Estimation of Commercial Fishing Trip Costs using Sea Sampling Data

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Abstract
When estimating commercial fishing costs, selection bias can impact any model derived from non-census sampling methodologies. In the Northeastern U.S., commercial fishing operating cost models may suffer from selection bias, as they are often estimated using data collected for biological, rather than economic, purposes. We investigate the effects of sampling bias on trip-cost model estimations using weighted/unweighted least squares and Heckman Sample Selection models. Results suggest (1) The propensity for a trip to carry an observer is not random with respect to costs, and (2) Selection bias exists in the majority of cost models investigated. To gauge the magnitude of selection bias, we compare results of the unweighted least squares and Heckman models. The differences between models can lead to erroneous conclusions at the sub-fleet level and in estimating trip cost maxima. Results suggest assessing and correcting for selection bias is necessary when using sampled fishing cost data.

Key Words: Fishing Trip Cost Estimation, Heckman Selection, Missing Data, OLS, Selection Bias, WOLS
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1. Introduction

Commercial fishing variable costs (i.e., trip costs) play a critical role in assessing the impacts of management decisions, empirically testing economic theory, as well as estimating and tracking the economic performance of the most profitable and at-risk fisheries over time (Lee and Thunberg 2013; Walden and Kitts 2014; Steele et al. 2016; Hutniczak et al. 2019; Lawrence, Quintana, and Arina 2018). For example, in the Northeast US, trip cost modeling was essential in estimating Individual Fishing Quota lease market transactions within the Northeastern General Category Scallop fishery (Jin, Lee, and Thunberg 2019). Additionally, trip cost models have been used to track the Northeast Multispecies fleet's economic performance since the implementation of the Catch Share Program in 2010 (Murphy et al. 2018). More generally, profitability is a key metric in developing and evaluating socioeconomic and integrated ecological–economic fisheries models used to inform management decisions (e.g. Holland, Pinto Da Silva, and Kitts 2013; Nielsen et al. 2017).

Although accurate cost estimation is crucial in fisheries economic analyses, fishing costs are often the least known component in many economic studies due to data limitations. In the Northeast region, researchers have historically employed restrictive equilibrium assumptions to derive costs from revenue data (Edwards and Murawski 1993), or relied on infrequent cost surveys of small samples of fishing vessels. For example, Lynch, Doherty, and Draheim (1961) evaluated the competitiveness of the New England groundfish fleet using cost data from 25 trawlers gathered from 1953-1957. Regional operating costs and revenues incurred in year 1967 were collected by the U.S. Census Bureau's Census of Commercial Fisheries; however, this effort was not repeated in subsequent years (Thunberg et al. 2015). The National Marine Fisheries Service published a series of "Basic Economic Indicator" statistical reports containing regional costs and earnings from the early 30's to the early 70's for multiple fisheries (NMFS 1978, NMFS 1974). Crutchfield and Gates (1985) examined costs and returns between 1976 and 1982. Jin et al. (2002) compiled fishing vessel cost data from several sources including early survey data (NMFS 1974, 1978) and data from the Capital Construction Fund (CCF) (Gautam and Kitts 1996). Relatively recent cost studies in the region include Georgianna and Cass (1998), Georgianna, Cass, and Amaral (1999), and Lallemand et al. (1998, 1999). Annual vessel fixed cost data have also been collected in the 2006-2008, 2011, 2012 and 2015 Northeast Fisheries Science Center (NEFSC) Annual Cost Survey.

For the past two decades, a more systematic approach to collecting fishing trip cost data has been employed by the NEFSC through the Northeast Fisheries Observer Program (NEFOP). This data collection effort includes onboard data collectors primarily collecting bycatch and biological data along with commercial trip cost information (fuel, oil, bait, ice, groceries, water, supplies, and damage costs). Similarly, the At-Sea Monitoring Program (ASM), enacted in 2010 under the 16th Amendment to the Northeast (NE) Multispecies Fishery Management Plan (FMP), collects economic trip-level data from sector vessels within the groundfish fishery.[2] Though consistent economic trip cost data are collected by both programs, the selection of trips is driven by differing stratifications that do not include variables associated with cost outlays. The sampling stratification framework for NEFOP, the Standardized Bycatch Reporting Methodology (SBRM), is designed to provide estimates of bycatch for the Northeast region's fisheries with the

[2] The ASM program requirements were introduced under Amendment 16 to the groundfish FMP which changed the management of allocated groundfish stocks from DAS to a catch share system, operating under Annual Catch Limits (ACLs [i.e., hard quota limits]). Although Amendment 16 provided an option to fish under a limited access common pool, the vast majority of groundfish fishermen now operate within a "sector", in which they can buy and sell quota. ASM focuses on collecting the weights and lengths of retained and discarded fish from groundfish sector trips with the primary goal of monitoring quota utilization rates and catch to ensure ACLs are not exceeded within the groundfish fishery. In contrast, the NEFOP program was developed to estimate bycatch across all federally managed fisheries.

objective of obtaining a coefficient of variation (CV) no greater than 30% for each specific species group while accounting for the relative importance of the discards among fleets (NMFS 2008; Wigley et al. 2011). The 30% CV precision standard dictates fleet-specific sample sizes, where fleets are defined by fishing trip characteristics (i.e., fishing gear, access area, region, trip category, and mesh size). The ASM program also collects discard information using onboard data collectors but specifically focuses on the groundfish fishery Catch Share Program (NOAA Fisheries 2018b) and uses a different sampling stratification (sector, gear, mesh category, and broad stock area). Therefore, ASM and NEFOP observers have similar stratification variables (i.e., trip characteristics) with the exception of groundfish sectors. Within the SBRM strata (i.e., SBRM fleet type), trips are randomly selected for NEFOP observation. Because sampling is driven by precision-based sample sizes, only about 2-6% of all commercial fishing trips are sampled per calendar year (Das 2014). Additionally, allocating observer effort across trips within a stratum is extremely challenging given the spatial extent of the management area (spanning from Cape Hatteras, North Carolina, to the Atlantic US-Canadian border). Therefore, the total number of potential trips that can be sampled at any point in time within a region is constrained by the travel distance possible for onboard data collectors, despite pre-trip notification lead times. Further, issues of safety, such as vessel condition, can further constrain the set of trips sampled by onboard data collectors. Although unavoidable, these realities may introduce cost biases in terms of which fishing trips ultimately carry an onboard data collector. Selection bias may also stem from the method in which these trip cost data are collected, considering that the appropriate stratification and sample sizes for estimating bycatch discards are most likely different from those for estimating vessel trip costs. If these biases exist and are not accounted for, relevant economic analyses may lead to erroneous conclusions, which in turn may negatively affect management decisions and regulatory outcomes. Further, selection bias may impact any cost estimation model which relies on sampling design methods and data collection—common practice in the US, UK, Australia, and Southeast Asia (Thunberg et al. 2015; Lawrence, Quintana, and Arina 2018; ABARES 2019; FAO 2018). When left unexamined, sampling biases in cost estimation could impact commercial fishing performance measures on an international level.

The objective of this study is to assess the existence and magnitude of potential selection bias in out-of-sample fishing trip cost predictions when using sampled economic data. We estimate fishing trip cost functions using three different methods and explore the presence of sampling bias in fishing trip cost estimation. Lastly, we compare the discrepancies across model predictions to better understand the impacts of model choice given the existence of selection bias.

In statistics, there are two different types of missing data: i) item non-response, defined as missing variables for an observed survey unit (in our case a fishing trip) and ii) unit non-response, defined as a fully unobserved survey unit. This study focuses on the latter. Missing data may have significant effects on model estimation results (e.g., biased or inconsistent estimators), because the sample data may not be representative of the population.

There are three types of unit non-response (Rubin 1976; Greene 2012): i) Survey units which are missing completely at random (MCAR) given that the probability of observing a unit is independent of both the explanatory and outcome variables of interest. When data are MCAR, the analyses performed on the data are unbiased, since the sampled data are representative of the population. ii) Missing at random (MAR) occurs when the probability of observation is independent of the outcome variable but not the explanatory variables, such that the conditional probability of observation is random. (iii) Missing not at random (MNAR) are data in which the probability of observation is systematically related to the outcome variable of interest.

Because vessel trip sampling is stratified random and the strata are chosen for the purpose of discard estimation, it is unlikely that trip cost data are MCAR. Two popular solutions to missing data are inverse probability weighting and Heckman-type selection corrections (Imbens and Wooldridge 2007). The inverse probability weighting method is based on the assumption that the data are MAR or "selection on observables", such that the entire population has some representation within the sample, but representation is disproportional relative to the population. The Heckman-type model is typically used to address MNAR or "selection on unobservables", where units of the population have no representation such that they are missing entirely from the sample and thus cannot be weighted (Greene 2012; Imbens and Wooldridge 2007).

Unfortunately, there is no single correct way to address sampling bias. Considerable disagreement exits on survey weighting and weighted regressions (Gelman 2007). Although studies by DuMouchel and Duncan (1983), Pfeffermann (1993), and Winship and Radbill (1994) provide guidance on the suitability of weighting and how to weight, their recommendations are typically based on a set of assumptions on model properties. For large datasets, theory cannot provide a clear answer and empirical analysis is the key. In this study, we investigate three methods for estimating trip cost functions for four fishing gear groups (trawl, dredge, gillnet and longline) over two trip duration categories, single-day and multi-day trips.

2. Methods and Technical Approach

2.1. Weighted Regressions

One common approach to correct sampling bias is to use weighted regressions. The basic idea is straightforward, following the concept of MAR. For the regression:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (1)$$

where **Y** is the dependent variable (natural log of fishing trip cost), **X** includes the independent variables, $\boldsymbol{\beta}$ is a vector of coefficients to be estimated, and $\boldsymbol{\varepsilon}$ is the error term. Generally, fishing costs are affected by gear type, vessel characteristics (e.g., size, horsepower, and age) and vessel operation (e.g., duration at sea) (Jin 2008; Das 2014).

The ordinary least squares (OLS) estimators are given by:

$$\widehat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y} \quad (2)$$

and the weighted OLS (WOLS) estimators are given by:

$$\widehat{\boldsymbol{\beta}}_W = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\mathbf{Y} \quad (3)$$

where **W** is a diagonal matrix whose ith diagonal element is $w_i = 1/p_i$, and p_i is the probability of being sampled. The purpose of sampling weights is to make the distribution of the set of variables in the sampled data approximate the distribution of those variables in the population from which the sample was drawn. Note, however, that if the errors in the unweighted sample were homoscedastic with variance σ^2, using sample weights will induce heteroscedasticity where, for observation i, the variance becomes $w_i^2\sigma^2$.

2.2. Heckman Sample Selection Model

A popular method to address MNAR is to use the Heckman Sample Selection Correction Model, hereafter referred to as the Heckman or Heckman Selection Model (Heckman 1979). In this case, the missing data are caused by "incidental truncation" (Greene 2012). Data are truncated when a subset of observations either above or below a threshold are missing, and only truncated data are available for regression analysis. It is "incidental" because the truncation is not by survey design but some other decision/selection process. With incidental truncation, OLS is biased.

The fishing trip cost estimates may be biased because cost data are only collected from trips which carry an onboard data collector. Further, the selection of the sample from the population is non-random, such that the trips which are not selected to carry an onboard data collector are excluded from the dataset entirely and may differ in costs relative to trips which do carry an onboard data collector. Heckman's selection model can be written as follows (Heckman 1979; Cameron and Trivedi 2005):

$$y_i^* = \mathbf{x}_i{}' \boldsymbol{\beta} + v_i \tag{4a}$$

$$d_i^* = \mathbf{z}_i{}' \boldsymbol{\alpha} + u_i \tag{4b}$$

$$y_i = \begin{cases} y_i^* & if\ d_i^* > 0 \\ - & if\ d_i^* \leq 0 \end{cases} \tag{4c}$$

$$y_i = \mathbf{x}_i{}' \boldsymbol{\beta} + v_i \quad if\ y_i = y_i^* \tag{4d}$$

The y_i^* and d_i^* in equations 4a and 4b represent unobserved latent variables. Equation 4a describes the underlying regression relationship between the logged trip cost for the i^{th} trip y_i^* and $\mathbf{x}_i$, a vector of exogenous variables determining the cost of a trip. The propensity for a trip to have their costs collected by an onboard data collector is described by Equation 4b where $\mathbf{z}_i$ is a vector of variables governing a trip's selection or exclusion. Unlike y_i^* and d_i^*, y_i is observed if $d_i^* > 0$: trip costs are collected only when a data collector is onboard, otherwise trip costs are left unknown (equation 4c). The error terms of the latent models (v, u) are assumed to have a bivariate normal distribution (BN) with zero mean and standard deviations σ and 1, respectively (equation 5).

$$\begin{bmatrix} u \\ v \end{bmatrix} \sim BN \left\{ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2 & \rho \\ \rho & 1 \end{bmatrix} \right\} \tag{5}$$

If the correlation between u_i and v_i is not equal to zero (i.e., $\rho \neq 0$) the cost estimates in equation 4d will be biased. To investigate this source of bias given the assumptions above, the following maximum likelihood function can be estimated:

$$L = \prod_{y \neq sampled} 1 - \Phi\left(\frac{\mathbf{z}'\boldsymbol{\alpha}}{1}\right) \prod_{y = sampled} \Phi\left\{\left(\mathbf{z}'\boldsymbol{\alpha} + \frac{\rho}{\sigma^2}\left(y - \mathbf{x}'\boldsymbol{\beta}\right)\right)\sqrt{1 - \frac{\rho^2}{\sigma^2}}\right\} \times \frac{1}{\sigma}\phi\left(\frac{(y - \mathbf{x}'\boldsymbol{\beta})}{\sigma}\right) \tag{6}$$

The maximum likelihood estimation method in equation 6, also known as the Full Information Maximum Likelihood (FIML), simultaneously tests and corrects for incidental truncation within equation 4 and is computationally more efficient than Limited Information Maximum Likelihood estimators (Bushway, Johnson, and Slocum 2007; Puhani 2000). Using the FIML method, ρ can be estimated and the null-hypothesis ($\rho = 0$) can be tested to detect selection bias within the model. This process will ultimately determine if the Heckman Selection method is required for fishing trip cost estimation.

In this paper, we use three different cost modeling techniques—OLS, WOLS, and the Heckman Selection Model. In addition, a probit regression model is used to calculate the inverse probability weights of the WOLS models and to estimate the propensity for trip costs to be collected on a commercial fishing trip. We build upon previous studies to inform the right-hand variables of the trip cost function. As a result, the independent variables consist of vessel characteristics, trip characteristics, regional/temporal controls, and price control variables (Jin 2008; Das 2014). Vessel characteristics such as vessel size, age, and horsepower control for variations in fuel efficiency, vessel speed, and other determinants of fishing costs. Fuel expenditures are also affected by the price of fuel and by the number of gallons used per trip, which are controlled for using diesel prices and the number of hours the vessel was absent from port. Operating costs can also be impacted by fish stock abundances (Clark and Munro 1975; Hannesson 2007) by affecting search times, bait requirements, and/or the use of other inputs. For this reason, we use season and year fixed effects to control for stock abundance and other systematic cost changes across time. Additionally, the average weekly wages for marina workers serves as an approximation of crew member opportunity costs and controls for possible fluctuations in input use. The probability that a trip's costs are recorded by an onboard data collector is modeled as a function of the independent variables of the cost equation, along with characteristics that impact the physical allocation of data collectors to specific fishing trips. The variables used to capture variations in the allocation of onboard data collectors include: (i) the SBRM fleet type, which defines the stratification of NEFOP observer coverage, (ii) the groundfish sector identification number, as ASM additionally stratifies observers on groundfish sectors, and (iii) the number of employed observers during the time the trip took place to control for observer availability. A full list of independent variables, their descriptions, and the models in which they are used is given in Table 1. Using the modeling techniques described above, we assess a trip's probability of carrying an onboard data collector, investigate the need for weighting, and test and correct for selection bias in the estimation of population-level trip costs.

3. Data

The project database was compiled using information from two main sources: (i) vessel trip reports (VTR) and (ii) observer data containing trip cost information. As previously described, VTR are required from any fishing trip taken on a federally permitted vessel, collecting information on trip characteristics, such as the timing of the trip, trip location, gear, and catch compositions, but not input or output price data.[3] The VTR records were used to identify all commercial fishing trips taken from 2007-2015. Observer data (NEFOP & ASM) containing trip cost information were merged into the VTR dataset, creating a database of all trips taken during this time period, some of which carried an onboard data collector who recorded trip cost data while the remainder of the trips in the dataset have no trip cost record.[4]

The trips were coded into SBRM fleet types according to the 2013 SBRM definition of fishing fleet classifications, as shown in Table 2 (NEFSC/GARFO 2013).[5] From the VTR record, the trip's gear, region of departure, and mesh sizes were used to identify each trip's respective SBRM fleet type.

Groundfish sector affiliations (Sector IDs) were obtained from the Moratorium Qualification Review System (MQRS) database and were merged into the project database using the vessel permit number and the year variables.[6] Average weekly wages of marina workers and New York Harbor diesel prices were taken from secondary sources and used in the trip cost models.[7] Vessel characteristics (e.g., age, horsepower and gross tons) were retrieved from the Permit database. All other variables in the analysis were provided via the VTR data records and were retained in the full project dataset. As noted, to keep the analysis tractable, we focus on trips which operated under four important gear groups: trawl, dredge, gillnet, and longline.

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[3] A full description of VTR requirements can be found in the NOAA Fisheries Greater Atlantic Region website (NOAA Fisheries 2018a).
[4] The NEFOP and ASM records were merged into the VTR database using a hierarchical matching algorithm based on the vessel hull number, gear type, fishing area, and date sailed/landed. The VTR serial number, which is assigned i) at the beginning of a fishing trip ii) when a trip changes statistical area or iii) when a vessel changes the gear on a fishing trip, was used as a separate merging variable following the hierarchical merge to ensure all possible trips which carried an onboard data collector were matched with their correct VTR record.
[5] The analysis also includes a 57th SBRM fleet type which categorizes trips that do not identify with any of the 56 SBRM 2013 fleet type specifications.
[6] Sectors were active from May 2010 to present day.
[7] Data retrieved from the Quarterly Census of Employment and Wages page of the Bureau of Labor Statistics website and from the Department of Energy website, respectively.

Within each gear group, the trips are broken into two trip durations, single-day (≤ 24 hours) and multi-day (> 24 hours).[8]

4. Estimation Results

4.1. Unweighted and Weighted Regressions

We developed OLS and WOLS models to estimate the trip costs for four gear groups at the day and multi-day trip level. The WOLS sampling probabilities, estimated using probit models (Appendix A), suggest that the probability of a trip carrying an onboard data collector is not random.[9] This, of course, is not surprising given that SBRM and ASM sampling is stratified to address biological concerns and data are not MCAR. The significance and sign of the independent variable coefficients vary across gear types and trip durations, suggesting that the propensity for a trip to carry an observer is not generalizable across sub-fleets or trip lengths. An example of the WOLS and OLS results is presented in Table 3, where the trawl single-day and multi-day trip estimates are presented for the two modeling methods. The additional models can be found in Appendix B. In all models, the dependent variable (**Y**) is the natural log of trip costs in 2010 constant dollars.[10] The continuous independent variables are also logged. As previously mentioned, the right hand variables consist of vessel characteristics (vessel gross tons, horsepower, and age) along with hours absent from port, the opportunity cost of crew given by average weekly wages of marina workers, season in which the trip took place, diesel price, and

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[8] The various gear types and trip durations are expected to differ in both technologies and fishing behavior such that their underlying cost functions are unique. Chow tests were employed to assess the existence of structural breaks in the day and multi-day trip cost models and to assess whether gear-type model coefficients are statistically different. Results suggest that there are significant differences ($\alpha = 0.01$) in model coefficients when comparing the two trip durations and various gear-type models.

[9] A significance level (α) of 0.01 was used for all hypothesis testing.

[10] Costs were deflated using the U.S. Department of Commerce's Gross Domestic Product Implicit Price Deflator quarterly index (https://fred.stlouisfed.org/series/GDPDEF).

year.[11] OLS models were also tested for heteroskedasticity using the Breusch-Pagan/Cook-Weisberg Test for Heteroskedasticity. Because of heteroskedasticity, standard errors were clustered on the seasonal quarter.

For the log-log function, previously described, the regression coefficient ($\boldsymbol{\beta}$) on each independent variable can be interpreted as the average percentage increase in trip costs associated with one percent increase in the independent variable. For example, for trawl day trips, a 1% increase in vessel horsepower leads to an increase in trip costs of 0.48% (OLS estimation) or 0.43% (WOLS estimation).[12] The non-logged categorical variables can be interpreted as a semi-logged function. For example, a trawl vessel that takes a day trip in seasonal quarter 2 incurs a trip cost that is 3.4% lower (OLS estimation) or 7.1% lower (WOLS estimation) than the baseline (Table 3).

The coefficients from the OLS and WOLS regressions look quite different in some cases. As recommended by Winship and Radbill (1994) and DuMouchel and Duncan (1983), we implemented F tests to compare the OLS and WOLS models.[13] The null hypothesis suggests there is no difference between $\widehat{\boldsymbol{\beta}}$ and $\widehat{\boldsymbol{\beta}}_W$. If the null hypothesis is rejected, we conclude that $\widehat{\boldsymbol{\beta}}$ and $\widehat{\boldsymbol{\beta}}_W$ have significantly different expectations. The F test statistics are significant at the 1% level for all model comparisons (Appendix C) indicating that there are significant differences between the OLS and WOLS models and weighting is necessary in all cases.

[11] Diesel prices and average weekly wages for marina workers were also adjusted to 2010 constant U.S. dollars using the U.S. Department of Commerce's Gross Domestic Product Implicit Price Deflator quarterly index (https://fred.stlouisfed.org/series/GDPDEF).
[12] The negative coefficient on vessel age, though not statistically significant, may be controlling for additional effects such as the behavior or experience of the vessel owner/operator, such that the older vessels may be reflecting differences in purchasing habits or skill, which affects trip costs. Additionally a vessel buyback program was conducted in the late 1990's, which may have resulted in only the most efficient old vessels in the fleet, while newer vessels have more heterogeneous characteristics (Federal Register No. 168 [Aug. 28, 1996]: 44300-44305).
[13] Winship and Radbill expand upon the use of DuMouchel and Duncan's F test methods, including correcting for heteroskedastic errors prior to test implementation. Both papers were used to guide the execution of the F test.

4.2. Heckman Selection Models and Estimations

According to Little and Rubin (1987), for the Heckman method to work in practice, the observational probability prediction of d_i^* must include variables that are independent of y_i^* after controlling for other covariates. Otherwise, collinearity problems may lead to results that are not robust (Puhani 2000). In this study, the variables that impact the propensity of a trip to be observed by an onboard data collector, also known as the selection variables, are the independent variables included in the cost equation and three additional variables: i) the SBRM fleet type, ii) the groundfish sector ID, and iii) the number of observer employees (as shown in the probit equations in Appendix A).[14] The probit model results in Appendix A demonstrate that a functional relationship exists between the probability that a commercial fishing trip will carry an observer and the vessel trip characteristics under the SBRM and ASM sampling schemes.

As previously mentioned, multicollinearity issues within the Heckman FIML function can cause non-robust estimation and can contribute to type II error, such that the presence of selection bias is falsely rejected in the Heckman Selection model. Multicollinearity issues were assessed using an evaluation of the hessian matrix via the condition number and eigenvalues. Standard errors were clustered on seasonal quarter to control for heteroskedasticity in a manner similar to the (W)OLS models. Low condition numbers and the prevalence of significant values within the Wald Test of Independent Equations (null hypothesis $\rho = 0$) suggest that multicollinearity issues are not contributing to type II error when estimating the Heckman Selection models.

The Heckman FIML estimation results for the trawl day and multi-day trip models are presented in Table 4, and the results of the three remaining gear types are presented in Appendix

[14] Groundfish Sector IDs are included in the probit/selection models for gears that operate under a limited access groundfish permit and are subject to ASM coverage (i.e., trawl, gillnet, and longline gears).

D. The tables contain model coefficients and p-values for both the trip cost equation (corrected for selection bias) and the selection equation. The Heckman selection models rely on information from trips that carry onboard data collectors as well as information on those that do not carry onboard data collectors. For this reason, the number of trips with reported trip cost information (uncensored observations) and the number of trips without trip cost information (censored observations) are also presented.[15] The correlation coefficient (ρ) between the two error terms, ν_i and u_i along with the Wald Test of Independent Equations (null hypothesis $\rho = 0$), used to interpret whether the model suffers from selection bias, are presented at the bottom of each table. Results suggest that the Wald Test of Independent Equations is significant for seven of the eight gear/trip duration models. The longline day trip model was the only model which failed to reject the null hypothesis. There are some reasons to expect that longline daytrip models would be unaffected by selection bias: i) This gear group is not heavily stratified within the SBRM sampling schema, allowing the sample of these trips to be more representative of the longline daytrip population and ii) the longline day trips have relatively low variation in some vessel and trip characteristics (i.e., vessel age, vessel gross tons, price of diesel) in comparison to the vessels taking day trips in other gear categories, which could indicate homogeneity in longline day trips. The interplay between these two factors likely explains why longline daytrips are unaffected by selection bias and further highlights mechanisms driving selection bias within alternative gear types. Overall, these results suggest that selection bias is present in the estimation of fishing trip cost functions across all gear types and in the majority of models examined.

[15] Note that the total sample (censored and uncensored observations) informing the Heckman selection model may not equate the total number of observations in the dataset due to the functionality of the Heckman model, such that observations were dropped in cases of sparse matrices.

4.3. Model Predictions

Given that the majority of Heckman model results suggest the presence of selection bias, the Heckman method should be used to correct these model predictions. In practice, once incidental truncation is known to be present, estimation using OLS or WOLS models becomes unnecessary due to selection bias in each (Heckman 1979: Terza and Welch 1982; Gatzlaff and Haurin 1998; Puhani 1997; Puhani 2000; Hug 2003; Fonta and Ichoku 2006). We present the OLS results here, however, to quantify the differences in cost predictions driven by selection bias.

Using the model estimation results from the OLS and Heckman models, we estimate the trip costs for all commercial fishing trips in the 2007-2015 database. The mean model predictions for all gear types and trip durations are shown in Table 5, along with the percent differences between the OLS and Heckman results. As noted above, the dependent variable in all model estimations is the natural log of the trip cost and requires retransformation. The cost predictions presented have been retransformed using Duan's (1983) smearing method. When comparing mean OLS cost predictions to those of the Heckman Selection model, the means differ, on average, by 8% and range from less than 1% to 42%. The largest percent difference in mean model trip cost predictions (42%) results from the longline multi-day trip model where the Heckman model predictions are notably higher than those of the OLS, on average ($8,505 and $5,534, respectively.) This result is driven by differences in the characteristics of sampled trips versus unsampled trips. The longline multi-day trips sampled (i.e., had trip cost data collected) had an average trip duration of 66 hours. The total population of longline multi-day trips, on the other hand, had an average trip duration of 133 hours. The large difference in average trip duration from trips sampled for cost information and unsampled trips suggests that the longest duration longline trips, those incurring significantly higher costs, are missing completely from the sample, but are correctly reflected in the Heckman Selection model predictions. Lastly, the various gear types were combined to compare the percent differences between OLS and Heckman mean model predictions at the day and multi-day trip level. The percent differences between models are greater for day trips (12%) than multi-day trips (2%), when comparing OLS and Heckman mean model predictions. In all gears but longline, the proportion of observer coverage was higher for multiday trips as compared to day trips, despite 82% of all trips in the time series being day trips.[16] This partially explains the relatively higher differences in the OLS-Heckman mean model prediction comparison for day trips. Lower observer coverage rates can compound the impacts of selection bias across multiple cost-related variables. This is highlighted by the dredge gear where only 1% of dredge day trips were observed by an onboard observer and there is an 8.98% difference between OLS and Heckman average cost predictions for this fleet segment. Conversely, about 7% of dredge multi-day trips were observed and the percent difference between OLS and Heckman average cost predictions is less than one percent.

A Kolmogorov–Smirnov test was conducted to compare the distributions of the predicted trip costs from the Heckman and (W)OLS models for each of the eight gear types and trip durations (Table 6). After correcting for repeated testing through Holm's method, the p-values for all WOLS vs. OLS and WOLS vs. Heckman comparisons are statistically significant at the 1% level for each gear type and trip duration, indicating real differences between the predicted cost distributions. The OLS vs. Heckman comparisons are all significantly different, with the exception of the gillnet day trip model. Further visual comparisons of the OLS and Heckman model distributions demonstrate that the models differ most in the right-hand tails,

[16] Here, the proportion of multi-day and day trips is referring to the ratio of observed multi-day trips to unobserved multi-day trips as well as observed day trips to unobserved day trips.

suggesting that trip cost maxima will be highly dependent on controlling for selection bias and model selection. In summary, the use of different modeling techniques can produce significantly different results for various economic performance measures, such as net returns and profitability, when assessed at the sub-fleet level. These results highlight the importance of correcting for selection bias in trip cost estimation and the importance of model choice.

5. Conclusion

Fishing trip cost estimates based on data collected by onboard observers serve as the foundation of many economic analyses used to assess and shape management and regulatory actions in the Northeast region. Potential biases in the cost estimates may lead to erroneous conclusions. We have investigated the prevalence of sampling bias in the 2007-2015 sea sampling data and the impacts of selection bias on trip cost estimation.

The results suggest that the probability of a trip being observed by an onboard data collector is not MAR and observational probability is affected differently according to gear type and trip duration. This result was expected given the stratified design based on biological data collection. The probability of a trip carrying an observer is affected by vessel characteristics (vessel speed, horsepower, age), trip characteristics/trip timing (trip duration, price of diesel, the opportunity cost of the crew, and the year and season in which the trip took place) and lastly, factors which impact the direct delegation of onboard data collectors (SBRM fleet types, groundfish sector affiliations, and the number of observers). Next, F-test results suggest there are significant differences between the expectations for all eight OLS/WOLS modeling pairs, implying that weighting may lead to significant improvements in model estimation. The final, most critical, conclusion is that the Heckman sample selection model results suggest that selection bias is a substantial problem in the estimation of cost functions for all multi-day trip models and for all but one of the single-day trip models of the four different gear types investigated. Given this finding, the Heckman model estimation is superior to that of the (W)OLS as it corrects for selection bias in the affected models. The selection is most likely driven by the stratification of onboard data collectors, such that trip costs are missing not at random (MNAR) causing incidental truncation in the distribution of sampled trip costs. Once selection bias is detected, the use of the Heckman Selection model is warranted, as OLS estimates are biased. In this manuscript we quantify the differences between the OLS and Heckman selection model predictions by comparing mean trip cost predictions and by identifying differences in the trip cost distributions using non-parametric testing.

Average OLS and Heckman mean model predictions differ by about 8%, on average, and range from 1-42%. The difference between the OLS and Heckman Selection mean model predictions highlights the magnitude of selection bias and how this bias can affect economic analyses which rely on these model predictions. The model predictions were pooled by trip duration to highlight the magnitude of the bias between day and multi-day trips, which suggest that the difference in average mean model predictions is larger for the day trip predictions compared to multi-day predictions.

Further testing suggests that there are significant differences between almost all of the estimated cost distributions when comparing across the different modeling methods. The differences in distributions suggests that using different modeling techniques to analyze costs could result in moderately different conclusions at the aggregate level but could yield drastically different results when analyzing at the sub-fleet level. Furthermore, discrepancies across the model distributions tend to be greatest for larger cost predictions which can lead to errors in assessing or reporting trip cost maxima. In conclusion, our results suggest that selection bias is present and can lead to erroneous conclusions pertaining to trip cost estimation. Given that cost estimates are most often based on sample data and not population-level data, selection bias is an important issue to investigate in future cost analyses.

This paper focuses on data that are MNAR as a consequence of using data collected for biological, rather than economic, data needs to estimate at-sea commercial fishing costs. This discrepancy in the data collection stratification ultimately generates bias in the trip cost model estimates. Though the mechanism driving missing data may be different, data that are MNAR may be prevalent in commercial fishing cost estimation around the world, as many collection efforts are non-mandatory (Thunberg et al. 2015; Lawrence, Quintana, and Arina 2018; ABARES 2019; FAO 2018; Daurès, Trenkel and Guyader 2013; Liese and Stoffle 2012). When cost data are collected on a voluntary basis, specific economic groups of commercial fishermen may be missing from a data collection effort as an unintended consequence of sampling design, leading to data that are MNAR. Biased trip cost estimates could alter fleet-wide performance measures in any fishery using voluntary data, or data collected from sources designed to meet alternate program goals. Voluntary commercial fishing cost data are collected by various government agencies and Non-Departmental Public Bodies across the globe (e.g., the US, UK, France, Australia, and Southeast Asia), suggesting that data which are MNAR may be the norm, not the exception, in commercial fisheries cost data (Thunberg et al. 2015; Lawrence, Quintana, and Arina 2018; ABARES 2019; FAO 2018; Daurès, Trenkel and Guyader 2013; Liese and Stoffle 2012).

The optimal method for controlling for selection bias in trip cost models would be to institute mandatory census data collection. In cases where mandatory data collection is not feasible, random sample survey design (Rossi, Wright and Anderson 2013; Christensen, Johnson and Turner 2011) is recommended. Given our results and the methodology provided by previous fishing cost collection efforts (Daurès, Trenkel and Guyader 2013; Lam et al. 2011; Thunberg et al. 2015; Overstreet, Perruso and Liese 2018), we suggest the cost survey sampling design should consider stratifying on the various gear types, fishing trip durations (i.e. day and mutli-day trips), and vessel characteristics. If data collection efforts are unable to be designed around cost data collection or in cases where data are possibly MNAR, a probit or logit model, as shown in Appendix A, can be implemented as an initial indication of selection bias in cost modeling data. This would necessitate having trip characteristics available for both trips on which costs are recorded as well as trips with no costs recorded, an issue which also should be considered when developing cost data collection efforts. The results of these initial tests can inform whether the development of a Heckman Selection model is necessary for unbiased cost estimation. In conclusion, this manuscript outlines a practical approach for investigating potential bias with available data, and a manner to correct for the existence of selection bias in cost model estimates.

References

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences). 2019. "Australian fisheries economic indicators." http://www.agriculture.gov.au/abares/research-topics/fisheries/fisheries-economics/fisheries-economic-indicators#northern-prawn-fishery--financial-and-economic-performance-2017.

Bushway, S., B.D. Johnson, and L.A. Slocum. 2007. "Is the magic still there? The use of the Heckman two-step correction for selection bias in criminology." *Journal of quantitative criminology* 23(2): 151-178.

Cameron, A.C., and P.K. Trivedi. 2005. *Microeconometrics: methods and applications.* Cambridge university press.

Clark, C.W., and G.R. Munro. 1975. "The Economics of Fishing and Modern Capital Theory: A Simplified Approach*." Journal of Environmental Economics and Management* 2(2): 92-106.

Christensen, L.B., B. Johnson, and L.A. Turner. 2011. *Research methods, design, and analysis.* Pearson Education, Inc.

Crutchfield, S.R., and J.M. Gates. 1985. "The impact of extended fishery jurisdiction on the New England otter trawl fleet." *Marine Resource Economics* 2(2):153-173.

Das, C. 2014. "Northeast Trip Cost Data - Overview, Estimation, and Predictions." NOAA Technical Memorandum, NMFS-NE-227, National Marine Fisheries Services, Woods Hole, MA.

Daurès, F., V. M. Trenkel, and O. Guyader. 2013. "Modelling the fishing costs of French commercial vessels in the Bay of Biscay." *Fisheries Research* 146(1): 74– 85.

Duan, N. 1983. "Smearing estimate: a nonparametric retransformation method." *Journal of the American Statistical Association* 78:605-610.

DuMouchel, W.H., and G.J. Duncan. 1983. "Using sample survey weights in multiple regression analyses of stratified samples." *Journal of the American Statistical Association* 78(38):535-543.

Edwards, S.F., and S.A. Murawski. 1993. "Potential economic benefits from efficient harvest of New England groundfish." *North American Journal of Fisheries Management* 13:437-449.

FAO (Food and Agriculture Organization). 2018. "Socio-economics of Trawl Fisheries in Southeast Asia and Papua New Guinea." Papers Presented at the Regional Workshop on Trawl Fisheries Socio-economics, 26-27 October 2015, Da Nang, Viet Nam and Socio-economic Write-shop, 25-26 April 2016, Cha Am, Thailand.

Fonta, M.W., and E. H Ichok. 2006. "Statistical efficiency of the OLS, Heckman's 2-Step and ML estimators in addressing sample selection bias in social science research." African Econometric Society (AES) conference on econometric modelling for Africa, July 2006, Dakar, Senegal.

Gatzlaff, D. H., and D. R. Haurin. 1998. "Sample selection and biases in local house value indices." *Journal of Urban Economics* 43(2): 199-222.

Gautam, A.B., and A.W. Kitts. 1996. "Data Description and Statistical Summary of the 1983-1992 Cost-Earnings Data Base for Northeast U.S. Commercial Fishing Vessels." NOAA Technical Memorandum, NMFS-NE-112, National Marine Fisheries Services, Woods Hole, MA.

Gelman, A. 2007. "Struggles with survey weighting and regression modeling." *Statistical Science* 22(2):153–164.

Georgianna, D., and A. Cass. 1998. “The Cost of Hook Fishing for Groundfish in the Northeastern United States.” University of Massachusetts Dartmouth Research, North Dartmouth, MA.

Georgianna, D., A. Cass, and P. Amaral. 1999. “The Cost of Fishing for Sea Scallops in Northeastern United States.” University of Massachusetts Dartmouth Research, North Dartmouth, MA.

Greene, W.H. 2012. *Econometric Analysis (7th Edition).* Boston, MA: Pearson Education.

Hannesson, R. 2007. “A note on the ‘stock effect.” *Marine Resource Economics 22*(1): 69-75.

Heckman, J.J. 1979. “Sample selection as a specification error.” *Econometrica* 47(1):153–161.

Holland, D.S., P. Pinto Da Silva, and A.W. Kitts. 2013. “Evolution of Social Capital and Economic Performance in New England Harvest Cooperatives.” *Marine Resource Economics* 30(4):371-392.

Hug, S. 2003. “Selection bias in comparative research: The case of incomplete data sets.” *Political Analysis* 11(3): 255-274.

Hutniczak, B., D. Lipton, J. Wiedenmann, and M. J. Wilberg. 2019. “Valuing changes in frequency of fish stock assessments*.” Canadian Journal of Fisheries and Aquatic Sciences*. 76(9): 1640-1652.

Imbens, G., and J. Wooldridge. 2007. “Missing Data: A Minicourse on What’s New in Econometrics?” National Bureau of Economic Research, Summer Institute. Royal Sonesta Hotel, Cambridge, MA.

Jin, D. 2008. “Development of Commercial Fishing Vessel Cost Models.” NMFS Northeast Fisheries Science Center Project Report. Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, MA.

Jin, D., E. Thunberg, H.L. Kite-Powell and K. Blake. 2002. “Total factor productivity change in New England groundfish fisheries: 1964-1993.” *Journal of Environmental Economics and Management* 44(3):540-556.

Jin, D., M.Y. Lee and E. Thunberg. 2019. “An Empirical Analysis of Individual Fishing Quota Market Trading.” *Marine Resource Economics* 34 (1): 39-57.

Lallemand, P., J.M. Gates, J. Dirlam and J.H. Cho. 1998. “The Costs of Small Trawlers in the Northeast.” Department of Environmental Natural Resource Economics Research, University of Rhode Island, Kingston, RI.

Lallemand, P., J.M. Gates, J. Dirlam and J.H. Cho. 1999. “The Costs of Large Trawlers in the Northeast.” Department of Natural Resource Economics Research, The University of Rhode Island, Kingston, RI.

Lam, V.W., U.R. Sumaila, A. Dyck, D. Pauly, and R. Watson. 2011. “Construction and first applications of a global cost of fishing database.” *ICES Journal of Marine Science*, 68(9): 1996-2004.

Lawrence, S., M. M. Quintana and M. Arina. 2018. “Economics of the UK Fishing Fleet 2017.” Seafish Report No. SR728. Seafish Economics. Seafish.

Lee, M.Y., and E. Thunberg. 2013. “An Inverse Demand System for New England Groundfish: Welfare Analysis of the Transition to Catch Share Management.” *American Journal of Agricultural Economics* 95(5):1178-1195.

Liese, C., and B. Stoffle. 2012. “St. Croix, U.S. Virgin Islands, small scale fisheries costs and earnings study: report on the design, implementation, and descriptive results.” National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Miami.

Little, R. J. A., and D. B. Rubin. 1987. *Statistical Analysis with Missing Data*. New York: John Wiley & Sons.

Lynch, E. J., R.M. Doherty and G. P. Draheim. 1961. “The Groundfish Industries of New England and Canada, A Comparative Analysis.” United States Fish and Wildlife Service Circular 121, Department of Interior, Washington D.C.

Murphy, T., G. Ardini, M. Vasta, A. Kitts, C. Demarest, J. Walden and D. Caless. 2018. “2015 Final Report on the Performance of the Northeast Multispecies (Groundfish) Fishery (May 2007 – April 2016).” US Dept. Commerce, Northeast Fish Science Center Reference Document, Woods Hole, MA.

NMFS (National Marine Fisheries Service). 1974. “Basic Economic Indicators: Atlantic and Pacific Groundfish 1932-72.” Current Fisheries Statistics No. 6271, COM-74-11638, Economic Research Laboratory, Washington, DC.

NMFS (National Marine Fisheries Service). 1978. “Fisheries of the United States, 1977.” Current Fishery Statistics No. 7500. Data Management and Statistics Division. National Oceanic and Atmospheric Administration (NOAA), Dept. of Commerce (DOC). Washington, DC.

NMFS (National Marine Fisheries Service). 2008. “Magnuson-Stevens Fishery Conservation and Management Act Provisions; Fisheries of the Northeastern United States; Northeast Region Standardized Bycatch Reporting Methodology Omnibus Amendment.” Federal Register, Vol. 73, No. 18, Monday, January 28, 2008. p. 4736-4758.

NOAA (National Oceanic and Atmospheric Administration) Fisheries, Greater Atlantic Region. 2018a. “Vessel Reporting.” https://www.greateratlantic.fisheries.noaa.gov/aps/evtr/index.html.

NOAA (National Oceanic and Atmospheric Administration) Fisheries, Greater Atlantic Region. 2018b. “Sector Operations Plan, Contract, and Environmental Assessment Requirements (FY 2019-20)” https://archive.fisheries.noaa.gov/garfo/sustainable/species/multispecies/sector/sector_ops_guidance_fy2019-20.pdf

Nielsen, J.R., E. Thunberg, D.S Holland, J.O. Schmidt, E.A. Fulton, F. Bastardie, A.E. Punt, I. Allen H. Bartelings, M. Bertignac, E. Bethke, S. Bossier, R. Buckworth, G. Carpenter, A. Christensen, V. Christensen, J.M. Da-Rocha, R. Deng, C. Dichmont, R. Doering, A. Esteban, J.A. Fernandes, H. Frost, D. Garcia, L. Gasche, D. Gascuel, S. Gourguet, R.A. Groeneveld, J. Guillén, O. Guyader, K.G. Hamon, A. Hoff, J.H. Horbowy, T. Hutton, S. Lehuta, L.R. Little, J. Lleonart, C. Macher. S, Mackinson, S. Mahevas, P. Marchal, R. Mato-Amboage, B. Mapstone, F. Maynou, M. Merzéréaud1, A. Palacz, A. Pascoe, A. Paulrud, E Plaganyi, R. Prellezo. E.I. van Putten, M. Quaas, L. Ravn-Jonsen, S. Sanchez, S. Simons, O. Thébaud, M.T. Tomczak, C. Ulrich, D. van Dijk, Y. Vermard, R. Voss, S. Waldo. 2017. “Integrated ecological–economic fisheries models—Evaluation, review and challenges for implementation.” *Fish and Fisheries 19:1-29.*

NEFSC/GARFO (Northeast Fisheries Science Center and Greater Atlantic Regional Office). 2013. “Proposed 2013 Observer Sea Day Allocation.” Prepared for Northeast Regional Coordinating Committee. NOAA Fisheries, Woods Hole, MA.

Overstreet, E., L. Perruso and C. Liese. 2018. “Economics of the U.S. South Atlantic Snapper-Grouper Fishery - 2016.” NOAA Technical Memorandum NMFS-SEFSC-730. 104 p.

Pfeffermann, D. 1993. “The role of sampling weights when modeling survey data.” *International Statistical Review* 61(2):317-337.

Puhani, P.A. 1997. “Foul or Fair? The Heckman Correction for Sample Selection and Its Critique. A Short Survey.” Discussion Papers, Zentrum für Europäische Wirtschaftsforschung (ZEW), Mannheim, 97-07E.

Puhani, P.A. 2000. “The Heckman correction for sample selection and its critique.” *Journal of Economic Surveys* 14(1):53-68.

Rossi, P.H., J.D. Wright and A.B. Anderson. 2013. *Handbook of survey research.* Academic Press.

Rubin, D.B. 1976. “Inference and missing data.” *Biometrika* 63(3): 581-592.

Steele, L., R.G. Feeney, M. Bachman, M. Cieri, S.E. Weeks, J.J. Deroba, M.A. Lee, M. Dean, M. Hall-Arber, C.L. Nordeen, T. Cardiasmenos, D. Palmer, B. McAfee, J. Didden, R. Zobel. 2016. “Atlantic herring fishery specifications for the 2016-2018 fishing years (January 1, 2016 - December 31, 2018).” 2016. Professional Paper. New England Fishery Management Council, United States, National Oceanic and Atmospheric Administration, Woods Hole, MA.

Terza, J. V. and W. P. Welch. 1982. “Estimating demand under block rates: Electricity and water.” *Land Economics* 58(2), 181-188.

Thunberg, E., J. Agar, S. Crosson, B. Garber-Yonts, A. Harley, A. Kitts, T. Lee, C. Lian, C. Liese, M. Pan, et al. 2015. “A Snapshot of NOAA Fisheries Data Collection of Commercial Fishery Costs.” NOAA Tech. Memo NMFS-F/SPO-154, U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

Walden, J.B., and N. Kitts. 2014. “Measuring fishery profitability: An index number approach.” *Marine Policy* 43:321-326.

Wigley, S.E., J. Blaylock, P.J. Rago, J. Tang, H.L. Haas and G. Shield. 2011. “Standardized Bycatch Reporting Methodology 3-year Review Report – 2011 (Part 1).” Northeast Fisheries Science Center Reference Document 11-09. NOAA Northeast Fisheries Science Center, Woods Hole, MA.

Winship, C. and L. Radbill. 1994. “Sampling weights and regression analysis.” *Sociological Methods & Research* 23(2):230-257.

Appendix A1. Trip Observation Probability: Probit Estimates, Trawl

	Day Trip			Multi-Day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	0.213***	9.740	0.000	0.122***	4.790	0.000
Ln Vessel Gross Tons	0.043***	4.190	0.000	0.265***	12.680	0.000
Ln Vessel Age	0.008	0.580	0.565	-0.033	-1.600	0.109
Ln Hours Absent	0.019	1.510	0.131	0.125***	10.490	0.000
Ln Diesel Price	0.084*	1.840	0.066	0.126**	2.530	0.011
Ln Average Weekly Wage	0.728***	15.200	0.000	0.411***	8.710	0.000
Seasonal Quarter						
2	-0.059***	-2.760	0.006	0.071***	3.410	0.001
3	-0.060***	-2.760	0.006	0.156***	7.260	0.000
4	-0.055***	-2.880	0.004	0.047**	2.490	0.013
Calendar Year						
08	-0.240***	-7.090	0.000	-0.062*	-1.710	0.088
09	0.082***	2.600	0.009	0.117***	3.230	0.001
10	0.010	0.240	0.810	0.201***	5.070	0.000
11	0.028	0.630	0.532	0.279***	5.790	0.000
12	0.036	0.800	0.423	0.103**	2.060	0.040
13	0.155***	4.040	0.000	0.118***	2.730	0.006
14	0.141***	3.140	0.002	0.167***	3.510	0.000
15	0.188***	4.450	0.000	0.172***	3.710	0.000
SBRM Fleet Type						
6	0.247***	11.150	0.000	0.095***	3.390	0.001
7	0.043	1.640	0.102	-0.108***	-3.730	0.000
8	0.499***	21.490	0.000	0.556***	22.120	0.000
9	-0.186	-1.420	0.154	-0.001	-0.010	0.993
10	--	--	--	-0.422	-0.980	0.327
11	-0.243***	-3.110	0.002	-0.373***	-3.560	0.000
14	--	--	--	-0.323	-1.160	0.248
15	--	--	--	0.306	1.460	0.145
16	1.370***	5.000	0.000	--	--	--
17	1.393***	3.920	0.000	0.543***	6.930	0.000
18	-0.175	-0.450	0.653	-1.759***	-8.690	0.000
19	-0.462***	-11.250	0.000	-0.697**	-2.470	0.013
39	--	--	--	-0.315**	-2.200	0.028
40	0.670***	8.320	0.000	0.625***	16.960	0.000
52	-0.110	-0.800	0.426	-0.387**	-2.010	0.044
53	0.028	0.180	0.858	--	--	--
57	0.256***	4.920	0.000	-0.052	-1.160	0.248
Groundfish Sector ID						
3	0.429***	5.090	0.000	--	--	--
5	0.080	1.500	0.135	0.080**	2.090	0.036
6	0.430***	5.840	0.000	0.586***	6.640	0.000
7	-1.022***	-7.970	0.000	0.003	0.060	0.955
9	-0.158	-0.820	0.414	0.039	0.720	0.469
10	0.280***	7.110	0.000	0.561***	2.790	0.005
11	0.403***	6.430	0.000	--	--	--
12	0.406***	15.120	0.000	0.160***	3.580	0.000

	Day Trip			Multi-Day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
13	0.457***	5.860	0.000	0.260	0.820	0.411
15	0.378***	10.440	0.000	0.178	1.170	0.244
16	-0.091**	-2.570	0.010	-0.063*	-1.720	0.086
17	-0.414***	-3.080	0.002	0.050	1.220	0.224
18	0.164***	6.920	0.000	-0.096**	-2.160	0.031
19	-0.414	-1.410	0.160	-0.172**	-2.250	0.024
20	0.435***	9.150	0.000	0.144***	2.610	0.009
22	-0.168**	-2.470	0.014	-0.073	-1.130	0.258
27	-0.148***	-7.620	0.000	0.009	0.300	0.762
Ln Number of Observers	0.551***	10.760	0.000	0.381***	7.570	0.000
Intercept	-10.654***	-26.600	0.000	-8.644***	-22.150	0.000
# of Observations	154309			71335		
# of Observed Trips	8438			8242		
# of Unobserved Trips	145871			63093		
Log Likelihood	-28972.398			-22264.325		
	$\chi2$		P > $\chi2$	$\chi2$		P > $\chi2$
Likelihood Ratio Test	7506.37***		0.000	6538.97***		0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix A2. Trip Observation Probability: Probit Estimates, Dredge

	Day Trip			Multi-Day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	-0.122***	-2.760	0.006	0.055*	1.710	0.088
Ln Vessel Gross Tons	-0.044**	-2.170	0.030	-0.111***	-4.650	0.000
Ln Vessel Age	-0.011	-0.360	0.722	-0.035*	-1.850	0.064
Ln Hours Absent	0.031	0.930	0.351	0.009	0.450	0.652
Ln Diesel Price	-0.089	-0.760	0.446	-0.090	-1.250	0.211
Ln Average Weekly Wage	0.338***	2.680	0.007	0.193***	2.820	0.005
Seasonal Quarter						
2	0.100**	2.200	0.028	-0.057*	-1.920	0.055
3	0.188***	3.890	0.000	-0.080**	-2.560	0.010
4	0.126**	2.480	0.013	-0.071**	-2.160	0.031
Calendar Year						
08	0.274***	2.970	0.003	0.313***	6.040	0.000
09	0.306***	3.400	0.001	0.150***	2.880	0.004
10	0.387***	3.600	0.000	-0.224***	-3.500	0.000
11	0.455***	3.830	0.000	-0.140*	-1.930	0.054
12	0.195	1.550	0.122	-0.011	-0.140	0.888
13	0.746***	7.450	0.000	0.110*	1.750	0.080
14	0.772***	6.540	0.000	0.042	0.570	0.569
15	0.594***	5.920	0.000	0.138**	2.150	0.031
SBRM Fleet Type						
31	0.400***	4.680	0.000	0.489***	6.170	0.000
32	0.349**	2.400	0.016	0.133**	2.200	0.028
33	0.580*	1.700	0.090	0.255***	4.050	0.000
34	-0.238***	-5.250	0.000	-0.841***	-13.760	0.000
35	-0.266***	-5.390	0.000	-0.769***	-11.420	0.000
36	0.265**	2.400	0.016	0.119*	1.900	0.058
37	0.463**	2.170	0.030	0.202***	3.130	0.002
54	-1.312***	-6.140	0.000	--	--	--
55	-0.946***	-4.200	0.000	--	--	--
57	-0.824***	-11.130	0.000	-0.669***	-8.610	0.000
Ln Number of Observers	0.276**	2.050	0.040	0.578***	6.950	0.000
Intercept	-4.999***	-4.930	0.000	-5.044***	-8.310	0.000
# of Observations	62851			47109		
# of Observed Trips	945			3111		
# of Unobserved Trips	61906			43998		
Log Likelihood	-4505.6			-10426.9		
	$\chi2$		P > $\chi2$	$\chi2$		P > $\chi2$
Likelihood Ratio Test	797.49***		0.000	2066.42***		0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix A3. Trip Observation Probability: Probit Estimates, Gillnet

		Day Trip			Multi-Day Trip		
Variable		Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power		0.017*	1.670	0.095	-0.031	-1.140	0.253
Ln Vessel Gross Tons		0.090***	9.180	0.000	0.115***	4.430	0.000
Ln Vessel Age		0.056***	4.420	0.000	0.012	0.310	0.756
Ln Hours Absent		-0.008	-0.730	0.468	0.054	1.520	0.127
Ln Diesel Price		-0.151***	-3.550	0.000	-0.185	-1.650	0.100
Ln Average Weekly Wage		0.469***	11.270	0.000	0.499***	3.330	0.001
Seasonal Quarter							
	2	-0.190***	-8.960	0.000	-0.068	-1.370	0.171
	3	-0.168***	-8.190	0.000	-0.068	-1.130	0.259
	4	-0.157***	-8.340	0.000	-0.090*	-1.760	0.078
Calendar Year							
	08	-0.375***	-12.340	0.000	-0.111	-1.360	0.174
	09	-0.396***	-13.070	0.000	-0.266***	-2.930	0.003
	10	-0.054	-1.500	0.134	0.133	1.420	0.157
	11	-0.059	-1.480	0.140	0.212*	1.910	0.056
	12	-0.153***	-3.850	0.000	0.009	0.080	0.937
	13	-0.186***	-5.210	0.000	-0.168*	-1.690	0.091
	14	-0.166***	-4.050	0.000	0.173	1.520	0.128
	15	-0.089**	-2.250	0.024	-0.022	-0.210	0.837
SBRM Fleet Type							
	23	-0.020	-0.690	0.491	--	--	--
	24	0.012	0.430	0.666	--	--	--
	25	0.152	0.980	0.329	--	--	--
	26	0.422***	15.710	0.000	0.517***	8.260	0.000
	27	0.261***	8.960	0.000	0.218***	4.280	0.000
	57	-0.034	-0.920	0.356	-0.199*	-1.720	0.086
Groundfish Sector ID							
	3	0.766***	23.870	0.000	0.358***	5.230	0.000
	5	0.259*	1.770	0.077	--	--	--
	6	0.753***	16.820	0.000	0.068	0.700	0.482
	7	0.662***	10.920	0.000	0.283***	3.320	0.001
	10	0.770***	21.130	0.000	0.145	1.350	0.179
	13	0.875***	25.170	0.000	0.383***	4.980	0.000
	15	0.684***	16.730	0.000	0.042	0.340	0.736
	18	0.542***	4.210	0.000	--	--	--
	19	0.256***	2.860	0.004	--	--	--
	22	--	--	--	0.092	0.970	0.334
	27	0.200***	7.040	0.000	-0.155***	-2.760	0.006
Ln Number of Observers		0.772***	16.230	0.000	0.191	1.490	0.137
Intercept		-8.663***	-25.480	0.000	-5.898***	-5.210	0.000
# of Observations		132104			14012		
# of Observed Trips		10712			1360		
# of Unobserved Trips		121392			12652		
Log Likelihood		-32309.28			-4078.63		
		$\chi2$		P > $\chi2$	$\chi2$		P > $\chi2$
Likelihood Ratio Test		9734.25***		0.000	770.45***		0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix A4. Trip Observation Probability: Probit Estimates, Longline

	Day Trip			Multi-Day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	0.235***	2.870	0.004	0.535***	2.680	0.007
Ln Vessel Gross Tons	0.234***	4.540	0.000	0.127	1.030	0.305
Ln Vessel Age	0.176***	2.770	0.006	0.241	1.390	0.163
Ln Hours Absent	0.033	1.070	0.286	-0.056	-0.480	0.632
Ln Diesel Price	0.415**	2.090	0.037	-0.141	-0.490	0.627
Ln Average Weekly Wage	-1.006*	-1.660	0.097	-0.202	-0.420	0.675
Seasonal Quarter						
2	-0.166	-1.400	0.161	0.049	0.270	0.789
3	-0.318**	-2.260	0.024	0.102	0.480	0.634
4	0.279***	3.920	0.000	0.494***	2.840	0.005
Calendar Year						
08	-0.348***	-2.770	0.006	0.196	0.820	0.413
09	-0.005	-0.040	0.968	-0.028	-0.110	0.911
10	0.349**	2.480	0.013	0.152	0.490	0.621
11	-0.251	-1.480	0.138	-0.489	-1.280	0.201
12	-0.072	-0.450	0.654	-0.463	-1.010	0.312
13	-0.690***	-4.450	0.000	--	--	--
14	-0.903***	-5.260	0.000	0.252	0.640	0.523
15	-1.253***	-4.900	0.000	0.507	1.390	0.165
SBRM Fleet Type						
2	1.438***	4.590	0.000	1.614***	7.480	0.000
Groundfish Sector ID						
3	0.807***	4.570	0.000	-0.206	-0.540	0.591
13	1.116***	6.260	0.000	-0.091	-0.140	0.888
15	0.086	0.380	0.702	--	--	--
21	0.729***	3.510	0.000	--	--	--
27	0.147	0.850	0.394	-0.153	-0.480	0.631
Ln Number of Observers	0.527***	3.250	0.001	0.550	1.350	0.176
Intercept	-1.615	-0.410	0.681	-7.735**	-2.020	0.043
# of Observations	8494			1836		
# of Observed Trips	664			148		
# of Unobserved Trips	7830			1688		
Log Likelihood	-1943.68			-405.12		
	$\chi2$		P > $\chi2$	$\chi2$		P > $\chi2$
Likelihood Ratio Test	772.18***		0.000	218.86***		0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix B1. Trip Cost Function: Unweighted and Weighted Regression Results, Dredge

	Day Trip				Multi-Day Trip			
Variable	OLS Coef.	P>|t|	WOLS Coef.	P>|t|	OLS Coef.	P>|t|	WOLS Coef.	P>|t|
Ln Vessel Horse Power	0.640***	0.001	-0.024	0.935	0.233***	0.001	0.261**	0.027
Ln Vessel Gross Tons	0.232***	0.007	-0.008	0.937	0.391***	0.000	0.376***	0.005
Ln Vessel Age	0.029	0.484	0.280	0.248	-0.048**	0.019	-0.100***	0.003
Ln Hours Absent	0.279***	0.008	0.269*	0.073	1.071***	0.000	1.097***	0.000
Ln Diesel Price	0.830**	0.041	2.272***	0.002	0.451***	0.002	0.654**	0.027
Ln Average Weekly Wage	-0.150	0.323	-0.091	0.904	-0.059	0.266	-0.268*	0.057
Seasonal Quarter								
2	-0.128***	0.007	-0.485**	0.019	-0.035***	0.005	-0.152***	0.003
3	-0.054**	0.029	-0.299	0.103	-0.001	0.893	-0.132***	0.001
4	0.041**	0.025	0.775*	0.090	0.028*	0.088	0.026	0.247
Calendar Year								
08	-0.168	0.439	-1.380*	0.060	0.034	0.260	-0.101	0.356
09	-0.137	0.101	-0.047	0.945	-0.099**	0.017	-0.127	0.185
10	-0.400**	0.014	-0.763	0.387	0.000	0.998	0.005	0.949
11	-0.594**	0.041	-1.764**	0.043	0.084*	0.090	-0.018	0.869
12	-0.415	0.150	-1.677*	0.089	0.135***	0.009	0.015	0.888
13	-0.478**	0.025	-1.585**	0.034	0.218***	0.009	0.001	0.997
14	-0.349*	0.087	-1.390*	0.071	0.160*	0.081	0.025	0.853
15	-0.166	0.276	-0.242	0.669	0.091*	0.062	0.094	0.425
Intercept	1.424	0.179	4.622	0.434	0.554*	0.068	1.799*	0.082
# of Obs.	945		945		3111		3111	
R^2	0.42		0.46		0.87		0.89	

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix B2. Trip Cost Function: Unweighted and Weighted Regression Results, Gillnet

	Day Trip				Multi-Day Trip			
Variable	OLS Coef.	P>|t|	WOLS Coef.	P>|t|	OLS Coef.	P>|t|	WOLS Coef.	P>|t|
Ln Vessel Horse Power	0.057**	0.014	0.103***	0.002	0.038	0.142	0.025	0.255
Ln Vessel Gross Tons	0.140***	0.006	0.164**	0.012	0.132**	0.037	0.103	0.177
Ln Vessel Age	-0.177***	0.005	-0.171**	0.011	0.049**	0.014	0.043	0.104
Ln Hours Absent	0.686***	0.000	0.578***	0.004	0.890***	0.000	0.882***	0.000
Ln Diesel Price	0.454**	0.032	0.485*	0.075	0.326*	0.098	0.280	0.336
Ln Average Weekly Wage	0.249	0.154	0.166	0.277	0.630	0.254	0.978*	0.067
Seasonal Quarter								
2	-0.027**	0.034	-0.196***	0.003	0.003	0.954	-0.039	0.502
3	-0.077***	0.004	-0.264***	0.004	0.097	0.239	0.130*	0.064
4	-0.117**	0.015	-0.244**	0.012	-0.171**	0.012	-0.302***	0.009
Calendar Year								
08	0.060	0.400	0.088	0.322	-0.043	0.742	-0.025	0.748
09	-0.100	0.203	-0.123	0.285	-0.255	0.186	-0.403	0.224
10	0.019	0.690	0.063	0.396	-0.119	0.252	-0.133	0.353
11	0.062	0.345	0.091	0.221	0.094	0.291	0.103**	0.022
12	0.012	0.868	0.040	0.708	0.043	0.347	0.067**	0.032
13	0.023	0.681	0.002	0.979	-0.031	0.671	-0.002	0.950
14	0.116*	0.083	0.119	0.189	0.006	0.937	0.070	0.328
15	-0.040	0.654	-0.071	0.540	-0.130*	0.066	-0.142	0.326
Intercept	1.513	0.217	1.984	0.134	-1.891	0.550	-3.931	0.142
# of Obs.	10712		10712		1360		1360	
R^2	0.42		0.38		0.68		0.61	

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix B3. Trip Cost Function: Unweighted and Weighted Regression Results, Longline

	Day Trip				Multi-day Trip			
Variable	OLS Coef.	P>|t|	WOLS Coef.	P>|t|	OLS Coef.	P>|t|	WOLS Coef.	P>|t|
Ln Vessel Horse Power	0.935**	0.016	0.710*	0.087	-0.235	0.469	0.147	0.817
Ln Vessel Gross Tons	-0.195	0.206	0.197	0.189	0.095	0.271	0.213*	0.062
Ln Vessel Age	0.304	0.167	0.521	0.157	-0.489	0.123	-0.314	0.358
Ln Hours Absent	0.375***	0.000	0.325***	0.001	0.649***	0.003	0.628**	0.021
Ln Diesel Price	0.634	0.108	-0.436	0.696	0.255*	0.052	0.573	0.101
Ln Average Weekly Wage	-1.372	0.305	3.422	0.466	-1.356**	0.044	-0.857	0.257
Seasonal Quarter								
2	-0.026	0.876	1.222	0.235	0.336***	0.006	0.165	0.146
3	-0.392	0.249	1.355	0.168	0.064	0.281	-0.350**	0.041
4	0.709**	0.025	1.282**	0.016	0.320**	0.016	0.287	0.209
Calendar Year								
08	0.584**	0.036	0.390	0.248	-0.079	0.709	0.092	0.789
09	0.129	0.342	-0.317	0.303	0.032	0.862	0.361	0.365
10	0.020	0.899	-0.269	0.156	-0.124	0.616	0.148	0.739
11	-0.137	0.663	0.769	0.424	-0.168	0.741	0.009	0.987
12	-0.322	0.380	-0.077	0.906	-0.686	0.197	-0.759	0.264
13	-0.107	0.738	0.727	0.368	--	--	--	--
14	-0.165	0.651	1.380	0.108	-0.089	0.740	0.082	0.650
15	-0.593*	0.092	-0.296	0.117	0.173	0.397	0.481	0.284
Intercept	7.518	0.306	-24.632	0.432	16.416**	0.010	9.625*	0.063
# of Obs.	664		664		148		148	
R^2	0.48		0.74		0.63		0.81	

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix C. Unweighted vs. Weighted Regression Models: F Test

Source	df	F	Significance (p)
Trawl Day Trip			
Regression	17	206.040***	< 0.001
Weights	18	2.640***	< 0.001
Trawl Multi-Day Trip			
Regression	17	1690.780***	< 0.001
Weights	18	54.330***	< 0.001
Dredge Day Trip			
Regression	17	42.09***	< 0.001
Weights	18	67.01***	< 0.001
Dredge Multi-Day Trip			
Regression	17	1211.300***	< 0.001
Weights	18	8.580***	< 0.001
Gillnet Day Trip			
Regression	17	199.780***	< 0.001
Weights	18	16.990***	< 0.001
Gillnet Multi-Day Trip			
Regression	17	190.110***	< 0.001
Weights	18	6.770***	< 0.001
Longline Day Trip			
Regression	17	48.780***	< 0.001
Weights	18	36.750***	< 0.001
Longline Multi-Day Trip			
Regression	16	21.760***	< 0.001
Weights	17	7.640***	< 0.001

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Table Appendix D1. Trip Cost Function: Heckman Sample Selection Model, Dredge

	Day Trip			Multi-day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	0.700***	7.240	0.000	0.178***	20.070	0.000
Ln Vessel Gross Tons	0.247***	9.170	0.000	0.423***	21.040	0.000
Ln Vessel Age	0.075***	3.140	0.002	-0.007	-0.870	0.384
Ln Hours Absent	0.200***	6.710	0.000	0.969***	32.860	0.000
Ln Diesel Price	0.895***	5.120	0.000	0.449***	5.660	0.000
Ln Average Weekly Wage	-0.271***	-7.820	0.000	-0.181***	-4.310	0.000
Seasonal Quarter						
2	-0.190***	-3.740	0.000	-0.056***	-4.870	0.000
3	-0.163***	-2.780	0.005	-0.019*	-1.780	0.074
4	-0.011	-0.340	0.737	0.058***	4.350	0.000
Calendar Year						
08	-0.314***	-3.390	0.001	-0.176***	-6.300	0.000
09	-0.216***	-8.070	0.000	-0.243**	-2.520	0.012
10	-0.575***	-5.550	0.000	-0.037*	-1.750	0.080
11	-0.812***	-5.470	0.000	0.002	0.050	0.960
12	-0.501***	-3.260	0.001	-0.021	-0.600	0.548
13	-0.764***	-7.920	0.000	0.055**	2.010	0.044
14	-0.665***	-6.650	0.000	0.023	0.370	0.712
15	-0.396***	-6.290	0.000	-0.054	-0.920	0.357
Intercept	3.342***	8.010	0.000	3.152***	6.970	0.000
σ	0.72			0.674		
# of Uncensored Obs.	945			3111		
Observation function (probit)						
Ln Vessel Horse Power	-0.122**	-2.190	0.028	0.062*	1.700	0.089
Ln Vessel Gross Tons	-0.055**	-2.360	0.018	-0.147***	-6.720	0.000
Ln Vessel Age	-0.009	-0.190	0.849	-0.032*	-1.690	0.092
Ln Hours Absent	0.024	0.430	0.668	-0.066**	-2.200	0.028
Ln Diesel Price	-0.079	-1.140	0.254	-0.074	-0.900	0.370
Ln Average Weekly Wage	0.350**	2.200	0.027	0.106***	2.640	0.008
Seasonal Quarter						
2	0.103***	2.890	0.004	-0.040***	-8.060	0.000
3	0.193***	5.380	0.000	-0.070***	-11.300	0.000
4	0.123***	4.520	0.000	-0.061***	-4.480	0.000
Calendar Year						
08	0.258***	8.810	0.000	0.380***	9.820	0.000
09	0.298***	3.630	0.000	0.232	1.450	0.146
10	0.373***	6.150	0.000	-0.082	-1.030	0.304
11	0.439***	3.780	0.000	-0.003	-0.050	0.962
12	0.177	1.600	0.109	0.133	1.400	0.160
13	0.735***	8.300	0.000	0.181***	2.650	0.008

	Day Trip			Multi-day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
14	0.755***	8.640	0.000	0.168**	1.970	0.049
15	0.589***	9.590	0.000	0.253**	2.100	0.035
SBRM Fleet Type						
31	0.374***	4.360	0.000	0.324***	3.930	0.000
32	0.518***	4.390	0.000	0.454***	3.550	0.000
33	0.801**	2.150	0.031	0.620***	5.370	0.000
34	-0.202**	-2.250	0.024	-0.552***	-4.460	0.000
35	-0.266*	-1.840	0.066	-0.445***	-2.790	0.005
36	0.313**	2.580	0.010	0.524***	3.340	0.001
37	0.856***	3.190	0.001	0.643***	5.420	0.000
54	-1.035***	-3.310	0.001	--	--	--
55	-0.796	-1.580	0.113	--	--	--
57	-0.794***	-5.150	0.000	-0.229**	-2.150	0.032
Ln Number of Observers	0.298**	2.180	0.029	0.359***	5.600	0.000
Intercept	-5.157***	-6.510	0.000	-3.476***	-5.680	0.000
ρ	-0.746			-0.906		
# of Censored Obs.	61906			43998		
Total Obs.	62851			47109		
		χ2	P > χ2		χ2	P > χ2
Wald Test of Independent Equations		8.26***	0.0041		92.58***	0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix D2. Trip Cost Function: Heckman Sample Selection Model, Gillnet

		Day Trip			Multi-day Trip		
Variable		Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power		0.064***	7.680	0.000	0.081***	2.710	0.007
Ln Vessel Gross Tons		0.104***	7.470	0.000	0.097***	2.700	0.007
Ln Vessel Age		-0.171***	-8.720	0.000	0.055***	3.260	0.001
Ln Hours Absent		0.658***	19.130	0.000	0.794***	29.330	0.000
Ln Diesel Price		0.511***	5.460	0.000	0.407***	8.210	0.000
Ln Average Weekly Wage		-0.180***	-3.150	0.002	0.256	0.660	0.508
Seasonal Quarter							
	2	-0.023***	-2.900	0.004	0.011	0.350	0.727
	3	-0.141***	-7.400	0.000	0.083*	1.840	0.066
	4	-0.058***	-4.460	0.000	-0.116***	-3.880	0.000
Calendar Year							
	08	0.113***	3.200	0.001	-0.010	-0.130	0.898
	09	-0.059	-0.870	0.385	-0.111	-1.440	0.149
	10	-0.209**	-2.110	0.035	-0.340***	-2.760	0.006
	11	-0.215**	-2.290	0.022	-0.230***	-3.710	0.000
	12	-0.227***	-3.390	0.001	-0.202**	-2.120	0.034
	13	-0.161**	-2.150	0.031	-0.171**	-2.430	0.015
	14	-0.121*	-1.710	0.087	-0.309***	-5.070	0.000
	15	-0.191**	-2.270	0.023	-0.310***	-7.390	0.000
Intercept		5.176***	9.790	0.000	1.810	0.720	0.471
σ		0.570			0.661		
# of Uncensored Obs.		10712			1360		
Observation function (probit)							
Ln Vessel Horse Power		0.020***	3.270	0.001	-0.010	-0.430	0.665
Ln Vessel Gross Tons		0.088***	3.810	0.000	0.124***	7.860	0.000
Ln Vessel Age		0.056***	2.870	0.004	0.003	0.130	0.894
Ln Hours Absent		-0.035	-1.490	0.135	0.049*	1.670	0.094
Ln Diesel Price		-0.163**	-2.220	0.026	-0.165	-0.790	0.428
Ln Average Weekly Wage		0.435	1.490	0.135	0.388***	3.140	0.002
Seasonal Quarter							
	2	-0.185*	-1.880	0.061	-0.074*	-1.880	0.061
	3	-0.152	-1.310	0.189	-0.050	-1.030	0.301
	4	-0.139***	-9.550	0.000	-0.045***	-5.510	0.000
Calendar Year							
	08	-0.347***	-3.250	0.001	-0.077	-0.850	0.395
	09	-0.375***	-3.110	0.002	-0.193*	-1.650	0.099
	10	0.003	0.010	0.993	0.202*	1.720	0.086
	11	0.009	0.030	0.975	0.295***	3.240	0.001
	12	-0.078	-0.290	0.772	0.110	0.640	0.524
	13	-0.129	-0.430	0.667	-0.099	-0.730	0.468

	Day Trip			Multi-day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
14	-0.092	-0.290	0.770	0.289***	4.060	0.000
15	-0.029	-0.100	0.923	0.088	0.650	0.514
Groundfish Sector ID						
3	0.605***	9.490	0.000	0.204***	4.860	0.000
5	0.332***	3.700	0.000	--	--	--
6	0.792***	16.950	0.000	-0.054***	-2.710	0.007
7	0.573***	11.200	0.000	0.096	1.010	0.314
10	0.616***	10.090	0.000	-0.021	-0.130	0.893
13	0.783***	22.560	0.000	0.401***	7.220	0.000
15	0.592***	8.660	0.000	-0.093	-0.720	0.472
18	0.461*	1.900	0.057	--	--	--
19	0.110	0.600	0.546	--	--	--
22	--	--	--	0.062	0.440	0.662
27	0.115*	1.840	0.066	-0.193***	-2.670	0.008
SBRM Fleet Type						
23	-0.065	-0.960	0.337	--	--	--
24	0.051	0.880	0.377	--	--	--
25	0.047	0.340	0.735	--	--	--
26	0.439***	15.030	0.000	0.574***	5.780	0.000
27	0.310***	3.300	0.001	0.361***	4.900	0.000
57	-0.068	-1.020	0.306	-0.197	-0.930	0.351
Ln Number of Observers	0.673*	1.800	0.072	0.051	0.260	0.799
Intercept	-7.917***	-10.820	0.000	-4.773***	-12.610	0.000
ρ	-0.652			-0.862		
# of Censored Obs.	121392			12652		
Total Obs.	132104			14012		

	χ^2	$P > \chi^2$		χ^2	$P > \chi^2$
Wald Test of Independent Equations	18.56***	0.000		131.06***	0.0000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Appendix D3. Trip Cost Function: Heckman Sample Selection Model, Longline

	Day Trip			Multi-day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	0.930***	5.160	0.000	-0.459*	-1.820	0.069
Ln Vessel Gross Tons	-0.194	-1.630	0.103	0.081	1.210	0.227
Ln Vessel Age	0.286**	2.080	0.038	-0.676***	-4.180	0.000
Ln Hours Absent	0.383***	19.110	0.000	-1.697***	-2.980	0.003
Ln Diesel Price	0.663**	2.150	0.032	0.791***	9.500	0.000
Ln Average Weekly Wage	-1.250	-1.230	0.217	0.361***	3.010	0.003
Seasonal Quarter						
2	0.005	0.030	0.975	0.051	0.300	0.763
3	-0.368	-1.430	0.153	-0.207	-1.100	0.271
4	0.728***	5.370	0.000	-0.073	-1.620	0.106
Calendar Year						
08	0.557***	4.530	0.000	-0.323***	-3.170	0.001
09	0.133	1.010	0.310	-0.113	-1.140	0.254
10	0.112	0.490	0.623	-0.413***	-3.330	0.001
11	-0.086	-0.410	0.684	-0.099	-0.330	0.743
12	-0.264	-1.000	0.318	-0.800	-1.530	0.125
13	-0.088	-0.300	0.765	--	--	--
14	-0.174	-0.500	0.616	0.038	0.150	0.878
15	-0.635	-1.610	0.107	0.181	0.480	0.633
Intercept	6.509	1.190	0.233	21.567***	5.270	0.000
σ	0.692			0.774		
# of Uncensored Obs.	664			148		
Observation function (probit)						
Ln Vessel Horse Power	0.246	1.200	0.230	0.571***	5.250	0.000
Ln Vessel Gross Tons	0.233***	3.930	0.000	0.109	1.600	0.110
Ln Vessel Age	0.178***	3.340	0.001	0.246***	2.980	0.003
Ln Hours Absent	0.035	0.400	0.690	-0.111*	-1.840	0.066
Ln Diesel Price	0.409	0.890	0.375	-0.131	-0.800	0.422
Ln Average Weekly Wage	-1.061	-0.440	0.659	0.061	0.110	0.913
Seasonal Quarter						
2	-0.172	-0.590	0.552	0.064	0.820	0.413
3	-0.321	-0.860	0.390	0.087	1.200	0.231
4	0.288**	2.420	0.016	0.429***	6.760	0.000
Calendar Year						
08	-0.338	-1.160	0.246	0.198*	1.930	0.053
09	-0.001	0.000	0.998	-0.015	-0.050	0.964
10	0.370	1.030	0.303	0.123	0.310	0.759
11	-0.239	-0.480	0.629	-0.400	-0.730	0.466

	Day Trip			Multi-day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
12	-0.057	-0.190	0.852	-0.513	-1.190	0.233
13	-0.680	-1.250	0.212	--	--	--
14	-0.889	-1.460	0.143	0.126	0.370	0.715
15	-1.243	-1.360	0.173	0.396*	1.650	0.099
Groundfish Sector ID						
3	0.766	1.270	0.205	0.018	0.090	0.930
13	1.124**	2.080	0.038	-0.728	-1.180	0.237
15	0.078	0.640	0.524	--	--	--
21	0.692**	2.500	0.012	--	--	--
27	0.134	0.400	0.688	-0.133	-0.590	0.553
SBRM Fleet Type						
2	1.491	1.370	0.170	1.297***	4.520	0.000
Ln Number of Observers	0.508***	3.950	0.000	0.496	1.290	0.196
Intercept	-1.285	-0.080	0.934	-8.935***	-4.750	0.000
ρ	0.164			-0.921		
# of Censored Obs.	7830			1688		
Total Obs.	8494			1836		
		χ^2	$P > \chi^2$		χ^2	$P > \chi^2$
Wald Test of Independent Equations		0.22	0.6359		9.33***	0.002

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Table 1. Probit, Weighted and Unweighted Ordinary Least Squares ((W)OLS), and Heckman Selection Independent Variable Descriptions

Independent Variable	Description	Units	Model*
Vessel Horse Power	Vessel engine horsepower.	kW	P, O, WO, H, HS
Vessel Gross Tons	Vessel weight in gross metric tons.	Tons	P, O, WO, H, HS
Vessel Age	Age of vessel (from when the vessel was built to calendar year 2015).	Years	P, O, WO, H, HS
Hours Absent	Hours the vessel was absent from port (from home port to destination) during a commercial fishing trip.	Hours	P, O, WO, H, HS
Diesel Price	Price of Ultra-Low Sulfur Number 2 diesel (New York Harbor) adjusted to 2010 U.S. constant dollars. Obtained from Department of Energy website.	$/Gallon	P, O, WO, H, HS
Average Weekly Wage	Average weekly wages for marina workers by state as an approximation of crew member opportunity costs, adjusted to 2010 U.S. constant dollars. Obtained from the Quarterly Census of Employment and Wages page of the Bureau of Labor Statistics website.	$/Week	P, O, WO, H, HS
Seasonal Quarter	Categorical variable specifying the season in which the fishing trip commenced using three-month time periods within a financial calendar (Q1, Q2, Q3, Q4).	Categorical Variable	P, O, WO, H, HS
Calendar Year	The calendar year in which the fishing trip commenced.	Categorical Variable	P, O, WO, H, HS
SBRM Fleet Type	The 2013 Standard Bycatch Reporting Methodology Fleet Type which categorizes each trip by the gear type, region, access area, trip category, and mesh size of that particular trip in order to stratify and sample trips according to biological data needs.	Categorical Variable	P, HS
Groundfish Sector ID	A categorical variable describing (1) a LAGF vessel's corresponding groundfish sector (seventeen total active sectors used in this analysis), (2) common pool vessels or (3) if the vessel is neither in a sector or the common pool.	Categorical Variable	P**, HS**
Number of Observers	The number of onboard vessel observers employed during the month and year that the trip was taken.	Numeric Value	P, HS

**Describing the models in which the independent variable is incorporated, where P= Probit, WO = WOLS, O = OLS, H = Heckman Selection model (Trip cost regression), HS = Heckman Selection model (Selection Equation).*

*** The Groundfish Sector ID was not included in the dredge probit or Heckman Selection as dredge gear is not a primary gear for groundfish fishing and therefore is not subject to additional groundfish monitoring imposed by the At Sea Monitor program.*

Table 2. Standardized Bycatch Reporting Methodology (SBRM) Fleet Type Definition (2013)

NO.	Gear Type	NEGEAR	Access Area	Trip Cat.	Region	Mesh
1	Longline	10	OPEN	all	MA	all
2	Longline	10	OPEN	all	NE	all
3	Hand Line	20	OPEN	all	MA	all
4	Hand Line	20	OPEN	all	NE	all
5	Otter Trawl	50	OPEN	all	MA	sm
6	Otter Trawl	50	OPEN	all	MA	lg
7	Otter Trawl	50	OPEN	all	NE	sm
8	Otter Trawl	50	OPEN	all	NE	lg
9	Scallop Trawl	52	AA	GEN	MA	all
10	Scallop Trawl	52	AA	LIM	MA	all
11	Scallop Trawl	52	OPEN	GEN	MA	all
12	Scallop Trawl	52	OPEN	LIM	MA	all
13	Otter Trawl, Ruhle	54	OPEN	all	MA	lg
14	Otter Trawl, Ruhle	54	OPEN	all	NE	sm
15	Otter Trawl, Ruhle	54	OPEN	all	NE	lg
16	Otter Trawl, Haddock Separator	57	OPEN	all	MA	lg
17	Otter Trawl, Haddock Separator	57	OPEN	all	NE	lg
18	Shrimp Trawl	58	OPEN	all	MA	all
19	Shrimp Trawl	58	OPEN	all	NE	all
20	Floating Trap	80	OPEN	all	MA	all
21	Floating Trap	80	OPEN	all	NE	all
22	Sink, Anchor, Drift Gillnet	100	OPEN	all	MA	sm
23	Sink, Anchor, Drift Gillnet	100	OPEN	all	MA	lg
24	Sink, Anchor, Drift Gillnet	100	OPEN	all	MA	xlg
25	Sink, Anchor, Drift Gillnet	100	OPEN	all	NE	sm
26	Sink, Anchor, Drift Gillnet	100	OPEN	all	NE	lg
27	Sink, Anchor, Drift Gillnet	100	OPEN	all	NE	xlg
28	Purse Seine	121	OPEN	all	MA	all
29	Purse Seine	121	OPEN	all	NE	all
30	Scallop Dredge	132	AA	GEN	MA	all
31	Scallop Dredge	132	AA	GEN	NE	all
32	Scallop Dredge	132	AA	LIM	MA	all

Table 2 *Continued.* Standardized Bycatch Reporting Methodology (SBRM) Fleet Type

NO.	Gear Type	NEGEAR	Access Area	Trip Cat.	Region	Mesh
33	Scallop Dredge	132	AA	LIM	NE	all
34	Scallop Dredge	132	OPEN	GEN	MA	all
35	Scallop Dredge	132	OPEN	GEN	NE	all
36	Scallop Dredge	132	OPEN	LIM	MA	all
37	Scallop Dredge	132	OPEN	LIM	NE	all
38	Danish Seine	160	OPEN	all	MA	all
39	Mid-water Paired & Single Trawl	170	OPEN	all	MA	all
40	Mid-water Paired & Single Trawl	170	OPEN	all	NE	all
41	Pots and Traps, Fish	181	OPEN	all	MA	all
42	Pots and Traps, Fish	181	OPEN	all	NE	all
43	Pots and Traps, Conch	183	OPEN	all	MA	all
44	Pots and Traps, Conch	183	OPEN	all	NE	all
45	Pots and Traps, Hagfish	186	OPEN	all	MA	all
46	Pots and Traps, Hagfish	186	OPEN	all	NE	all
47	Pots and Traps, Shrimp	190	OPEN	all	NE	all
48	Pots and Traps, Lobster	200	OPEN	all	MA	all
49	Pots and Traps, Lobster	200	OPEN	all	NE	all
50	Pots and Traps, Crab	300	OPEN	all	MA	all
51	Pots and Traps, Crab	300	OPEN	all	NE	all
52	Beam Trawl	350	OPEN	all	MA	all
53	Beam Trawl	350	OPEN	all	NE	all
54	Dredge, Other	381	OPEN	all	MA	all
55	Ocean Quahog/Surfclam Dredge	400	OPEN	all	MA	all
56	Ocean Quahog/Surfclam Dredge	400	OPEN	all	NE	all

Table 3. Trip Cost Function: Unweighted and Weighted Regression Results, Trawl

	Day Trip				Multi-Day Trip			
Variable	OLS Coef.	P>|t|	WOLS Coef.	P>|t|	OLS Coef.	P>|t|	WOLS Coef.	P>|t|
Ln Vessel Horse Power	0.480**	0.016	0.426**	0.013	0.429***	0.001	0.446***	0.002
Ln Vessel Gross Tons	0.211***	0.001	0.243**	0.019	0.435***	0.000	0.477***	0.001
Ln Vessel Age	-0.026	0.482	-0.034	0.293	-0.028	0.354	0.061	0.573
Ln Hours Absent	0.773***	0.000	0.693***	0.001	1.002***	0.000	0.988***	0.000
Ln Diesel Price	0.497***	0.003	0.586**	0.010	0.569***	0.001	0.513*	0.069
Ln Average Weekly Wage	-0.024	0.837	-0.156**	0.036	0.366***	0.008	0.139	0.122
Seasonal Quarter								
2	-0.034	0.173	-0.071	0.140	0.029***	0.007	0.069***	0.004
3	-0.042	0.156	-0.054	0.200	0.054***	0.006	0.049**	0.018
4	0.023**	0.048	0.040	0.211	-0.032**	0.010	0.063**	0.040
Calendar Year								
08	0.141	0.107	0.131	0.140	0.118*	0.063	-0.033	0.731
09	-0.057	0.205	0.007	0.826	-0.018	0.673	-0.037	0.670
10	-0.016	0.674	0.033	0.430	-0.007	0.873	0.010	0.892
11	0.021	0.745	0.064	0.276	0.079	0.311	0.152	0.153
12	0.062	0.319	0.069	0.443	0.063	0.390	0.131	0.139
13	0.035	0.577	0.056	0.489	0.054	0.323	0.114	0.255
14	-0.002	0.926	0.016	0.757	0.060	0.253	0.140	0.139
15	-0.103	0.117	-0.086	0.435	-0.029	0.477	-0.018	0.886
Intercept	0.196	0.526	1.346***	0.008	-3.535***	0.008	-2.688**	0.025
# of Obs.	8438		8438		8242		8242	
R^2	0.46		0.44		0.82		0.78	

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Table 4. Trip Cost Function: Heckman Sample Selection Model, Trawl

	Day Trip			Multi-Day Trip		
Variable	Coef.	z	P>|z|	Coef.	z	P>|z|
Ln Vessel Horse Power	0.431***	3.120	0.002	0.375***	10.900	0.000
Ln Vessel Gross Tons	0.214***	10.390	0.000	0.364***	12.170	0.000
Ln Vessel Age	-0.056	-1.330	0.183	0.014	0.590	0.556
Ln Hours Absent	0.681***	23.570	0.000	0.890***	55.860	0.000
Ln Diesel Price	0.440***	6.500	0.000	0.483***	6.230	0.000
Ln Average Weekly Wage	-0.929***	-20.360	0.000	-0.164**	-2.360	0.018
Seasonal Quarter						
2	-0.097***	-6.000	0.000	-0.082***	-9.640	0.000
3	-0.123***	-7.990	0.000	-0.099***	-10.350	0.000
4	0.054***	3.360	0.001	-0.045***	-4.500	0.000
Calendar Year						
08	0.209**	2.070	0.038	0.092*	1.920	0.055
09	-0.206***	-2.760	0.006	-0.137**	-2.560	0.010
10	-0.361***	-8.800	0.000	-0.201***	-7.280	0.000
11	-0.406***	-3.490	0.000	-0.199***	-2.590	0.009
12	-0.352***	-3.490	0.000	-0.146*	-1.800	0.071
13	-0.371***	-3.260	0.001	-0.085**	-2.290	0.022
14	-0.467***	-5.760	0.000	-0.129***	-2.640	0.008
15	-0.525***	-7.650	0.000	-0.167*	-1.720	0.085
Intercept	8.377***	9.200	0.000	2.083***	3.740	0.000
σ	0.825			0.60		
# of Uncensored Obs.	8438			8242		
Observation function (probit)						
Ln Vessel Horse Power	0.187**	2.550	0.011	0.131**	2.180	0.029
Ln Vessel Gross Tons	0.036***	3.420	0.001	0.234***	3.670	0.000
Ln Vessel Age	0.017	0.390	0.693	-0.020	-0.420	0.674
Ln Hours Absent	-0.011	-0.310	0.754	0.096***	4.370	0.000
Ln Diesel Price	0.086	0.610	0.544	0.112	1.280	0.202
Ln Average Weekly Wage	0.845***	5.610	0.000	0.332*	1.840	0.066
Seasonal Quarter						
2	-0.019	-0.260	0.792	0.073***	4.180	0.000
3	-0.019	-0.250	0.801	0.154***	8.390	0.000
4	-0.049*	-1.660	0.096	0.061***	3.040	0.002
Calendar Year						
08	-0.198	-0.970	0.333	-0.018	-0.480	0.628
09	0.127**	2.040	0.041	0.159***	4.930	0.000
10	0.145	0.580	0.563	0.290***	7.650	0.000
11	0.200	0.870	0.384	0.392***	6.180	0.000
12	0.204	0.770	0.442	0.223*	1.870	0.062
13	0.292	1.340	0.181	0.208***	4.520	0.000
14	0.317	1.240	0.216	0.286***	7.710	0.000
15	0.336***	4.580	0.000	0.265**	2.290	0.022

Table 4 *Continued*. Trip Cost Function: Heckman Sample Selection Model, Trawl

Variable		Coef.	z	P>|z|	Coef.	z	P>|z|
Groundfish Sector ID							
	3	0.397***	8.010	0.000	--	--	--
	5	0.243	1.610	0.106	0.092***	3.570	0.000
	6	0.365**	2.030	0.043	0.473***	5.100	0.000
	7	-0.834***	-3.280	0.001	-0.010	-0.230	0.816
	9	0.259	0.620	0.538	0.128***	3.630	0.000
	10	0.166***	2.630	0.008	0.211	1.090	0.278
	11	0.264***	12.660	0.000	--	--	--
	12	0.309***	7.010	0.000	0.210***	4.060	0.000
	13	0.461***	6.050	0.000	0.304	1.220	0.224
	15	0.361***	13.000	0.000	0.203	1.480	0.138
	16	-0.033	-0.430	0.669	-0.042*	-1.780	0.076
	17	-0.105	-0.540	0.593	0.178***	10.010	0.000
	18	0.115**	2.110	0.035	-0.136**	-2.290	0.022
	19	0.035	0.150	0.879	-0.040	-0.870	0.386
	20	0.408***	13.690	0.000	0.205***	4.140	0.000
	22	-0.027	-0.290	0.769	0.009	0.170	0.864
	27	-0.089***	-3.370	0.001	0.043	1.520	0.129
SBRM Fleet Type							
	6	0.163***	3.220	0.001	0.057	1.100	0.273
	7	0.045**	2.050	0.041	-0.043	-0.950	0.342
	8	0.377***	4.950	0.000	0.568***	13.590	0.000
	9	-0.100	-0.360	0.719	-0.230***	-7.290	0.000
	10	--	--	--	-0.150	-0.460	0.644
	11	-0.177**	-2.470	0.014	-0.402***	-2.960	0.003
	14	--	--	--	-0.435	-1.150	0.250
	15	--	--	--	0.230*	1.700	0.088
	16	1.298***	2.680	0.007	--	--	--
	17	0.890***	8.610	0.000	0.567***	7.460	0.000
	18	0.072	0.310	0.759	-1.665***	-6.470	0.000
	19	-0.439***	-4.790	0.000	-0.654***	-3.800	0.000
	39	--	--	--	0.002	0.010	0.993
	40	0.906***	26.470	0.000	0.635***	4.220	0.000
	52	-0.189**	-2.280	0.023	-0.357***	-6.750	0.000
	53	-0.085	-0.720	0.472	--	--	--
	57	0.278***	3.710	0.000	0.024	0.220	0.823
Ln Number of Observers		0.381	1.600	0.109	0.197***	2.740	0.006
Intercept		-10.512***	-7.290	0.000	-7.235***	-4.310	0.000
ρ		-0.821			-0.880		
# of Censored Obs.		145871			63093		
Total Obs.		154309			71335		
			χ^2	$P > \chi^2$		χ^2	$P > \chi^2$
Wald Test of Independent Equations			137.27***	0.000		537.54***	0.000

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.

Table 5. Mean Model Predictions: Fleet Total Cost Estimation

Gear	Trip Length	Predictions	OLS	WOLS	OLS WOLS (%) Difference	Heckman	OLS Heckman (%) Difference
Trawl	Day	154369	418.84	409.96	2.14	494.94	16.65
	Multi-Day	71460	6920.74	6986.37	0.94	7102.77	2.60
Dredge	Day	64167	788.02	1107.78	33.73	862.09	8.98
	Multi-Day	47181	9606.66	9870.62	2.71	9522.85	0.88
Gillnet	Day	132116	199.97	197.77	1.11	219.76	9.43
	Multi-Day	14012	889.30	880.96	0.94	946.79	6.26
Longline	Day	8585	374.99	549.96	37.83	364.48	2.84
	Multi-Day	2379	5533.83	5186.25	6.48	8505.11	42.33
All Gears	Day	359237	403.24	459.91	13.13	456.20	12.32
	Multi-Day	135032	7208.91	7328.88	1.65	7334.27	1.72

Table 6. Kolmogorov–Smirnov Equality of Distributions Test: Predicted Trip Costs

	D	P- value	Corrected
Trawl Daytrip			
Heckman OLS	0.074***	< 0.001	< 0.001
Heckman WOLS	0.093***	< 0.001	< 0.001
OLS WOLS	0.022***	< 0.001	< 0.001
Dredge Day Trip			
Heckman OLS	0.053***	< 0.001	< 0.001
Heckman WOLS	0.101***	< 0.001	< 0.001
OLS WOLS	0.134***	< 0.001	< 0.001
Gillnet Day Trip			
Heckman OLS	0.090***	< 0.001	< 0.001
Heckman WOLS	0.097***	< 0.001	< 0.001
OLS WOLS	0.009***	< 0.001	< 0.001
Longline Day Trip			
Heckman OLS	0.046***	< 0.001	< 0.001
Heckman WOLS	0.146***	< 0.001	< 0.001
OLS WOLS	0.135***	< 0.001	< 0.001
Trawl Multi-Day Trip			
Heckman OLS	0.074***	< 0.001	< 0.001
Heckman WOLS	0.072***	< 0.001	< 0.001
OLS WOLS	0.012***	< 0.001	< 0.001
Dredge Multi-Day Trip			
Heckman OLS	0.055***	< 0.001	< 0.001
Heckman WOLS	0.067***	< 0.001	< 0.001
OLS WOLS	0.014***	< 0.001	< 0.001
Gillnet Multi-Day Trip			
Heckman OLS	0.166***	< 0.001	< 0.001
Heckman WOLS	0.154***	< 0.001	< 0.001
OLS WOLS	0.022***	0.002	0.002
Longline Multi-Day Trip			
Heckman OLS	0.172***	< 0.001	< 0.001
Heckman WOLS	0.184***	< 0.001	< 0.001
OLS WOLS	0.064***	< 0.001	< 0.001

Note: *, **, and *** indicate statistical significance at the 10, 5, and 1% levels, respectively.