Adapting to Environmental Risk: Evidence from the U.S. West Coast's Most Valuable Fishery

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Abstract

The effect of environmental shocks on natural resource-extracting firms is determined in part by regulations that constrain their activities. I evaluate how a novel policy to ensure seafood safety following marine heat waves, introduced in response to harmful algal blooms, influenced harvesters' performance in the West Coast's most valuable fishery. Granular, vessel-level microdata allows me to track behavioral adjustments made by individual vessels, including substitution in fishing location and changes in overall fishing effort. While prices received by vessels for their catch were lower under the policy than under a no-evisceration counterfactual, vessel behavior changed little in aggregate, and fleet production was largely unaffected. While the policy worked as designed by maintaining harvest flow when the fishery would otherwise be subject to temporary spatial closures, I find significant heterogeneity in vessel-level impacts, with small vessels worse off than large vessels. This research documents a case of largely successful regulatory adaptation to a climate-linked shock while also highlighting the differential effects on segments of the regulated industry.

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JEL Classification: Q22, Q28

1 Introduction

A central question in the economics of natural resources is how firms adjust to altering environmental risk. Economists have long recognized that there is generally a difference between short-run and long-run adjustment. When some inputs, technologies, or operating practices are fixed, then observed responses to a shock may differ substantially from responses after firms have had time to adapt. In the climate adaptation literature, Burke and Emerick (2016) use this principle to distinguish between short-run responses to weather and longer-run responses to climate change as they pertain to agricultural outcomes, noting that Samuelson's Le Chatelier principle predicts smaller behavioral elasticities in the short run when firms face fixed constraints. Because environmental shocks and resource productivity are frequently correlated, a natural resource extracting firm must adjust to both the shock and changes in how they are regulated. In recent decades, across several natural resource markets, regulators have increasingly turned to instruments that are either market-based or less constraining on firms' operations than traditional command-and-control instruments [1]. Measuring the total effect of environmental shocks on natural resource firm performance involves the challenging task of accounting for how firms respond to both the shock and subsequent near-term regulatory changes that may coincide.

Marine fisheries are often highly regulated inside nations' territorial waters, and are subject to frequent environmental and ecological shocks. Climate change is already reshaping marine ecosystems via changes in species distributions, altered oceanographic conditions, and an increasing frequency of ecological disruptions, challenging management systems (Pinsky et al., 2018). Along the U.S. West Coast, marine heatwaves and ocean warming have been linked to severe blooms of the diatom *Pseudo-nitzschia*, resulting in unprecedented domoic acid events, fishery closures, and delays to Dungeness crab harvests (Trainer et al., 2020). Emerging evidence further suggests that climate variability plays an important role in determining the frequency, intensity, and spatial extent of domoic-acid-producing harmful algal blooms, giving rise to concerns that those disruptions may become increasingly common under future ocean conditions (Kessouri et al., 2026). Such climate-linked shocks are prompting managers to seek regulatory mechanisms that preserve economic activity while protecting conservation objectives (Reimer et al., 2024). Recent work on climate-ready fisheries argues that adaptive capacity depends not only on the flexibility of harvesters

[1] For example carbon payments in forestry (Cho et al., 2019) and individual fishing quotas (IFQs) in fisheries (Acheson et al., 2015; Kauer et al., 2018)

but is also a property of management institutions themselves, as management can restrict or expand the set of available responses to harvesters (Reimer et al., 2024). To complement traditional command and control regulatory tools, managers increasingly turned to what can be termed adaptive management instruments that relax some limitations while maintaining others, allowing fishing activity to continue under modified conditions. Because they alter incentives by multiple channels simultaneously, preserving access while changing product quality, marketability, or operating costs, the effects of such a policy is ambiguous.

Prior work on the Dungness crab fishery concentrates on closures. The economic toll of complete closures has been documented in detail, most notably for the 2015–2016 harmful algal bloom that devastated West Coast crab communities (Ritzman et al., 2018; Holland and Leonard, 2020; Jardine et al., 2020). More recent work shows that harvesters adapt to such interruptions through a combination of temporal reallocation, spatial redistribution, and diversification across fisheries (Wu et al., 2026). Wu et al. (2026) estimate that closure reduces expected crab revenue by approximately 98.5 percent and document several adaptive margins through which harvesters partially mitigate losses. Together, this literature establishes how substantial the economic costs closures can have while also showing the importance of behavioral adaptation has. Yet this literature focuses primarily on closures, leaving open how harvesters respond when managers instead deploy adaptive regulatory measures that preserve access under modified conditions. Related work by Abken and Jardine (2026) estimate that evisceration reduces ex-vessel prices by 26.5–33.5 percent and lowers fishery value by approximately $10.5 million in Washington. While these findings show that evisceration imposes meaningful economic costs, they leave open how harvesters respond behaviorally. Adaptive policy instrument effects are not obvious: avoiding closure and allowing fishing with restrictions may confer uneven benefits on firms, for example, favoring particular ports that may benefit larger vessels more than smaller vessels.

Empirically determining how an instrument performs amid an environmental shock requires richer micro behavioral data compared to what is needed to study closures. This paper assesses how one such instrument, evisceration, affects harvesters' behavior. Evisceration is best understood as an adaptive management policy because, rather than prohibiting harvest altogether, it preserves harvesters' ability to harvest by modifying the conditions under which harvest can occur. When the neurotoxin domoic acid accumulates in crab viscera above regulatory thresholds at the same time as the edible meat remains safe, agencies

may permit harvest to continue on the condition that the toxin- laden viscera be removed before sale (Free et al., 2022). The mechanism enforces market constraints by construction: it averts a full closure, yet it eliminates access to the premium live-crab market and forces output into lower-value processed channels. Oregon, which became the first state to authorize such orders in 2017, offers an empirically advantageous setting for studying them. Its Dungeness crab fishery is the most valuable on the U.S. West Coast, and its structure as a limited-entry derby fishery, a regulated-open-access regime in which harvesters race to land catch before the season effectively ends, concentrates the bulk of seasonal harvest within the first six to eight weeks (Dewees et al., 2004). This compression is methodologically useful: it sharply limits the temporal and spatial margins over which a harvester can adjust, isolating the price channel from slower behavioral responses.

By exploiting the staggered variation in the timing and geographic scope of these orders, a causal effect of the policy can be estimated. Between 2016 and 2023, Oregon imposed evisceration requirements on individual management zones at different points in the fishing season, generating treatment variation across both space and time. The empirical strategy pairs a difference-in-differences design with a stacked event study, and draws on vessel-level logbook microdata matched to dealer transaction records and to satellite vessel-monitoring tracks. This combination permits separation of the price effect from behavioral responses, identification of effort reallocation across space, and estimation of heterogeneity across vessel types, margins that area-level aggregates obscure.

The central finding is that the negative effecct of evisceration orders occurs almost entirely through prices. Orders reduce ex-vessel prices by roughly 10-15% per pound, and the decline materializes within days of implementation. Aggregate landings and effort, by contrast, remain largely unchanged, which indicates that vessels absorb the shock through revenue compression rather than through exit or relocation. This inelastic short-run supply is consistent with the high switching costs of a derby fishery, in which gear placement, local ecological knowledge, and processing relationships cannot be redeployed or changed within a brief order window.

The fleet-wide average result, however, conceals substantial distributional heterogeneity. Small vessels bear disproportionate burdens relative to their larger counterparts, both because they lack the holding capacity and processing access required for evisceration and because they depend on the premium price

that the order removes. The price penalty is itself uneven across ports as it is markedly larger in ports dominated by smaller buyers and attenuated where large, high-volume processors operate, a pattern consistent with an incidence that depends on downstream bargaining conditions (Matulich et al., 1996). Such evidence suggests that the burden falls hardest on the agents least equipped to redeploy capital or absorb a price shock.

This pattern is consistent with the short-run behavioral adjustments firms make. In a derby fishery defined by passive gear, established buyer relationships, and a compressed harvest season, vessels have limited scope to redeploy effort in response to a short-lived regulatory shock. Harvesters therefore absorb the shock through lower revenues rather than through changes in fishing behavior. The finding is instructive precisely because it separates economic effect from behavioral response: an adaptive instrument can impose meaningful costs while leaving production decisions almost untouched. More broadly, the results bear on the economics of climate adaptation in resource industries. As marine heatwaves, harmful algal blooms, and other climate-linked disruptions grow more frequent, managers will increasingly seek alternatives to complete closure. Oregon's experience suggests that such alternatives can preserve economic activity during these events without causing major disruptions to harvesting behavior. Some evidence indicates that the costs of the policy fall unequally across vessels and ports, a distributional feature that merits attention as these instruments become routine. However, the alternatives to requiring evisceration are either a closure to some or all harvest areas and, at the other extreme, allowing contaminated crab to be sold, neither of which leaves harvesters or indeed consumers better off. These differences qualify but do not overturn the central conclusion: evisceration orders largely preserve fishing activity during domoic acid events and the burden of adjustment operates through prices rather than through changes in harvest behavior.

2 Conceptual Framework

Evisceration orders alter the market environment that harvesters face but do not change their opportunity to harvest. When domoic acid accumulates in crab meat or viscera and reaches a level beyond regulatory thresholds, then regulators may permit harvest but enforce evisceration. Specifically, if meat tests exceed 20 ppm, then regulators may choose to close the fishery entirely (since the edible portion is unsafe), but

if only viscera results are above 30 ppm (and meat is below 20 ppm), agencies have the option to allow fishing under an evisceration order (Free et al., 2022). Since evisceration requires the removal of the internal organs, gills, i.e., the viscera of a crab, the crab cannot be sold live. Thus, access to more lucrative live or whole crab markets is prevented by this requirement, and potential ex-vessel revenues from harvested crab are shifted into lower-value channels.

Essentially, the effect of the evisceration order should operate through ex-vessel revenues (prices) through harvest rather than access to the resource. Let vessel i's short-run profit in period t be defined as:

$$\pi_{it} = p_{it}q_{it} - C(q_{it}, e_{it}) - V_{it}(e_{it}, l_{it}, m_{it}) \tag{1}$$

where p_{it} is the price per pound for vessels, q_{it}, is the harvest amount, C is a function of harvest, q_{it} and fishing effort e_{it}, l_{it} is fishing location, m_{it} represents vessel i's downstream processing option. The term V_{it} denotes short-run adjustment costs that include costs associated with redeploying gear, steaming to new fishing grounds, and/or changing the dealer they sell their harvest to. The evisceration order is a restriction not on harvest but on how the harvest must be processed, which in turn limits the set of processing channels, the live or premium channels, a vessel might face under the policy. Holding all other factors fixed, the policy restriction lowers the price harvests can obtain, *ceteris paribus*

$$p_{it}^{1} \leq p_{it}^{0}$$

Now, because those premium channels for eviscerated crab are removed, the most immediate effects should be seen in the prices harvesters obtain, not necessarily through landings. The extent to which vessels respond to the policy depends on the elasticity of vessel behavior in the short-run. Several unique features of the fishery limit adjustment. First, the fishery is a derby fishery, where vessels harvest much of the crab early in the season as they race to take all available legal crab. The gear also limits a vessel's ability to respond, as crab are caught using steel pots that must be baited, placed on the ocean floor, and retrieved later. Furthermore, vessels have local knowledge of fishing grounds and may also have processor relationships that limit their ability to respond to a relatively short-lived policy shock. These are consistent with

the Le Chatelier principle: inputs in the short run are fixed, and thus behavioral responses to a temporary policy shock should be smaller in the short run than they would otherwise potentially be in the long run (Samuelson, 1947; Milgrom and Roberts, 1996).

If vessels cannot quickly or costlessly redeploy gear, change fishing locations, find new processors (buyers), and/or otherwise change their production processes, then evisceration should reduce ex-vessel revenues primarily through lower prices, not necessarily because of lower landings, effort, or changes in fishing behavior. Of course, this does not necessarily hold for all vessels, as larger vessels have greater capacity for holding crab, can stay at sea for longer, and have the ability to travel further distances than smaller vessels; thus, larger vessels, through their capacity through high volume of harvest, might be less dependent on price compared to smaller vessels. This points to heterogeneous policy effects across vessels. Vessels with a lower ability to adjust in the short-run, e.g. smaller vessels, should face higher losses compared to larger vessels.

The downstream processor structure also adds another source of heterogeneity. Again, since the policy shifts eviscerated crab into alternative processing channels, the importance of local port processing capacity comes into focus. If larger processors are found in some ports, then vessels landing in those ports may face less of an adverse price effect for eviscerated crab, as some processors may lack the storage or willingness to deal with the eviscerated crab. The empirical results show evidence that is consistent with this mechanism, as the price effect is less severe in ports with larger processors. Therefore, in ports with smaller processors, the price penalty for vessels landing their harvest in those ports should be greater than those of vessels landing in ports with larger processors.

The analysis tests the elements of the preceding conceptual framework. First, it estimates the policy's effect on ex-vessel prices. Then, it estimates the effect on vessel behavior margins through landings, effort, participation, and fishing location. Finally, the analysis examines whether policy effects vary across vessels and ports.

3 Background

Domoic acid, a neurotoxin produced by certain algal blooms, causes Amnesic Shellfish Poisoning and poses serious health risks if contaminated seafood is consumed(Lewitus et al., 2012). The U.S. West Coast Dun-

geness crab fishery has experienced several domoic acid outbreaks, notably the 2015 event that delayed or closed crab seasons in California, Oregon, and Washington (Ritzman et al., 2018) . Studies of the 2015 closure documented severe economic losses and social impacts on fishing communities (Ritzman et al., 2018; Jardine et al., 2020; Mao and Jardine, 2020; Holland and Leonard, 2020; Fisher et al., 2021; Free et al., 2022). Ritzman et al. (2018) described how prolonged closures disrupted livelihoods and eroded trust in management, especially when regulatory responses appeared inconsistent across state lines (Free et al., 2022). Holland (2000) estimated that the 2015–16 California season delay reduced Dungeness crab revenue, though the loss was less than initially feared due to adaptive behavior and later season catch-up. Similarly, Mao and Jardine (2020) found that once the fishery eventually opened, consumer crab prices remained relatively stable, indicating the market adjusted to the temporary supply shock without long-term price spikes or crashes. These findings suggest that fishermen and markets can exhibit resilience to one-time closures, though short-term hardships are significant. In the wake of the 2015 HAB disaster, West Coast states explored more flexible management responses.

This policy was first used in Oregon during the 2016–2017 season with emergency adoption, and more formally during the 2017–18 and 2018–19 seasons (ODFW, 2017b,e, 2018). California and Washington followed: California legalized evisceration orders in 2021 (SB-80) as a management option McGuire (2021), and Washington adopted an emergency rule in 2021 to allow evisceration, using it on the south coast in early 2021 (WDFW, 2021). Evisceration orders can reduce the burden of HABs by enabling some harvest to continue when it would otherwise be halted (Free et al., 2022). Importantly, they segment the fishery spatially – often, only certain zones with high viscera toxin are under evisceration requirements, while the other areas operate normally. This fine-scale management was facilitated by more intensive biotoxin monitoring; for example, Oregon doubled its crab sampling sites (from 5 to 12) and established smaller management zones after 2017 (ODFW, 2017d,c,a), allowing targeted actions (like zone-specific evisceration orders) rather than coastwide closures.

Prior research suggests this has economic downsides. Hackett et al. (2005) noted that eviscerated crabs often receive lower market prices. This price discount arises because removing viscera prevents sale of live or whole crabs—a premium market—and instead forces the product into cooked or processed channels. The loss of the lucrative live/fresh whole crab market (popular in seafood restaurants and export) means

fishermen may earn less per pound under an evisceration order. On the other hand, having the fishery open even at a lower price can be better than remaining completely closed (with zero revenue).

There is evidence that industry opinions on evisceration orders are split along fleet demographics: larger fishing vessels tend to support evisceration orders more than smaller vessels, since bigger operators prioritize landing high volumes (even at a lower price) whereas small-scale crabbers depend on getting the best price for a limited catch (Free et al., 2022). Smaller vessels also may lack onboard holding capacity or nearby processing facilities for evisceration, making it harder for them to participate in an evisceration opening. Jardine et al. (2020) found that smaller boats were disproportionately impacted by the 2015 closures, which suggests that any policy (like evisceration) that allows partial fishing could likewise have unequal benefits within the fleet.

4 Data

The Oregon Department of Fish and Wildlife (2022) is the principal source of this research's empirical data on Dungeness crab fishing activity. The primary data source is the monthly logbook entries submitted by vessel operators to ODFW. These logbooks offer a detailed self-reported, account of each vessel behavior. Crab pots are baited and systematically arrayed in linear formations, referred to as strings. Strings are then allowed to 'soak', or rest on the ocean floor and trap crab that are drawn by the bait. Pots are then pulled and the crab collected, after a soak time that varies depending on location, time of the season, local crab abundance, and other factors determining the preferences of a vessel's crew. Pulled and emptied pots may then be re-baited and reset in a string either in the same location, or moved elsewhere, before the vessel returns to port. Regulatory measures instituted by the Oregon Department of Fish and Wildlife in 2006 implemented a three tired pot system for each permit the allocation per permit was determined based on the vessels' effort during the 1995/1996 and 2000/2001 fishing seasons (Oregon Department of Fish and Wildlife, 2022). The three tiers limit the number of pots to 300, 400, or 500 depending on the permit. The fishery is also closed from mid-August until December 1 to mitigate the harvest of recently molted soft-shell crabs, a period after the summer mating season. A season may be delayed, at least in some areas, for several reasons, including suboptimal meat quality, domoic acide, and or price negotiations between the industry and processing entities. Logbooks provide the location of these 'strings' and include the num-

ber of crab pots used, their average soaking depth measured in fathoms, soak duration reported as days the pots were left, and the estimated weight and value of the catch associated with each string. In the 2007-2008 season, the Oregon logbook program started requiring manual submission of these entries to ODFW, which then undergoes a process of digital entry and archiving. In the program's first four years (from 2007-2008 to 2010-2011), ODFW comprehensively recorded all submitted logbook entries. However, in the subsequent seven years (2011/2012 to 2017/2018), the department recorded only randomly selected 30 percent of the logbooks based on port and week. Since the 2018/2019 season, ODFW has returned to the practice of complete logbook entry and has worked to provide a complete account of otherwise sampled seasons. Therefore, the completeness of logbook data varies across different years within the study period from 2007 to 2020. The Oregon fish ticket dataset for the Dungeness crab fishery is a secondary data source. Wholesale purchasers must document these transactions formally (OAR (2021a) & OAR (2021b)). These records, termed fish tickets, contain detailed information, including the crab's weight and monetary value, the transaction date, and the port where the sale occurred. These tickets also provide vessel-specific details such as vessel length and pot limit.

Additional data comes from the ODFW's domoic acid testing, which indicates the level of domoic acid in Dungeness crabs and razor clams and other bivalves. The testing data comes from the Oregon Department of Agriculture's shellfish monitoring program which generally tests shellfish along the Oregon coastline twice a month Oregon Department of Agriculture (nd). Tests measure toxin concentration separately in the crab meat and in the viscera. The records of these test results are listed by date and location (often tied to the same management zones or ports). Additionally, because bivalve shellfish like razor clams and mussels are known early indicators of domoic acid events in crab, since bivalves are an important food source of Dungeness crab, data on domoic acid levels in co-occurring bivalve samples is also used, as well as the fact that elevated domoic acid (>20 ppm) in razor clams also mandates surveillance testing in crab for those zones by rule (Rasmuson, 2013). The dataset, thus, includes time-series data of razor clam domoic acid levels for key coastal sites where available. These environmental indicators will help to provide an analysis of lead-lag relationships. The domoic acid data is aligned with fishery data on a timeline. For each management zone and week of the season, we know the domoic acid status (e.g., highest viscera ppm measured, whether it exceeded the action threshold) and whether any management action was in place

(no action, evisceration order, or full closure). This structured dataset enables a quantitative look at how often evisceration orders were associated with exceeding certain toxin thresholds and how quickly prices and fishing effort responded to those orders. The management zones defined by ODFW and other agencies are illustrated in figure 1.

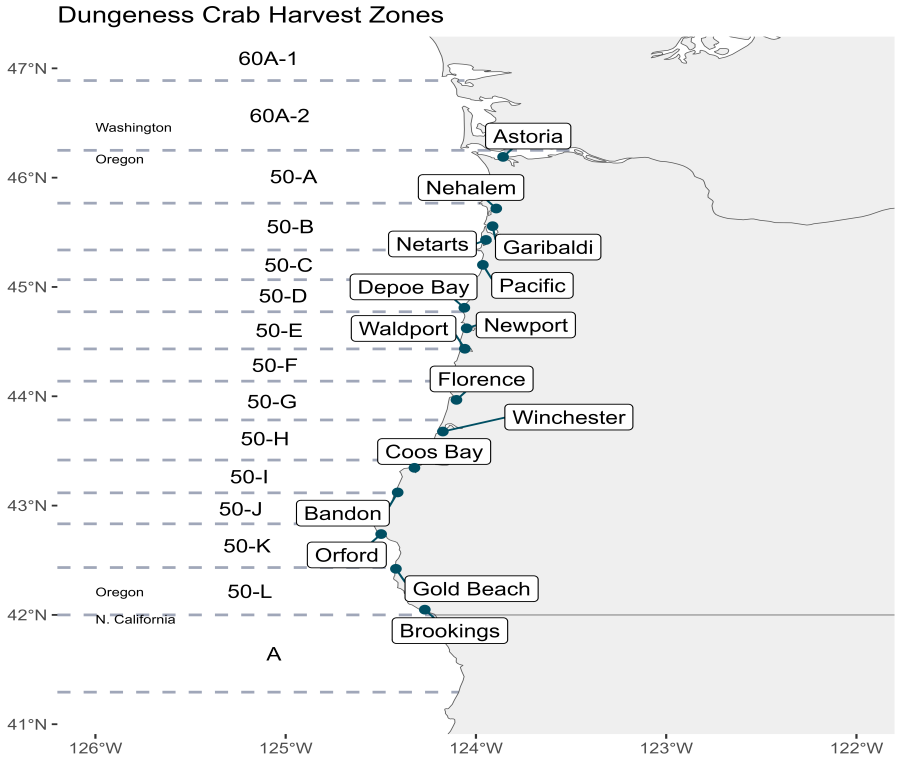


Figure 1 Management areas as defined by respective agencies

Table 1 summarizes the evisceration orders for the Dungeness crab fishery from the 2016-2017 to the 2022-2023 seasons. As seen in the table, the dates of the policy start for each particular area are noted, as well as the announcement and end date. The policy start dates apply retroactively to these orders. For example, in the 2016-2017 season, test results were not available until February 2, 2017, the date officials announced the order; nevertheless, it applied to any crab harvested from the sample date.

A series of control variables are also included in some of the regression analysis. Ocean climate and weather data comes by using the E.U. Copernicus Marine Service Information Global Ocean Waves Reanalysis (E.U. Copernicus Marine Service Information, 2025c,a,b), Global Ocean Biogeochemistry Hindcast , and Global Ocean Physics Analysis and Forecast product. The data acquired from the Marine Service provides data on significant wave height, wave swells, daily chlorophyll, nitrate, phosphate, silicate, dissolved oxygen, primary production, sea surface and bottom ocean temperatures. Fuel costs were obtained from

Table 1 Evisceration Orders

Season	Violative Areas	Buffers	Policy Start	Policy End	Announcement Date
2016–2017	50-H, 50-G, part of 50-I	NA	1/25/2017	2/10/2017	2/2/2017
2017–2018	50-L	50-K	2/16/2018 50-K 2/13/2018 50-L	2/27/2018	2/16/2018
2018–2019	50-K	50-J, 50-L	2/11/2019 50-K 2/14/2019 50-J, 50-L	3/22/2019 50-L	2/14/2019
2018–2019	50-K, 50 L	50-J	2/14/2019 50-J & 50-L	3/26/2019 50-K & 50-J	2/14/2019
2018–2019	50-L	50-K	5/8/2019 50-L 5/10/2019 50-K	5/22/2019 50-K & 50-L	5/10/2019
2022-2023	50-I	50-H, 50-J	4/27/2023 50-I & 5/1/2023 50-H, 50-J	5/11/2023	5/1/2023

Note: Multiple policies may apply within a season. Start and end dates reflect implementation by sub-area.

the Pacific States Marine Fisheries Commission (PSMFC, nd) and supplemented by the Weekly Retail Gasoline and Diesel Prices series available from the U.S. Energy Information Administration (U.S. Energy Information Administration, 2025). As indicated by Dewees et al. (2004) weather and fuel costs go into the decision making of crab vessels. Fuel costs are a proxy for vessel costs, a similar assumption made in prior literature, e.g., Bucaram et al. (2013).

As an additional matter to address potential composition bias from differential vessel participation during evisceration periods, the data is dis-aggregated and analyze treatment effects by vessel characteristics. Rather than analyzing outcomes at the area-week level, an additional dataset is constructed with the outcome being area-week-vessel type cells, where vessel type is defined by boat size (large ≥50 feet, medium 30-50 feet, small <30 feet) and pot limit (200, 300, or 500 pots) following (Liu et al., 2023; Dewees et al., 2004). This approach ensures the comparison of like vessels to like vessels: treatment effects for large

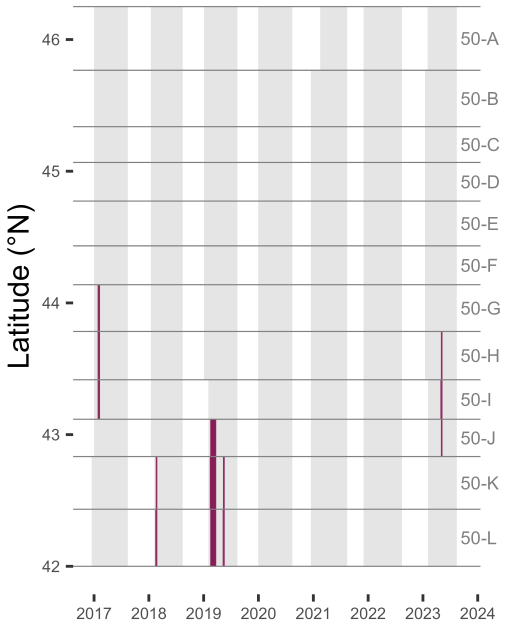


Figure 2 Seasonal openings and evisceration orders by Oregon crab management area. Light gray bands indicate periods when the commercial season is open for each management area. Red bands denote intervals during which an evisceration order is in effect for the corresponding area. The vertical axis represents latitude-based management areas, and the horizontal axis shows calendar time.

vessels are identified by comparing large vessels in evisceration weeks to large vessels in control weeks, holding fleet composition constant. The vessel type indicators enter the regression directly, capturing persistent capacity differences, while the evisceration-vessel type interactions test whether treatment effects vary across vessel types.

Table 2 presents summary statistics comparing areas that experience evisceration orders during a season (treated=1) to those that do not (treated=0). Treated areas exhibit several systematic differences from control areas. Most notably, treated areas have significantly higher catch per unit effort (9.31 vs 6.07 lbs/pot, $p<0.01$). Treated areas also have higher revenue and landings per vessel, consistent with these areas being more productive fishing grounds. Interestingly, treated areas have fewer active vessels (9.0 vs 10.5) and a lower share of large vessels (23% vs 32%, $p<0.01$), suggesting evisceration orders do not exclusively target the largest, most industrial fishing operations. Importantly, total area-level landings and pot usage are statistically balanced ($p=0.86$ and $p=0.60$ respectively), indicating that treated and control areas are comparable in overall fishing intensity despite differences in fleet composition. These systematic differences motivates the use of area fixed effects, which absorb all time-invariant productivity and compositional dif-

Table 2 Summary Statistics by Evisceration Status

	Untreated Areas		Treated Areas			
	Mean	Std. Dev.	Mean	Std. Dev.	Diff. in Means	p
Price per Pound ($/lb)	4.77	1.63	4.45	1.38	-0.31	<0.01
Revenue per Vessel ($/week)	4785.44	8396.99	6854.74	11409.66	2069.30	<0.01
Landings per Vessel (lbs/week)	1333.37	2893.36	2045.04	3792.38	711.66	<0.01
Total Landings (lbs)	27719.14	91316.32	28569.02	76905.82	849.87	0.86
Average Pots per Vessel	161.48	116.56	165.17	117.28	3.69	0.60
Catch per Unit Effort (lbs/pot)	6.07	6.41	9.31	10.35	3.24	<0.01
Number of Active Vessels	10.48	10.98	8.99	7.72	-1.49	<0.01
Share of Large Vessels (%)	0.32	0.29	0.23	0.25	-0.09	<0.01

ferences between areas. Treatment effects are identified from within-area temporal variation comparing each area's outcomes when under evisceration orders versus when not, rather than from cross-sectional comparisons between inherently different areas. VMS data provided by the National Marine Fisheries Science Office of Law Enforcement records vessel location at approximately hourly intervals for vessels required to participate in the program. Of 625 unique vessels in the logbook data, 406 appear in the VMS data. After filtering out port activity, implausible speeds, and telemetry errors, 103,780 trips are identified, defined as a vessel departing and returning to port, with an average trip duration of 3 days. Trips are matched to fish tickets using landing dates as a filter and to logbook strings using a 5.6 km spatial buffer around reported string coordinates, accounting for the hourly polling interval and typical fishing speeds of 0.5–3.0 knots (Gerritsen and Lordan, 2010). These steps are summarized in Figure 3.

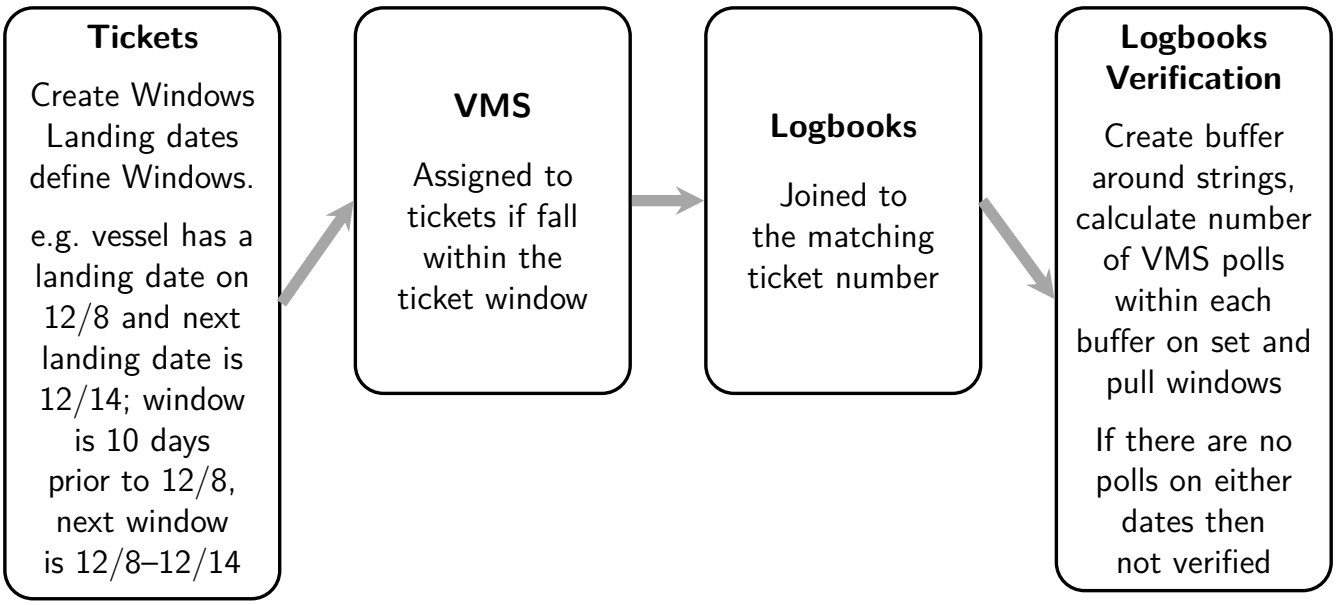


Figure 3 VMS Dataset Process.

Table 3 shows the number of trips and a few selected characteristics of the data identified in the final dataset using VMS. Of note are the differences between boat types. As noted previously, vessels are heterogeneous: larger vessels go on longer trips, catch more crab, and therefore generate more revenue than smaller vessels. Larger vessels, both large and medium types, are overrepresented in the VMS data compared to smaller vessels.

Table 3 Vessel Trips

Variable	Vessel Type		
	Large $N = 11{,}853$[1]	**Medium** $N = 18{,}651$[1]	**Small** $N = 1{,}701$[1]
Trip Duration (days)	1.37 (1.31)	0.52 (0.53)	0.28 (0.14)
Length	63.52 (9.93)	40.14 (5.77)	27.40 (1.74)
Ex-vessel revenue	34,225.10 (47,501.83)	7,781.33 (12,119.47)	2,164.87 (2,360.83)
Landings	10,955.88 (15,965.91)	2,367.29 (3,759.75)	764.58 (916.46)

Notes: [1] Mean (standard deviation).

5 Empirical Strategy

The baseline model design utilizes a differences-in-differences design to exploit the variation in the timing and implementation orders for the Oregon dungeness crab fishery. The core specification is a two-way fixed effect model of the form:

$$Y_{itsw} = \gamma Evis_{isw} + \beta X_{isw} + \alpha_i + \delta_{sw} + \epsilon_{isw} \tag{2}$$

where: Y_{isw} is the outcome variable of interest (either ex-vessel price per pound or weekly fishing effort for ex-vessel prices in area i in season s at season week w). The variable γ captures the causal effect of evisceration before, during, and after implementation of the policy announcement. Control variables are X_{it}, which might include total landings, fuel prices, weather, and other related controls. Area fixed effects are γ_i that control for time-invariant differences between fishing areas (e.g., some zones might naturally have higher prices or different processing infrastructure). Season-week fixed effects are δ_{sw} that control for overall market trends and industry-wide seasonality. The primary DiD analysis employs season-week fixed effects based on calendar dates rather than weeks-since-opening. Using calendar dates controls for season and calendar effects, which include weather patterns, holiday effects, and market conditions, while preserving variation in treatment timing relative to the fishery stage. This is because fishing seasons open at staggered dates across the management areas; thus, controlling for calendar weeks ensures that the analysis compares areas facing similar external conditions at the same point in time. Finally, ϵ_{it} is the error term and are clustered at the level to account for serial correlation within areas. To further address these questions an event study frame works is applied as it is well-suited for analyzing policy interventions with clearly defined implementation dates (Miller, 2023). This method allows estimates the dynamic effects of evisceration orders on market prices and vessel behavior over time while controlling for external factors such as seasonality and broader market trends. In this regard, a stacked event-study design is adopted following Cengiz et al. (2019); Wing et al. (2024)). The data is centered around the implementation of each evisceration order, again that is the date the policy was announced. A 14-day window is also employed. This approach enables the pooling of all treated area-season events into a single regression, yielding a coherent

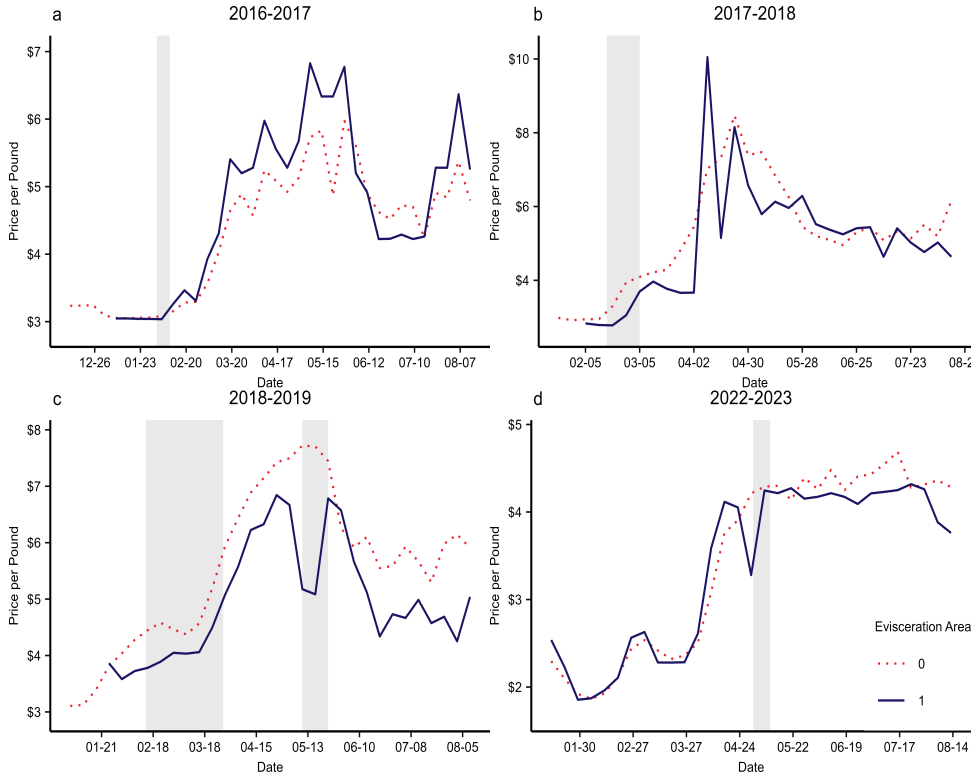


Figure 4 Treatment groups are defined as any area that placed under an evisceration order and control groups are areas that never had one.

set of dynamic treatment effects. This method allows for the visualization of the timing and magnitude of policy effects while ensuring that baseline trends in the fishery are controlled.

The treatment and control group outcomes are plotted in figure 4 to graphically consider pre-treatment parallel trends. The treatment group is any area in a given season that was placed under an evisceration order, either as a violative or buffer zone; control groups would then be areas that did not. The outcome in this is the average ex-vessel price per pound for crab caught in those groups. In all three panels, prices between both groups are fairly similar before the treatment window, especially early on in the season—this supports the assumption of parallel trends. In panel (a), there is not a clear divergence between treatment and control groups; for panel (b), a strong divergence appears post-treatment with a sharp rebound several weeks after; in panel (c), a similar pattern is seen. Differences in magnitude and timing of effects suggest the treatment may not have a uniform effect across years–this could reflect market conditions, timing of treatment, learning and adaptive behavioral as well as other seasonal factors.

The event study regression is as follows:

$$Y_{ist} = \left(\sum \gamma_j D_{i,t-j} \right) + \beta X_{ist} + \alpha_i + \delta_{st} + \epsilon_{ist} \tag{3}$$

where: Y_{iat} is the outcome variable of interest (either ex-vessel price per pound or weekly fishing effort for ex-vessel prices in area i at time t). $D_{i,t-j}$ is an indicator variable for an event time j, where $D_\tau = 1$ if time t falls within the event window for zone i, and 0 otherwise. The variable γ_j captures the dynamic impact of evisceration orders before, during, and after implementation. Control variables are X_{it}, which might include total landings, fuel prices, weather, and other related controls. Area fixed effects are γ_i that control for time-invariant differences between fishing areas (e.g., some zones might naturally have higher prices or different processing infrastructure). Season-day fixed effects are δ_{st}, defined by days since opening and not calendar dates that control for control for general within-season patterns (e.g., early-season intensity, mid-season depletion), ensuring that our event-time coefficients capture deviations from normal fishery dynamics around treatment implementation rather than broader seasonal trends. Finally, ϵ_{ist} is the error term.

By estimating this model, it is possible to assess whether ex-vessel prices decrease significantly when an evisceration order is implemented. The analysis can also determine if fishing vessels alter their behavior in anticipation of such an order when bivalve toxin levels are high and how quickly markets and fishing efforts recover once an evisceration order is lifted. Using calendar-date fixed effects in the DiD preserves identifying variation across treatment timing, while using season-day (days-since-opening) fixed effects in the event study is necessary to properly align multiple treatment events that occur at different points in the fishing season.

Spatial spillover effects are examined to identify whether fishing effort increases in nearby areas that are not subject to evisceration orders, suggesting effort displacement rather than a total reduction in fishing activity. The Dungeness crab fishery also exhibits characteristics that require different temporal controls for different outcomes. Figure 4 illustrates this institutional feature through two contrasting patterns. Panel a shows that fishing dynamics follow area-specific 'fishery time.' Average landings per vessel peak dramatically in weeks 1-2 after area opening, reaching over 12,000 pounds per vessel as fishers engage in intense derby-style competition to harvest accumulated crab stocks. Catch rates then decline steadily as local populations deplete, falling to roughly 500 pounds per vessel by week 20. This derby pattern repeats

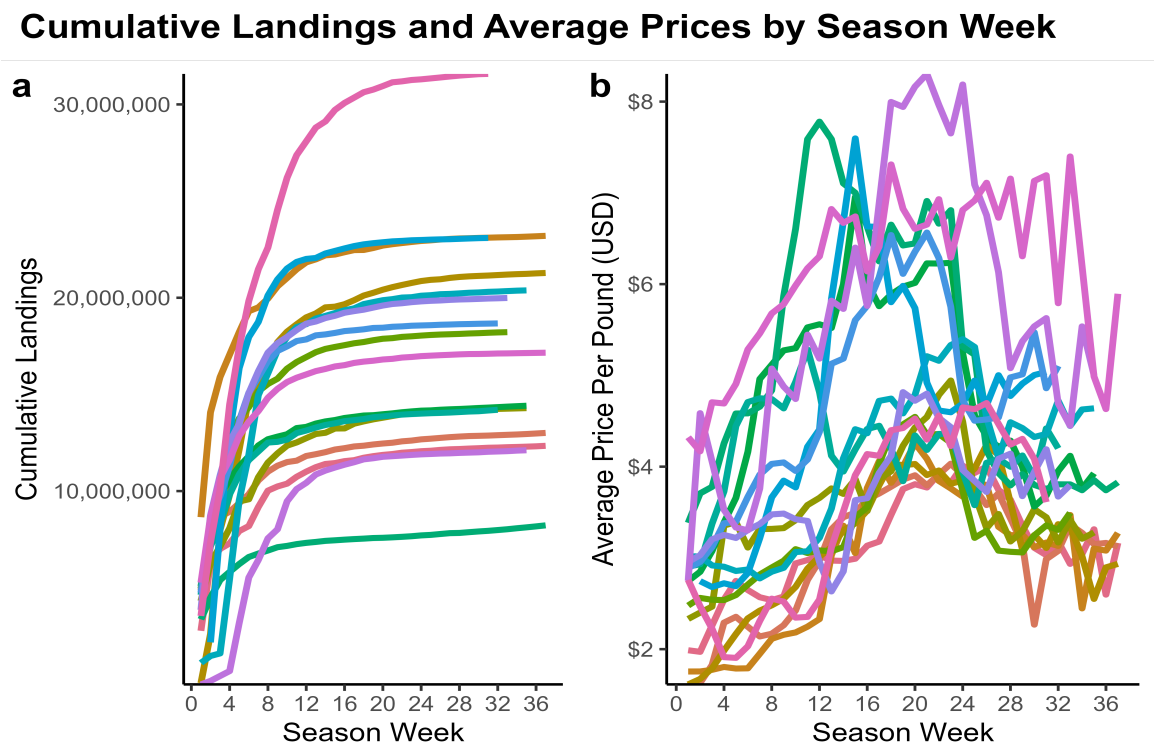


Figure 5 Timing Dynamics in the Dungeness Crab Fishery

Panel a (Left): Cumulative Landings for Each Season. Panel b: Average Weekly Price across All Seasons

for each area at its own opening date: an area opening in late January exhibits the same first-week intensity as one opening in early December. Panel b's figure shows prices follow seasonal trends. Beginning in December, prices rise steadily and move broadly together as the season progresses, peaking in April-May before declining in the summer months. This pattern reflects market-level dynamics: all Dungeness crab, regardless of source area, sells into integrated wholesale and retail markets where prices respond to total regional supply and seasonal demand. This dual structure arises because fishing effort responds to local biological conditions (area-specific stock abundance and depletion). In contrast, prices respond to regional market conditions (aggregate supply across all areas). A vessel fishing in an area's opening week faces the market price prevailing at that calendar time, not a price determined by its local area.

These contrasting dynamics motivate the empirical strategy. In the price regression, the use of calendar-week fixed effects controls for market-wide supply and demand conditions. In the landings and effort regressions, include fishery-week controls to account for area-specific derby dynamics and patterns of stock depletion. This approach ensures the comparison of outcomes at appropriate temporal scales and market

prices across calendar-equivalent periods where unified markets operate, and of fishing behavior across fishery-equivalent stages where local biological conditions prevail.

6 Results

This section reports the causal effects of evisceration orders on market outcomes and fishing behavior. Identification here comes from repeated, spatially heterogeneous orders in Oregon, generating staggered variation in exposure across zones and weeks. Because Oregon tickets do not record catch area, to measure vessel–week treatment effects, tickets are matched to logbooks, and the resulting data are allocated to their respective management zones using reported string coordinates. This spatially explicit exposure measure allows estimation not only of average effects on ex-vessel prices but also of changes in mechanism outcomes in effort and in the reallocation of fishing activity across space, and of heterogeneity by vessel type. The analysis begins with baseline price estimates (DiD and event-study), then presents robustness checks, and finally shows how behavioral responses help interpret the price effects.

6.1 Price Outcomes

Following previous research, which has considered the effect of evisceration orders on commercial fishing on the West Coast, the baseline specification is used to estimate the effect of evisceration on ex-vessel prices (Jardine et al., 2020; Abken and Jardine, 2026). Using the typical two way fixed effects DiD model the estimates are similar to Abken and Jardine (2026) and are presented in table 4. Column (1) shows the raw correlation without controlling for spatial or temporal heterogeneity: evisceration orders are associated with prices that are 92 cents per pound lower ($p<0.001$). However, this unconditional estimate conflates treatment effects with systematic differences between areas that do and do not experience evisceration orders. Column (2) adds area fixed effects, controlling for time-invariant characteristics of each fishing zone. The coefficient remains negative and significant (-$0.67, $p<0.001$), but the magnitude declines as we account for the fact that certain areas may systematically differ in baseline price levels. Column (3), is the baseline specification and adds season-week fixed effects to control for within-season patterns and year-to-year variation in market conditions. These fixed effects absorb market-wide supply, demand conditions. The

treatment effect stabilizes at -$0.52 per pound (p<0.001), representing approximately a 10% reduction relative to the sample mean price of $4.80 per pound. Column (4) adds fleet composition controls to address potential selection bias from differential vessel participation during evisceration periods. The coefficient remains virtually unchanged (-$0.515, p<0.001), and neither the share of large vessels nor the number of active vessels significantly affects prices. This stability suggests that compositional changes are not driving our main results—the price reduction reflects the direct market effect of evisceration requirements rather than changes in which vessels are fishing. Column (5) adds derby controls. The estimate shows an effect -$0.75 per pound and is economically and statistically significant. Columns (6) presents the same specification as column (5) but using log-transformed prices, allowing for percentage interpretation. Across all specifications, the treatment effect is robustly negative, ranging from 10-11% in the preferred specifications (columns 5 and 6) [2]. This price reduction is substantial and consistent with prior expectations: evisceration orders force crabs into lower-value market channels by eliminating the premium live/whole crab market, while simultaneously imposing additional processing costs on buyers and harvesters. Column three uses weights specific to the outcome considered: prices are weighted by total amount of harvest as are vessel landings, the panel for pots are weighted by the total number of pots. Using the estimates from column 3, the model specification finds that ex-vessel prices, on average, for crab harvested in areas under evisceration are about 40 cents lower compared to areas that are not.

Table 5 shows effects on average landings per vessel. The preferred specification (Column 5) shows evisceration orders reduce landings by 959 pounds per vessel per week (p<0.001). Column 6 presents results using log-transformed landings. The coefficient is smaller and statistically insignificant (-0.158, p>0.10), indicating the treatment effect operates primarily through absolute rather than proportional changes. This pattern also suggests heterogeneous effects across vessel types. This would mean that the aggregate landings reduction is, potentially, driven by large vessels reducing catch substantially in absolute terms, while smaller vessels may experience proportionally similar (or even null) effects. Table 10 explores this heterogeneity explicitly, showing that (larger vessels / higher pot-limit vessels) account for most of the ag-

[2] Alternative specifications using fishery-time (weeks-since-opening) fixed effects in the DiD framework absorb nearly all treatment variation (R^2 Within < 0.01) because evisceration orders tend to occur at specific stages of the fishing season when domoic acid risks peak. This over-controls for the timing variation to exploit. Conversely, using calendar-date fixed effects in event studies would prevent proper alignment of treatment events occurring at different calendar times but similar fishery stages.

Table 4 Effect of Evisceration Orders on Dungness Crab Vessel Outcomes

	Dependent Variable					
	Price per Pound					Log(Price per Pound)
	(1)	(2)	(3)	(4)	(5)	(6)
Evisceration Order	-0.917***	-0.670***	-0.516***	-0.515***	-0.748***	-0.150***
	(0.254)	(0.166)	(0.150)	(0.135)	(0.184)	(0.034)
Num.Obs.	6143	6143	6143	6143	6143	6143
R2	0.002	0.039	0.906	0.906	0.907	0.922
R2 Adj.	0.002	0.038	0.893	0.894	0.894	0.912
Season-Week FE	No	No	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes	Yes
Composition Controls	No	No	No	Yes	Yes	Yes
Derby Controls	No	No	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

Controls: % large vessels and number of active vessels

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

gregate landings response. The insignificant log specification also reflects the substantial heterogeneity in landing capacity across vessel types [3].

Table 6 examines effects on average ex-vessel revenue per vessel, which combines the price and quantity impacts documented in previous tables. Columns 1-4 show a progression from unconditional correlation to our baseline difference-in-differences specification with composition controls. Without derby timing controls, evisceration orders appear to increase revenues by approximately $2,300-$3,100 per vessel per week (Columns 1-4, p<0.05), a counter-intuitive result given the documented price reductions. However, Column 5, the preferred specification including derby timing controls reveals the true treatment effect. After accounting for the opening-week revenue surge evisceration orders reduce average weekly revenue per vessel by $3,746 (p<0.001). The sign reversal between Columns 4 and 5 demonstrates the importance of controlling for derby dynamics: the positive coefficients in earlier specifications reflect confounding between evisceration timing and naturally high-revenue periods rather than a true treatment effect. The revenue decline ($3,746) reflects the combined impact of lower prices (Table 4: -$0.75/lb) and reduced landings (Table 5: -959 lbs/week). Column 6 presents results using log-transformed revenues, showing a 31.5% re-

[3] Absolute landings changes (captured by levels specifications) are dominated by high-capacity vessels, while proportional changes (captured by log specifications) weight small and large vessels equally.

Table 5 Effect of Evisceration Orders on Dungeness Crab Vessel Outcomes

	Dependent Variable					
	Landings					Log(Landings)
	(1)	(2)	(3)	(4)	(5)	(6)
Evisceration Order	726.353	792.687***	741.902**	663.269**	-959.365***	-0.158
	(461.436)	(189.688)	(299.306)	(293.334)	(259.066)	(0.097)
Num.Obs.	6143	6143	6143	6143	6143	6143
R2	0.000	0.020	0.743	0.751	0.765	0.785
R2 Adj.	0.000	0.018	0.709	0.717	0.733	0.755
Season-Week FE	No	No	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes	Yes
Composition Controls	No	No	No	Yes	Yes	Yes
Derby Controls	No	No	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

Controls: % large vessels and number of active vessels

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

Table 6 Effect of Evisceration Orders on Dungeness Crab Vessel Outcomes

	Dependent Variable					
	Revenue					Log(Revenue)
	(1)	(2)	(3)	(4)	(5)	(6)
Evisceration Order	2655.379**	3064.216***	2541.375**	2281.303*	-3746.132***	-0.315**
	(1342.879)	(840.616)	(1142.951)	(1140.387)	(1041.533)	(0.125)
Num.Obs.	6143	6143	6143	6143	6143	6143
R2	0.001	0.028	0.718	0.728	0.751	0.722
R2 Adj.	0.000	0.026	0.680	0.691	0.716	0.684
Season-Week FE	No	No	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes	Yes
Composition Controls	No	No	No	Yes	Yes	Yes
Derby Controls	No	No	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

Controls: % large vessels and number of active vessels

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

duction ($p<0.01$). The significant log specification—in contrast to the insignificant log result for landings (Table 5, Column 6) indicates that proportional revenue losses are relatively consistent across vessel types. This suggests that while larger vessels experience greater absolute revenue losses, vessels of all sizes face

similar percentage declines, likely because both prices (which affect all vessels equally in a unified market) and quantities (where effects may be concentrated among larger vessels) contribute to total revenue impacts.

Table 7 presents the results on measures of vessel effort including average pots per vessel and catch per unit of effort (CPUE). Column 1 is a simple linear model, column 2 introduces both area and season-week fixed effects, while columns 3 and 4 add additional controls for both composition and the derby. Column 5 is the same as column 4 only it is a log transformation of the dependent variable. Results follow the trend of previous estimates. Evisceration reduces on average, the number of pots pulled per vessel, but not overall fleet effort. Nor does evisceration effect CPUE measures, which makes intuitive sense. The policy should not effect how efficient vessels are to catch crab but it should affect their willingness to set gear.

Table 7 Effect of Evisceration Orders on Dungeness Crab Vessel Effort

	(1)	(2)	(3)	(4)	(5)
Effort (avg pots)					
Evis	56.298***	28.371	24.391	-31.260***	-0.220**
	(18.256)	(16.193)	(15.393)	(8.250)	(0.082)
R2	0.002	0.645	0.657	0.659	0.610
R2 Adj.	0.001	0.597	0.610	0.612	0.557
CPUE					
Evis	3.386***	3.005***	2.819***	-0.476	0.118
	(1.082)	(0.745)	(0.766)	(0.564)	(0.067)
R2	0.002	0.822	0.830	0.846	0.769
R2 Adj.	0.001	0.798	0.807	0.824	0.737
Total Pots					
Evis	1803.721***	919.587	1044.726***	-281.074	-0.264**
	(626.952)	(545.725)	(294.376)	(285.501)	(0.093)
R2	0.001	0.753	0.866	0.868	0.852
R2 Adj.	0.001	0.719	0.848	0.850	0.832
Strings					
Evis	32.126**	7.798	10.905**	-3.592	-0.180**
	(12.693)	(13.367)	(4.215)	(5.996)	(0.066)
R2	0.001	0.767	0.910	0.911	0.867
R2 Adj.	0.001	0.735	0.898	0.899	0.849
Num.Obs.	6143	6143	6143	6143	6143
Season-Week FE	No	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes
Composition Controls	No	No	Yes	Yes	Yes
Derby Controls	No	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

Controls: % large vessels and number of active vessels

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

6.2 Spillover Effects

A concern for harvesters and management, as well as a threat to casual identification, are spillover effects. Although these policies are relatively infrequent throughout a season and short-lived, they may still induce spillover effects. To test for spatial spillovers, then, a comparison is made between vessel activity in control border areas (adjacent to eviscerated zones) and pure control areas during evisceration periods. Table **??** shows no evidence of spillovers, where the dependent variable is the number of distinct vessels that set gear in an area not under the policy but that had gear set in treated areas. Border areas experience a statistically insignificant 1.4% increase in vessel counts during evisceration, while pure control areas see a 9.9% increase . Neither effect is statistically significant from zero, suggesting vessels do not systematically relocate from eviscerated to adjacent areas, at least as far as logbook records are concerned.

Table 8 Effect of Evisceration Orders on Vessel Movement

	(1)	(2)	(3)	(4)
Evis	-0.007	-0.068	-0.820**	-0.065
	(0.018)	(0.044)	(0.301)	(0.120)
Neighbor Evis			0.920**	1.095**
			(0.367)	(0.415)
Evis × Neighbor Evis				-1.012**
				(0.421)
Num. Obs.	6,143	6,143	6,143	6,143
R2	0.000	0.116	0.316	0.349
R2 Adj.	0.000	0.025	0.245	0.282
Season–Week FE	No	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

The absence of spatial spillovers may reflect high switching costs in the Dungeness crab fishery. Evisceration orders are relatively short-lived, with an average policy period of around 18 days, which if one removes the first 2018-2019 order, the policy period is on average around 12 days. Because of this short time vessels may find it unprofitable to relocate to unfamiliar fishing grounds for such brief periods as indicated in previous studies (Girardin et al., 2017). Additionally, fishing grounds may not be perfect substitutes: differences in depth, bottom type, crab abundance, and historical fishing patterns may limit vessels' ability or willingness to switch locations. Finally, if evisceration orders do not substantially reduce catch rates

in treated areas (e.g., due to limited enforcement or brief duration), vessels may lack strong incentives to relocate [4].

6.2.1 Vessel Subgroups

To further look at the heterogeneous effects of evisceration the data is broken further down into vessel types. Using the permit data vessels are deemed to be small-sized, medium-sized, and large-vessels following Dewees et al. (2004); Liu et al. (2023): vessels shorter than 30 feet are categorized as small, vessels between 30 and 50 feet are medium-sized vessels, and any vessel over 50 feet in length is a large vessel. These series of regressions also use calendar-week fixed effects with controls for fishery timing(opening week, early season, late season dummies) to account for market seasonality and area specific derby dynamics. The results are presented in tables 9 and 10. By analyzing area-week-vessel type cells rather than area-week aggregates, the comparison between types and groups is direct, i.e. outcomes for large vessels under evisceration to large vessels without evisceration, holding vessel composition constant. Column 5 in table 9 shows that evisceration reduces average weekly revenue per vessel by $2,949 for large vessels ($p<0.01$), with medium vessels earning $2,960 less and small vessels earning $5,836 less than large vessels on average (both $p<0.001$). The insignificant interaction terms again indicate proportional treatment effects across vessel types.

Column 5 in table 9 presents the preferred specification with derby timing controls. Evisceration orders reduce average landings per vessel by 793 pounds per week for the baseline category (large vessels). The coefficients on vessel type dummies confirm the capacity heterogeneity: medium vessels land 923 pounds less per week than large vessels , while small vessels land 1,806 pounds less. These gaps reflect capacity constraints from vessel size and gear allocation. The interaction terms between evisceration and vessel type are statistically insignificant and small in magnitude (+74 and +24 pounds). This indicates that evisceration orders affect all vessel types proportionally. The 793-pound reduction for large vessels represents the proportional impact on medium and small vessels. The massive opening-week effect (+8,304 pounds, $p<0.001$) operates uniformly across vessel types, confirming that derby dynamics are a fishery-wide phenomenon rather than a vessel-specific one.

[4] An alternative model uses VMS data to model spillovers by considering how much time a vessel spends 'fishing' or crabbing and produces qualitatively identical conclusions.

Table 9 Effect of Evisceration Orders on Dungness Crab Vessel Outcomes

*

Dependent Variable= Average Revenue						
	(1)	(2)	(3)	(4)	(5)	(6)
Evis	2152.622***	1750.077**	1946.116*	1946.116*	-2948.743**	-7277.586**
	(756.491)	(698.264)	(1008.357)	(1008.357)	(1012.801)	(2493.349)
Medium		-2990.152***	-2988.173***	-2988.173***	-2959.589***	1109.023
		(676.022)	(677.478)	(677.478)	(666.092)	(1129.305)
Small		-5881.254***	-5874.339***	-5874.339***	-5835.692***	592.017
		(847.194)	(846.199)	(846.199)	(828.743)	(1232.078)
Evis · Medium			-203.779	-203.779	91.038	3128.921
			(1148.884)	(1148.884)	(1596.958)	(3531.124)
Evis · Small			-781.181	-781.181	-517.503	4397.534
			(2285.436)	(2285.436)	(2576.784)	(4080.454)
Opening Week					29601.210***	29312.017***
					(3321.671)	(3193.448)
Early Season					-369.311	-512.049
					(968.588)	(1015.080)
Late Season					-311.252	-264.811
					(1178.133)	(1040.513)
Potlimit 300						4027.919**
						(1565.529)
Potlimit 500						8415.128***
						(1937.197)
Evis · Potlimit 300						4066.527
						(3274.950)
Evis · Potlimit500						4423.048**
						(1966.215)
Medium · Potlimit300						-2283.472
						(1426.304)
Small · Potlimit300						-5138.458**
						(1959.867)
Medium · potlimit500						-4526.205**
						(1640.539)
Evis · Medium · Potlimit300						-3591.941
						(3683.066)
Evis · Small · Potlimit300						-5407.658
						(3938.151)
Num.Obs.	21027	21027	21027	21027	21027	21027
R2	0.000	0.455	0.455	0.455	0.471	0.502
R2 Adj.	0.000	0.436	0.436	0.436	0.452	0.483
Season-Week FE	No	Yes	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes	Yes
Derby Controls	No	No	No	No	Yes	Yes

* p < 0.1, ** p< 0.05, *** p< 0.01

Robust standard errors in parentheses clustered by area

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

Table 10 Effect of Evisceration Orders on Dungeness Crab Vessel Outcomes

*

Dependent Variable= Average Landings						
	(1)	(2)	(3)	(4)	(5)	(6)
Evis	545.820**	480.917**	495.985*	495.985*	-792.936**	-1987.450**
	(259.616)	(202.280)	(247.792)	(247.792)	(284.755)	(688.759)
Medium		-930.647***	-930.534***	-930.534***	-922.561***	376.065
		(211.082)	(211.757)	(211.757)	(208.396)	(377.019)
Small		-1817.539***	-1816.789***	-1816.789***	-1806.088***	216.070
		(271.256)	(271.431)	(271.431)	(266.266)	(418.076)
Evis × Medium			-10.831	-10.831	74.251	949.108
			(311.511)	(311.511)	(424.047)	(937.989)
Evis × Small			-85.360	-85.360	23.911	1369.840
			(631.875)	(631.875)	(711.833)	(1098.381)
Opening Week					8303.921***	8212.060***
					(780.017)	(741.660)
Early Season					-294.554	-335.668
					(275.502)	(291.209)
Late Seaosn					54.379	70.317
					(221.665)	(182.035)
Potlimit300						1297.261**
						(511.485)
Potlimit500						2584.007***
						(634.425)
Evis · Potlimit300						1168.819
						(902.809)
Evis · Potlimit500						1151.710*
						(587.521)
Medium · Potlimit300						-785.572
						(464.555)
Small · Potlimit300						-1742.615**
						(650.337)
Medium · Potlimit500						-1431.408**
						(545.929)
Evis · Medium · Potlmit300						-1079.687
						(999.008)
Evis · Small · Potlimit300						-1487.973
						(1085.512)
Num.Obs.	21027	21027	21027	21027	21027	21027
R2	0.000	0.483	0.483	0.483	0.494	0.517
R2 Adj.	0.000	0.465	0.465	0.465	0.475	0.499
Season-Week FE	No	Yes	Yes	Yes	Yes	Yes
Area FE	No	Yes	Yes	Yes	Yes	Yes
Derby Controls	No	No	No	No	Yes	Yes

* p < 0.1, ** p< 0.05, *** p< 0.01

Robust standard errors in parentheses clustered by area

Derby controls: dummies for opening week (1-3), early season (4-6), late season (12+).

6.3 Event Study

To capture dynamic effects, a series stacked event-study regressions centered on the start of each evisceration order. This approach follows Cengiz et al. (2019) and Wing et al. (2024) in that for each evisceration event, the data is centered on the onset of treatment in, that is the evisceration policy event using the announcement date of the order as the origin. These separate panels are then stacked into a single dataset. Specifically, for each management area a and season s in which an evisceration order is imposed, the start week t^0_{as} is defined and the corresponding event time variable is constructed $\tau = t - t^0_{as}$. The resulting panel is restricted to a symmetric window $\tau \in [-K, K]$ around the treatment start. The window is 14 days to and from each event in question. This design allows testing of pre-trends and recovery dynamics. The event study analysis adopts a more restrictive specification with area-season fixed effects. This choice reflects the different identification strategies: the DiD models estimate average treatment effects using all available variation, while the event study examines the dynamic treatment response within specific evisceration episodes, requiring tighter controls for area-season specific shocks. This more restrictive specification controls for all time-invariant characteristics specific to each area-season combination (e.g., Area 50-A during the 2018-2019 season). This is crucial because evisceration orders are not randomly distributed across seasons—later seasons saw increased use of this policy tool as monitoring infrastructure improved and agencies gained experience with implementation (Free et al., 2022). Without area-season fixed effects, the resulting estimates would confound the treatment effect with secular trends in crab prices that correlate with the temporal pattern of policy adoption. The area-season specification ensures the identification of treatment effects from within-area-season variation in the timing of evisceration orders, comparing treated weeks to untreated days within the same area and season. This provides the cleanest identification strategy given the data structure, though it comes at the cost of reduced precision due to less identifying variation. As pointed out by Wing et al (2024), the simple stacked regression does not identify a causal effect, and to correct for this bias the sample weights need to be constructed of the form:

$$Q_{sa} = \begin{cases} 1, & \text{if } D_{sa} = 1, \\ \dfrac{N^D_a / N^D_{\Omega_k}}{N^C_a / N^C_{\Omega_k}}, & \text{if } D_{sa} = 0. \end{cases}$$

So that each group is weighted by a weight that is proportional to its sub-experiment's share of total variance as a result of treatment. Figure 4 presents event-study estimates examining the dynamic effects of evisceration orders on market outcomes and vessel participation. The analysis reveals three key findings. First, prices respond quickly to evisceration implementation, declining by $1.00 per pound within 2-3 days of order initiation (Panel a). This immediate price response is consistent with markets rapidly adjusting to the loss of premium live crab channels and increased processing requirements. Second, these price reductions translate into revenue losses, with vessels experiencing declines of $5,000-10,000 in average daily revenue during evisceration periods (Panel b). Most importantly, Panels c and d reveal that fishing behavior exhibits remarkable inelasticity in response to these price shocks. Neither landings per vessel (Panel c) nor the number of active vessels (Panel d) show any treatment effects.

Figure 6 presents event study estimates examining the dynamic effects of evisceration orders on market outcomes and vessel participation. The analysis reveals three key findings. First, prices respond quickly to evisceration implementation, declining by $1.50-2.00 per pound within 2-3 days of order initiation (Panel a). This immediate price response is consistent with markets rapidly adjusting to the loss of premium live crab channels and increased processing requirements. Second, these price reductions translate into substantial revenue losses, with vessels experiencing declines of $5,000-10,000 in average daily revenue during evisceration periods (Panel b). Most importantly, Panels c and d reveal that fishing behavior exhibits remarkable inelasticity in response to these price shocks. Neither landings per vessel (Panel c) nor the number of active vessels. Panel c shows that weighted catch per unit effort—total landings divided by total pots across all active vessels—remains stable during evisceration periods. This confirms that fishing productivity is unaffected by evisceration requirements. The observed revenue losses stem entirely from lower prices rather than reduced harvest efficiency, as vessels continue to catch crab at pre-treatment rates despite the policy. The figures and estimates make use of a weighted CPUE (total landings/total pots) rather than vessel-level averages because it accounts for potential composition effects. If smaller, less efficient vessels exit during evisceration, average vessel-level CPUE could mechanically increase even if true productivity is unchanged. The weighted measure avoids this bias by calculating efficiency at the aggregate area-level, giving appropriate weight to the actual fishing activity occurring. Panel d shows significant changes during evisceration periods. The stability of vessel participation is particularly striking - despite

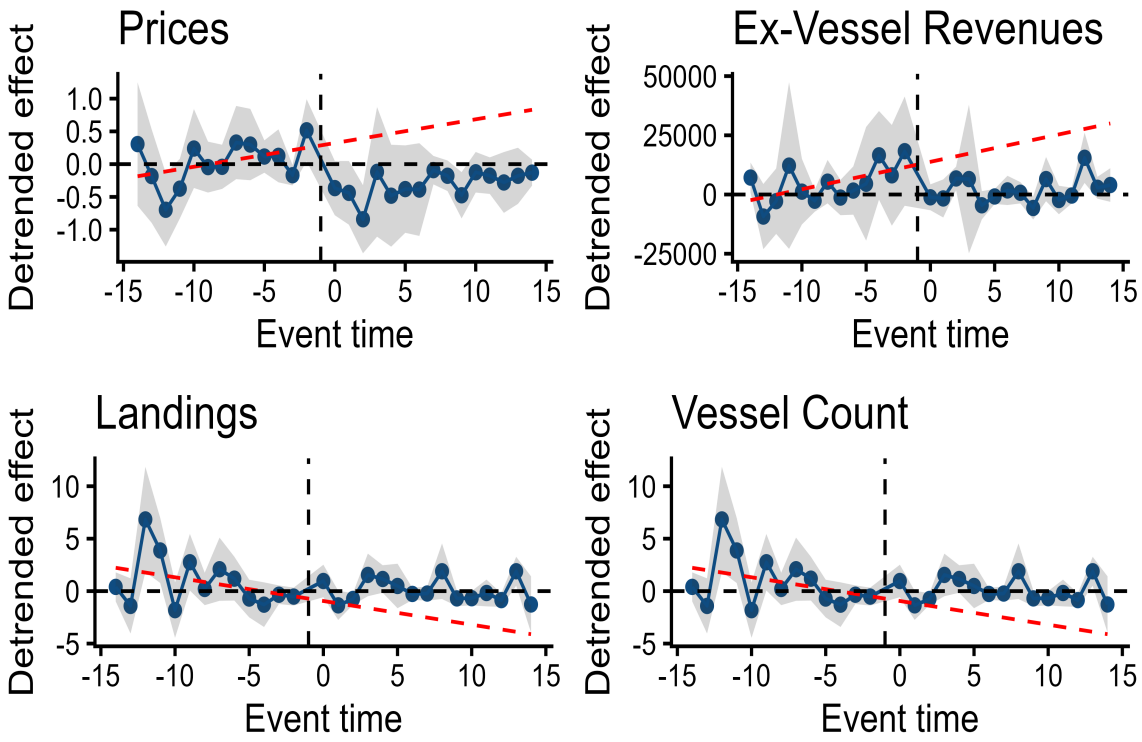


Figure 6 Dynamic Effects of Evisceration Orders on Market Outcomes and Vessel Participation

Figures present event study estimates following the stacked format as presented in Cengiz et al. (2019) and correspond to each of the time period in the treatment window.Event study estimates showing the effect of evisceration orders on key outcomes. Each panel plots coefficients from separate regressions of the outcome variable on event-time dummies, with 95% confidence intervals (standard errors clustered by area). Event time is measured in days relative to evisceration order implementation (day 0). All specifications include area-season and season-day fixed effects. Panel a shows that prices decline by approximately $1.50-2.00 per pound within 2-3 days of implementation. Panel b shows corresponding revenue declines of $5,000-10,000 per vessel. Panels c and d demonstrate that neither landings per vessel nor the number of active vessels changes significantly during evisceration periods, indicating highly inelastic short-run supply. The price reduction without behavioral adjustment suggests vessels face high switching costs that prevent relocation to unaffected areas. 95 % confidence intervals are plotted with point estimates. Standard errors are clustered at the area level.

facing 40-50% price reductions, vessels continue fishing at pre-treatment intensity rather than exiting or relocating to unaffected areas. This inelastic supply response is consistent with the high switching costs inherent in the Dungeness crab fishery, where vessels have substantial investments in gear placement, local ecological knowledge, and processing relationships that cannot be quickly redeployed. The pattern of results - large price effects with no quantity adjustment - indicates that evisceration orders impose their costs primarily through market channels rather than by disrupting fishing operations. Vessels effectively absorb the policy shock through lower revenues rather than adjusting fishing effort, suggesting limited short-run adaptation capacity in this derby-style fishery.

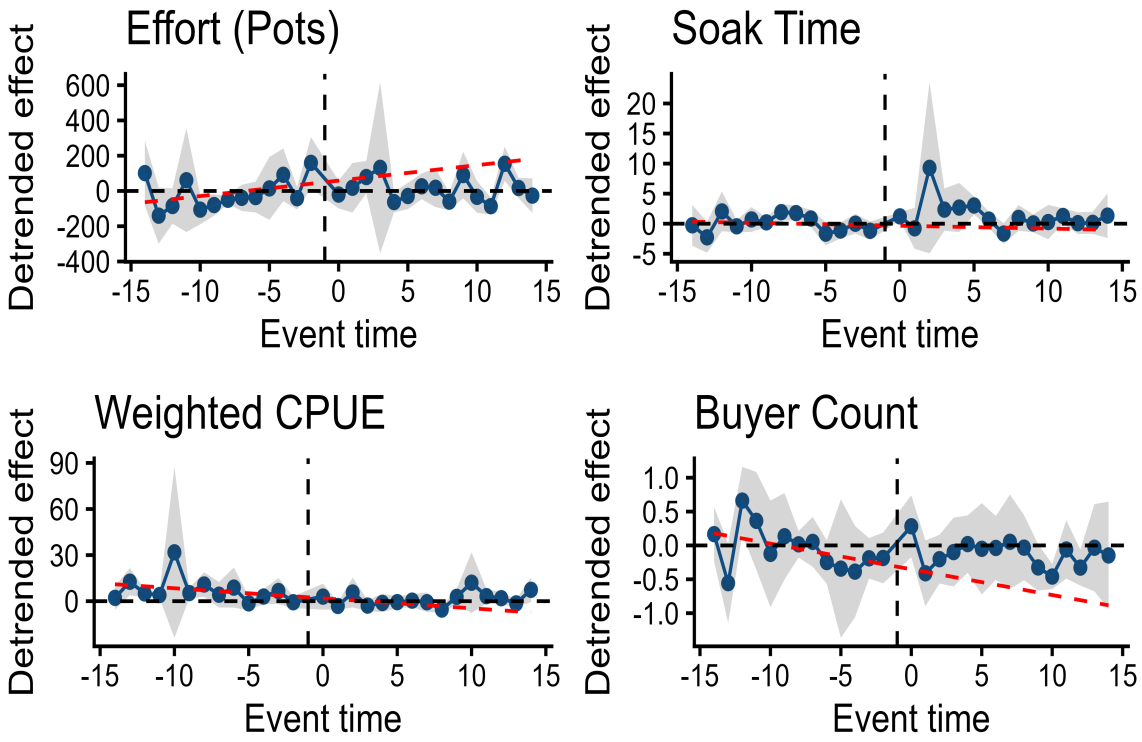


Figure 7 Dynamic Effects of Evisceration Orders on Fishing Operations

Event study estimates showing the effect of evisceration orders on fishing behavior and market structure. Each panel plots coefficients from separate regressions of the outcome variable on event-time dummies, with 95% confidence intervals (standard errors clustered by area). Event time is measured in days relative to evisceration order implementation (day 0). All specifications include area-season and season-day fixed effects. Panel a shows no significant changes in pot usage during evisceration periods. Panel b indicates slight increases in soak time in later periods, though estimates are imprecise. Panel c demonstrates that catch per unit effort (CPUE) remains stable throughout, suggesting fishing productivity is unaffected by evisceration requirements. Panel d shows no systematic changes in the number of active buyers/dealers, indicating processing infrastructure remains operational during evisceration periods. Collectively, these results indicate that evisceration orders do not disrupt core fishing operations or market structure, with price effects (Figure 1) occurring without corresponding changes in fishing behavior or processing capacity.95 % confidence intervals are plotted with point estimates. Standard errors are clustered at the area level.

To further examine whether evisceration orders disrupt fishing operations beyond price effects, Figure 7 presents event study estimates for fishing behavior and market structure variables. Panel a shows that pot usage—the primary measure of fishing effort—exhibits no systematic response to evisceration orders. Point estimates fluctuate around zero throughout the event window, with a slight positive spike around day 7 that is not statistically significant. This stability in effort deployment is consistent with vessels being constrained by pot limits and pre-positioned gear that cannot be easily relocated in response to short-term policy shocks. Panel b examines soak time, which could theoretically change if vessels alter their fishing strategies under evisceration requirements. While some later periods show positive coefficients suggesting slightly longer soak times, the wide confidence intervals and lack of a clear pattern indi-

cate no robust effect. Any potential increase in soak time does not translate into efficiency losses, as Panel c demonstrates that catch per unit effort (CPUE) remains stable throughout the treatment window. The flat CPUE response indicates that evisceration requirements do not affect the biological productivity of fishing operations—vessels continue to catch crab at similar rates regardless of whether they must eviscerate before sale. Finally, Panel d examines whether processing infrastructure contracts during evisceration periods by tracking the number of active buyers and dealers in each area. The estimates show no significant changes, indicating that the processing sector maintains operational capacity despite the additional evisceration requirements. This finding suggests that processors are able to adapt to the policy without reducing their participation in affected areas, at least over the time horizons examined in our event study. Taken together, Figures 6 and 7 paint a consistent picture: evisceration orders impose economic costs through substantial price reductions (40-50%), but do not trigger the extensive behavioral adjustments that might be expected from such large price shocks. Vessels continue fishing at similar intensity, with similar efficiency, and in similar numbers. This pattern of large price effects without quantity or operational responses highlights the constrained nature of short-run adjustment in derby fisheries, where switching costs, capacity constraints, and the compressed fishing season limit vessels' ability to respond to temporary regulatory shocks.

6.4 Does Testing Provide Information?

Additionally, the analysis is extended to incorporate domoic acid levels in both crabs and bivalves. Because bivalve contamination often precedes crab contamination due to the relationship between Dungeness crab and bivalves, and razor clam domoic acid testing results directly relate to whether or not crab testing occurs, it serves as an early warning signal that may influence fishers' expectations and behavior before an evisceration order is officially issued. By integrating these environmental indicators, whether vessels and markets respond preemptively to rising bivalve toxin levels can be assessed and whether such early responses mitigate or exacerbate the economic impact of evisceration orders.

The baseline model is extended to estimate the effect evisceration has on a vessel's probability of moving their sets towards areas that are not under an evisceration order. To capture this behavioral margin, a linear probability model (LPM) with fixed effects is employed. This provides an intuitive way to inter-

Table 11 Vessel

Dependent Variable= Moved String(s) to Untreated Area						
	(1)	(2)	(3)	(4)	(5)	(6)
Evis	0.103***	0.122***	0.120***	0.120***	0.119***	0.040
	(0.001)	(0.039)	(0.039)	(0.039)	(0.039)	(0.065)
Medium		0.000	0.000	0.000	-0.000	-0.000
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Small		-0.001	-0.001	-0.001	-0.001	-0.002
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Medium · Evis		-0.023	-0.025	-0.025	-0.025	0.019
		(0.045)	(0.045)	(0.045)	(0.045)	(0.047)
Small · Evis		-0.130***	-0.131***	-0.130***	-0.130***	-0.055
		(0.039)	(0.038)	(0.038)	(0.038)	(0.056)
DA Violation Crab			0.036	0.036	0.035	0.040
			(0.035)	(0.035)	(0.035)	(0.035)
DA Violation Bivalve				-0.010	-0.010	-0.009
				(0.006)	(0.006)	(0.006)
300 Potlimit						0.002*
						(0.001)
500 Potlimit						0.001
						(0.002)
300 Potlimit· Evis						0.015
						(0.052)
500 Potlimit · Evis						0.111
						(0.069)
Num.Obs.	80337	80337	80337	80337	80336	80336
R2	0.059	0.127	0.128	0.128	0.128	0.137
R2 Adj.	0.059	0.079	0.080	0.080	0.080	0.089
Season-Day FE	No	Yes	Yes	Yes	Yes	Yes
Vessel FE	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by vessel

pret coefficients directly as changes in probability. Compared to nonlinear models such as logit or probit, the LPM avoids complications with interpretation and facilitates the inclusion of vessel and time fixed effects to control for unobserved heterogeneity. In addition to vessel and time fixed effects, the specification also includes controls for environmental and economic conditions that directly influence fishing decisions and/or affect Dungeness crab. Ocean climate and weather data (wave height, swells, chlorophyll, nutrients, oxygen, temperatures, and primary production) capture the physical and biological constraints on crab dis-

tribution and fishing safety, while fuel cost data reflect variation in operational expenses across time, such control variables for weather and ocean conditions have been used in other studies (Soykan et al., 2014; Riekkola et al., 2024). These variables, combined with fixed effects, help isolate the effect of evisceration orders and domoic acid signals from broader environmental shocks or cost fluctuations that might otherwise confound vessel location choices. Although the LPM has known limitations its intuitive results and its compatibility with a fixed-effects framework make it a practical choice for this policy setting, where the primary interest lies in estimating average marginal effects rather than predicting individual probabilities. These estimates are shown in table 11. The regression results indicate that vessels are more likely to move their strings to untreated areas when their strings have been previously set in areas under an evisceration. This is a robust finding across each of the model specifications. However, although it is robust, the estimate is approximately 0.12, or roughly 12%, more likely to set pots in untreated areas. This is consistent with the previously presented findings. Vessels seem to be, as whole, unwilling to move into areas unfamiliar to them. This interpretation is justified by previous literature (Holland and Sutinen, 2000; Girardin et al., 2017).

6.5 Heterogeneous Price Impacts Across Ports

In this setting, suppliers, the upstream portion of the supply chain (the vessels), sell their catch to buyers (the dealers), the downstream segment of the supply chain. The fishery setting, specifically in this case, is a limited-entry derby fishery in which harvesters sell to a concentrated processing sector. Ex-vessel prices are typically determined through bargaining rather than a centralized auction, and processors differ in scale and processing capacity. A policy requiring landings to be sold eviscerated rather than live alters both the set of feasible product forms and the timing and capacity constraints faced by buyers. One would expect that live product commands a premium relative to other forms of crab (eviscerated, cooked, frozen), due to quality differentiation, market access, and downstream demand. The evisceration requirement, therefore, removes the high-value outlet and imposes additional handling and throughput constraints on processors. As emphasized by Matulich et al. (1996), when processing capital is non-malleable, such constraints can alter raw-fish prices by altering bargaining conditions rather than final demand. In the short run, processing capacity is non-malleable: equipment, labor, and logistics cannot be costlessly adjusted within the season.

As a result, the evisceration requirement shifts processors' effective demand for raw fish downward and/or increases their marginal costs, implying a reduction in equilibrium ex-vessel prices. This is the direct policy effect and motivates the expectation that the policy dummy enters negatively in price regressions.

Table 12 Heterogeneous Price Impacts of Evisceration Orders Across Ports and Buyer Structure

	(1)	(2)	(3)	(4)
Panel A				
Evis	-0.517***	-0.511***	-0.510***	-0.509***
	(0.106)	(0.111)	(0.108)	(0.115)
Port-Large Dealer	-0.264***			
	(0.043)			
PortGroup-Large Dealer		-0.300***		
		(0.070)		
Port Top 8			-0.125*	
			(0.060)	
Port Group Top 8				-0.135*
				(0.075)
R^2	0.898	0.898	0.897	0.897
R^2 Adj.	0.892	0.892	0.891	0.891
Panel B				
Evis	-1.269***	-1.051***	-0.849	-1.804***
	(0.345)	(0.151)	(0.573)	(0.494)
Port-Large Dealer	-0.269***			
	(0.043)			
Evis: Port-Large Dealer	0.937***			
	(0.334)			
PortGroup-Large Dealer		-0.304***		
		(0.069)		
Evis: PortGroup-Large Dealer		0.654***		
		(0.142)		
Port Top 8			-0.127*	
			(0.060)	
Evis: Port Top 8			0.460	
			(0.675)	
Port Group Top 8				-0.138*
				(0.074)
Evis: Port Group Top 8				1.699**
				(0.549)
Num. Obs.	10,768	10,825	10,768	10,825
R^2	0.898	0.898	0.897	0.897
R^2 Adj.	0.892	0.892	0.891	0.891
FE: Area-Port	X	X	X	X
FE: Season-Week	X	X	X	X
Controls	Yes	Yes	Yes	Yes

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses clustered by area. Derby controls: dummies for opening week (1–3), early season (4–6), late season (12+).

Table 12 shows that the price impacts of evisceration orders vary across ports and dealers. A larger dealer is defined as having average seasonal landing volume in pounds above the 90th percentile prior to the 2016-2017 season; a Top 8 dealer is simply among the eight largest dealers over the same period. These separate measures are used to assess sensitivity and as a robustness check that buyer size is not an artifact of its definition. Port refers to the specific landing port, while Port Group refers to the PACFIN regional aggregation; the two levels of spatial aggregation are used to assess whether price heterogeneity reflects local buyer access or broader regional market structure. While evisceration reduces ex-vessel prices by approximately 50 cents per pound on average, the magnitude of this effect is substantially larger in ports and regions dominated by smaller buyers. In contrast, vessels landing in ports with greater exposure to large, high-volume or in PACFIN regions, dominated by larger buyers, experience significantly smaller price penalties. Such results suggest that the economic incidence of evisceration depends on access to processing capacity and market outlets.

7 Discussion

The findings show that the evisceration policy, while allowing vessels to continue fishing rather than closing completely, imposes negative market effects on harvesters, primarily through prices. Ex-vessel prices are estimated to fall by roughly 40 cents per pound; ex-vessel revenues, on average, similarly decrease by $3,746. While the analysis finds some negative effects of the policy on vessel landings and effort, the event study findings show these are not economically meaningful. Some evidence suggests vessels relocate from treated to untreated areas, but this effect is also largely negligible. Importantly, heterogeneous responses indicate that small vessels bear disproportionate burdens, while larger vessels are less affected by the policy.

This is in contrast to the findings of Wu et al. (2026), who study the effects of full closures and find that under complete closures harvesters adapt intertemporally: during closures harvesters will adapt spatially, and substitute into other fisheries, but fish intensively once the closure is lifted, and revenues rebound sharply after the closure is lifted. Evisceration orders, by contrast, operate differently. By allowing harvesters the ability to catch crab, the rebound effect of harvesters having the incentive to fish intensively through higher revenues after closures is moderated, as the main constraint on the fishery through evis-

ceration is the value of the harvested product, not an inability or restriction to harvest. Thus, the limited changes in effort, vessel participation, and location, found in the above analysis, complement the findings by Wu et al. (2026).

The results estimated through the analysis in this study are also congruent with previous research on the evisceration policy in the Dungeness crab fishery. As such it supports the findings of Abken and Jardine (2026), who found that the evisceration policy in Washington state reduces ex-vessel prices by 26.5-33.5% and results in a $10.5 million loss in market value. In contrast to previous studies that use spatial-temporal models or classify vessels into behavioral types to analyze the change in spatial behavior of fishing fleets (e.g., Liu et al. (2023); Soykan et al. (2014); Riekkola et al. (2024)), this paper utilizes regulatory intervention with clearly defined timing to exploit pre-policy baselines to identify causal effects on economic outcomes, and traces out how the policy is transmitted through prices, quantities, and vessel behavior. Results indicate that the effects of the evisceration policy operate largely through prices, as prices fall rapidly during the days following policy implementation, while landings, ex-vessel revenues, and other vessel behavioral margins (effort and participation) do not exhibit similar rapid adjustment. Given that the policy is relatively short-lived, the observed revenue losses during evisceration can largely be attributed to lower prices. Evisceration effectively eliminates access to live markets, which forces vessels to sell their catch to less lucrative markets. At the same time, both processors and vessels face short-run constraints that limit their ability to fully adjust to the policy shock.

Taken together with Wu et al. (2026), the results suggest that the form of regulation determines the margins along which harversters adapt. Wu et al. (2026) show that the dominant response occurs through the temporal margin, with fishing activity rebounding sharply after a closure is lifted as harvesters return to the relatively high returns available in the Dungeness crab fishery. A policy like evisceration preserves access to the resource but restricts how harvesters can sell the extracted resource, narrowing the set of relevant short-run responses. The observed price reduction under evisceration appears to be insufficient to induce harvesters to adapt along similar margins found by Wu et al. (2026). The absence of significant change in vessel behavior should not be seen as a lack of adaptive capacity among harvesters; rather, it shows how the policy shifts the focus to which margins of adjustment are economically relevant.

Future work would need to consider a vessel's choice to leave port when confronted with weather hazards and seasonal delays (Vassan, 2024). These results, then, highlight the role of institutional and market constraints that shape the margins of adjustment following a policy shock. The event-study estimates provide the clearest identification evidence in the analysis. Prices respond within days of order implementation, and no detectable anticipatory response appears beyond what rising domoic acid levels in co-occurring bivalves already explain; this supports the claim that harvesters are not selectively entering or exiting around treatment in ways that would bias the estimates. The rapidity of the price response also implies that harvesters have negligible opportunity to hedge through timing adjustments, which reinforces the interpretation that revenue losses are structurally imposed rather than partially avoidable. The analysis leaves one important methodological limitation unaddressed: because the identification strategy focuses on aggregate behavioral margins, it does not fully resolve compositional changes within those aggregates, including the possibility that certain vessel types selectively abstain during evisceration periods. Sant'Anna and Xu (2026) demonstrates that such compositional changes can bias difference-in-differences estimators even when standard identifying assumptions are satisfied; the extent to which that bias affects the present estimates warrants further analysis in subsequent work.

8 Conclusion

Climate change is raising the demand for adaptive fisheries. Adaptive fishery management must preserve economic activity amid ecological upheaval without jeopardizing public health or conservation objectives, and the evisceration order is one such policy attempt aimed at those goals. Rather than close the fishery when domoic acid accumulates in crab viscera, managers permit harvest to continue under modified market conditions. Oregon evidence shows that this partial opening sustains fishing activity during these biotoxin events, though it does so at a cost borne primarily by prices rather than by harvest behavior. The instrument therefore preserves physical harvest while compressing revenue.

Using staggered evisceration orders in the Oregon Dungeness crab fishery, the research results show how harvesters adjust to an adaptive regulatory shock. Tracing the policy through prices, quantities, and vessel behavior, the results show that the adjustment is almost entirely through prices. Ex-vessel prices fall by roughly 10 to 15 percent within days of implementation and recover as orders are lifted, while land-

ings, effort, and participation move little. Harvesters continue to fish despite losing the premium live-crab market, which locates the policy's effect in revenue rather than in production. Evisceration thus preserves physical harvest while compressing what that harvest earns.

The result is consistent with standard economic predictions on short-run behavioral adjustment. When gear is passive (pre-positioned), the harvest season is compressed, and buyer relationships are fixed, the behavioral elasticities available to a firm are small, exactly as the Le Chatelier principle predicts under binding short-run constraints. The evidence is broadly consistent with that prediction: harvesters absorb the shock through lower revenue rather than through relocation or exit, because the margins along which they might otherwise adjust are unavailable within a brief order window. Measured against a full closure, the instrument plausibly delivers substantial benefit, even as much of its cost appears to be transmitted through lower prices and revenues.

The analysis carries several limitations that temper its claims. The estimates are reduced-form and capture broad behavioral responses to a novel instrument; they do not recover the vessel-level decision process underlying participation, movement, or buyer choice. More fundamentally, reduced-form estimates recover behavior under the regulatory environment observed in the data. If adaptive management instruments become more common or more persistent, harvesters may alter production practices, buyer relationships, or investment decisions in ways that are not captured by short-run responses. Structural approaches would be better suited to evaluating such longer-run adaptation. A secondary finding deserves mention: the price effect is not distributed uniformly, falling more heavily on smaller vessels and on ports served by smaller buyers. This heterogeneity is suggestive rather than definitive, and it warrants dedicated treatment before it can carry weight. Compositional change poses a related concern, since vessels that wait out evisceration periods rather than participate can bias difference-in-differences estimates when treatment alters the composition of observed firms, and a structural discrete-choice framework supplies a natural way to address both margins directly.

The more general lesson concerns how regulatory structure interacts with firm flexibility. As marine heatwaves, harmful algal blooms, and similar disruptions become more frequent, managers will more frequently rely on adaptive instruments. The evidence here suggests that such instruments can preserve economic activity even under severe environmental constraints. In Oregon's Dungeness crab fishery, evis-

ceration orders maintained harvest, effort, and participation during contamination events while averting the far larger losses associated with a full closure. At the same time, the costs of doing so were not distributed evenly across vessels and ports. Climate-ready fisheries management therefore calls for not only flexible regulatory tools, but careful attention to who bears the costs when those tools are deployed. Adaptive regulation can work, but its performance depends on the institutional and economic context in which it operates.

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A Appendix

A.1 Data Construction

The primary analysis uses a dataset constructed from logbook entries matched to the ticket data. Tickets indicate the date on which a vessel records a sale to a dealer and do not give information on where the vessel harvested the crab. The spatial information is derived from the reported logbooks. The logbooks provide a vessel's self-reported start and end points for a string, the date the gear was pulled, and the length of time the gear was set (soaking).[5]The caveat is that logbooks are self-reported and do not match all tickets, with the percentage of tickets that match logbooks varying widely across seasons. While the matched logbook-ticket data underreports the total landings, the sample means of ex-vessel prices of both groups, the complete ticket dataset, and the matched logbook subset, are not statistically different using a t-test, suggesting that although the matched data is incomplete, they appear representative notwithstanding the volume mismatch. The dataset is constructed as follows. Logbooks are matched to tickets. Using the spatial coordinates from the logbooks, the pots along the string are simulated under the assumption of an even distribution, meaning each pot is assigned a percentage of the total harvest reported for that string. Then these simulated pots are summed for each area and vessel, as well as the port of landing, using the reported logbook spatial coordinates for location and date, which is key since strings can be placed across management areas. This method allows the catch from each string to be allocated spatially by area. These pots, revenues, and prices are averaged by each vessel's reported landing date before being further aggregated across all vessels on a weekly or daily basis. Then, the weather data, fuel price data, and testing data are attached to the corresponding weekly or daily dataset.

A.1.1 VMS

Further data provided by the National Marine Fisheries Science Office of Law Enforcement (NMFS OLE) is available in the form of vessel-monitoring system data. This data is acquired from satellite surveillance systems that are primarily used to monitor the location and movement of commercial vessels. Not all vessels participate in the program, as only certain vessels are required to do so. Those vessels that are required to

[5]While it is true that, as Abken and Jardine (2026) report, the ticket data does not report a catch area variable, this can be inferred from the reported matched logbooks.

participate include vessels with a limited entry 'A' permit for groundfish; vessels that use non-groundfish trawl gear to fish in the exclusive economic zone (EEZ), which extends 200 nautical miles beyond a nation's territorial sea; or any vessel that uses open access gear to fish groundfish in the EEZ or land any groundfish harvested in the EEZ. Generally, vessels are required to transmit accurate signals 15 minutes every 24 hours throughout the fishing year unless they have an exemption due to vessel maintenance, being in port, experience a long-term departure from the fishery, or some other valid reason allowed by the NFMS OLE code 660.14(d)3(ii). In the provided dataset, transmission signals occur roughly every hour, except when the vessel is in port, no longer in use, or conceivably for some other exception and or telemetry error. Due to these requirements, the number of vessels in logbooks and VMS data differs. The logbook data shows 625 unique vessels, but only 406 appear in the VMS data. VMS data provides 25 million observations of these vessels' activity, which, after filtering out vessel inactivity and other VMS anomalies, leaves 103,780 potential "trips," defined as the vessel steaming out of port and then returning to port. The average trip duration is 3 days, and the trips are matched to the fish tickets using the reported landing dates as a filter. These trips can be matched to the logbooks using the ticket number. Prior to trip identification, VMS polls (records) representing non-seagoing or port/inland states are removed, as are records flagged as erroneous. For the remaining pings, the time elapsed between successive pings within each vessel track is computed by ordering records chronologically and calculating the lagged time difference (in hours). This inter-poll interval is used as a measure of segment duration and as a diagnostic for signal gaps. Fishing trips are delineated for each vessel using a sequential time sequence. Trips were initiated when a vessel transitioned to a seagoing state (e.g., a 'DEPART' event, or an 'AT SEA' event immediately following an 'ARRIVE' event). While a trip was 'open', all qualifying at-sea events were assigned a trip identifier. Trips are terminated when (i) an 'ARRIVE' event occurred (with the arrival record retained as part of the trip), or (ii) a large temporal gap between consecutive pings exceeded a predefined threshold (used to detect VMS signal breaks, e.g., 4 hours). All VMS records without an assigned trip ID were excluded from trip-level spatial summaries. Furthermore, duplicate polls (identical timestamps and coordinates for each vessel) were removed. Trip duration is calculated as the difference between the trip's end and start timestamps (in days). To associate VMS activity with each ticket, a temporal window is constructed for each vessel's ticket that represents plausible fishing activity leading up to the landing date. For each vessel, an 'end-of-day' times-

tamp is created for the ticket landing date (23:59:59 local time). The start of the window begins as the later of:

(i) A fixed lookback window prior to the landing date (e.g., 12 days), and

(ii) The end time of the previous ticket for that vessel (to prevent overlap and double counting across sequential tickets).

This produces a variable-length ticket window with an associated duration (days). VMS records are then matched to tickets by vessel ID, but the match is constrained by time: VMS trip end times must fall within the ticket's window. Records with no VMS match were retained and flagged with a binary indicator to support later diagnostics of unmatched tickets. A series of filters is then used to remove likely erroneous VMS polls following (Liu et al., 2023). Specifically, polls are excluded if they are inconsistent with reported landing ports, exhibit implausible speeds, or occur within port buffers at low speeds. To match VMS pings to logbook strings, logbook records are joined to ticket-linked VMS data by vessel ID and ticket number. Retaining only 'AT SEA' VMS observations for each logbook haul, a broad temporal window spanning ±1 day around the set date and ±1 day around the pull date is used, and thus only VMS pings occurring within these windows are kept. Logbooks are then assessed by constructing a line segment between the start and end coordinates and measuring distances from candidate VMS pings to this line; a logbook record is considered supported if at least one set or pull-window ping fell within a specified distance threshold (e.g., 5.6 km) accounting for the hour polling interval and average speed of a vessel actively fishing being between 0.5-3 knots. A 5.6 km buffer is used to account for logbook entry errors and the upper threshold for vessel speed that is commonly as a speed that is characteristic of fishing (Gerritsen and Lordan, 2010).These steps are summarized in figure 3.

A.2 Sensitivity to Temporal Fixed Effect Specifications

Appendix Table A1 examines the robustness of our main results to alternative definitions of time fixed effects. Column 1 reproduces our preferred specification using calendar-date season-week fixed effects, which shows evisceration orders reduce prices by $0.52 per pound. Column 2 substitutes fishery-week fixed effects (weeks since season opening) for calendar-week controls. This specification produces an at-

tenuated and statistically insignificant coefficient of -$0.04. The attenuation occurs because evisceration orders are not randomly distributed across fishery weeks—they systematically occur 8-15 weeks into the season when domoic acid risks peak following winter upwelling patterns. The fishery-week fixed effects absorb much of this systematic variation, reducing within-group variation (R^2 Within falls from 0.010 to 0.004). Essentially, this is comparing 'Week 10 with evisceration' to 'Week 10 without evisceration' across different areas and seasons, but there are few control observations at those specific fishery weeks, leaving insufficient variation for precise estimation. Column 3 includes both calendar-date and fishery-week fixed effects simultaneously. The point estimate becomes more negative (-$0.7), but the standard error nearly doubles (0.24 vs. 0.14) due to collinearity between the two temporal control sets. The fact that the point estimate remains negative and significant despite the loss of precision suggests the treatment effect is robust, but the specification sacrifices statistical power unnecessarily. Column 4 uses coarser calendar-month rather than calendar-week fixed effects, producing an even larger negative effect of -$0.88. This specification has greater statistical power because it uses less granular time controls, though it may not fully account for within-month variation in market conditions. The consistency in sign and significance across Columns 1 and 4 confirms that the main results are not artifacts of the specific temporal aggregation. Column 5 removes all within-season time controls, including only area and season fixed effects. The treatment effect is -$0.66, similar in magnitude to other specifications but with much higher R^2 Within (0.195), indicating that the treatment variable explains substantial within-area-season variation when we do not partial out weekly or monthly patterns. This specification may be biased if evisceration timing correlates with within-season price trends, which is why the preferred specification is with within-season time controls. Across all specifications except Column 2 (fishery-week FE), the treatment effect ranges from -$0.52 to -$0.88 per pound and is statistically significant. The fishery-week specification is an outlier not because evisceration has no effect, but because non-random treatment timing relative to fishery stage causes this specification to over-control and absorb treatment variation. The preferred calendar-week specification (Column 1) balances the need to control for time-varying confounds while preserving sufficient identifying variation, making it the most appropriate choice for estimating average treatment effects.

Table A1 Effect of Evisceration Orders on Dungness Crab Vessel Outcomes

	Baseline	Derby Controls	Weighted (Baseline)	Weighted (Derby)	Fishery Week FE	Area-Season FE
Evis	-0.515***	-0.748***	-0.433***	-0.255***	-0.042	-0.664***
	(0.135)	(0.184)	(0.076)	(0.079)	(0.118)	(0.084)
pct_large_vessels	-0.083	-0.083	0.030	0.035	-0.087	-0.463**
	(0.152)	(0.152)	(0.041)	(0.039)	(0.141)	(0.178)
n_active_vessels	-0.007	-0.007	0.000	0.001	-0.006	-0.047***
	(0.006)	(0.006)	(0.002)	(0.002)	(0.007)	(0.005)
opening_weekTRUE		0.195*		-0.332***		
		(0.099)		(0.043)		
early_seasonTRUE		0.613***		-0.095		
		(0.179)		(0.090)		
late_seasonTRUE		0.075		0.517		
		(0.257)		(0.359)		
Num.Obs.	6143	6143	6130	6130	6143	6143
R2	0.906	0.907	0.969	0.969	0.885	0.576
R2 Adj.	0.894	0.894	0.964	0.965	0.873	0.574
R2 Within	0.010	0.012	0.019	0.029	0.004	0.195

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area

This table examines robustness of the main price effects to alternative specifications and weighting schemes. Column 1 reproduces our baseline specification with calendar week fixed effects and composition controls. Column 2 adds derby timing controls (opening week, early season, late season dummies) to account for systematic within-season price patterns—this is our preferred specification. Columns 3-4 weight observations by pre-treatment baseline landings to emphasize economically important fishing areas; the weighted estimates are somewhat smaller but remain negative and significant. Column 5 uses fishery week fixed effects (weeks since area-specific opening) instead of calendar week fixed effects. The attenuated coefficient (-$0.042) in this specification reflects that fishery week fixed effects over-control for the systematic timing of evisceration orders: domoic acid events occur at predictable stages of the fishing cycle, and fishery week FE absorb this variation as part of "normal" seasonal patterns rather than as policy-relevant shocks. The low within-R^2 (0.004) confirms limited identifying variation remains after these controls. Column 6 uses area-season fixed effects, the most restrictive specification, which produces similar results to our preferred specification (-$0.664). Across all specifications except the fishery week model, evisceration orders consistently reduce prices by $0.25-$0.75 per pound.

A.3 Vessel Heterogeneity

Figure ?? shows the distribution of average weekly landings per vessel across fishing season stages, by vessel characteristics. Panel a shows heterogeneity by pot limit (200, 300, or 500 pots), while Panel b shows variation by vessel size (large ≥50 feet, medium 30-50 feet, small <30 feet). Box plots show median (center line), interquartile range (box), and 1.5×IQR whiskers, with outliers plotted individually. The dramatic opening-week heterogeneity–with 500-pot vessels reaching 40,000-60,000 pounds while 200-pot vessels peak around 10,000 pounds–illustrates how capacity constraints shape derby fishing outcomes. All vessel types exhibit sharp declines across season stages as local stocks deplete, converging toward low levels (500-2,000 lbs) by late season regardless of vessel capacity. The extreme right-skew in landings distributions, particularly for large and high-pot-limit vessels during opening weeks, explains why log specifications produce different results than levels specifications (see Table 5, Column 6): treatment effects operate primarily through absolute changes among high-capacity vessels rather than proportional changes across all vessel types.

In similar fashion ?? shows the distribution of average ex-vessel revenues across the season by vessel types. Again panel a is by pot limit, and panel b is by vessel size. Similar conclusions can be made. Larger vessels have consistently higher revenues as do vessels with higher pot limits. The same trend over the course of the season is also illustrated. The intial week sees substantial revenues that declines dramtically as the season reaches even into mid portion of the season.

A.4 Vessel Exit

Following along the lines of possible vessel behavior is the hypothesis that evisceration orders can cause vessels to exit the fishery. Vessels will continue to operate in the fishery so long as it remains profitable. To analyze this extensive margin, the analysis adopts a survival analysis framework and follows Bloomquist and Waldo (2021). Essentially, this analysis addresses whether the policy increases the probability that a vessel exits the fishery during the season.

Let i index fishing vessels, s index fishing seasons, and $w = 1, \ldots, W_s$ index weeks within season s. A vessel is considered at risk in week w if it has participated in at least one fishing operation earlier in season s. An exit occurs when a vessel ceases fishing activity for a week during the season, conditional on having

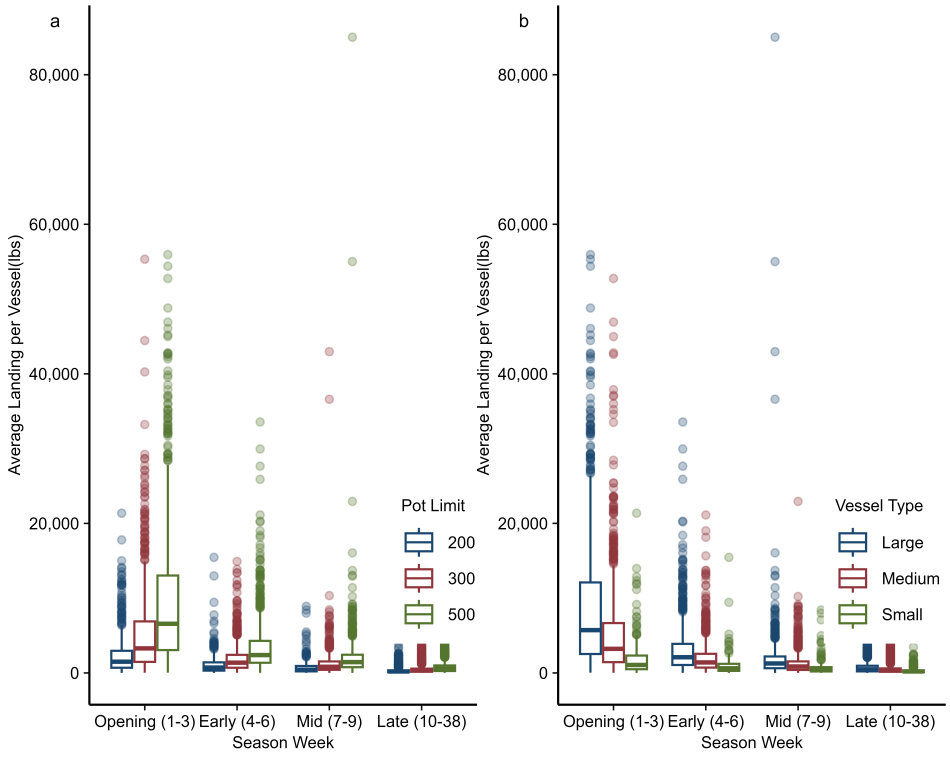


Figure 8 Vessel Landings Across Types

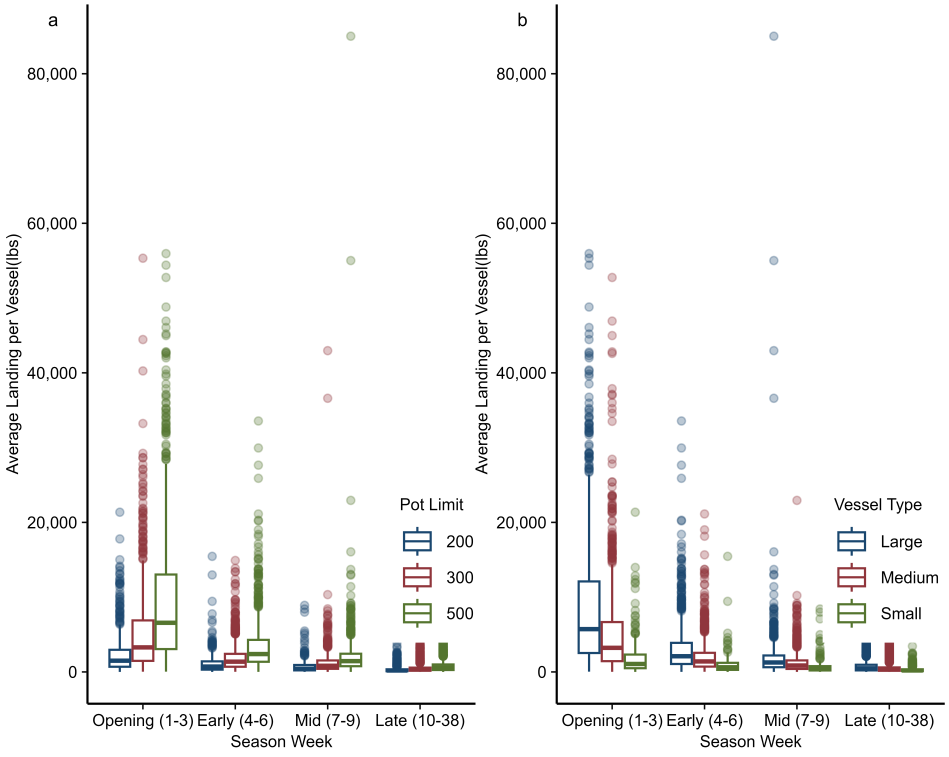


Figure 9 Revenues Across Vessel Types Revenues are adjusted to 2020 USD prices.

been active up to week $w-1$. Ceasing activity means, in this case, that a vessel has no landings and no gear in the ocean. Vessels may have multiple spells within a season. Let T_{is} denote a discrete non-negative random variable measuring the number of weeks vessel i remains active in season s.

The main quantity of interest is the weekly hazard of seasonal exit, defined as the conditional probability that vessel i exits in week w of season s, given that it has remained active through week $w-1$:

$$\lambda_{isw} = P(T_{is} = w \mid T_{is} \geq w, x_{isw}) = F\left(x'_{isw}\beta + \gamma_{sw}\right).$$

The model variables include x_{isw}, a vector of observed explanatory variables measured at the vessel–season–week level; β, a vector of parameters to be estimated; and γ_{sw}, which captures baseline duration dependence. The function $F(\cdot)$ is a cumulative distribution function that ensures the hazard lies in the unit interval. Consistent with Blomquist and Waldo (2021), duration dependence is modeled non-parametrically by specifying γ_{sw} as a full set of week-of-season dummy variables, allowing the exit hazard to vary flexibly over the course of the season.

The main explanatory variable of interest captures within-season conditions experienced by the vessel, measured at the weekly level. These may include vessel characteristics (e.g., vessel length) or time-varying local conditions. Season fixed effects are included to account for inter-seasonal variation in stock conditions, prices, regulations, and other factors common to all vessels within a season. Identification of within-season exit behavior therefore relies on intra-season, intra-vessel variation.

Under standard assumptions for discrete-time duration models, the parameters of the hazard function can be estimated by maximum likelihood, treating the data as a binary outcome indicating exit in week w conditional on survival to that week. As in the reference study, the analysis considers alternative distributional assumptions for $F(\cdot)$, including logistic, probit, and complementary log–log specifications, to verify that the main results are robust across different distribution functions.

Control variables include the average weekly price of Dungeness crab per pound; the weekly average diesel fuel price per gallon; the average weekly eastward wind; the average weekly northward wind; vessel length; and the share of Dungeness crab revenue. Following Mundlak (1978) and Blomquist and Waldo (2021), correlated random effects are used to control for unobserved vessel heterogeneity by including time-averaged vessel-level means of time-varying covariates.

The estimated coefficients describe how changes in weekly conditions affect the probability of exiting the fishery before the end of the season. Because the model is nonlinear, average marginal effects are reported, evaluated over the observed distribution of covariates. These results are shown in Table 14, with marginal effects reported in Table 15.

Table A2 Evisceration and Season Exit

	(1)	(2)	(3)
Panel A: No Controls			
Evis	-0.035	0.001	-0.064
	(0.189)	(0.101)	(0.160)
R^2 (McFadden)	0.329	0.329	0.328
Log likelihood	-15,428.341	-15,423.334	-15,436.042
Observations	39,599	39,599	39,599
Panel B: Controls			
Evis	0.250	0.143	0.198
	(0.193)	(0.106)	(0.159)
Revenue	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Fuel	0.036	0.015	0.028
	(0.043)	(0.024)	(0.036)
East Wind	-0.037***	-0.021***	-0.022*
	(0.014)	(0.008)	(0.012)
North Wind	-0.088***	-0.050***	-0.070***
	(0.007)	(0.004)	(0.006)
Crab Price	0.282***	0.171***	0.180***
	(0.025)	(0.014)	(0.018)
Crab Share	-0.211*	-0.122*	-0.174*
	(0.123)	(0.068)	(0.103)
R^2 (McFadden)	0.555	0.556	0.552
Log likelihood	-15,004.750	-15,000.255	-15,054.910
Observations	26,756	26,756	26,756

Notes: Robust standard errors in parentheses clustered by vessel. ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels, respectively. Controls include revenue, fuel price, wind conditions, crab price, and crab revenue share. Time-varying vessel averages are omitted for brevity. Dummies for duration and season–week are included in all specifications.

Table A3 Average Marginal Effect (AME) of Evisceration on Season Exit

Term	Estimate	Std. Error	Statistic	p-Value	Conf. Low	Conf. High	Model
Panel A: No Controls							
Evis	-0.004	0.022	-0.187	0.852	-0.048	0.232	Logit
Evis	0.000	0.022	0.006	0.995	-0.043	0.007	Probit
Evis	-0.009	0.022	-0.407	0.684	-0.052	0.548	Cloglog
Panel B: Controls							
Evis	0.031	0.025	1.235	0.217	-0.018	0.081	Logit
Evis	0.032	0.025	1.294	0.196	-0.016	0.080	Probit
Evis	0.030	0.025	1.179	0.239	-0.020	0.080	Cloglog

Notes: Reported coefficients are average marginal effects (AMEs) of evisceration orders on the probability of exiting the fishery during the season. Estimates are evaluated at the observed distribution of covariates. Specifications differ by assumed distribution of the hazard function (logit, probit, complementary log–log). Control specifications include revenue, fuel prices, wind conditions, crab prices, crab revenue share, duration dummies, season–week fixed effects, and correlated random effects.

The analysis above focuses on how the policy of evisceration affects the probability that a vessel exits the crab fishery during the season, and not whether a vessel decides to permanently leave the fishery. The above results show that evisceration is associated with a higher probability of exiting the fishery, but this estimate is not statistically significant. The control variables in the model have expected signs, except for crab price, which is positive. The positive coefficient on crab likely reflects the fact that price is endogenous to within-season market conditions since prices follow market outcomes. The vessel-level mean price for crab is negative, so a higher price in general reduces the probability that a vessel exits the fishery.

A.5 Event Study

Table reports the regression results following Wing et al. (2024).

Table A4 Event Study Regression Results

	Price($per pound)	Revenue	Landings	n Active Vessels
	(i)	(ii)	(iii)	(iv)
Treated × Event-time = -14	-0.6933*	51,605.9	16,804.1	-1.179*
	(0.3268)	(32,135.5)	(10,890.3)	(0.6373)

Continued on next page

Table continued from previous page

	Price($per pound)	Revenue	Landings	*n* Active Vessels
	(i)	(ii)	(iii)	(iv)
Treated × Event-time = -13	-0.0036	-1,276.7	-369.8	1.048
	(0.2576)	(3,170.4)	(947.2)	(1.503)
Treated × Event-time = -12	0.2161	-1,120.7	-506.0	5.587
	(0.2181)	(3,910.1)	(1,253.3)	(3.515)
Treated × Event-time = -11	0.0937	19,689.1	5,578.2	6.144**
	(0.3735)	(17,344.2)	(5,633.6)	(2.491)
Treated × Event-time = -10	0.2144	10,228.6**	2,401.1**	1.885**
	(0.2524)	(3,375.1)	(1,080.9)	(0.7661)
Treated × Event-time = -9	-0.1003	5,746.1	1,740.2	3.487**
	(0.1749)	(4,218.5)	(1,150.7)	(1.263)
Treated × Event-time = -8	-0.4489**	12,616.5**	3,770.9**	1.531
	(0.2000)	(4,309.3)	(1,223.6)	(1.053)
Treated × Event-time = -7	0.1432	3,922.5	1,105.4	1.226
	(0.1899)	(2,977.9)	(887.2)	(1.749)
Treated × Event-time = -6	-0.2609	6,775.5	1,980.5*	1.184
	(0.2684)	(3,782.7)	(1,069.1)	(1.267)
Treated × Event-time = -5	0.3033	11,522.4	3,004.9	0.7810
	(0.2291)	(10,336.9)	(2,738.2)	(0.5635)
Treated × Event-time = -4	0.2028	21,033.7**	5,143.9**	1.414
	(0.2143)	(7,428.1)	(1,837.8)	(0.8281)
Treated × Event-time = -3	-0.1346	12,613.3	3,313.9	0.6966
	(0.2321)	(12,761.9)	(3,491.3)	(0.5953)
Treated × Event-time = -2	0.1820	24,561.5	6,569.1	1.096**
	(0.3962)	(15,106.1)	(4,055.5)	(0.4896)

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	Price($per pound)	Revenue	Landings	*n* Active Vessels
	(i)	(ii)	(iii)	(iv)
Treated × Event-time = 0	-0.2368	1,442.3	358.3	0.5126
	(0.1812)	(1,914.3)	(667.7)	(0.8040)
Treated × Event-time = 1	-1.203***	5,799.1	2,045.6	0.5051
	(0.2779)	(4,201.0)	(1,423.0)	(0.7206)
Treated × Event-time = 2	-0.4058	5,771.3	2,218.8	0.4544
	(0.3807)	(4,794.7)	(1,823.9)	(0.7002)
Treated × Event-time = 3	-0.3890	10,002.8	3,447.2	2.725
	(0.5378)	(13,030.4)	(4,353.7)	(1.702)
Treated × Event-time = 4	-1.633***	1,783.9	947.4	1.874
	(0.2943)	(2,105.5)	(691.8)	(1.201)
Treated × Event-time = 5	-0.9118***	4,569.5**	1,617.8***	0.3687
	(0.1897)	(1,477.6)	(502.4)	(1.216)
Treated × Event-time = 6	-0.7755***	8,156.7***	2,359.8***	0.7314
	(0.2239)	(1,715.0)	(380.8)	(0.7063)
Treated × Event-time = 7	-0.6130	4,005.3	1,327.7	1.600*
	(0.3516)	(5,518.1)	(1,473.7)	(0.8506)
Treated × Event-time = 8	-0.3597	105.9	213.0	3.043*
	(0.2590)	(2,074.3)	(569.3)	(1.614)
Treated × Event-time = 9	-0.8215***	9,834.4	4,034.5*	1.163
	(0.1798)	(5,914.0)	(1,984.3)	(0.8148)
Treated × Event-time = 10	-0.4278	5,688.7*	1,505.3*	-1.073
	(0.3320)	(3,145.8)	(796.1)	(0.6122)
Treated × Event-time = 11	-0.5578*	-990.5	-112.2	0.2272
	(0.2886)	(1,898.9)	(502.9)	(0.6258)

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Table continued from previous page

	Price($per pound)	Revenue	Landings	*n* Active Vessels
	(i)	(ii)	(iii)	(iv)
Treated × Event-time = 12	-0.0876	13,929.7**	3,675.8**	0.0653
	(0.2820)	(6,038.6)	(1,548.7)	(0.9056)
Treated × Event-time = 13	-0.8083**	644.2	465.5	1.984
	(0.3352)	(1,873.9)	(508.6)	(1.948)
Treated × Event-time = 14	-0.2096	1,258.7	372.9	1.400
	(0.1690)	(2,232.9)	(637.3)	(0.8803)
Observations	1,533	1,533	1,533	1,533
R^2	0.09035	0.12313	0.12416	0.08080
Within R^2	0.01963	0.04584	0.04208	0.02679
Treated in Sub-experiment FEs	✓	✓	✓	✓
Event-time FEs	✓	✓	✓	✓

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A5 Leave-One-Sub-Experiment-Out Robustness

Sub-experiment Dropped	Estimate	SE	t-statistic	p-value	No. Coefficients	Clusters	WCB p-value	WCB 95% CI
None (Full Sample)	-0.775	0.259	-2.995	0.012	2	12	0.021	[-1.3375, -0.0667]
Feb 2017	-0.932	0.286	-3.262	0.008	2	12	NA	NA
Feb 2018	-0.867	0.375	-2.315	0.041	2	12	NA	NA
Feb 2019	-0.904	0.378	-2.392	0.036	2	12	NA	NA
May 2019	-0.281	0.080	-3.493	0.005	2	12	0.002	[-0.5007, -0.096]
May 2023	-0.920	0.259	-3.547	0.005	2	12	NA	NA

Table A6 reports the treated and control areas for each sub-experiment. Because the evisceration order in the 2016-2017 season did not utilize the management areas that were defined after that season's conclusion the event study design does not include area 50-I as a treated area.

Table A6 Sub-experiment Composition

Sub-Experiment	Season	Treatment Date	# Treated	# Control	Treated	Controls
1	2016-2017	2017-02-02	2	9	50-G 50-H	50-A 50-B 50-C 50-D 50-E 50-F 50-J 50-K 50-L
2	2017-2018	2018-02-16	2	10	50-K 50-L	50-A 50-B 50-C 50-D 50-E 50-F 50-G 50-H 50-I 50-J
3	2018-2019	2019-02-14	3	9	50-J 50-K 50-L	50-A 50-B 50-C 50-D 50-E 50-F 50-G 50-H 50-I
4	2018-2019	2019-05-10	2	10	50-K 50-L	50-A 50-B 50-C 50-D 50-E 50-F 50-G 50-H 50-I 50-J
5	2022-2023	2023-05-01	3	9	50-H 50-I 50-J	50-A 50-B 50-C 50-D 50-E 50-F 50-G 50-K 50-L

A.6 Spillover Robustness Check VMS

An alternative model uses VMS data to model spillovers by considering how much time a vessel spends 'fishing' or crabbing. This model does not consider soak time and also assumes that the form of the vessel fishing hours can be estimated using a linear function. Fishing effort was summarized using a 5 X 5 km spatial grid. A regular grid was generated and assigned to management areas. VMS records were filtered to remove implausible vessel speeds (>30 knots) and restricted to positions recorded while vessels were at sea. Fishing activity was identified based on vessel speed, with positions classified as fishing when the mean speed was between 0.5 and 3.0 knots. These fishing positions were then joined to the grid to assign each position to a grid cell and management area. Fishing effort was then calculated by summing up the duration of fishing activity within each management area and time period, expressed as total hours fished.

Table A7 Effect of Evisceration Orders on Dungeness Crab Vessel Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Evis	2.311*	2.306*	1.581	0.162	-1.284	1.373	1.829
	(1.270)	(1.270)	(1.796)	(1.709)	(2.204)	(2.551)	(2.556)
Evis × Boattype_medium			1.219		1.575	-3.360*	-3.561**
			(1.774)		(1.662)	(1.817)	(1.791)
Evis × Boattype_small			-0.182		-1.316	-4.356	-4.830*
			(2.207)		(2.231)	(2.686)	(2.674)
Evis × Potlimit300				3.391**	3.769**	3.003	3.097*
				(1.532)	(1.518)	(1.854)	(1.826)
Evis × Potlimit500				1.628	2.355	3.766*	3.994**
				(1.772)	(1.621)	(2.018)	(1.972)
Neighbor Evis						-0.346	1.150
						(1.470)	(2.419)
Evis × Neighbor Evis							-2.485
							(2.699)
Num. Obs.	45,076	45,018	45,018	45,018	45,018	44,979	44,979
R2	0.086	0.086	0.086	0.086	0.086	0.049	0.049
R2 Adj.	0.067	0.067	0.067	0.067	0.067	0.037	0.037

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses clustered by area