Whale-Watching and Herring Fishing:

Joint or Independent Production

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Abstract

The effects of "localized depletion" of a pelagic fishery (herring) on a non-extractive marine activity (tourism) are investigated. Proponents of the localized depletion theory claim that intense fishing effort can lead to areas that are unsuitable for predators like tuna, groundfish, and whales. This leads to poor outcomes for the fishing and whale-watching industries. However, there has been no consensus in the scientific community about the existence of this phenomenon. Localized depletion would be consistent with an economic theory of joint production, in which nearshore herring stocks are an input in production of both herring and whale-watching trips. A unique dataset of daily whale-watching outcomes is combined with fishing effort and oceanographic data. This dataset is used to test the hypothesis that intensive fishing effort increases the search time of whale-watching companies. Our results suggest that while fishing has a statistically significant impact on sightings, this magnitude of this effect is fairly small. Sightings seem to be determined mostly by large scale oceanographic processes. These results should be of interest to policymakers in determining future fishing regulations.

Key words: whales, fishing, panel data, search, Ecosystem Based Management

JEL classification: Q57, Q26, Q22

Introduction

Ecosystem based management has becomes an important decision-making framework for regulation of marine resources. Under this rubric, regulation aims to move away from a single species framework in favor of a more holistic approach. All users of the ecosystem, both extractive and non-extractive, and all species are considered in the decision-making calculus. The impact of fishing effort on whale-watching outcomes in the Gulf of Maine is characterized using a unique panel of whale-watching search times. I combine trip level whale-watching data with oceanographic data extracted from the Gulf of Maine Ocean Observing System (GoMOOS) and fishing data extracted from National Marine Fisheries Service's (NMFS) Vessel Trip Report (VTR) and Vessel Monitoring System (VMS) databases.

Managing systems with multiple stakeholders and interacting species requires tremendous amounts of information, from both economic and biological perspectives. The economic literature on multispecies systems has focused on predator-prey interaction, recently adding valued, non-harvested species to the theoretical models (Hannesson 1983; Ragozin and Brown 1985; Brown, Berger, and Ikiara 2005; Hoekstra and van den Bergh 2005). A separate strain of literature has examined jointness in production of fish, both theoretically (Agar and Sutinen 2004), and empirically (Squires 1987; Squires and Kirkley 1991; Bisack and Sutinen 2006). However, there has been comparatively little empirical research that has examined the impacts of fishing on a non-extractive ecosystem use.

The non-extractive industry, whale-watching, is growing in New England, and accounts for for roughly $30M of revenues per year (Hoyt 2001). This industry depends on high abundances of whales close to shore, within range of their vessels. The whales are near shore because they are feeding on the small fish, including herring, that are an important food source (Overholtz, Link, and Suslowicz 2000; Read and Brownstein 2003). Herring themselves are also the target of a fishery, with recent annual landings of $12-15M (NMFS pers. comm).

From an economic perspective, herring are supplied by the ecosystem. It is harvested directly, and used as an input in whale production. In turn, whales are an input in the production of whale-watching trips. Proponents of the "localized depletion" hypothesis maintain that intense fishing leads to lower stocks of whales (as well as the valued fish that feed on herring). If true, localized depletion may justify closing certain areas to herring fishing.

The Herring Fishery

Atlantic herring are a pelagic, schooling fish found abundantly in the Gulf of Maine. The herring fishery has been important in New England for centuries; however, intense fishing pressure by foreign fleets in the 1960s and 1970s collapsed the fishery by the late 1970s (Anthony and Waring 1980). Stock levels have since recovered to historically high levels after these fishing pressures decreased.

The Gulf of Maine-Georges Bank herring complex is managed by the New England Fisheries Management Council (NEFMC) as a single stock, despite some evidence that there are two separate stocks of herring (Stevenson and Scott 2005). There are a total of four fishing zones; the inshore Gulf of Maine fishery is most likely to interact with whale-watching activities. Each zone is allocated a total allowable catch (TAC); when the TAC is reached the fishing zone is closed. The fishery has recently transitioned from an open- to a limited-access fishery.

In the inshore Gulf of Maine region, herring typically school in large aggregations and rise to the surface at night. The fishery is prosecuted using two types of fishing gear, midwater trawls and purse seines. Purse seining involves encircling an entire school of fish near the surface with a large net (usually towed by a smaller boat). This method has declined in importance; it requires calm seas, shallow waters, and is labor intensive. It is also only effective at night, when herring cannot see and avoid the nets. The industry has shifted to trawl and paired-trawl vessels, which are more efficient and can fish at more depths.

For the 2007 season, NEFMC made major revisions to the herring Fishery Management Plan (FMP). After lobbying by whale-watching, recreational, and hook-and-line fishing interests, NEFMC closed the inshore region to trawling during the summer months (June-September). These groups claimed that trawling leads to localized depletion of herring, reducing the abundance of whales and larger fish. To date, there is no conclusive scientific evidence for this theory of localized depletion; however, it is under investigation by NMFS. This closure may have far reaching economic consequences for the lobster industry, which depends on a steady supply of herring for bait. Lobster fishermen in Maine have a historical preference for fresh bait and rely heavily on the inshore fishery to supply that bait (NOAA 2006).

The inshore Gulf of Maine herring fishery is also subject to a seasonal spawning closure. When herring spawn, they move inshore and aggregate tightly. During this time, they are particularly susceptible to fishing. However, fishing is prohibited during this time for conservation reasons (New England Fisheries Management Council 1999). Whales are not subject to these restrictions; their abundance in the nearshore area is likely to be high, as they take advantage of high aggregations of prey.

The Whale-watching Industry

The productive waters of the Gulf of Maine are used by many species of large cetaceans as a summer feeding ground. Humpback whales have fairly strong site fidelity at both large and small scales; they consistently use the Gulf of Maine to feed on herring and sand lance (Robbins 2007). Despite this site fidelity, whales can cover large distances in search of prey and may move beyond the range of whale-watching vessels when prey is scarce. These whales are most commonly associated with the sandy bottomed waters off the coast of Massachusetts. Fin whales also spend summers feeding in the Gulf of Maine, primarily on herring and mackerel. Unlike humpback whales, little is known about fin whale site preferences; however, they are more associated with the rocky bottomed waters off the coast of New Hampshire and Maine. Humpback and fin whales are most desired species and, along with the smaller minke whales, are the most commonly seen species.

Whale-watching companies are based in many ports in the Gulf of Maine, ranging from Provincetown, Massachussetts to Halifax, Nova Scotia (Figure 1). Most companies have a home searching area that is limited by the speed of their vessel and their location relative to prominent oceanographic features (banks and ledges). However, the companies based in Gloucester, MA have an option of two areas, Jeffrey's Ledge and Stellwagen Bank. Jeffrey's Ledge is a deeper, rocky-bottomed area in which fin whales are relatively abundant while Stellwagen Bank is a sandy-bottomed, shallower area where humpback whales are relatively abundant.

No special equipment is used for finding whales, captains and naturalists rely on their eyes and experience to find whales when they surface to breathe. Whale-watching is typically a summer activity; most firms operate daily or twice-daily trips from May through Labor Day. These trips are of roughly fixed duration, typically 3 to 4 $\frac{1}{2}$ hours in length. Firms guarantee that customers will sight a whale, providing a strong incentive to find whales. In general, whales are most likely to be found close to banks and ledges, where ocean upwelling causes their prey to aggregate in large numbers. The locations of these oceanographic features are common knowledge to all firms.

Search is costly to both producers and consumers of whale-watching trips. For producers, extensive search leads to high consumption of fuel. For consumers, extensive search means less time is available for actual viewing of whales.

A resource conflict has developed between "environmental" groups and herring fishermen concerning the appropriate level of harvesting in the inshore region. This conflict has pitted herring fishermen that use trawl gear against almost all other stakeholders, including whale-watching groups, hook-and-line fishermen, lobstermen, sportfishermen, and conservation groups. These groups claim that trawling creates "localized depletion" of forage fish in the nearshore area, which leads to decreased abundances of whales and large predatory fish.

Behavioral and Ecological Model

A true ecosystem based model would include all species, their interconnections, and various human uses. This would require far more information currently available; examination of the impact of herring fishing on whale-watching is still possible and policy relevant.

A simple ecological model of localized depletion following Anderson (2002) begins by dividing the Gulf of Maine into two areas, a nearshore area that is suitable for whale-watching and an offshore area that is not suitable for whale-watching. In the absence of fishing, herring aggregations are distributed uniformly across the ecosystem; the nearshore area will have the same density of herring as the offshore area. Herring fishing in the nearshore causes temporarily low abundances of herring: localized depletion.

Whales are highly mobile and follow large aggregations of fish, resulting in a steady-state distribution that is proportional to the abundance of fish. In response to low levels of prey, whales move offshore to feed. The system re-equilibrates as both herring and whale redistribute through the ecosystem. As a model of within-year dynamics, we abstract away from natural mortality, reproduction, and migration out of the two areas. Mathematically, the dynamics of the system can be represented as the following set of differential equations:

$$\begin{aligned}
&\dot{W}_{Nt} = \text{a}\left[\frac{W_{Ot}}{H_{Ot}} - \frac{W_{Nt}}{H_{Nt}}\right] \\
&\dot{W}_{Ot} = -\dot{W}_{Nt} \\
(1)\quad &\dot{H}_{Nt} = \text{b}\left[\frac{H_{Ot}}{K_O} - \frac{H_{Nt}}{K_N}\right] - d(W_{Nt}H_{Nt}) - y_{Nt} \\
&\dot{H}_{Ot} = -\text{b}\left[\frac{H_{Ot}}{K_O} - \frac{H_{Nt}}{K_N}\right] - d(W_{Nt}H_{Nt}) - y_{Ot}
\end{aligned}$$

Where:

W_{Nt}, W_{Ot}:	Nearshore and offshore whale stocks
H_{Nt}, H_{Ot}:	Nearshore and offshore herring stocks
$\dot{W}_{Nt}$,$\dot{W}_{Ot}$:	The rate of change of the nearshore and offshore whale stock
$\dot{H}_{Nt}$,$\dot{H}_{Ot}$:	The rate of change of the nearshore and offshore herring stock
a, b:	A speed of adjustment parameters
K_O,K_N:	Herring carrying capacity in the nearshore and offshore areas
$d(\cdot)$:	Mortality of herring due to predation by whales
y_{Nt}, y_{Ot}:	Harvest of herring in the nearshore and offshore areas

In this model, whales are sensitive to the distribution of their prey; they respond by moving to areas in which their prey are relatively abundant. Herring diffuse through the ecosystem and are subject to both predation and fishing mortality. To understand localized depletion, it is helpful to examine the limiting case of $b = 0$, that is H_N and H_O are isolated populations. In this case, nearshore harvest (y_{Nt} reduces the amount of nearshore herring H_N and eventually whales respond by leaving the nearshore area for more favorable locations.

The searching behavior of vessels is simple. Whale-watching vessels leave their home ports in search of whales, traveling toward ledges and banks, where whales are likely to be seen. Because they are sighted visually, search and travel are *not* mutually exclusive activities. Vessels stop traveling when a whale is sighted. Searching time depends on many factors, including the traveling speeds, visual conditions, unobservable skill, and abundances of whales in the searching area. Vessels combine quasi-fixed factors of production with environmental quality to produce whale-watching trips. While the goals of the whale-watching firm are fairly complex, minimization of search time is closely tied to profits (and consumer welfare measures). For trips that find whales quickly, fuel consumption is low and customer satisfaction is likely to be high. For trips that do not find whales quickly, fuel consumption is higher and customer satisfaction is lower.

Whale-watching search time is decreasing in the abundance of whales in the nearshore area, formally:

(2) $\text{Search}_{it} = f(W_N)$

and

(3) $\dfrac{\partial \text{Search}_{it}}{\partial W_N} < 0$

The model of localized depletion generates the hypothesis that previous (lagged) fishing effort increases search times through an ecological system.

Data and Econometric Model

In this analysis, three sources of data are used: five whale-watching organizations provided trip-level data, fishing effort and catch data was extracted from the NMFS Vessel Monitoring System (VMS) and Vessel Trip Report (VTR) datasets, and oceanographic data was obtained from the Gulf of Maine Oceanographic Observation System (GoMOOS).

The whale-watching vessels analyzed in this study overlap spatially with the herring fishing grounds. Vessels that depart from Gloucester, MA often search for whales on both Stellwagen Bank and Jeffrey's Ledge. Vessels that depart from New Hampshire and northern Massachusetts will typically only use the Jeffrey's Ledge area. For Gloucester vessels, this data spans the 2002-2006 whale-watching seasons, while data from New Hampshire and northern Massachusetts vessels spans the 2003-2006 seasons. The data collected from whale-watching firms includes time of departure and time of sighting, from which search times can be calculated. Of the 2,517 trips, 179 (7.11%) did not sight a whale and were dropped from the analysis, leaving 2,301 observations.

In order to control for oceanographic conditions that may affect the ability of whale-watching vessels to locate whales, oceanographic data was extracted from GoMoos. Two measures were used, visibility and wind speed. Poor visibility directly affects the ability of a whale-watching boat to find whales. This may be caused by haze, fog, or rain. Additionally, high winds can cause whitecaps to form on the surface of the ocean. This introduces visual clutter and may decrease the ability for a searcher to find whales.

Whale-watching areas are defined by using oceanographic contours provided by the US Geological Survey, specifically the 80 meter contour on Jeffrey's Ledge and the 30 meter contour on Stellwagen Bank. Using ArcMap, these contours were then buffered by two and five miles and a convex hull was created between the whale-watching ports and the oceanographic features. The resulting feature represents areas to which whale-watching vessels are most likely to travel.

Figure 2 includes the locations of whale-watching ports for the vessels studied, the locations of data buoys, and a representation of the Stellwagen Bank and Jeffrey's Ledge whale-watching areas.

Fishing effort is quantified using two NMFS datasets. The Vessel Trip Report (VTR) dataset is composed of self-reported logs that include trip dates, locations, and catch amounts. On a good trip, a herring vessel may catch upwards of 100 metric tons of herring. The VTR data are used directly to construct a measure of fishing effort.

An alternative measure of fishing activity is constructed using the Vessel Monitoring System (VMS). VMS is required for major vessels in the herring fishery. This system reports the position of a fishing vessel at intervals of 30 minutes to 1 hour. From this spatio-temporal data, the average speeds can be inferred.

The VMS data is combined with VTR data to select only the herring fishing trips. Palmer and Wigley (2007) used the VMS system to locate fishing effort at a fine scale and compare it to reported fishing locations for a variety of fishing gears. Their technique correlated vessel speeds with activities, based on knowledge of the profiles of vessels in the fishery. This method performed well relative to using logbook data to allocate catch to spatial regions. In the herring fishery, the distributions of speeds are strongly bi- or tri-modal.

In the trawl fishery, the very slow speeds correspond to hauling gear, slow speeds to trawling, and high speeds to traveling (Figure 3). In the seine fishery, fishing and hauling gear typically take place at very slow speeds while traveling occurs at very high speeds, resulting in a bimodal distribution seen in Figure 4. Observations between the peaks likely represent periods of transition between activities. While VMS can be used for very fine scale location and time observations of fishing effort, the amount of fish actually caught is not reported along with the locations. For all gear types, a vessel is classified as fishing if vessel speed is below 5 knots.

To finalize the construction of the fishing effort indicators, the VMS and VTR locations are plotted in ArcMap, and the observations that lie within the defined whale-watching areas are extracted.

These are then aggregated to form a daily measure of fishing effort in each of the two areas. The VMS measure of fishing yields the number of vessels actively fishing in each area while the VTR measure is the actual catch in each area. Table (1) contains summary statistics for oceanographic and fishing measures.

The model to be estimated is:

$$
\begin{aligned}
SearchTime_{it} = \beta_1 Wind_{it} + \beta_2 Visibility_{it} + \beta_3 itSpawn + \beta_4 Fishing_{it} \\
+ \beta_5 PreviousFishing_{it} + \beta_6 Gloucester * Fishing_{it} \\
+ \beta_7 Gloucester * PreviousFishing_{it} + u_i + e_{it}
\end{aligned}
\tag{4}
$$

Yearly dummy variables are included to capture large-scale oceanographic changes. Vessels departing from Gloucester, MA can select from two large areas; we include interactions of the fishing effort indicators with a dummy variable to allow for the possibility of averting behavior. Because those vessels have access to two whale-watching grounds, they may be able to minimize the impact of fishing by using alternative sites. The fixed-effects model is used to estimate equation (4), alternatively using VTR and VMS measures for fishing effort. A seven day moving sum of fishing effort is used to aggregate lagged fishing measures into a single variable.

In light of (1) and (4), a source of model mis-specification is readily apparent: daily abundances of herring and whales are omitted from the model and are unmeasurable. To the extent that fishermen are fish in areas with high abundances of herring, the fishing effort variables are endogenous and contemporaneously dated herring catch may be an indicator of high prey abundance. However, localized depletion maintains that fishing effort causes subsequent searching times to increase.

This misspecification may introduce a second problem. The unmeasured whale and herring abundances are likely to be moderately persistent. When these abundances do not enter the model, the residual terms of equation (4) are likely to be autocorrelated, and inference following the fixed effects estimators will be invalid. The errors modeled as following an AR(1) process:

$$(5) \quad u_{it} = \rho_i u_{it-1} + e_{it}$$

Furthermore, the whale-watching vessels utilize the overlapping or very similar areas of the Gulf of Maine, implying that the cross-sections face similar unobserved shocks, leading to contemporaneously correlated errors. Formally:

$$(6) \quad E[u_{it} u_{jt}] \neq 0$$

An alternative to the traditional fixed-effects estimator has been developed for use in panels with relatively small cross-sections and large time dimensions (Parks 1967; Kmenta 1986; Beck and Katz 1995). In general this method involves pooling and estimating by feasible generalized least squares (FGLS). This group of estimators has been developed to account these two problems, contemporaneously correlated and autocorrelated errors.

The procedure of Parks (1967) and Kmenta (1986) consists of performing the Prais-Winsten transformation to remove autocorrelation, reestimating a pooled model, another transformation to remove the contemporaneous correlation, and finally estimating a pooled model on the twice-transformed data.

Using Monte Carlo studies, Beck and Katz (1995) show that the standard errors generated by this procedure are too small, leading to overconfidence in the point estimates. Because coefficients estimated without correcting for contemporaneous correlation are unbiased, they advocate omitting the final transformation and computing standard errors that are robust to cross-sectional correlation.

Estimation Results

The results of estimation using fixed effects is presented in Table 2. For brevity, only results are presented using the 5-mile buffered whale-watching areas. The results are qualitatively similar when the 2-mile buffered whale-watching areas. The model fit is fairly low, with R^2 statistics ranging from 0.083 to 0.09; however, the joint F-statistics indicate that the model does have explanatory power. Across the four specifications, the lagged fishing variables on Jeffrey's Ledge are positive and statistically significant. This implies that fishing causes future search times to increase; however, these effects are relatively small.

The effects of fishing on Stellwagen Bank are not statistically significant. Fishing occurs very infrequently on Stellwagen Bank, and even less frequently during the whale-watching season. There are other, non-commercially fished prey that live around Stellwagen Bank, which provide suitable food for whales, even in absence of herring.

Interaction of the Gloucester dummy variable with the fishing variables also produces insignificant coefficient estimates, suggesting that the impact on Gloucester-based whale-watching vessels is similar to that of the northern vessels.

The negative coefficient on the Spawn dummy variable provides support for the underlying biological model. Increases in prey abundances during the spawning period results in lower searching times by whale-watching vessels. As expected, high visibility decreases searching time, by increasing the searching ability of whale-watching vessels. However, wind speeds are not found to have an effect on search times.

The yearly dummy variables are included to control for large scale oceanographic processes and are highly significant and similar in magnitudes specifications. The 2002 dummy variable was dropped from the estimation; the coefficients may be interpreted as an average change in search time relative to search time in 2002. On average, trips in 2005 and 2006 found whales faster while trips in 2003 found whales slower. The effect of the 2004 dummy variable was not robust across specifications, but trips in that year may have taken slightly more time to find whales.

The coefficients estimated using the Beck and Katz (1995) FGLS procedure are qualitatively similar to those estimated by fixed effects (Table 3). We find an autocorrelation (ρ) parameter of approximately 0.21 in all four models and R^2 measures of 0.16-0.17. Spawning herring and high visibility decrease search times and interactions of the Gloucester dummy with fishing effort indicators are not significant. The yearly dummies are also qualitatively similar to those estimated by fixed effects.

In this analysis, we are assuming that previous dated herring fishing will decrease the abundances of whales though an ecosystem mechanism. Fishing vessels are profit-maximizing entities and are likely to fish only in areas of high abundances of herring, leading to endogeneity of the contemporaneously dated effort variables. However, previous dated fishing measures can be viewed as predetermined and are free of the endogeneity problem.

Use of a moving sum of fishing catch and effort imposes some structure on the model. In particular, this aggregation implies that *all* fishing effort within the “window” has an identical effect on subsequent search time, and that fishing prior to that “window” has no effect on fishing. Unfortunately, the ecological model gives little guidance as to the size of that window.

Hendry and Mizon (1978); Beck (2001) and many others advocate modeling the dynamics by including a lagged dependent variable instead of calculating robust standard errors. However, it is not clear that inclusion of a lagged dependent variable is likely to correct this specification problem, as previous search times are not directly related to current search times.

It is reasonable to believe that fishing (contemporaneous and lagged) and low-visibility can cause vessels to fail to sight any whales. To the extent that this occurs, the estimated coefficients may be biased. Not examining and modeling the failure of whale-watching vessels to sight whales may underestimate the true interactions of the herring and whale-watching industries.

Conclusions

In this analysis, the effects of herring fishing on the whale-watching industry are quantified. We find that fishing causes search times to increase on subsequent days; however, this effect is relatively small. Consistent with our ecological model, we find that search times tend to decrease when herring are aggregating inshore to spawn during the late summer.

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Figures

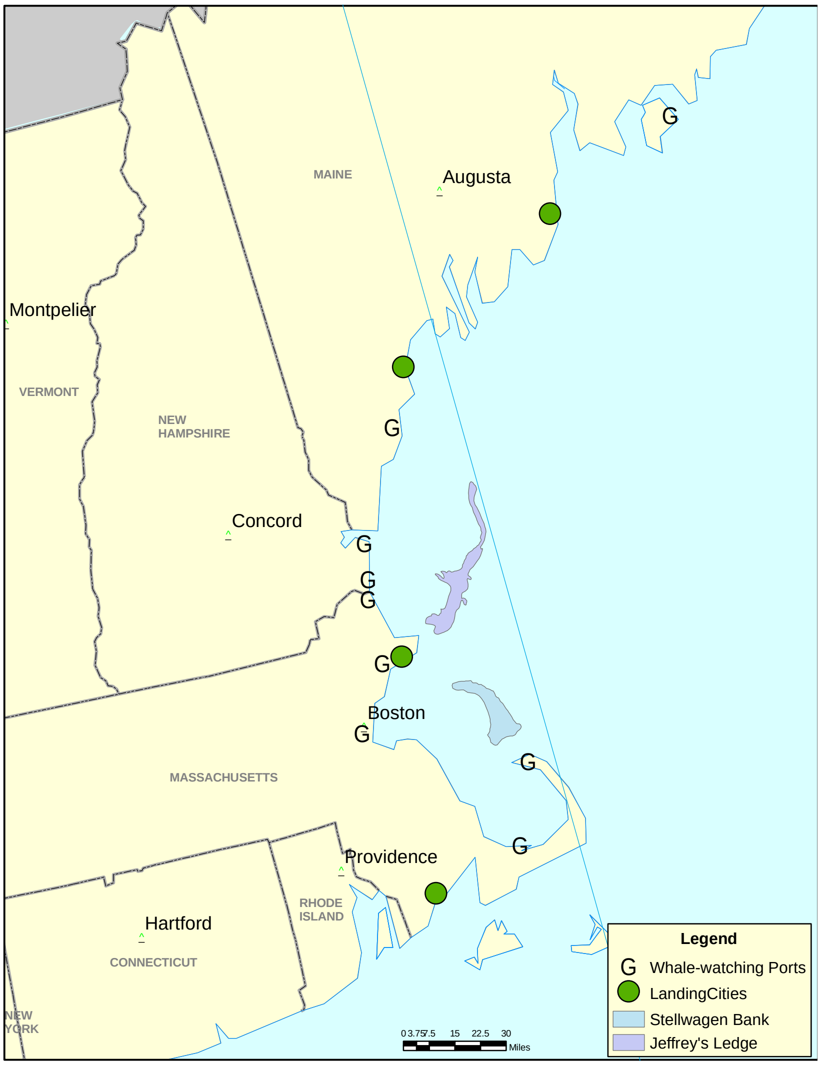

Figure 1. Location of whale-watching ports,fishing ports, and oceanographic features in the Gulf of Maine.

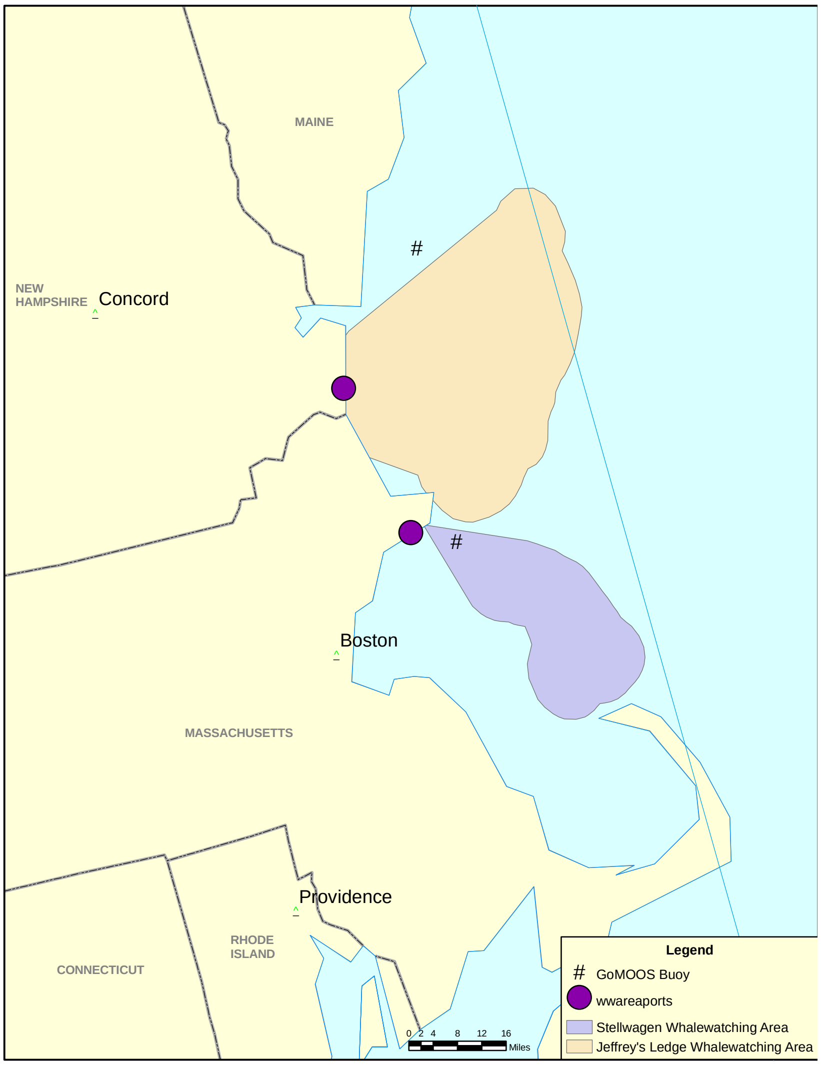

Figure 2. Study area including data buoys, whale-watching area, and home ports vessels analyzed

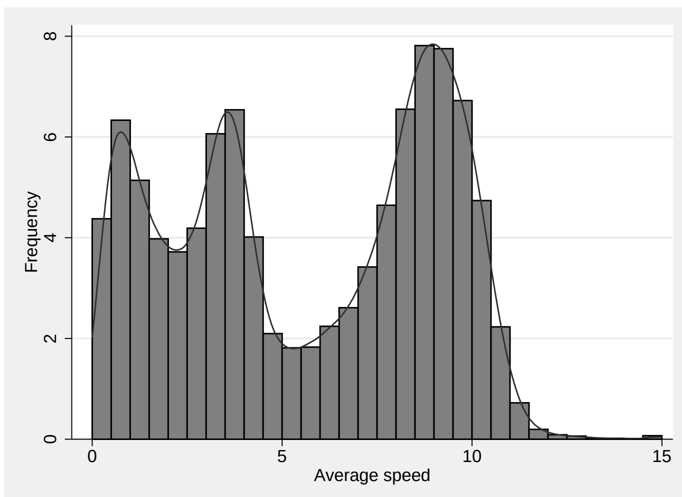

Figure 3. Histogram and Kernel Density of Speed of Trawl Vessels. The tri-modal distribution has peaks corresponding to hauling, fishing, and steaming behavior.

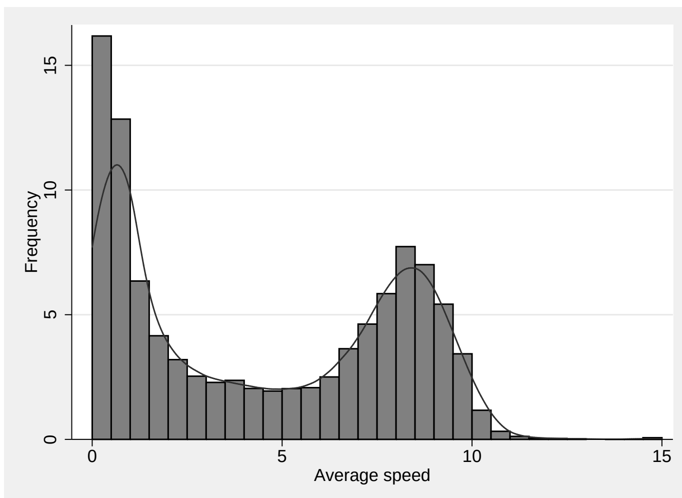

Figure 4. Histogram and Kernel Density of Speed of Seine Vessels. For seine vessels, hauling and fishing activities are indistinguishable from each other, yet occur as much slower speeds than steaming.

Tables

Variable	Abbreviation	Units	Mean	Std. Dev.	Min	Max
Dependent Variable, n=2301						
Search Time	Search	Minutes	91.7	39.5	12	411
Oceanographic Variables n=1763						
Wind		Meters/second	5.86	3.14	0	18.9
Visibility		Kilometers	2.59	0.617	0.026	2.96
Fishing Measures, n=1763						
Jeffrey's Ledge Catch	JLCatch	Metric tons (mt)	47.3	138	0	1190
Jeffrey's Ledge Catch, 7 day Lag	JLCatch Lag	Metric tons (mt)	330	635	0	3950
Jeffrey's Ledge Trips	JLTrip	Fishing trips	0.610	1.47	0	11
Jeffrey's Ledge Trips, 7 day Lag	JLTrip Lag	Fishing trips	4.26	6.69	0	34
Stellwagen Bank Catch	SBCatch	Metric tons (mt)	5.53	45.8	0	923
Stellwagen Bank Catch, 7 day Lag	SBCatch Lag	Metric tons (mt)	38.9	174	0	206
Stellwagen Bank Trips	SBTrip	Fishing trips	0.178	0.641	0	9
Stellwagen Bank trips, 7 day Lag	SBTrip Lag	Fishing trips	1.25	2.84	0	22
Dummy Variables, n=2301						
Spawn Closure	Spawn	=1 if fishery closed due to spawning	9.21%			
Gloucester	Glou	=1 if based in Gloucester	50.6%			

Table 1. Search Time, Fishing, and Oceanographic Lagmary statistics.

	(1)	(2)	(3)	(4)
Wind	-.109	-.171	-.203	-.227
	(.429)	(.427)	(.426)	(.425)
Visibility	-7.090***	-7.070***	-7.241***	-7.221***
	(1.218)	(1.216)	(1.211)	(1.209)
Spawn	-16.949***	-17.324***	-18.121***	-17.859***
	(2.758)	(2.747)	(2.744)	(2.738)
JLTrips	-.200	-.330		
	(.813)	(.809)		
JLTrips Lag	.715***	.698***		
	(.230)	(.222)		
Glou X JLTrips	1.667	1.656		
	(1.143)	(1.136)		
Glou X JLTrips Lag	-.038	-.123		
	(.308)	(.296)		
JLCatch			.013	.014
			(.010)	(.010)
JLCatch Lag			.006**	.006**
			(.003)	(.003)
Glou X JLCatch			-.002	-.004
			(.013)	(.013)
Glou X JLCatch Lag			.004	.004
			(.003)	(.003)
SBTrips	-7.066			
	(4.420)			
SBTrips Lag	.233			
	(1.444)			
GLou X SBTrips	4.478			
	(5.108)			
Glou X SBTrips Lag	-1.642			
	(1.783)			
SBCatch			.042	
			(.204)	
SBCatch Lag			-.052	
			(.081)	
Glou X SBCatch			-.092	
			(.208)	
Glou X SBCatch Lag			.031	
			(.083)	
D2003	8.007***	7.512***	7.111***	7.036***
	(2.461)	(2.432)	(2.397)	(2.396)
D2004	5.022**	4.270*	3.833	3.573
	(2.561)	(2.517)	(2.502)	(2.483)
D2005	-13.564***	-14.166***	-14.637***	-14.958***
	(2.412)	(2.384)	(2.390)	(2.379)
D2006	-12.972***	-13.516***	-15.133***	-15.200***
	(2.510)	(2.484)	(2.502)	(2.496)
R^2	.085	.083	.091	.09
F Statistic	14.166	18.796	15.305	20.613

Table 2. Results of Estimation using Fixed Effects. N=2301. Standard Errors in parentheses

	(5)	(6)	(6)	(8)
Wind	.089	.050	.012	-.007
	(.458)	(.456)	(.454)	(.454)
Visibility	-6.775***	-6.760***	-6.939***	-6.910***
	(1.348)	(1.347)	(1.343)	(1.339)
Spawn	-16.634***	-16.976***	-17.746***	-17.477***
	(3.246)	(3.237)	(3.201)	(3.196)
JLTrips	-.500	-.608		
	(.983)	(.979)		
JLTrips Lag	.689**	.671**		
	(.305)	(.295)		
Glou X JLTrips	1.548	1.546		
	(1.217)	(1.212)		
Glou X JLTrips Lag	.057	-.019		
	(.365)	(.352)		
JLCatch			.012	.013
			(.013)	(.012)
JLCatch Lag			.006*	.005
			(.003)	(.003)
Glou X JLCatch			-.005	-.007
			(.014)	(.014)
Glou X JLCatch Lag			.005	.005
			(.004)	(.004)
SBTrips	-6.027			
	(5.252)			
SBTrips Lag	.076			
	(1.953)			
Glou X SBTrips	4.378			
	(5.700)			
Glou X SBTrips Lag	-1.418			
	(2.192)			
SBCatch			.059	
			(.225)	
SBCatch Lag			-.066	
			(.111)	
Glou X SBCatch			-.109	
			(.227)	
Glou X SBCatch Lag			.046	
			(.113)	
R^2	.166	.166	.17	.169
χ^2	280	273	296	292
ρ	.21	.214	.207	.208

Table 3. Estimation Results Using Beck and Katz (1995)'s FGLS Procedure: Firm dummies supressed for brevity. Standard Errors in parentheses are robust to contemporaneous correlation. N=2301.