Economic Impacts of Harmful Algal Blooms on Fishery-Dependent Communities

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Abstract

The recreational razor clam fishery is the largest recreational bivalve fishery in the Pacific Northwest and a major source of tourism-related income to small communities in the region. Delays and closures of recreational shellfisheries due to the increasing frequency of harmful algal blooms (HABs) threaten to have significant negative impacts on fishery dependent communities. Coupling previous recreational shellfishing expenditure estimates from the literature with a novel dataset of daily visits to local businesses, we estimate a range of economic impacts resulting from the cancellation of razor clam digs at Long Beach, WA, the most popular beach in the State for recreational clam diggers. Our results indicate that a full season closure can lead to lost sales revenues of $16,875 for gas stations, $117,600 for food stores, $217,800 for accommodations and $491,400 for food service places for a total lower bound economic impact of $843,675. We discuss the opportunity for early warning systems, like the Pacific Northwest HAB Bulletin, to guide policy and facilitate business decisions that hedge the risk of revenue losses associated with dig cancellations.

Keywords: foot traffic data, survey data, economic impact, fishery-dependent community, recreational shellfishing, Pacific Northwest

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1. Introduction

Along the Washington and Oregon coasts, the razor clam (*Siliqua patula*) fishery is the largest recreational bivalve shellfish fishery in the region and a major source of tourism-related income to small communities along the coast, generating as much as $40 million in Washington (Daniel Ayres, Washington Department of Fish and Wildlife (WDFW), *pers. comm.*) and $12 million in Oregon annually (Matthew Hunter, Oregon Department of Fish and Wildlife (ODFW), *pers. comm.*). Similarly, the commercial Dungeness crab (*Metacarcinus magister*) fishery is one of the West Coast's most valuable fisheries that is key to social and economic wellbeing of coastal communities (Fuller et al., 2017; Ritzman et al., 2018; NOAA, 2022). The increasing frequency of harmful algal blooms (HABs) due to multiple stressors including ocean warming (McCabe et al., 2016; McKibben et al., 2017), ocean acidificiation (Tatters et al., 2012), and nutrient speciation (Radan and Cochlan, 2018) can lead to season delays or closures of these fisheries. Since the early 1990s, Pseudo-*nitzschia,* a microscopic algae that produces the toxic domoic acid, which at high levels causes Amnesic Shellfish Poisoning (ASP) to those who consume contaminated shellfish, has been a large concern in the region. ASP can be fatal or lead to memory loss, disorientation, gastrointestinal distress, seizures, and coma (Washington Departments of Health (WDOH), n.d.; Perl et al., 1990; Teitelbaum et al., 1990; Todd, 1993; Grant et al., 2010; Grattan et al., 2021). Resulting delays and closures of recreational fisheries threaten to have significant negative impacts on fishery-dependent communities (Ritzman et al., 2018). It is known that HABs can lead to significant negative socio-economic consequences which have been observed at local, regional, national, and even international levels (Hoagland et al., 2002; Jin et al., 2008; Adams et al., 2018; Jin et al., 2020). Common impacts of HABs include losses of commercial fish harvests and recreational fishing opportunities and catches, human illnesses (Hoagland et al., 2009 and 2014), reductions in the wellbeing of coastal residents and visitors (Dyson and Huppert, 2010; Bechard, 2019, 2020), and reduced profits for local businesses (Morgan et al., 2009; Larkin and Adams, 2007).

Several studies have used in-depth reviews and/or offered assessments of the socioeconomic impacts of HABs on communities in the Pacific Northwest. Through these studies it has become clear that the scale of economic impacts depends primarily upon the extent of the closures. Already in the 1990s, the cost of HAB-driven closures (1991-1992) to commercial and recreational razor clam fisheries was estimated to be as high as $23 - $28 million in Washington and Oregon together (National Research Council, 1999; Trainer, 2002). Others estimated impacts for the same closure in the early 1990s at $0.66 to $6.72 million for the fall and spring season respectively (Anderson et al., 2000; Hoagland et al., 2002). A few years later, Ayres and Reed (2004) estimated the collective impacts of commercial, subsistence and recreational fisheries from HAB closures over the 2002 - 2003 season, at $10 million dollars. In April of 2008, Dyson and Huppert (2010) surveyed clammers at four beaches along Washington's Pacific coast (Mocrocks, Copalis, Twin Harbors, and Long Beach) (Figure 1) to estimate visitor expenditures in the recreational razor clam fishery. They found that the average expenditure per clam digging party ranged from $269 at

Mocrocks beach to $413 at Long Beach, totaling overall expenditures of $24 million for the 2007–2008 season. For a full year closure of all four beaches, the negative economic impacts were estimated to comprise the loss of 339 full-time-equivalent jobs, $10.6 million in labor income, and $29 million in total sales impact (in 2008 dollars). Huppert and Trainer (2014) also reported estimates for the Quinault Indian Nation commercial razor clam fishery ranging from $117,000 for a half-year single beach closure to $1.42 million for a full-year closure of all beaches (in 2007 dollars).

Additionally, the amount that recreational clammers would be willing to pay to reduce beach closures to one or less than one per year, according to the 2008 survey, was estimated at $662,000, greatly exceeding the annual $150,000 (Huppert and Trainer, 2014), that was at the time (since 2005) allocated by the Washington State legislature for the phytoplankton monitoring system that provides early warning of HAB events, under the Olympic Region Harmful Algal Bloom (ORHAB). Funding uncertainties for the Pacific Northwest (PNW) HAB Bulletin (NANOOS n.d.), that is key to providing forecasts and allowing managers to decide how, when and where to close shellfisheries, have persisted since then, putting at risk the resilience of coastal communities (Chadsey et al., 2012; Kourantidou et al., 2022).

More recently, Ritzman et al. (2018) examined the economic and sociocultural impacts of the closures of Dungeness crab and razor clam fisheries during the unprecedented 2015 HAB event on two fishing-dependent communities (Crescent City, California and Long Beach, Washington), using semi-structured interviews of people in the fishing, hospitality, and retail industries, and of local government officials, recreational harvesters, among others. The interview results indicated that economic hardships extended beyond fishing-related operations, permeating through to other sectors, particularly the hospitality industry. HAB-affected community members expressed a desire for clearer, more thorough, and more rapid dissemination of information regarding the management of fisheries closures and the health risks associated with HAB toxins.

In this study we focus on local economic impacts of HABs in the area of Long Beach, WA (Figure 1), using a novel micro data set. The study area is one of the most popular destinations for recreational razor clam fishing in the Pacific Northwest, with the local community being heavily dependent on the fishery. Unlike most existing studies of HAB impacts on recreational fisheries which build on direct observation of fishing activities, we investigate HAB impacts by analyzing local business activities which are closely linked to the recreational fishing. First, we utilize multivariate regression modeling and daily foot traffic data (SafeGraph) to measure the impact of HABs on visitations to local businesses both during and between confirmed razor clam digs. We then develop monetary estimates of these impacts by adapting previous survey results that capture recreational clam digging expenditures (Dyson and Huppert, 2010). Our results confirm previous findings of significant economic impacts of HABs on local economies and offer insights how the PNW HAB Bulletin could help prevent a portion of these impacts by offering opportunities for effective risk management through adaptation mechanisms available to the communities and local businesses affected.

In Washington, the recreational razor clam fishery serves as a major source of tourist-related income to small communities along the coast. Between October and May, as many as 400,000 recreational harvesters visit the Washington beaches to participate in a series of short-term, monthly harvest “openers”. The recreational razor clam fishery alone can generate up to $40 million dollars for these fishery dependent communities during the slow “shoulder” seasons (Daniel Ayres, WDFW, *pers. comm.*).

The beaches are generally closed for recreational shellfishing in Washington until they are opened by management agencies. Each clam digging period is short in duration to allow sufficient time for state fishery and human health managers to ensure razor clams are free of toxins. Increased toxin monitoring is often triggered by forecasts published in the PNW HAB Bulletin which may lead to season delays and/or closures. The WDOH and WDFW, together with tribes in the State of Washington hold the responsibility for managing shellfish fisheries and deciding upon delays and/or closures. The original protocol that these two authorities established for sampling typically performed around recreational clamming openers has later expanded to a much more comprehensive protocol that tracks bloom dynamics of *Pseudo-nitzschia* (Chadsey et al., 2012). The ORHAB partnership has been instrumental in management of HAB events, coordinating efforts of different authorities and knowledge produced through monitoring and predictions to help protect coastal economies, including those depending on tourism. Thanks to the PNW HAB Bulletin, local resource managers are better positioned with respect to advance notice of forthcoming HABs, and therefore better able to design adaptive strategies (i.e., early opening of clamming season) and to help prevent, to the extent possible, cancellation of traveling plans. Nevertheless, despite improvements over time, adverse effects of HABs on coastal economies persist.

2. Materials and Methods

2.1 Data

Our first data source (“foot traffic data”) for this analysis comes from SafeGraph Inc. (Denver, CO; www.safegraph.com) and contains aggregated, anonymized location data from numerous applications used on mobile devices such as tablets and smart phones from January 2018 to September 2021. SafeGraph’s mobile device panel comprises roughly 45 million devices across the United States. Visitor foot traffic information is compiled from mobility data collected via mobile device “pings” for points of interests (POIs) (e.g., business establishments) with records on location, category and brand, geocoordinate, and whether a business was open or closed during a specific period in the sample time series. The foot traffic data to specific POIs can be used to understand consumer behavior. For the study, we examined the total number of visits across four business sectors including food stores, gas stations, lodging, and food service and drinking places.

Each of these four business sectors are, respectively, denoted by the following North American Industry Classification System (NAICS) categories 445, 447, 721, and 722. NAICS were developed for use by Federal statistical agencies to conveniently summarize and publish data on the U.S. business economy (U.S. Census Bureau; https://www.census.gov/naics/). We followed SafeGraph's recommendations on normalizing data by upsampling the number of visits based on the sampling rate of mobile devices in their panel in our study area. The assumption here is that this adjustment allows our data to more accurately reflect the total number of visits to businesses in the study area by accounting for sampling bias. The upsampling procedure is straightforward and utilizes data on the average number of devices residing in the study area and population of the study area from the American Community Survey – a monthly survey conducted by the U.S. Census Bureau that supplements the Decennial Census. We divide the population of the study area by the average number of devices residing in the study area to create a multiplier which is then used to scale the raw visit counts from SafeGraph.

The shellfishing open and closure data were compiled from WDFW news bulletins (https://wdfw.wa.gov/news). Initial news releases publish expected razor clam dig dates based on annual razor clam stock assessments and projected tides for the five major public razor clam management zones (Long Beach, Twin Harbors, Copalis Beach, Mocrocks Beach, and Kalaloch). After the dates for harvesting are approved by the WDFW Director and WDOH determines marine toxin levels sufficiently low for safe consumption, a final news release is published to confirm and/or update the previously projected dig days. We compiled data on confirmed dig days for Long Beach, WA for our study period of January 2018 - September 2021.

Table 1 provides a summary of the key variables for our analysis. Over the 45-month period our sample covers, 129 clam digs (days) were scheduled with 31 of those digs being canceled due to either a HAB event or the COVID-19 pandemic. Given Long Beach's history as a tourist destination, it is no surprise that daily visits to accommodations and food service places make up the majority of foot traffic across the four NAICS categories considered in our analysis.

Figure 2 visually summarizes daily visits across the four NAICS categories in Long Beach. This representation highlights the seasonal nature of visits to local businesses with peaks in the summer months and troughs in the shoulder seasons. Another important highlight that can be gleaned from the figure is the coincidence of razor clam digs with the shoulder season months. There was a relatively long period of few razor clam digs occurring at Long Beach from spring of 2018 until late fall of 2019. Dig periods still occurred in the other management zones. If tide and weather conditions are not favorable or safe for digging at particular beaches WDFW will not open that beach for razor clam harvesters.

2.2 Model

We use an autoregressive distributed lag (ARDL) model to estimate the effect of razor clam dig closures on visits to local businesses. Our regressors include a suite of indicator variables that denote whether a daily visit occurred on a scheduled and confirmed razor clam dig day (*Scheduled*), a canceled razor clam dig day (*Canceled*), a U.S. federal holiday (*Holiday*), a weekend (*Weekend*), or while WA's stay at home orders were in place during the COVID-19 pandemic (*StayAtHome*). We interact the scheduled indicator with the weekend and holiday indicators to capture potential differences in visitation during digs scheduled for times when recreational diggers might be more available. Specifically, the model is formulated as:

$$\begin{aligned} y_{ist} = \alpha_{0i} &+ \beta_1 Scheduled_{it} + \beta_2 Weekend_{it} + \beta_3 Holiday_{it} + \beta_4 StayAtHome_{it} \\ &+ \beta_5 Canceled_{it} + \beta_6 Scheduled_{it} \times Weekend_{it} + \beta_7 Scheduled_{it} \times Holiday_{it} \\ &+ \beta_8 Precipitation_t + \beta_9 MinTemperature_t + \beta_{10} y_{ist-1} + \beta_{11} y_{ist-2} \\ &+ \beta_{12} y_{ist-3} + \alpha_{1i} Year + \delta_s + \epsilon_{ist} \end{aligned}$$

Where *y* is the number of visits to a business of NAICS code *i* in month *s* on day *t*. *Year* is a linear time trend in visitation for each NAICS code while δ_s is a month fixed effect.

The coefficient, β_5, captures our primary effect of interest – the impact of scheduled dig cancellations on visitation within NAICS code *i*. We hypothesize this impact to be negative based on previous results in the literature confirming that recreational clam digs drive a large influx of visitors to beaches in the study area (e.g., Dyson and Huppert, 2010; Jin et al., 2020). While the sign is expected to be negative, the magnitude of this effect remains an empirical question.

We also include three lags of the dependent variable to account for correlation among visits in previous days. Clamming parties stay an average of 2.62 nights in Long Beach according to Dyson and Huppert (2010) and thus we based the number of lags on this value for a typical three-night, four-day trip. Importantly, we include an annual trend variable to capture systematic trends in our data and month fixed effects to control for seasonal differences that are important for this tourist reliant region. We examine the stationarity of daily visits using the augmented Dickey-Fuller test (Dickey and Fuller, 1979) and confirm whether the residuals from our model are autocorrelated. For all four business categories, the augmented Dickey-Fuller test rejects the null of nonstationarity at the 1% confidence level. We find no evidence that the residuals are autocorrelated.

3. Results

The results from the ARDL Model in Table 2 confirm previous empirical and anecdotal evidence that scheduled razor clam digs attract visitors to Long Beach. We report the adjusted R-squared value for the regression models used in our analysis. This statistic summarizes how much of the variance in the data is explained by the regression model while accounting for the number of independent variables included in the model. This statistic most often lies between 0 and 1, though in cases of especially poor model fit it can be negative (Wooldridge, 2009). The adjusted R-squared value for each of the four empirical models ranges between 0.383 to 0.722 suggesting that the model specification accounts for a substantial amount of the variance in foot traffic across the NAICS categories considered. In addition, we can also assess the model fit using the F statistic which tests the null hypothesis that all model coefficients are equal to zero. This statistic is statistically significant at the 1%-level for each of our models. Thus, we can reject the null that all model coefficients are equal to zero. Taking these results together we consider our model specifications to sufficiently explain the variance in our data for reliable interpretation of the reported results.

As indicated by the coefficients for the variable "Scheduled dig day," on scheduled dig days, the number of visits increase by 3, 44, 133, and 210, respectively, across food stores, gas stations, accommodations, and food service and drinking places. All of these increases are statistically significant except for food stores. We interpret the insignificant effect of scheduled clam digs on visitation to food stores to reflect the fact that food is a necessity, i.e., including for locals, regardless of whether a clam dig is occurring. As one might expect, visitation across the four sectors is negatively affected as precipitation increases and positively affected as minimum air temperature increases. Similarly, there was a significant effect on visitation across all four sectors during the period Pacific County's stay at home orders were in place due to the COVID-19 pandemic. The negative coefficients for the variable "Canceled" capture our primary effect of interest, how canceled clam digs affect visitation. The estimation results indicate there are 14, 56, 121, and 312 less visits per day, on average, to gas stations, grocery stores, lodging, and food service and drinking places, respectively. While the effect of a canceled dig is only significant for visitation to gas stations and food service places, taken together, these results suggest potentially significant losses in sales to local businesses.

While canceled recreational razor clam digs have important negative impacts to the community it is important to place that within the context of other factors affecting foot traffic to area businesses. For example, for every inch of precipitation experienced on a given day in Long Beach, foot traffic is significantly reduced across food stores, gas stations, and food service and drinking places by 8, 19, and 100 visits, respectively. While this reduction in visitation is not trivial for local businesses, the magnitude of this effect is far less than the impacts of a canceled clam dig. Further, the absolute value of the canceled dig effect is greater than that of the scheduled dig effect for food stores, gas stations, and food service and drinking places which we interpret as evidence that canceled clam digs affect foot traffic of both Long Beach residents and those traveling from other areas to participate in clam digs. This further affirms the important relationship between clam digs and the success of local businesses.

Based on the result above, we can estimate the partial economic impact of canceled clam digs on the Long Beach economy (Table 3). Given the nature of this analysis, our estimates serve only as a lower bound estimate of impacts to these sectors as they do not account for other socioeconomic effects, like lost employment opportunities associated with reduced visitation that might be correlated with impacts on other sectors. Using Dyson and Huppert's (2010) estimates of expenditures per clam digging party and average clam digging trip characteristics, we can calculate an estimated expenditure per person per day in a clam digging party across gas stations, grocery stores, accommodations, and food service places, respectively. For the sales impact calculation we assume an average of 75 clam digs per year[2] with one-quarter of the digs being canceled in a given season, on average. We chose to assess the impact of a one-quarter season closure as approximately one-quarter of clam digs scheduled over the past thirty years have been canceled due to marine biotoxins associated with HABs. Lost business revenues sum to $843,675 across the four business sectors considered in this study, assuming a full recreational clam season closure. The majority of this impact ($491,400) is faced by food service and drinking places.

4. Discussion

As mentioned above, the WA razor clam season occurs during the "shoulder season" of October to May- a generally slow time for tourism-dependent communities like Long Beach (Ritzman et al., 2018). Thus, communities rely on clam digs as a valuable catalyst of economic activity during this time period making the effects of dig cancellations all the more significant (Moore et al., 2019; Moore et al., 2020). Often the hospitality industry in Long Beach is forced to compensate for lost tourism associated with shellfishing closures by reducing employee hours to the "bare bones minimum" or by hiring fewer staff the following season (Ritzman et al., 2018). Morgan et al. (2009) estimated that the mere presence of HABs near beachfront restaurants reduced daily sales by $1,204 - $5,180 (2021 dollars), which translates to anywhere between $90,300 and $388,500 in lost sales, assuming a HAB event occurred on 75 business days in a given year. These estimates are on par with those estimated in our analysis albeit in slightly different contexts. Nonetheless this comparison suggests that our analytical approach is a valuable tool for assessing business-level impacts of razor clam closures for different business sectors, such as lost revenues due to decreased visitation to a particular establishment. As noted above, our estimates serve only as a lower bound estimate of impacts to these four sectors. Indeed, the full economic impacts of HAB events (i.e., the multiplier effects) on the local economy can only be captured by a regional economic model (e.g., an input-output model) (Jin et al., 2020).

The availability of predictions on future environmental conditions is known to provide significant, positive economic benefits for a number of different natural resource-based sectors such as that of US agriculture (Adams et al., 1995; Solow et al., 1998) and the PNW salmon fishery (Costello et al., 1998). Similarly, forecasts of HAB occurrence carry a positive economic value, in terms of

[2] This estimate is based on thirty years of scheduled clam dig data graciously provided by Daniel Ayres at WDFW.

reduction in damage expected, in the case of New England shellfisheries (Jin and Hoagland, 2008). One specific mechanism that drives these economic benefits is anticipatory actions taken in response to the forecast which can translate into direct cost savings. In the case of our study, an example of this might be a restaurant carrying less perishable inventory if the likelihood of a HAB event is predicted to be high by the PNW HAB Bulletin. While these cost savings can help offset some revenue losses, such predictions cannot entirely solve the broader, negative socioeconomic effects related to lost employment opportunities. In the long run, investments to diversify the local economy may have to be considered as an option to adapt to changing environmental conditions that result in increased HAB events.

There are some limitations to this study that are important to note. Even after following the recommended upsampling procedure there is still the potential that sampling bias affects our results. Importantly, recreational diggers may be more or less likely to opt into this panel. Relatedly we do not know the exact proportion of county population that hold recreational digging licenses to attribute lost revenues among fishers and non-fishers. At any rate the methods herein give us a reasonable upper bound estimate that is consistent with prior studies. Another limitation is the sample period; it covers only the most recent four years of foot traffic to the region. Given the long history of razor clam digs in the region and related closures resulting from HAB occurrence and longer time series of daily visits would be preferred. However, the daily-scale of our data and the consistent seasonal cycles allow us to capture visitor behavior in response to exogenous shocks like the closure of the recreational razor clam fishery. Should more data become available it would greatly strengthen the potential of our methodology to serve as an example analysis for policy makers and analysts in other places/coastal communities suffering the consequences of HAB events on recreational activities.

5. Conclusion

The analysis of the foot traffic data together with the razor clam management data, provides evidence for significant negative local economic impacts of recreational shellfishing closures in Long Beach, WA. This result is consistent with previous findings in the scant literature studying effects of HABs in the Long Beach area along with the broader literature exploring the impacts of shellfishing and beach closures in other geographic regions. Our study is unique in several ways. First, to our knowledge, this is the first study utilizing daily foot traffic data to estimate the reduction in business activities associated with HAB events in the hospitality sector of coastal communities. As noted in the introduction, unlike most existing studies which are based on direct measures of recreational activities, we examine the changes in business activity levels in tourism-related sectors, highlighting the connectivity between recreational harvesting and local economic activities in coastal communities. Finally, the estimation of sector-specific impacts provides useful information to coastal business owners and managers for their efforts to design adaptation mechanisms and mitigate the negative impacts of HAB events which are expected to grow in frequency and severity in the coming years.

Our results further bolster the need to generate transparent risk communication by scientists, resource managers, and the media to help community members better understand HABs so that they can share this information among themselves and, importantly, timely to the visitors in the area. Only then can fishery-dependent communities, like Long Beach, effectively plan and implement strategies to reduce the burdens introduced by increasingly occurring HAB-related beach and fishing closures.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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Table and Figures

Table 1. Recreational shellfishing and foot traffic data descriptive statistics.

Variable	Value
Number of scheduled clam digs	129
Number of canceled clam digs due to HABs	27
Number of canceled clam digs due to COVID-19	4
Mean daily visits (SD)	
Food stores (NAICS 445)	140.23 (80.66)
Gas stations (NAICS 447)	351.92 (207.30)
Accommodations (NAICS 721)	1,553.09 (983.34)
Food service and drinking places (NAICS 722)	2,223.80 (1,172.15)

Table 2. Model of change in foot traffic during recreational clamming closures.

	(1)	(2)	(3)	(4)
	Food stores	Gas stations	Accommodations	Food service and drinking places
Daily visits	Coefficient (Standard error)			
Scheduled dig day (=1 if confirmed dig day)	3.14	44.202***	132.859**	210.083***
	(6.86)	(14.30)	(59.23)	(78.72)
Weekend (=1 if Saturday or Sunday)	-18.165***	51.187***	-29.332	187.097***
	(4.40)	(8.62)	(42.81)	(68.17)
Holiday (=1 if U.S. federal holiday)	-11.986	32.159	-128.134	-150.962
	(12.25)	(25.82)	(121.47)	(120.84)
Stay at home order (=1 if orders were in place)	-15.315***	-73.785***	-533.043***	-776.981***
	(5.65)	(12.78)	(58.78)	(82.92)
Canceled (=1 if dig canceled)	-14.617	-56.483***	-121.148	-312.249***
	(8.98)	(18.97)	(85.13)	(101.12)
Scheduled x Weekend	1.635	-12.519	-45.411	-135.136
	(10.04)	(22.45)	(69.27)	(96.83)
Scheduled x Holiday	26.290*	-44.727	107.423	-190.558
	(15.06)	(59.61)	(474.27)	(252.53)
Precipitation (inches)	-8.195**	-19.494***	-31.191	-100.291***
	(3.34)	(6.89)	(26.84)	(33.43)
Minimum temperature (° F)	0.596*	0.952	8.660***	12.250***
	(0.34)	(0.69)	(2.79)	(3.50)
$Visits_{t-1}$	0.449***	0.481***	0.810***	0.690***
	(0.04)	(0.07)	(0.05)	(0.07)
$Visits_{t-2}$	-0.001	-0.051	-0.344***	-0.316***
	(0.04)	(0.05)	(0.04)	(0.05)
$Visits_{t-3}$	0.053	-0.085***	0.038	0.003
	(0.03)	(0.03)	(0.02)	(0.02)
Constant	53.013***	-62.123**	27.438	-2.438

	(15.18)	(28.22)	(110.27)	(140.48)
Year trend	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Observations	1,364	1,364	1,364	1,364
Adjusted R^2	0.383	0.654	0.722	0.679
Residual Std. Error	63.367	121.89	518.542	663.576
F statistic	36.215***	108.319***	148.335***	121.230***

Note: Heteroskedasticity- and autocorrelation-consistent standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3. Impact on sales revenue by business sector.

Sector	$ / person / day (2021 dollars)	Full season closure	25% season closure
Food stores	15	$16,875	$4,219
Gas stations	28	$117,600	$29,400
Accommodations	24	$217,800	$54,450
Food Service places	21	$491,400	$122,850

Figure 1. Map of the study area in the Pacific Northwest (Washington state, Olympic Peninsula), including the five major public razor clam management zones (Long Beach, Twin Harbors, Copalis, Mocrocks, and Kalaloch) highlighted in orange. The thicker orange coloring of the Long Beach area visually highlights our study area

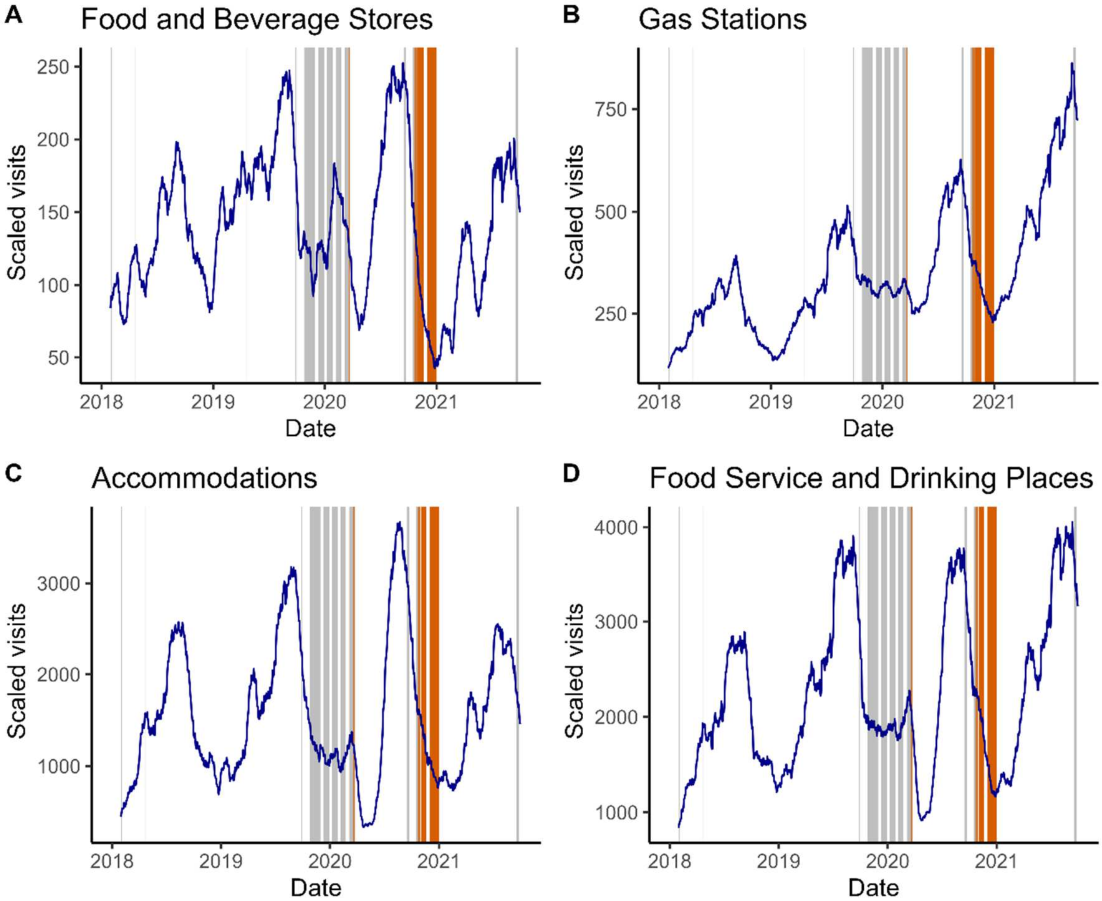

Figure 2. Summaries of the 30-day moving average of daily visits across the four NAICS categories in Long Beach, WA during the study time series are shown in blue. Gray vertical bars indicate razor clam dig periods. Orange vertical bars indicate razor clam dig closure periods.