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Abstract

We examine the effects of the Deepwater Horizon oil spill on landings, revenues, and effort in the commercial blue crab fishery. A key contribution of our work is that it goes beyond simple pre-post analysis and uses a difference-in-differences method to identify the causal effects of the spill. We compare affected areas to two different counterfactuals - Atlantic states, as well as Louisiana basins that were less exposed to the spill - which essentially provides upper and lower bounds on the magnitude of the impact. When using the Atlantic as a counterfactual for the Gulf states, we find that the spill resulted in a 75-85% decrease in landings in the months immediately following the spill, followed by a relatively swift recovery. While there is some evidence of potential longer-term impacts, we cannot estimate these effects precisely. Because of the potential for substitution between Gulf and Atlantic crab, we view these results as an upper bound on the true impact. When comparing Louisiana basins that were more versus less affected by the spill, we identify a 50% drop in crabbing trips in basins that were more affected following the spill; however, we find little impact on landings, likely because the spill and the resulting closures changed the relationship between effort (trips) and landings. Overall, our findings suggest that the Deepwater spill did result in substantial, short-term losses to the blue crab fishery, but that the fishery also exhibited a high degree of resilience and recovered quickly as soon as the closures were ended.

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1 Introduction

On April 20, 2010, an explosion on BP's Deepwater Horizon oil rig initiated the largest oil spill in the history of maritime drilling, killing 11 workers and ultimately resulting in the release of approximately four million barrels of oil into the Gulf of Mexico over an 87-day period (EPA, 2018). Shorelines along the Alabama, Florida, Louisiana, and Mississippi coastlines were impacted, and over \$6 billion in immediate damage claims paid by the Gulf Coast Claims Facility (GCCF) between August, 2010 and March, 2012 (Eastern Research Group (ERG), 2014).[1]

Given the size of the spill and previous experience with the ecological impacts of the 1989 Exxon Valdez spill in Alaska, damage to Gulf Coast fisheries was expected to be large, driven by at least two possible mechanisms: a) the biological impacts related directly to the oil spill and associated contamination at the individual, population, and community levels; and b) policy decisions (such as fishing ground closures and freshwater releases) that either directly affect the ability to fish in given waters or indirectly affect physical quantities of biomass.

On the biological side, although causality is difficult to establish, an increase in skin lesions was reported by fishers for such species as red snapper, yellowedge grouper, tilefish, and other species immediately following the spill, with incidence declining in subsequent years (Murawski, et al., 2014). Economically important species such as red snapper and blue crab were spawning in the Gulf during the spill, and potential exposure to oil raised questions as to how the movement, dispersal, and settlement of larva and young fish would ultimately impact population levels (Szedlmayer and Mudrak, 2014; Jones, et al., 2015). However, biological research has generally not found long-term community-level impacts on type, abundance, or size of fish in regions affected by the spill, though some short-run declines have been documented for blue crab and grass shrimp (Able, et al., 2015; Moody, et al., 2013; Fodrie, et al., 2014). On the policy side, freshwater diversions were linked to oyster mortality along the Mississippi River in Louisiana which affected that particular fishery, with some substitution towards Texas oysters (Carroll, et al., 2016). Perhaps more important to other fisheries were closures, which could affect both biological and economic activity.

Approximately 22 percent of annual physical catch and 24 percent of landed value of fish in the Gulf in the years before the spill came from areas subject to closure (McCrea-Strub, et al., 2011), and the reduced fishing pressure resulting from the closure has been identified as one potential reason for the lack of negative community-level impacts following the spill

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[1] The GCCF was created by BP to settle individual and business claims, and was replaced by the Court Supervised Settlement Program on June 4, 2012 (ERG, 2014).

(Hale, et al., 2016). However, Ainsworth, et al. (2018) use an "end-to-end" ecosystem model to simulate the effects of the Deepwater spill, finding that closures had minimal biological impacts on biomass level (primarily due to the relatively short time of closure), though oiling and related indirect effects were predicted to decrease biomass levels by a maximum of between 25-75 percent in the relatively short run, depending on the species group. Sumalia, et al. (2012), in an ex ante study based largely on imposed assumptions about losses of biomass and closure records, suggested that revenue losses for crustaceans across the Gulf would range from \$360 million to \$2.3 billion over the course of seven years due to these factors, constituting an estimated 75 to 85 percent of all commercial fishery losses. Prior to the spill, the blue crab fishery in the Gulf was the third most valuable in terms of landings, behind brown and white shrimp.

The differential in estimates about short term biomass losses and corresponding long term recovery of economically valuable species, coupled with the ability of both marine and human life to adapt to changing environmental conditions in the face of biological and policy changes, motivates the demand for statistically rigorous, ex-post analysis of commercial fishery outcomes following oil spills such as Deepwater Horizon. As such, this paper provides such an analysis for one economically relevant Gulf species (blue crab) using a difference-in-differences type analysis using public data sources. Because a perfect control region is generally unavailable, we use trends from two possible regions (the Atlantic states and less exposed Gulf basins) to bound the analysis. The structure of the data allows us to estimate not only the short-term effects on the commercial blue crab fishery, but also the recovery time (and hence the resilience) associated with recovery following the spill. We focus on the blue crab fishery because it is one of the most economically important fisheries for Louisiana as well as several other Gulf states. In addition, the data on blue crab catch are available at a sufficiently disaggregated level to allow a comparison of key outcomes in basins that were more versus less affected by the spill.

This work is best viewed as a complement to a report issued by the U.S. Bureau of Ocean and Energy Management (BOEM), which estimated that the spill cost the commercial fishing industries in the Gulf between \$94.7 to \$1.6 billion through the end of calendar year 2010, with Louisiana shrimp, oyster, blue crab, and menhaden fisheries bearing the brunt (Carroll, et al., 2016).[2] It compared fishery outcomes by state and species in 2010 to an assumed baseline of 2009 under two scenarios (one comparing total revenues and one holding prices constant), and used input-output modeling to consider supply-chain impacts, but was limited

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[2] Our work is also related to a number of studies that have estimated the value of recreational fishing and other shoreline losses due to the spill (Alvarez, et al., 2014; English, et al., 2018; Glasgow and Train, 2018; and Whitehead, et al., 2018, among others).

to short-run year-over-year changes.

Our contribution is to perform an ex-post analysis of the short-term and long-term outcomes of the oil spill. We go beyond simple pre-post analysis of landings volumes and trends (as in the BOEM study), and apply various identification strategies from the econometric literature.[3] Doing so is important because of declines in landings prior to 2010, likely due to a variety of factors including increased competition from imports, high fuel prices, and natural disasters (Hanson and Baker, 2012; Impact Assessment, Inc., 2013). Thus, any attempt to identify the causal impact of the oil spill must disentangle the pre-existing trends in landings from the effect of the spill. Furthermore, by controlling for effort in some of our specifications, we shed light on potential behavioral changes that may have taken place following the spill, helping to disentangle the effects of biological losses, behavioral changes, and policies. Finally, there is a high probability of changes in spatial distribution in biomass and effort in response to the spill, and such changes should factor into the analysis as well. We perform analysis over several geographies to explore these effects. As the BOEM study notes, "definitive impact estimates derived solely by the oil spill will remain conjecture without further empirical examination of the complex cause and effect relationships that have influenced the revenues in these fisheries" (Carroll et al., 2016, p. 4).

The rest of this paper is organized as follows. Section 2 describes the data sources that we use to measure the impacts of the Deepwater spill on fisheries; Section 3 presents our empirical methods; Section 4 summarizes results, and Section 5 concludes.

2 Data Sources

2.1 Fisheries Data

We use two sources of data to quantify the impact of the spill on blue crab landings. First, we downloaded data on blue crab landings between 2000 and 2014 from NOAA's Commercial Landings database.[4] This database provides data on commercial fisheries landings in terms of pounds as well as revenues, by month, species, and state. Figure 1 shows annual (Panel (a)) and monthly (Panel (b)) blue crab landings summed over the five Gulf states: Alabama, Louisiana, Mississippi, Texas, and the west coast of Florida. In addition, given the relative

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[3] Two other studies have similarly used difference-in-difference methods to examine various impacts of the Deepwater spill. Aldy (2014) examines changes in employment, wages, and other economic indicators in coastal versus non-coastal counties and parishes in the Gulf states following the spill, and finds little evidence of negative economic impacts. van der Ham and Mutsert (2014) compare shrimp abundance and size in basins that were more affected by the spill, relative to those that were less affected, and find an increase in abundance in the former.

[4] As of October 28, 2018: https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/.

distance of Florida and Texas from the Deepwater spill, we also show landings summed over the most affected states: Alabama, Louisiana, and Mississippi.

Regardless of whether we include Florida and Texas, there is a clear drop in landings when the Deepwater spill occurs in 2010. However, the figure also illustrates the challenge of quantifying the causal impact of the Deepwater spill by comparing pre-2010 and post-2010 data: there was a clear downward trend in annual blue crab landings between 2000 and 2009, so assuming that the entire drop in landings between 2009 and 2010 (or 2009 and 2011) is due to the Deepwater spill will likely result in an overestimate of the causal impact. As we discuss in more detail in Section 3, we thus compare changes in crab landings in the five Gulf states with changes in crab landings in 13 Atlantic seaboard states, with the latter serving as a proxy counterfactual.

Figure 1 also demonstrates a sharp drop in landings in 2005, during Hurricane Katrina. Because this major event may have caused not only a one-time shock to the commercial fishing industry, but also a change in pre-existing trends, we begin our analysis in 2006. More detailed summary statistics for landings and revenues can be found in Table A.1.[5]

We also obtained more disaggregated data on commercial trips, landings, and revenues in Louisiana from the Louisiana Department of Wildlife and Fisheries (LADWF); summary statistics can be found in Table A.2.[6] These data are provided by month, species, basin, and gear type used. Over 99 percent of blue crab landings involve the use of pots and traps; thus, we do not distinguish between different gear types in our analysis. We further focus our analysis on eight basins that account for over 99 percent of total blue crab landings between 2006 and 2015. In addition, in a few rare cases, providing landings data by month and basin might have resulted in inadvertent disclosure of confidential vessel information; in these cases, LADWF aggregated the data from these month x basin cells to the level of the month. We dropped these aggregated data, which include less than 0.5 percent of total landings in the eight basins during this time period, from the analysis.

Figure 2 shows annual (Panel (a)) and monthly (Panel (b)) trips and landings in the eight Louisiana basins that we examine.[7] These graphs go back to 2000; however, as with the NOAA data, we limit our analysis to 2006 and after, in order to avoid conflating effects from Hurricane Katrina with effects from the Deepwater spill. This figure illustrates drops in both trips and landings in 2010. Unlike in the NOAA data for the Gulf states, overall landings in Louisiana do not demonstrate a clear trend prior to 2010. Figure 3 shows the

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[5] This table presents summary statistics separtely for Gulf and Atlantic states; data from 2006 to 2014 are pooled. We deflate revenues using the monthly consumer price index (CPI) for fish and seafood (city average for all urban consumers, seasonally adjusted), where we normalize the index to one in January 2006.

[6] As with the NOAA data, we deflate revenues using the monthly CPI for fish and seafood.

[7] Figure A.1 shows trips and landings in each individual basin.

locations of the eight basins, and illustrates how trips and landings evolved in each basin between 2009 and 2011. In each panel, darker colors indicate higher landings. Panel (a) illustrates that trips and landings were highest in the eastern basins. In Panel (b), we see that annual landings fell in all basins between 2009 and 2010; and Panel (c) shows the extent of recovery in landings by 2011.

2.2 Oiling and Closure Data

GIS data detailing the extent of oiling was obtained from the NOAA Environmental Response Management Application (ERMA), developed by NOAA's Office of Response and Restoration, the University of New Hampshire and the U.S. EPA.[8] These data contain Synthetic Aperture Radar (SAR) image polygons and National Environmental Satellite, Data, and Information Service (NESDIS) image polygons delineating cumulative areas of oiling between April 2010 and August 2011. Figure 4 shows the maximum extent of oiling caused by the Deepwater spill, as well as the cumulative number of days for which oiling was observed. Oiling was observed for nearly 60 days near the wellhead, and for shorter periods of time near the coastline.

Oiling data were mapped onto the NOAA Fisheries Statistical Sampling Areas and Louisiana Basins to determine the maximum number of days of oiling per grid unit. The boundaries of NOAA Fisheries Statistical Sampling Areas in the Gulf of Mexico were provided by the NOAA National Marine Fisheries Service, and the boundaries of Louisiana basins were provided by the US Fish and Wildlife Service. GIS data were compiled and analyses were conducted in ArcGIS v10.6 (ESRI Corp., Redlands, CA). We assigned each basin the maximum number of days of oiling observed within the basin's boundaries. Table 1 summarizes the number of days for which oiling was observed in the eight Louisiana basins. The number of cumulative days of oiling was highest in the Mississippi River basin (18 days), followed by the Barataria basin (12 days) and the Lake Pontchartrain basin (10 days).

During the spill, up to 37 percent of U.S. Gulf of Mexico waters were closed to fishing, with all Federal restrictions eventually lifted almost exactly one year from the onset of the event. This action was taken after sensory testing from the National Marine Fisheries Service (NMFS) and Food and Drug Administration (FDA) found "no detectable oil or dispersant odors or flavors in the samples," and chemical analysis did not meet thresholds for safety concerns (Federal Register, 2014). Some State waters, such as oiled areas in Barataria Basin in Louisiana, remained closed to fishing until June 2015 (Graham, et al., 2015).

We compiled data on fisheries closures from various sources. Closure announcements

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[8] As of October 28, 2018: https://erma.noaa.gov/gulfofmexico/erma.html.

made by the LADWF and the Louisiana Department of Health detailed the dates of closure announcement, the areas affected, and the fisheries affected (commercial or recreational fishing, crab, oyster, and shrimp) within Louisiana State waters. LADWF provided the authors with GIS data on the extent of state waters closure areas, as announced. GIS data on NOAA federal fisheries closures affecting all types of fisheries were obtained from ERMA. State and federal closures were mapped onto Louisiana basins and NOAA Fisheries Statistical Sampling Areas to determine the months during which each basin and grid unit experienced one or more closure event, and the type(s) of fishery affected.

Table 1 documents the months during which the eight Louisiana basins considered this in analysis were closed to crabbing. We identified a basin as closed whenever any part of the basin was closed at some point during the month. Parts of all basins were closed just after the spill, in May 2010; by October 2010, most of the basins had been re-opened, but the Barataria and Mississippi River basins (those with the most cumulative oiling) remained closed throughout the year.

3 Empirical Strategy

Prior analyses of the Deepwater spill have largely focused on pre-post differences in landings (see, e.g., Carroll, et al., 2016). However, the landings data in Figure 1 suggest that pre-post comparisons may conflate pre-existing trends with the effects of the Deepwater spill. We address this concern by applying a difference-in-differences approach, comparing how landings in "treatment" areas changed after the spill with how landings in "control" areas changed. A critical factor in a difference-in-differences analysis is to identify an appropriate counterfactual. Ideally, this would be an area that would have exhibited the same pattern as the treatment area in the absence of the treatment; however, any trends affecting the control area that do not also affect the treatment area (and for which we cannot perfectly control) will necessarily bias the estimated effects.

We identify two different counterfactuals in our analyses. First, when analyzing the state-level data from NOAA, we compare changes in the Gulf states (which experienced the spill) to changes in the Atlantic states (which did not experience the spill).[9] We posit that the Atlantic states are a reasonable counterfactual for the Gulf states, because trends in overall demand for crab, and in competition between domestic and imported crab, should affect Gulf and Atlantic crab in the same way.[10] Moreover, both regions experience similar types

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[9] The Atlantic states we include are: Connecticut, Delaware, Florida Inland Lakes, Florida East Coast, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, and Virginia.

[10] To the extent that demand for Gulf crab in particular may have fallen after the Deepwater spill, this

of environmental shocks, (e.g., hurricanes) that may impact landings. However, it should be noted that this control group is imperfect in two ways. First, biological and behavioral conditions may differ between the Gulf and Atlantic states, as may the timing and severity of environmental shocks. To the extent possible, we address such differences by including monthly time dummies and by controlling for hurricane activity. Second, and potentially more concerning, the Deepwater spill may have resulted in a substitution of Atlantic crab for Gulf crab. Figure 5 shows annual landings in the Gulf versus the Atlantic states. In 2010, we see a drop in Gulf landings, and a concurrent rise in Atlantic landings. The rise in Atlantic landings is substantially larger than the fall in Gulf landings, and thus may reflect a rise in demand for blue crab that might - in the absence of the Deepwater spill - have increased demand for Gulf crab as well. However, the rise may also reflect substitution, in which case our estimates of the impact of the Deepwater spill on Gulf landings, relative to Atlantic landings, will be biased upwards. We therefore consider this estimate an upper bound on the true effect.

We first estimate the average change in monthly landings before and after the Deepwater spill, in the Gulf states relative to the Altantic states, as follows:

$$Y_{st} = \beta Gulf_s * Post_t + \lambda hurricane_{st} + \alpha_t + \alpha_s + \varepsilon_{st} \tag{1}$$

where where Y_{st} is the outcome of interest (log of landings or revenues) for state s and time t. $Gulf_s$ is an indicator variable that equals one for Gulf states, and zero for Atlantic states. $Post_t$ is an indicator variable that equals zero prior to May 2010 and one starting in May 2010. We control for hurricanes using an indicator variable, $hurricane_{st}$ which is equal to one if state s was affected by a hurricane at time t, zero otherwise. α_t represents a series of indicator variables for each month, and controls for any shocks or trends (e.g., changes in overall demand for crab) that affect both treatment and control states in the same way at the same time. α_s represents a series of indicator variables (fixed effects) that control for any time-invariant effects that are specific to each state (e.g., the fact that catch is higher in Louisiana than in Alabama). The coefficient of interest, β, captures the change in average landings or revenues in the Gulf states, relative to the Atlantic states, over the post oil spill period. That is, it provides the pre-post difference in average log of landings or revenues, controlling for state-specific characteristics and for changes that affected all states at the same time.

We also aim to trace out the recovery path from the Deepwater spill by estimating the following:

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can be considered part of the effect of the spill, which operates through the demand channel.

$$Y_{st} = \sum_p \beta_p Gulf_s * I_p + \lambda hurricane_{st} + \alpha_t + \alpha_s + \varepsilon_{st}$$

$$I_p = \{2010q2, 2010q3, 2010q4, 2011, 2012, 2013, 2014, 2015\} \quad (2)$$

This specification mirrors that of Equation 1, but allows the effect of the spill to vary over time; I_p is a series of indicator variables for time periods. We estimate the effect separately in each quarter post-Deepwater in 2010, and for each year from 2011-2015. In the Appendix, we also show results where we allow the effect to differ in each quarter following the spill.

We then turn to the Louisiana basin-level data to construct a second counterfactual. In this case, all eight basins were affected by the Deepwater spill to some extent. Therefore, we use the extent of exposure to oil to distinguish between treatment and control areas. In our main specifications, we classify the four basins that were exposed to nine or more days of oiling (Barataria, Lake Pontchartrain, Mississippi River, and Terrebone) as "treatment" areas, and the four that were exposed to one or zero days of oiling (Atchafalaya, Calcasieu River, Mermentau River, and Vermilion-Tech) as "control" areas. We estimate the following:

$$Y_{bt} = Treatment_b * Post_t + \alpha_t + \alpha_b + \varepsilon_{bt} \quad (3)$$

where Y_{bt} is the outcome of interest (log of landings or revenues) for basin b and time t. $Treatment_b$ is a dummy variable that equals one for treatment basins, and zero for control basins, and α_b represents a series of dummy variables (fixed effects) that control for any time-invariant effects that are specific to each basin. $Post_t$ and α_t are the same as defined above. In this case, the coefficient of interest, β, captures changes in average landings or revenues in the treatment basins, relative to the control basins, after the oil spill. As with the state-level data, we also estimate a model that allows the effects to vary over time:

$$Y_{bt} = \sum_p \beta_p Treatment_b * I_p + \alpha_t + \alpha_b + \varepsilon_{bt}$$

$$I_p = \{2010q2, 2010q3, 2010q4, 2011, 2012, 2013, 2014, 2015\} \quad (4)$$

Figure 3 shows that the four treatment basins are in the eastern state waters, while the four control basins are to the west. Moreover, the treatment basins are those which had higher landings prior to the Deepwater spill. Thus, we might be concerned that the control basins might have had different trends even in the absence of the spill. However, this concern is mitigated by the pre-spill trends shown in Figure 6. While average landings and trips were substantially higher in the treatment basins prior to 2010, this difference is absorbed by the basin indicators α_b; importantly, the treatment and control basins exhibited similar *trends* in trips and landings prior to the spill.

Figure 6 also shows that both treatment and control basins exhibited a drop in trips and landings in 2010. This is not surprising, since the control basins were also affected by the closures for at least some period of time. Thus, the estimates of the effect of the Deepwater spill using this counterfactual are likely to be biased downwards, since both control and treatments basins were likely affected. In other words, the estimates serve as a lower bound on the true impact.

We also mitigate this possible downward bias by measuring treatment in terms of the degree of exposure to oiling. We estimate models similar to those shown in Equations 3 and 4, but instead of a 1/0 indicator for whether a basin is exposed to oil, we include the number of days of exposure from Table 1. In these specifications, we identify the effect of the Deepwater spill by estimating how each additional day of exposure affected trips and landings.

Finally, we examine whether the Deepwater spill affected the *relationship* between landings and trips, which serves as a proxy for the efficacy of effort. Any changes in this relationship are likely brought about through one of two channels: (1) biological changes among blue crab following the spill (due to species mortality or spatial movement) and/or (2) behavioral changes among crabbers (for example, crabbing in different subareas of the same basin that may differ in terms of biological productivity). To examine whether there were any changes in this relationship following the spill, we estimate the following specification:

$$\begin{aligned} Y_{bgt} = \gamma Trips_{bt} + \mu Trips_{bt} * Treatment_b + \eta Post_t * Trips_{bt} + \Omega Post_t * Treatment_b \\ + \beta Post_t * Treatment_b * Trips_{bt} + \alpha_t + \alpha_b + \varepsilon_{bgt} \quad (5) \end{aligned}$$

where Y_{bt} is the log of landings, and $Trips_{bt}$ is the log of trips, for basin b and time t. To illustrate the effects of interest captured by Ω and β, we can visualize the relationship between log of landings and log of trips as a straight line. In this case, Ω captures the change in the intercept of this line following the Deepwater spill; and β captures the change in the slope. As above, we also examine whether these changes vary over time following the spill:

$$
\begin{aligned}
Y_{bgt} = \gamma Trips_{bt} + \mu Trips_{bt} * Treatment_b + \sum_p \eta_p I_p * Trips_{bt} + \sum_p \Omega_p I_p * Treatment_b \\
+ \sum_p \beta_p I_p * Treatment_b * Trips_{bt} + \alpha_t + \alpha_b + \varepsilon_{bgt} \\
I_p = \{2010q2, 2010q3, 2010q4, 2011, 2012, 2013, 2014, 2015\} \quad (6)
\end{aligned}
$$

4 Results

4.1 State-Level Analysis

Table 2 shows the baseline results for the state-level analysis in which we compare changes in Gulf landings to changes in Atlantic landings, based on Equation 1. All specifications include month and state fixed effects, and standard errors are clustered at the state level. As noted above, Texas and the west coast of Florida were further from the Deepwater spill and thus may not have been as substantially affected as the other Gulf states; therefore, we show results both including and excluding these two states from the treatment group. To avoid including potential treatment effects in the control group, in specifications where we exclude Texas and the west coast of Florida from the treatment group, we drop them from the analysis entirely.

Columns (1) through (3) show results for landings, while Columns (4) through (6) show results for revenues. Column (1) shows baseline results excluding Florida and Texas. The coefficient on the interaction between $Gulf_s$ and $Post_t$ indicates that average monthly landings in the Gulf states fell by approximately 44 percent after the Deepwater spill, relative to landings in the Atlantic states.[11] Similarly, the coefficient Column (4) indicates that average monthly revenues in Alabama, Louisiana and Mississippi fell by approximately 40 percent, relative to the Atlantic states. In Columns (2) and (4), we include an indicator variable for hurricanes that affected certain states in certain years. The coefficients on hurricanes are not statistically distinguishable from zero, and the coefficients on the interaction terms remain similar.

In Columns (3) and (6), we include Texas and the west coast of Florida in the treatment group. Consistent with the hypothesis that these states were less affected by the Deepwater spill, including them attenuates the coefficients on the interaction term. The coefficients

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[11] Since the dependent variable is in logs, and the interaction term is a dummy variable, we estimate the magnitude of the effect as $exp(\beta) - 1$=$exp(-0.573) - 1$=-0.436$\approx$ 44%.

suggest that average landings and revenues fell by about 35% and 32%, respectively, over the five Gulf states relative to the Atlantic states.

Figures 7 and 8 examine how changes following the spill vary over time, by plotting the coefficients on the interaction between the treatment indicator and the degree of exposure in each post-spill time period. These figures show that the average declines in post-spill landings and revenues are largely driven by reductions in landings and revenues during the second and third quarters of 2010. These figures plot the coefficients, and 95% confidence intervals, on each time period post-Deepwater from Equation 2. Panel (a) of each figure shows results that exclude Texas and the west coast of Florida, while Panel (b) includes these states in the treatment group. Panel (a) shows that just after the Deepwater spill, average monthly landings and revenues in Alabama, Louisiana and Mississippi fell by nearly 85 percent relative to Atlantic landings and revenues; if Texas and Florida are included, as in Panel (b), the drop during the second quarter of 2010 is about 75 percent. By 2011 onwards, the magnitude of the effect was not generally different from zero in a statistically significant manner in either case. However, it is worth noting that the point estimates remained fairly large in magnitude, suggesting potential declines in landings of 30% through 2014.

As discussed in Section 2.1, the immediate magnitude of the impact should be interpreted as an upper bound on the true impact of the Deepwater Horizon Spill, as it is driven not only by the fall in Gulf landings in 2010, but also by the rise in Atlantic landings. To the extent this rise reflects not just an exogenous increase in demand, but a substitution between Gulf and Atlantic crab, the estimated impact is biased upwards.

4.2 Louisiana Basin-Level Analysis

For the basin-level analysis, we begin by examining the impact of the Deepwater spill on the number of crabbing trips in Table 3. For all basin-level analyses, we include month and basin dummies, and cluster standard errors at the basin level.

The specification in Column (1) uses an indicator variable equal to one for treatment basins. The coefficient on the interaction between $Treatment$ and $Post$ is positive and not statistically significant, suggesting no average difference between treatment and control basins following the Deepwater spill. In Column (2), we examine the relationship between an indicator for whether any part of a basin is closed at some point during a particular month, and trips. The coefficient on the closure dummy, -0.464, is significant at the 10 percent level and implies a 37 percent reduction in trips in treatment basins relative to control basins, following Deepwater. In Column (3) we control for closure and treatment status at the same time; the coefficient on closure is somewhat larger in magnitude, and remains significant at the 10 percent level, while the coefficient on treatment status remains positive and not significant.

In Column (4) and (5), we measure treatment by the degree of exposure - that is, the number of days of cumulative oiling (from Table 1). Column (4) controls for closure while Column (5) does not. In both cases, the results are similar to those in Columns (1)-(3): that is, when pooling all post-spill time periods together, closure is associated with an average reduction in trips, but number of days of oil exposure is not.

In Figure 9, we examine how changes following the spill vary over time, by plotting the coefficients on the interaction between the treatment indicator and the degree of exposure in each post-spill time period.[12] As with the state-level results on landings, we find evidence of a short-term impact followed by recovery. In both cases, we see a substantial drop in the number of trips during the third quarter of 2010, followed by a recovery period. In Panel (a), the coefficient for the third quarter of 2010, -0.63, suggests a 47 percent drop in the number of trips in treatment basins relative to control basins. In Panel (b), the coefficient on the third quarter of 2010, -0.083, suggests that each additional day of exposure to oiling results in an 8 percent decline in trips. If the effect were linear, the Lake Pontchartrain basin, which was exposed to 10 days of oiling, would thus have experienced approximately an 80 percent drop in trips.

In Table 4 and Panels (a) and (b) of Figure 10, we show an analogous set of results, with landings (instead of trips) as the dependent variable. As in the case of trips, the average post-Deepwater results in Table 4 show no statistically significant effect of oil exposure on landings. The time-varying results in Figure 10 also suggest a similar pattern of decline and recovery; however, the magnitude of the effect in the third quarter of 2010 is smaller. The coefficient on the treatment indicator in Panel (a) suggests that treatment status results in a 10 percent decline in landings, while the coefficient on the number of days of exposure in Panel (b) suggests that each additional day of oiling would result in a 3 percent decline. Moreover, neither coefficient is statistically distinguishable from zero at conventional levels. We confirm similar findings for revenues.[13]

What explains the fact that we find a short-term impact on trips but not on landings? To explore this question, we examine whether the *relationship* between trips and landings changed during and after the Deepwater spill. Figure 11 shows plots of the log of landings against the log of trips, separately for control and treatment basins. We focus on the third quarters of 2009, 2010, and 2011 (before DH, just after the spill, and a year after DH). For each time period, we show the individual, basin-level observations as well as a line of best

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[12] The results in Figure 9 control for closure.

[13] Results in which the dependent variable is the log of revenue are available from the authors upon request.

fit. We can interpret the slope of this line as the incremental amount of landings we would expect for an increase in the number of trips.

First consider the control basins in Panel (a) of Figure 11. Between 2009 and 2010, the line of best fit shifts downward but remains approximately parallel to the original line. In other words, the *incremental* amount of landings for an increase in the number of trips has remained approximately the same in the control basins, but the *total* amount of landings is lower. In 2011, the line shifts up, close to the pre-Deepwater line. One possible explanation for this result is that crabbers may have been forced, via closures, to move to less productive areas.

In Panel (b), we observe a different pattern for treatment basins. Between 2009 and 2010, the slope of line of best fit becomes flatter - that is, for a given increment in the number of trips, we see a smaller increase in the number of landings, which may be indicative of biological process that change the underlying relationship between landings and trips. However, in the bottom left corner of the graph, we observe trips substantially below the usual number observed, likely due to the closures. For these trips, we see a level of landings that is higher than would have been predicted based on a simple extrapolation of the 2009 data. As in the control basins, the relationship between trips and landings in 2011 reverts closer to the relationship observed in 2009.

One potential concern is that the effect observed for treatment basins may be driven by the outliers in the bottom left of Panel (b), which are from the Mississippi River basin. Therefore, in Panel (c), we exclude observations from the Mississippi River basin, and find similar results.

In Table 5 and Figure 12, we quantify these changes in the landings-trips relationship. Column (1) of Table 5 presents a simple regression with log of landings as the dependent variable, and log of trips as the main independent variable of interest. We control for month and basin dummies. The coefficient on trips, 1.05, indicates an approximately unit-elastic relationship: for every 1 percent increase in trips, we observe a 1 percent increase in landings.

In Column (2), we add a control for closure, and find that - controlling for the number of trips - closure is actually associated with *higher* landings. Similarly, Column (3) shows that controlling for trips, landings are higher in basins that are more exposed to oil. Columns (4) and (5) confirm these results when simultaneously controlling for closure and treatment status, and when measuring treatment in terms of degree of exposure, respectively. This is consistent with the evidence in Figure 11 - recall that, in the treatment basins, the level of landings given relatively low trips in 2010 was actually higher than we would have expected based on the landings-trips relationship observed in 2009.

In Columns (7) and (8) we further examine whether the relationship between landings and trips changed after the Deepwater spill, in areas more exposed to oiling. To do so, we include a triple interaction between trips, an indicator for post-Deepwater time periods, and treatment status. We also control for all underlying interactions (trips by a post-Deepwater indicator, trips by treatment, and treatment by a post-Deepwater indicator). The average effects post-Deepwater do not exhibit any changes. However, Figure 12 plots the coefficients on treatment by time (Panel (a)), and on the triple interaction between trips, treatment, and time (Panel (b)) over time, and confirms that the relationship did indeed change in the third quarter of 2010. The result in Panel (b) can be interpreted as the change in the slope of the line of best fit between landings and trips, while the results in Panel (a) can be interpreted as the change in the (extrapolated) intercept. In the third quarter of 2010, the intercept was higher for treatment basins, while the slope was lower, consistent with the lines of best fit shown in Figure 11.

Taken together, our findings suggest that some combination of oiling and closures associated with the Deepwater spill reduced the number of crabbing trips. This reduction in the number of trips likely reduced competition between crabbers, and may have allowed recovery of the stock. Thus, the amount of landings was relatively high in basins that had the fewest trips, and the incremental increase in landings for an increase in crabbing trips was reduced because of this effect. The overall impact on total landings in treatment basins, therefore, was relatively small despite the sharp reduction in the number of trips. From a resilience perspective over the entire fishery, the ability of some crabbers to spatially substitute (at some efficiency costs) in the short run, coupled with the likely increased biomass growth resulting from closures (through reduction in trips) in the medium run, served to mitigate the direct welfare losses induced by policy closures.

4.3 Robustness Checks

In this section, we document two checks to assess the robustness of the results. First, we might be concerned that the treatment and control areas exhibited differences in trends prior to the Deepwater spill. Figures 5 and 6 suggest that this is unlikely to be the case; however, we also test for potential differences more formally using a placebo test. To do so, we re-estimate Equations 2, 4, and 6, but also include interactions between the treatment indicator and dummies for each quarter in 2009, as well as quarter 1 in 2010. If the treatment and control basins exhibit different outcomes in the five quarters prior to the Deepwater spill - from the first quarter of 2009 to the first quarter of 2010 - this suggests a threat to our identification strategy.

Figure A.2 shows the state-level results; we present results that exclude Texas and the west coast of Florida, but results are similar if they are included. There is no statistically significant placebo effect; in contrast to the actual results observed during 2010, most coefficients in the placebo periods are close to zero, or slightly positive, and none are statistically distinguishable from zero.

Similarly, Figure A.3 shows little difference between control and treatment basins in Louisiana prior to the Deepwater spill; while a few coefficients are negative, they are substantially smaller than the post-Deepwater impact found in the third quarter of 2010 and are not statistically significant. As discussed above, because of the change in the relationship between trips and landings, we did not observe a statistically significant effect on landings or value in the basin-level analysis. Figures A.4 through A.5 confirm these post-Deepwater results, and also show little evidence of a pre-Deepwater placebo effect.

The second robustness check concerns the fact that, in both sets of analyses, we have a small number of clusters. Although we cluster all standard errors at the state or basin level, such estimates may be biased if the number of clusters is small. To address this challenge, we re-estimate standard errors for our main specifications using the wild bootstrap method proposed by Cameron and Miller (2015). Results (available upon request) confirm that the statistically significant effects observed during the second and third quarters of 2010 remain robust to this method.

5 Conclusion

In this paper, we used a difference-in-differences approach to examine the effects of the Deepwater Horizon spill on landings and revenues in the Gulf blue crab fishery. While several studies have examined how overall landings changed following the spill, our analysis allows us to disentangle the effects of the spill from other common underlying factors between fisheries affected by and not affected by the spill, such as changes in the demand for seafood as well as increased competition from imported seafood. We compare affected areas to two different counterfactuals - Atlantic states, as well as Louisiana basins that were less exposed to the spill - which provide upper and lower bounds on the magnitude of the impact.

When we compare landings in the Gulf to those in the Atlantic, our findings confirm that there was a substantial drop in the number of blue crab landings in the Gulf states immediately following the Deepwater spill in 2010 (85% if the treatment group includes only Alabama, Louisiana, and Mississippi; 75% if it includes Texas and the Florida west coast). Our findings also suggest that there is substantial resilience in this fishery; once closures were ended, landings and revenues recovered quickly. There is limited evidence of potential longer-term impacts, but the available, aggregate data do not allow us to estimate these effects precisely. Concurrent with the decrease in Gulf landings in 2010, we observe an increase in Atlantic landings; therefore, we cannot rule out that at least some part of the difference-in-differences effect is caused by substitution. We therefore interpret these results as an upper bound on the true causal impact of the Deepwater spill.

When we examine Louisiana basins that were more versus less affected by the spill, we find a substantial drop in crabbing trips after the spill (nearly 50% in the third quarter of 2010), but little change in landings or value. To reconcile these seemingly inconsistent findings, we examine whether the Deepwater spill affected the relationship between trips and landings. We find that in basins that were more affected by the spill and associated closures, and therefore had a small number of trips, the amount of landings was higher than would have been expected given the number of trips. However, the incremental increase in landings for an increase in trips was reduced.

Our analyses suggest several important takeaways. First, using a difference-in-differences method to isolate the effects of the Deepwater spill on the blue crab fishery, we find that the spill and the associated policy response did have a substantial, short-term effect on overall Gulf landings, as well as on effort. Second, our analysis suggests that the spill affected the relationship between effort (trips) and landings; in areas affected by the spill and the closures, it was easier to catch more fish with low levels of effort, but the returns to additional effort were also lower.

Perhaps most importantly, our analysis shows the resilience of the commercial blue crab fishery to short-term shocks. While the Gulf-level analysis suggests some potential longer-term impacts, once the closures were ended, trips and landings rose swiftly. One reason for this relatively swift recovery may be that the closures allowed the stock time to recover, thereby overcoming any negative biological impacts of the spill.

Our findings also suggest an avenue for future research. The overall blue crab fishery appears to have recovered swiftly, but reports suggest that the spill may have changed the composition of the industry. On one hand, the prolonged closure may have forced some crabbers out of business. On the other hand, the number of commercial blue crab licenses issued increase in several Louisiana parishes in 2010, potentially because of the Vessels of Opportunity (VOO) program, which required participants to have commercial licenses (Impact Assessment, 2013). Obtaining vessel-level data on blue crab landings would allow an examination of whether the spill had differential impacts on different groups of crabbers, including small versus large operators, and new entrants versus existing crabbers.

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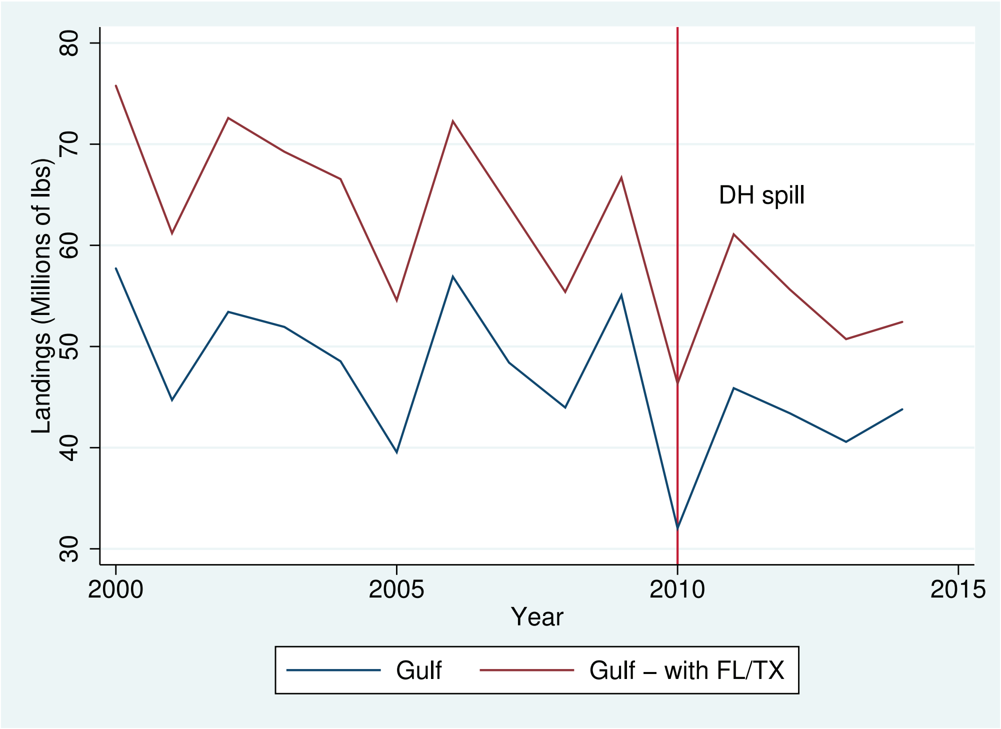
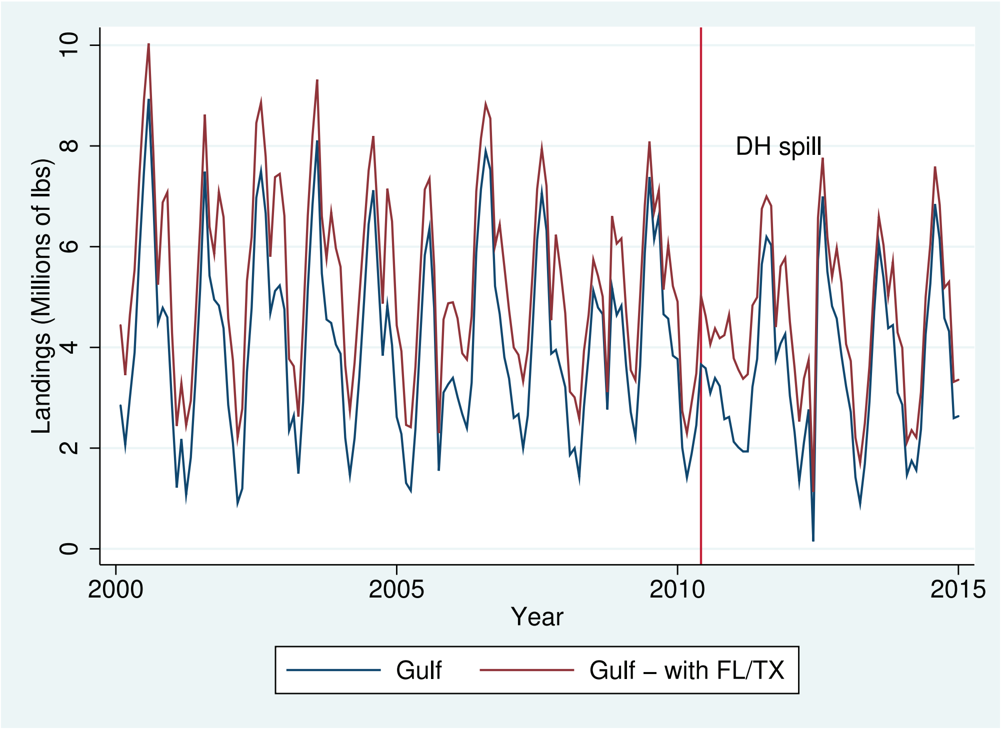
Figure 1: Gulf Blue Crab Landings

(a) Annual



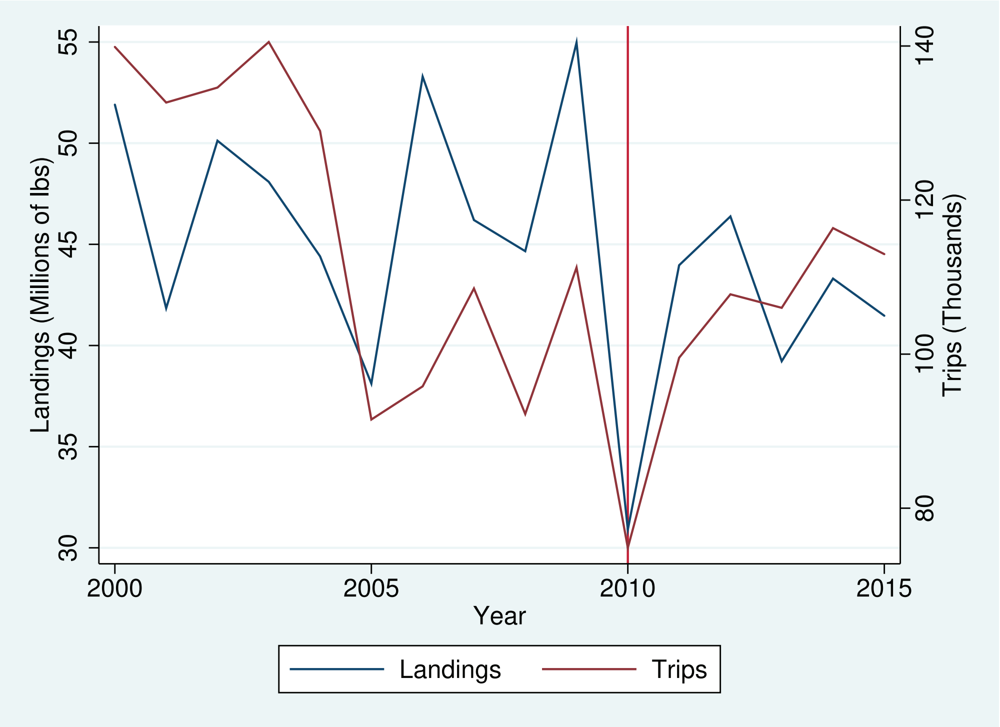
(b) Monthly



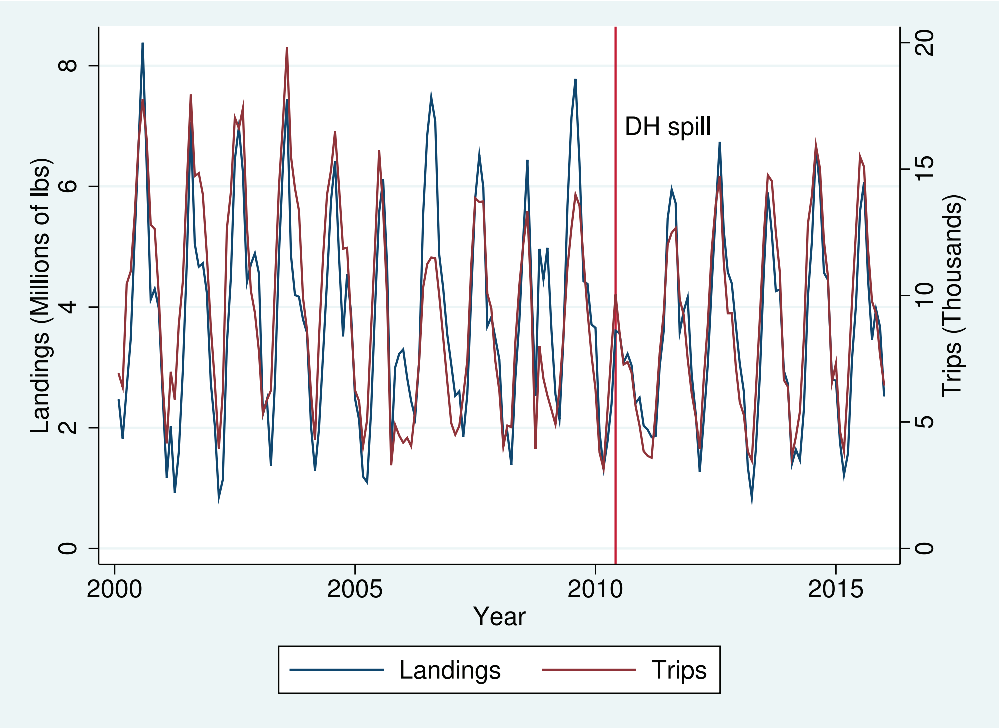
Annual and monthly commercial blue crab landings in the Gulf states (Alabama, Louisiana, Mississippi, Texas, and the west coast of Florida). Authors' calculations based on monthly landings data downloaded from the NOAA Commercial Landings database. Panel (a) shows landings aggregated to the annual level, while Panel (b) shows monthly landings. The vertical line in each figure indicates the Deepwater Horizon spill in April 2010.

Figure 2: Louisiana Blue Crab Trips and Landings

(a) Annual

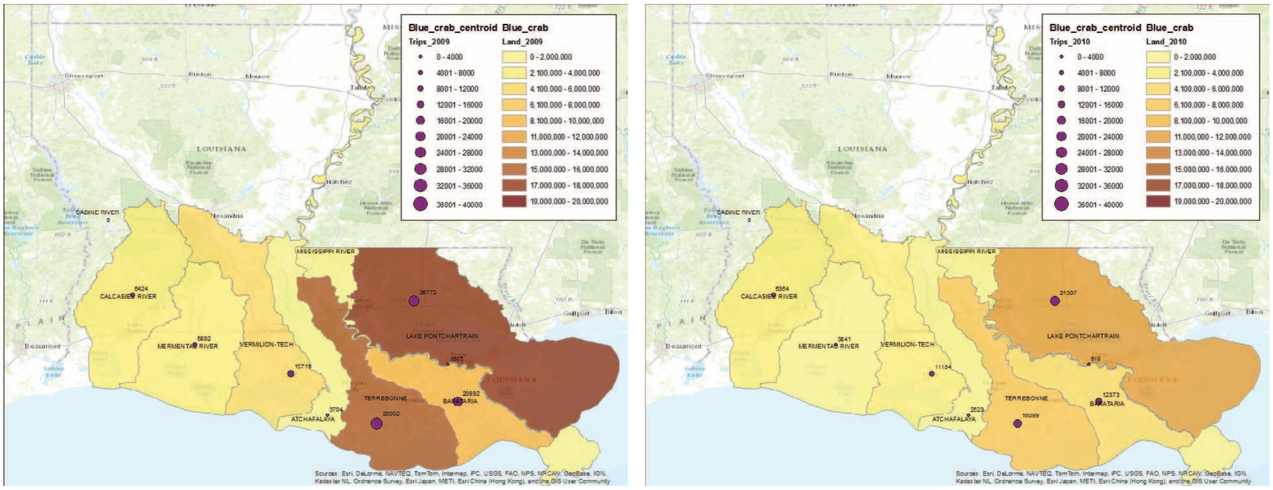


(b) Monthly



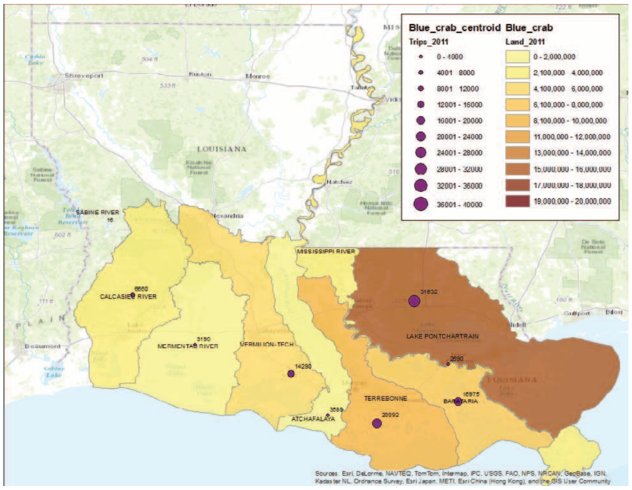
Annual and monthly commercial blue crab landings and associated crabbing trips in Louisiana. Authors' calculations based on data provided by the Louisiana Department of Wildlife and Fisheries. Panel (a) shows landings aggregated to the annual level, while Panel (b) shows monthly landings. The vertical line in each figure indicates the Deepwater Horizon spill in April 2010.

Figure 3: Louisiana Blue Crab Trips and Landings by Basin, 2009-2011


(a) 2009

(b) 2010

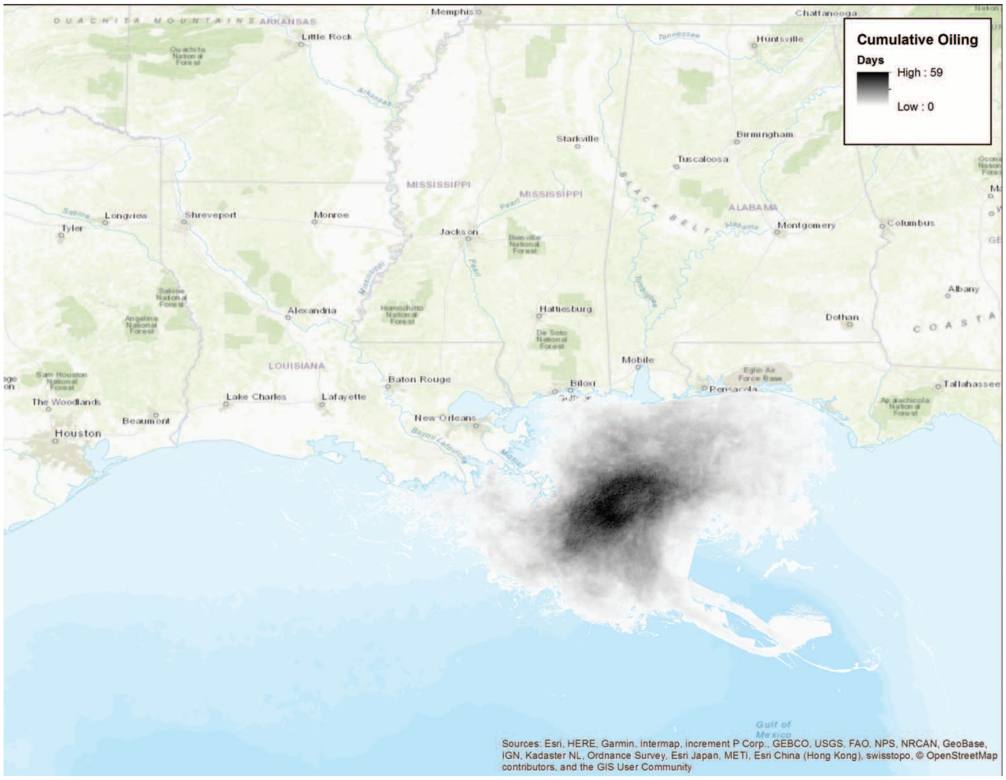
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community


(c) 2011

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

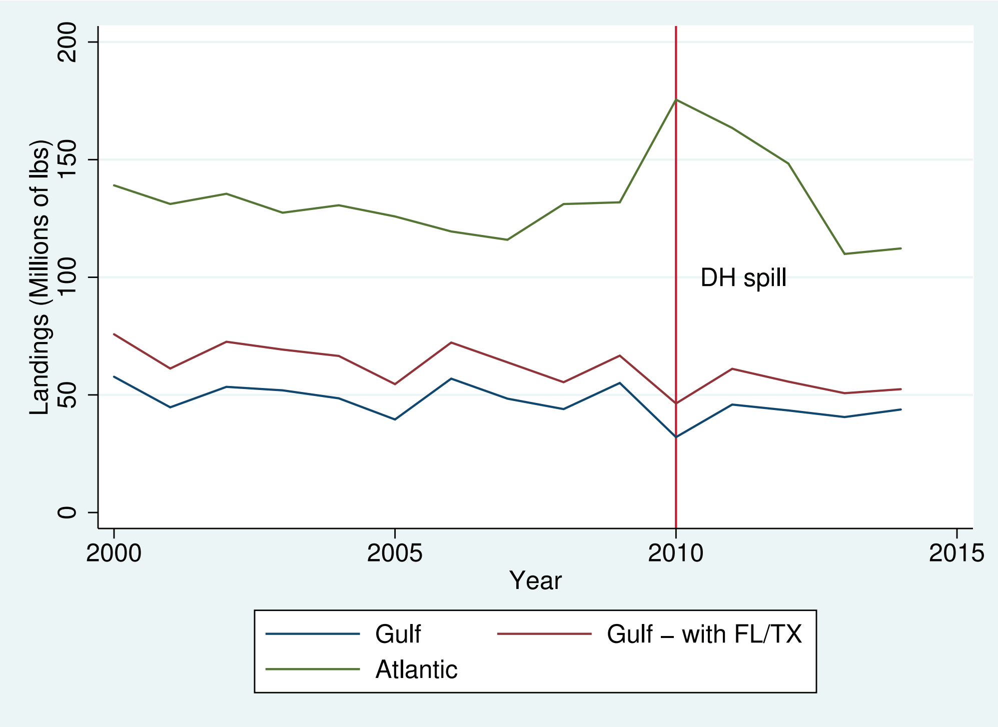
Annual commercial blue crab landings (in pounds) and number of crabbing trips in eight basins in Louisiana in 2009, 2010, and 2011. Authors' calculations based on data provided by the Louisiana Department of Wildlife and Fisheries.

Figure 4: Extent of Oiling Following Deepwater Horizon Spill



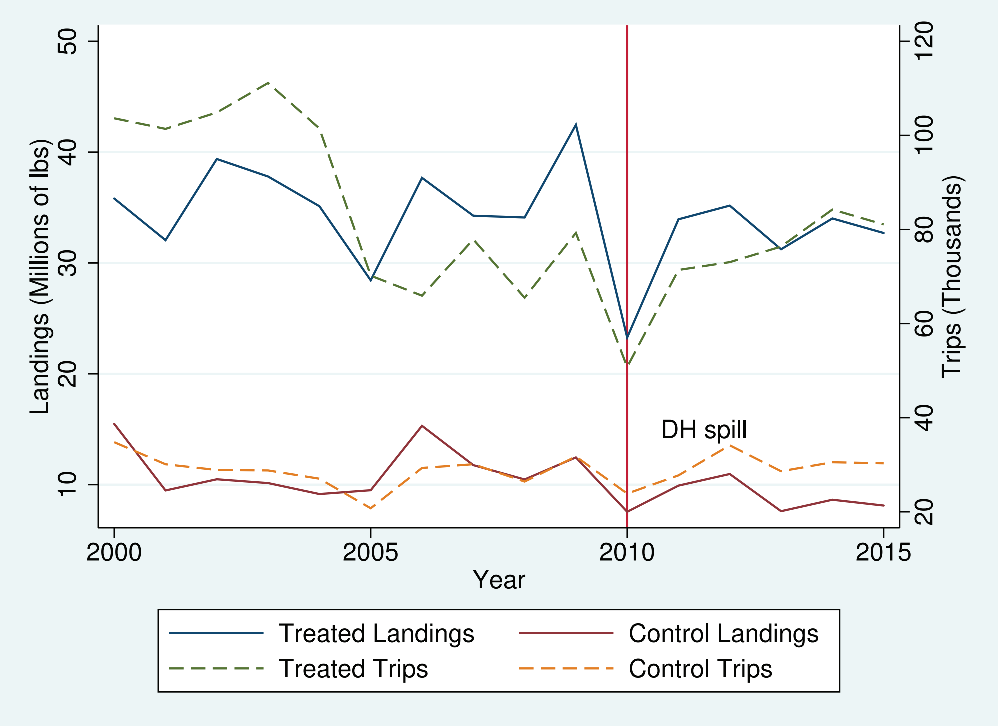
Number of cumulative days of oiling observed following the Deepwater Horizon spill. Map data are from the Environmental Response Management Application (ERMA) tool (https://erma.noaa.gov/gulfofmexico/erma.html) developed by the NOAA Office of Response and Restoration, the University of New Hampshire, and the U.S. Environmental Protection Agency.

Figure 5: Blue Crab Landings, Gulf vs Atlantic



Annual commercial blue crab landings in the Gulf states and the Atlantic states. Authors' calculations based on monthly landings data downloaded from the NOAA Commercial Landings database. The vertical line in each figure indicates the Deepwater Horizon spill in April 2010.

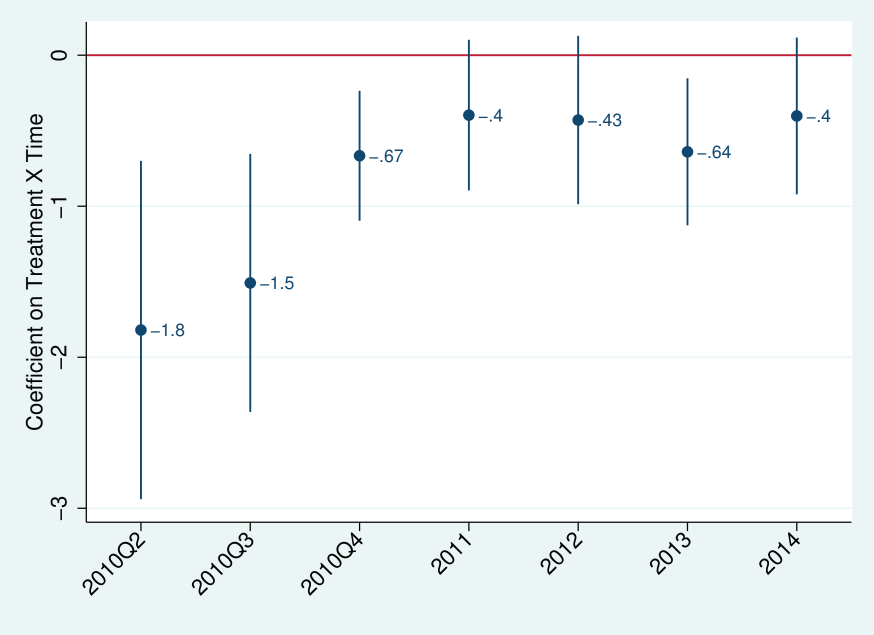
Figure 6: Louisiana Blue Crab Trips and Landings by Treatment Status



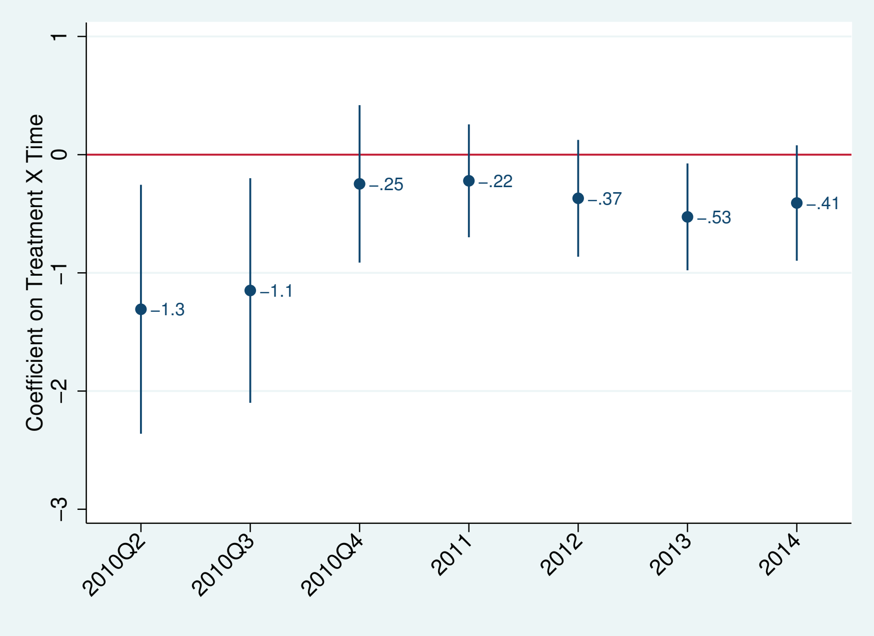
Annual commercial blue crab landings and crabbing trips in Louisiana basins defined as treatment and control, as discussed in the text. Authors' calculations based on data provided by the Louisiana Department of Wildlife and Fisheries. The vertical line in each figure indicates the Deepwater Horizon spill in April 2010.

Figure 7: Impact of the Deepwater Horizon Spill on Gulf Crab Landings

(a) Excluding Florida and Texas



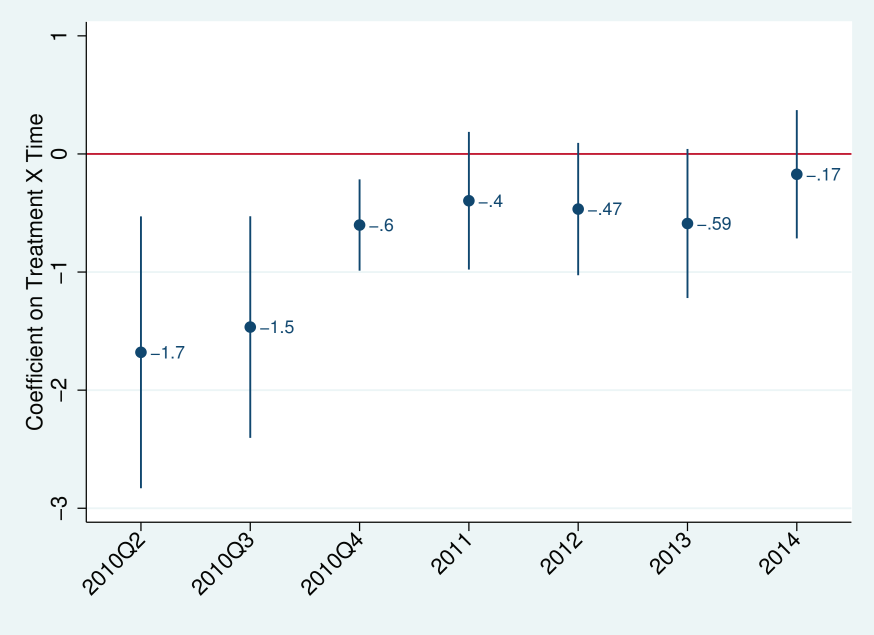
(b) Including Florida and Texas



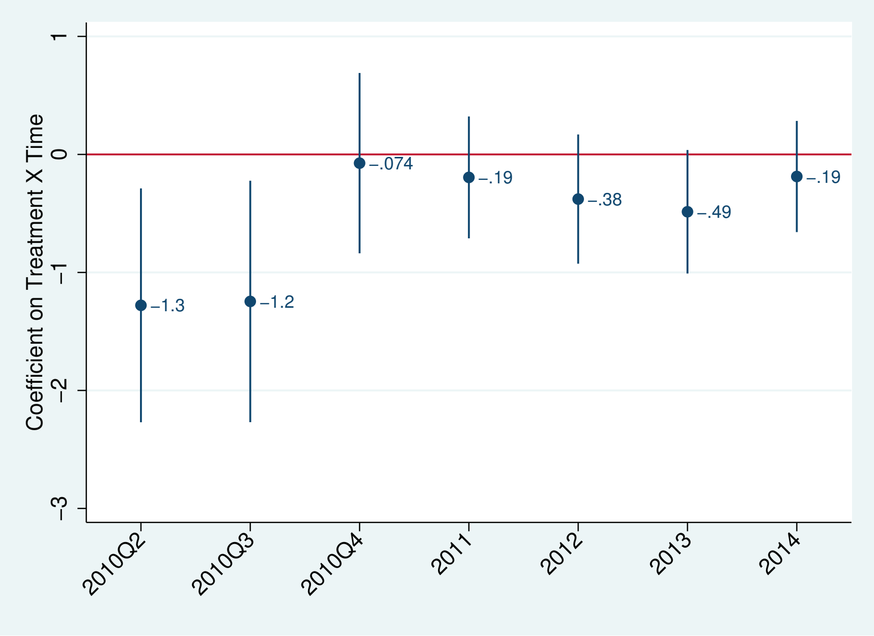
Coefficients from a difference-in-differences regression comparing changes in the log of crab landings in the Gulf states versus the Atlantic states following the Deepwater Horizon spill. In Panel (a), the Gulf states include Alabama, Louisiana, and Mississippi; Texas and the Florida west coast are not included in either the treatment or control groups. In Panel (b), the Gulf states include Alabama, Louisiana, Mississippi, Texas and the Florida west coast. Standard errors are clustered at the state level, and 95 percent confidence intervals are shown.

Figure 8: Impact of the Deepwater Horizon Spill on Gulf Crab Revenues

(a) Excluding Florida and Texas



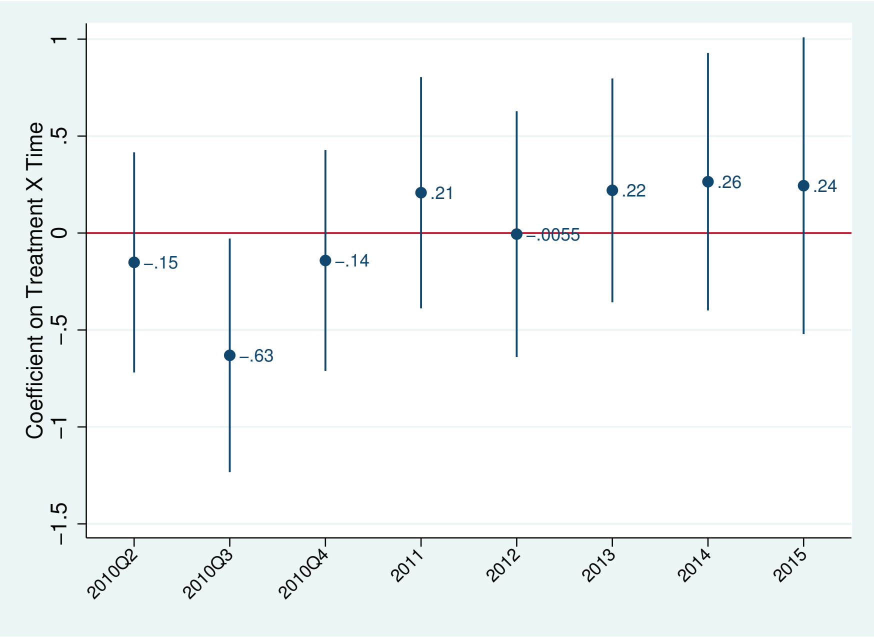
(b) Including Florida and Texas



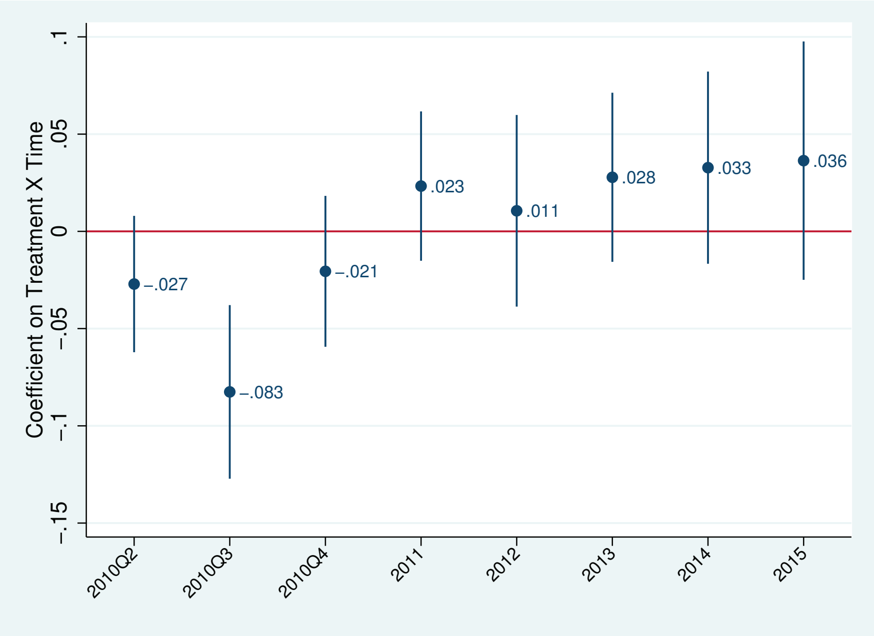
Coefficients from a difference-in-differences regression comparing changes in the log of crab revenues in the Gulf states versus the Atlantic states following the Deepwater Horizon spill. In Panel (a), the Gulf states include Alabama, Louisiana, and Mississippi; Texas and the Florida west coast are not included in either the treatment or control groups. In Panel (b), the Gulf states include Alabama, Louisiana, Mississippi, Texas and the Florida west coast. Standard errors are clustered at the state level, and 95 percent confidence intervals are shown.

Figure 9: Impact of the Deepwater Horizon Spill on Louisiana Crabbing Trips

(a) Treatment / Control



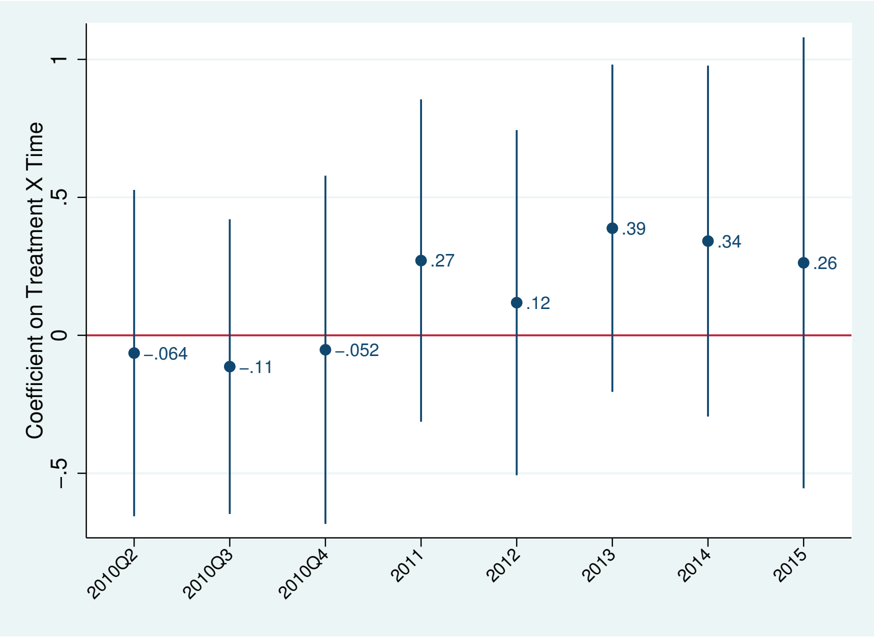
(b) Degree of Oiling



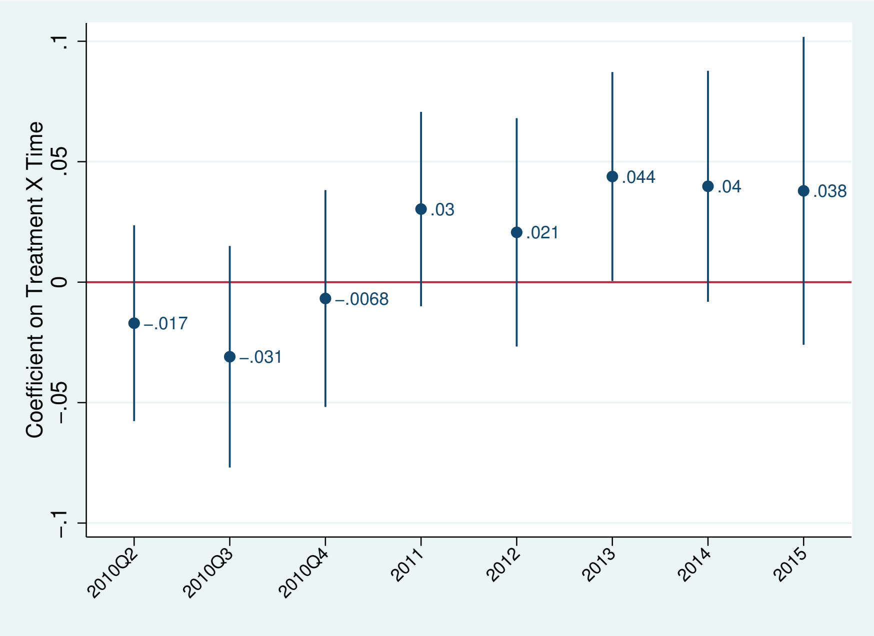
Coefficients from the interaction between treatment and post-Deepwater time period from a difference-in-differences regression (dependent variable is log of crabbing trips). In Panel (a), we compare the four treatment basins with the four control basins. In Panel (b), we compare basins by degree of exposure to oiling, which is measured in terms of the number of days of cumulative oiling observed. Specifications include controls for closure. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

Figure 10: Impact of the Deepwater Horizon Spill on Louisiana Crab Landings

(a) Treatment / Control



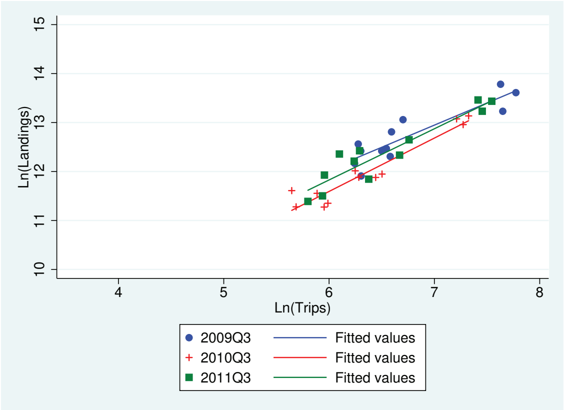
(b) Degree of Oiling

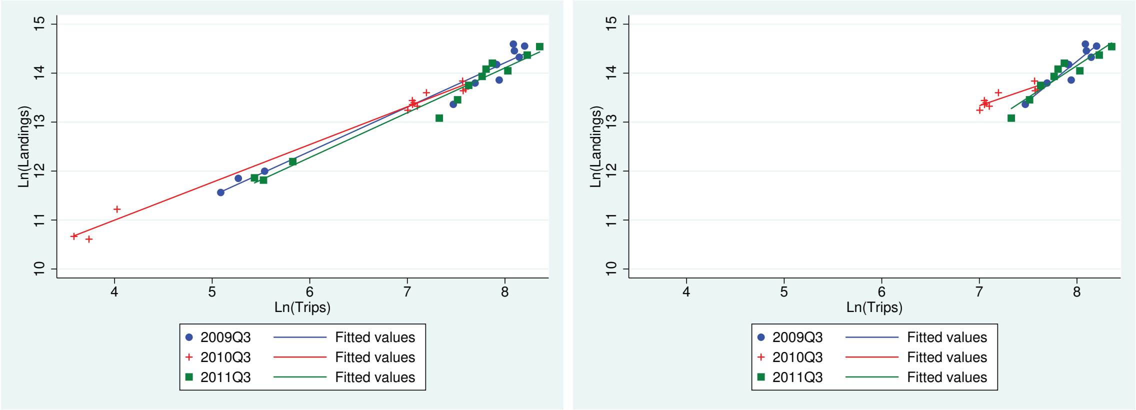


Coefficients from the interaction between treatment and post-Deepwater time period from a difference-in-differences regression. (dependent variable is log of landings). In Panel (a), we compare the four treatment basins with the four control basins. In Panel (b), we compare basins by degree of exposure to oiling, which is measured in terms of the number of days of cumulative oiling observed. Specifications include controls for closure. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

Figure 11: Relationship Between Landings and Trips in Q3, by Treatment Status

(a) Control Q3



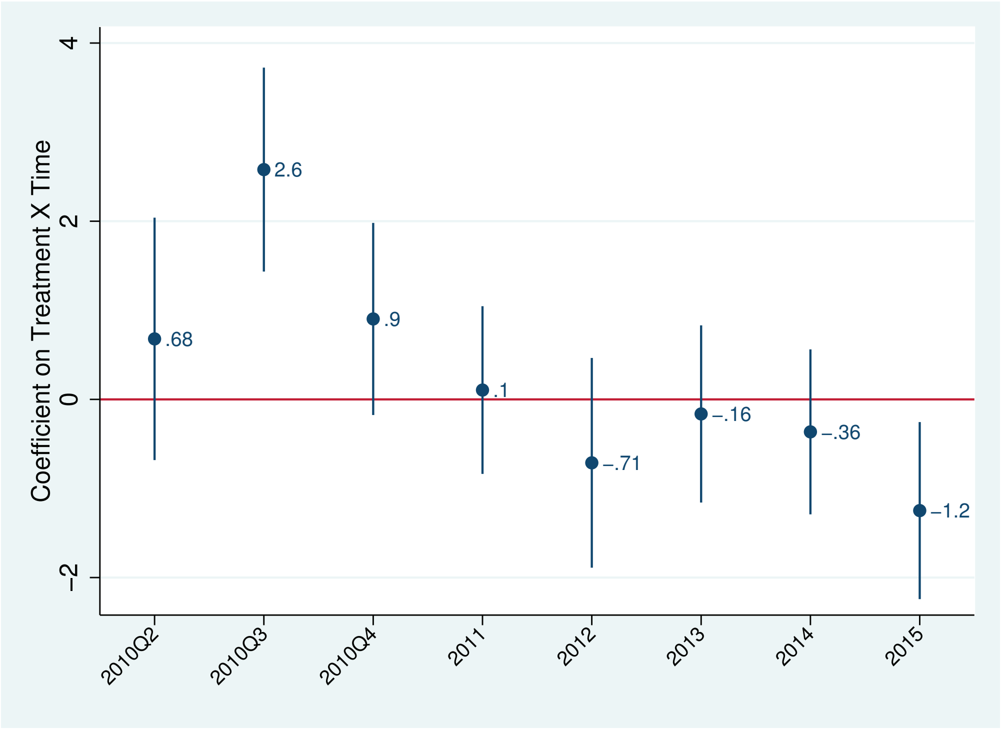

(b) Treatment Q3

(c) Treatment Q3, Excluding Mississippi River Basin

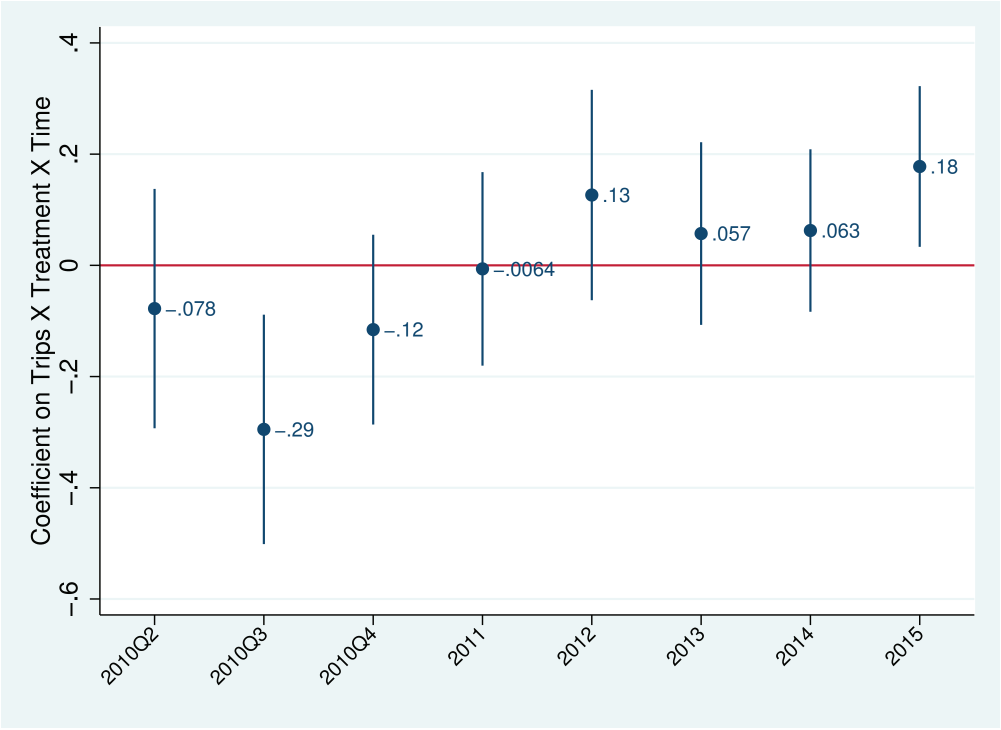
Scatter plots showing log of crab landings versus log of crabbing trips in treatment versus control basins in Louisiana during the third quarters of 2009, 2010, and 2011. For each quarter, the line of bet fit is also shown.

Figure 12: Impact of the Deepwater Horizon Spill on Louisiana Crab Landings-Trips Relationship

(a) Treatment x Time



(b) Trips x Treatment x Time



Coefficients from a difference-in-differences regression examining the relationship between the log of crab landings and the log of crabbing trips in basins in treatment and control basins following the Deepwater Horizon spill. Panel (a) shows the coefficients on an indicator for treatment interacted with each post-spill period, while Panel (b) shows the coefficients on the log of trips interacted with an indicator for treatment and each post-spill period. Specifications include controls for closure. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

Table 1: Extent of Oiling and Closures in Louisiana Basins

		Closed in 2010								
Basin	Days Oiled	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atchafalaya	1		X							
Barataria	12		X	X	X	X	X	X	X	X
Calcasieu River	0		X							
Lake Pontchartrain	10	X	X	X	X	X	X			
Mermentau River	1		X	X						
Mississippi River	18	X	X	X	X	X	X	X	X	X
Terrebonne	9		X	X	X	X	X			
Vermilion-Tech	1		X							

Number of days of cumulative oiling, as well as closure, for eight basins in Louisiana, based on sources as described in the text. Each area is indicated as being closed in a particular month if at least some portion of the basin was closed at some point during the month.

Table 2: Impact of the Deepwater Horizon Spill on Gulf Crab Landings and Revenues

VARIABLES	(1) Landings	(2) Landings	(3) Landings	(4) Value	(5) Value	(6) Value
Gulf x Post	-0.573***	-0.572***	-0.442**	-0.511**	-0.509**	-0.379*
	(0.174)	(0.174)	(0.186)	(0.211)	(0.209)	(0.205)
Hurricane		0.0466	0.0124		0.105	0.106
		(0.307)	(0.231)		(0.382)	(0.270)
Constant	11.50***	11.50***	11.51***	10.88***	10.88***	10.94***
	(0.252)	(0.252)	(0.229)	(0.327)	(0.327)	(0.297)
Observations	1,798	1,798	2,014	1,798	1,798	2,014
R^2	0.707	0.707	0.703	0.722	0.722	0.719
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year/Month FE	Yes	Yes	Yes	Yes	Yes	Yes
FL/TX	No	No	Yes	No	No	Yes

Dependent variable names are shown in column headings and are in logs. $Gulf$ x $Post$ is an indicator variable equal to one for Gulf states following the Deepwater Horizon spill, zero otherwise. Standard errors are clustered at the state level. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 3: Impact of the Deepwater Horizon Spill on Louisiana Crabbing Trips

VARIABLES	(1) Trips	(2) Trips	(3) Trips	(4) Trips	(5) Trips
TreatedxPost	0.117		0.161		
	(0.236)		(0.250)		
Closure		-0.464*	-0.523*		-0.574*
		(0.202)	(0.246)		(0.276)
Days Oiled x Post				0.0187	0.0227
				(0.0174)	(0.0184)
Constant	5.031***	4.986***	5.030***	5.057***	5.055***
	(0.238)	(0.265)	(0.239)	(0.260)	(0.260)
Observations	959	959	959	959	959
R^2	0.900	0.902	0.903	0.902	0.906
Year/Month FE	Yes	Yes	Yes	Yes	Yes
Basin FE	Yes	Yes	Yes	Yes	Yes

Dependent variable is log of crabbing trips. $Treatment$ is an indicator variable equal to one for treatment basins, zero for control basins. $DaysOiled$ is equal to the number of cumulative days of oiling in the basin. $Post$ is an indicator variable equal to one following the Deepwater Horizon spill, zero otherwise. $Closure$ is an indicator variable equal to one if any part of the basin was closed at any point during the month. Standard errors are clustered at the basin level. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 4: Impact of the Deepwater Horizon Spill on Louisiana Crab Landings

VARIABLES	(1) Landings	(2) Landings	(3) Landings	(4) Landings	(5) Landings
TreatedxPost	0.228		0.254		
	(0.240)		(0.253)		
Closure		-0.222	-0.316		-0.377
		(0.143)	(0.196)		(0.224)
Days Oiled x Post				0.0290	0.0316
				(0.0180)	(0.0189)
Constant	11.59***	11.52***	11.59***	11.62***	11.61***
	(0.247)	(0.253)	(0.248)	(0.267)	(0.267)
Observations	959	959	959	959	959
R^2	0.875	0.872	0.876	0.879	0.880
Year/Month FE	Yes	Yes	Yes	Yes	Yes
Basin FE	Yes	Yes	Yes	Yes	Yes

Dependent variable is log of landings. $Treatment$ is an indicator variable equal to one for treatment basins, zero for control basins. $DaysOiled$ is equal to the number of cumulative days of oiling in the basin. $Post$ is an indicator variable equal to one following the Deepwater Horizon spill, zero otherwise. $Closure$ is an indicator variable equal to one if any part of the basin was closed at any point during the month.Standard errors are clustered at the basin level. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 5: Impact of the Deepwater Horizon Spill on Relationship Between Landings and Trips in Louisiana

VARIABLES	(1) Landings	(2) Landings	(3) Landings	(4) Landings	(5) Landings	(6) Landings	(7) Landings
Trips	1.050***	1.066***	1.043***	1.058***	1.050***	1.053***	1.063***
	(0.0342)	(0.0421)	(0.0278)	(0.0365)	(0.0346)	(0.0515)	(0.0496)
Trips x Post						-0.0601	-0.0561
						(0.0480)	(0.0461)
TripsxTreated						0.0188	0.0249
						(0.0734)	(0.0781)
TreatedxPost			0.105*	0.0839*		-0.00208	-0.0898
			(0.0493)	(0.0436)		(0.321)	(0.322)
TripsxPostxTreated						0.0219	0.0310
						(0.0547)	(0.0544)
Closure		0.272*		0.237*	0.227*		0.232
		(0.124)		(0.111)	(0.111)		(0.132)
Days Oiled x Post					0.00776***		
					(0.00186)		
Constant	6.278***	6.205***	6.343***	6.266***	6.305***	6.282***	6.232***
	(0.202)	(0.246)	(0.192)	(0.232)	(0.228)	(0.349)	(0.344)
Observations	959	959	959	959	959	959	959
R^2	0.971	0.972	0.972	0.972	0.972	0.972	0.973
Year/Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basin FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Dependent variable is log of crab landings. *Trips* indicates the log of trips. *Treatment* is an indicator variable equal to one for treatment basins, zero for control basins. *DaysOiled* is equal to the number of cumulative days of oiling in the basin. *Post* is an indicator variable equal to one following the Deepwater Horizon spill, zero otherwise. *Closure* is an indicator variable equal to one if any part of the basin was closed at any point during the month.Standard errors are clustered at the basin level. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Appendix

Table A.1: Blue Crab Landings and Revenues in the Gulf and Atlantic by State

State	Landings (million pounds)					Revenues (million $)				
	Mean	SD	Min	Max	%	Mean	SD	Min	Max	%
Gulf										
Alabama	0.13	0.08	0.01	0.57	1%	0.10	0.05	0.01	0.36	1%
Florida West Coast	0.83	0.39	0.21	1.71	5%	2.45	1.74	0.26	6.59	14%
Louisiana	3.62	1.61	0.03	7.46	23%	3.33	1.71	0.03	9.65	19%
Mississippi	0.05	0.03	0.01	0.15	0.3%	0.05	0.03	0.01	0.13	0.3%
Texas	0.23	0.14	0.01	0.83	1%	0.22	0.13	0.01	0.63	1%
Atlantic										
Connecticut	0.01	0.01	0.00	0.07	0.05%	0.01	0.01	0.00	0.10	0.04%
Delaware	0.31	0.26	0.00	1.03	2%	0.42	0.40	0.00	1.51	2%
Florida Inland Lakes	0.01	0.01	0.00	0.03	0.02%	0.02	0.01	0.00	0.03	0.03%
Florida East Coast	0.29	0.11	0.07	0.54	2%	0.46	0.14	0.21	0.79	3%
Georgia	0.30	0.12	0.04	0.58	2%	0.30	0.10	0.06	0.67	2%
Maine	0.25	0.17	0.05	0.98	2%	0.09	0.06	0.02	0.34	1%
Maryland	3.45	3.31	0.00	11.99	20%	4.80	4.49	0.00	15.04	25%
Massachusetts	0.85	0.34	0.35	1.81	5%	0.65	0.34	0.20	2.54	4%
New Hampshire	0.02	0.04	0.00	0.33	0.09%	0.01	0.01	0.00	0.05	0.04%
New Jersey	0.47	0.48	0.00	2.25	3%	0.61	0.61	0.00	2.74	3%
New York	0.02	0.05	0.00	0.36	0.13%	0.02	0.03	0.00	0.24	0.08%
North Carolina	2.28	1.81	0.02	5.85	14%	2.11	1.78	0.02	6.22	12%
Rhode Island	0.35	0.21	0.06	0.91	2%	0.21	0.13	0.04	0.59	1%
South Carolina	0.38	0.18	0.08	0.89	2%	0.39	0.15	0.13	0.80	2%
Virginia	2.79	1.79	0.00	7.22	15%	2.12	1.55	0.00	6.21	11%

Summary statistics for monthly blue crab landings and revenues, by state, downloaded from the NOAA Commercial Landings database. Data for 2006-2014 are pooled. Revenues are deflated to January 2006 values using the monthly CPI for fish and seafood (city average for all urban consumers, seasonally adjusted). % indicates percent of total across all states included in the table.

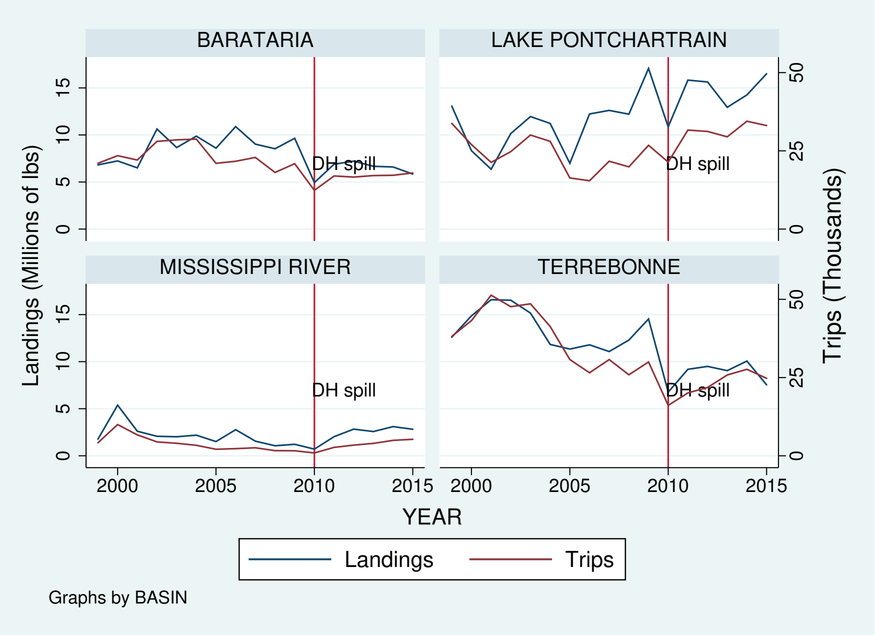
Table A.2: Blue Crab Trips, Landings and Revenues in Louisiana by Basin

State	Trips (thousands)					Landings (million pounds)					Revenues (million $)				
	Mean	SD	Min	Max	%	Mean	SD	Min	Max	%	Mean	SD	Min	Max	%
Atchafalaya	0.38	0.23	0.04	0.99	4%	0.17	0.13	0.01	0.77	4%	0.15	0.09	0.01	0.44	4%
Barataria	1.51	0.64	0.52	2.97	18%	0.63	0.35	0.11	1.52	17%	0.59	0.32	0.17	1.90	17%
Calcasieu River	0.52	0.20	0.14	0.95	6%	0.18	0.09	0.04	0.47	5%	0.18	0.09	0.04	0.42	5%
Lake Pontchartrain	2.19	0.97	0.43	4.26	26%	1.16	0.45	0.27	2.18	32%	1.24	0.67	0.27	3.61	35%
Mermentau River	0.34	0.16	0.05	0.73	4%	0.11	0.07	0.02	0.28	3%	0.11	0.06	0.02	0.25	3%
Mississippi River	0.25	0.18	0.03	0.76	3%	0.17	0.14	0.01	0.62	5%	0.15	0.14	0.00	0.65	4%
Terrebonne	2.08	0.85	0.58	4.00	25%	0.85	0.43	0.14	2.09	23%	0.72	0.41	0.15	2.55	20%
Vermilion-Tech	1.19	0.62	0.13	2.45	14%	0.40	0.23	0.03	1.18	11%	0.42	0.24	0.03	1.21	12%

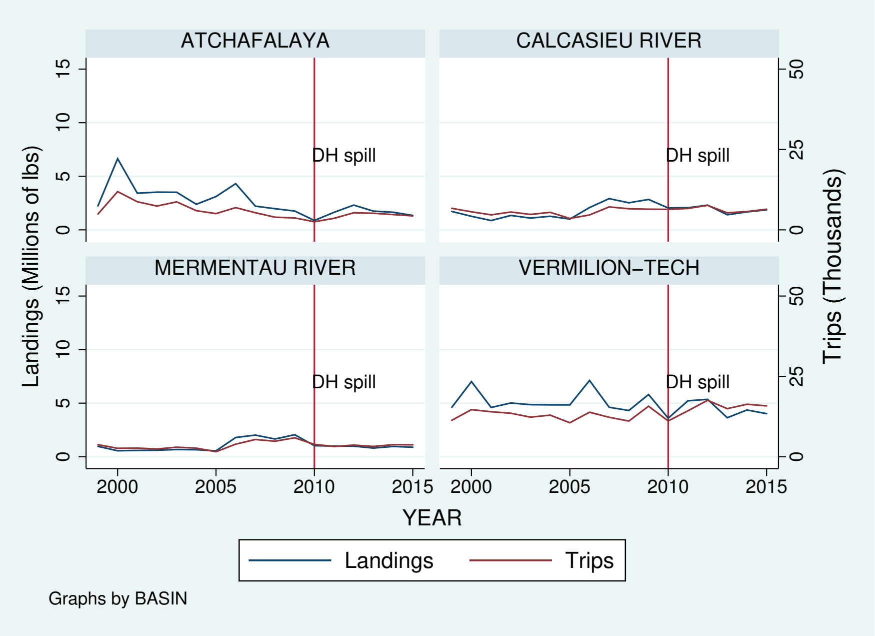
Summary statistics for monthly blue crab trips, landings and revenues, by basin, based on authors' calculations using data provided by the Louisiana Department of Wildlife and Fisheries. Data for 2006-2015 are pooled. Revenues are deflated to January 2006 values using the monthly CPI for fish and seafood (city average for all urban consumers, seasonally adjusted). % indicates percent of total across all basins included in the table.

Figure A.1: Louisiana Blue Crab Landings Over Time by Basin

(a) Treatment Basins

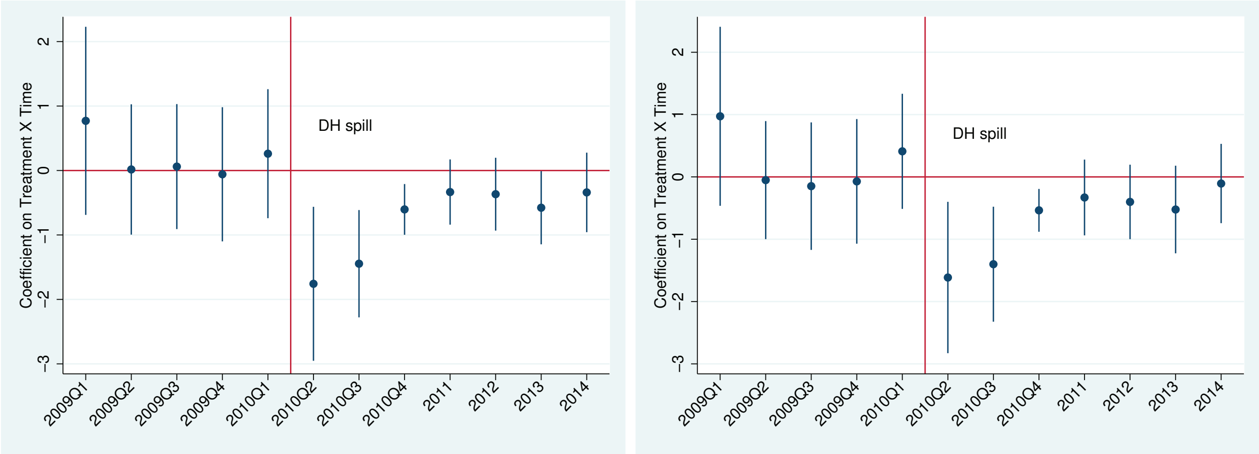


(b) Control Basins



Annual commercial blue crab landings and associated crabbing trips in Louisiana, by basin. Authors' calculations based on data provided by the Louisiana Department of Wildlife and Fisheries. Panel (a) shows treatment basins, while Panel (b) shows control basins. The vertical line in each figure indicates the Deepwater Horizon spill in April 2010.

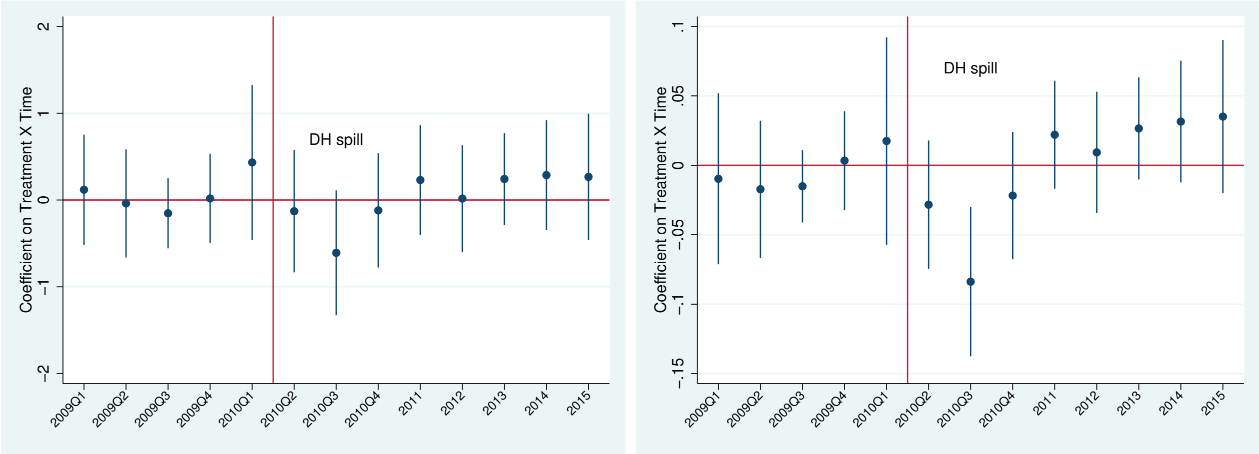
Figure A.2: Placebo Test: Gulf Crab Landings and Revenues


(a) Landings

(b) Revenues

Coefficients from a difference-in-differences regression comparing changes in the log of crab landings (Panel (a)) and revenues (Panel (b) in Gulf versus Atlantic states prior to the Deepwater Horizon spill (2009Q1 through 2010Q1, the placebo period) as well as following the Deepwater Horizon spill (2010Q2 onwards). Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

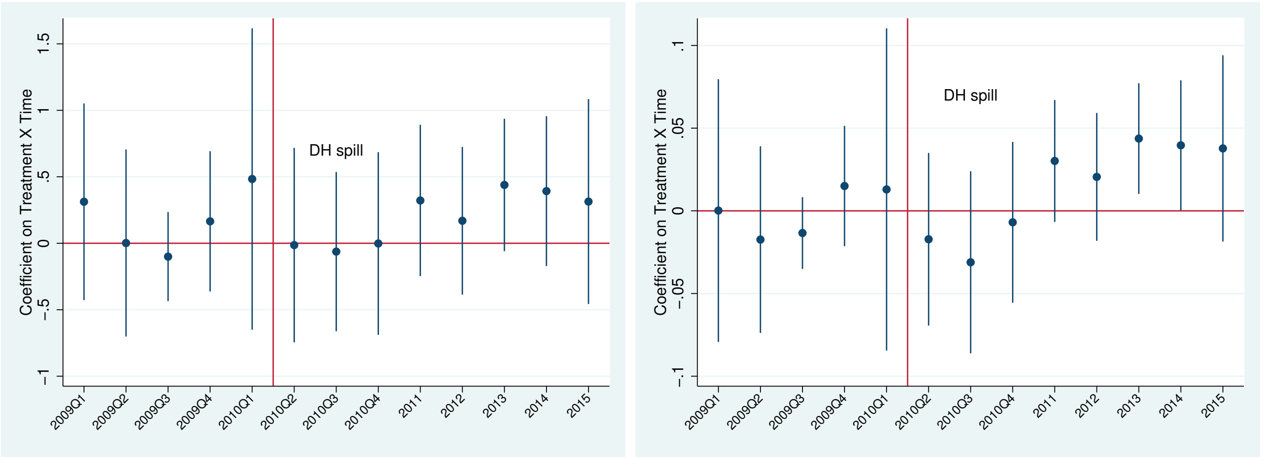
Figure A.3: Placebo Test: Louisiana Crabbing Trips


(a) Treatment / Control

(b) Degree of Oiling

Coefficients from the interaction between treatment and pre-Deepwater (placebo) as well as post-Deepwater time periods from a difference-in-differences regression. In Panel (a), we compare the four treatment basins with the four control basins. In Panel (b), we compare basins by degree of exposure to oiling, which is measured in terms of the number of days of cumulative oiling observed. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

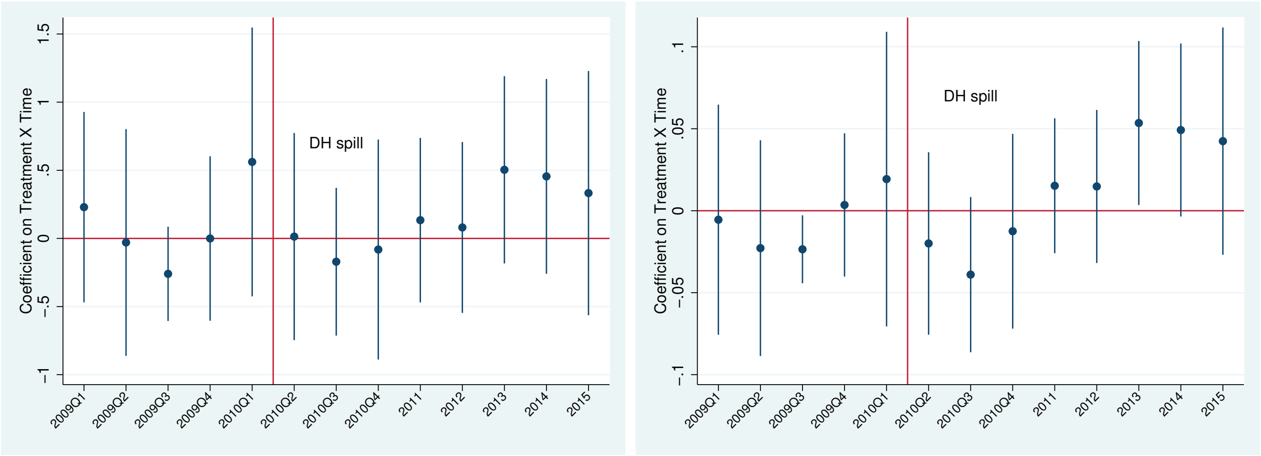
Figure A.4: Placebo Test: Louisiana Crab Landings


(a) Treatment / Control

(b) Degree of Oiling

Coefficients from the interaction between treatment and pre-Deepwater (placebo) as well as post-Deepwater time periods from a difference-in-differences regression. In Panel (a), we compare the four treatment basins with the four control basins. In Panel (b), we compare basins by degree of exposure to oiling, which is measured in terms of the number of days of cumulative oiling observed. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.

Figure A.5: Placebo Test: Louisiana Crab Revenues


(a) Treatment / Control

(b) Degree of Oiling

Coefficients from the interaction between treatment and pre-Deepwater (placebo) as well as post-Deepwater time periods from a difference-in-differences regression. In Panel (a), we compare the four treatment basins with the four control basins. In Panel (b), we compare basins by degree of exposure to oiling, which is measured in terms of the number of days of cumulative oiling observed. Standard errors are clustered at the basin level, and 95 percent confidence intervals are shown.