areas and locations within areas for each port.



DATA MANIPULATION

Before doing the analysis of the fishermen's attitudes towards risk, I manipulated data from the Logbooks and Landings files by using the procedures illustrated in Figure 4. The purpose of this data processing was to: (1) eliminate from the analysis data that were of suspicious validity because of discrepancies between the Logbooks and Landings information; (2) eliminate from the analysis data that would produce biased estimates of catch rates because the reported catches probably did not include the entire catch; and (3) to fill in missing price data.

Figure 4 Flow chart of data processing steps.



The Logbooks file contained the fishermen's estimates of their tow-by-tow catches, and the Landings file contained the fish dealers' measured weights of the landings for each trip. There were sometimes large discrepancies between the two data sets. For a given fishing trip the quantities of fish reported in the Logbooks files may have differed from those in the Landings due to errors in the fishermen's estimate of catch or due to errors in the data processing by ODFW. If the total weights estimated by the fishermen were not reasonably close to those from the fish dealer, then the estimates of the tow-by-tow catches probably were not reliable.

Inconsistencies Between Hailed Weights and Measured Weights

For each ticket number, I compared the landings by species reported in the Landings file with total hailed weight by species reported in the Logbooks file. I also compared the total over all species in each file. The ratio between hailed weight by species and measured weight for those species, and the ratio between hailed weight over all species and measured weight over all species are the indicators of the consistency between the two data sets. If, for a given ticket number, the ratios are all equal to one, then the information in the two data sets are identical. In contrast, ratios that differ from one indicate inconsistency between the two data sets. The following example illustrates how the ratios were created:

For a fishing trip, the boat made three tows and the skipper reported his catches in his Logbook as: 100 lbs. of lingcod (*Ophiodon elongatus*) and 200 lbs. of widow rockfish (*Sebastes entomelas*) for Tow 1; 300 lbs. of widow rockfish for Tow 2; and 200 lbs. of Lingcod for Tow 3.

The total hailed weights were 300 lbs. of lingcod and 500 lbs. of widow rockfish, for a total over all species of 800 lbs. Now, suppose the weight by species and over all species reported on the Landings ticket were 300 lbs. of lingcod and 550 lbs. of widow rockfish, for a total over all species of 850 lbs.

The ratios between the hailed and measured weights are:

Hailed Lingcod/measured Lingcod = 300/300 = 1;

Hailed widow rockfish/measured widow rockfish = 500/550 = 0.91;

Hailed over all species/measured over all species = 800/850 = 0.94.

Some discrepancies between the two data sets may be the result of errors during data entry and processing by ODFW. Most of the discrepancies, however, are probably the result of the fishermen's inability to accurately judge their tow-by-tow catches. Examination of the calculated ratios indicate that for many fishing trips the ratios did not equal one. For my analysis I accepted data for a trip if the ratios were between 0.75 to 1.25, provided the landings for a species were greater than 1,000 lbs. If the landings for a particular species were small (1,000 lbs or less), I did not care if the hailed to measured weight was outside the range 0.75 to 1.25 because this species would have contributed little to the overall landings.

Screening of Trips Affected by Trip Limits

During the 1970's, the groundfish fishery on the US west coast expanded enormously (Pikitch, Erickson. and Wallace, 1988). Early in the 1980's, many groundfish stocks were rapidly declining and some species, such as widow and yellowtail rockfish, were already overexploited (Pacific Fishery Management Council, 1993). Acting under the authority of the Magnuson Fishery Conservation and Management Act, the Pacific Fishery Management Council established a Groundfish Fishery Management Plan with the objectives of preventing the overharvest of individual species and maintaining a year-round fishery. Many species were regulated by means of annual quotas on landings and the landings of some species were also restricted by trip limits, which are quotas on the amount that may be landed by one trip or over some short time period, such as a week. The levels of the trip limits that were established depended on the species, fishing area, and time of year.

When landings for a trip were over the trip limits, it is likely that some of the catches had been discarded and the data reported in the logbooks did not include the entire catch, and it suggests either that the fishermen were unaware of the trip limit regulation, that they were intentionally breaking the law and willing to risk a fine, or that they misjudged their catches. Given the difficulty of accurately judging catch weights and species mix at sea, it seems most likely that fishermen over the trip limits had simply misjudged their catches. When their catches were close to the limits, the fishermen should have stopped the next tow to avoid trip limits violation, unless they misjudged their catches from former tows and, consequently, had not realized that their accumulative catches were close to the trip limits. If fishermen were accurate in judging their catch, but they found that their catches were over the limits, it seems likely that they would have discarded the surplus catch and would have recorded in their logbooks only the amounts they had retained. In this case the catch rates for those locations where some catches were discarded would not reflect the actual catch rates.

For the 1991 groundfish fishery trip limits were in effect for the following species (Pacific Fishery Management Council, 1993):

- Widow rockfish: The trip limit was 10,000 lbs. per week, with only 1 landing per week above 3,000 lbs and no restrictions on landings less than 3,000 lbs.

- Sebastes complex: The Sebastes complex consists of numerous species of rockfish including yellowtail rockfish (*S. flavidus*) and bocaccio rockfish (*S. paucispinus*), but excluding widow rockfish, Pacific ocean perch (*S. alutus*) and thornyhead rockfish (*Sebastolobus spp.*). The trip limit was 25,000 lbs. per week with no more than 5,000 lbs. of yellowtail rockfish. The biweekly limit was set at 50,000 lbs. with no more than 10,000 lbs of yellowtail rockfish, or 12,500 lbs. twice per week with no more than 3,000 lbs. of yellowtail rockfish. There were no restriction on landings less than 3,000 lbs.

In 1991 there were slightly different trip limits for Sebastes complex for the areas south of Coos Bay. There the limit was on landings of bocaccio rather than yellowtail rockfish. In Oregon the landings of bocaccio are small compared to the landings of yellowtail rockfish and the trip limit for North of Coos Bay is more restrictive. For simplicity I applied the Sebastes complex trip limit for North of Coos Bay to all landings in Oregon.

- Pacific ocean perch: The trip limit was 20% by weight of all groundfish on board or 3,000 lbs., whichever was less. Any landings less that 1,000 lbs. (regardless of the percentage on board) were not restricted.

- Deepwater complex: This group of fish includes sablefish (*Anoplopoma fimbria*), Dover sole (*Microstomus pacificus*), and thornyheads. The weekly trip limits were 27,500 lbs. per week, with no more than 1,000 lbs. of sablefish or 25% of the deepwater complex, whichever was greater, and no more than 7,500 lbs. of thornyheads.

The trip limits described above were in effect as of January 1, 1991. Two trip limits were changed during the year. The trip limit for yellowtail rockfish north of Coos Bay was reduced from 5,000 lbs. per week to 5,000 lbs once per two weeks effective on April 24. Another trip limit that changed, effective on September 25, was the trip limit for widow rockfish. This trip limit was reduced from 10,000 to 3,000 lbs with no restriction on the number of landings per week.

Any fishing trips where the weekly limits had been met or exceeded were excluded from further analysis. The ticket numbers for fishing trips that had experienced one or more trip limits were identified and cross-checked against trips that had consistent data in the Logbooks file. Any ticket numbers contained in both files were excluded from further analysis and the remaining data saved.

I did not include trips that may have been operating under the biweekly trip limits options. To be eligible for the biweekly option fishermen were supposed to make a declaration to ODFW in advance of fishing. The database does not include this information so there is no method to distinguish between trips that were using a biweekly limit and trips that were in violation of the weekly limits.

Estimating Missing Prices and Landed Value

For my analysis of fishing location choice and risk preferences I needed statistics on the gross revenue per hour that fishermen might obtain from fishing at each individual fishing location. During 1991 dealers were not required to report on the tickets the values of the fish they bought, although many did report this information. For those tickets that did not include fish values I calculated values for the landed species based on the quantities of the individual species landed and the average fish prices. I derided the average fish prices from the tickets that included data on fish prices.

Except for the market category "miscellaneous flatfish", which may have included illegal landings of Pacific halibut, the fish prices were relatively constant through the year (Table 1). The price for miscellaneous flatfish was very high relative to other months during January through February, and also in May, but very low in March and October. Beside these months the prices were roughly the same. However, there were some species that had average prices which varied from month to month, but the differences were small. For example, there was a gradual increase during the year in the prices for sand sole and sablefish.

For the data from the Landings and Logbooks files that had consistent hailed weights and that were not from trips affected by trip limits, I calculated the gross revenue of the catch for each tow using the formula:

$$\text{Gross revenue} = \sum P_s.C_s$$

where P_s is the price per pound of species S and C_s is the hailed weight in pounds of species S.

The prices for each species were taken from the Landings file and the hailed weight by species were taken from the usable data in the Logbooks file, after matching the two data sets based on ticket number. For those trips that were missing fish prices in the Landings file, I derived estimates of price using the following procedures. From the Landings file, I used all ticket records with landings of any species greater than zero and with prices greater that zero to calculate the value and the average price of each species by port and month. The following formulas were used.

For each trip the landed value for each species was calculated

[value] = [price][weight of fish landed]

For each species the average price by port and month was calculated as

(average price) = (total value)/(total weight of fish landed)

The trips that were missing prices in the Landings file were replaced by the average prices for the corresponding port and month.

Table 1 The monthly average prices in dollars per pound were relatively constant for each species.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	.324	.341	.340	.332	.334	.330	.330	.332	.335	.336	.342	.340
Rocksole			.320	.320	.300	.308	.309	.304	.302	.304	.355	.327
Petrale sole	.813	.826	.827	.829	.821	.835	.829	.843	.830	.823	.841	.829
Dover sole	.291	.310	.310	.309	.308	.308	.309	.308	.310	.310	.310	.310
Rexsole	.312	.323	.322	.315	.317	.317	.316	.316	.321	.320	.341	.340
Starry flounder	.280	.305	.300	.296	.293	.297	.298	.300	.292	.300	.329	.311
Sanddab	.301	.320	.310	.306	.308	.309	.304	.308	.317	.318	.316	.320
Sand sole	.361	.377	.360	.362	.378	.384	.420	.431	.430	.429	.499	.506
Curlfin sole			.340	.338	.317	.336	.301	.301	.302	.304	.317	.317
Arrowtooth flounder	.115	.114	.117	.116	.117	.113	.111	.116	.116	.122	.120	.111
Miscellaneous flatfish	2.974	3.000	1.007	1.967	2.779	2.472	1.996	1.967	1.425	0.794	1.967	1.967
Small rockfish	.271	.281	.282	.282	.283	.282	.282	.304	.280	.284	.287	.283
Pacific ocean perch	.290	.300	.301	.300	.300	.300	.300	.300	.300	.302	.318	.320
Widow rockfish	.274	.272	.272	.283	.272	.271	.271	.272	.263	.264	.289	.290
Yellowtail rockfish	.291	.298	.299	.299	.299	.298	.300	.300	.299	.301	.319	.319
Thornyhead rockfish	.420	.465	.466	.463	.457	.486	.456	.456	.447	.449	.461	.469
Miscellaneous rockfish	.295	.300	.303	.301	.299	.300	.301	.302	.302	.303	.318	.322
Pacific Whiting			.051	.069	.054	.050	.045	.054	.048	.043	.046	.047
Pacific cod	.262	.301	.304	.300	.301	.299	.300	.300	.300	.301	.336	.336
Lingcod	.310	.322	.321	.320	.320	.328	.321	.321	.322	.324	.339	.341
Sablefish	.361	.377	.360	.362	.378	.384	.420	.431	.430	.429	.499	.506

Average, Variance, and Third Moment of Gross Revenue per Hour

For each of the defined fishing locations (Figure 3) I calculated the average gross revenue per hour, and its variance and third moment (skewness) by gear type and vessel category. The gear type and vessel categories are described below. The average, variance and third moment are used as explanatory variables in the variance-discounting model that I used for interpretating fishermen's attitudes towards risk. Details of this model are given in the Data Analysis section. I used the following procedures to calculate the average gross revenue per hour and its variance and third moment.

After screening out data that may have been mis-reported or influenced by trip limits, from the tow-by-tow data on catches and prices I calculated the average gross revenue per hour, its variance, and third moment for a given fishing location off a given port by gear type and vessel class (boat length). I assumed that the reward characteristics varied between locations and that fishermen were aware of the differences. I assumed that the area covered by a tow was within a single location, and assigned tows to locations using a computer program that marked and grouped the tows based on the starting tow locations. The selected tows in a given location had information on the species caught, their quantities, and the duration for each tow. The expected reward from fishing at a given location was measured by the average gross revenue per hour, which is the dollar value of the landed fish per hour of fishing. For each location and vessel class, I converted the catches by species to dollar values by multiplying the quantities of each species by their prices. The sum of the dollar values from all species, which is the gross revenue of the catch for that location, was converted to an average rate (dollars per hour) by dividing by the total hours of towing that the fishermen reportedly spent fishing at that location.

There were two main types of trawl gear used in the groundfish fishery in 1991; bottom trawls and midwater trawls. The bottom trawls included two sub-categories: sole nets, which were trawls equipped with chains on the foot of the net for use on sand or mud bottoms; and bottom trawls equipped with roller gear for use on rocky or rough bottom (Hanna, 1988). These gear types differ in their fishing characteristics. The Logbooks data file also included a code for a "generic" bottom trawl, which would have been either a sole net or a bottom trawl equipped with roller gear. The trawls equipped with roller gear generally landed a different mix of species than the generic bottom trawls or the sole nets (Table 2). Therefore, I analyzed tows using this type of gear separately from tows using sole net and generic bottom trawl gear, but I combined these two other gear types. There were few data for landings by roller gear for Astoria and Newport. Sufficient data on catches by roller gear were available only for Coos Bay.

Midwater trawl gear is designed to catch fish off the bottom in midwater. During the 1991 groundfish fishery, the species targeted by midwater trawlers were mainly Pacific whiting and widow rockfish. Midwater trawls are larger than bottom trawls and are generally towed for shorter times (Hanna, 1988; Nedelec and Prado, 1990). While fishing with midwater trawls, most of the time at sea is spent searching for fish, and the towing times are as short as 10 to 30 minutes (Extension Marine

Advisory Program, 1981). As a result, it is difficult to define the actual fishing time for midwater trawls and determining the catch rate for midwater gear is problematic. For simplicity in this research I excluded from the analysis data from any tows made with midwater gear.

All fishing boats and fishermen are not identical, and differences in boat size and wealth could influence the fishermen's decisions and affect their attitudes towards risk. In my analysis I classified the data on gross revenue per hour at each fishing location on the basis of fishing vessel size. Because different classes of fishing boats likely have varying operating costs and represent different levels of investment, the data were grouped into smaller more homogeneous sets with respect to fishing boat size. Also, any tows that had a duration longer than five hours were excluded from the calculations because the catches from these tows would likely have come from several fishing locations. There were 1514 out of 11,272 tows for which the durations were longer than five hours. There were 25 tows that reported durations of zero; these were also excluded because they indicated missing data.

The Observed Preferences for Fishing Location

The final step in data preparation was to measure how much the fishermen preferred each location. For the individual fishing locations within a given fishing area, I measured the observed utility from fishing at a given location using the ratio of the number of first tows at that fishing location relative to the total number of first tows that occurred at all locations in the same fishing area. For example, suppose

Table 2 The species caught (pounds) in Oregon groundfish fishery in 1991 by type of fishing gear.

Species	Gear			
	Midwater trawls	Bottom trawls equipped with roller gear	Bottom trawls using sole nets	Generic bottom trawls
English sole	0	92510	1369629	154258
Rocksole	0	37	3485	212
Petrale	0	404430	1194212	114301
Dover sole	0	4785501	10535987	1184222
Rexsole	0	54166	759361	38914
Starry flounder	0	3159	650843	11707
Butter sole	0	0	507	0
Sanddab	0	70685	424006	34306
Sand sole	0	464	476342	71393
Curlfin sole	0	118	2303	0
Arrowtooth flounder	0	341675	3743316	130682
Miscellaneous flatfish	0	176	5910	862
Small rockfish	2301	1427600	634113	365233
Pacific ocean perch	3000	415769	997418	54273
Widow rockfish	3147792	2662970	294096	276517
Yellowtail rockfish	120479	2331733	413251	178151
Thornyhead rockfish	3188	3185024	2236329	750486
Miscellaneous rockfish	12651	3569665	1817165	454857
Pacific whiting	25209051	7629	69579	0
Pacific cod	50	192676	803050	46558
Lingcod	42	1760038	868173	96501
Sablefish	770	1727199	2208464	474860

there were ten tows at fishing location number one in the fishing area 10-20 nautical miles off Astoria, which had 11 fishing locations and a total of 40 tows over all these locations. The observed utility for this location would be 10/40.

I restricted my analysis to the first tows of the fishing trips, because at the start of a trip, all fishermen have similar information (past experience and collective knowledge) regarding the quality of different grounds as well as the distance of the grounds from alternative sets. I presumed that these two factors would have the most influence on the fishermen's decision about where to go fishing. Additionally, the decision about where to make a subsequent tow may depend on the success of the previous tows and on the cost of moving between locations. As a consequence the analysis of where fishermen go for their second or third tows is much more complicated.

IV. METHOD: DATA ANALYSIS

THE VARIANCE-DISCOUNTING MODEL

The processed data were analyzed to determine the fishermen's attitudes towards risk using a modified form of the variance-discounting model (Stephens and Krebs, 1986). The model describes the expected utility as a linear combination of the mean reward and the higher moments of reward

$$E[U] \approx a + b\mu + c\sigma^2 + dM3$$

where μ is the mean reward, σ^2 is the variance of the reward and M3 is the third moment (skewness) of reward. This relationship can be viewed as a third order Taylor series approximation to some continuous function that relates utility and reward. The third moment was included in the approximation because catch per unit effort data are often highly right skewed. The unknown parameters, a, b, c, and d, were estimated from the data using the following logistic regression model in which the logit of the expected population proportion was a linear combination of the explanatory variables:

$$\text{logit}(\pi) = \log[\pi/(\pi-1)] = a + b\mu + c\sigma^2 + dM3$$

where π is the probability that the fishermen choose a particular fishing location in preference to other locations i.e., the utility.

The observed preference for each location is the dependent variable and the average gross revenue per hour, and its variance and third moment are the independent variables. Under normal circumstances, one would expect parameter b to have a positive value because higher rewards provide higher utility.

If parameter c is zero, the fishermen are risk-neutral. If parameter c is negative, fishermen are risk-averse. Otherwise they are risk-prone. The coefficient d measures how the utility function curvature is changing. The case that c is greater than zero and d is less than zero indicates that the utility function is changing from concave-up to concave-down and that the fishermen are switching from being risk-prone to risk-averse.

TESTING THE GOODNESS OF FIT

Others studies dealing with choice of fishing location have applied the logistic regression model in their analyses (Bockstael and Opaluch, 1983; Dupont, 1993). The logistic regression model is a special form of generalized linear model designed specifically for modelling a population proportion in terms of explanatory variables (Ramsey and Schafer, 1993.

In this study the data on the distribution of first tows across fishing locations were fitted using the Generalized Linear Interactive Modelling program (GLIM), a computer program designed specifically for fitting generalized linear models (Healy, 1988). For the data from a given category of port, fishing area, and boat length, I used GLIM to calculate measures of goodness of fit, which are described as the deviance, for a suite of possible models. The deviance, which is analogous to the residual sum of squares in standard least square regression, is calculated as:

$$\text{Deviance} = 2\sum \{[y \ln(y/\mu)] + (n-y) \ln[(n-y)/(n-\mu)]\}$$

where y is observed response; μ is the response estimated from the logistic regression model; and n is the number of observations.

If the model has been correctly specified, the deviance will be approximately distributed as a Chi-square random variable (McCullagh and Nelder, 1983). The discrepancy between the deviance for a set of observations and the maximum possible deviance measures the response variation that cannot be explained by the model for π (Ramsey and Schafer, 1993.

For a logistic regression the null model contains a single explanatory variable and the model predicts a common proportion for all observations. If an explanatory variable is added to the model and if the coefficient for the extra variable is zero, fitting the reduced and fuller model will have the same results and the same deviance. If the coefficients are not zero, the fuller model will explain the variation in the response variables better than the reduced model and its deviance will be smaller. Testing the significance of the extra variable can be done by fitting both models and comparing the sizes of deviances using the extra sum of squares test (Ramsey and Schafer, 1993 McCullagh and Nelder, 1983). The difference between the deviance of the two models (the drop in deviance) measures the predictive power of the extra variable. For example, the model logit(π) = A is a reduced version of the full model logit(π) = A + B and the difference in deviance between the two models measures the explanatory power of B. For testing the significance of the extra explanatory variable I calculated F ratios using the following formula:

$$\text{F-test} = \frac{\text{Drop in deviance/(Drop in degrees of freedom)}}{\text{Full model deviance/Full model degree of freedom}}$$

If the full model has been correctly specified, then this F ratio will approximately follow the corresponding theoretical F distribution.

According to the variance-discounting model, the major factors influencing the expected utility of a given choice of fishing location are the average gross revenue per hour, its variance, and third moment. The analysis started with the simplest null model with one explanatory variable, following by a model with two variables, etcetera. For a given data category, I examined the following set of nested models:

(1). E(U) = Area;

(2). E(U) = Area + Area.Ave ;

(3). E(U) = Area + Area.Var;

(4). E(U) = Area + Area.Ave + Area.Var;

as well as the full model:

(5). E(U) = Area + Area.Ave + Area.Var + Area.M3.

Model (1) tests whether there is uniform utility within a given fishing area, but different utilities between fishing areas. Model (2) allows the utility to vary with the average gross revenue per hour within each fishing area. Model (3) allows the utility to vary with the variance of gross revenue per hour within each fishing area, but without regard to the average gross revenue per hour. Model (4) allows the utility to vary with both the average and variance of gross revenue per hour. Model (3) differs from model (4) by the point that model (3) measures the absolute effect of variance on utility, but model (4) measures the effect of variance after first accounting for differences in average gross revenue per hour. Model (5) is the full model, which includes all three factors. I tested the significance of a parameter by comparing the deviance of the fuller model, which includes that parameter, with the deviance of the nested model, which does not include that parameter. For example, to test the significance of the variance as a factor I compared the deviance from model (2) with the deviance from model (4). The significance of the change in deviance was measured by comparing the ratio with the corresponding theoretical F distribution.

In this research I used weighted logistic regression to account for different levels of imprecision in the observed independent variables. This procedure differs from standard practice where one assumes that the independent variables are measured with perfect accuracy and weights are applied to adjust for unequal levels of precision in the observed dependent variable. In this research the independent variables (average gross revenue per hour and its variance and third moment) were estimates based on different sample sizes. For some locations there were large numbers of tows and the average gross revenue per hour was known quite precisely, but in other locations there were a limited number of tows and the estimates of the average, variance, and third moment were much less precise. By applying weighted logistic regression I attempted to put the data from each location on the same scale.

TESTING FOR SEASONAL FISHING PATTERNS

Due to the fact that the groundfish fishery has many target species, the landings by species can vary through time. For example, in 1991 the percentage of Dover sole in the landings at Astoria and Newport were high during December through April, and the percentage of thornyhead rockfish in the landings at Coos Bay were high in November and December (Table 3, 4, and 5). These shifts in landings may be an indication that fishing patterns changed during the year. The average gross revenue per hour for a fishing location, which I calculated on an annual basis, might not be accurate because it might be unduly influenced by the aggregation of tows within particular months. I did a series of further analyses to verify that there was no evidence of seasonal changes in fishing pattern, which might otherwise confound my results. I organized the data into categories by quarter of year, port, fishing gear, fishing area, and boat length and tested whether there were changes in the distributions of first tows by quarter. The test used each quarter as the time period instead of the month due to the limited data on a monthly time scale. The null hypothesis was that the distribution of first tows varied by location but was constant through the year. I compared the goodness of fit to the model

$$E(U) = \text{Location}$$

with the goodness of fit to the alternative model

$$E(U) = \text{Location.Quarter}$$

where U is the ratio of the number of first tows at a fishing location to the total number of the first tows occurred at all locations the fishing area.

The formal significance test procedures were similar to those described earlier for testing the factors in the variance-discounting model. If Quarter is not a significant factor, the deviance from the null and alternative models should approximately be the same.

Table 3 Monthly landings by species as a percentage of the total groundfish landed in Astoria.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	1.2	4.2	1.2	0.9	2.3	3.6	4.3	3.7	4.2	5.5	3.4	0.8
Rock sole												
Petrale sole	9.1	5.8	1.1	0.5	0.7	1.2	1.1	0.7	0.8	1.5	3.2	5.8
Dover sole	30.4	24.6	37.8	35.5	18.6	12.6	12.4	15.4	18.3	21.9	22.2	27.2
Rexsole	1.7	4.7	1.0	1.1	2.2	3.1	2.2	1.7	2.2	3.1	1.7	0.9
Starry flounder		0.01	1.4	0.1	4.3	1.4	3.7	3.3	2.4	0.3	2.9	
Butter sole				0.02								
Sanddab	0.3	0.9	0.6	1.1	1.2	1.7	0.8	0.4	0.3	1.1	0.5	0.3
Curlfin sole						0.01						0.01
Arrowtooth sole	6.3	4.5	5.0	6.4	14.5	20.6	10.3	17.5	11.7	8.3	6.0	5.2
Miscellaneous flatfish						0.07	0.01			0.07		
Small rockfish	0.5	0.4	0.4	0.5	0.9	0.4	0.4	0.4	0.5	1.0	0.7	1.1
Pacific ocean perch	3.8	4.8	3.5	3.0	3.3	3.0	3.0	3.9	4.1	4.6	4.2	3.5
Widow rockfish	12.4	16.3	8.9	3.5	4.5	8.8	9.7	8.9	21.6	16.6	8.1	20.7
Yellowtail rockfish	7.8	11.6	9.3	7.8	4.7	4.6	3.5	5.3	5.7	5.2	8.2	6.6
Thornyhead rockfish	3.9	3.9	3.1	2.5	3.8	2.4	1.7	1.9	4.5	7.5	12.4	7.3
Miscellaneous rockfish	8.9	9.6	6.9	10.8	12.2	9.0	8.6	11.0	11.4	11.1	11.0	7.6
Pacific whiting				0.4	15.7	15.1	26.6	12.8				
Pacific cod	0.6	0.7	1.0	1.4	2.5	5.6	4.5	5.3	2.5	2.2	1.1	0.6
Lingcod	7.4	2.1	10.8	18.5	3.6	3.0	3.6	4.1	4.7	2.9	5.4	4.6
Sablefish	5.2	5.0	4.9	4.8	4.1	2.9	2.1	2.9	4.3	6.5	7.9	7.8

Table 4 Monthly landings by species as a percentage of the total groundfish landed in Newport.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	0.7	0.7	3.8	2.9	1.2	0.9	1.1	0.6	0.5	0.5	0.3	1.8
Rock sole					0.1	0.01						0.02
Petrale sole	2.3	1.6	2.9	1.8	0.6	0.6	0.8	0.4	0.1	0.1	0.1	2.7
Dover sole	12.6	12.3	13.1	19.3	11.6	5.1	6.7	5.5	4.0	3.0	2.8	16.3
Rexsole	0.3	0.5	1.6	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.5
Starry flounder		0.02		0.02	0.1	0.1	0.2	0.1	0.2	0.02	0.01	0.02
Butter sole												
Sanddab	0.6	0.04	1.6	0.7	0.01	0.2	0.1	0.02	0.03	0.01	0.02	0.2
Curlfin sole												
Arrowtooth sole	0.5	0.8	0.7	1.3	1.3	0.9	1.1	0.2	0.2	0.3	0.1	0.3
Miscellaneous flatfish	0.02	0.01	0.02				4.3					
Small rockfish	22.5	16.0	12.0	4.4	4.6	6.3	0.6	3.9	0.9	1.8	2.4	21.0
Pacific ocean perch	2.1	2.3	1.7	0.5	0.5	0.7	11.4	0.4	0.4	0.3	0.4	1.9
Widow rockfish	36.2	37.0	33.1	14.1	7.3	5.8	2.0	7.7	7.0	0.6	0.5	5.2
Yellowtail rockfish	4.4	6.1	8.1	3.4	1.6	1.2	4.6	1.1	1.1	0.5	0.6	4.5
Thornyhead rockfish	8.9	12.6	10.7	11.3	6.7	4.4	4.7	3.0	4.0	3.8	3.5	15.9
Miscellaneous rockfish	1.6	3.3	2.6	7.8	8.9	3.6	5.0	3.5	5.2	2.4	0.8	7.4
Pacific whiting				23.5	47.4	64.8	57.2	69.3	71.7	84.0	86.1	12.6
Pacific cod	0.02	0.1	0.5	0.3	0.5	0.5	0.4	0.4	0.04	0.04	0.01	0.2
Lingcod	2.7	0.6	1.9	1.4	2.13	1.6	1.1	0.8	0.7	0.5	0.1	0.6
Sablefish	4.5	5.6	5.3	6.5	4.2	2.5	2.9	2.6	2.2	1.8	1.8	8.8

Table 5 Monthly landings by species as a percentage of the total groundfish landed in Coos Bay.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	1.5	2.7	1.5	1.6	1.9	2.9	2.3	1.4	2.1	1.7	0.9	0.9
Rocksole					0.04	0.01			0.01			
Petrale sole	13.2	4.4	1.2	1.9	0.9	1.0	0.7	0.4	0.6	0.7	2.8	14.3
Dover sole	34.5	37.9	44.1	45.4	32.6	27.2	27.3	22.3	24.4	32.3	31.0	29.9
Rexsole	0.6	0.4	0.2	0.1	0.3	0.4	0.1	0.02	0.04	0.02	0.04	0.2
Starry flounder		0.04			0.01	0.6	0.4	0.8	0.1	0.04		
Butter sole												
Sanddab	0.9	2.0	3.6	0.4	1.1	2.1	2.9	0.1	1.6	1.7	0.8	0.02
Curlfin sole						0.01	0.02	0.1	0.01			
Arrowtooth sole	0.4	0.4	0.2	0.5	1.7	2.2	2.1	1.5	1.1	1.4	0.7	1.1
Miscellaneous flatfish												
Small rockfish	3.4	3.6	3.8	3.5	3.7	7.7	4.6	2.0	3.5	3.9	3.0	3.5
Pacific ocean perch	0.1	0.3	0.1		0.2	0.04	0.3	0.1	0.1	0.02	0.1	0.2
Widow rockfish	12.8	14.7	11.1	4.0	3.4	4.4	6.8	8.7	13.2	2.7	1.5	1.2
Yellowtail rockfish	4.0	3.3	1.8	3.7	2.2	2.0	1.2	0.8	1.2	1.9	3.1	1.8
Thornyhead rockfish	13.4	14.0	13.	9.3	10.2	12.1	13.1	18.3	16.1	20.4	32.1	27.4
Miscellaneous rockfish	7.6	6.6	8.54.4	11.2	20.2	17.3	18.9	8.4	12.3	16.1	8.7	5.7
Pacific whiting				4.4	7.6	2.2	2.8	20.8	9.5			
Pacific cod		0.01		0.03	0.02	0.1	0.1	0.03	0.03	0.1	0.02	0.02
Lingcod	0.4	2.6	0.6	2.1	2.7	4.3	3.8	1.6	1.4	3.4	1.4	0.5
Sablefish	7.0	6.9	9.3	11.2	10.5	9.3	9.9	9.4	9.1	11.0	11.8	12.3

V. RESULTS

Although the original data file on landings by trip contained information on a total of 4,335 trips from the three ports, most of these data were eliminated from the analysis because of inconsistencies with the logbook data or because of the likely influence of trip limits (Table 6). Not only were many trips excluded from the analysis, but many vessels were also excluded (Table 7). More than 50 percent of the total vessels that went fishing each month had some trips excluded either because of bad information for the hailed weights or because their landings were over the trip limits. Because so much of the data was eliminated, it is important to determine whether the data that remained in the analysis were still representative of the general fishery. To do this I examined the relative number of trips excluded by month and by port.

The total number of trips from each port were relatively evenly distributed across the months (Table 6). The only evidence of a strong seasonal pattern in fishing activity was the tendency for large numbers of trips from Newport during May through September and from Astoria during March through November. The percentage of usable trips during these months was high relative to other months. For Coos Bay, the percentage of usable trips was high from April through August, but this pattern was not as strong as the corresponding patterns in Astoria and Newport. When comparing between the three ports, the percentage of usable trips for a given month was variable. For example, in January the percentage of usable trips was only slightly different between the three ports, in the range 18.3-22.6 %, but in June they were very different ranging from of 43.2% in Astoria to 26.4% in Coos Bay.

Table 6 The total number of trips by month by port and the number of trips excluded due to inconsistency between the hailed weights and the measured weights, or due to landings that were over the trip limits.

Port	Numbers of Trips	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newport	Total	104	90	109	116	161	193	184	178	144	116	57	74
	Usable	19	21	25	38	69	71	84	70	49	32	11	14
	Inconsistent	57	43	56	56	60	63	54	68	50	54	29	35
	Trip limit	45	35	36	37	35	66	63	57	55	41	15	23
Astoria	Total	103	108	105	83	129	139	142	141	157	164	104	52
	Usable	20	19	33	35	65	60	43	38	72	96	43	8
	Inconsistent	27	30	24	26	38	33	30	28	29	28	18	22
	Trip limit	58	65	51	29	31	35	62	70	59	34	18	12
Coos Bay	Total	115	118	125	83	126	125	120	125	138	115	85	107
	Usable	26	29	23	28	48	33	46	39	35	29	20	22
	Inconsistent	42	36	39	30	48	37	24	30	36	38	34	32
	Trip limit	36	30	34	22	27	27	34	42	50	39	40	48

Total = Number of fishing trips from the original data file (Ticket file)
Inconsistent = Number of fishing trips excluded due to the inconsistency between hailed weights and measured weights.
Trip limit = Number of fishing trips excluded due to landings that were over trip limits.
Usable = Number of fishing trips included in the analysis of fishing location preferences
The sum of the inconsistent records plus those in violation of trip limits is greater than the total number of records because some records were inconsistent and in violation of trip limits.

Table 7 The total number of fishing vessels by month by port and the number vessels that had some trips excluded due to inconsistency between the hailed weights and the measured weights, or due to landings that were over the trip limits.

Port	Numbers of vessels	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Newport	Total	29	35	35	34	38	40	39	40	39	41	30	31
	Inconsistent	24	26	27	24	27	28	27	25	21	27	18	20
	Trip limit	16	14	17	18	13	17	22	23	20	20	10	13
Astoria	Total	21	21	27	22	24	23	24	24	29	27	25	19
	Inconsistent	16	14	12	13	17	15	17	16	12	14	12	10
	Trip limit	16	16	16	10	11	11	15	19	18	15	10	8
Coos Bay	Total	27	28	28	24	25	28	25	26	28	34	28	27
	Inconsistent	18	17	15	18	17	19	14	15	16	19	18	17
	Trip limit	13	10	12	8	10	9	9	10	14	16	15	19

Total = Number of fishing vessels from the original data file (Ticket file)
Inconsistent = Number of fishing vessels that had some trips excluded due to the inconsistency between hailed weights and measured weights
Trip limit = Number of fishing vessels that had some trips excluded due to landings that were over trip limits.

There was little evidence of seasonal pattern for the trips that had inconsistent hailed weights. The percentage of trips that had inconsistent data was relatively uniform across all months in all ports, except for the month of December in Astoria, which was very high compared to other months for that port. The percentage of trips that had inconsistent data was different between the ports in a given month. Newport generally had the highest percentage of trips with inconsistent data , except in May, during which Coos Bay had the highest percentage of inconsistent data.

The percentage of trips that were in violation of trip limits was different between months in all ports. This percentage was very high in January for Newport (43.7%), during January through March for Astoria (48.6-60.2%), and during November through December for Coos Bay (47.1 and 44.9%). This percentage was very low (only 15.5%) in May for Newport and in November for Coos Bay (17.3%). The percentage of trips that were in violation of trip limits was also different between the three ports for a given month.

Although the percentage of trips that I included in my analysis was not consistent between ports or months, I have no reason to believe that the data I used are not representative of the fishery.

The data from the usable trips (Table 6) were grouped into categories by vessel length, gear type, port, fishing area, and location within each area. For each category I tabulated the number of first tows, the total number of tows, the average gross revenue per hour, and its variance and third moment. Some categories of port, vessel, gear and fishing area were not used in the analysis of fishing location preferences because there were few observations of first tows in those fishing areas. I limited my analysis with the variance discounting model to categories for which there were data on the average gross revenue per hour and its moments for at least four different locations within the fishing area (Tables 8-17) and a total of at least of ten first tows within the area. The data for the categories I excluded from my analysis are listed in Appendices 1-19.

There was evidence that the distributions of first tows were distributed independently of the average gross revenue per hour ($/Hour). There were cases where the greatest number of first tows occurred at locations that had relatively low average gross revenue per hour. For example, for 50-59 foot vessels fishing in the area 30-40 nautical miles off Newport with generic bottom trawls (which would have been either a sole net or a bottom trawl equipped with roller gear), the highest number of first tows occurred at location number 4, which did not have the highest average gross revenue per hour (Appendix Table 9). There was greater consistency between the distribution of the total number of tows at each location and the distribution of average gross revenue per hour. For example, in area 20-30 nautical miles off Astoria (Table 9) for the 50-59 and 60-69 foot boats, the two locations that had the greatest total number of tows also had the highest average gross revenue per hour.

At all locations the average gross revenue per hour was over-dispersed; the average gross revenue per hour was less than the variance. In addition, for most locations the distribution of gross revenue per hour was right skewed, which indicated that most of the observed values of gross revenue per hour at a given location were greater than the average gross revenue per hour for that location, i.e., the mean was less than the median.

Different vessel classes differed in their average gross revenue per hour. Generally, the bigger boats tended to have higher average gross revenue per hour, except for fishing vessels fishing in the area 10-20 nautical miles off Astoria, for which the average gross revenue per hour of the 50-59 foot boats were generally lower than those of the 30-39 foot boat (Table 8). For all ports, the smaller boats fished in areas closer to the ports than the bigger ones. The small 30-39 foot boats limited their fishing to within 40 nautical miles off Astoria. There was no evidence that a particular vessel class fished in specific locations that differed from other vessel classes fishing within the same area.

TESTING FOR SEASONAL FISHING PATTERN

All of the tests for a seasonal pattern in the distributions of first tows failed to reject the null hypothesis of no seasonal pattern, except for boats in the 50-59 foot boat length category that used generic bottom trawls (bottom trawl/sole net) and fished in the area 30-40 nautical miles off Newport, and that fished in the area 40-50 nautical miles off Coos Bay (Table 18-21). For these two categories the tests rejected the null hypothesis at the 95% confidence level. In 14 of 16 tests there was insufficient evidence to reject the null hypothesis of no seasonal pattern in the distribution of the first tows. Therefore, in my subsequent analyses I assumed that there was no seasonal fishing pattern, and I disregarded season as a confounding factor.

RESULTS BY PORT

The various variance discounting models were applied separately to the observed distributions of first tows for trips originating from each port. For each port, the models were applied first to the different categories of fishing gear and areas without regard to boat length category (Table 22A, 23A, 24A, and 25A) and then additional terms were added to account for boat length differences (Table 22B, 23B, 24B, and 25B). For the fishing vessels operating with bottom trawls equipped with roller gear, there was only one vessel length category, 60-69 feet (Table 26). The first row of each table shows results for the model that tests for a uniform distribution of tows in each fishing area. The second row gives results for the model which tests the significance of the average gross revenue per hour (Ave). The third and fourth rows give results for models that test the significance of the variance. The fifth row gives results for the model that tests the significance of the third moment.

In the tests for uniform distributions of tows across fishing locations the null model predicts that the same proportion of the first tows occurs at each location within a given fishing area. If the null model were true the deviance would be a Chi-square random variable. For every port-gear combination tested the null model was rejected at the 99% confidence level, indicating that the fishermen did not select their first tows in a random manner.

For each port and gear category the F-tests in Tables 23B, 24B, 25B, and 26 indicate whether the coefficients on the terms for the average gross revenue per hour (Ave) and the variance (Var) and third moment (M3) were significant. The signs of the coefficients indicate the fishermen's preferences and how the preferences vary with changes in the average gross revenue per hour. For example, the fitted model

$$R = 0.8 + 0.5 \text{ Ave},$$

in which the coefficients for Var and M3 are zero, indicates that a one unit increase in the average gross revenue corresponds to an increase of 0.5 logit (π). In this case the fishermen's preferences are increasing when the average gross revenue per hour increases, the fishermen are risk-neutral, and the utility curve is linear (Figure 1A.).

Table 8 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 0-10 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)														
	30-39					50-59					60-69				
	FT	NT	$/Hr	Var	M3	FT	NT	$/Hr	Var	M3	FT	NT	$/Hr	Var	M3
1	0	2	180.6	0.40	0.01	15	24	72.6	1.16	0.00	2	12	204.3	17.51	0.65
2						5	13	62.5	1.58	0.08	1	11	187.5	9.65	1.34
3	0	7	122.7	6.56	0.72	0	3	79.3	4.17	0.13	0	13	169.6	7.51	0.68
4											1	8	105.7	1.23	0.01
5	1	6	136.6	6.52	-0.09	0	2	161.2	0.27	0.00	0	13	160.7	41.53	21.25
6	1	3	128.7	0.48	0.00	0	2	69.8	0.01	0.00	6	20	203.2	15.11	2.93
7	0	2	22.1	0.19	0.00	0	2	25.4	0.05	0.00	4	13	131.9	11.81	1.49
8	3	3	165.2	917.42	1224.60						1	25	183.7	35.89	14.49
9	2	8	102.4	8.50	0.84	2	4	84.4	2.46	0.14	14	44	212.4	34.73	17.83
10	2	21	99.9	15.06	4.19	2	7	45.4	0.96	0.04	13	53	221.5	22.38	6.27
11	5	27	190.2	20.78	3.81	6	25	109.4	17.42	4.41	5	54	224.6	50.84	33.65
Tot	14	79				20	82				47	266			

Loc = Fishing location; FT = Number of first ; NT = Total number tows;
$/Hr = Average gross revenue per hour; Var = Var * 10^{-3};
M3 = Third moment * 10^{-6}; Tot = Total number

Table 9 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)				
	60-69				
	FT	NT	$/Hr.	Var	M3
1	1	2	36.0	0.94	0.01
2	0	5	68.8	0.36	0.01
3	0	7	172.1	5.00	-0.11
4	1	4	112.7	8.25	-0.04
5	0	2	129.0	1.67	0.02
6	1	10	132.2	10.77	1.34
7	0	10	186.3	11.80	1.29
8	2	10	119.5	3.33	0.10
9	1	11	101.7	2.46	-0.05
10	5	70	191.1	90.84	100.32
11	1	55	153.1	9.84	1.99
Tot	12	186			

Table 10 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)									
	40-49					50-59				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1										
2	0	2	99.8	7.78	0.36					
3	3	5	97.8	5.40	0.47					
4										
5	5	14	83.8	0.44	0.01	0	3	68.2	0.51	0.00
6	1	2	27.9	0.44	0.00	3	15	77	1.91	0.14
7	3	25	68.4	0.85	0.02	6	39	76.8	2.25	0.31
8	2	26	90.6	13.05	4.67	7	31	98.6	36.39	31.74
9	0	9	70.7	1.55	0.08	0	15	81.9	3.35	0.39
10										
11										
Tot	11	83				16	103			

Table 11 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 20-30 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)									
	50-59					60-69				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1										
2										
3										
4	11	58	109.7	6.88	1.52	2	27	136.6	14.29	3.14
5	3	38	86.5	1.67	0.06	6	15	84.2	2.70	0.14
6	4	32	88.6	1.87	0.11	0	8	73.5	1.14	0.02
7	3	30	80.8	1.67	0.07	2	9	141.4	57.54	35.99
8	2	11	62.3	2.76	0.29	1	5	150.6	27.23	7.22
9	2	28	85.3	5.47	1.42	1	6	101.6	0.76	0.02
10	1	11	56.4	0.36	0.00	0	5	73.4	2.08	0.07
11	0	6	53.4	0.36	0.00					
Tot	26	214				12	75			

Table 12 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 30-40 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)									
	60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1										
2										
3						1	8	494.1	131.91	19.09
4	3	14	98.1	4.10	0.48	2	18	233.4	60.55	31.99
5	1	11	267.8	1403.03	3994.33	2	30	289.9	202.65	322.36
6	1	10	325.2	853.06	2123.70	3	17	143.6	14.22	2.90
7	2	2	268.4	29.90	2.01	1	6	199	4.90	0.05
8						1	3	80.9	2.00	-0.11
9	0	6	91.6	2.47	0.05	0	4	145.1	5.89	-0.05
10	1	14	114.3	1.91	0.04	1	5	87.4	3.77	0.17
11	3	7	81.9	0.74	0.01					
Tot	11	64				11	91			

Table 13 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 0-10 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	50-59				
	FT	NT	$/Hr.	Var	M3
1					
2					
3					
4					
5	5	11	76.8	2.31	0.10
6					
7	2	6	64.2	1.95	0.08
8	5	8	131.2	3.87	0.01
9	9	14	68.9	0.70	0.00
10	7	14	79	2.44	0.12
11					
Tot	28	53			

Table 14 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)									
	40-49					50-59				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	0	7	104.5	5.65	0.39					
2	2	18	83.5	1.77	0.05	4	32	116.5	116.77	137.05
3	3	9	77.8	1.33	-0.01	5	25	205.3	100.17	79.52
4	5	12	100	3.99	0.43	9	15	67.3	5.55	0.79
5	5	6	109.6	1.35	-0.07	4	19	158.8	6.03	0.19
6	0	5	65.9	0.98	0.05	6	11	73.8	1.72	0.00
7	2	4	58.3	4.63	0.45	6	14	95.6	8.03	1.67
8	3	9	93.2	15.45	4.13	5	24	92.6	2.22	0.11
9	0	4	56.2	1.93	0.07	1	18	68.2	1.57	0.09
10	0	4	70.1	0.92	0.01					
11										
Tot	20	78				40	158			

Table 15 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 20-30 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	50-59				
	FT	NT	$/Hr.	Var	M3
1	4	48	130.5	3.16	0.03
2	7	36	109.7	3.02	0.02
3	6	35	130	5.14	0.36
4	5	16	167.4	8.14	0.46
5	1	2	123.3	0.05	0.00
6	0	4	485.4	2.57	-0.11
7	0	2	125.4	9.76	-0.37
8					
9	4	45	82.3	5.74	1.65
10	2	19	187.4	53.15	25.41
11					
Tot	29	207			

Table 16 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 30-40 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	50-59				
	FT	NT	$/Hr.	Var	M3
1	1	45	113.4	5.35	0.84
2					
3					
4					
5					
6					
7					
8	2	16	200.2	13.66	0.88
9	6	57	129.6	6.30	0.19
10	1	24	121.8	3.36	0.07
11					
Tot	10	142			

Table 17 Data on fishing location preferences and success rates for fishing vessels operating with bottom trawl equipped with roller gears in the fishing area 10-20 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	60-69				
	FT	NT	$/Hr.	Var	M3
1					
2	1	8	117.4	1.16	-0.02
3					
4	0	4	62.9	0.50	-0.01
5	3	10	123.5	14.69	3.46
6	4	9	166.6	68.33	34.37
7	1	7	136.7	31.94	9.48
8	1	8	145.2	94.02	67.86
9	0	2	78.3	3.10	0.01
10	0	2	22.2	0.12	0.00
11					
Tot	10	50			

The fitted model

$$R = 0.4 + 0.3\ \text{Ave} - 0.1\ \text{Var},$$

in which only the coefficient for M3 is zero, indicates that logit (π) increases by 0.3 with a one unit increases in average gross revenue but decreases by 0.1 with a one unit increase in the variance. The fishermen's preferences are increasing when the average gross revenue per hour increases, but the preferences decrease as the variance of the gross revenue per hour increases, the utility curve is concave-down (see Figure 1B), and the fishermen are risk-averse. If the coefficient for variable Var had been positive, it would imply that the fishermen's preferences increase with increasing variance in the gross revenue per hour; the utility curve would be concave-up and the fishermen would be risk-prone.

In the following fitted model, which includes a non-zero coefficient for the third moment,

$$R = 0.3 + 0.6\ \text{Ave} - 0.5\ \text{Var} + 0.2\ \text{M3}$$

the logit (π) increases by 0.6 units for each one unit increase in average gross revenue per hour, decreases by 0.5 units for each one unit increase in the variance, and increases by 0.2 units for each one unit increase in the third moment. In this case the curvature of the utility curve is increasing (Figure 5A), which implies that the fishermen are risk-averse, but would become risk-prone with higher levels of gross revenue per hour. In contrast, if the coefficient for variable Var had been positive and the coefficient for variable M3 had been negative, then logit (π) would increase by 0.6

units for each unit increase in average reward and would increase by 0.5 units for each unit increase in the variance, but would decrease by 0.2 units with each unit increase in the third moment. In this case the curvature of the utility curve is decreasing (Figure. 5B), which implies that the fishermen are risk-prone, but would become risk-averse at higher levels of gross revenue per hour.

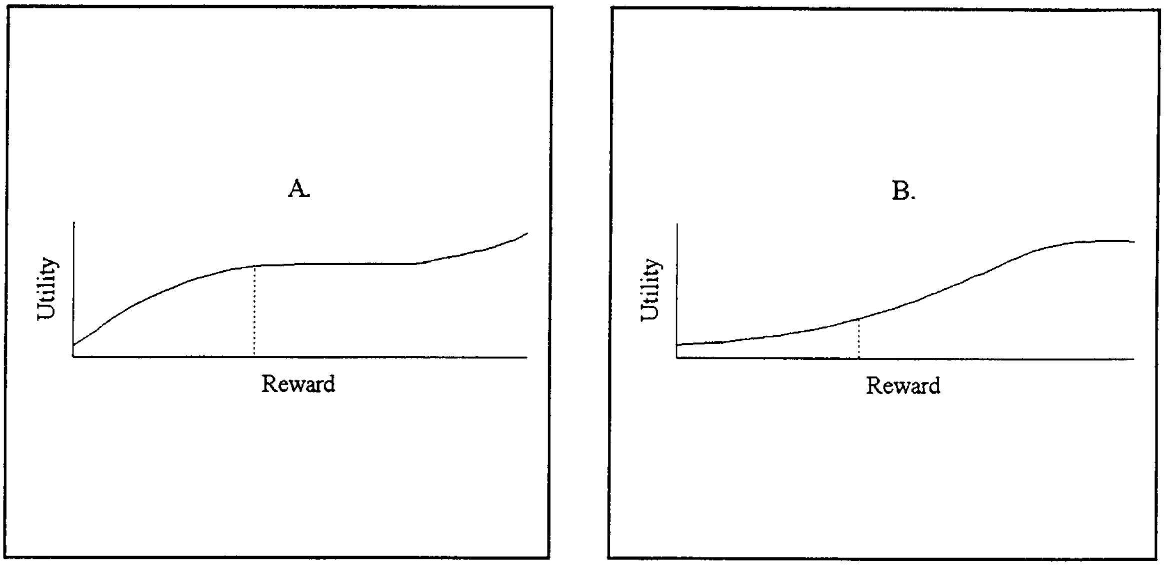
Table 18 Results from testing for seasonal fishing patterns for fishing vessels operating with generic bottom trawls off Astoria.

Area (nautical mile)	Boat Length (Feet)	Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
0-10	30-39	Loc	-	21.0	24	-	-	-
		Loc.Qtr	Qtr	16.3	18	4.7	6	0.87^{ns}
	50-50	Loc	-	35.0	22	-	-	-
		Loc.Qtr	Qtr	28.7	13	6.4	9	0.32^{ns}
	60-69	Loc	-	45.9	45	-	-	-
		Loc.Qtr	Qtr	33.3	33	12.7	12	1.51^{ns}
10-20	60-69	Loc	-	30.7	43	-	-	-
		Loc.Qtr	Qtr	16.5	23	14.2	20	0.99^{ns}

Loc = Fishing Location;
Qtr = Quarter.

For each category of port, fishing area, gear, and boat length I tabulated in Table 27 the logistic regression parameter estimates and standard errors based on the

Figure 5 (A) Fishermen are risk-averse and would become risk-prone with higher levels of reward. (B) Fishermen are risk-prone and would become risk-averse at lower levels of reward. If fishermen are risk neutral the utility function is a straight line.



results of the F-tests in Tables 23B, 24B, 25B, and 26. For example, the analysis in Table 23B of vessels operating with generic bottom trawls off Astoria indicated that the coefficients for Ave and Var are significant at the 95% confidence level but the coefficient for M3 is not. Included in Table 27 are the parameter estimates and standard errors corresponding to the model

Area.Ave.Blen + Area.Var.Blen,

but the values for M3 are listed as zero. My interpretation of the parameter estimates with regard to the fishermen's attitudes towards risk are shown in Table 28.

Astoria

There were four categories of data from Astoria for which I conducted a formal analysis of fishing location preferences: all of the vessels used the gear generic bottom trawl/sole net. The vessels fishing in the area 10-20 nautical miles off Astoria were in the boat length categories of 30-39 feet, 50-59 feet, or 60-69 feet (Table 8); the vessels fishing in the area 20-30 nautical miles off Astoria were in the 60-69 foot category (Table 9).

As shown in Table 22B, I was unable to successfully fit the model Ave.Blen + Var.Blen and the model Ave.Blen + Var.Blen + M3.Blen. Normally, the GLIM program tries to fit the data using an iterative approach until there is convergence. In some situations, such as fitting a logit model to data with many zero proportions (the Y variable), the iterative process may not converge (Healy, 1988). When I examined the data for the 50-59 foot boats I found that a large number of the first tows were in fishing location number one (Table 8) and four out of nine fishing locations did not have any first tows. Additionally, some fishing locations had very low values for the average gross revenue per hour and variance. As a consequence, the GLIM program never converged when fitting the models to the complete data set for Astoria. Given the problems mentioned above, I decided to exclude the data for the 50-59 foot boats and re-analyze the remaining data (Table 23A and 23B).

Table 19 Results from testing for seasonal fishing patterns for fishing vessels operating with generic bottom trawls off Newport.

Area (nautical mile)	Boat Size (Feet)	Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
10-20	40-49	Loc	-	23.3	26	-	-	-
		Loc.Qtr	Qtr	14.9	16	8.4	10	0.88^{ns}
	50-59	Loc	-	20.2	24	-	-	-
		Loc.Qtr	Qtr	12.6	13	7.7	11	0.72^{ns}
20-30	50-59	Loc	-	57.4	38	-	-	-
		Loc.Qtr	Qtr	27.3	27	30.1	11	2.71^{**}
	60-69	Loc	-	18.7	22	-	-	-
		Loc.Qtr	Qtr	14.6	14	4.2	8	0.50^{ns}
30-40	60-69	Loc	-	23.2	21	-	-	-
		Loc.Qtr	Qtr	14.1	11	9.1	10	0.71^{ns}
	70-79	Loc	-	21.1	23	-	-	-
		Loc.Qtr	Qtr	10.9	13	10.3	10	1.23^{ns}

Loc = Fishing Location;
Qtr = Quarter;
** = significant at the 99% confidence level.

Table 20 Results from testing for seasonal fishing patterns for fishing vessels operating with generic bottom trawls off Coos Bay.

Area (nautical mile)	Boat Size (Feet)	Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
0-10	50-59	Loc	-	19.243	23	-	-	-
		Loc.Qtr	Qtr	14.789	15	4.454	8	0.565^{ns}
10-20	40-49	Loc	-	17.7	27	-	-	-
		Loc.Qtr	Qtr	6.5	15	11.2	12	2.18^{ns}
	50-59	Loc	-	51.2	44	-	-	-
		Loc.Qtr	Qtr	35.8	30	15.5	14	0.92^{ns}
20-30	50-59	Loc	-	39.9	37	-	-	-
		Loc.Qtr	Qtr	24.7	22	15.1	15	0.90^{ns}
30-40	50-59	Loc	-	30.1	28	-	-	-
		Loc.Qtr	Qtr	13.4	19	16.7	9	2.64^{*}

Table 21 Results from testing for seasonal fishing patterns for fishing vessels operating with bottom trawls equipped with roller gears off Coos Bay.

Area (nautical mile)	Boat Size (Feet)	Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
10-20	60-69	Loc	-	16.1	24	-	-	-
		Loc.Qtr	Qtr	9.1	14	7.0	10	1.08^{ns}

Loc = Fishing Location;
Qtr = Quarter;
* = significant at the 95% confidence level.

Table 22A. Results of statistical analysis of fishing vessels operating with generic bottom trawls off Astoria.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area	Uniform distribution	2665.1	38			
Area.Ave	Ave	2442.5	36	222.6	2	1.64^{ns}
Area.Var	Var	2287.8	36	377.4	2	2.97^{ns}
Area.Ave+Area.Var	Var (given Ave)	2281.6	34	160.9	2	1.20^{ns}
Area.Ave+Area.Var+Area.M3	M3	2247.0	32	34.6	2	0.25^{ns}

Table 22B. Results of statistical analysis of fishing vessels operating with generic bottom trawls off Astoria.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area.Blen	Uniform distribution	2526.6	36			
Area.Ave.Blen	Ave	1764.1	32	762.5	4	3.46^{*}
Area.Var.Blen	Var	2130.3	32	396.5	4	1.49^{ns}
Area.Ave.Blen+Area.Var.Blen	Var (given Ave)	Iter.Div.	28			
Area.Ave.Blen+Area.Var.Blen +Area.M3.Blen	M3	Iter.Div.	24			

Ave = Average Gross Revenue per hour ($/Hr.); Var = Variance;
M3 = Third moment; Blen = Boat length;
ns = Not significant at 95% confidence level;
* = Significant at 95% confidence level.

There was a highly significant reduction in deviance (99% confidence level) when I added average gross revenue per hour to the null model that ignored boat length differences (Table 23A), but neither adding terms for the variance nor for the third moment gave any further significant reduction in deviance (95% confidence level). The reduction in deviance was also highly significant (99% confidence level) when I added average gross revenue per hour to the null model that included boat length differences (Table 23B), and when the variable variance was subsequently added to the model, there was a further significant reduction in the deviance (95% confidence level). There was no significant reduction in the deviance when I subsequently added the third moment to the model.

In the models for fishermen fishing in the area 0-10 nautical miles off Astoria with boat length classes of 30-39 feet and 60-69 feet there were negative coefficients for the variance term, which indicated that these fishermen were risk-averse (Table 27). In the models for fishermen fishing in the area 10-20 nautical miles off Astoria with 60-69 foot boats there was a positive coefficient for the variance term but the coefficient on the term for the average gross revenue per hour (Ave) was negative (Table 27), which indicates that these fishermen tended to avoid locations with higher rewards. This is contrary to the basic theory of the variance-discounting model. However, a closer look at these data suggested that the fishermen may have been unable to detect differences in the average gross revenue per hour due to the very large variances at some locations (Table 9).

Table 23A. Results of statistical analysis of fishing vessels operating with generic bottom trawls off Astoria, excluding data for 50-59 foot vessels.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area	Uniform distribution	2077.7	29			
Area.Ave	Ave	1526.2	27	551.5	2	4.88**
Area.Ave+Area.Var	Var (given Ave)	1365.7	25	163.6	2	1.50^{ns}
Area.Ave+Area.Var+Area.M3	M3	1313.5	23	52.2	2	0.46^{ns}

Table 23B. Results of statistical analysis of fishing vessels operating with generic bottom trawls off Astoria, excluding data for 50-59 foot vessels.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area.Blen	Uniform distribution	2062.1	28			
Area.Ave.Blen	Ave	1301.9	25	760.2	3	4.87**
Area.Ave.Blen+Area.Var.Blen	Var (given Ave)	952.1	22	349.7	3	2.69*
Area.Ave.Blen+Area.Var.Blen +Area.M3.Blen	M3	866.6	19	85.6	3	0.63^{ns}

Ave = Average gross revenue per hour ($/Hr.); Var = Variance;
M3 = Third moment; Blen = Boat Length;
ns = Not significant at 95% confidence level;
* = Significant at 95% confidence level;
** = Significant at 99% confidence level.

Newport

There were six categories of data used in the formal analysis of location choice for boats fishing out of Newport (Table 27). All of the vessels used the same gear, generic bottom trawl/sole net.

When the variable average gross revenue per hour was added to the null model there were significant reductions in the deviance both for the model that ignored boat length differences (Table 24A, 95% confidence level) and for the model that included boat length differences (Table 24B, 95% confidence level). When the variables "variance" and "third moment" were subsequently added to the models the reductions in deviance were not significant at the 95% confidence level either for the model that ignored boat length differences or the model that did not.

In the models for fishermen operating 10-20 nautical miles off Newport, in either 40-49 or 50-59 foot boats the coefficient on the terms for the average gross revenue per hour were positive (Table 27) and these fishermen appear to be risk-neutral (Table 28). This was also the result for fishermen operating 20-30 nautical miles in 50-59 foot boats. However, in the three remaining categories for Newport (60-69 foot boats operating 20-30 and 30-40 nautical miles for port, and 70-79 foot boats operating 30-40 nautical miles form port) the coefficients on the terms for the average gross revenue per hour were negative and the results were inconclusive with regard to the fishermen's attitudes towards risk (Table 28). To avoid locations that produce higher rewards is contrary to the idea of utility maximization. However, just as I found in the data set for fishermen fishing in the area 20-30 nautical miles off

Newport with 60-69 foot boats, a closer look at the data sets for these three categories showed very large of variances for some locations (Tables 11 and 12).

Coos Bay

In my analysis of fishing location choice by fishermen operating vessels from Coos Bay I separated the data on the basis of gear type: generic bottom trawl/sole net versus roller gear. For the fishing vessels using generic bottom trawl/sole net, when I added the variable average gross revenue per hour to the null model, there were no significant reductions in the deviance at the 95% confidence level both for the model that ignored boat length differences (Table 25A) and for the model that included boat length differences (Table 25B). These result suggests that these fishermen were completely unresponsive to changes in the average gross revenue per hour, which is contrary to the basic utility model underlying the analysis.

For the fishing vessels using roller gear there was only one data category available, 60-69 foot fishing vessels fishing in the area 20-30 nautical miles off Coos Bay (Table 17). Average gross revenue per hour was the only significant factor at the 95% confidence level (Table 26) and the coefficient on this term was positive, which indicates that these fishermen appear to be risk-neutral (Table 28).

Table 24A. Results of statistical analysis for fishing vessels operating with generic bottom trawls off Newport.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area	Uniform distribution	1440.2	39	-	-	-
Area.Ave	Ave	1122.9	36	318.1	3	3.40^{*}
Area.Var	Var	1339.8	36	100.3	3	0.90^{ns}
Area.Ave+Area.Var	Var	992.1	33	130.0	3	1.44^{ns}
Area.Ave+Area.Var+Area.M3	M3	846.7	30	145.4	3	1.72^{ns}

Table 24B. Results of statistical analysis for fishing vessels operating with generic bottom trawls off Newport.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area.Blen	Uniform distribution	1389.1	36	-	-	-
Area.Ave.Blen	Ave	634.7	30	754.5	6	5.94**
Area.Var.Blen	Var	823.3	30	565.8	6	3.44*
Area.Ave.Blen+Area.Var.Blen	Var	562.2	24	74.4	6	0.52^{ns}
Area.Ave.Blen+Area.Var.Blen +Area.M3.Blen	M3	498.3	18	64.0	6	0.39^{ns}

Ave = Average gross revenue per hour ($/Hr.); Var = Variance;
M3 = Third Moment; Blen = Boat Length;
ns = Not significant at 95% confidence level;
* = Significant at 95% confidence level;
** = Significant at 99% confidence level.

Table 25A. Results of statistical analysis for fishing vessels operating with generic bottom trawls off Coos Bay.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area	Uniform distribution	935.0	32	-	-	-
Area.Ave	Ave	910.6	28	24.4	4	0.19^{ns}
Area.Var	Var	865.8	28	69.2	4	0.56^{ns}
Area.Ave+Area.Var	Var	850.7	24	59.9	4	0.42^{ns}
Area.Ave+Area.Var+Area.M3	M3	431.7	20	419.0	4	4.85^{**}

Table 25B. Results of statistical analysis for fishing vessels operating with generic bottom trawls off Coos Bay.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-test
Area.Blen	Uniform distribution	935.0	31	-	-	-
Area.Ave.Blen	Ave	869.8	26	65.2	5	0.39^{ns}
Area.Var.Blen	Var	863.7	26	71.3	5	0.43^{ns}
Area.Ave.Blen+Area.Var.Blen	Var	811.7	21	58.1	5	0.30^{ns}
Area.Ave.Blen+Area.Var.Blen +Area.M3.Blen	M3	368.7	16	443.1	5	3.85^{**}

Ave = Average gross revenue per hour ($/Hr.); Var = Variance;
M3 = Third Moment; Blen = Boat Length;
ns = Not significant at 95% confidence level;
** = Significant at 99% confidence level..

Table 26. Results of statistical analysis for 60-69 foot fishing vessels operating with bottom trawls equipped with roller gear off Coos Bay.

Model	Test of	Deviance	Df	Reduction in Deviance	Df	F-ratio
Area	Uniform distribution	75.5	7	-	-	-
Area.Ave	Ave	36.1	6	39.4	1	6.54^{*}
Area.Var	Var	69.1	6	6.4	1	0.55^{ns}
Area.Ave+Area.Var	Var	22.0	5	14.1	1	3.21^{ns}
Area.Ave+Area.Var+Area.M3	M3	21.7	4	0.3	1	0.02^{ns}

Ave = Average gross revenue per hour ($/Hr.); Var = Variance;
M3 = Third Moment; Blen = Boat Length;
ns = Not significant at the 95% confidence level;
* = Significant at 95% confidence level.

Table 27 Logistic regression estimates for the variance-discounting model of fishing location preferences. Standard errors are shown in parentheses. "ns" indicates non-significant coefficients as determined in previous F-tests (Tables 23B, 24B, 25B, and 26).

Port	Area (Nautical mile)	Gear	Boat Length (Feet)	μ	Ave	Var	M3
Astoria	0-10	Bottom trawl/ Sole gear	30-39	-3.91 (0.33)	0.017 (0.0020)	-7.77 (0.00042)	0
			60-69	-9.68 (0.44)	0.043 (0.0023)	-0.032 (0.0026)	0
	10-20	Bottom trawl/ Sole gear	60-69	-1.62 (0.45)	-0.0084 (0.0038)	0.032 (0.0027)	0
Newport	10-20	Bottom trawl/ Sole gear	40-49	-1.92 (0.47)	0.0054 (0.0057)	0	0
		Bottom trawl/ Sole gear	50-59	-3.78 (0.45)	0.043 (0.0053)	0	0
	20-30	Bottom trawl/ Sole gear	50-59	-7.52 (0.27)	0.065 (0.00027)	0	0
		Bottom trawl/ Sole gear	60-69	-0.56 (0.34)	-0.078 (0.0029)	0	0
	30-40	Bottom trawl/ Sole gear	60-69	-1.044 (0.22)	-0.0041 (0.0013)	0	0
		Bottom trawl/ Sole gear	70-79	-1.36 (0.21)	-0.00097 (0.00084)	0	0
Coos Bay	0-10	Bottom trawl/ Sole gear	50-59	-1.25 (0.062)	0	0	0
	10-20	Bottom trawl/ Sole gear	40-49	-1.99 (0.072)	0	0	0
		Bottom trawl/ Sole gear	50-59	-2.0021 (0.039)	0	0	0
	20-30	Bottom trawl/ Sole gear	50-59	-1.67 (0.035)	0	0	0
	30-40	Bottom trawl/ Sole gear	50-59	-0.79 (0.057)	0	0	0
	10-20	Roller gear	60-69	-5.37 (0.77)	0.029 (0.0054)	0	0

Table 28 Summary of the fishermen's attitudes towards risk.

Port	Area (Nautical mile)	Gear	Boat Length (Feet)	Attitudes Towards Risk
Astoria	0-10	Bottom trawl/Sole gear	30-39	risk-averse
			60-69	risk-averse
	10-20	Bottom trawl/Sole gear	60-69	inconclusive
Newport	10-20	Bottom trawl/Sole gear	40-49	risk-neutral
		Bottom trawl/Sole gear	50-59	risk-neutral
	20-30	Bottom trawl/Sole gear	50-59	risk-neutral
		Bottom trawl/Sole gear	60-69	inconclusive
	30-40	Bottom trawl/Sole gear	60-69	inconclusive
		Bottom trawl/Sole gear	70-79	inconclusive
Coos Bay	0-10	Bottom trawl/Sole gear	50-59	inconclusive
	10-20	Bottom trawl/Sole gear	40-49	inconclusive
		Bottom trawl/Sole gear	50-59	inconclusive
	20-30	Bottom trawl/Sole gear	50-59	inconclusive
	30-40	Bottom trawl/Sole gear	50-59	inconclusive
	10-20	Roller gear	60-69	risk-neutral

VI. DISCUSSION

One would expect that commercial logbook data would reflect aspects of risk-sensitive foraging as found in earlier investigations. For example, Bockstael and Opaluch (1983) found that fishermen in New England were risk-averse, and Dupont (1993) found that fishermen in the British Columbia salmon fishery were risk-prone. However, unlike these earlier investigations, in this research I found for many categories of the data that the fishermen did not respond in a positive manner to increasing reward. The coefficients on the terms for the average gross revenue per hour in some cases were zero or negative (Table 27). According to the assumption that fishermen attempt to maximize their profits, one would expect them to prefer locations that yielded higher gross revenue per hour, and in the utility function the coefficient for the average gross revenue per hour should be positive. The negative coefficients suggest that fishermen preferred lower average gross revenue per hour, which is illogical and contrary to the basic assumption of profit maximization.

OBSERVATIONS BY PORT

Astoria

When I applied the set of variance-discounting models to the data for each port, Astoria was the only one for which I found significant coefficients on the terms for the variance in the gross revenue per hour (Table 23 B). Of the three Astoria data categories that I was able to fully analyze, I found that two showed evidence of risk-aversion (Table 28), with positive coefficients on the terms for the average gross revenue per hour and negative coefficients on the terms for the variance (Table 27). The third category I classified as "inconclusive" with regard to risk attitudes because the coefficient on the term for the average gross revenue per hour was negative. The coefficients on the term for the third moment were not significant in the models for any of the three ports.

With regard to the influence of the third moment, Caraco and Chasin (1984) stated their belief that evidence for such influence is rare in the literature. It appears then that my finding was not unusual. My results implied that the fishermen did not respond to the direction of skewness in catch rates and that the utility function for these fishermen did not have an inflection point.

Newport

In my analysis of the data for Newport I found that the coefficients were not significant on the terms for both the variance and the third moment of gross revenue per hour, but the coefficients were significant for the terms for average gross revenue per hour (Table 24 B); in three of the six data categories they were positive (Table 27). I interpreted positive coefficients on the terms for the average gross revenue per hour when coupled with non-significant coefficients for the variance terms, as evidence of risk neutrality. The negative coefficients on the terms for the average gross revenue per hour, which I found for three of the six data categories, are contrary to the theory that underlies the variance-discounting model. I classified the results for these categories as "inconclusive" with regard to risk attitudes (Table 28).

Coos Bay

In my analysis of the data for Coos Bay the coefficients on the terms for the average gross revenue per hour were not significant for five of the six data categories (Tables 25 B and 26) and I classified these five categories as "inconclusive" with regard to risk attitudes (Table 28). The remaining category had a positive coefficient on the term for the average gross revenue per hour and a non-significant coefficient for the variance term (Table 27), which I interpreted as evidence of risk neutrality. Although most of these fishermen were apparently unresponsive to differences between fishing locations in the average gross revenue per hour, my analysis indicated that for all ports the distributions of first tows were significantly different from the uniform distribution that random selections of fishing locations would have produced.

FACTORS AFFECTING THE RESULTS

The results of my formal analyses were ambiguous regarding how fishermen decide on where to go fishing. The way they responded to uncertainty for individual fishing locations often appeared irrational and differed from what natural foragers in theory would do. Fishermen's decisions may be either more complicated than those of natural foragers and the variance-discounting model may be inappropriate for fishermen, or there may be problems with the data. In the following section I discuss potential problems with the data that may have affected the results of this research.

Potential Data Errors.

Even though this research screened out much of the data that potentially was inaccurate, unexpected errors could have been overlooked and may be the cause of the sometimes inconsistent and inconclusive results. The following errors may have affected the results:

1). Excluded data. More than 50% of the fishing trips each month were excluded from the formal analysis with the variance-discounting model either because of discrepancies between the tow-by-tow hailed catches and the official landed weights reported by the processor or because the trips were over the trip limits (Table 6). Consequently, the average gross revenue per hour for a fishing location, which was calculated from the tow-by-tow catches, may not be accurate because it was averaged only from some trips, specifically only the "usable" trips, and it excluded the catches from the "bad" trips. For a fishing location that happened to have bad tows, the true average gross revenue per hour may have been lower or higher than what I estimated. In addition, the average gross revenue per hour may not represent the value from all fishing vessels because many fishing vessels were excluded because all their trips were eliminated (Table 7).

2). Effect of trip limits. Under the single species trip limits, landings of certain species over the trip limits were prohibited (See method: data preparation), but fishermen could discard excess catch at sea. As a result, the average gross revenue per hour for trips that hit the limits was probably smaller than the true average gross revenue per hour; the catch rates reported in the logbooks underestimated the real catch per hour. The errors from discarding fish due to trip limits may have affected the results of this research because the "usable" trips used in the analysis may have been under the trip limits because the skippers discarded some of their catches. The evidence of discarding due to trip limit regulations was strongly supported by the investigation of Pikitch, Erickson, and Wallace (1988) who found that discarding was mainly due to the trip limit regulations for Pacific ocean perch (*Sebastes alutus*), yellowtail rockfish (*S. flavidus*), widow rockfish (*S. entomelas*), sablefish (*Anoplopoma fimbria*, and the Sebastes complex (all rockfish except widow rockfish), in the groundfish fishery along the west coast off California, Oregon, and Washington. They also found that discarding of sablefish, a species with a higher price for larger fish, was mostly due to "high grading" in which smaller individuals were discarded and larger ones retained. About 60% of all discarded fish were discarded because of trip limits. They considered that the trip limit regulation resulted in high grading especially for the species with high prices. Their results imply that locations with high abundance of high price species would have more discarding than other locations. Hence, the average gross revenue per hour for some locations would be biased by the influence of trip limits.

In addition, changes in the trip limits for certain species may have affected the average gross revenue per hour in the same manner because certain species would have been selectively discarded more than others. During 1991 the trip limits for some species changed during the year. For example, the trip limits for yellowtail rockfish changed, effective on April 24, 1991, from 5,000 lbs. per week to one 5,000 lb. landing every other week. Changing the trip limits influences the amount of discarding: the more restrictive the policy, the more discarding there will be (Pikitch, Erickson, and Wallace, 1988). The magnitude of discarding during 1991 consequently varied depending on the species and the period of time. The trip limits for thornyhead, for example, effective on July 31, 1991, was increased to 12,500 lbs., while the overall trip limit on the deep water complex (thornyheads, Dover sole and, sablefish) remained the same. As a result, the effective trip limits for sablefish and Dover sole (the other two species in the deep water complex group) decreased. Hence, fishermen may have discarded more sablefish and Dover sole. In addition, sablefish are subject to high-grading because fishermen receive a higher price per-unit weight for the larger fish. Changes in the amount of discarding potentially affects the average gross revenue per hour, because certain species are more likely to be discarded than others and the prices differ between species. If discarding occurred at one fishing location, but not at the alternative locations, then the average catch and gross revenue per hour for this location would be underestimated relative to the average for the alternative ones.

The Assumption of Utility Maximization for the First Tow.

The research assumes that fishermen choose the first tow on an individual trip so as to maximize their utility. This assumption may not be valid. Fishermen may use the first tow to obtain information about catch rates in that fishing location, or to sample fish while on their way to some other destination.

The patches on which natural predators forage change with time (Stephens and Krebs, 1986), so too does the abundance of fish at fishing locations. Fishermen may know from previous trips that fish are abundant in a particular fishing location, and they probably keep that location in mind as an option for the next trip. However, they also know that with changing ocean conditions the fishing at that location may not be the same. Also, a poor fishing location may improve while a good one may degrade. So, fishermen may sample at previously good or bad locations. They may also sample locations out of habit or custom. Fishermen may behave the same as natural foragers who routinely sample at different foraging patches (Lendrem, 1986; Stephens and Krebs, 1986). In this situation, the first tow of a fishing trip may reflect the fishermen's attempts to gather information about catch rates rather than attempts to maximizing short-run utility.

To investigate whether fishermen use their first tows to sample fish I conducted some additional analyses. I reasoned that if the first tow on a trip is for sampling, fishermen would spend less time with this tow and the duration of the first tows would be less than the average duration of all the tows in that trip. The ratio of the time spent on the first tow over the average tow time on a trip would be less than one.

Table 29 shows the total number of first tows by port, the number of tows that have the ratio equal to one, less than one, and greater than one. As can be seen, there were essentially the same number of trips with ratios less than, and greater than one, which suggests that fishermen do not consistently use the first tows to sample the fish abundance, although some may be doing so.

Table 29. The total number of first tows by port and the ratio of the time spent on the first tow for the trip to the average time for an individual tow on that trip.

Port	Total Number of First Tows	R = 1	R > 1	R < 1
Astoria	373	62	126	185
Newport	388	34	195	125
Coos Bay	231	6	125	100
Total	992	102 (10.28%)	446 (44.96%)	444 (44.76%)

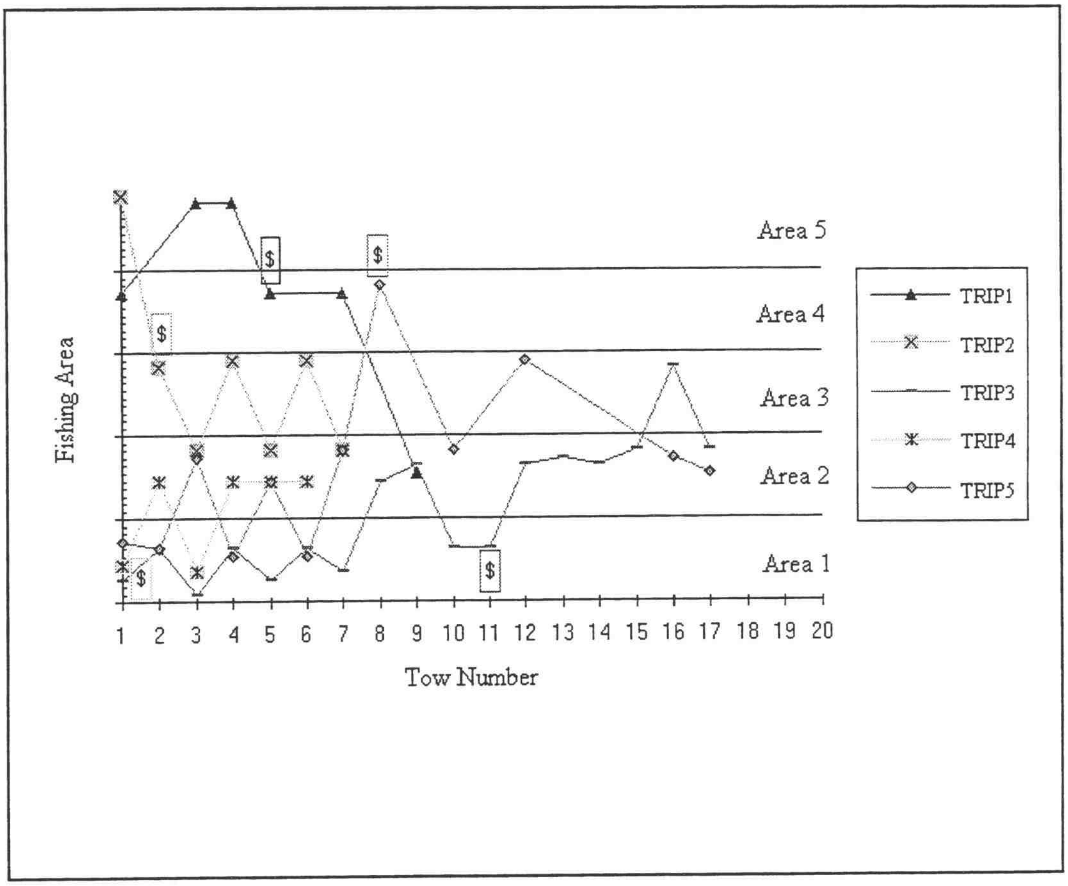
I conducted additional analyses with some randomly selected fishing vessels to investigate whether there were consistent patterns in the location of first tows. Figures 6-8 show the sequences of fishing locations for some trips made during 1991 by three arbitrarily selected fishing vessels, one boat from each port. From each vessel, I selected those trips that had complete information for more or less all tows, although some trips were missing the location information for a few tows. The x-axis shows the sequence of tows for each trip. The y-axis represents the fishing locations in each fishing area. Each horizontal band represents a different fishing area and the vertical placement within a band represents the fishing locations. The dollar sign symbol indicates the tow on each trip that produced the maximum average gross revenue per hour. With this diagram I wanted to explore two ideas: (1) fishermen use experience from recent trips to decide where to make their first tows: (2) fishermen, out of habit, organize their trips according to a fixed pattern. Figures 6A and 6B show the fishing trips for a fishing vessel from Astoria. For this fishing vessel, none of the first tows were in the same fishing locations as previous first tows. Moreover, all of the fishing trips seem to follow a different pattern. Even though there was evidence that this boat revisited certain locations, the revisiting was usually within the same trip. The diagrams for fishing trips from the other two vessels from Newport and Coos Bay (Figures 7 and 8 respectively) also show that fishing patterns change from trip to trip. These figures suggests that the fishermen did not use results from recent previous trips in deciding where to make their first tows. The revisiting of certain locations during a trip probably indicates that the fishermen were not making tows strictly based on habits but rather were using the most up-to-date information collected during the trip based on their samplings of different locations. Based on the available data, however, it is unclear how they made the decisions about where to fish.

Fishermen may use information from fishing trips that occurred during the same period of time in the previous year and plan their trips based on that source of information. The groundfish fishery has many possible target species and the species mix in the catch will vary depending on the trip limits and the seasonal distributions of the species. Landings by major species differ from month to month. For example, there were high percentages of widow rockfish in the landings during December through February in Astoria and during January through March in Newport and Coos Bay (Table 30, 31, 32). Some of the changing patterns in fishing locations may be a reflection of seasonal changes. My analysis of first tow locations from quarter to quarter found little evidence for significant seasonal changes in first tow locations, but the analysis had limited data and limited power to detect changes.

The Assumption of Equal Costs Within Fishing Areas.

In the design of my analysis of fishing location preferences the individual locations within a given fishing area were assumed to be equally costly to fish at because they were all roughly the same distance from port. Costs for fuel and travel time should be more or less equal at all locations within an area, but there may be other costs associated with certain areas. For example, some locations may be particularly rough and difficult to fish on successfully. Inexperience fishermen might damage or lose their fishing gear when operating in such areas. Even though fishing at a particular location could produce high rewards, the costs in terms of lost gear or time spent learning how to fish this location could affect the potential benefits. My analysis had no data with which to measure these types of costs.

Figure 6A Fishing patterns from trips 1-5 for a fishing vessel from Astoria.



Area 1 = Fishing area 0-10 nautical miles off Astoria;
Area 2 = Fishing area 10-20 nautical miles off Astoria;
Area 3 = Fishing area 20-30 nautical miles off Astoria;
Area 4 = Fishing area 30-40 nautical miles off Astoria;
Area 5 = Fishing area 40-50 nautical miles off Astoria.

Figure 6B Fishing patterns from trips 6-10 of a fishing vessel from Astoria (Continue from Figure 6A).

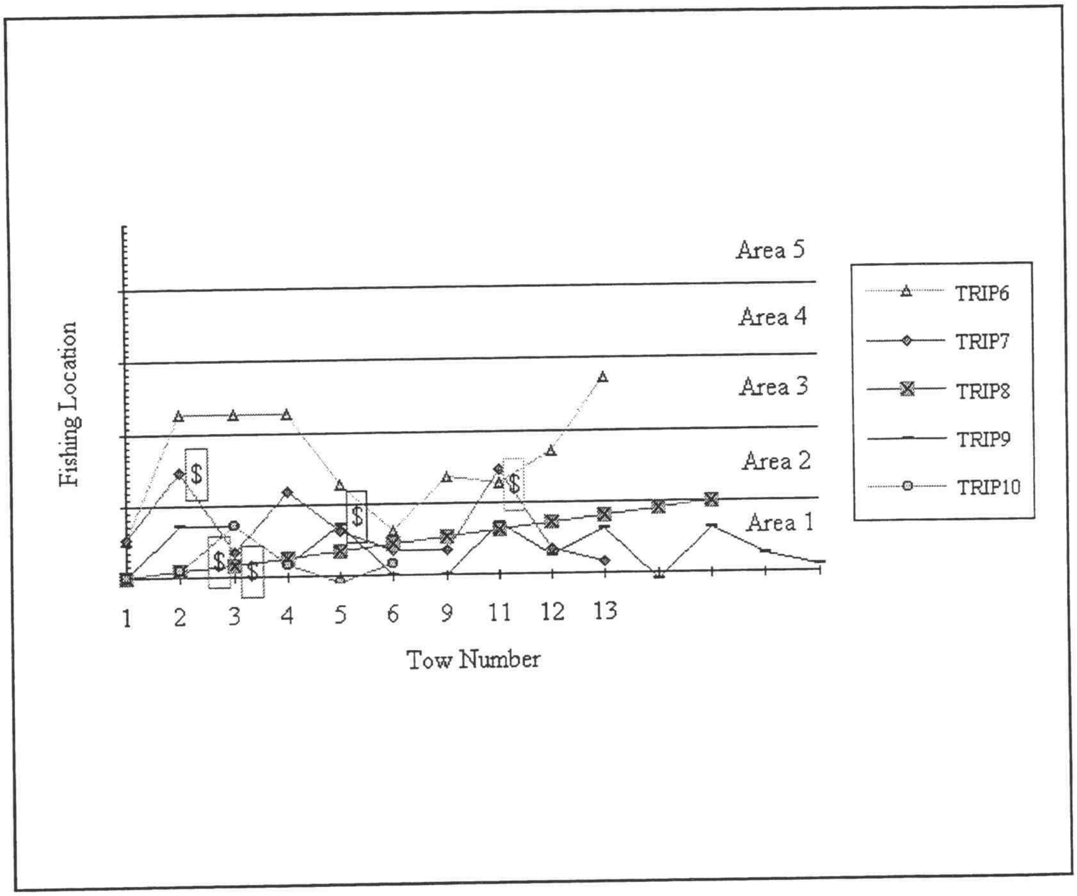
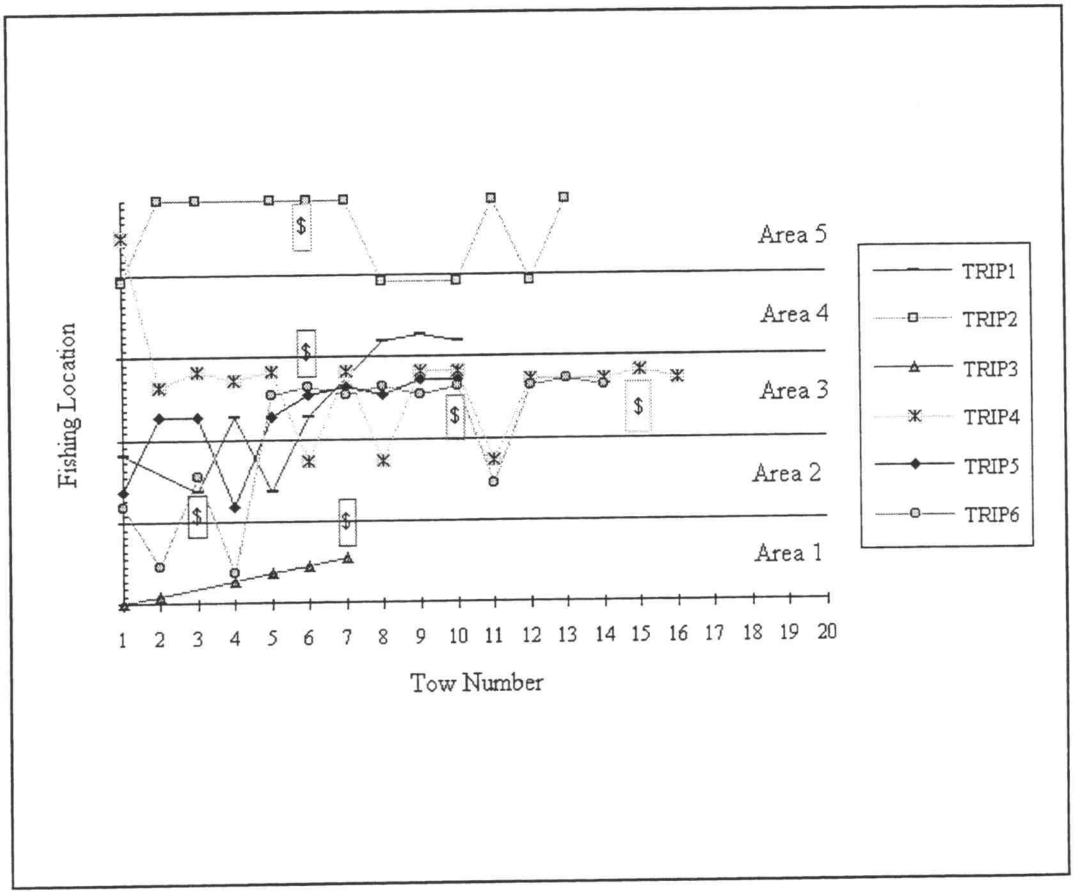
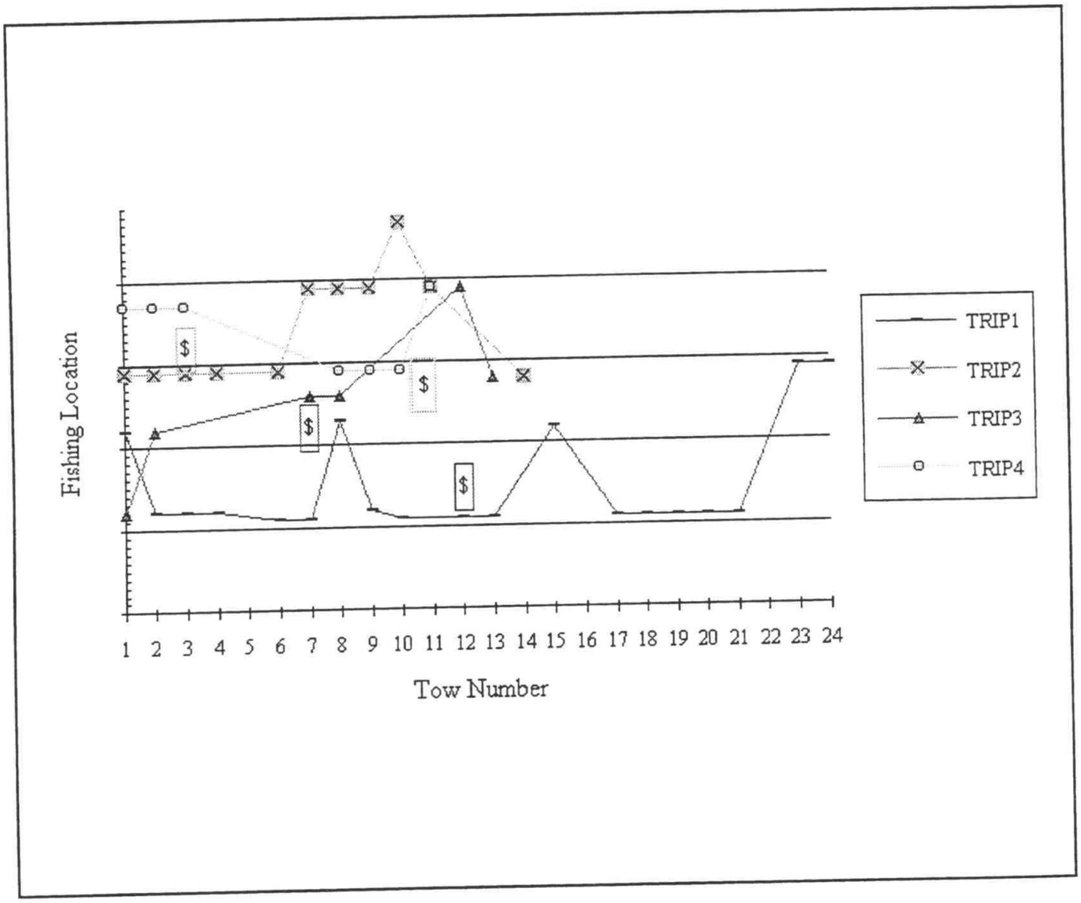


Figure 7 Fishing patterns of a fishing vessel from Newport.



Area 1 = Fishing area 0-10 nautical miles off Newport;
Area 2 = Fishing area 10-20 nautical miles off Newport;
Area 3 = Fishing area 20-30 nautical miles off Newport;
Area 4 = Fishing area 30-40 nautical miles off Newport;
Area 5 = Fishing area 40-50 nautical miles off Newport.

Figure 8 Fishing patterns of a fishing vessel from Coos Bay.



Area 1 = Fishing area 0-10 nautical miles off Coos Bay;
Area 2 = Fishing area 10-20 nautical miles off Coos Bay;
Area 3 = Fishing area 20-30 nautical miles off Coos Bay;
Area 4 = Fishing area 30-40 nautical miles off Coos Bay;
Area 5 = Fishing area 40-50 nautical miles off Coos Bay.

Table 30 Species landed as a percentage of the total monthly landings in Astoria.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	1.2	4.2	1.2	0.9	2.3	3.6	4.3	3.7	4.2	5.5	3.4	0.8
Rock sole												
Petrale sole	9.1	5.8	1.1	0.5	0.7	1.2	1.1	0.7	0.8	1.5	3.2	5.8
Dover sole	30.4	24.6	37.8	35.5	18.6	12.6	12.4	15.4	18.3	21.9	22.2	27.2
Rexsole	1.7	4.7	1.0	1.1	2.2	3.1	2.2	1.7	2.2	3.1	1.7	0.9
Starry flounder		0.01	1.4	0.1	4.3	1.4	3.7	3.3	2.4	0.3	2.9	
Butter sole				0.02								
Sanddab	0.3	0.9	0.6	1.1	1.2	1.7	0.8	0.4	0.3	1.1	0.5	0.3
Curlfin sole						0.01						0.01
Arrowtooth sole	6.3	4.5	5.0	6.4	14.5	20.6	10.3	17.5	11.7	8.3	6.0	5.2
Miscellaneous flatfish						0.07	0.01			0.07		
Small rockfish	0.5	0.4	0.4	0.5	0.9	0.4	0.4	0.4	0.5	1.0	0.7	1.1
Pacific ocean perch	3.8	4.8	3.5	3.0	3.3	3.0	3.0	3.9	4.1	4.6	4.2	3.5
Widow rockfish	12.4	16.3	8.9	3.5	4.5	8.8	9.7	8.9	21.6	16.6	8.1	20.7
Yellowtail rockfish	7.8	11.6	9.3	7.8	4.7	4.6	3.5	5.3	5.7	5.2	8.2	6.6
Thornyhead rockfish	3.9	3.9	3.1	2.5	3.8	2.4	1.7	1.9	4.5	7.5	12.4	7.3
Miscellaneous rockfish	8.9	9.6	6.9	10.8	12.2	9.0	8.6	11.0	11.4	11.1	11.0	7.6
Pacific whiting				0.4	15.7	15.1	26.6	12.8				
Pacific cod	0.6	0.7	1.0	1.4	2.5	5.6	4.5	5.3	2.5	2.2	1.1	0.6
Lingcod	7.4	2.1	10.8	18.5	3.6	3.0	3.6	4.1	4.7	2.9	5.4	4.6
Sablefish	5.2	5.0	4.9	4.8	4.1	2.9	2.1	2.9	4.3	6.5	7.9	7.8

Table 31 Species landed as a percentage of the total monthly landings in Newport.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	0.7	0.7	3.8	2.9	1.2	0.9	1.1	0.6	0.5	0.5	0.3	1.8
Rock sole					0.1	0.01						0.02
Petrale sole	2.3	1.6	2.9	1.8	0.6	0.6	0.8	0.4	0.1	0.1	0.1	2.7
Dover sole	12.6	12.3	13.1	19.3	11.6	5.1	6.7	5.5	4.0	3.0	2.8	16.3
Rexsole	0.3	0.5	1.6	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.5
Starry flounder		0.02		0.02	0.1	0.1	0.2	0.1	0.2	0.02	0.01	0.02
Butter sole												
Sanddab	0.6	0.04	1.6	0.7	0.01	0.2	0.1	0.02	0.03	0.01	0.02	0.2
Curlfin sole												
Arrowtooth sole	0.5	0.8	0.7	1.3	1.3	0.9	1.1	0.2	0.2	0.3	0.1	0.3
Miscellaneous flatfish	0.02	0.01	0.02				4.3					
Small rockfish	22.5	16.0	12.0	4.4	4.6	6.3	0.6	3.9	0.9	1.8	2.4	21.0
Pacific ocean perch	2.1	2.3	1.7	0.5	0.5	0.7	11.4	0.4	0.4	0.3	0.4	1.9
Widow rockfish	36.2	37.0	33.1	14.1	7.3	5.8	2.0	7.7	7.0	0.6	0.5	5.2
Yellowtail rockfish	4.4	6.1	8.1	3.4	1.6	1.2	4.6	1.1	1.1	0.5	0.6	4.5
Thornyhead rockfish	8.9	12.6	10.7	11.3	6.7	4.4	4.7	3.0	4.0	3.8	3.5	15.9
Miscellaneous rockfish	1.6	3.3	2.6	7.8	8.9	3.6	5.0	3.5	5.2	2.4	0.8	7.4
Pacific whiting				23.5	47.4	64.8	57.2	69.3	71.7	84.0	86.1	12.6
Pacific cod	0.02	0.1	0.5	0.3	0.5	0.5	0.4	0.4	0.04	0.04	0.01	0.2
Lingcod	2.7	0.6	1.9	1.4	2.13	1.6	1.1	0.8	0.7	0.5	0.1	0.6
Sablefish	4.5	5.6	5.3	6.5	4.2	2.5	2.9	2.6	2.2	1.8	1.8	8.8

Table 32 Species landed as a percentage of the total monthly landings in Coos Bay.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
English sole	1.5	2.7	1.5	1.6	1.9	2.9	2.3	1.4	2.1	1.7	0.9	0.9
Rocksole					0.04	0.01			0.01			
Petrale sole	13.2	4.4	1.2	1.9	0.9	1.0	0.7	0.4	0.6	0.7	2.8	14.3
Dover sole	34.5	37.9	44.1	45.4	32.6	27.2	27.3	22.3	24.4	32.3	31.0	29.9
Rexsole	0.6	0.4	0.2	0.1	0.3	0.4	0.1	0.02	0.04	0.02	0.04	0.2
Starry flounder		0.04			0.01	0.6	0.4	0.8	0.1	0.04		
Butter sole												
Sanddab	0.9	2.0	3.6	0.4	1.1	2.1	2.9	0.1	1.6	1.7	0.8	0.02
Curlfin sole						0.01	0.02	0.1	0.01			
Arrowtooth sole	0.4	0.4	0.2	0.5	1.7	2.2	2.1	1.5	1.1	1.4	0.7	1.1
Miscellaneous flatfish												
Small rockfish	3.4	3.6	3.8	3.5	3.7	7.7	4.6	2.0	3.5	3.9	3.0	3.5
Pacific ocean perch	0.1	0.3	0.1		0.2	0.04	0.3	0.1	0.1	0.02	0.1	0.2
Widow rockfish	12.8	14.7	11.1	4.0	3.4	4.4	6.8	8.7	13.2	2.7	1.5	1.2
Yellowtail rockfish	4.0	3.3	1.8	3.7	2.2	2.0	1.2	0.8	1.2	1.9	3.1	1.8
Thornyhead rockfish	13.4	14.0	13.4	9.3	10.2	12.1	13.1	18.3	16.1	20.4	32.1	27.4
Miscellaneous rockfish	7.6	6.6	8.5	11.2	20.2	17.3	18.9	8.4	12.3	16.1	8.7	5.7
Pacific whiting				4.4	7.6	2.2	2.8	20.8	9.5			
Pacific cod		0.01		0.03	0.02	0.1	0.1	0.03	0.03	0.1	0.02	0.02
Lingcod	0.4	2.6	0.6	2.1	2.7	4.3	3.8	1.6	1.4	3.4	1.4	0.5
Sablefish	7.0	6.9	9.3	11.2	10.5	9.3	9.9	9.4	9.1	11.0	11.8	12.3

Factors Having an Impact on Attitudes Towards Risk.

1). Wealth

One thing this research did not deal with is other factors such as wealth that may influence the fishermen's attitudes toward risk. In general, economists postulate that an individual decision maker's attitude toward risk will depend on the individual's level of wealth (Hanna, 1983).

This research tried to account for the influence of wealth on fishermen's attitudes towards risk by classifying the data by vessel size and assuming that fishermen operating the same class of vessel had similar wealth. Nevertheless, the research did not investigate the wealth of individual vessel operators. Within the same class of boat, the wealth of an individual vessel operator may vary depending on the economic situation that the vessel operator was facing. Specifically, some fishermen may have completely owned their vessels, while others may not have. Fishermen who had outstanding debts for their vessels would be in a different wealth class from those who did not. Also, fishermen who were in financial difficulties, for whatever the reasons, would be more likely to be risk-prone when compared to fishermen who were not facing this kind of problem.

The following example demonstrates how changing wealth could affect a decision makers' attitudes toward risk. When comparing fishermen to natural foragers, wealth is equivalent to energy reserves of natural foragers. Under normal conditions, natural foragers tend to select foods to maximize their energy intake (Caraco, Martindale, & Whittam, 1980; Lendrem, 1986; Stephens and Krebs, 1986). If they are risk-averse they will choose the less variable supplies, and they will prefer food supplies with high variability if they are risk-prone. However, when foragers are starving and their energy reserves are near exhaustion they are more likely to try and minimize the probability of starving rather than maximize their energy intake (Lendrem, 1986). In this case, otherwise risk-averse foragers become risk-prone. For example, experiments with dark-eyed Juncos (*Junco hyemalis*) have shown that these birds respond to changes in the variance of food reward when they are starving, but they are unwilling to do so when they are not starving; they normally prefer the constant food reward (Caraco, 1981).

2). Preferred target species

For the groundfish fishery, most fishermen have a stable arrangement with a processor who buys their catches (Smith and Hanna, 1990; Hanna, 1992; Smith and Hanna, 1993). Informally, processors may arrange for specific landings of some species. In this case fishermen may need to limit their catches of some species and increase their catches for other species for which there is high demand. Therefore, they may have preferred target species which are induced by their arrangements with the processor. They may choose locations that allow them to most easily satisfy their processor's orders, even though these locations do not produce the maximum gross revenue.

3). Weather

Weather is also a crucial factor that influences fishermen's attitudes toward risk. From a survey of vessel captains in Astoria, Newport, and Coos Bay, 77-100% of captains in each port considered weather as the most important source of risk in fishing (Hanna and Smith, 1993). How willing they are to take risks while fishing depends on the weather. Their fishing schedules and choice of locations may change due to the weather. They will tend to avoid bad weather either by canceling a trip or by changing their destination. I did not attempt to incorporate information on weather conditions into my analysis, but this additional factor might have influenced the results.

VII. CONCLUSIONS

Although I have identified some potential errors that may have influenced the results of my analysis of fishing location preferences, it is difficult in practice to rectify those errors because of the limited information available from the logbooks. The trip limit regulations in particular may have caused problems for the analysis. Trip limits result in the discarding of catch, which potentially distorts the actual catch rates for a location, especially in cases of high discard. If the logbooks had provided information about discarding, such as species and quantities of discarded fish for a location, it would have been possible to estimate catch rates more accurately. Unfortunately, this information was unavailable and there was no simple way to utilize information in the logbooks to solve this problem. Similarly, the problems due to factors such as wealth, which could either affect the results of the analysis or govern fishermen decisions, were beyond the contribution of logbooks. Besides using only logbooks and ticket files, future researchers may need to create or find other sources of information, such as a questionnaire specific for the analysis. However, questionnaires may be impractical because fishermen have varying levels of cooperation and willingness to share confidential information, such as financial status. Based on my research I have a few suggestions that could contribute to the success of future research in this area.

Fishing for certain species may occur during specific periods of year, in which case fishing location choices at certain times would be more specific to some locations, those locations where the target species was most abundant during that period of time. Rather than treating all fishing locations identically throughout the year, it might be more appropriate to group location choices and specify a set of location choices for a period of time within a year. Future researchers should analyze data from previous years to examine whether there is evidence of seasonal fishing patterns. If fishing differs depending on the period of time because target species abundance varies through time within a year, researchers need to analyze data over shorter time scales so that the data are more homogeneous within the same category of port, fishing area, boat length and period of fishing. Alternatively, the analyses could be limited to certain target species or group of species that are usually fished during the same period. Regarding the assumption of utility maximization for first tows, researchers should attempt to identify the key factors underlying fishermen's decisions of where to fish. Also helpful would be an investigation into fishing patterns by individual vessels. By reviewing fishing patterns from several years and identifying similarities, it might be possible to determine whether fishermen use the information from previous years.

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APPENDIX

Table A1 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 0-10 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)				
	40-49				
	FT	NT	$/Hr	Var	M3
1					
2					
3					
4	*0*	*2*	*80.4*	*2.72*	*-0.02*
5					
6					
7					
8					
9					
10					
11					
Tot	*0*	*2*			

Loc = Fishing locations; FT = Numbers of first tows; NT = Total numbers tows;
$/Hr = Average dollar per hour; Var = Var * 10^{-3}; M3 = Third moment * 10^{-6}; Tot = Total number

Table A2 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)														
	30-39					50-59					60-69				
	FT	NT	$/Hr	Var	M3	FT	NT	$/Hr	Var	M3	FT	NT	$/Hr	Var	M3
1															
2						0	3	69.3	4.05	0.05					
3	0	2	36.8	1.26	0.03										
4															
5						0	4	128.8	3.75	0.07					
6						0	3	74.40	0.50	0.00					
7						0	11	161.9	4.48	-0.09					
8						1	4	76.27	0.68	0.01					
9	1	9	79.9	3.11	0.27	1	6	80.0	1.85	0.09					
10	4	25	61.2	1.56	0.06	0	5	74.4	5.31	0.47	1	5	174.8	6.17	0.23
11	2	11	68.1	3.33	0.28	0	3	87.1	3.77	-0.12					
Tot	7	47				2	39				1	5			

Table A3 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 20-30 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)																								
	30-39					40-49					50-59					60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1																0	3	68.9	1.89	-0.01					
2																0	2	65.2	1.26	-0.01					
3																									
4	1	6	44.3	0.42	-0.01	0	4	133.2	2.89	0.01						1	10	134.6	58.87	21.30					
5											0	6	44.7	0.96	0.02	2	17	181.3	22.43	3.58	2	5	152.4	4.66	-0.04
6																0	3	179.1	20.45	-0.29					
7																0	3	241.6	104.54	34.80					
8																									
9																0	2	138.4	10.85	-0.81	1	6	282.2	26.57	-2.32
10	1	10	84.6	1.82	0.09						0	2	189.9	3.00	0.06	2	23	113.2	5.36	0.37	5	0	225.52	7.73	-0.13
11	1	5	56.9	0.71	0.00											3	43	158.3	5.53	0.30	0	4	232.8	24.21	0.13
Tot	0	12				1	8				0	8				8	106				8	15			

Table A4 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 30-40 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)																								
	40-49					50-59					60-69					70-79					80-89				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1																									
2	0	8	147	3.02	-0.01																				
3	0	4	84.3	1.41	0.05	1	2	496	243.37	-41.12	0	2	135.1	16.24	0.14	1	7	386.8	203.01	93.83	0	2	505.8	12.26	0.55
4						0	3	102.1	4.38	-0.10	1	5	140.8	4.98	0.39	0	2	90.49	0.00	0.00					
5						0	3	50.9	4.97	0.27	0	6	271.8	36.59	-1.85	0	2	112.8	0.12	0.00					
6																									
7																									
8																									
9											2	8	123	15.10	3.40	1	7	234.5	18.82	1.87	1	2	308	11.32	0.38
10											1	9	197.4	12.09	1.08										
11											0	5	83.01	3.67	0.02										
Tot	0	12				1	8				4	35				2	18				1	4			

Table A5 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 40-50 nautical miles off Astoria and that started their trips from Astoria.

Loc	Boat Length (Feet)														
	40-49					60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1															
2	0	2	125.5	13.02	1.36										
3						1	5	154.7	12.57	1.57	0	3	475.4	210.32	31.43
4															
5															
6															
7															
8															
9															
10						0	12	167.9	17.50	2.66	1	6	183.7	63.92	19.01
11						1	4	54.9	0.26	0.00					
Tot	0	2				2	21				1	9			

Table A6 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 0-10 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)														
	40-49					50-59					60-69				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	5	14	91.2	1.63	0.00	1	5	92.6	1.22	0.01					
2	1	4	80	0.41	-0.01	0	2	98.9	7.67	-0.24					
3	1	2	48.7	1.34	-0.02	0	4	81.1	1.06	-0.01					
4						0	2	79.3	0.48	0.01					
5						0	3	85.8	4.31	0.04					
6	1	5	86	1.02	-0.40	5	11	81.2	1.00	0.00					
7											1	2	53.5	0.79	0.00
8															
9	1	3	80.7	0.40	-0.01										
10	0	3	99.9	1.56	0.02	0	2	46.1	1.01	0.01					
11	0	9	85.5	1.38	0.01										
Tot	9	40				6	23				1	2			

Table A7 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)				
	60-69				
	FT	NT	$/Hr.	Var	M3
1					
2					
3					
4					
5	*1*	*2*	*108.3*	*1.58*	*0.02*
6	*0*	*2*	*106.4*	*2.97*	*-0.03*
7	2	*7*	*202.1*	*66.15*	*22.08*
8	*0*	*4*	*55.1*	*0.90*	*0.02*
9					
10					
11					
Tot	3	15			

Table A8 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 20-30 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)									
	40-49					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1										
2	0	2	108.2	0.02	0.00					
3										
4	0	32	92.7	3.63	0.32					
5	2	10	74.3	1.96	0.04	1	2	2.9	5.76	0.13
6	2	8	69.8	2.31	0.14	0	3	152.6	30.72	6.01
7	0	35	104.7	2.98	0.21					
8	2	18	94.9	4.56	0.60	0	3	160.6	56.50	11.44
9	1	21	76.1	1.11	0.02					
10	0	14	75.6	0.64	0.00					
11										
Tot	7	140				1	8			

Thable A9 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 30-40 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)									
	40-49					50-59				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1										
2										
3	*0*	*4*	*83.7*	*0.54*	*0.01*	*1*	*18*	*139.7*	*8.67*	*1.15*
4	*0*	*5*	*102.3*	*2.83*	*0.08*	*2*	*32*	*107.3*	*2.38*	*-0.02*
5										
6						*0*	*2*	*131.7*	*1.90*	*0.00*
7										
8										
9						*0*	*5*	*120.6*	*4.05*	*-0.05*
10	*0*	*10*	*67.93*	*1.78*	*0.06*	*0*	*30*	*94.5*	*1.85*	*0.03*
11	*2*	*20*	*79.3*	*1.09*	*-0.01*	*1*	*21*	*78.5*	*0.56*	*0.00*
Tot	2	39				4	108			

Table A10 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 40-50 nautical miles off Newport and that started their trips from Newport.

Loc	Boat Length (Feet)																				
	40-49					50-59					60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1																				
2																				
3																				
4						*0*	*2*	*151.1*	*4.03*	*0.00*	*2*	*20*	*149*	*5.74*	*0.20*	*0*	*3*	*170.4*	*37.32*	*4.23*
5											*0*	*4*	*103.4*	*10.88*	*1.67*					
6	*1*	*2*	*74.3*	*1.07*	*0.00*															
7						*0*	*2*	*82.6*	*0.16*	*0.00*	*0*	*4*	*118*	*3.74*	*-0.04*	*0*	*5*	*156.8*	*58.57*	*24.96*
8																				
9											*0*	*6*	*100.2*	*0.88*	*0.01*	*1*	*17*	*130.4*	*3.58*	*0.04*
10	*0*	*2*	*75.9*	*0.40*	*0.00*	*0*	*19*	*89.5*	*1.94*	*0.09*	*0*	*7*	*79.6*	*0.81*	*0.00*	*0*	*3*	*119.1*	*2.04*	*-0.08*
11	*0*	*24*	*83.9*	*0.55*	*0.00*	*1*	*22*	*89.8*	*1.28*	*0.00*	*0*	*5*	*58.7*	*0.90*	*-0.01*					
Tot	1	28				1	45				2	46				1	28			

Table A11 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 0-10 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	40-49				
	FT	NT	$/Hr.	Var	M3
1					
2					
3	*0*	*2*	*1.5*	*0.01*	*0.00*
4					
5					
6					
7					
8					
9					
10					
11					
Tot	0	2			

Table A12 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 10-20 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)				
	60-69				
	FT	NT	$/Hr.	Var	M3
1					
2					
3					
4	*2*	*14*	*164.3*	*9.10*	
5	*0*	*2*	*146.1*	*6.09*	
6					
7					
8					
9					
10					
11					
Tot	0	16			

Table A13 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 20-30 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)														
	40-49					60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*3*	*26*	*117.6*	*12.36*	*2.65*										
2	*0*	*9*	*127.2*	*1.57*	*0.00*						*0*	*2*	*71*	*6.85*	*0.17*
3	*1*	*6*	*135*	*2.80*	*-0.17*	*0*	*2*	*70.8*	*0.18*	*0.00*	*2*	*4*	*142.7*	*7.88*	*0.29*
4	2	*6*	*135*	*7.78*	*0.28*						*0*	*2*	*173.1*	*0.04*	*0.00*
5	*1*	2	*107.9*	*12.86*	*-0.11*						*1*	2	*56.1*	*0.13*	*0.00*
6	*0*	2	*73.8*	*0.66*	*0.01*										
7															
8															
9	*1*	*7*	*53.7*	*4.45*	*0.60*										
10	*1*	*3*	*44.8*	*0.21*	*0.00*										
11															
Tot	9	61				0	2				3	10			

Table A14 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 30-40 nautical miles off Coos Bay and that started Their trips from Coos Bay.

Loc	Boat Length (Feet)									
	40-49					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*1*	22	*140.3*	*5.32*	*0.13*	*1*	2	*114*	*0.41*	*0.00*
2	*0*	2	*99.1*	*2.06*	*0.03*					
3										
4										
5										
6										
7										
8	*0*	2	*98.5*	*2.33*	*-0.03*	*0*	*7*	*239.9*	*198.34*	*188.97*
9	*0*	2	*178.5*	*5.94*	*0.10*	*0*	*7*	*90.22*	*1.34*	*0.01*
10										
11										
Tot	1	28				1	16			

Table A15 Data on fishing location preferences and success rates for fishing vessels operating with generic bottom trawl in the fishing area 40-50 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)																			
	40-49					50-59					60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*1*	*25*	*252.5*	*78.09*	*43.05*	*0*	*5*	*144.5*	*5.45*	*0.08*	*0*	*2*	*106.2*	*4.75*	*-0.14*					
2																				
3																				
4																				
5																				
6																				
7																				
8																*0*	*2*	*48.3*	*0.49*	*-0.01*
9						*2*	*15*	*176.8*	*5.88*	*0.91*										
10						*0*	*22*	*220.6*	*37.67*	*11.55*										
11																				
Tot	1	25				2	42				0	2				0	2			

Table A16 Data on fishing location preferences and success rates for fishing vessels operating with bottom trawl equipped with roller gears in the fishing area 10-20 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Fee)				
	80-89				
	FT	NT	$/Hr.	Var	M3
1					
2	*1*	*2*	*223.6*	*9.30*	*-0.05*
3					
4					
5	*1*	*2*	*237.5*	*25.14*	*-0.40*
6	*2*	*3*	*190*	*148.32*	*58.89*
7					
8					
9					
10					
11					
Tot	*4*	7			

Table A17 Data on fishing location preferences and success rates for fishing vessels operating with bottom trawl equipped with roller gears in the fishing area 20-30 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)									
	60-69					80-89				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*0*	*2*	*120.9*	*0.02*	*0.00*	*0*	*4*	*243.1*	*17.96*	*-0.48*
2	*1*	*5*	*162.3*	*50.09*	*18.45*	*0*	*2*	*40.22*	*1.76*	*0.01*
3	*0*	*4*	*225.1*	*25.64*	*2.65*					
4	*2*	*4*	*82.74*	*1.28*	*-0.02*					
5	*1*	*3*	*48*	*0.74*	*0.02*	*0*	*3*	*109.1*	*5.90*	*-0.21*
6	*0*	*3*	*530.8*	*4122.34*	*11269.75*					
7	*0*	*3*	*115.8*	*1.39*	*0.03*					
8										
9	*0*	*3*	*128.5*	*20.62*	*3.26*					
10										
11										
Tot	4	27				0	9			

Table A18 Data on fishing location preferences and success rates for fishing vessels operating with bottom trawl equipped with roller gears in the fishing area 30-40 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)														
	60-69					70-79					80-89				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*2*	*12*	*180.5*	*15.79*	*2.21*										
2	*0*	*3*	*298.6*	*98.36*	*7.34*	1	3	136.5	16.24	0.34					
3															
4															
5															
6															
7											*1*	2	*53.5*	*0.79*	*0.00*
8	*3*	*18*	*260.6*	*35.34*	*4.01*										
9	*0*	*9*	*80.4*	*0.46*	*0.00*										
10															
11															
Tot	5	42				1	3				1	2			

Table A19 Data on fishing location preferences and success rates for fishing vessels operating with bottom trawl equipped with roller gears in the fishing area 40-50 nautical miles off Coos Bay and that started their trips from Coos Bay.

Loc	Boat Length (Feet)									
	60-69					70-79				
	FT	NT	$/Hr.	Var	M3	FT	NT	$/Hr.	Var	M3
1	*1*	*25*	*223.1*	*48.46*	*22.00*	*0*	*2*	*272*	*0.38*	*0.01*
2										
3										
4										
5										
6										
7										
8	*1*	*7*	*213.6*	*81.23*	*36.72*	*0*	*3*	*321.7*	*839.89*	*965.61*
9										
10										
11										
Tot	2	32				0	5			