Dynamics of Heterogeneous Congestion Tolerance in the Location Choices of U.S. Gulf of Mexico Shrimp Fishermen

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Abstract: Location choice is one of the most important short-run decisions made by commercial fishermen. Previous studies of location choice by commercial fishermen have focused primarily on site fidelity, profit-maximization behavior, and risk attitudes as factors influencing their location choice behavior. Although the recreational literature gives extensive consideration to the influence of congestion on site selection, few studies have considered the influence of congestion tolerance on site selection in the commercial fishing sector. This study uses a mixed logit model to analyze the heterogeneous congestion tolerance in location choice among U.S. Gulf of Mexico shrimp fishermen. The dynamics of fishermen responses to economic conditions are compared and contrasted for two periods; the first period coinciding with relative economic stability in the industry and the second period coinciding with deteriorating economic conditions. Results suggest that congestion externalities have significant influence on the location choice of shrimp fishermen, but that congestion tolerance level differs among them. A better understanding of heterogeneous congestion tolerance should aid the implementation of management tools such as area closures.

Introduction

Location choice is one of the more important repeated decisions confronting commercial fishermen. Fishermen's site selection behavior is influenced by a wide array of factors including initial wealth, expected revenue and its variation, volatility in output price, fish abundance, site fidelity, and weather conditions (Bockstael and Opaluch (1983), Anderson (1982), Holland and Sutinen (2000), Mistiaen and Strand (2000), Breffle and Morey (2000), Smith (2005), Dupont (1993)). Few studies, however, considered how the congestion tolerance of fishermen (let alone the heterogeneity of congestion tolerance among fishermen) influences location choice. This is surprising given that (a) congestion externalities are thought to be important in the commercial fishing sector (i.e., Ward and Sutinen 1994[1]), (b) congestion externalities as a factor in location choice is a common theme in the recreational literature (i.e., Fisher and Krutilla (1972), Shelby (1980) and McConnell (1988), Michael and Reiling (1997), Schuhmann and Schwabe (2003), Boxall et al. (2005), and Timmins and Murdock (2007)), and (c) the potential for marine protected areas (MPAs) to create or exacerbate congestion externalities in some commercial fisheries, particularly those not subject to Limited Access Privilege Programs (LAPPs).[2] Ward and Sutinen's (1994) analysis was based on Gulf of Mexico shrimp harvesting activities during the 1965-1983 period. While they found evidence of congestion externalitiy (i.e., large fleet size is related to lower probability of a vessel's entry), the industry has changed substantially since the period of their analysis. While a portion of this change is likely the result of regulation,[3] the

[1] Ward and Sutinen examine congestion externalities in relation to the influence on entry/exit decisions among Gulf shrimp fishermen.
[2] There is some debate as to whether LAPP programs will resolve a congestion externality (see Boyce, 2001).
[3] The two primary regulatory changes that have been implemented since the early 1980s that have likely influenced harvesting activities include the mandatory use of Turtle Excluder Devices (TEDs) and Bycatch Excluder Devices (BRDS) in offshore waters.

majority of the change arises from increasing imports and the subsequent decrease in dockside prices, culminating in the erosion of industry profits in the early 2000s.[4]

This paper extends Ward and Sutinen's contribution by examining whether congestion externalities influence location choice by Gulf of Mexico shrimp fishermen and whether congestion tolerance is homogeneous among fishermen. In addition, the role played by congestion externalities in welfare estimation is analyzed by simulating the expansion of a currently implemented seasonal area closure (the Texas Closure). Finally, the dynamics of fishermen responses to economic changes are examined in order to assess the relative roles of congestion tolerance and changing economic conditions in the sector.

To accomplish these objectives, the paper proceeds as follows. In the next section of the study, the concept of congestion externality is considered. A brief description of the Gulf of Mexico shrimp harvesting sector is then presented. This presentation is followed by a review of the pertinent literature. Attention is then turned to a discussion of the econometric model, data sources, and explanatory variables used in the analysis, followed by a presentation of the relevant results. A hypothetical welfare analysis is then explored, emphasizing the importance of congestion externalities in location choice.

A Definition and Concepts

As shown by Boyce (2001), the cost function for fisherman *i* can be expressed as:

$$c^*(h_i\,,\, x_{-i}\,,\, w)$$

where $x_{-i} \equiv \sum_{j \neq i}^{N} x_j$ represents inputs by all fishermen other than fisherman i, h_i represents the harvest by fisherman i and w represents the per unit input cost. The cost function is increasing in each of its arguments and, expressed in this manner, it is the quantity of inputs being employed by other firm, x_{-i} that affects firm i's costs and hence generates the congestion externality.

The concept that a congestion externality is present only if aggregate inputs by other firms in the fishery, $\sum_{j \neq i}^{N} x_j$, influence the cost function of the i-th firm is somewhat narrow in nature. For example, Charles (1988) argues that the standard economic definition of the firm is overly restrictive when depicting the behavior of fishermen and his argument is supported by the work of Feeny et al. (1996). In their analysis of the Oregon trawl fishery, the researchers found that while non-pecuniary rewards were not the primary motivation among captains, they are

[4] In 1980, for example, imports equaled 255 million pounds (heads-off weight) and the Gulf of Mexico deflated dockside shrimp price equaled $1.76 per pound (based on the 1982-84 U.S. Consumer Price Index). By 2004, imports had increased to 1.5 billion pounds and the deflated dockside price had fallen to $0.76 per pound. See Keithly and Poudel (2009) for additional discussion of the recent increase in imports and impact on dockside price.

important. As suggested by the authors, furthermore, fishermen are willing to sacrifice some pecuniary rewards for non-pecuniary ones. Assuming fishermen prefer less congestion to more (beyond some threshold level), one can argue that a congestion externality may yield disutility to the fisherman at a level of aggregate inputs by other firms that are of an insufficient level to directly impact the firm's costs. For purposes of this study, this more inclusive concept of congestion externality is considered relevant. In terms of site choice, this implies that congestion externality may be an influential determinant of site choice even if the externality does not directly influence firm costs. Based on this more inclusive concept the congestion externality in a commercial fishery can be treated similarly to that often considered in the recreational literature.

Furthermore, Karpoff (1983) argues that non-pecuniary rewards are an income-normal good and, as such, are more likely to be consumed by fishermen with higher levels of wealth. Given the recent economic deterioration of the Gulf of Mexico shrimp fishery, one might hypothesize a concomitant decrease in the pursuit of non-monetary rewards. To the extent that a congestion externality sets in prior to any direct increase in costs, declining economic conditions in the shrimp fishery are likely to translate in increased congestion tolerance by individual fishermen.

The Industry

In general terms, the Gulf of Mexico shrimp harvesting sector is comprised of an inshore component and an offshore component. The inshore component consists of several thousand "smaller" boats and vessels[5] (i.e., generally less than 60 feet in length) that tend to harvest the small, immature shrimp in the nearby bays and shallow-water habitats.[6] The mobility of these craft is limited and trips tend to be of short duration (often a single day). The offshore component is primarily comprised of larger vessels (in excess of 60 feet). These vessels tend to make several trips per year, with an individual trip potentially lasting several weeks. The mobility of offshore vessels allows them to follow the migration patterns of shrimp (i.e., from nearshore to offshore waters) as well as move broadly from one area of the Gulf to another if warranted by economic conditions or regulation.[7]

Unlike the biological structure of most fisheries, the Gulf shrimp stock is generally considered to be an annual crop. Even though the yearly nature of the shrimp crop results in high annual variability in crop size and harvest, there has been no discernable long-run change in

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[5] A vessel is characterized as a commercial fishing craft in excess of five net tons. These craft are registered with the Coast Guard. Smaller craft are registered with the respective states.

[6] The small, immature shrimp tend to be present in the bays, estuaries, and other shallow water habitats. As they grow to maturity, the shrimp tend to emigrate to the deeper, offshore Gulf waters.

[7] Because the density of the shrimp in the shallow-water habitats can be high, catch per unit effort during the migration periods can also be high. Given the small size of the shrimp being harvested, however, price per pound of the harvested product tends to be relatively low. As shrimp migrate into the open waters, density tends to decline. The higher price received for the larger harvested product from offshore waters, however, has historically compensated for the lower catch per unit effort.

harvest during the past several decades. Since 1980, annual Gulf of Mexico shrimp production has ranged from about 200 million pounds to almost 260 million pounds (heads on weight) with a corresponding value from about $300 million to almost $600 million. Further, although still the largest Gulf of Mexico commercial fishery by value, the economic viability of the shrimp industry has been gradually deteriorating since the mid-to-late 1980s when Ecuador began successfully farming shrimp and exporting much of the output to the U.S. market. Due to a combination of factors, including both a declining output price and increasing input costs, this deterioration has been particularly pronounced since the early 2000s.[8] On the output price side, for example, the dockside shrimp price equaled $2.27 per pound in 2000. By 2004, the price had declined almost 40% to $1.43 per pound.[9] On the input side, prices for diesel fuel increased by about 30% during the same period, creating a classic "cost-price squeeze" on harvesters and leading to significant changes in the industry. These changes include a reduction in vessel numbers and a general increase in trip length among remaining participants. Therefore, a better and updated understanding of fishermen's behavior is necessary to assist the management of the fishery in changing economic environment. This study is particularly interested in modeling fishers' location choice behavior, including the concept of congestion externality, using a random utility model.

Literature Review

Bockstael and Opaluch (1983) are generally credited with laying the groundwork for behavioral modeling in the management of fisheries. Starting with random utility theory, their logit choice model incorporated two key factors affecting fishermen behavior – economic inertia and uncertainty in returns, with emphasis also being given to the impact of initial wealth positions on risk attitudes. The authors' major contribution was the recognition that regulations can have unanticipated effects if predictions of firm responses to management policies are not adequately considered. Holland and Sutinen (2000) extended this initial work by developing a nested-logit model of location choice that incorporated the variation in expected trip revenues, thus emphasizing the importance of past experience in site selection behavior. Mistiaen and Strand (2000) used a random parameter/mixed logit model to account for a lack of information about initial wealth and to analyze the heterogeneous risk preferences of fishermen. Smith (2005), in a study of the sea urchin fishery in California, distinguished between state dependence (site fidelity) and preference heterogeneity in location choice behavior, noting that the exclusion of state dependence may exaggerate the significance of the random parameters and thus the importance of preference heterogeneity.

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[8] See Travis and Griffin (Update of the Economic Status of the Gulf of Mexico Commercial Shrimp Fishery) for additional details.

[9] A survey administered by the United States International Trade Commission indicates that operating margins to vessel owners (prior to subtraction for salaries) fell from 1.4% in 2001 to negative 9.8% in 2002 before recovering marginally to negative 6.6% in 2003.This survey was conducted as part of an antidumping investigation to determine whether the domestic industry was being materially injured as a result of imports.

All the aforementioned papers incorporated various factors such as initial wealth, past experience, and expected returns and their variation (as the measure of financial uncertainty) in the location choice decision-making process. None of the studies, however, considered whether congestion externalities might also influence location choice by commercial fishermen. This is surprising because, as noted in the introduction, it has been an area of considerable interest in the recreational literature. Freeman and Havemean (1977), for example, discussed the economic theory of congestion from the consumer's perspective. The authors argued that any personal interaction with other users may reduce the utility of a visit. They also pointed out the potential endogeneity problem in modeling because a particular individual's consumption adds to aggregate consumption. Early work, including that of Fisher and Krutilla (1972), Shelby (1980) and McConnell (1988) included congestion as one of the attributes that comprise the utility of the recreation experience. More recent empirical recreational demand studies (Michael and Reiling (1997), Schuhmann and Schwabe (2003), Boxall et al. (2005), and Timmins and Murdock (2007)) have focused on the modeling of heterogeneous congestion preferences and the endogeneity of the congestion variable.[10]

Given that individuals often seek solitude in recreational activities and that disutility sets in at a very early stage with respect to the interaction with other users at a particular site, most recreational demand studies model disutility as a continuous increasing function in relation to congestion. With respect to commercial fishing activities, however, an individual's disutility from site congestion may not set in until congestion reaches some threshold level. It is generally assumed that this threshold level coincides with a level of overall effort that results in increasing costs for the individual independent of the influence of effort on stock size. For example, increases in effort from a high level of stock abundance may impact an individual's catch per unit effort and revenues but will not directly impact that individual's total costs per unit of time. At some point, however, additional effort at a given site can be expected to directly influence an individual's total costs, perhaps from factors as simple as the additional navigation required to avoid collisions with other vessels. Thus, it is hypothesized in this study that the relationship between the expected utility of a chosen site and any congestion externalities is generally concave for commercial fishermen.

A concave relationship between site choice and congestion externalities would be consistent with Buchanan's (1965) theory of clubs, whereby the initial increases in club participation results in the sharing of costs (searching costs in the case of commercial fishery).

[10] Michael and Reiling (1997) showed that regulators should consider the possibility that some users might be more congestion averse. Schuhmann and Schwabe (2003) demonstrate that ignoring congestion effects will lead to omitted-variable bias. Boxall et al. (2005) emphasize that an individual's decision in choosing a recreational site depends on the number of other individuals who behave in a similar manner. Timmins and Murdock (2007) list three consequences of ignoring congestion in RUM estimation: the omission of congestion as effective rationing device, the biasedness in estimation of other variables, and inaccurate estimation of the welfare effects.

Beyond some level of participation, however, congestion begins to set in and the benefits of consuming goods or services declines.[11] Wilson (1990) discussed club theory with respect to the commercial fishery by analyzing "the problem of producing knowledge about the location of fish." In the case of a shrimp fishery, there are no formal clubs for information and search-cost sharing, but fishermen do share information informally. As a result, a location choice generally has to be a place visited by other fishermen, thus indicating the potential for economically meaningful catches. However, when too many fishermen (the standard for "too many" might be different for different individuals) are going to a site, a fisherman might choose to go to other sites either because they expect a smaller share of the potential catch at the crowded site or they have other concerns about the "heavy traffic level" at that site.

Econometric Model

For the purposes of the current analysis, a discrete choice model with respect to spatial decision-making is employed. This study is different from other spatial decision-making studies of commercial fishermen, however, as it directly incorporates a congestion externality indicator in the discrete choice model. The general model, which is consistent with the basic random utility model (RUM) originally proposed by McFadden (1974, 1981), makes use of two assumptions. The first of these assumptions is that fishermen make location choices among several discrete alternatives (fishing areas). The second assumption is that the alternative chosen is the one which generates the highest expected utility.

The general model for this study is:

$$EU_{ijt} = E\overline{U}(\boldsymbol{\beta}, \mathbf{X_{it}}, \mathbf{Y_{jt}}, \mathbf{Z_{ijt}}) + \varepsilon_{ijt} \qquad eq.1$$

where $\boldsymbol{\beta}$ is the parameter vector; $\mathbf{X_{it}}$ includes individual-specific and time-specific characteristics such as vessel length, seasonality, and management-based (i.e., Texas closure) dummy variables; $\mathbf{Z_{ijt}}$ includes individual and alternative-specific characteristics such as loyalty (state dependence variable), expected revenue and its variation; and $\mathbf{Y_{it}}$ includes alternative-specific and time-varying characteristics such as costs and congestion indicators. Testing of the hypothesized concave relationship between expected utility and congestion also requires that linear and the quadratic terms of the congestion indicator be included in the model. To adequately account for heterogeneous preferences and congestion tolerance among fishermen, the analysis employs a flexible-form mixed logit[12] model that allows for non IIA error patterns, correlation among observations, and preference variation among the fishermen. As suggested by Revelt and Train (1998), mixed logit models allows for the efficient estimation of parameters when repeated choices are made by the individuals being modeled.

[11] Sandler and Tschirhart (1980) give a detailed illustration of the theory and its applications.

[12] Mixed logit model as opposed to conditional logit also corrects the potential inconsistency and overestimation of the parameters when state dependence variable is present in the model. Heckman (1984) gives a detailed discussion on state dependence and heterogeneity.

The probability function for a conditional logit model can be expressed as

$$P_{ijt} = \frac{\exp[E\overline{U}(\boldsymbol{\beta}, \mathbf{X_{it}}, \mathbf{Y_{jt}}, \mathbf{Z_{ijt}})]}{\sum_{j=1}^{J} \exp[E\overline{U}(\boldsymbol{\beta}, \mathbf{X_{it}}, \mathbf{Y_{jt}}, \mathbf{Z_{ijt}})]} \qquad eq.\ 2$$

If the parameter vector $\boldsymbol{\beta}$ is not fixed, then the conditional probability can be obtained by integrating over the density of $\boldsymbol{\beta}$. The result of this integration is called mixed logit probability, which has the form

$$L_{ijt} = \int P_{ijt}(\boldsymbol{\beta}) f(\boldsymbol{\beta}) d\boldsymbol{\beta} \qquad eq.\ 3$$

where P_{ijt} is the conditional logit probability and $f(\boldsymbol{\beta})$ is the density function of $\boldsymbol{\beta}$. In practice, the density $f(\boldsymbol{\beta})$ is usually characterized by some set of parameters which are themselves estimated. Indirect information about $\boldsymbol{\beta}$ can be obtained from the estimation of the parameters that describe the population distribution of $\boldsymbol{\beta}$. If we define the parameter vector that describes the density of $\boldsymbol{\beta}$ as $\boldsymbol{\theta}^*$, the probability function takes the form:

$$L_{ijt} = \int P_{ijt}(\boldsymbol{\beta}) f(\boldsymbol{\beta} \mid \boldsymbol{\theta}^*) d\boldsymbol{\beta} \qquad eq.\ 4$$

A couple of distributions can be specified to estimate the parameters of $\boldsymbol{\beta}$. The normal distribution is the distribution most frequently considered in applied analysis since it is often a good approximation of the population distribution. Due to the integrals in the probability function, the Log likelihood function for mixed logit model cannot be solved explicitly. Simulation methods for estimation are discussed in Train (2002). This study uses the PROC MDC in SAS to estimate the mixed logit models.

Data Considerations

The data used in the location choice model is a combination of the Vessel Operating Unit File (VOUF) and the Shrimp Landings File (SLF).[13] Information in the VOUF, which is collected on an annual basis, includes vessel and gear characteristics. The SLF has detailed information on individual shrimp trips, including catch and price received by individual vessels on a per trip basis as well as geographical information covering the spatial distribution of landings and effort. The geographical information has three major components – a harvesting location (subarea) defined on a statistical grid of longitude and latitude, a harvesting depth based on the fathom zone where harvesting is reported, and a record that identifies the port where the

[13] The files are maintained by the National Marine Fishery Service..

harvest was landed. The combination of subarea and fathom zone yields a total of 210 statistical areas[14] (Figure 1).

Preliminary examination of the data suggests that vessels home ported in Texas fished primarily in statistical subareas 14-21. Vessels home ported in Louisiana, Mississippi, and Alabama (LAM) primarily fished in statistical subarea 10-18.[15] This segregation in the observed differences in primary fishing areas between the Texas home ported vessels and the LAM home ported vessels led us to treat each of these two groups independently in the location choice modeling.[16] For Texas-based vessels, the potential number of statistical subareas that could be included in the analysis totaled 80 (i.e., 8 grids multiplied by 10 depths) while the number for LAM-based vessels totaled 90 (i.e., 9 grids multiplied by 10 depths).

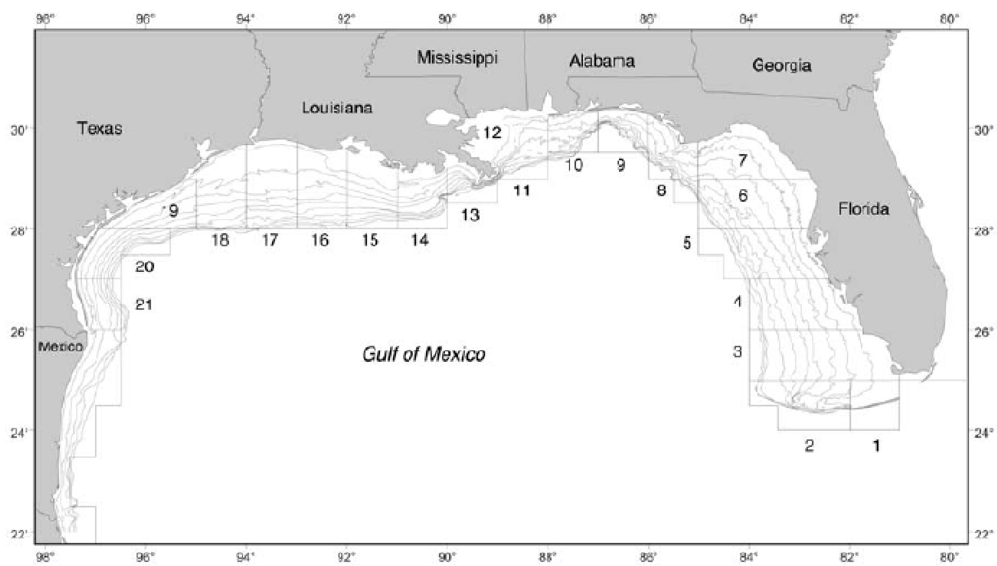

Figure 1. Relationship of 1^o longitude/latitude statistical grids with fathom zones in the U.S. Gulf of Mexico (from Nance, et al. 2006)

As might be expected, not all of the potential statistical subareas available to either the Texas-based vessels nor the LAM-based vessels receive an adequate number of harvesting visits to be used in any spatial analysis (i.e., some of the subareas are either not traditional fishing locations or have not yielded many recordable harvests). To ensure that any given spatial location has enough observations for analysis, the subareas were aggregated into newly defined

[14] These 210 statistical areas are based on 21 subareas and ten fathom zones (defined in the data set as intervals of water depth in 5 fathom increments from the U.S. shoreline out to 50 fathoms).
[15] Preliminary examination of the data suggested that vessels home ported in Florida exhibited little mobility and, hence, these vessels are not included in the analysis.
[16] Note that subarea 14, 15, 16, 17, 18 are visited by both TX and LAM vessels. This means that there is an overlapping area for the two independently treated areas.

grids.[17] This process yielded 25 aggregated grids for the Texas-based vessels, and 20 aggregated grids for the LAM-based vessels.[18]

Two five-year periods (1995-1999 and 2000-2004) were chosen to capture fishermen's location choice behavior and its changes. The first five-year period can be characterized as one of relative financial stability for the overall fleet. The second five-year period can be characterized as one of rapidly deteriorating economic conditions associated with a rapidly declining dockside price and increasing costs.[19] Only large vessels (vessel length >= 60 feet) who had recorded harvests at least once in either of the five year period are considered in the analysis.

For the Texas-based vessels, 971 vessels made approximately 42 thousand trips in 1995-1999 while 948 vessels made about 30 thousand trips in 2000-2004. For the LAM-based vessels,[20] almost 34 thousand trips were made by 689 vessels during the first five-year period of analysis while 32 thousand trips were made by 722 vessels during the second five-year period of analysis.[21]

Variable Considerations

Based upon theory and relevant research on location choice modeling, the econometric model was specified as the following:

$$\begin{aligned} EU_{ijt} &= \beta_0 + \beta_1 \cdot vel + \beta_2 \cdot wer + \beta_3 \cdot vcof + \beta_4 \cdot dist + \beta_5 \cdot loy + \beta_6 \cdot crwd + \beta_7 \cdot crwd2 \\ &+ \beta_8 \cdot season1 + \beta_9 \cdot season2 + \beta_9 \cdot txcl + \varepsilon_{ijt} \end{aligned}$$
.

[17] These grids are aggregations of the statistical grid/fathom zone information contained in the SLF. Given that the aggregation is designed with the twin goals of gaining enough observations per location and keeping the geographic expanse of each grid at a minimum, trips to some infrequently visited subareas that lay at the outer spatial edges of harvesting activity are deleted from the data (approximately 5-7 percent of all trips). In general, aggregation decisions are based on two factors: (a) ensuring a sufficient number of observations per location for statistical analysis and (b) use in the management process. As such, attempts are made to aggregate in a manner that would be most useful for management purposes subject to the constraint of a sufficient number of observations.

[18] Aggregation in a tabular format is provided in Appendix A.

[19] While additional years of data were available for analysis, the northern Gulf of Mexico witnessed two major hurricanes (Katrina and Rita) in 2005. Because of these hurricanes and their disruption on fishing patterns, a decision was made not to include data beyond 2004 in the analyses.

[20]Approximately 10 percent of the total trips by the Texas-based and LAM-based vessels visited more than one of the newly defined grids on a single trip. In these cases, the dominant location (i.e., the one that contributed the highest proportion to the trip catch was assigned as the fishing location due to the lack of information on the sequence of visiting the sites.

[21] The selection of the sample for LAM area does not reflect the fact that the fleet size has shrunk in the second five years. A higher proportion of LAM vessels staying in the industry might be due to the sunk cost involved or habit change inertia of those vessels. Since the consistency of the site choosing behavior (which is ensured by the criterion of appearing at least once each year) is more important in this study, the disproportion of the sample in LAM area during 2000-2004 is of little concern.

A brief discussion of the explanatory variables[22] considered in this study is presented below.

Vessel Length (vel): This variable serves as a proxy for a vessel's mobility, with vessel size being positively correlated with ability to travel farther.

Expected Revenue (wer): Based on the assumption that shrimp fishermen share information about past catch experience at different locations (through either formal financial ties among vessels that provide incentives for information sharing or through family/social arrangements), the weighted average fleet revenue during the previous 10 days is used as a proxy for the expected revenue of a particular vessel trip to a given grid location.[23]

Coefficient of Variation of Expected Revenue (vcof): Variation of the expected revenue as a measurement of uncertainty in the expected revenue is calculated based on the same assumption in calculating expected revenue. A positive parameter estimate for the variable indicates a risk-loving attitude towards financial uncertainties and a negative one implies risk-aversion.

Distance (dist): The distance traveled to a fishing location weighted by the monthly diesel price index is used in this study as a proxy for the cost of the trip,[24] where distance is determined using a GIS (geographic information system) routine that calculates the straight-line distance from a vessel's departure port to the centroid of each fishing location grid.

Loyalty (loy): Previous research suggests that an individual's current choice behavior is to some extent influenced by his past decisions (termed site fidelity in some fishery studies or state dependence in general studies). This study employs the method proposed by Guadagni and Little (1983) in conjunction with the smoothing parameter estimation as proposed by Fader, Lattin, and Little (1992) to estimate loyalty for use in the respective analyses (with loyalty to a given site

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[22] In the model to be analyzed, some interaction terms such as the interaction between intercepts and vessel length are created to avoid the singularity problem in estimation.

[23] To obtain an estimate of this proxy variable, days fished are first standardized using the method proposed by Griffin, Shah and Nance (1997) and Griffin (2006). Then the average expected revenue is obtained as the ratio of the sum of the fleet revenue over the sum of the standardized days fished during the ten-day period prior to departure. This ratio is weighted by the vessel's portion of the fleet revenue each year to account for vessel difference. Note that the departure date of a trip is given only for a segment of the total trips (the interviewed data), therefore beginning date of the other trips was estimated via OLS where trip length is specified as a function of unstandardized days fished, linear and quadratic terms of distance and area dummy variables. From there the ten days can be defined.

[24] Cost data for the fishery is not routinely collected. Any attempt to estimate it, furthermore, would be complicated and would require numerous simplifying assumptions.

potentially varying between Texas-based vessels and LAM-based vessels in those grids that overlap).[25]

Congestion Externality (crwd): For the purposes of this study, the expected congestion externality (crwd) is proxied by the number of vessels per unit area for any site during the past ten days.[26] Conceptually, it yields a measure of fishing intensity on a per unit area basis, with itself being an indicator of the "traffic level" during the past ten days.[27] Following Wilson (1990) and Schuhmann and Schwabe (2003), the analysis also includes the squared term of the congestion externality measure (crwd2). In the simplest case of homogeneous reaction of the fishermen towards congestion, the parameter estimate for the linear term is hypothesized to be positive while that for the quadratic term to be negative. This implies that there exists a congestion threshold after which the "traffic level" is not acceptable to a typical fisherman.

Season: A dummy variable is used to "capture" seasonal catch fluctuations in each area of this study. Three seasons are defined for the LAM area: season1 (December-April), season2 (May-June), and season3 (July-November). For the TX area they are season1 (January-May), season2 (June-September), and season3 (October-December).[28]

Texas Closure (txcl): The Texas Closure, a seasonal management event that closes harvesting in all but the inshore waters off of the Texas coast, is modeled using a dummy variable approach. In general, the Texas Closure occurs from mid-May to mid-July each year, with some variation in the specific regulatory dates. [29]

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[25] The variable loyalty used by Guadagni and Little (1983) to measure true state dependence is an exponentially weighted average of the past purchase history of the individual. Specifically, the model has the structure of

$$LOY_j^i(t) = \lambda LOY_j^i(t-1) + (1-\lambda) y_j^i(t-1)$$

where $LOY_j^i(t)$ is loyalty of individual i to alternative j on choice occasion t, $y_j^i(t)$ is a dummy variable indicating whether individual i chose alternative j on choice occasion t or not, and λ is a smoothing parameter which takes the value between zero and one.

Several methods were proposed by previous studies to estimate the smoothing parameter λ, and the one used here is by Fader, Lattin, and Little (1992). The basic idea is as the following: Since loyalty is nonlinearly dependent on a single parameter λ, and λ cannot be estimated directly as an ordinary logit coefficient, a Taylor series is used to expand the loyalty variable at a starting value λ_0. If the derivatives of loyalty with respect to λ are bounded in an interval containing both λ_0 and the maximum likelihood estimate value of λ, then the second and higher order terms in the Taylor expansion will approach zero as λ_0 approaches its maximum likelihood estimate value. Therefore, only loyalty and the first derivative of it are included in the conditional logit model to estimate λ iteratively. The model estimation is then divided into two steps: first, estimate λ using LOY and its first derivative; second, plug the optimal value of λ in to calculate LOY and include LOY into the model to estimate all the parameters.

The initial value of LOY is taken as the same for all the alternatives, being one divided by the total number of alternatives (i.e. it is 1/20 and 1/25 for each alternative in LAM and TX area, respectively). Ten years (1995-2004) data are used to estimate λ for each area. The estimates for both areas are around 0.79.

[26] Given the lag structure, the potential endogeneity problem as discussed by Michael and Reiling (1997) becomes moot.

[27] The underlying assumption associated with this variable is that the level of traffic changes slowly and, as such, previous traffic provides an accurate indicator of expected current traffic.

[28] Note that there is some difference in the definitions of the seasons for the two areas, which are based on the observation of the fleet harvest level in each month in each area.

[29] A detailed illustration of the area and time is in appendix B.

Results and Interpretation

The results for mixed logit estimation of the location choice behavior for the two time periods of interest are presented in Table 1 (LAM model) and Table 2 (TX model)[30][31] . Using the method proposed by Hensher and Greene (2003) for determining which continuous variables should be treated as random, all continuous variables were treated as random for purposes of this analysis.[32]

Table 1 Parameter Estimates---LAM Area

	1995-1999		2000-2004	
Parameter	*Estimate*	*Pr > |t|*	*Estimate*	*Pr > |t|*
Loyalty (mean)	4.33	<.0001	4.6795	<.0001
Loyalty (s.d.)	-1.264	<.0001	1.4004	<.0001
Expected revenue (mean)	0.0496	<.0001	-0.00414	0.7008
Expected revenue (s.d.)	-0.00504	0.9765	-0.00242	0.9937
Variation of ER (mean)	-0.0289	0.4792	-0.0276	0.0001
Variation of ER (s.d.)	0.037	0.9265	0.000211	0.9992
Distance (mean)	-0.0296	<.0001	-0.0166	<.0001
Distance (s.d.)	-0.00983	<.0001	0.006462	<.0001
Congestion (mean)	0.0313	<.0001	0.0191	<.0001
Congestion (s.d.)	-0.00043	0.9365	0.000289	0.9455
Congestion squared (mean)	-0.00021	<.0001	-8.4E-05	<.0001
Congestion squared (s.d.)	-0.00012	<.0001	-4.4E-05	<.0001

Table 2 Parameter Estimates---TX Area

[30] Due to space limitations, parameter estimates associated with the discrete variables and their interaction terms are not presented in the respective tables. Full tables with all estimates are available in appendix C.

[31] A couple of goodness-of-fit values are reported by SAS, ranging from 0.55 (McFadden's LRI) to 0.99 (Estrella) for LAM models and 0.43 (McFadden's LRI) to 0.97 (Estrella) for TX models. There is not much difference in goodness-of-fit for models over the two periods in the same area.

[32] The tests work by running conditional logit model first, constructing artificial variables and re-run conditional logit model including these artificial variables. The null hypothesis of no random coefficients on attributes *x* is rejected if the coefficients of the artificial variables are significantly different from zero.

	1995-1999		2000-2004	
Parameter	*Estimate*	*Pr > |t|*	*Estimate*	*Pr > |t|*
Loyalty (mean)	3.8181	<.0001	4.3324	<.0001
Loyalty (s.d.)	0.9061	<.0001	0.0972	0.9023
Expected revenue (mean)	0.0203	<.0001	0.005905	0.3324
Expected revenue (s.d.)	-0.00619	0.5076	0.0018	0.985
Variation of ER (mean)	-0.1058	<.0001	-0.042	<.0001
Variation of ER (s.d.)	0.1042	0.0081	-0.0201	0.7598
Distance (mean)	-0.0462	<.0001	-0.0242	<.0001
Distance (s.d.)	0.025	<.0001	-0.0124	<.0001
Congestion (mean)	0.026	<.0001	0.0112	<.0001
Congestion (s.d.)	0.001443	0.557	-0.00495	0.0033
Congestion squared (mean)	-9.4E-05	<.0001	-3.9E-05	<.0001
Congestion squared (s.d.)	5.85E-05	<.0001	1.82E-05	0.0041

As indicated in the tables, most of the estimated parameters have expected signs.[33] Past site selection behavior was significantly associated with the probability of current site selection behavior, a finding which is consistent with previous studies (e.g., Holland, 2000). This is an indication of habit persistence, inertia related to exploration of other locations, or familiarity combined with risk aversion. However, the statistical significance of the standard deviation of the random parameter for loyalty implies that there is a significant variation in loyalty among fishermen (with the exception of the TX 2000-2004 model).

In addition, fishermen were found to be sensitive to changes in costs. Specifically, increased distances from port to any specific grid, or an increase in fuel price, translated to a decreased probability of that site being visited, *ceteris paribus*. The statistical significance of the standard deviation of the random parameter for distance, however, implies considerable variation among fishermen with respect to the influence of cost on site selection.

[33] Some of the signs for standard error of the random parameters are negative. This is because it is the variances of the random parameters that were estimated in the simulated likelihood. Then the square root of the estimated variance was taken to get the standard deviation, which was randomly given the sign of either positive or negative. In interpretation the standard deviations are all treated as positive.

The dynamics of fishermen's response to economic factors across the two time periods is obvious. For both areas, fishermen are revenue driven in location choice during the first period, but not in the second period when the economic situation is less favorable. LAM fishers acted as if they were risk-neutral in the first five years, but risk-averse in 2000-2004. TX fishers held different attitudes towards financial uncertainties in 1995-1999, with about 85% of them acting as if they were risk-averse. In the second five years, however, they acted as if they were uniformly risk-averse.

The mean of the random parameter for the linear term of the congestion externality is positive for both areas and for both periods. The mean of the squared term parameter exhibits a negative sign for both areas in both periods, confirming that the relationship between expected utility and the congestion externality is concave (Figure 2 shows the relationship for LAM area in 1995-1999, with figures for other areas and periods being similar). When calculated at the mean of the two parameters, the congestion tolerance threshold for LAM fishermen increases from 74.52 in 1995-1999 to 113.69 in 2000-2004, and that for TX fishermen increases from 138.3 to 143.6. This indicates that if the congestion tolerance of the shrimp fishermen was treated homogeneous, they would show higher tolerance towards congestion in the second period.

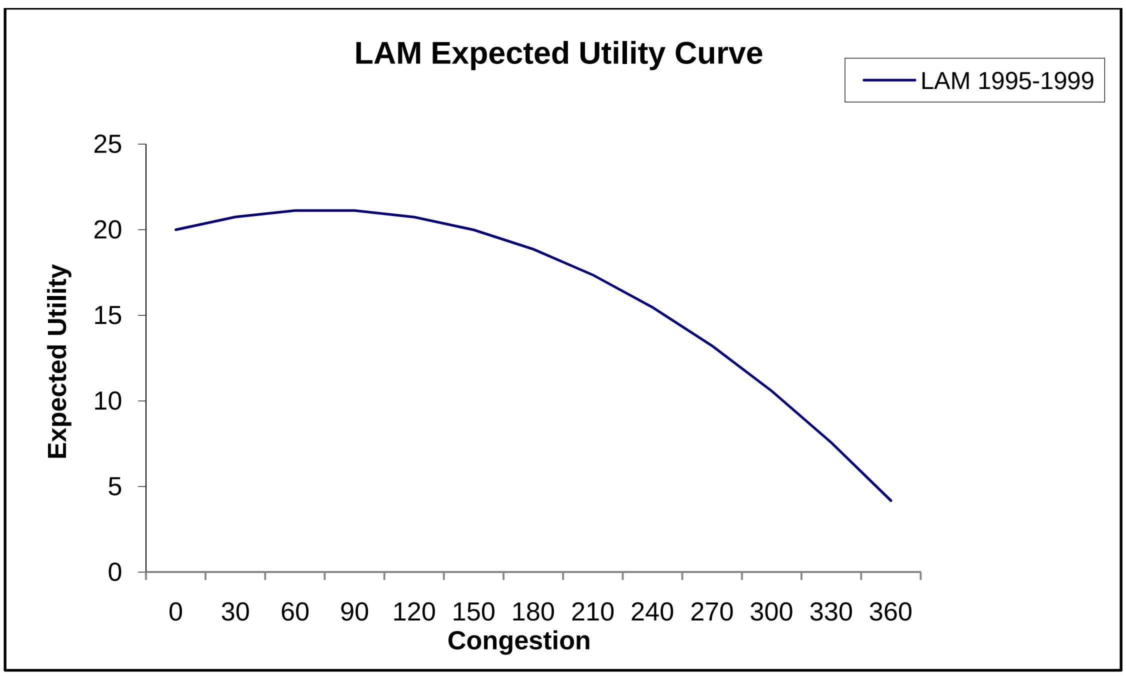

Figure 2 . LAM area 1995-1999 (at the estimated mean of the random parameters)

To see whether their congestion tolerance is heterogeneous, we need to check the standard deviations of the random parameters for congestion externality. For the LAM area, the standard deviations of the linear term random parameters are not significant. However, the standard deviations of the parameters for the squared terms are significantly different from zero. This implies that the congestion tolerance thresholds calculated based on the parameters of the linear and quadratic terms are also random.[34] Hence, one can conclude that tolerance to congestion varies from one individual to another for LAM fishermen. The TX area has similar results, with the only difference being that the standard deviation of the linear term random parameter is significant.[35] Table 3 illustrates the threshold levels for each area and time and the standard deviations of them, which are calculated using delta method.[36]

The distribution for the threshold for the LAM and TX areas are presented in Figures 3 and 4. There is, as indicated, a portion of the population that has a zero or negative value for the threshold in both periods. This implies that a small proportion of the fishermen would be adversely impacted from congestion even at very low levels. In other words, similar to the case in recreational demand, some shrimpers prefer solitude. If the heterogeneity of the congestion tolerance among fishermen is taken into account, it appears as though some portion of the population has an increased congestion tolerance level in the second five years for LAM area (Figure 3). One of the possible explanations for the change is that, given the economic pressures on the industry in the period 2000-2004, shrimp harvesters are more willing to tolerate congestion and crowding in their pursuit of economic viable catches.[37] If we consider less congestion as non-pecuniary rewards, this result echoes Karpoff (1983), who argues that non-pecuniary rewards are an income-normal good and, as such, are more likely to be consumed by fishermen with higher levels of wealth. Given the recent economic deterioration of the Gulf of Mexico shrimp fishery, one might hypothesize a concomitant decrease in the pursuit of non-monetary rewards. To the extent that a congestion externality sets in prior to any direct increase in costs, declining economic conditions in the shrimp fishery are likely to translate in increased congestion tolerance by individual fishermen.

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[34] The threshold is calculated as setting the first derivative of expected utility with respect to congestion as zero. Specifically, threshold= $\frac{-2\hat{\beta}_{congestion}}{\hat{\beta}_{congestion\ squared}}$.

[35] Due to the normal distribution assumption for the random parameters, there is a small portion (less than five percent for LAM area and around five percent for TX area in 1995-1999) of the population that always has positive attitudes towards congestion. For TX 2000-2004, a tiny portion of the population even exhibits convex relationship between expected utility and congestion level. However, the majority of the population has expected concave relationship.

[36] Since the threshold is a nonlinear function of the estimates of congestion terms, its variance cannot be directly derived from the variances of those estimates. Instead, the derivative of the threshold expression $\frac{-2\hat{\beta}_{congestion}}{\hat{\beta}_{congestion\ squared}}$, which makes a 2×1 vector, and the variance-covariance matrix of the congestion estimates (a 2×2 matrix) are used. The threshold is asymptotically normal since the congestion random parameters are assumed normally distributed. A detailed description of the delta method is in Greene (2008) pp68-69.

[37] It could be due to difference in the sample for the two periods. Or, the fishermen in 1995-1999 are different to some extent from the fishermen in 2000-2004 in terms of congestion tolerance level. However, the same models were run for fishers who stayed for the whole 10 years which accounts for about 45%-50% of the population and similar results were obtained.

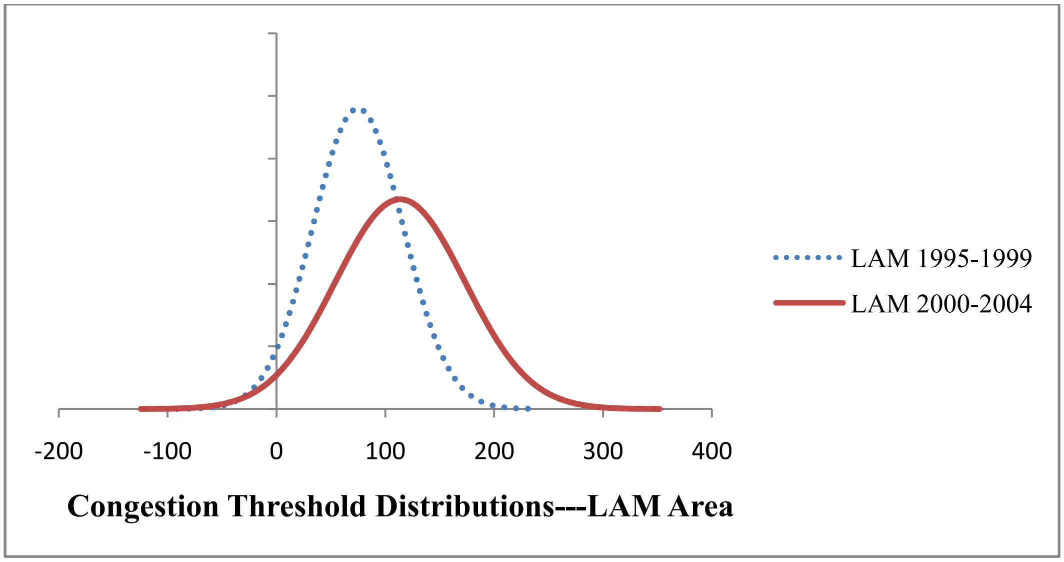

Figure 3 Distribution of congestion threshold (LAM area)

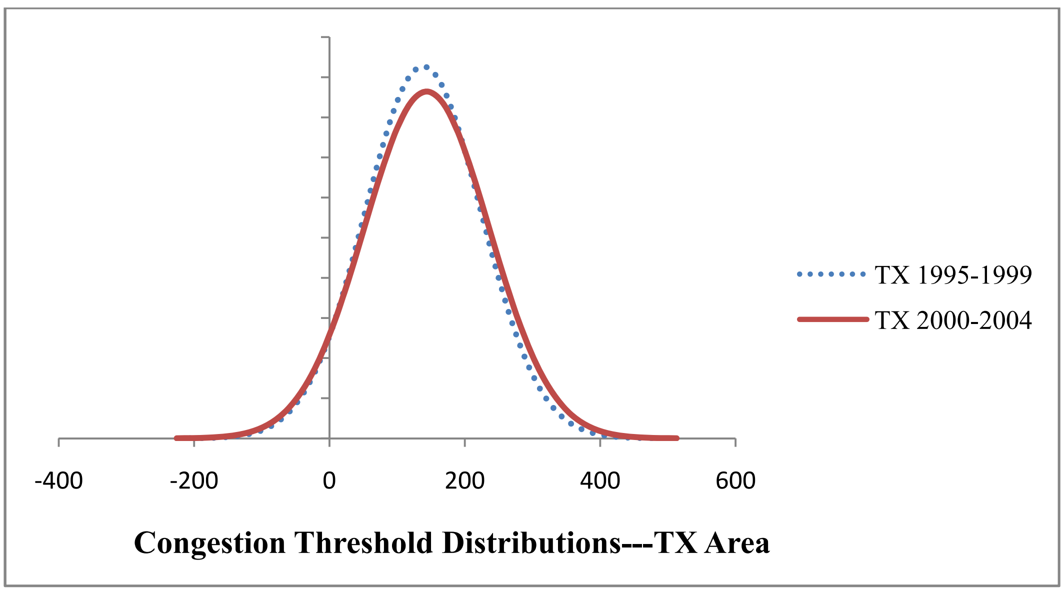

Figure 4 Distribution of congestion threshold (TX area)

Table 3 Threshold and its standard deviation

	Congestion linear	Congestion squared	S.d. of Congestion linear	S.d. of Congestion squared	Congestion threshold	s.d. of Congestion threshold
lam9599	0.0313	-0.000209	0	0.000116	74.88	41.5604
lam0004	0.0191	-8.40E-05	0	4.40E-05	113.69	59.55215
tx9599	0.026	-0.000094	0	0.0000585	138.30	86.06836
tx0004	0.0112	-0.000039	0.004953	0.0000182	143.59	92.31682

Welfare application

The Texas Closure was implemented in 1981 as a means of protecting smaller, juvenile shrimp from early harvest and thereby enhancing the revenues that could be generated from the overall fishery. While much of the welfare loss attributable to the closure reflects vessel relocation costs (i.e., displacement of vessels that would chose to fish in an area in the absence of the closure), displacement of these vessels may also generate/exacerbate congestion externalities in areas of the Gulf not subject to the closure. The generation and/or exacerbation of these externalities may result in area switching among some vessels that are not directly impacted by the Texas Closure (i.e., vessels that would chose not to fish in the closed area even in the absence of the closure).

The manner in which data for the two areas (TX and LAM areas) were constructed allows the examination of the impact of the Texas Closure on LAM-based vessels. Evidence[38] shows that the TX closure, in addition to the creation of relocation costs, exerted a "traffic" burden on vessels fishing in the neighboring grids. If the burden is ignored, the costs associated with the TX closure tool will be underestimated. To better assist in measuring the welfare loss due to an area closure, a simultaneous area closure of the rest of the TX area is simulated to determine the magnitude of underestimation[39] assuming the same pattern of relocation and thus the same increased congestion level (for instance, the congestion level doubled for grid 2 and 19). The welfare loss associated with the simulated area closure is calculated for the model with congestion variables included and then for the model without congestion variables. The difference between the two cases provides an indication of how important congestion is to the welfare losses associated with this management policy.

The theoretical derivation of compensating and equivalent variation in the RUM is presented by Small and Rosen (1981) and Hanemann (1999). The basic intuition is that the "marginal willingness-to pay for a quality change is given by the marginal utility of quality, converted to monetary units via the marginal utility of income." Following Parsons and Kealy (1992) and Train (1998), the welfare change can be measured as

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[38]Some simple statistics show that during TX closure, around two thirds of the TX vessels who fished in TX closure grids would go to non-closure grids (grid 5, 6,7,17 and part of grid 8 and grid 9), which are overlapping with the left part of LAM area (grid 3, 4, 8, 9, 13, 17, 20). Meanwhile two fifth of the LAM vessels who normally fished in the overlapping areas are observed moving further east (Note that TX home ported vessels who traditionally fished in the overlapping grids might also move further east also but are not counted here. Therefore for the whole fleet there should be more vessels moving further east). In addition, average congestion level during TX closure increased for most LAM grids compared to the time before and after TX closure for all years.

[39] In other words, the hypothetical area closure affects all the TX grids. As a result, lots of TX vessels as well as LAM vessels who normally fish in those grids are supposed to move further east to LAM area that is not overlapping with TX area (i.e. grids 1, 2, 6, 7, 11, 12, 15, 16, 19). An alternative is to measure the welfare loss due to TX closure in current grids. However, this would involve comparing welfare level of the sample with the welfare level before TX closure is implemented before 1981.

$$\frac{1}{\beta_y}\cdot \ln\{\frac{\sum_j \exp(x_{ijt}\beta')}{\sum_j \exp(\tilde{x}_{ijt}\beta')}\} = \{\ln(\sum_j \exp(x_{ijt}\beta')) - \ln(\sum_j \exp(\tilde{x}_{ijt}\beta'))\}/\beta_y \qquad eq. 4$$

where x is the vector of original attributes and $\tilde{x}$ is the vector of the new attributes. The attributes are of individual i for alternative j on choice occasion t. β_y is the cost coefficient indicating the marginal utility of income[40].

The welfare loss equation is applied first to a model with congestion variables, or the full model. Then the same equation is used in calculating welfare loss from a model ignoring the congestion variables, or the reduced model.[41] Table 4 gives the welfare loss for each year using the full model and the reduced model, respectively.

Table 4 Yearly Welfare Losses for Hypothetical Area Closure in LAM Area (in U.S. dollar)

		Full model		Reduced model	
Year	Trips	Lower bound	Upper bound	Lower bound	Upper bound
1995	6991	-121297	-247335	-91757.2	-183308
1996	6511	-121301	-247344	-102342	-204454
1997	6850	-139898	-285265	-127751	-255215
1998	6741	-141396	-288320	-102442	-204654
1999	6430	-117827	-240260	-105047	-209859
2000	6506	-110708	-221416	-109333	-218666
2001	6303	-85201.8	-170404	-83629.9	-167260
2002	6742	-178445	-356889	-115375	-230749

[40] To calculate the welfare change associated with the hypothetical extension of the Texas Closure, the procedure is as follows. First, the hypothetically closed sites are eliminated from the choice set, thus x is constrained to $\tilde{x}$. Second, the coefficient for weighted distance divided by the diesel price at the base month (i.e., converting the diesel price index into a dollar amount) is determined. This yields an estimate on the cost coefficient based on the assumption that it takes one gallon of diesel per kilometer traveled (Note that the coefficient is based on traveling while steaming rather than trawling. The distance variable as previously considered in the report reflects travel to the fishing ground rather than trawling activities. Trawling, of course, consumes more fuel per hour than does steaming). This assumption may be somewhat unrealistic. Because no published studies that provide an estimate of fuel usage per unit of distance for the Gulf shrimp fishery could be found in the literature, other sources (sales of shrimp vessels that mention fuel usage per hour and knots traveled per hour; telephone calls with selected shrimp industry members and others) were utilized to estimate fuel consumption per unit of distance traveled (Of course, the actual fuel usage would depend on both individual vessel characteristics such as vessel size, single versus twin screw, whether the generator is being run, etc. and weather conditions since fuel consumption is likely to increase by a third or more under 'rough' seas). While the provided information varied, estimates generally fell in the range of 1.5 gallons per nautical mile to 3.0 gallons per nautical mile. These estimates are used to derive a final cost coefficient. Given this range, both a lower-bound and upper-bound estimate of welfare losses are calculated.

[41] Note that in both cases the welfare is calculated at the estimated mean of the random parameters.

2003	6195	-171226	-342452	-111938	-223875
2004	6560	-166748	-333497	-115341	-230682

Note: Due to the fuel efficiency difference in vessels, the welfare loss is calculated within the range of the most efficient use of fuel and the least efficient use of fuel. For the period 1995-1999 (base January 1995), the most and least efficient use of fuel was $0.89 and $1.78 per kilometer, respectively. For the period 2000-2004 (base January 2000), the most and least efficient use of fuel was $1.10 and $2.20 per kilometer, respectively or $0.737 and $1.47 per kilometer excluding federal and state taxes.

From Table 4 it can be seen that for the first five years, the underestimated yearly welfare loss due to ignoring congestion can be as high as $80,000 for the first period and as high as $120,000 for the second period of time. This means that, in the extreme case, if the congestion externality is ignored in the model, the welfare loss from smaller choice set due to area closure will be underestimated by one third. If the whole fleet behaves the same way as those vessels in the sample, the magnitude of the loss should be larger. Certainly the magnitude in reality depends on the heterogeneous congestion preferences and a fishermen's relocation choice. In addition, if the fleet size continues shrinking due to the unfavorable economic situation, congestion externalities may not be a big concern for this specific fishery.[42]

Conclusion

This paper contributes to the literature by including congestion externalities in a location choice model for commercial fishermen in the Gulf of Mexico shrimp fishery for two periods of time. Based on the theory of clubs, the congestion externality should make a positive contribution to the expected utility of choosing a location until a certain threshold is reached. After the threshold level is reached, the externality's contribution turns negative due to the desire of fishermen to avoid heavy traffic levels and/or competition for catch. A mixed logit was used to incorporate heterogeneity in individual congestion tolerance levels. Besides the crowding variables, other variables such as past experience (site fidelity/loyalty), expected revenues, financial risks attitudes, proxy for costs were included in the model. The results demonstrate that congestion externalities can play a significant role in the location choice behavior of commercial fishermen. The results also confirmed the hypothesis of a concave relationship between the expected utility of location choice and the congestion level. In addition, fishermen's tolerance towards congestion was found to be heterogeneous, with some fishermen appearing to be completely intolerant towards congestion. Welfare losses due to a hypothetical area closure, based on models with and without congestion variables, indicate that ignoring congestion externalities in location choice models of commercial fisheries may underestimate the calculated welfare loss by as much as one third.

[42] Note that there is some variation among the years in terms of welfare loss. This might be due to the different samples taken for each year.