MODELING ENTRY, STAY, AND EXIT DECISIONS OF THE LONGLINE FISHERS IN HAWAII[1]

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ABSTRACT

A behavioral study on the entry, stay and exit decisions of the fishers in Hawaii's longline fishery was undertaken in a random utility framework by applying the multinomial logit (unordered) model. Pooled annual cross-sectional and time-series (1991-98) data were used. The empirical results confirm that the entry, stay, and exit decisions are significantly associated with the earning potential of fishers, crowding externality, resource abundance and some managerial factors. The probability of a vessel to stay (or exit) in the fishery increased (or decreased) for an increase in the earning potential of a fisher. A larger fleet size shows vessels were more inclined to exit from the fishery than stay in the fishery. The probability of vessel entry (or exit) was also positively (or negatively) associated with an increase in stock levels of major target species. Further, a vessel was more likely to stay in the fishery when the vessel owner was a Hawaii resident or a vessel captain. Simulation of the probability for a vessel to enter, stay, or exit for a change in fleet size or stock level was also carried out.

Keywords: Vessel entry-stay-exit; choice; multinomial logit; longline fishery; Hawaii

INTRODUCTION

The effect of entry and exit on the competitive performance of firms occupies a prominent role in theoretical discussions of industry behavior [27]. An explanation of the rise and fall of firms' output levels is not sufficient to account for the changes in the industry's output, since output changes are often accompanied by changes in the number of firms in the industry. An important adjustment mechanism in the theory of the long run competitive market consists of firms entering or leaving the industry when profits are above or below normal levels. Under the free entry equilibrium condition, the equilibrium number of firms is determined by the condition that economic profit equals zero [19,17].

The entry-stay-exit process is also associated with an adjustment in capacity utilization. When market demand is unknown, excessive entry may be observed and a wave of exits is expected to follow. Over time, firms learn the size of the market demand and capacity converges to the true size of the market [41]. A declining industry must reduce its capacity to remain profitable [14,15]. Firms learn about their efficiency as they operate in the industry. Efficient firms grow and survive [22]. Government regulation by means of quota, permits, licenses, etc., also affects capacity adjustment [37]. Exit can also be associated with the aging of the capital since it requires more maintenance to produce the same output [9].

Entry and exit occurrences of firms (fishers or vessels) in the fishing industry are assumed to be more pronounced than in other industries due to production uncertainty/stochasticity and the "open-access" nature of ocean resources.[2] As a result, a fisher may geographically relocate his vessel to another fishery when profit condition warrants. Entry to and exit from a fishery is a long-run choice depending on the relative profitability across alternative fisheries or fishing locations. Long-run decisions can involve new vessel purchases as well as exit from or entry to the fishing industry [30].[3] A profitable/or unregulated "open-access" fishery also tends to attract new capital in the form of new or improved vessels that may lead to depletion of fish stock and rent dissipation. On the other hand, existing vessels may continue to operate profitably without attracting additional entry, simply because capital costs for new entrants may be prohibitive. The potential threat of stock depletion and its impact on reduced profitability may also deter new entrants from risking their capital. Over-expansion during the profitable initial development of a fishery may result in an equilibrium in which rent only cover variable costs, but not the sunk fixed costs. The ultimate bio-economic equilibrium may still yield positive rents to exceptionally skilled fishers [5].

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[2] Although the high sea fishery is characterized by "open access" from an international perspective, the fishery at the national level is usually under a local jurisdiction.
[3] Entry and exit is a long run choice because the decision to purchase or modify a vessel incurs substantial capital cost which has to be recovered from subsequent earned fishery revenue.

The marine fishery is an important natural resource of the United Sates. However, its fishery has been suffering from over-capitalization and over-exploitation.[4] The excess capital results in a number of problems, such as rent dissipation, juvenile fishing, incidental bycatch, and high discards [43]. Because of these problems, a continuous phenomenon of entry and exit of some vessels in a fishery can be expected. As a result, externalities tend to be transferred from a more regulated fishery to a less regulated fishery because of fishers' motive for a profit in a fishery. Movement of many Atlantic longliners to the Pacific in the late 1980s to early 1990s and the movement of Hawaii's longliners to Californian waters and the South Pacific in late 2000 in search of more productive fishing grounds are a few examples of vessel entry-exit.

Although Japanese immigrants introduced the longline fishing technology to Hawaii in the early twentieth century, the fishery has only witnessed a sheer surge in the number of longline vessels recently. A large number of modern, capital-intensive longline vessels entered Hawaii from the continental USA during the late 1980s. The high demand for swordfish in the mainland USA and the high-grade tuna demand in Japan might also have favored the growth of the longline fishery in Hawaii. Thus, in a relatively short time span, the longline fishery in Hawaii has grown to be the largest and most prominent commercial fishery in the state. After an initial surge of vessels in the late 1980s, the process of vessel entry and exit continued in a limited number throughout the 1990s. Each year there are some entering and some exiting vessels. But a large number of vessels exited after a regulation that banned swordfish harvest in the summer of 2000.

It is crucial to understand analytically the underlying process of vessel entry-exit in the longline fishery. Entry and exit of fishing vessels to and from a fishery affects aggregate fishing effort and fish supply. There may be several reasons for vessel movements, such as relative profitability between different fisheries or fishing locations, stock fluctuations and resource abundance levels, regulatory measures, fleet congestion, and vessel-specific managerial issues. In some instances, some of the vessels staying in a fishery may not be operating profitably, but may be there just to cover the operating costs. Despite widespread entry-exit of firms in the fishing industry, there are very few studies related to the behavioral process of fishing vessel entry to and exit from a fishery. So far there has been no systematic study about the underlying behavioral process on vessel entry-stay-exit in pelagic fisheries. Such a study would be important in understanding the underlying dynamics of natural resources in general, and long run fleet dynamics and fish supply process in particular.

In this paper, a behavioral model of entry, stay and exit decision of the longline fishers in Hawaii is developed. The analysis is carried out in a random-utility framework, and the analytical model is estimated by applying the *multinomial logit (unordered)* model. Annual cross-sectional and time-series data for the period 1991-98 was used in the analysis. Factors affecting the vessel entry-stay-exit decisions of fishers in the longline fishery were analyzed. The marginal effect of a change in the characteristics of the fisher and other external factors on the probability of entry, stay, or exit decisions was also estimated. The predictive performance of the model was examined by comparing the observed outcome with the estimated probabilities of each entry, stay, and exit decision. Finally, the probability of entry, exit and stay decisions in the longline fishery was simulated under different fleet sizes and stock conditions. We believe that this research would make an important contribution to the body of fishery economics literature. In subsequent sections, a brief description of the longline fishery and evolution of the entry-stay-exit of the longline vessels in Hawaii is presented, followed by a conceptual/empirical model specification, discussion of the results, and conclusion.

LONGLINE FISHERY AND VESSEL ENTRY-STAY-EXIT

The pelagic longline fishery in Hawaii is generally confined in the mid-North Pacific Ocean in the range of $40^\circ N$ to the equator, and $145^\circ W$ to $175^\circ E$ [33]. In 1998, the longline fishery accounted for 85% of the state's commercial catch that totaled nearly 29 million pounds with an ex-vessel value of about $47 million [20]. Landings of important pelagic species in Hawaii's longline fishery include three tuna species (bigeye tuna, *Thunnus obesus;* yellowfin, *T.albacares;* and albacore, *T. alalunga*), three billfish species (swordfish, *Xiphias gladius;* striped marlin, *Tetrapturus audax;* and blue marlin, *Makaira mazara*), and several miscellaneous pelagic species. Bigeye tuna has been a major target species since the 1950s. Swordfish was a minor species until the 1990s when it became the major target species with the entry of modern longline vessels targeting swordfish [7,10]. Until June 2000, there was no limit on the total allowable catch on any commercially important species. Recently, swordfish harvest has been banned due to concern over the impact of longline swordfish fishing on protected species like marine turtles. As a result, a large number of vessels exited after this regulation came into effect.

[4] Depletion of swordfish stocks in the North Atlantic Ocean is a good example [29].

Hawaii's longline fishery has witnessed a dramatic change in vessel movement in the past two decades. Pooley [32] noted that there might have been less than 15 longline vessels in 1975, but as many as 45 vessels in 1984. The number of permitted longline vessels quadrupled from 37 vessels in 1987 to a high of 141 vessels in 1991. This number then leveled off at about 120 vessels from 1992 through 1994, declined slightly to 103 vessels in 1996, and then increased to 125 vessels in 2000 [21]. It appears that between 1975 and 1991, the number of longline vessels grew exponentially, declined during 1991-96, and grew again mildly during 1997-2000. There are several reasons for the growth of longline vessels over the past three decades. A favorable export-oriented fishery policy of the state of Hawaii, the increased demand for swordfish in the continental USA, and the demand for high quality tuna in Japan in the late 1980s also triggered the surge of longline vessels. Vessels in Hawaii also had a comparative advantage over other vessels not only in the export market, but operationally they were fuel-efficient and less labor-intensive relative to the vessels used in other fisheries [32]. Moreover, the growth in the longline fishery could be due to relatively more abundant fish resources and less vessel congestion as compared to other fishing regions in the United States.

The National Marine Fisheries Services (NMFS) instituted the permit and logbook requirement for all U.S. domestic longline vessels operating in the Western Pacific in order to monitor the longline fleet. The vessels were issued longline fishing permit applications beginning 27 November through December 1990. Initially, 145 general longline permits were issued, and by the first week of 1991, 155 vessels had been issued permits. During 1991, there were 23 vessels from the U.S. east coast, 60 from the Gulf of Mexico, 18 from U.S. west coast, and 62 from Hawaii itself. On April 23rd, 1991, Federal "limited entry" permits were required in addition to the general longline permits. Subsequently, 163 such permits were issued during 1991. The "limited entry" plan temporarily restricted the number of longline vessels participating in Hawaii's pelagic longline fishery in order to assess the optimal fleet size [10]. As of 2001, there were 164 Federal limited entry permits issued for the Hawaii based longline fishery [21].

Table 1 Number of active longline vessels and year-to-year entry-exit-stay of the vessels

Year	Number of Active Vessels (Population)	Number of Active Vessels (Sample)*	Choices of the Active Vessels (Sample)		
			Stay**	Entry	Exit**
1991	141	126	104	-	22
1992	123	109	97	7	5
1993	122	113	94	8	11
1994	125	108	59	2	47
1995	110	69	50	6	13
1996	103	63	47	6	10
1997	105	74	51	19	4
1998	114	93	68	24	1

Source: Data (sample) compiled from NMFS longline logbook records. Data on the number of active vessels (population) is from the WPRFMC [44]. The number of active vessels in 1988, 1989, 1990, and 1999 were 50, 88, 138 and 119, respectively.

* This summary of statistics was generated from the dataset where the trip level information from the Federal logbook was matched with the State's trip record for the period 1991-98.

** The number of vessels active in the current year but have decided to stay and exit in the following year.

The initial surge of longline vessels resulted in some conflicts with the near-shore fishers and may have impacted endangered species, and possibly caused localized overfishing. Some longline fishing vessels had started exiting from Hawaii in the early 1990s. Of the registered longline vessels in 1991, 18 left the state and started fishing elsewhere, four switched to bottom fishery, five switched to lobster fishing, and 18 were not in operation for various reasons, i.e., they were under repair, impounded, for sale, or inactive for unknown reasons [10]. There were 49 vessels that had never left the Hawaiian fishery ever since they entered Hawaii's longline fishery during 1991-1998. Similarly, there were 45 cases where a vessel once exited, but then returned to fishing in Hawaii. Among the returning vessels, some made a final exit during a subsequent year while others are still actively fishing. Milder levels of entry and exit of longline vessels continued throughout the 1990s, but a one-time massive exit occurred only after the recent swordfish harvest ban in the summer of 2000. A recent lawsuit charging that the longline fishery is a threat to the survival of turtle populations has led to this injunction barring the longliners from harvesting swordfish. This has forced a substantial proportion of longline vessels harvesting swordfish to leave Hawaii or to switch to tuna fishing. Of the existing 57 vessels engaged in targeting swordfish (out of the 125 active longline vessels in 2000), about 40 of them were displaced to the continental USA for other fishing opportunities there; 12

have been currently retained by NMFS for scientific research on ways to reduce sea turtle interaction with swordfish fishing. The rest of the other vessels might either have adapted to longline tuna fishing or might have gone to Western Samoa, as that island has recently experienced a surge in longline vessels there [44]. Table 1 presents the details about entry, stay, or exit of longline fishing vessels on a year-to-year basis for the period 1991-98.[5]

The vessels considered for entry, exit, and stay in the analysis have different entry and exit points during this period.[6] Each year there are some incoming or exiting vessels. There were more vessels exiting from the longline fishery than entering during the first half of the 1990s, and the reverse was true in the second half of the decade. Some of the vessels entering in the later half of the 1990s were returning vessels.

CONCEPTUAL FRAMEWORK

Let's make some behavioral assumptions about a typical commercial fisher in the context of a vessel entry, stay, or exit decision. A fisher invests capital in a fishing vessel and incurs initial fixed investment and recurrent expenses annually, but then expects a stream of future returns from it. The return is supposedly sufficient to cover the fixed investment and operating expenses, including a return for entrepreneurship with an ultimate objective of maximizing the net present value of the investment to achieve a return rate at least equal to the market rate of return. The fisher operates in a fishery or fishing region where he expects to achieve these objectives.[7] The fisher decides on the potential locations for business based on prior knowledge about the fishery acquired through inheritance from family business, partnership, or experience gained as a captain or crew member. This includes knowledge about the prices, market, stock conditions, weather and sea environments, and other regulatory information. It is also assumed that fishers have some networking with their fellow fishers to remain self-informed about the opportunities and incentives in other fisheries and to share experiences within or outside a fishery so that one may relocate their business to another area when need arises.

For a new entrant to a fishery the initial years may not be profitable relative to incumbent fishers' as the new fisher may have to adapt to a new fishing environment, e.g., locating a productive fishing ground, deciding which species to catch, etc.[8] Thus, the new entrant's performance in the new fishery is also assumed to be a reflection of his performance in the old fishery, at least in the initial years to the new fishery.[9] If the annualized rate of return is as expected, the fisher may remain in the current fishery; else he will move to an alternate fishery or fishing location. The fisher evaluates this each year by considering the total costs and sales, perceived stock abundances, and fleet congestion level. Based on the past year's performance, he decides whether to stay in the same fishery or exit to an alternate fishery or fishing location. In making the decision, he also considers the transaction cost of his decision. Overall, it is assumed that efficient fishers or vessels will remain in the fishery and inefficient ones will exit.

We can accommodate the above situation in the random utility maximization (RUM) framework provided by McFadden [28]. In the RUM hypothesis, the decision maker can be described as facing a choice among a finite and exhaustive set of mutually exclusive J alternatives. He chooses an alternative j in J if and only if $U_{ij}>U_{il}$ for $l\neq j$. Since utility is not directly observable, one has to examine variables presumably associated with the utility attached to each choice. Preferences are described by a well-behaved utility function whose arguments include a vector of exogenous constraints on current decision-making. For a given individual i, the probability that a choice j within the choice set C is made can be expressed as: $P_c^i(j) = P[U_j^i = \max_{l\in C} U_l^i] \quad \forall\ l, j\in C,\ l\neq j$

where U_j^i is the maximum utility attainable for an individual i if he chooses a decision $j=1,\ldots\ldots,J$.

Typically, the linear utility function is specified as the function of observable variables that are assumed to impact the relative utility of alternative choices. Specifically, the utility function can be decomposed into a systematic (deterministic) term (V) and a stochastic component (ε) as in Greene [16]:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \theta' Z_{ij}(X_i, W_{ij}) + \varepsilon_{ij} = X_i\beta_j + W_{ij}\alpha + \varepsilon_{ij} \qquad (1)$$

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[5] Active Vessel (sample) = Stay + Entry + Exit. The number of active vessels (sample) is based on the data generated from matching the Federal logbook and State's trip record. Population-wide actual number of vessels is higher as shown in the second column in Table 1.

[6] A same vessel may make multiple exit or reentry during 1991-98. If it does, it is considered as a separate case.

[7] A fisher could also leave the fishery for an alternative form of employment. In this case, the wages earned would have to be greater than the return to labor from fishing. Firms will continue to switch between fisheries until, for marginal firms, the utility between fisheries are equal [42].

[8] Michael Foy from New Jersey, a participant in the 2nd International Fishers Forum 2002, shared his experience that the first eight months of his entry year to Hawaii's longline fishery were not profitable. He operated longline vessel in Hawaii during 1991-94.

[9] This assumption is made since past performance data for an entrant vessel or fisher usually are not available for the modeling exercise. One may then presume that a vessel was not performing as well in the old fishery may seek to enter to a new fishery for better income prospectus.

where **θ**, $\boldsymbol{\beta}_j$ and **α** are vectors of coefficients providing information on the marginal utilities with respect to the relevant characteristics. U_{ij} is interpreted as the indirect utility function. The deterministic component V_{ij} can be thought of as the expected utility the individual can obtain and the random component ε_{ij} represents unobservable factors, measurement errors, and unobservable variations in preferences and/or random individual behavior [11]. The error term is assumed to be uncorrelated across choices, and this assumption leads to the independence of the irrelevant alternative property in the choice model, i.e., outcome categories can be plausibly assumed to be distinct in the eyes of each decision-maker. Utility depends on characteristics specific to the choices as well as to the individual-specific (or vessel specific in entry-stay-exit decision analysis here). W_{ij} are the attributes of the choices for which the values of variables vary across choices and possibly across the individuals as well. X_i contains the characteristics of the individual and same for all choices.[10] The unobserved component of the utility is assumed, through extreme value distribution, to have a zero mean; the observed part of the utility, V_{ij}, is the expected or average utility [39]. The parameters of this function that are used to predict the relative probabilities of individual choices can be estimated using various discrete choice statistical methods, such as the *conditional logit* and *multinomial (unordered) logit* models [16,24,25,26,34]. The statistical model is driven by the probability that choice j is made, which is $P_{ij} = Pr(V_{ij} - V_{il} > \varepsilon_{il} - \varepsilon_{ij})$ for $\forall\, l \neq j$. Since ε_{ij} and ε_{il} are random variables, the difference between them is also a random variable. Let Y_i be a random variable that indicates the choice made. If (and only if) the J disturbances are independent and identically distributed with Weibull distribution as $F(\varepsilon_{ij}) = exp(-e^{-\varepsilon_{ij}})$, then the probability that the decision-maker will choose alternative j is given as in Greene [16].

In the absence of choice specific attributes in the vessel entry-stay-exit decision study, the choice-specific W_{ij} variable drops out from the utility function in equation (1) and the appropriate model is the *multinomial (unordered) logit*, and the selection probabilities are given by[11]

$$P_{ij} = e^{X_i^{'}\beta_j} \Big/ \sum_{j=1}^{J} e^{X_i^{'}\beta_j} \tag{2}$$

For J alternatives in the *multinomial logit* model, only J-1 distinct parameter vectors may be identified. The logit is given by the model:

$$ln\left[\frac{P_{ij}}{P_{i0}}\right] = X_i^{'}\beta_j \tag{3}$$

We can also find the marginal effect of each characteristic on probability j by differentiating j^{th} probability (P_j) with respect to the explanatory variable (X_k) variable as:

$$\delta_{jk} = \frac{\partial P_j}{\partial X_k} = P_j[\beta_j - \sum_{j=1}^{J-1} P_{jk}\beta_{jk}] \tag{4}$$

where δ_{jk} is the value of the estimated marginal effect of k^{th} variable on P_j.

The *multinomial logit* model is estimated iteratively using the maximum likelihood procedure. The model makes the assumption known as the independence of irrelevant alternatives where all outcomes are to be different from each other. The model can be evaluated using one of the following goodness-of-fit, tests as in Judge et al. [23]: a) a comparison of the actual share in the sample for each alternative with predicted share allows an evaluation of different model specifications; b) the log likelihood chi-square test: under the null hypothesis, all coefficients in a model are equal to zero implies that all alternatives are equally likely; c) the likelihood ratio index (Pseudo ρ^2) and the model is a perfect predictor if ρ^2=1.

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[10] X_i may contain other factors whose values are invariant to the choices one makes.

[11] The specific equation to estimate the probability of an alternative j in the *multinomial logit (unordered)* model is $\Pr(Y = j) = \exp(X_i^{'}\beta_{jk}) \Big/ 1 + \sum_{j=1}^{J-1}\exp(X_i^{'}\beta_{jk})$. The probability for the reference or base category can simply be calculated as $Pr(Y=0)=[1-(P_1+\ldots+P_{J-1})]$.

EMPIRICAL PROCEDURES

Previous works

Earlier works on vessel entry-exit were primarily concerned with capital theoretic bioeconomic models [1,6,8,35]. In these models, the number of fishing vessels in a fleet equilibrates instantly by the mechanism of firm entry-exit for any deviation from the zero profit condition. Some other works are related to fishery regulations, such as entry restrictions through a "limited entry" system, seasonal or area closures, and a transferable quota system [3,4,12,13,38]. Many of these studies analyze the effect of entry regulations on the economic rent of the incumbent or potential entrant fishers rather than their entry, stay, and exit behavior.

Behavioral studies in fisheries, such as fishery choices, fishing location choices, and vessel entry-stay-exit process are emerging very recently long after an initial study by Bocksteal and Opaluch [2] on fishery choices. The only available behavioral studies about fishing vessel entry-exit are by Ward [42], Ward and Sutinen [43] and Ikiara and Odink [18]. Ward and Sutinen [43] have studied vessel entry-stay-exit behavior in the Gulf of Mexico shrimp fishery. They assumed that an individual firm uses myopic profit maximization as its entry-exit criteria, and the alternatives available to a fishing firm are mutually exclusive. Although Ward [42] mentioned using the *multinomial logit* (*unordered*) model in a vessel entry-stay-exit analysis in the Gulf of Mexico shrimp fishery, according to the Ward and Sutinen [43] paper, the results appear to have been generated with the *ordered probit* procedure.[12] The variables included in their model were the price of shrimp, the unit harvest cost, fleet size, vessel length, gross tonnage, shrimp abundance, vessel mobility, and vessel bought/sold information. The price received by the fishers is the major utility indicator in their analysis, and unit harvest cost reflects the stock externality. They found that the crowding externality as represented by fleet size had a significant negative impact on the probability of entry of a shrimp vessel to the Gulf of Mexico shrimp fishery. Shrimp vessels from other regions were found to be more willing to enter the fishery when profit increased. There was no evidence supporting that an entry decision was influenced by stock variation.

On the other hand, Ikiara and Odink's [18] study was about fishers' resistance to exit fisheries in Kenya's Lake Victoria. Their major finding was that fishers there were not able to exit from the fisheries for lack of alternative fisheries and employment opportunities.

Empirical Model

Our approach to a behavioral analysis of fishing vessel entry-exit differs from previous works in a few aspects. We extend the modeling approach applied in the literature to accommodate how an individual fisher operating in a highly migratory pelagic fishery makes the entry-stay-exit decision on a year-to-year basis. We applied the *multinomial logit* (*unordered*) model in the longline vessel entry-stay-exit analysis. In the present study, the vessel entry-stay-exit model was specified assuming that the decision to stay or exit from the fishery depends on the previous period's annual relative revenue as a proxy of the annual earning potential of the fisher, fleet congestion level, and stock conditions of major targeted species (swordfish and bigeye tuna) along with other factors like residency, captainship, and vessel age.[13] This research is expected to enhance the current state of knowledge on fishers' vessel entry-stay-exit decisions, which may in turn be useful in understanding longline fleet dynamics.

The deterministic component of the indirect utility function in the *multinomial logit* model was empirically specified as

$$V_{ijt+1} = \beta_0 + \beta_1 REVGT_{it} + \beta_2 FLEET_t + \beta_3 TUNANDX_t + \beta_4 SWORDNDX_t + \beta_5 VAGE_i + \beta_6 RESID_i + \beta_7 CAPT_i \qquad (5)$$

The response variables are the decisions of the fishers indexed as *j* by the i^{th} fisher. Therefore, the discrete dependent variables are ENTRY to the longline fishery, STAY in the longline fishery, and EXIT from the longline fishery, with an assigned numeric value unique for each choice. Entry, stay, and exit decisions are defined on a year-to-year basis. A vessel is defined as an ENTRY if it was not in the previous year's (t-1) fleet but is active in the current year (t). If a vessel was active in the previous year (t-1), the current year (t), and will also operate in the subsequent year (t+1), it is defined as a STAY vessel. Finally, if a vessel is active in the current year's (t) fleet but will not operate in the subsequent year (t+1), it is defined as an EXIT vessel. If an EXIT vessel reappears after a lapse of one year, the vessel is considered as an ENTRY vessel. Therefore, the same vessel may have a different entry-stay-exit status depending on when it entered or exited in the given timeframe during 1990-99.

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[12] Both Ward [42], and Ward and Sutinen [43] are the same study.

[13] Captainship refers to a case where the vessel owner is also the vessel captain.

The explanatory variables for the decision to enter, stay and exit in the longline fishery are annual revenue per gross ton vessel capacity (REVGT), fleet size (FLEET), stock abundance indices for major targets—namely, bigeye tuna (TUNANDX) and swordfish (SWORDNDX), vessel age (VAGE), residency of the vessel owner (RESID), and captainship (CAPT). The total number of parameters estimates will be (J-1)K, where K refers to the number of explanatory variables. β_j is a vector of coefficients to be estimated.

The relative income from longline fishing in terms of annual revenue per gross ton of vessel capacity (REVGT) is expressed as thousands of US$/Year/Gross tonnage capacity. As mentioned earlier, the annual revenue generated is considered here as the annual earning potential of a fisher where his fishery specific knowledge, experience, skills are also assumed to be embedded in and it is, therefore, an individual-specific variable. It is assumed that the fisher with high income potential is more likely to remain in the fishery, while the fisher with low income potential may continually search for a better opportunity elsewhere in the other fisheries by the vessel entry-exit process. It is assumed that an entrant's performance is not better than those who are already in the fishery, at least in their beginning years in the new fishery. Further, an entrant's performance in the new fishery is assumed to reflect his potential income performance in the old fishery. This assumption is made since past performance data for an entrant vessel or fisher are usually not available to include in the model. One may then presume that a vessel underperforming in an old fishery may seek to enter to a new fishery for a better income opportunity. An entrant's underperformance in the new fishery is assumed to be due to many uncertainties related to the nature of the fishery, fishing habitat, seasonal fluctuations, etc., in the fishery where he decides to enter. New entrants may also observe the incumbent fishermen's information in building their own expected return from the fishery. The survivability of a new firm depends on the ability to learn about the new environment.

The fleet size (FLEET) variable is included in the model to examine the congestion effect or crowding externality. Because of the "open access" nature of the fishery, there may be many vessels operating in the fishery that can adversely affect an individual firm's return from fishing, causing some vessels to exit from the industry.[14] The fleet size is expressed as the aggregated annual net tonnage (in 1,000 net tonnage) of all the active longline vessels operating in the fishery in any given year under a local jurisdiction.[15] Annual cumulative net tonnage is assumed to be a better proxy of the congestion level or effect, because it accounts for both the number of vessels and each boat's carrying capacity.

Vessel entry, stay and exit can also be related to the annual abundance of major targeted species. In Hawaii's longline fishery, bigeye tuna and swordfish are the major target species because they have high demand and also fetch a better price. It is interesting to see how the fluctuation in major fish stock level affects the entry, stay and exit decisions of the fishers. It is presumed that entry (or exit) is positively (or negatively) related to an increase (or decrease) in the fish stock level. The annual stock abundance index for bigeye tuna (TUNANDEX) and swordfish (SWORDNDEX) were included in the model to examine entry-exit behavior. The annual stock index is created using the trip level catch per unit effort (CPUE), measured in terms of the number of fish caught per 1,000 hooks for each species in a trip by a fisher for the entire fleet during 1991-98. The trip level CPUE for each species in the entire fleet was aggregated annually and averaged over all fishers, and an annual species-specific stock index was created treating the 1992 CPUE as a base year. Therefore, all fishers face the same stock index for a given species at a given year. The indices are expressed in percentages.

Vessel age (VAGE) is an important factor in vessel entry-stay-exit choice. As the lifespan of a vessel is finite, newer vessels replace the older ones and physically too-old vessels may exit because of the higher cost of operation and maintenance cost. Entrant vessels are assumed to be newer ones. Vessel age is expressed in years when a fisher decides to enter, exit, or stay.

Two dummies are included in the model, one for the residency of the vessel owner (RESID), and the other one for the case where the owner is also a vessel captain (CAPT). The economic significance of these variables is related with the principal-agent problem.[16] In a fishery, there may be an asymmetric information problem where one economic agent knows something that another economic agent does not. One may not be able to observe the costs associated with the principal and agent, but the utility of the principal is observed through his decision to exit or

[14] The high sea where the longline fishery operates is characterized by "open access" from an international perspective, but may be regulated by the "limited entry" permit system or other kinds of regulations locally.

[15] Because of the "open access" nature of the high sea fishery, there may be many international vessels or vessels from other states operating in the same fishery. Since their fleet size is unknown, only the fleet size under Hawaii's (a local) jurisdiction is considered in the analysis as a measure of crowding externality.

[16] In the principal-agent problem framework, the principal wants to induce the agent to take some action which is costly to the agent. The principal may be unable to directly observe the action of the agent but instead observes some output that is determined at least in part by the actions of the agent. In this situation the principal has to design an incentive payment. The principal may choose a utility function which maximizes his utility, subject to the constraints imposed by the agent's optimizing behavior [40].

remain in a fishery. The principal exits when he perceives disutility from the entrepreneurship, and may enter or stay if there is utility. For example, a hired vessel captain might have a better idea of how much he could produce than the vessel owner does. It is assumed that a fisher's production efficiency is improved if the vessel owner is also a captain. Moreover, he can supervise other vessel crewmembers and save the portion of the captain's share of the harvest as well. Similarly, a fishing trip may be more profitable when the vessel owner is a local resident, who might have an edge in better management of his business, such as planning trips and target, marketing, and close supervision of vessel crew. The dummy variable CAPT takes a value of one (1) if the owner is the vessel captain, and zero otherwise. Residency location of the vessel owner was identified by assigning a dummy variable that takes a value of one (1) if the owner is a resident of Hawaii, and zero otherwise.

The Data

The U.S. National Marine Fisheries Service's (NMFS) Honolulu Laboratory logbook and the State of Hawaii's Division of Aquatic Resources (HDAR) catch records are the key sources for the entry-stay-exit analysis of the vessels in the longline fishery. The NMFS logbook data provides information on catch and fishing effort while the HDAR data provides information on fish revenue by species. Besides these data, additional vessel-specific information for longliners (such as tonnage, horsepower, size, residency, vessel transaction, etc.) was obtained from the data maintained by the U.S. Coast Guard. The HDAR data are maintained at the trip level, while NMFS logbook data are maintained at the set level. Therefore, the initial task involved the transformation of the logbook data from set level to trip level. Then, the data from the two sources were merged. For the period from 1991-98, the total trip-level longline observations in the NMFS logbook and HDAR datasets were 10,597 and 8,618, respectively, of which 6,666 (i.e., respectively about 63% and 77% of total observations) were matched. The matched data represented about 77% of the total catch and revenue during 1991-98. Since entry-stay-exit is a long-run decision, data for each fisher or vessel were aggregated annually and analyzed on a year-to-year basis. The matched trip level records were further condensed to 755 annual observations for the period 1991-98, but only 347 observations were usable due to the need for complete data for all variables under consideration.[17]

Limitation of the model and data

The vessel entry-stay-exit model can be further enriched if one has information about a vessel's pre-entry or post-exit performance records related to catch or revenue in alternate fisheries. Entry and exit decisions are also affected by fishery policies and regulations in the alternative fisheries from where the vessel migrated from or where it immigrated to. But such information was not available. It will, therefore, be to the advantage of the policy-makers to keep a link/track record for each entering and exiting vessel about its previous (for entering vessels) and future (for the exiting vessels) performances in the alternate locations or fisheries for future research purposes.

RESULTS AND DISCUSSION

We first present the descriptive statistics of the vessels entering, exiting and staying in the longline fishery during 1991-98 in Hawaii. They typically represent the average characteristics of those vessels making different decisions. The annual revenue (both absolute and relative) from the fishery was highest for the vessels that chose to stay in the fishery, but was lowest for the exiting vessels. Annual revenues per gross tonnage were US$4,412, $2,496, and $2,198 for the stay, entry, and exit vessels, respectively. Similarly, the annual number of trips, total trip days at sea, and the number of hooks/sets used were higher with the vessels choosing to stay in the fishery than with those of entrants or exiting vessels. The details about vessel characteristics by entry, stay, and exit decision are presented in the Table 2.

The estimated results from the *multinomial logit* model are presented in Table 3. The psuedo ρ^2 indicates that the model explains about 21% of the variation in entry-stay-exit choice behavior. The model also satisfied the independence of irrelevant alternative property suggesting that these outcomes are different from each other.[18] The loglikelihood ratio chi-square value was also significant. Most of the variable's parameter estimates were statistically significant, except vessel age.

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[17] Although the data size used in the model estimation was reduced from 755 observations to 347 observations, the data used in the analysis was fairly representative as the mean characteristics presented in Table 3.2 were similar for both sets of data. Omitting relevant variables in an attempt to include all 755 observations produced wrong signs for some of the variables.

[18] The χ^2 (k) for the omitted choice categories were -2.13, 0.92 and 0.31with a degree of freedom (k) equal to 8, 7, and 7 for the entry, exit and stay choices, respectively.

Table 2 Characteristics of longline vessels making entry, stay, & exit choices

			Sample			Population		
Variables	Unit	Choice	N	Mean	Std.Dev.	N	Mean	Std.Dev
Revenue	US$/Year	Entry	48	2,41,324	1,76,532	73	219,287	164,994
		Stay	250	3,46,509	1,75,092	569	361,048	198,148
		Exit	49	1,99,893	1,21,143	113	167,550	122,799
Revenue/Gton*	US$/Year/Gton	Entry	48	2,496	2,208	73	2,387	2,302
		Stay	250	4,412	2,577	569	4,336	2,468
		Exit	49	2,198	1,675	113	1,811	1,479
Number of Trips	Trips/Year	Entry	48	6.33	3.85	73	6.22	3.94
		Stay	250	9.12	3.94	569	9.92	4.16
		Exit	49	4.80	2.52	113	4.97	3.05
Tripdays	Days/Year	Entry	48	96.62	57.41	73	88.89	55.16
		Stay	250	117.00	46.81	569	118.61	45.73
		Exit	49	64.10	32.26	113	57.73	33.97
Sets	Sets/Year	Entry	48	74.33	46.65	73	69.27	44.82
		Stay	250	95.36	40.28	569	94.89	37.36
		Exit	49	49.00	25.12	113	44.54	27.89
Hooks	Hooks/Year	Entry	48	99,895	83,054	73	90,792	76,643
		Stay	250	1,26,026	81,843	569	109,471	69,299
		Exit	49	56,177	40,549	113	49,359	43,400

*Gton=gross tonnage vessel capacity.
N is the number of observation in the population and in the sample dataset.

Table 3 Parameter estimates from the *multinomial logit (unordered)* model on entry, stay, and exit choices

VARIABLES	$Log(P_X/P_S)$	$log(P_N/P_S)$
REVGT	-0.4526^{***}	-0.3411^{***}
	(0.1152)	(0.0959)
FLEET	0.8230^{***}	-0.6007^{**}
	(0.2210)	(0.2396)
AGE	-0.0033	-0.0098
	(0.0149)	(0.0150)
TUNANDX	-0.0930^{***}	0.0589^{**}
	(0.0284)	(0.0303)
SWORDNDX	-0.0909^{*}	0.1337^{***}
	(0.0526)	(0.04823)
RESID	-1.0548^{**}	-1.2754^{***}
	(0.4533)	(0.4506)
CAPT	-1.0192^{**}	-0.6955
	(0.4700)	(0.4742)
Intercept	12.5941^{***}	-10.58^{**}
	(4.3837)	(5.0128)
N= 347	LR (2(14) = 114.39	Prob. > χ 2 = 0.0000
	Pseudo ρ2 = 0.2096	Log Likelihood = -215.63

PN, PS and PX are probability of entry, stay, and exit, respectively.
***, ** and * are statistically significant at 1%, 5% and 10% level, respectively. Figures in parentheses are the standard errors.

The results from the *multinomial logit* model in Table 3 are discussed first. The coefficient on REVGT suggests that the odds of staying in the fishery rather than exiting from the fishery increase with higher potential income. Similarly, the relative annual revenue was significantly higher for an incumbent vessel than for an entrant vessel. It also suggests that the entering vessels may not have made a higher income in their previous fisheries as well in the new fishery, at least in the beginning years.

The odd of exit from the fishery rather than staying in the fishery were significantly higher when the fleet size (FLEET) or congestion effect increased. On the other hand, the odds of entry to the fishery significantly decreased when fleet size in the new fishery increased. The odds of a vessel exiting from the fishery were significantly lower when fish stock levels increased, as indicated by the bigeye tuna (TUNANDX) and swordfish stock index (SWORDNDX) coefficients. Similarly, the odds of vessel entry to the fishery were significantly higher with an increase in the stock levels of these species. Similarly, the negative coefficient on the variable RESID suggests that a nonresident of Hawaii had a higher likelihood of exiting from the fishery than staying. The entering vessels were also found to be more likely nonresidents of Hawaii. Owners of the exiting vessels had a higher likelihood to have employed a hired captain as opposed to owners of vessels remaining in the fishery.

The linear marginal effects on the probability of an outcome were also evaluated at the fleet mean value of the regressor variables, and the results are presented in Table 4. The signs of the marginal effects estimates are mostly similar to the parameter estimates of the multinomial logit coefficients.[19] For an increase in the annual potential earning, the probability that a vessel will stay in the fishery increases, but the probability that a vessel will exit decreases. For example, for every 1,000 dollars increase in annual potential income, the probability of a vessel exiting from the fishery decreased by 3.15%, and the probability for a vessel remaining in the fishery increased by 6.02%. The probability of vessel entry was significantly higher when there was an increase in the bigeye tuna and swordfish stock abundance. For example, the vessel entry probability increased by 0.65% and 1.36% for each percent increase in the bigeye tuna and swordfish stock indices, respectively. Similarly, a vessel is significantly less likely to exit when there is an increase in bigeye tuna and swordfish stock levels. The vessel exit probability decreased by 0.76% and 0.81% for each percent increase in the bigeye tuna and swordfish stock indices, respectively. The effect of stock abundance has a statistically significant effect on the probability of vessel entry and exit, indicating an attractiveness of the fishery.

Similarly, the marginal effect of the fleet size had a significant impact on the probability of vessel entry or exit. For an increase in fleet capacity by every 1,000 net-tons, the probability of vessel entry to the fishery decreased by 6.52%, and the probability of vessel exit increased by 6.83%. If the vessel is owned by a Hawaii resident and the vessel owner is also a captain, the probability of the vessel staying in the fishery increased by 22.92% and 15.63%, respectively. It appears that most of the entering and exiting fishers were nonresidents of Hawaii who mostly used hired captains.

Table 4 Marginal effects on the probability of an outcome for a change in regressor

Variables (Xs)	$\partial P_X/\partial X_K$	$\partial P_S/\partial X_K$	$\partial P_N/\partial X_K$	Mean of Xs
REVGT	-0.0315***	0.0602***	-0.0287***	3.8347K
	(0.0073)	(0.0109)	(0.0082)	
FLEET	0.0683***	0.0031	-0.0652***	5.3652K
	(0.0171)	(0.0269)	(0.0213)	
AGE	-0.0001	0.0010	-0.0009	16.48years
	(0.0011)	(0.0017)	(0.0014)	
TUNANDX	-0.0076***	0.0011	0.0065**	103.83%
	(0.0022)	(0.0034)	(0.0027)	
SWORDNDX	-0.0081**	-0.0055	0.01369***	66.23%
	(0.0038)	(0.0057)	(0.0043)	
RESID	-0.0803	0.2292***	-0.1488**	0.86
	(0.0537)	(0.0854)	(0.0737)	
CAPT	-0.0933*	0.1563*	-0.0629	0.87
	(0.0605)	(0.0831)	(0.0600)	

P_N, P_S and P_X are probability of entry, stay, and exit decisions, respectively. X_k or Xs are explanatory variables. ***, **, & * are statistical significance at 1%, 5%, and 10% levels, respectively. Figures in the parentheses are the standard error.

Using the parameter estimates from the *multinomial logit* model, the predictive performance of the model on the vessel entry, stay, and exit choices by fishers was examined at the fleet level mean values of the variables

[19] In multinomial response models, a change in Pr (Yi=j) does not necessarily have the same sign as β_{jk} [34].

under consideration. As shown in Table 5, there was a very close match between the actual proportion of entry, stay, and exit numbers and the model's prediction of the proportion for all choice categories. Indeed, the model was able to predict the choices correctly in 81% of the observations used in model estimation.

Table 5 Actual vs. predicted proportion of entry-stay-exit choices

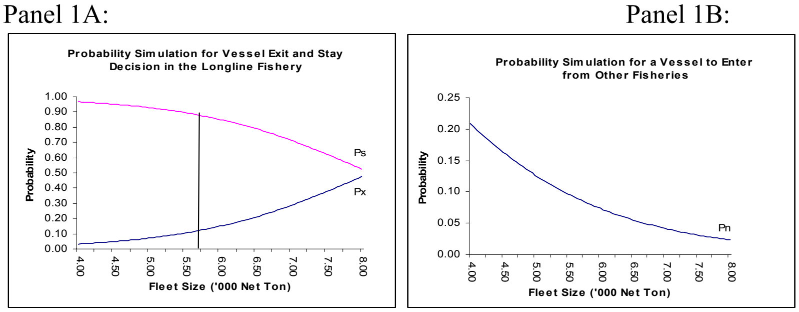
Choices	Number of observations and their proportions in the		Predicted Probabilities**
	Population	Sample*	Percent
Entry	73 (9.67%)	48	10.78%
Stay	569 (75.36%)	250	80.87%
Exit	113 (14.97%)	49	8.34%
Total	755	347	100%

*The observations used in the *multinomial logit* model estimation
** Predicted probabilities computed at mean fleet values.

Finally, the probability of vessel stay, exit, or entry was simulated using the estimated model coefficients (Figures 1 through Figure 3). The policy simulation was carried out under different levels of stock and fleet, holding the values of other variables constant. In each figure there are two panels. The first panel is about the choice between stay and exit, and the second panel is about the vessel entry probability. Although a fisher has the freedom to make any choice, i.e., entry to a new fishery, remaining in the fishery or exit from the fishery, when one is already in a fishery he faces only two choices in reality: either stay in the fishery or exit from the fishery. Similarly, a fisher from another fishery also faces two choices: either to enter or not enter to the new fishery. Since the multinomial logit is the natural extension of the binary logit model or simultaneous estimation of the binary logit model, one may use the binary logit estimates for the vessel entry, stay, and exit for simulation purposes. Therefore, the first panel uses the logit coefficients of the exit vs. stay as given in Table 3 and the second panel uses the logit coefficients of the entry vs. stay as given in the same table. The simulation related to vessel entry to the new fishery is relative to those not-entering.[20]

Figure 1 Probability of entry-stay-exit simulation with fleet size

Panel 1A: Panel 1B:



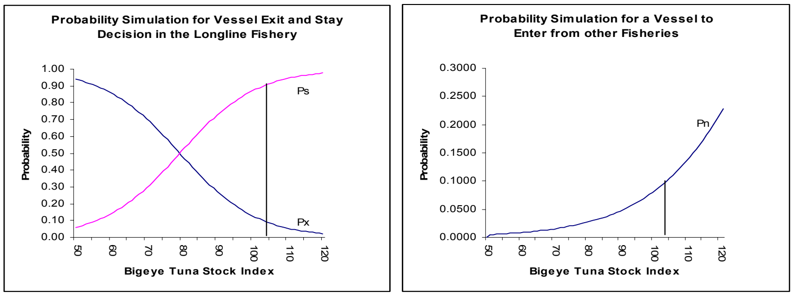
Note: Pn, Ps, and Px denote the probability of vessel entry, stay, and exit, respectively. The vertical line represents the mean fleet size during 1991-98.

The simulation exercise was carried out for a fleet size ranging between 4,000 to 8,000 net tonnage.[21] With an increase in fleet size, the probability of vessel stay (or exit) decreased (or increased) as shown in Figure 1A. The probability of a vessel choosing to stay in the fishery decreased at a slower pace for an increase in fleet size from low fleet size up to the mean fleet size, but it decreased rapidly once the fleet size surpassed the mean fleet size. Similarly, the attractiveness for a vessel enter to the fishery from other fisheries declined when fleet size increased as shown in Figure 1B.

Figure 2 Probability of entry-stay-exit simulation with bigeye tuna stock level

Panel 2A: Panel 2B:

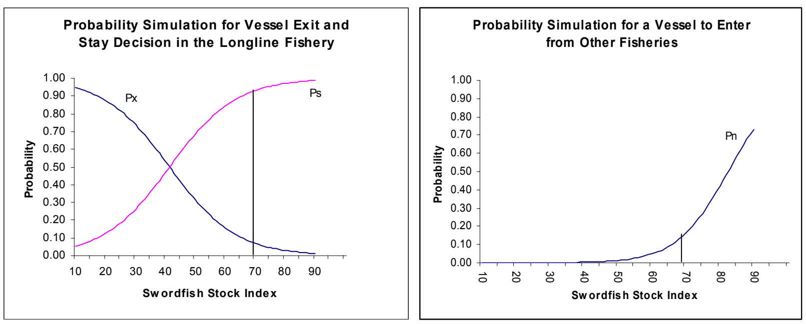
[20] Since we do not have information for those not entering into Hawaii's longline fishery from other fisheries, one may use the logit coefficients of entry vs. stay for the entry probability approximation.
[21] Annual average longline fleet capacity for the period 1991-98 was about 5.37 thousands of net tonnage.



Note: Pn, Ps, and Px denote the probability of vessel entry, stay, and exit, respectively. The vertical line represents the mean annual bigeye tuna stock index during 1991-98.

Figure 3 Probability of entry-stay-exit simulation with swordfish stock level

Panel 3A: Panel 3B:



Note: Pn, Ps, and Px denote the probability of vessel entry, stay, and exit, respectively. The vertical line in the figure is the mean annual swordfish stock index during 1991-98.

The effect of stock abundance on the probability of vessel entry, stay or exit was also simulated. Two stock conditions were considered for the simulation—bigeye tuna and swordfish stocks (Figures 2 and 3). These simulations indicate that the probability of vessel stay (or exit) increases (or decreases) with an increase in the stock level of each of these species, as shown in the first panels of Figures 2A and 3A. On the other hand, the probability of vessel entry from another fishery also increases for an increase in the stock level of these species, as shown in the second panels in Figures 2B and 3B. A very high stock level attracts more vessels enter to the fishery. The results are plausible, given the recent evidence on the massive vessel exit after the recent swordfish harvest ban. For example, the model predicts a sheer increase in the probability of vessel exit when there is a low swordfish stock level (Figure 3A). In the recent swordfish harvest ban case, the swordfish stock abundance in Hawaii's longline fishery can be considered virtually very low as fishers are prohibited from harvesting this species.[22] Because of this regulation, there occurred a massive exit of almost all the longline vessels engaged in swordfish harvest to try seeking opportunities in other locations or fisheries. Several have left Hawaii to join the California longline fleet, which is not currently subject to the same restrictions as the Hawaii-based vessels. Of the 57 vessels engaged in swordfishing activity (out of the 125 active longline vessels), about 40 of them moved to California for other fishing opportunities there; 12 have been retained in Hawaii by NMFS for the controlled field experiments to find ways to reduce sea turtle interaction with swordfishing [36]. The remaining vessels might either have adapted to longline tuna fishing or might have gone to Western Samoa, as the island has recently experienced a surge in longline vessels there [44].

CONCLUSIONS

In this paper, fishers' behavior in relation to vessel entry, exit, and stay decision in Hawaii's longline fishery during 1991-98 was examined. A behavioral model of entry, stay and exit decisions was developed in a random-utility framework, and was estimated by applying the *multinomial logit (unordered)* model. Even during this short timeframe, the entry and exit of longline vessels were pronounced and some fishers were geographically relocating their vessels from one fishery to another. The empirical results confirm that the entry, stay, and exit

[22] The swordfish harvest ban may have increased the real swordfish stock abundance, but its virtual abundance was drastically decreased.

decisions are significantly associated with the earning potential of a vessel, with fleet size, and with stock conditions of major targeted species (swordfish and bigeye tuna), as well as with other factors like residency and vessel captainship.

The results from this study suggest that a longline vessel was more likely to exit from the fishery when its annual earning potential was lower. With an increase in the annual potential earning of a vessel, the probability that it would stay in the fishery increased. Higher levels of vessel congestion in the fishery also influenced fishers to exit from the fishery. With a larger fleet, vessels were less reluctant to enter or willing to exit from the fishery. Clearly the crowding externality had a significant impact on a fisher's entry, stay, or exit decision. Fishers were also found to make entry, stay, or exit decisions based on their perceived abundances of major species such as swordfish and bigeye tuna. High stock levels provided incentives to the fishers to continue to remain in the fishery, or made them less willing to exit. Increases in stock levels in the longline fishery attracted fishers from other fisheries. Similarly, a vessel owned by an absentee owner (Hawaii nonresident) was more likely to enter or exit from the fishery. A vessel was more likely to stay in the fishery if the vessel owner was a Hawaii resident. It was also found that the vessel was more likely to remain in the fishery if its owner was also the vessel captain. The effect of vessel age had little impact on the entry-stay-exit decision.

The predictive performance of the model regarding probability of vessel entry, stay, and exit was close to the actual proportion of choices made by fishers at the fleet level. The simulation exercise carried out in this paper provides an indicative change in vessel movement when there is a change in fleet size and resource abundance, and the information from it may be used in formulating fishery policy or management in future. Fishers' responses to both the stock and crowding externalities suggest that fishery resource abundance affects not only the nearshore fishery but that of the high sea. This suggests some justifications for the enforcement of a "limited entry" permit system, seasonal or area closure, and delineating between nearshore and offshore fishery in favor of small-scale fishery. In addition, optimum fishery effort through the cooperation of both domestic and international fishery administrations, therefore, would be needed for the long-run sustainability of Hawaii's longline fishery. It will also be to the advantage of the policy-makers to keep a link/track record for each entering and exiting vessel about its previous (for entering vessels) and future (for the exiting vessels) performances in the alternate fisheries for future research purposes. The vessel entry-stay-exit decision model can be further enriched if one has information about a vessel's pre-entry or post-exit performance records related to catch or revenue in alternate fisheries, and information about the fishery policies and regulations in other fisheries from where the vessel migrated from or where it immigrated to.

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