# Predicting the economic impacts of the 2017 West Coast salmon troll ocean fishery closure

## Abstract

The ocean salmon fishery on the US West Coast has faced periodic closures of varying extents in order to protect vulnerable runs. These closures can have serious consequences for fishers and fishing communities, and have necessitated the release of millions of dollars of federal disaster aid. The 2017 ocean Chinook troll fishery (the major salmon ocean fishery) is closed between southern Oregon and northern California to protect the Klamath River fall Chinook, which is forecast to return in low numbers. A model of vessel fishing choices was used in combination with an established input-output model to estimate the potential economic impact of this closure on fishers and fishing communities. The analysis predicts that this closure of the ocean fishery will result in a loss of $5.8-$8.9 million in income, $12.8-$19.6 million in sales, and 200-330 jobs. These estimates are only a partial estimate of the economic impacts of the 2017 salmon regulations, as they do not fully account for the effects of the limited season outside of the closed ocean area or the effects on other salmon fisheries (e.g. the gillnet and recreational fisheries). The impacts are not distributed evenly in space, with the largest relative losses occurring in the Coos Bay, Brookings, and Eureka regions. This information may be useful as policymakers consider mitigating economic losses in the fishery and associated communities. Early estimates of economic impacts of fishery closures may also enable quicker determination of the need and extent of disaster assistance and a more timely response.

Key words: salmon fishery, California Current, fishery disaster, fishery closure, economic impacts, fishing behavior, input-output model

## 1. Introduction

The US West Coast ocean salmon troll fishery is a major fishery in the region, with annual nominal ex-vessel landings valued at $12.4 to $35.8 million over the past 5 years (Figure 1). The ocean fishery is a mixed-stock fishery, and the season is typically structured to limit the impacts of harvest on weaker stocks, some of which are protected under the Endangered Species Act. As a result, the fishery has faced multiple closures of various extents over the past several decades. For example, in 2008 and 2009, the fishery was closed completely south of Cape Falcon, Oregon following the collapse of the Sacramento River fall Chinook, which historically provided 80-85% of ocean catches in California [1]. This resulted in the declaration of a federal disaster and the release of $107 million in federal aid to salmon fishermen, charter boat operators, processors, and other salmon-dependent businesses. Two other partial closures in 2006 and 2010 affected smaller portions of the coast (see Figure 2 and Table 1 for an overview of all recent spatial closures).

[Figures 1,2 and Table 1 about here]

On the West Coast, most fishermen participate in a variety of fisheries, which may help buffer against the short-term (annual to decadal) variability of stocks. Fisher cross-participation thus connects harvested species and human communities that are not directly linked ecologically, and changes in fishing behavior have the potential to either amplify or dampen the effects of biological variation. Though theory suggests that fishermen may shift some or all of their effort into alternate fisheries when other stocks are scarce, Richerson and Holland [2] found that in the case of the 2008-2009 salmon ocean fishery closure, most salmon trollers did not increase their participation in other fisheries. Instead, nearly half of the fleet ceased fishing entirely during the closure, meaning they did not participate in salmon fishing or any other fishery (including fisheries that they typically participated in prior to the closure). This may be because they could not recoup their costs (e.g. crew, fuel, repairs) if they did fish and/or because alternate sources of income outside of fishing became more attractive. This resulted in ~$45 million in lost landings revenue, of which ~$35 million could be attributed to lost salmon revenue and the remaining to revenue lost from other fisheries. This loss had serious implications for fishers, fishing-dependent businesses, and local fishing communities [3]. These results also indicate that though many fishermen have somewhat diversified fishing portfolios, their ability to offset losses is limited because of the seasonality of fisheries (i.e. there may be few substitutable options during the regular salmon season) and limited-entry regulations (i.e. fishermen cannot move into most fisheries without owning or purchasing an existing permit). Acknowledging these complexities of fisher behavior is key for fishery sustainability and management [4, 5].

Over the past several years, both marine and freshwater salmon habitat conditions have generally been poor for salmon growth and survival. The severe drought of 2011 to 2017 likely reduced freshwater survival for many runs [e.g. 6, 7], and the marine heatwave of 2013-2015 known as "the Blob" resulted in higher sea surface temperatures and reduced productivity across much of California Current [8]. In addition, the Pacific Decadal Oscillation shifted to a positive phase in 2014, which historically has been linked to lower salmon production for West Coast stocks [9-11]. Salmon catches have been declining since 2012, and in April 2017 the Pacific Marine Fisheries Council recommended closing the ocean fishery between the Florence, Oregon to Horse Mountain, California. This was precipitated by record low returns of the Klamath River fall Chinook. In June of 2017, the Governors of California and Oregon asked the Secretary of Commerce to declare the salmon fishery a catastrophic regional disaster in 2016 and 2017.

Quantifying the impact of a poor fishing season can be difficult, as fishers may adjust their behavior in unexpected ways, and this in turn may affect fishing-dependent businesses and communities. Here, a modified version of an existing model of West Coast salmon troller behavior [2] in combination with an established input-output model was used to create a spatially-explicit estimate of the lost income, jobs, and sales that are likely to be associated with the 2017 salmon closure. Disaster assistance is often subject to long delays and is not available when it is most needed. For example, in the case of the 2005-2006 salmon disaster in California and Oregon, aid funds were not appropriated until May 2007, and distributed beginning August 2007 through March 2008 [12]. In several other cases, fishermen have waited several years for a decision, only to have their requests for aid ultimately denied [13]. The final decision depends on the number of people affected by the fishery resource disaster and the magnitude of economic hardship they experience [13]. Thus, early predictions of the economic impacts of fishery closures may enable a quicker determination of the need and extent of disaster assistance and a more timely and effective response.

## 2. Methods

### *2.1 Overview*

A vessel-based approach was used to model the impact of a fishery closure. First, the group of vessels that participated in salmon troll fishing prior to the closures that occurred between 2006 and 2010 was identified. The probability that a vessel will participate in fishing of any kind, and if so, if it will participate in salmon troll fishing in each year was modeled, based on the presence of a closure and characteristics of the vessel. This set of behavioral models (parameterized on vessels' responses to the 2006-2010 closures) was then used to make predictions about the vessels identified as salmon trollers in more recent years. Specifically, the probability they will fish in 2017 was estimated, and if so, the probability that they will participate in the salmon troll fishery given the extent of the current closure. Finally, an input-output model was used to estimate the economic impact of this predicted behavior, on income, employment, and sales. To quantify uncertainty, a Monte Carlo approach was used, where vessels behave probabilistically according to the models.

### *2.2 Vessel identification and characteristics*

Most vessels that participate in the ocean salmon troll fishery participate in multiple fisheries. In order to identify relevant vessels, vessels were selected that were active in the salmon troll fishery prior to 2006 (when the first spatial closure in the past several years was put into place). These vessels met two simple criteria: 1) They made at least $1,000 from salmon troll fishing during 2001-2005, and 2) they fished at least 2 years during 2001-2005. These vessels are referred to as the 2001-2005 vessels. These vessels, and their response to the 2006, 2008, 2009, and 2010 closures were used to parameterize a participation model designed to predict response to fishery closures.

The composition of vessels that participate in the current fishery has changed since the early 2000s, especially since many vessels active in salmon trolling then left the fishery after the large-scale closures of 2008-9 [2]. Thus, the current group of focal vessels was defined as any vessel that made $>1,000 from salmon troll 2012-2016 and fished at least 2 years in that period. These are referred to as the 2012-2016 vessels. The participation models parameterized using the 2001-2005 vessels were then used to predict the responses of the 2012-2016 vessels to the 2017 partial salmon fishery closure.

### *2.3 Choice to fish*

Not all vessels participate in fishing every year, and presence of a closure may affect whether a vessel chooses to go fishing in a given year. A modified version of the model of [2], which predicts whether or not a vessel will participate in fishing in a given year based on vessel characteristics and the presence of a spatial fishery closure, was used to model the choice to fish. Though [2] focused on the large-scale 2008-2009 salmon troll fishery closure, the modified version incorporates information from the smaller-scale closures of 2006 and 2010 to inform predictions about the current closure. First, a broad cohort of vessels active in the salmon troll fishery over 2001-2005 (the years before the 2006 closure) was identified. Any vessel that 1) averaged over $1000 in annual revenue from salmon troll fishing 2) fished at least 2 years in this period was included in the cohort. Next, a set of vessel characteristics were identified that may predict responses to a closure. Chosen vessel characteristics include latitudinal center of gravity (LCG; a measure of fishing location along the coast), latitudinal inertia (LI, a measure of spatial range), mean total inflation-adjusted revenue, revenue diversification (in terms of inverse Herfindahl-Hirschman index; HHI), and percent of total revenue from salmon troll fishing. For details of how vessel characteristics were selected and calculated, see [2]. To account for the impact of a spatial closure, a dummy variable was included that takes on a value of 1 if a given vessel's LCG was inside a closed area in a given year and 0 if not. Thus, the expected probability $p_{yi}$ that vessel $i$ participates in fishing (salmon troll and/or other fisheries) in year $y$ was modeled using a binomial generalized linear mixed model with a complimentary log-log link and a vessel-level random intercept as

$$
\begin{aligned}
\log(-\log(1-p_{yi})) = {} & \alpha + \beta_1 y + \beta_2 LCG.in.closure_i + \beta_3 revenue_i + \beta_4 HHI_i + \beta_5 percent.troll_i + \beta_6 LCG_i + \\
& \beta_7 LI_i + \beta_8 years.fished_i + \beta_9 LCG.in.closure_i \cdot revenue_i + \beta_{10} LCG.in.closure_i \cdot HHI_i + \\
& \beta_{11} LCG.in.closure_i \cdot percent.troll_i + \beta_{12} LCG.in.closure_i \cdot LCG_i + \beta_{13} LCG.in.closure_i \cdot LI_i + \\
& \beta_{14} LCG.in.closure_i \cdot years.fished_i + a_i
\end{aligned}
\tag{1}
$$

where $a_i$ is the normally-distributed random intercept term with mean zero. The complimentary log-log link was chosen because it can take on an asymmetrical shape, allowing uneven numbers of ones and zeroes [14]. Year was defined as the number of years since defining the focal vessels (i.e. years since 2001). If a vessel does fish in that year, the probability it participates in the salmon troll fishery was modeled using the same model structure as above. To aid in model fitting and interpretation, we centered and scaled all continuous variables [15]. Area under curve (AUC) of the receiver operating characteristic (ROC) was used to evaluate model fits [16]. To construct the ROC $k$-fold cross-validation was used, where vessels were randomly divided into groups of 100, the model trained on all but one group, then tested on the selected group. This process was then repeated for each group. To evaluate model performance a common rule of thumb was used where AUC 0.6 is failed, 0.6 < AUC 0.7 is poor, 0.7 < AUC 0.8 is fair, 0.8 < AUC 0.9 is good, and 0.9 < AUC 1.0 is excellent.

### *2.4 Predicted participation and revenue*

Vessel characteristics for the 2012-2016 vessel group were used to predict fishery participation in 2017 using the models described above. To do so, for each focal vessel the predicted probability of fishing was estimated as well as the predicted probability of participating in the salmon troll fishery if the vessel does go fishing. To characterize the uncertainty around the predictions, 10,000 Monte Carlo simulations were performed where vessels were allowed to fish (or not) according to their predicted probabilities. The total revenue from each species/gear group landed in each area was then calculated, based on the vessels that are predicted to be active. No salmon troll catches were assumed to be landed inside the closed area. Outside the closed areas, vessel revenue in each area, species, and gear group was assumed to be equal to the vessel's past 5-year average. This was done under both closure and non-closure scenarios, allowing comparison of the predicted distribution of income, employment, and sales in each area under each scenario.

An alternate deterministic approach was also used where vessel participation was predicted based on an optimal classification threshold $c$, which accounts for the possibility of bias towards false positives or false negatives in the model predictions. In this case, vessels were predicted to fish when $p_{yi}>c$, where $c$ is the value that that equalizes model sensitivity (true positive rate) and specificity (true negative rate). Predicted revenues were then calculated as above.

### *2.5 Input/output model*

Input-output models are commonly used to estimate the wider economic impacts of output from a particular sector. While input-output models were originally used for quantifying the economic effects of exogenous final demand shocks, they are appropriate for use in situations of exogenous output changes, such as a change in fishing output, provided proper adjustments are made [17]. The input-output model for Pacific Coast Fisheries [IO-PAC; 18] was used to translate predicted ex-vessel revenue into spatially-explicit measures of income, sales, and employment associated with the focal vessels. The IO-PAC model was designed to estimate the economic impacts resulting from policy, environmental, or other changes that affect fishery harvest. The model was constructed by customizing Impact Analysis for Planning (IMPLAN) regional input-output (IO) software (IMPLAN, MIG Inc. Hudson Wisconsin). Development of IO-PAC included customizing IMPLAN with an addition of 19 commercial fishing vessel types that produce 32 unique species and gear outputs. The model is spatially flexible and impact estimates can be generated for 18 different port study areas.

Economic impact estimates include the effects of changes in fish harvest on sales, income, and employment by harvesting vessels and processors. In this case, sales is defined as the estimated dollar value of production in the region summed across all industries and includes both final purchases and intermediate purchases that are used in the production of goods and services. Income is defined as all forms of employment and proprietor income (wages and benefits) generated by businesses directly or indirectly linked to fishers and processors.

Employment includes all full or part-time jobs generated by businesses directly or indirectly linked to the fishing industry. A change in vessel revenue not only affects the direct number of crew member positions on vessels, it also affects employment in businesses sectors that supply goods and services to fishing vessels. Additionally, changes in vessel revenue that results in changes in income affects household spending. The employment estimates here include employment changes from businesses that are affected by changes in household spending.

## 3. Results

### *3.1 Focal vessels*

1,585 vessels were identified that participated in the salmon troll fishery 2001-2005 and 1,505 that participated in the fishery 2012-2016, with 875 vessels appearing in both groups. This indicates that about half of the 2001-2005 group either stopped participating in the salmon troll fishery or stopped fishing entirely by 2012-2016. The salmon troll fishery is a limited entry fishery (with state-issued permits), but permits are transferable. It appears that many of the permits that had been held by vessels that exited the fishery following the 2008-2009 were purchased and activated by new entrants. The vessel groups identified are responsible for >98% of the total salmon troll revenue landed on the West Coast during their respective periods. The distributions of vessel characteristics are shown in Figure 3.

[Figure 3 about here]

### *3.2 Choice to fish*

For the model of general fishing behavior, all predictor variables were significant at the $p$=0.05 level, with the exception of the main effects of inertia and percent salmon troll, and the interaction between spatial closure/inertia (Figure 4). Inertia was not removed from the model because doing so resulted in the same AIC (15520). For the model of salmon troll fishing behavior, all predictors were significant at the $p$=0.05 level except the main effects of revenue, inertia, and center of gravity, and the interactions between spatial closure/revenue, spatial closure/number of years fished, and spatial closure/percent of revenue from salmon. The revenue terms were removed in the final model, as this resulted in a slightly lower AIC (11398 vs 11402; Figure 5). The AUC for the model of probability of fishing was 0.838 (95% DeLong confidence interval 0.832-0.845), and the AUC for the model of the probability of participating in the salmon troll fishery was 0.867 (95% DeLong confidence interval 0.861-0.874), indicating good model fit in both cases. As the validation test set predictions were only based on fixed effects, these values likely slightly underestimate the fit of the models.

[Figure 4 and 5 about here]

### *3.3 Predicted behavior and economic impacts*

In the absence of a closure, on average 1,332 (±11) vessels are expected to participate in fishing of any kind, and 1,159 (±14) are predicted to participate in the salmon troll fishery. In the case of a closure, 1,286 (±11) vessels are predicted to fish, and 1,000 (±13) are predicted to participate in the salmon troll fishery (Figure 6). With no closure, the focal vessels are predicted to generate $120.9 (±0.4) million in income, $242.4 (±0.8) million in sales, and 2,868 (±13) jobs. In contrast, with a closure, the focal vessels are predicted to generate $115.1 (±0.4) million in income, $229.6 (±0.9) in sales, and 2,661 (±13) jobs. This indicates that the current closure would result in a loss of ~$5.8 million in income, ~$12.8 million in sales, and 207 jobs (Figure 7).

[Figure 6 and 7 about here]

*3.4 Spatial impacts*

Unsurprisingly, the largest predicted relative economic impacts occur in the areas that are partly or entirely within the closed area. Coos Bay is most affected, with a 47% decrease in fishery related employment, 33% decrease in sales, and 31% decrease in income (Figures 8-10). Brookings, Eureka, and Fort Bragg also see considerable decreases. Though outside the closed area, Astoria, Bodega Bay, Crescent City, Monterey, Newport, and San Francisco also see relatively small declines. In Southern California and Washington, there is little predicted change associated with the closure scenario.

[Figures 8-10 about here]

*3.5 Comparison with deterministic predictions*

Cross-validation results indicate that the models tend to have a higher false positive than false negative rate, suggesting that the Monte Carlo results may over-predict overall participation. When using the optimal cutoff value, the models predict that without a closure, 1,210 vessels would fish, and of those, 916 would participate in the salmon troll fishery. In the case of a closure, the models predict that 1,136 vessels would fish, and 755 would participate in the salmon troll fishery (Figure 11). Without a closure, this method predicts the focal vessels would generate 2,960 jobs, $123.5 million USD in income, and $248.0 million USD in sales. In contrast, with the closure, the focal vessels are predicted to generate 2,632 jobs, $114.5 million USD in income, and $228.4 million USD in sales (Figure 12). Under these assumptions, the closure is predicted to result in a loss of 328 jobs, $8.9 million in lost income, and $19.6 million USD in sales. The distribution of spatial impacts were similar to the Monte Carlo predictions, with Coos Bay seeing a 49% decrease in employment, 36% decrease in sales, and 34% decrease in income

[Figure 11and 12 about here]

## 4. Discussion

Predicting fisher responses to regulations and closures is complex, especially when participants have diverse fishing strategies, locations, sizes, and other characteristics [e.g. 19]. The methods used in this paper account for this heterogeneity by predicting whether vessels will participate in fishing based on a set of characteristics and behavior in prior years. The current closure is predicted to result in ~50-75 vessels not fishing at all, and a further ~160 fishing but not participating in the salmon troll fishery. This then has important consequences for jobs, income, and local economies. These results suggest that these impacts are distributed unevenly across vessels and across space, with less diversified vessels and vessels more dependent on salmon being most vulnerable. Vessels and communities inside the closed area are unsurprisingly most affected, with Coos Bay area communities seeing up to ~50% declines in fisheries-related employment and up to ~35% declines in fishing-related income and sales relative to predicted non-closure values. This has the potential to have large effects on local communities, as the commercial fishing industry provides 2-20% of net earnings in Oregon coastal communities [21]. As the third-largest fishing port in Oregon in terms of both volume and revenue [21], Coos Bay and the surrounding communities appear to be the hardest-hit by the closure.

Though past closures can prove useful in predicting future impacts, there are important differences between past closures and the current closure. The spatial extent of the 2017 closure is much smaller than that of 2008-2009, and as a result, the impact on salmon troll vessels appears to be somewhat smaller. In 2008-9, nearly half of focal vessels ceased fishing during that time, while only ~14-24% are predicted not to fish in 2017. This is somewhat similar to the 2006 closure, when ~27% of focal vessels did not fish at all (Figure 13). Though the extent of the 2017 closure is similar to that in 2006, the conditions in the years preceding the closures differed. From 2001-2005, ocean salmon catches were relatively good, averaging >9.3 million pounds per year, dropping to 2.3 million in 2006. In contrast, from 2012-2016, salmon catches were generally poor, averaging 4.4 million pounds per year, with 2016 being a particularly bad year with total landings of 1.6 million pounds. Thus, the 2017 closure is somewhat unique in that it follows a set of poor years, and these models may not fully capture the effects of a closure following a sequence of poor years, as 2016 already saw a large drop in vessel participation (Figure 13).

[Figure 13 about here]

The lack of fishing participation predicted in this analysis during closures seems to reflect broader trends in West Coast fisher responses to closures. A recent survey[1] of West Coast fishers found that 79% had been affected by fishery closures in recent years. Of these fishers, only 40% said they responded to closures by participating in other fisheries, while 32% did work outside of commercial fishing and 35% did not do other work [20]. This indicates that the majority of fishers do not attempt to make up for income lost to closures by participating in other fisheries. Some fishers appear to choose to work in other industries during closures, which likely has wider economic impacts as they invest their time and resources in other activities.

This analysis focuses on the effects of the ocean closure and does not account for the conditions in other fisheries such as the commercial gillnet fishery. The gillnet fishery is active in rivers or estuaries, so it is not a mixed-stock fishery, and therefore is not

[1] Results are derived from a survey of vessels owners West Coast commercial fishing conducted in April 2017 by Washington Sea Grant and the Northwest Fisheries Science Center. The was a census of all active vessels and achieved a 50% response rate with over 1400 completed surveys survey.

usually affected by large-scale closures. However, low numbers of salmon returning to the Klamath Basin and elsewhere are likely to have significant economic effects on this fishery, especially as the fall Chinook fishery is closed on both the Klamath and Trinity Rivers in 2017. Recreational fishermen and associated businesses such as charter vessels and river guides are also likely to see negative effects. Together, this likely means that the necessary amount of disaster aid will be much higher than what is quantified here. For example, for the 2008-9 disaster, only ~40% of the disaster aid went to salmon trollers directly, with the rest going to gillnetters or other salmon-dependent businesses.

Outside of the closed area, the 2017 ocean regulations are predicted to have mixed, but generally negative effects on salmon ocean troll fishing. In most areas, the 2017 ocean troll regulations are expected to have relatively large negative impacts on income relative to 2016 and the 2012-2016 average [22]. However, north of Cape Falcon, Oregon and south of Pigeon Point, California, the impacts are likely to be positive. This analysis does not account for the effects of the season outside of the closure, so the total impacts on salmon troll fishing is likely to be more severe than documented here.

Understanding the behavior of fishers in the face of closures can help enable a faster and more efficient response to fishery disasters and potentially enable better adaptation to future changes and variability. The California Current ecosystem is inherently variable, and is likely to become more variable in the future [23], with potentially serious consequences for fisheries and associated businesses. As fishers move among fisheries in response to ecological and regulatory changes, changes in one fishery may influence the profitability and sustainability of other fisheries that are not directly liked ecologically via changes in fisher behavior. Future planned work includes an integrated set of models linking fishing behavior and the population dynamics of key fish stocks under environmental variability to create a coupled ecological-economic simulation model of West Coast fisheries.

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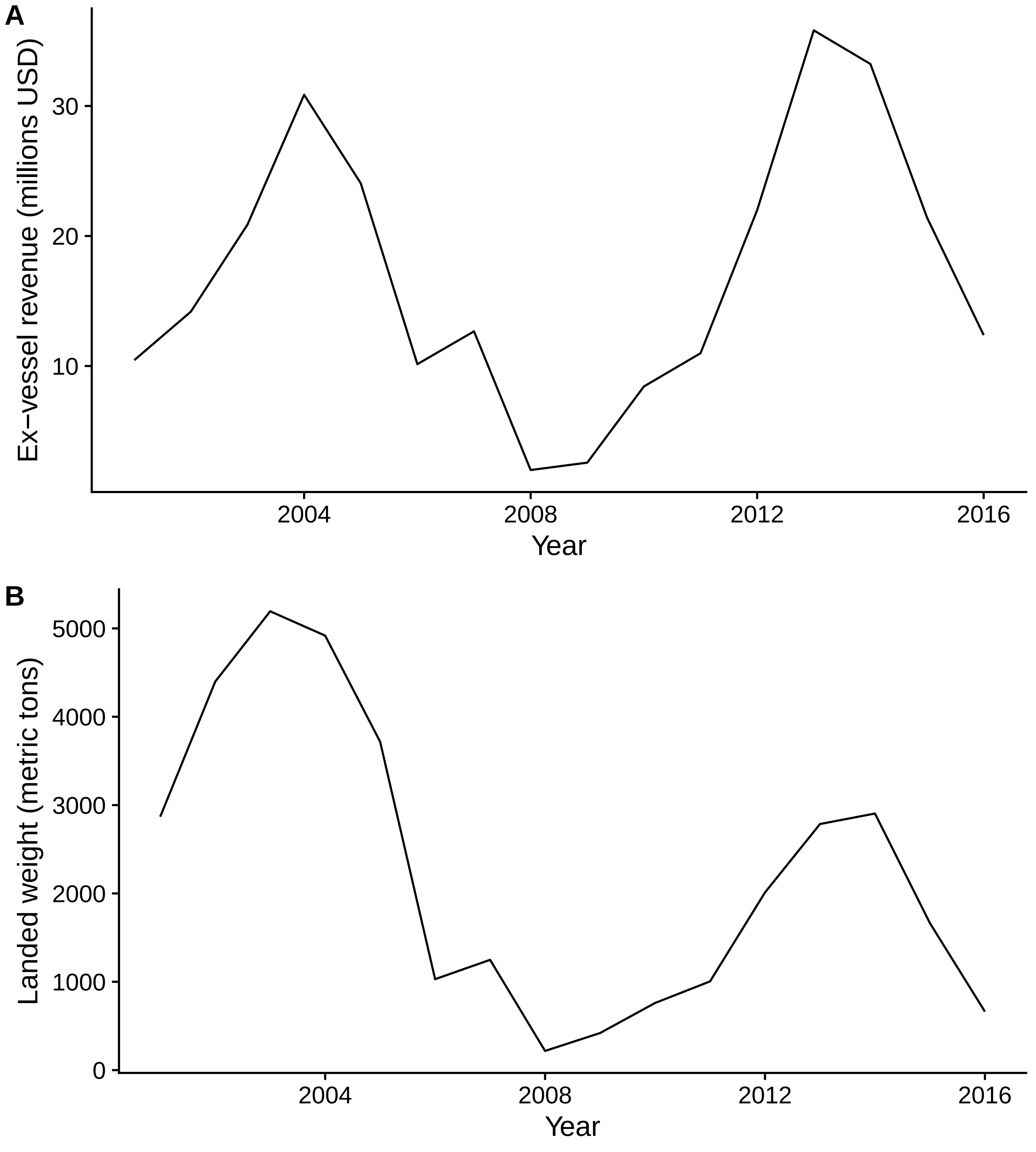
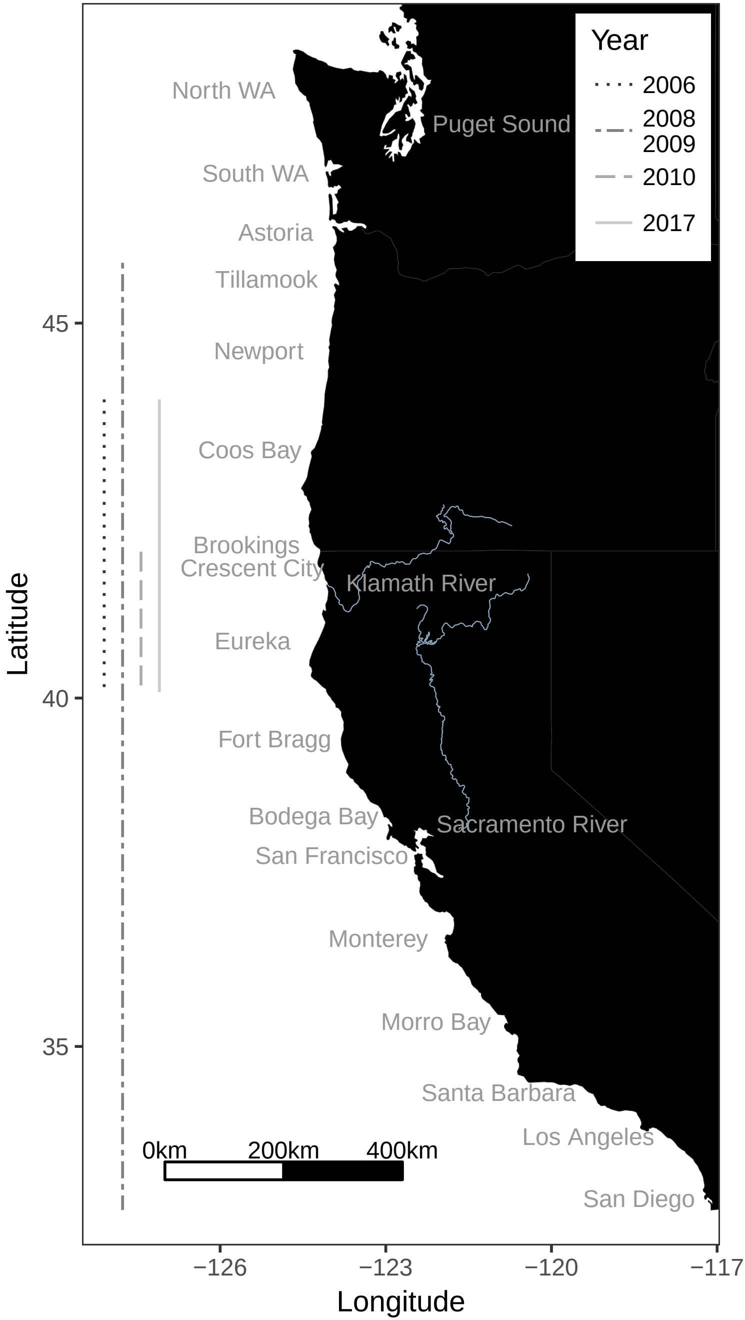
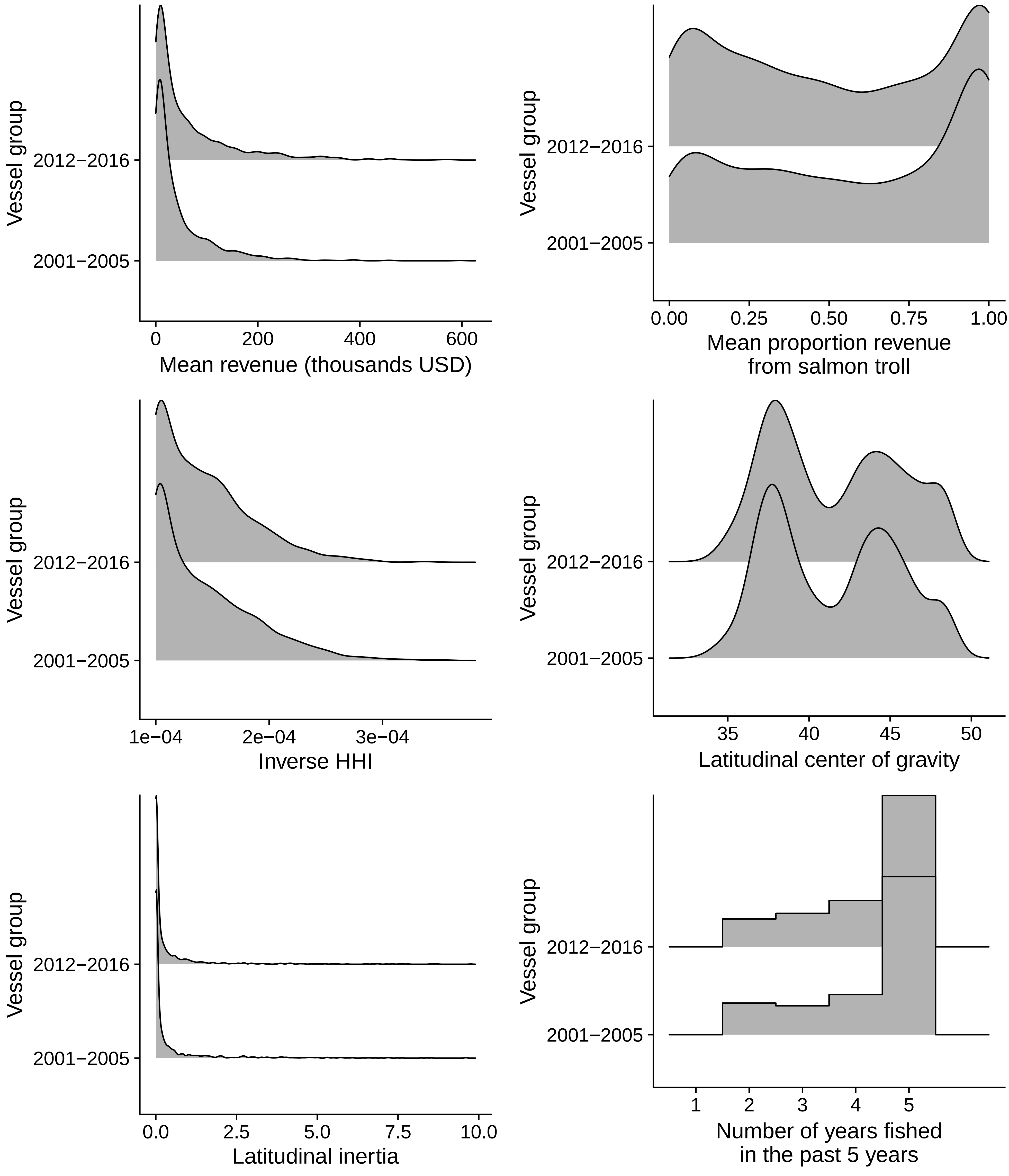
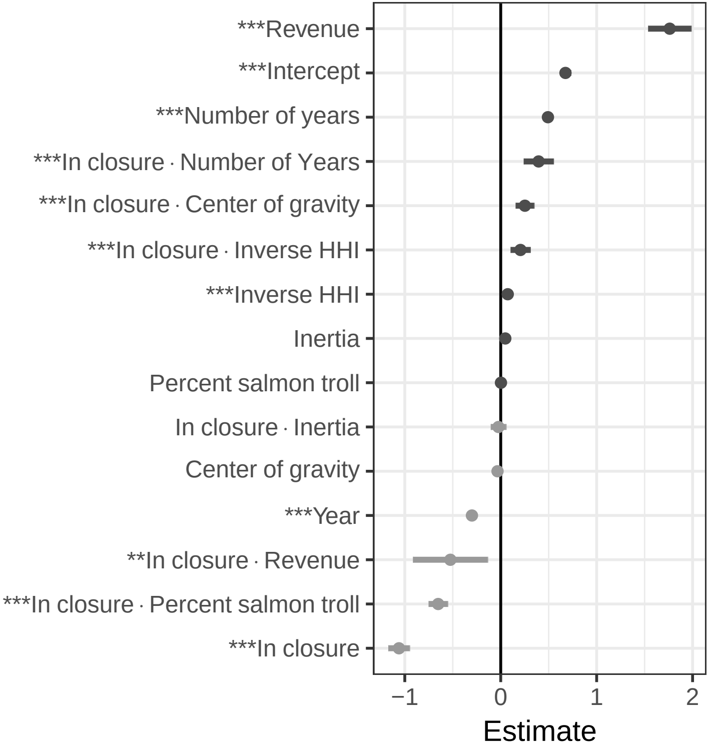
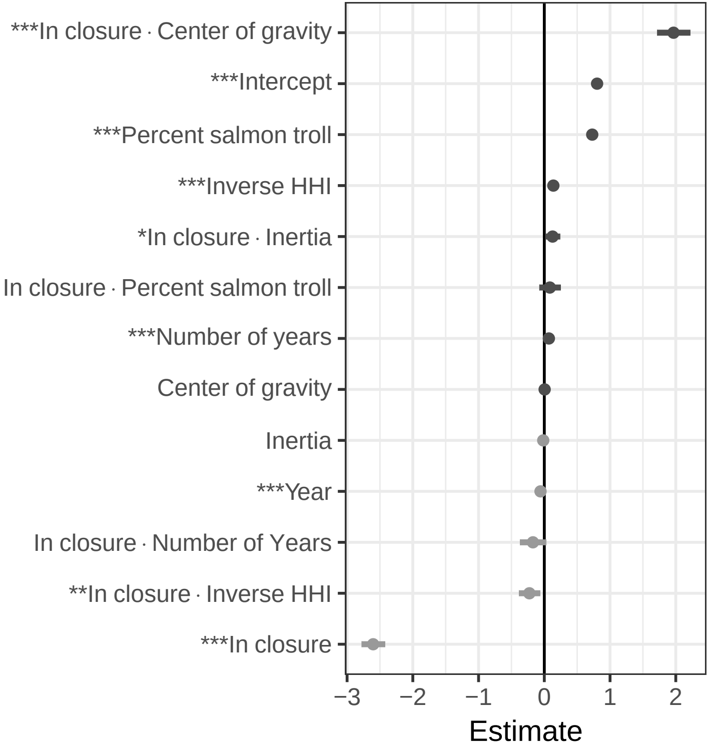

A
Ex−vessel revenue (millions USD)
30
20
10
2004
2008
2012
2016
Year
B
Landed weight (metric tons)
5000
4000
3000
2000
1000
0
2004
2008
2012
2016
Year


Year
2006
2008
2009
2010
2017
North WA
Puget Sound
South WA
Astoria
Tillamook
Newport
Coos Bay
Brookings
Crescent City
Klamath River
Eureka
Fort Bragg
Bodega Bay
Sacramento River
San Francisco
Monterey
Morro Bay
Santa Barbara
Los Angeles
San Diego
0km
200km
400km
45
40
35
Latitude
−126
−123
−120
−117
Longitude

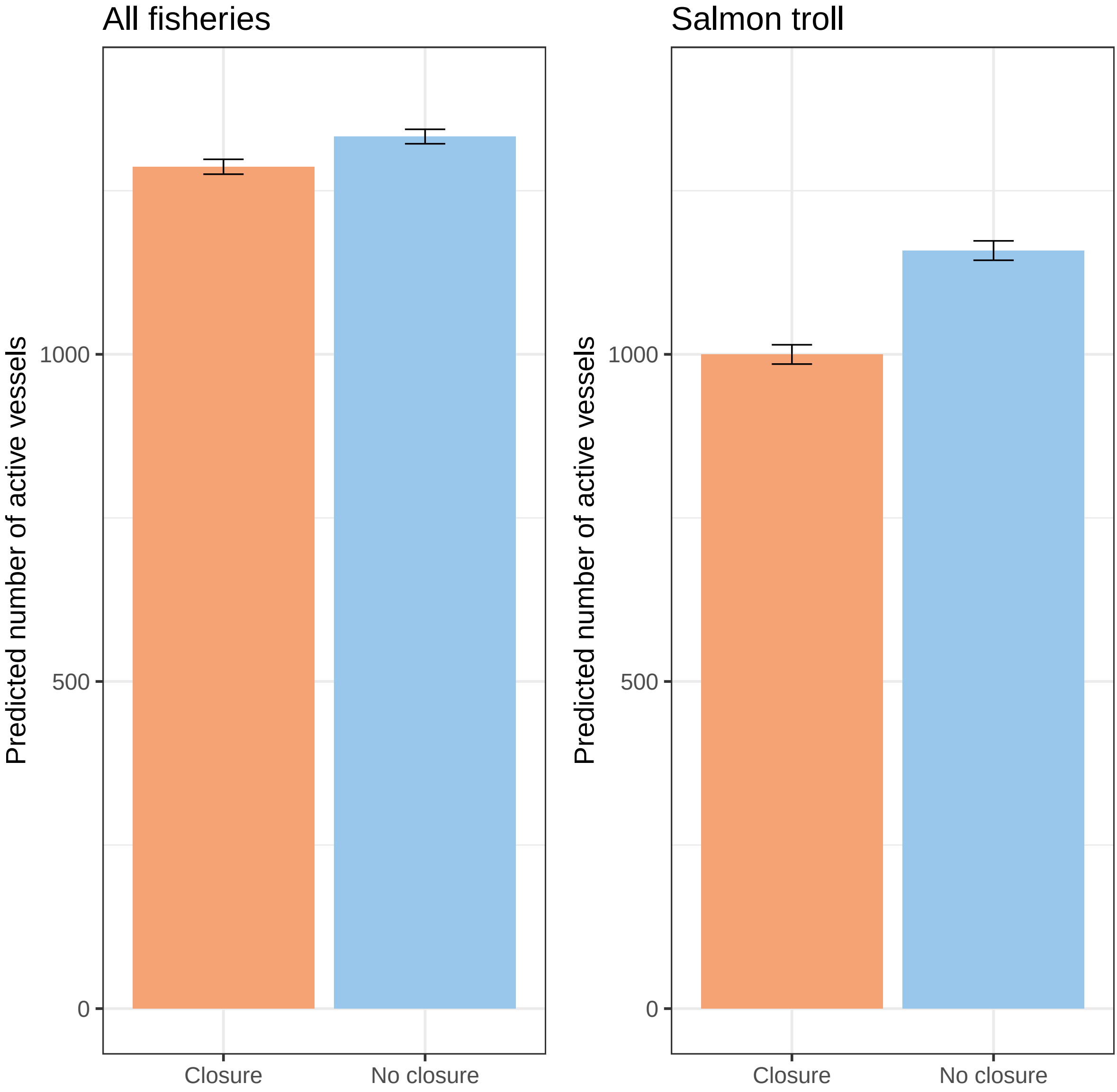


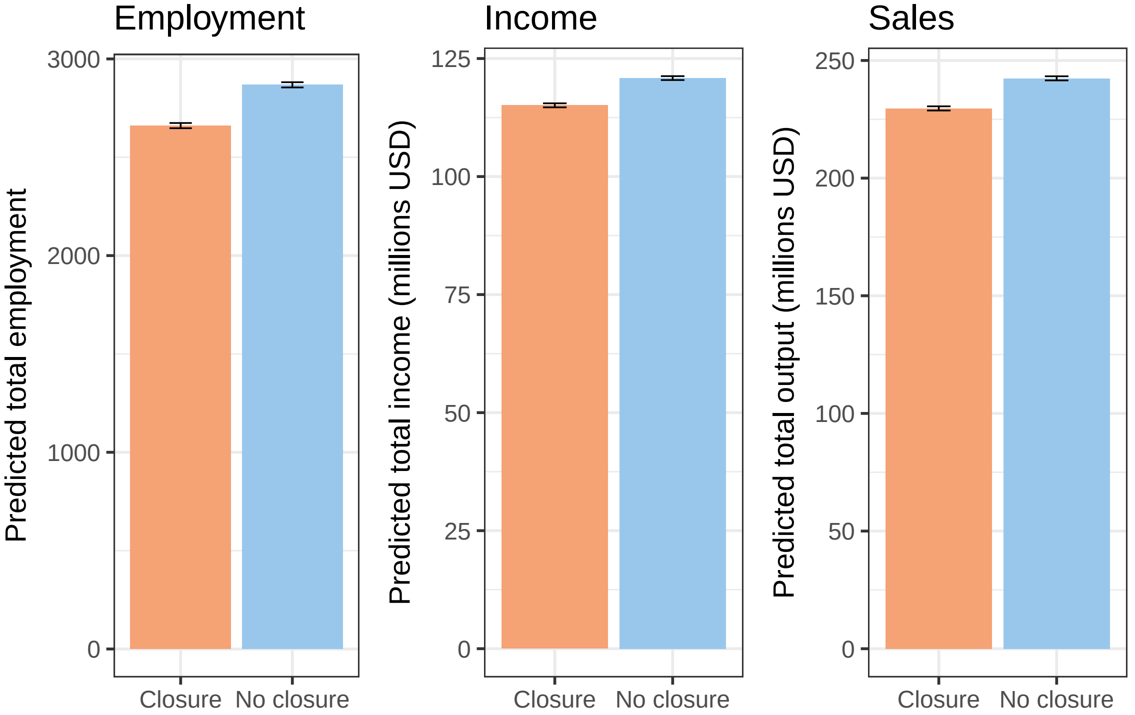
Vessel group
2012−2016
2001−2005
0
200
400
600
Mean revenue (thousands USD)
0.00
0.25
0.50
0.75
1.00
Mean proportion revenue
from salmon troll
1e−04
2e−04
3e−04
Inverse HHI
35
40
45
50
Latitudinal center of gravity
0.0
2.5
5.0
7.5
10.0
Latitudinal inertia
1
2
3
4
5
Number of years fished
in the past 5 years


***Revenue
***Intercept
***Number of years
***In closure · Number of Years
***In closure · Center of gravity
***In closure · Inverse HHI
***Inverse HHI
Inertia
Percent salmon troll
In closure · Inertia
Center of gravity
***Year
**In closure · Revenue
***In closure · Percent salmon troll
***In closure
−1
0
1
2
Estimate

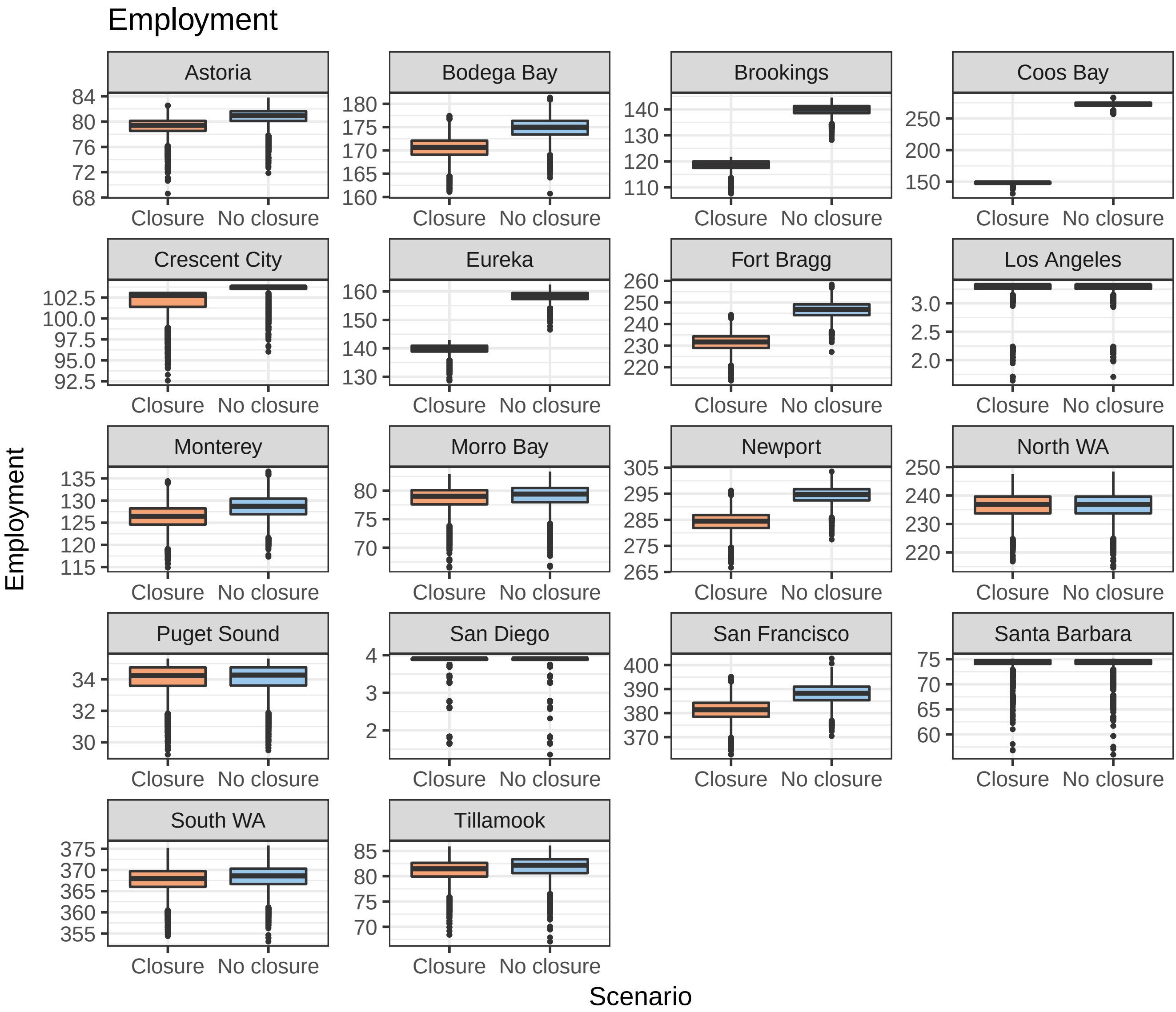


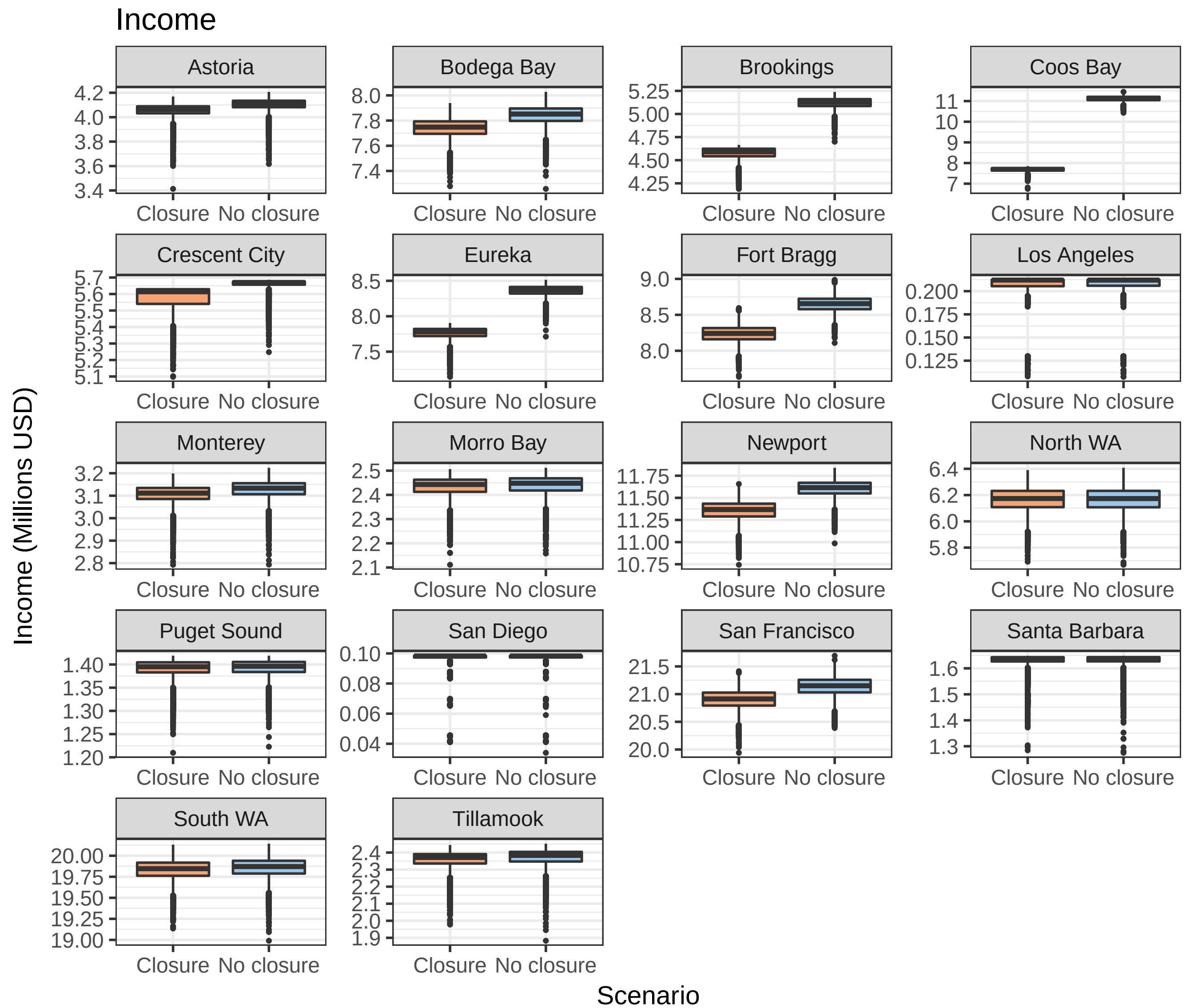
***In closure · Center of gravity
***Intercept
***Percent salmon troll
***Inverse HHI
*In closure · Inertia
In closure · Percent salmon troll
***Number of years
Center of gravity
Inertia
***Year
In closure · Number of Years
**In closure · Inverse HHI
***In closure
−3
−2
−1
0
1
2
Estimate

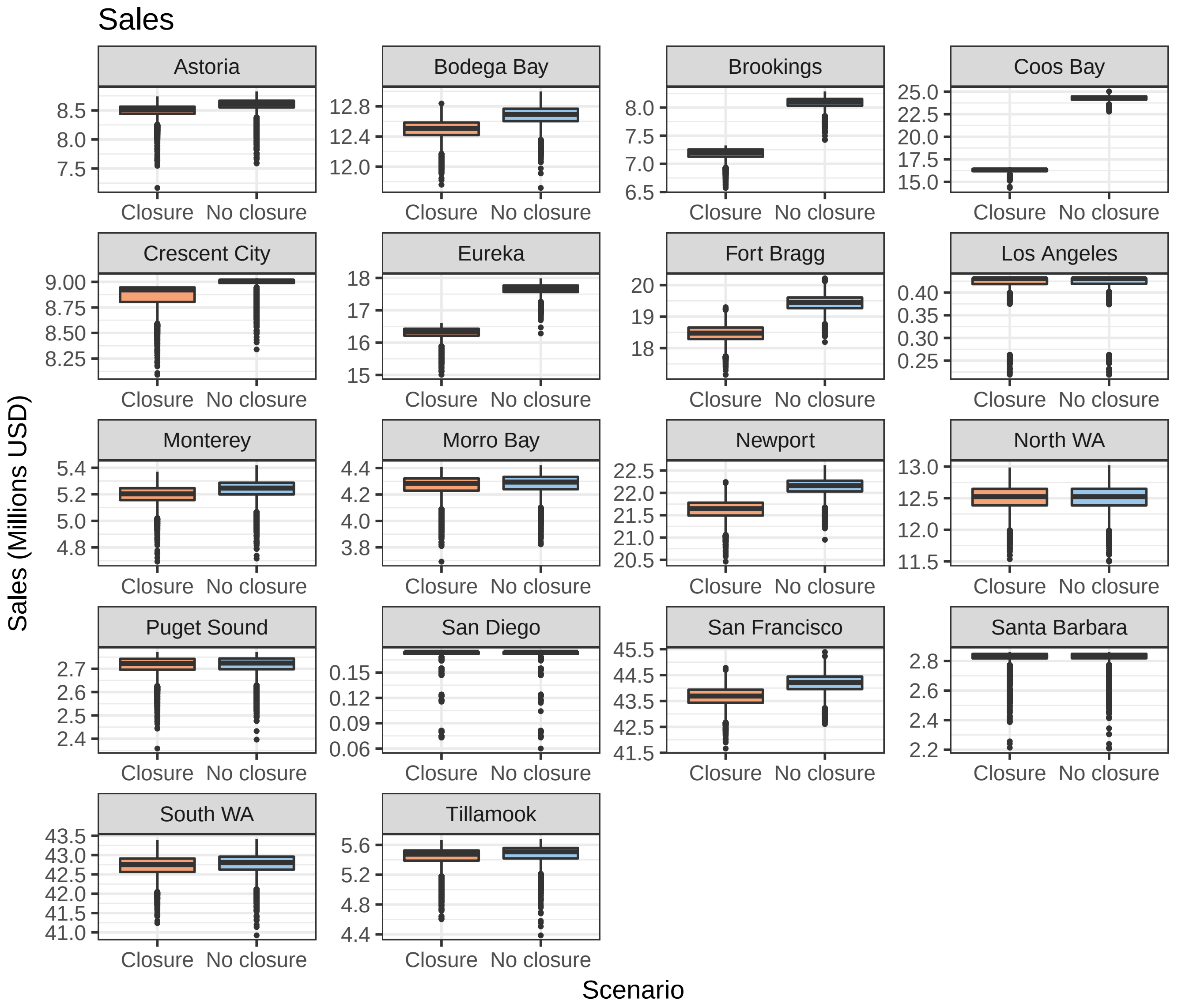

All fisheries
Salmon troll
Predicted number of active vessels
0
500
1000
Closure
No closure



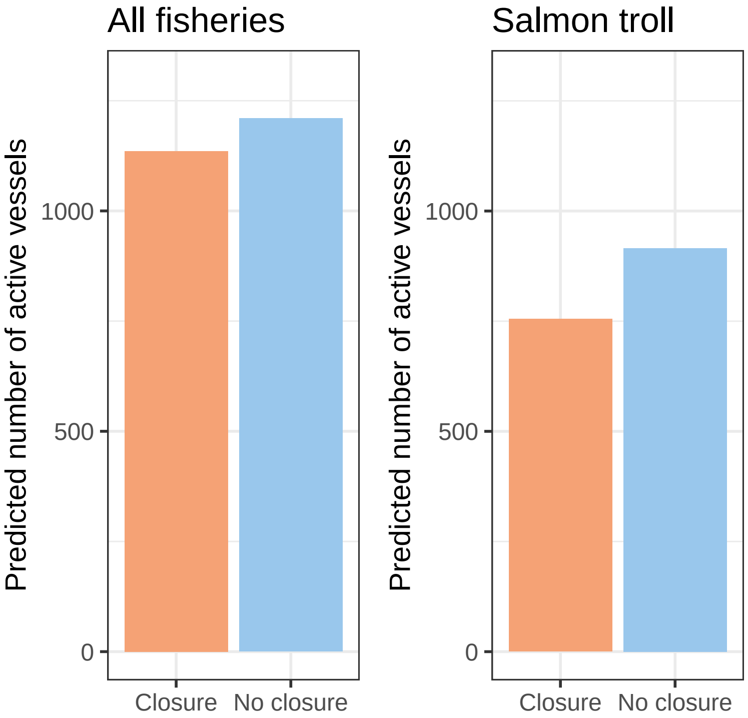
Employment
Income
Sales
Predicted total employment
Predicted total income (millions USD)
Predicted total output (millions USD)
3000
2000
1000
0
125
100
75
50
25
0
250
200
150
100
50
0
Closure
No closure
Closure
No closure
Closure
No closure


Employment
Astoria
84
80
76
72
68
Bodega Bay
180
175
170
165
160
Brookings
140
130
120
110
Coos Bay
250
200
150
Crescent City
102.5
100.0
97.5
95.0
92.5
Eureka
160
150
140
130
Fort Bragg
260
250
240
230
220
Los Angeles
3.0
2.5
2.0
Monterey
135
130
125
120
115
Morro Bay
80
75
70
Newport
305
295
285
275
265
North WA
250
240
230
220
Puget Sound
34
32
30
San Diego
4
3
2
San Francisco
400
390
380
370
Santa Barbara
75
70
65
60
South WA
375
370
365
360
355
Tillamook
85
80
75
70
Closure
No closure
Employment
Scenario

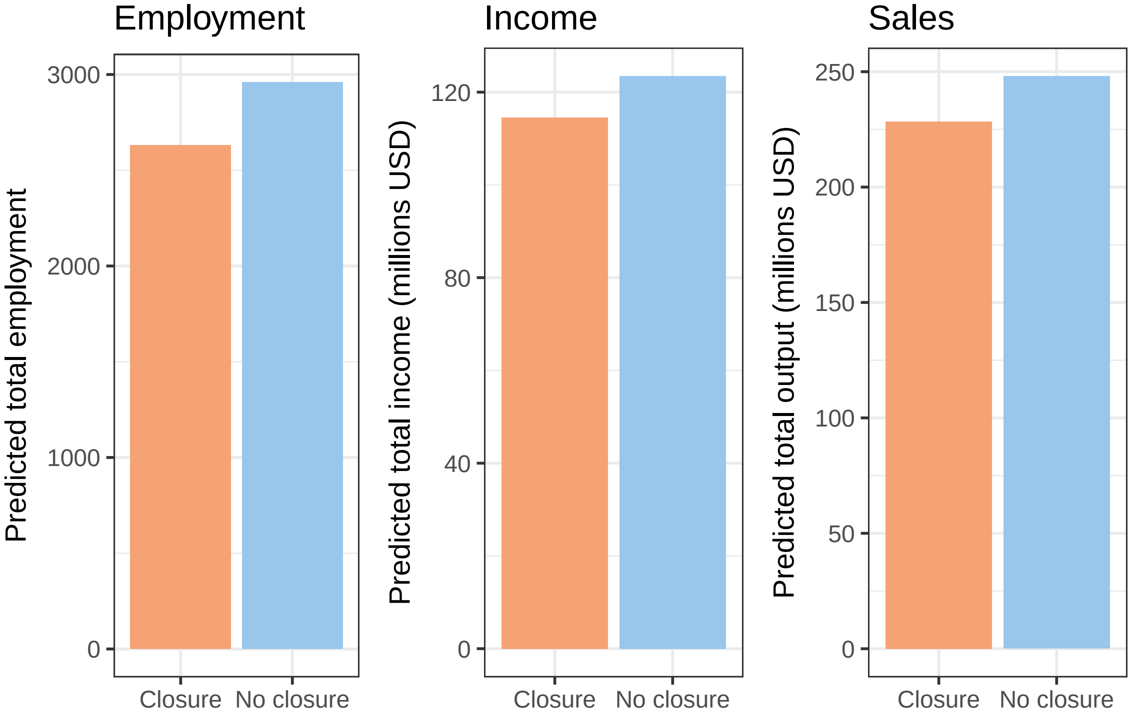

Income
Astoria
Bodega Bay
Brookings
Coos Bay
Crescent City
Eureka
Fort Bragg
Los Angeles
Monterey
Morro Bay
Newport
North WA
Puget Sound
San Diego
San Francisco
Santa Barbara
South WA
Tillamook
Closure
No closure
Income (Millions USD)
Scenario



Sales
Astoria
Bodega Bay
Brookings
Coos Bay
Crescent City
Eureka
Fort Bragg
Los Angeles
Monterey
Morro Bay
Newport
North WA
Puget Sound
San Diego
San Francisco
Santa Barbara
South WA
Tillamook
Closure
No closure
Sales (Millions USD)
Scenario



All fisheries
Salmon troll
Predicted number of active vessels
Predicted number of active vessels
1000
500
0
1000
500
0
Closure
No closure
Closure
No closure



Employment
Predicted total employment
3000
2000
1000
0
Closure
No closure
Income
Predicted total income (millions USD)
120
80
40
0
Closure
No closure
Sales
Predicted total output (millions USD)
250
200
150
100
50
0
Closure
No closure

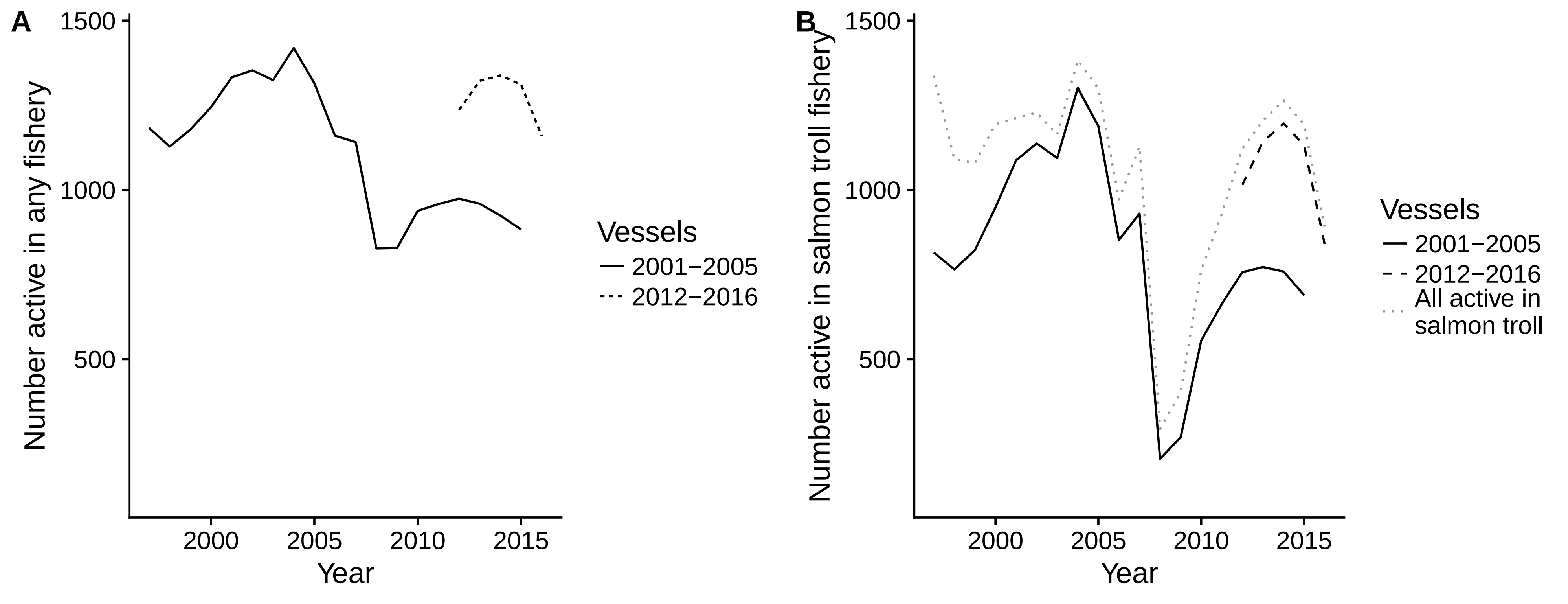

A
B
1500
1000
500
2000
2005
2010
2015
Year
Number active in any fishery
Number active in salmon troll fishery
Vessels
2001−2005
2012−2016
All active in
salmon troll

Table 1. Description of closures in the West Coast salmon ocean fishery since 2001.

| Season | Closed area | Cause |
|---|---|---|
| 2006 | Florence South Jetty to Horse Mountain | Klamath river fall Chinook |
| 2008 | South of Cape Falcon | Sacramento River fall Chinook |
| 2009 | South of Cape Falcon | Sacramento River fall Chinook |
| 2010 | OR/CA border to Horse Mountain | Sacramento River fall Chinook |
| 2017 | Florence South Jetty to Horse Mountain | Klamath River fall Chinook |