Safety Incidents in the West Coast Catch Shares Fisheries

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Executive Summary

The United States Coast Guard collects and maintains data on incidents at sea in the commercial fishing industry. Safety-related incidents include injuries, falls overboard, vessel collisions, deaths, pollution events, and equipment failures that require Coast Guard intervention. However, this information is not linked to the particular fishery in which a vessel was participating at the time of the incident. Linking to the fishery is important for research concerning fishing and vessel safety because institutions, regulations, physical regional characteristics (i.e., weather, currents, and navigational challenges), vessel characteristics (i.e., length, weight, age, maneuverability, and gear type), and captain and crew experience all affect fishing safety and incident rates. These attributes may vary greatly not only by region, but by the particular fishery (or fisheries) in which a vessel participates.

Linking Coast Guard incident data with fishery data requires significant additional effort by a researcher with access to fishing permit, landings, and fishery observer data. Much of this data is confidential and access is available only to National Marine Fisheries Service (NMFS) researchers under the requirements set forth in the Magnuson-Stevens Fishery Conservation and Management Act (MSA) at section 402(b), 16 U.S.C. 1881a(b).

This report matches Coast Guard incident data to fisheries data in two important West Coast fisheries: the sablefish fixed gear tier limit fishery and the catcher vessels participating in the West Coast limited entry groundfish trawl fishery. Both fisheries have undergone management transitions to catch shares (e.g., individual fishing quota) management in recent years. National Standard 10 of the MSA, NOAA Catch Shares Policy (NOAA, 2010), and the individual program goals of both catch share programs all include “improving safety in the fishery” as one of their stated goals (Amendment 14 of the Pacific Coast Groundfish Fishery Management Plan, 75 FR 32993, 75 FR 60868). In addition, both programs have recently or will soon be subject to a programmatic review, during which attainment of the program goals will be evaluated. Therefore, this matched dataset is of particular interest for these two fisheries.

This report also presents a method for calculating incident rates using a risk exposure based on estimated total days spent at sea. Annual total days at sea are estimated for each fleet, and an incident rate is calculated for each fleet. The West Coast sablefish tier limit fishery is evaluated from 1994 to 2012, and the West Coast groundfish trawl limited entry/catch share fishery is evaluated from 2002 to 2012. These time frames include periods before and after their respective catch share programs were put into place.

Coast Guard incident and casualty data that have been matched to fishery data have been used to evaluate changes in incident rates over time in other fisheries. In this report, however, we also discuss some of the problems with such data and how it should be appropriately used, given those problems. For example, without an identification strategy to establish causality, these data should not be used to claim that a particular factor “caused” a change in the number of incidents or incident rate. Even with an identification strategy, causality is very difficult to establish with sparse data like annual incident rates. In addition, the data measure the number of reported incidents, and should not necessarily be used to make conclusions about fishing safety in general.

Despite these caveats, the data developed in this report are important because ultimately, a reduction in safety-related incidents and deaths is the goal of safety policies. This report also highlights improvements that could be made in data collection and tracking, and cautions users on the interpretation of such data.

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1: Introduction

Fishing is one of the most dangerous jobs in terms of fatality rates in the United States (Bureau of Labor Statistics, 2012). While this is likely true worldwide, fatality and injury rate statistics that directly comparable across countries are seldom collected (Petursdottir, Hannibalsson, and Turner, 2001). Fishing is inherently dangerous; exposure to the elements, the strenuous work environment on a constantly moving, exposed, and potentially slippery platform, the necessity for vessels to carry shifting and ever changing loads, the rapid deterioration of vessels and gear caused by constant exposure to seawater, and the risks associated with open water all contribute to the danger. Research concerning fishing safety is increasingly recognizing that institutions, regulations, physical regional characteristics (i.e., weather, currents, and navigational challenges), vessel characteristics (i.e., length, weight, age, maneuverability, and gear type), and captain and crew experience, profoundly affect fishing safety and incident rates (Lambert et al., 2015). These attributes may vary greatly, not only by region, but also by the particular fishery (or fisheries) in which a vessel participates.

Casualties and other safety incidents at sea are responded to, investigated, and tracked by the U.S. Coast Guard. Other organizations, such as the National Institute of Occupational Health and Safety (NIOSH), use and supplement data collected and maintained by the Coast Guard to conduct occupational health-related research, including research related to the safety of commercial fisheries. However, the Coast Guard does not collect data on the fishery in which a vessel was participating when an incident occurred. Making this determination requires matching Coast Guard data to National Marine Fisheries Service (NMFS) federal fishing data and/or state fishing data. This matching process can be quite complicated due to the widely varying types, quality, amount, and confidentiality requirements of data available for different fisheries.[1] Even within the same geospatial region and target species, management may define distinct sectors under which the regulations and incentives vary. Analysts generally need to combine several data sources to determine the fishing target for a particular vessel's trip. Then, the effects of characteristics of the fishery can be considered for their potential effects on incident occurrence, casualty rates, risk exposure, the likelihood of future incidents, or other assessments of safety in the particular fishery or fisheries under study (Lambert et al., 2015).

Researchers at NIOSH have partnered with the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) to match Coast Guard data to several specific fishing sectors, including the Bering Sea/Aleutian Islands (BSAI) crab fishery (Lincoln and Woodley 2010) , the non-pollock groundfish cooperatives (the Amendment 80 fishery) (NMFS 2012, Northern Economics, Inc. 2014), the freezer longline license limitation

[1] Most of the data that would be appropriate for use is subject to confidentiality requirements set forth in the Magnuson-Stevens Fishery Conservation and Management Act (MSA) at section 402(b), 16 U.S.C. 1881a(b), which means that, unless the user meets one of the MSA exceptions, data can only be accessed and analyzed by NMFS researchers, individuals under contract with NMFS to do policy analysis of a fishery management action, or others doing work directly related to fishery conservation and management.

program fishery (NPFMC and NMFS 2013), the Gulf of Mexico red snapper individual fishing quota (IFQ) program (GMFMC 2013), and the Atlantic scallop General Category IFQ fishery (NMFS 2014). NMFS has an interest in the development of such datasets because under National Standard 10 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), "conservation and management measures shall, to the extent practicable, promote the safety of human life at sea" (MSA section 301(a)(10)).

The purpose of this report is to match Coast Guard-reported safety incident at sea data (such as injuries, falls overboard, vessel collisions, and deaths) to fishing data in two important fisheries in the West Coast region of the United States: the catcher vessel sector of the West Coast limited entry groundfish trawl fishery (vessels that deliver to shoreside or at-sea processors, but excluding the at-sea processors themselves, as well as the catcher-processor sector of the fishery) and the sablefish tier limit fishery. Both the limited entry groundfish trawl fishery and the sablefish tier limit fishery on the West Coast have undergone a management transition from limited entry programs to catch share (individual fishing quota) management in recent years. Because the NOAA Catch Shares Policy, as well as the language of the individual fishery catch share program regulations, include "improve safety in the fishery" as one of their stated goals, this data is of particular interest for these two fisheries.[2] To comply with the MSA, both programs must undergo a formal review to determine progress its goals. The sablefish tier limit fishery is currently undergoing its program review, and the groundfish trawl fishery catch shares program will undergo its program review beginning in 2016. The data produced in this report will be a part of both reviews.

Annual days at sea in each fishery are then estimated to allow the calculation of incident rates. Incidents divided by annual days at sea in each fishery is a rate that is comparable across fisheries.

However, we also caution against drawing strong conclusions about changes in fishing safety from this type of data, especially without a thorough analysis of risk exposure and the incentives influencing fisherman behavior. The Coast Guard vessel incident databases contain only reported incidents--not near misses, incidents that did not require reporting, or incidents that were purposefully not reported to avoid investigations, fines, or other penalties. There is also

[2] In 2010, NOAA announced its "Catch Share Policy", encouraging the consideration and adoption of catch shares management in U.S. fisheries. One of the stated goals of the Policy is to "promote safety" in fisheries. Theoretically, catch shares (the allocation of a portion of the catch limit to each participant in the fishery) can affect safety in the fishery and presumably, the rate of safety incidents, through a reduction or elimination the incentive to "race for fish." When fishermen race for fish, or fish as fast as possible to catch the maximum amount of fish before the collective seasonal catch limit is reached and the fishery is closed, a fishing season can be reduced to only a few days and involve around-the-clock fishing in life-threatening weather conditions (Wilen 1979, Homans and Wilen 1997, Deacon et al. 2011). Overloaded vessels, ignoring maintenance problems on vessels, and fishing in dangerous conditions may be commonplace (Ayeko 2002, Power et al. 2006, Woodley et al. 2009). However, because a portion of the catch limit, or quota, is allocated to each vessel under catch shares management, fishermen can fish their quota whenever they see fit. One of the many results of catch share management has been a significant decrease in the speed and intensity of fishing and a lengthening of the fishing season (Deacon et al. 2011, Brinson and Thunberg 2013). This is expected to increase safety in fisheries, as fishermen no longer need to work around the clock, they can return to port for repairs if something goes wrong with their vessel, and they do not need to fish in stormy or dangerous conditions.

likely to be some error in matching Coast Guard incident data to participation in specific fisheries because the target fishery cannot always be determined from the data available. Finally, there are statistical issues associated with the estimation of rare events, such as safety incidents in a fishery (where, for example, a few incidents may occur during a season of thousands of vessel-days fishing) (King and Zeng 2001). Causality is difficult to establish with such sparse data, even with an identification strategy, such as a valid instrument or comparison fishery. Without causality statistically established, it would be inappropriate to conclude that any particular factor or management action "caused" an effect on the incident rate in a fishery. These concerns will be further discussed in Section 5 of this report.

Despite these issues, developing an understanding of incident rates in fisheries is necessary and valuable. After matching incident data to fisheries, the data are useful for demonstration of the actual trends in incident, injury, and mortality rates over time in particular commercial fisheries, as well as for comparison across fisheries. Previous research on fishing safety has almost exclusively used Coast Guard incident and/or mortality data, so providing the data as a comparison to previous studies is worthwhile (Thomas et al. 2001, Jin and Thunberg 2005, Lincoln and Lucas 2010, Lambert et al., 2015). Comparisons across fisheries can yield insights about how different conditions, vessel characteristics, captain or crew characteristics, or management regimes affect fisherman behavior in a way that might be related to risk exposure or fishing safety. Safety incidents in commercial fishing are expensive, disruptive, and often tragic. Thus, a reduction in accidents and incidents is the ultimate goal of safety policies and regulations and should be tracked. This and other studies help to highlight improvements that could be made in data collection and tracking, as well as caution users on the interpretation of such data.

2: Data

Vessel incident data were acquired from two vessel incident databases maintained by the U.S. Coast Guard. Vessel incidents from the years 1962 through 2001 are maintained in the Marine Safety Information System (MSIS) database, and vessel incidents for 2002 through 2012 are from the Marine Information for Safety and Law Enforcement (MISLE) database. Incident categories vary somewhat by database. MSIS includes the categories: allision, breakaway, capsize, collision, equipment failure, explosion, fire, flooding, grounding, missing persons, casualty, pollution, sinking, and structural failure. MISLE includes the categories: abandonment, allision, capsize, collision, damage to cargo, damage to the environment, emergency response, evasive maneuvers, explosion, falls into water, fire, flooding, fouling, grounding, loss of electrical power, loss of stability, materiel failures (diving, non-vessels, and vessels), set adrift, sinking, and vessel maneuverability. Not all incident categories occurred in the fisheries included in this study.

Equipment and materiel failure, vessel maneuverability, and loss of electrical power incidents were dropped because they are not specifically safety incidents (although they could certainly lead to safety incidents) and are inconsistently reported over time. Vessel fouling[3] and pollution incidents were also dropped, as they may not be directly correlated with fishing safety. These types of incidents may be related to vessel maintenance, which could be affected by catch share or other types of management measures, but are excluded from the current report.[4]

The scale of fisheries to be included in this study was determined by the scale of management, and the need to provide data and information on fishing safety for management program reviews. Thus, included are all incidents by catcher vessels that participated either in the West Coast limited entry groundfish trawl fishery (which became part of the West Coast Groundfish Catch Share Program in 2011) from 2002 to 2012, and by participants in the sablefish tier limit fishery from 1994 to 2012 (which became the Sablefish Permit Stacking program in 2001). The West Coast groundfish trawl catch share program also includes a cooperative of catcher processor vessels, but they are not included in the current analysis because they are much larger vessels (average of 300 feet) with very distinct operations, and have been operating as a cooperative (and thus under a distinct institutional structure) since prior to the beginning of the dataset used in this report (2002).

These vessels can be identified by their fishing permits in each year, their gear and landings for a particular trip, and the location of fishing (West Coast of the United States: 30 degrees to 50 degrees North latitude and -115 degrees to -135 degrees West longitude). Most vessels participate in other fisheries in each year, so participation in the fisheries of interest must be separated from participation in other fisheries.

Fishing data were acquired from landings records (fish tickets) from 1994 to 2012, maintained by the Pacific Fisheries Information Network (PacFIN).[5] Landings data contain the date, location, type of gear used, landed weight and revenue of each species for each delivery.[6] All fish tickets for catcher vessels that participated either in the West Coast limited entry groundfish trawl fishery from 2002 to 2012 or the sablefish tier limit fishery from 1994 to 2012 were compiled for the analysis.

Some measure of risk exposure is needed to calculate incident rates. An estimate of the total number of days spent at sea by the fleet is used in lieu of full-time equivalent (FTE) workers or other commonly used measures, which will be discussed in the Methods section. To get days at sea, the location and date of each observed trip starts were obtained from the West

[3] Vessel fouling occurs when marine organisms attach themselves to parts of the vessel immersed in water. The accumulation of these organisms can cause damage to the hull structure and propulsion systems of vessels.

[4] There was evidence of an unusual increase in the number of reported "vessel maneuverability" incidents over time. It is suspected that the reporting and/or recording of these types of incidents increased over time in a way that is not representative of the occurrence of such events. No other incident category increased in the same manner. In the data from 1994 to 2001, we are unable to separate "vessel maneuverability" from other types of materials failures. We were unable to confirm this with Coast Guard sources, thus are unable to analyze these data without additional information. However, because the focus of our study is on safety-related incidents, exclusion of this category is a reasonable solution.

[5] More information available at www.psmfc.org.

[6] Multiple deliveries in one day occur 11 percent of the time in the sablefish tier limit fishery. For unobserved trips, it is impossible to determine the difference between a case where a vessel delivers a portion of their catch from one trip to one processor and another portion of their catch to another processor, and a case where a vessel takes two fishing trips in one day. Because our analysis of trip starts is at the daily level, when there are multiple fish tickets in one day we assume that the vessel took one trip in a day and split the delivery.

Coast Groundfish Observer data. In the sablefish fishery, approximately 20 percent of trips had federal observers on board for the time period 2002 to 2012. In the West Coast groundfish trawl fishery, 100 percent observer coverage was mandated in 2011. Thus, for 2011 to 2012, all trip start location and dates are known. For 2002 to 2010, approximately 20 percent of trips were observed.[7]

3: Methods

For each fishery, a brief analysis of each fishery and fishery management during the time period under study was conducted, and a description is provided in the next section. Then, the safety incident data were matched to fishing data to determine if each reported incident occurred while a vessel was participating in either the sablefish tier limit fishery or the West Coast limited entry/catch shares groundfish trawl fishery. For the sablefish tier limit fixed gear fishery, incidents were matched to vessel participation in the sablefish tier limit sector and the dates of the seasons for which fish ticket landings data are available (1994-2012). The West Coast limited entry groundfish trawl fishery is open year-round, so the incident data were matched based on participation in the fishery, which were determined from permits attached to the vessel and each trip's landings. Incidents were then matched by date to the most recent commercial landing (fish ticket) prior to or directly after the incident. The fish tickets (as well as fish tickets from proximate dates) were inspected to determine, to the best of our ability, that the vessel was indeed targeting either sablefish in the tier limit fixed gear sector or groundfish in the West Coast limited entry trawl fishery.

Because fishing effort (person-hours spent at sea) may vary from year to year due to management, season length, allowable catch, the number of vessels in the fishery, or other reasons, the incident rate more adequately describes incident trends than the number of incidents alone. The incident rate per full-time equivalent workers (FTEs) is the most standard way of reporting and evaluating safety incidents. For example, the Bureau of Labor Statistics[8] and the Occupational Safety and Health Administration[9] compile mortality rates per FTE and per hour worked for many occupations to facilitate comparisons across industries. However, adequate historical data identifying the number of crew on board each vessel does not exist for either fishery, precluding the calculation of rates per FTE or hours worked and necessitating the calculation of alternative statistics.

One alternative is to use the incident rate per vessel-days at sea. However, the exact number of days spent at sea by each vessel is also unknown given the available data. Fish tickets give only the date of delivery (at the end of each trip). Thus, we estimated days at sea by modeling the trip length of observed trips (sablefish: approximately 20 percent observer coverage for 2002-2012 and no observer coverage for 1994-2001; groundfish: approximately 20

[7] More information available at http://www.nwfsc.noaa.gov/research/divisions/fram/observation/index.cfm.
[8] http://www.bls.gov/iif/
[9] https://www.osha.gov/oshstats/index.html

percent coverage for 2002-2010 and 100 percent coverage for 2011-2012) as a function of vessel length, catch per trip, the date of the previous fish ticket, total allowable catch (TAC) (for the sablefish fishery only), subfishery (for the groundfish trawl sector only), gear, and port. The model was used to predict trip length for unobserved trips and for trips prior to observer coverage. Predicted trip lengths were adjusted so that a trip could not begin before the previous trip ended (which is indicated by the date of the fish ticket),[10] and then summed for all trips that occurred in each year.[11] The incident rate was then calculated as the number of incidents divided by the number of predicted days at sea.

4: Results

4.1 Sablefish tier limit fishery

The West Coast sablefish fixed gear tier limit fishery targets sablefish (*Anoplopoma fimbria*) off the coasts of California, Oregon, and Washington using pot and longline gear. The fishery's rationalization process began in the late 1990s. Prior to the tier system's full implementation in 2001, participation was capped by a limited access permit system, but the fishery was nevertheless characterized by the classic derby fishery-type problems of over-capitalization, an extremely short season, and a lack of financial viability of many vessels in the fleet (Hastie, 2001). Both the industry and regulators recognized the dangerous situations in which harvesters were being forced to fish, although no documentation of incidents or incident rates in the fishery has ever been done. To attempt to address safety concerns, the timing of the derby fishery was shifted to later in the year when West Coast weather is typically less stormy, adjusted to coincide with good tidal conditions, and a series of restrictions on the time of day when fishing was allowed and when vessels had to be in port immediately before and after the season were enacted (60 FR 11062). However, the seasons continued to condense and, correspondingly, safety concerns escalated (Amendment 14 of the Pacific Coast Groundfish Fishery Management Plan).

What was dubbed the "permit stacking program" was implemented in 2001, which allocated a "tier" of harvest privilege to each fishery participant (meaning the permit allowed the harvest of one of three possible percentages of the total allowable catch each year), and allowed vessels to register up to three tiered permits on a single vessel. Permits could be stacked through leasing or purchase arrangements. The program also extended the legal open fishing season. The season length increased from just 6 days in 1998 to 2.5 months in 2001, 6 months in 2002-2003, and 7 months (April-October) in 2004 to the present. The permit stacking program is still in place today, and constitutes a catch share program, although trading is restricted by the limited number of permits that can be attached to a vessel, the original number of endorsements

[10] Such adjustments were needed in approximately 2 percent of trips in each fishery.
[11] In the sablefish fishery we have no means to evaluate the performance of the model in the period prior to the catch shares program.

(permits) issued in each tier, and the percentages of the fleet's allocation that are used to calculate annual catch limits within each tier.

An average of 110 vessels actively participated in the fishery in each year from 1994 to 2012 (min=79, max=166). Average vessel length is 45 feet (min=17, max=110), and average vessel horsepower is 246 hp. Vessels fish with an average of 2.5 crewmembers, in addition to the captain (Lian, in prep.).

There were ten Coast Guard reported, safety-related incidents that were matched to the sablefish tier limit fishery from 1994 to 2012 (Figure 1). They included two allisions, two collisions, three groundings, one sinking, and one person injured. There were no fatalities. Damages (that were officially reported to the Coast Guard) totaled $430,000. The number of incidents that occurred in each year ranged from zero in most years to three in 1995 (Figure 1).

Results of the log-linear estimation of the trip length model show that vessel size, catch per trip, the number of days since the last delivery, annual total allowable catch, gear, sector, and port of delivery affect trip length (Table 1). The model fits well for observed trips (R^2 =0.84, RMSE=0.429). The model is used to predict days at sea for each trip, which are then summed to obtain an estimate of annual total days at sea for the fleet (Figure 2). The values shown in Figure 2 are used to calculate the annual incident rate (Figure 3). The average over the time period is 0.4 incidents per 1000 days at sea, and has a decreasing trend over time.

4.2 West Coast limited entry groundfish trawl fishery

The West Coast limited entry groundfish trawl fishery targets more than 30 groundfish species and rockfish complexes off the coasts of California, Oregon, and Washington using trawl gear.[12] Prior to 2011, the fishery was managed with a system that included limited access permits, harvest guidelines, trip, weekly, monthly, and bi-monthly landings limits, area restrictions, seasonal closures, and gear restrictions. These management measures were developed to assist in the rebuilding of several species that were declared overfished in 2003. Catch shares were implemented in 2011 with the goals of providing for a viable, profitable, and efficient groundfish fishery, and increasing operational flexibility. Vessel safety was not a significant concern in the development of the catch shares program, although the regulations include "improve safety in the fishery" as a goal (75 FR 32993). In the transition to the catch share program, vessels holding a limited entry permit were allocated individual quota shares based on historical catches.[13] The quota shares and quota pounds are transferable through both lease and sale. The fishing season is open year-round, and an average of 143 catcher vessels participated in the fishery in each year from 2002 to 2012 (min=114, max=218). The mean length of a vessel in the fishery is about 70 feet (min=27, max=148). Vessels fish with an average of 2.4 crewmembers, in addition to the captain (Steiner et al. 2015). Many vessels participate in other fisheries such as West Coast Dungeness crab, pink shrimp, tuna, and salmon, and some travel to Alaska to fish. Only incidents in the West Coast groundfish trawl fishery

[12] A very small number of vessels were allowed to fish trawl permits with fixed gear prior to 2011. A "gear-switching" provision in the catch share program allows trawl quota to be fished with fixed gear.
[13] Additional information on the regulations, including the Federal Register notice, can be found at the West Coast Region website: www.westcoast.fisheries.noaa.gov/fisheries/groundfish_catch_shares/.

(limited entry fishery prior to 2011, and the catch share/IFQ fishery for 2011 and after) are included in the analysis presented here, because each of the other fisheries has its own distinct risk factors and management structure. The West Coast groundfish trawl catch share program also includes a cooperative of catcher processor vessels, but they are not included in the current analysis because they are much larger vessels (average of 300 feet) with very distinct operations, and have been operating as a cooperative (and thus under a distinct institutional structure) since prior to the beginning of the dataset used in this report (2002). Catcher vessels that deliver to at-sea motherships, rather than or in addition to shore-based receivers and processors, are included in the analysis.

A total of 28 Coast Guard-reported, safety-related incidents that were matched to the West Coast limited entry groundfish trawl fishery from 2002 to 2012. These included four allisions, four collisions, four fires, six floodings, nine groundings, and one grounding and sinking. There were no fatalities, one injury, and $1,042,340 in total reported property damage (Figure 4). The number of incidents that occurred in each year ranged from zero in 2011 to six in 2009.

Results of the log-linear estimation of the trip length model show that vessel size, catch per trip, the number of days since the last delivery, annual total allowable catch, port of delivery, target species and gear, and catch per trip interacted with target species and gear all affect trip length (Table 2). The model fits reasonably well for observed trips (table 3, R^2 =0.61, RMSE=0.433), and is used to predict days-at-sea by trip, which are summed to obtain annual days-at-sea (Figure 5). Annual days-at-sea are used to calculate the annual incident rate (Figure 6). The average rate of incidents was 0.3 incidents per 1000 days at sea, and there is no apparent trend in the incident rate over time. Thus far, only 2 years of data are available for the period after the implementation of the catch share program.

5: Discussion

Both fisheries are relatively safe compared to other fisheries, in terms of incident and fatality rates (Thomas et al. 2001, Jin and Thunberg 2005, Lincoln and Lucas 2010, Lambert et al., 2015). Neither had a fatality in the time period in question, and incident rates were low, averaging 0.3 incidents per 1000 days at sea in the West Coast limited entry groundfish fishery, and 0.4 incidents per 1000 days at sea in the sablefish tier limit fishery.[14] There appears to be a declining trend in incident rates in the sablefish fishery that may be associated with the tier limit (individual fishing quota or catch share) program. There does not appear to be a discernable trend in the rate of incidents in the West Coast limited entry groundfish fishery.

[14] These statistics are not directly comparable to occupational hazard rates compiled by the Bureau of Labor Statistics and the Occupational Safety and Health Administration because incidents (rather than deaths) are used in this study, and estimating FTEs or hours worked from days at sea is not straightforward. Fishermen often work longer than 8 hour days, and the number of hours worked is likely to vary over time within these fisheries because of the management change that took place. We have no way to model or estimate this change.

However, as discussed briefly in the introduction, these results should be interpreted with caution. There are several important reasons why the incident rates presented in this paper may not be a good representation of the actual safety of the two fisheries.

First, incidents that resulted in deaths, required Coast Guard intervention, or were reported to the Coast Guard are collected and maintained in the Coast Guard's databases. However, it has been suggested that neglecting to report incidents to avoid Coast Guard action (including lengthy investigations and fines) is common.[15] Other studies have used supplementary data such as fishery observer data (Lucas et al., 2014), worker's compensation claims, workplace injury and mortality data collected by the U.S. Department of Labor and local hospital data (Thomas et al. 2001, Power et al. 2006). These data have similar reporting issues (Power et al. 2006). In addition, the self-employed are not included in U.S. Department of Labor workplace injury and mortality statistics, and many fishermen are self-employed. Data from larger vessels that are collected by the U.S. Department of Labor are often aggregated with the agricultural and forestry industries, making analyses of fisheries independently from other industries difficult (Thomas et al. 2001). State-level databases that rely on hospital data do not include injuries or falls overboard that did not result in hospitalization or death (Thomas et al. 2001). In addition, near misses, which help to characterize the risky nature of a fishery, cannot be accurately measured. These factors make the reliance on this data to accurately characterize the level of safety in fisheries disputable.

Second, matching the incident data to the fishery in which the vessel was participating has the potential for some errors. Generally, the fishery or target species is not directly reported on the fish ticket. Even using combined fish ticket and observer data, it is not always clear which fishery the vessel was participating in and assumptions must be made. For example, if the incident happened at the beginning of a season, no landings were made, and the incident caused the vessel to be unable to fish for a period of time, the incident may be incorrectly attributed to participation in the fishery it was targeting before the incident. Another example is if a fisher landed a variety of species, including groundfish (which is common on the West Coast), we may be unable to determine if the fisher was targeting groundfish (and thus, participating in the groundfish fishery) or if he or she was targeting one of the other species landed. The trip may then be attributed to the wrong fishery.

Another issue with attempting to analyze this type of data is the difficulty in establishing causality. Even if there was a statistically significant change in the incident rates in these fisheries, the annual statistics simply do not provide enough data to establish any sort of robust causality to the transition to catch share management. Some headway at defining an identification strategy using a comparison fishery has been made (Lincoln et al. 2007). However, even with an identification strategy (such as an instrument or a valid comparison fishery), causality is difficult to establish when the events that are being measured (such as safety or mortality incidents) are rare (King and Zeng 2001). Without causality statistically established, it would be inappropriate to conclude that catch shares (or another factor) “caused” any sort of effect on the incident rate in either fishery.

[15] West Coast Groundfish Observer program, NOAA Northwest Fisheries Science Center, Seattle, WA. Pers. Commun., 18 November 2013. See also Azaroff et al. (2002).

Finally, this study does not address the actual behavioral changes that economic theory predicts may result from management changes. For example, catch shares change the incentive structure of commercial fishing and mitigate many of the problems associated with the competitive race to fish that characterizes many fisheries around the world. The race for fish manifests itself in risky behavior such as fishing in any type of weather, overloading vessels, or neglecting maintenance. All of these behaviors are likely to be related to the occurrence of safety incidents, which, as discussed above, are difficult to measure. Other examples include area closures, which may cause a shift in the spatial pattern of fishing, regulations concerning vessel upgrades, modernization, or replacement which may result in older vessels remaining in a fishing fleet for longer than is optimal for vessel safety, or landings requirements, which require vessels to land harvest at a certain port. Pfeiffer and Gratz (2016) extend this study by empirically evaluating some of the underlying behavioral changes that are hypothesized to have occurred in the sablefish tier limit fishery: a reduction in individual voluntary risk exposure due to the different incentives faced by fishers operating under a catch share system.

Despite the issues discussed here, inspection of incident rates in fisheries is important. A long-term, sustained reduction in these types of expensive and often tragic incidents is the ultimate goal of safety policies and regulations, and should be tracked. Such tracking is impossible without significant effort to match incident data to the fisheries in which they occurred. This paper serves to make this data available for two West Coast fisheries and comparable to existing research on safety incidents in other fisheries (Thomas et al. 2001, Jin and Thunberg 2005, Lincoln and Lucas 2010). This and other studies help to highlight improvements that could be made in data collection and tracking, as well as caution users on the interpretation of such data.

Figures 1-6

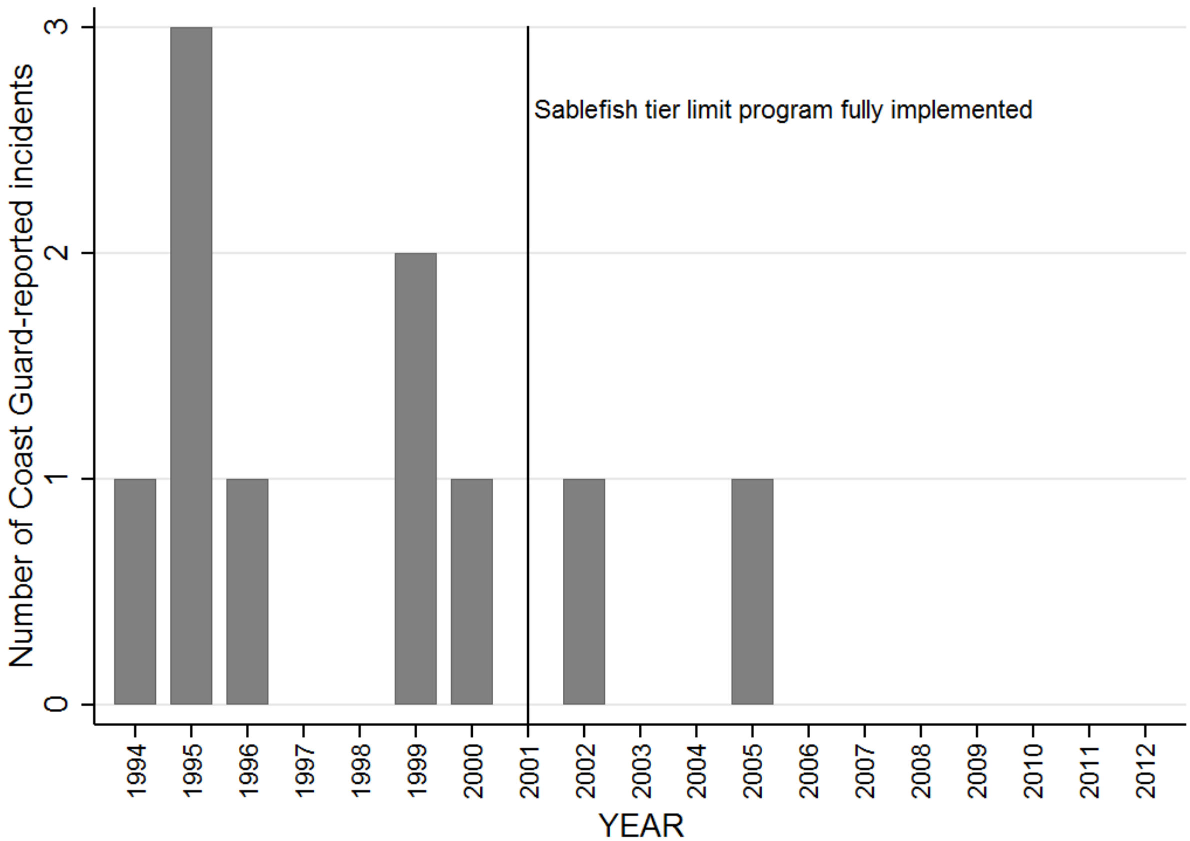

Figure 1: Number of Coast Guard-reported incidents in the sablefish tier limit fishery (1994-2012)

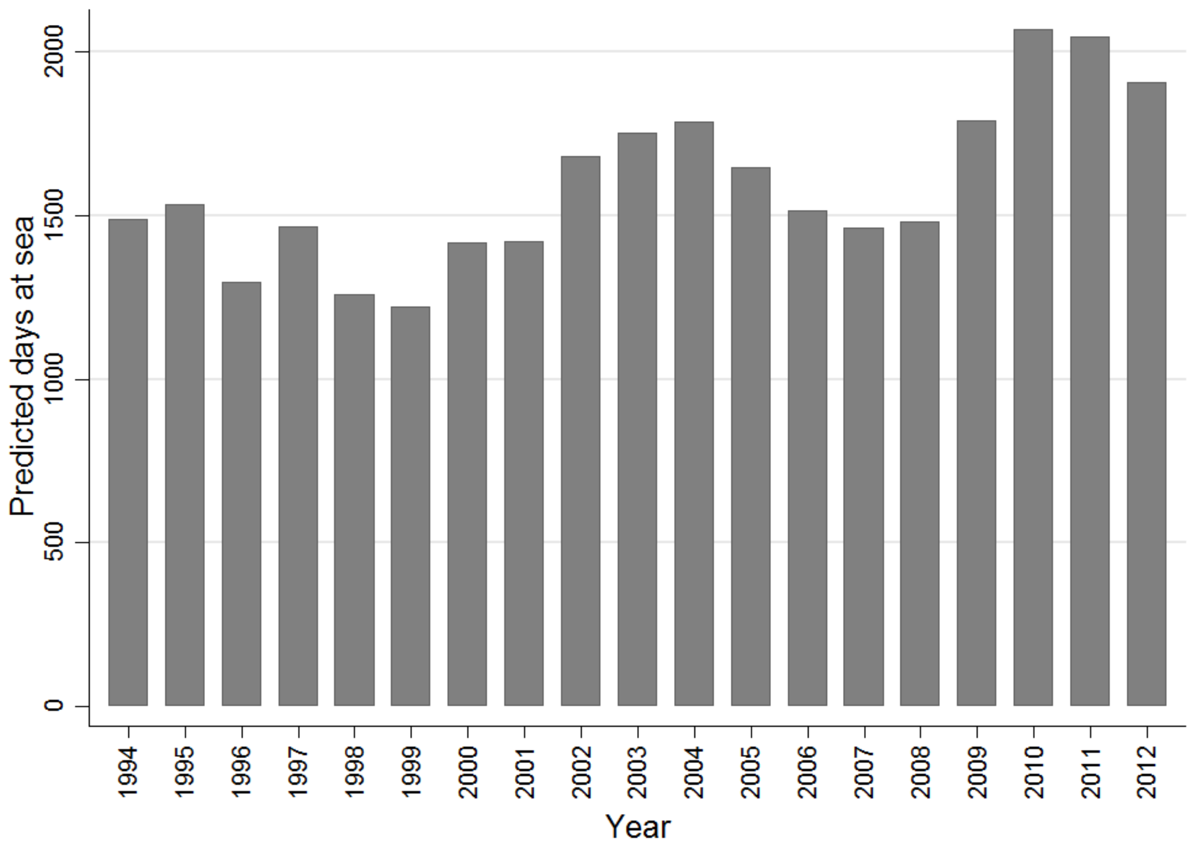

Figure 2: Predicted days at sea in the sablefish tier limit fishery (1994-2012).

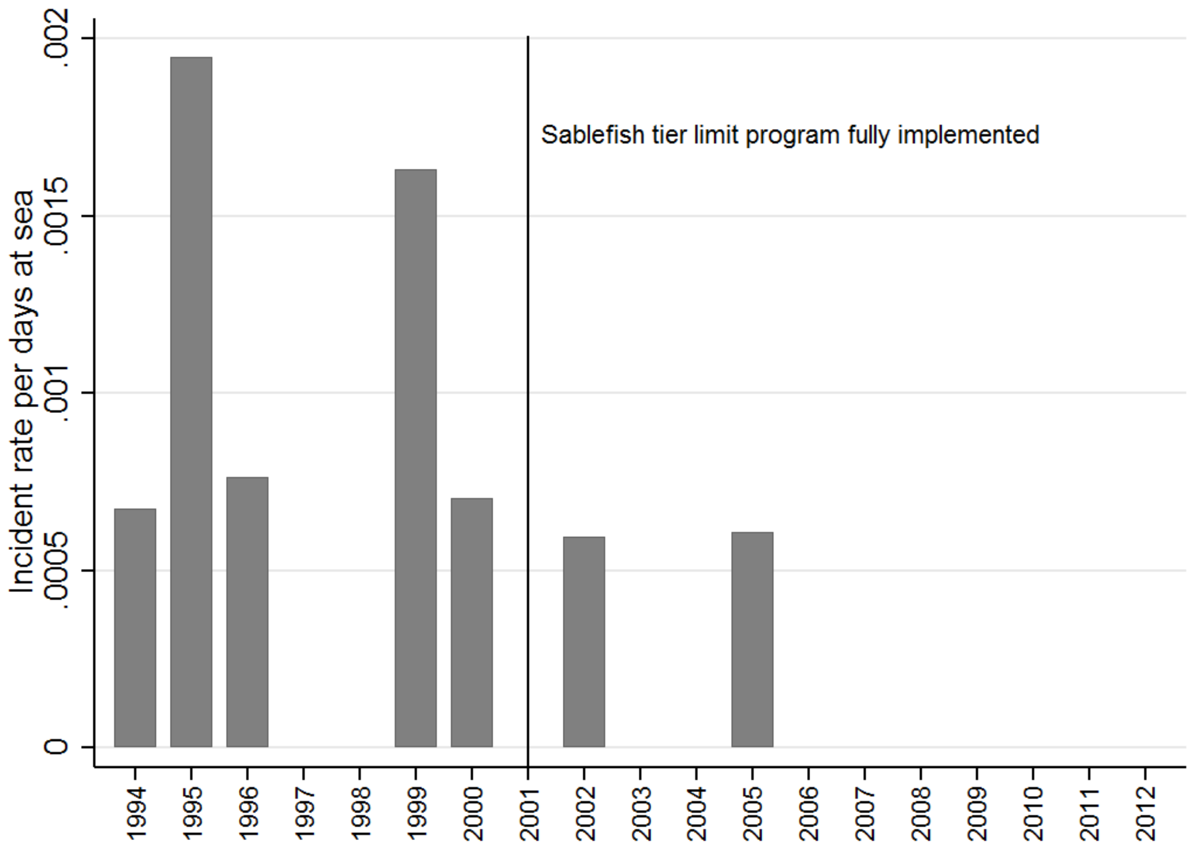

Figure 3. Incident rate (number of Coast Guard-reported incidents per predicted days at sea) in the sablefish tier limit fishery (1994-2012).

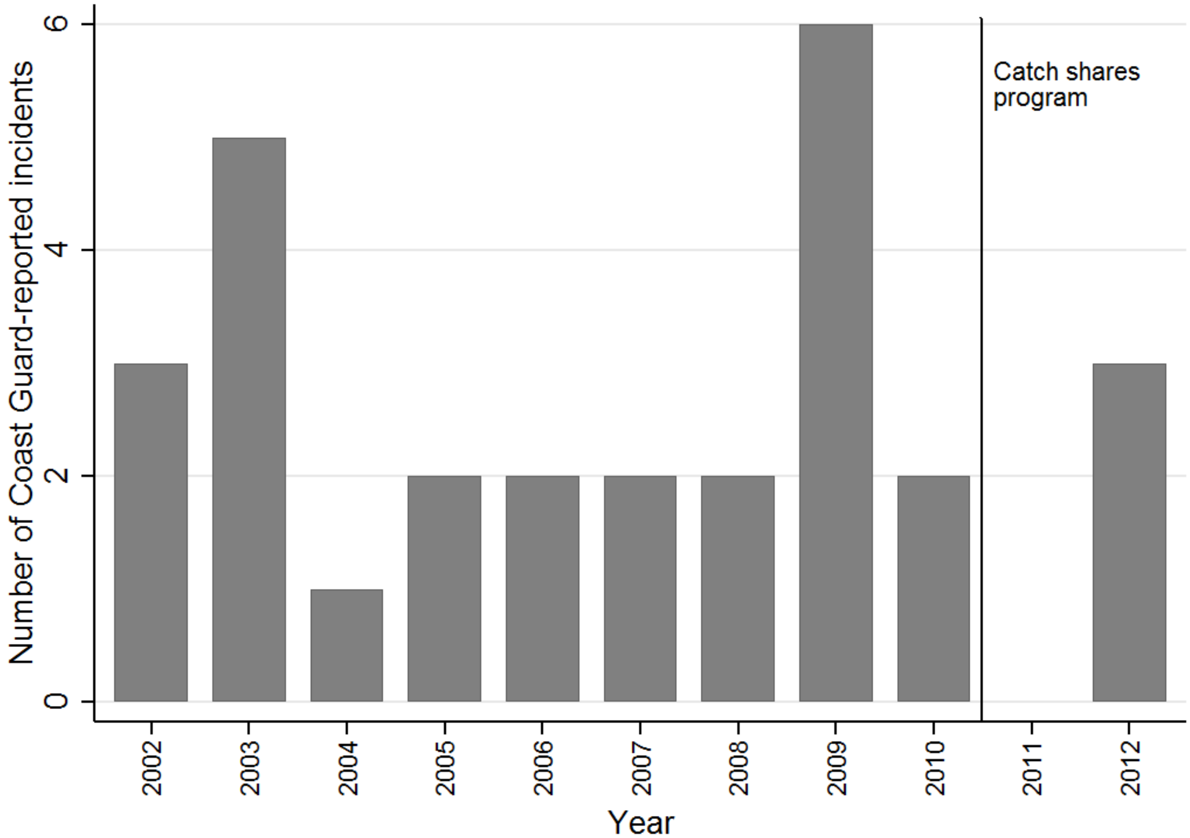

Figure 4. Number of Coast Guard-reported incidents in the West Coast limited entry groundfish trawl fishery (2002-2012).

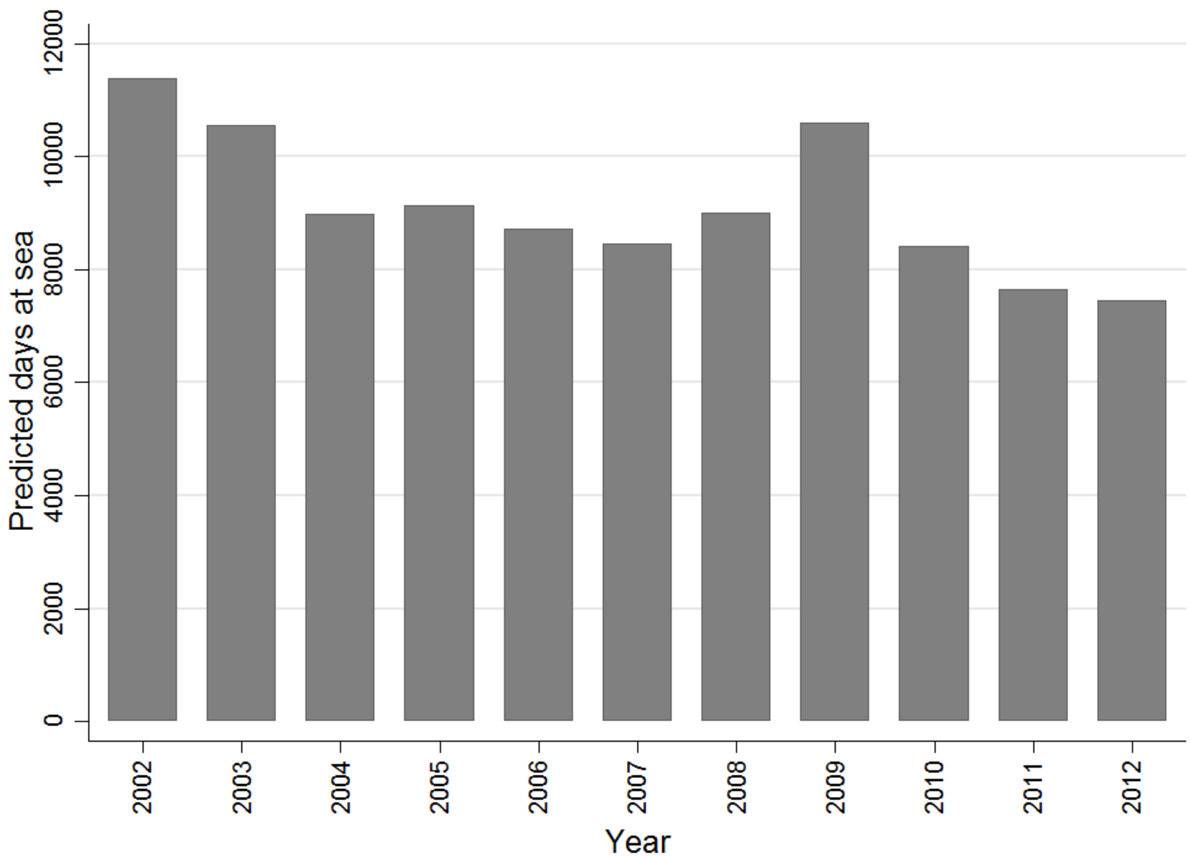

Figure 5. Predicted days at sea in the West Coast limited entry groundfish trawl fishery (2002-2012).

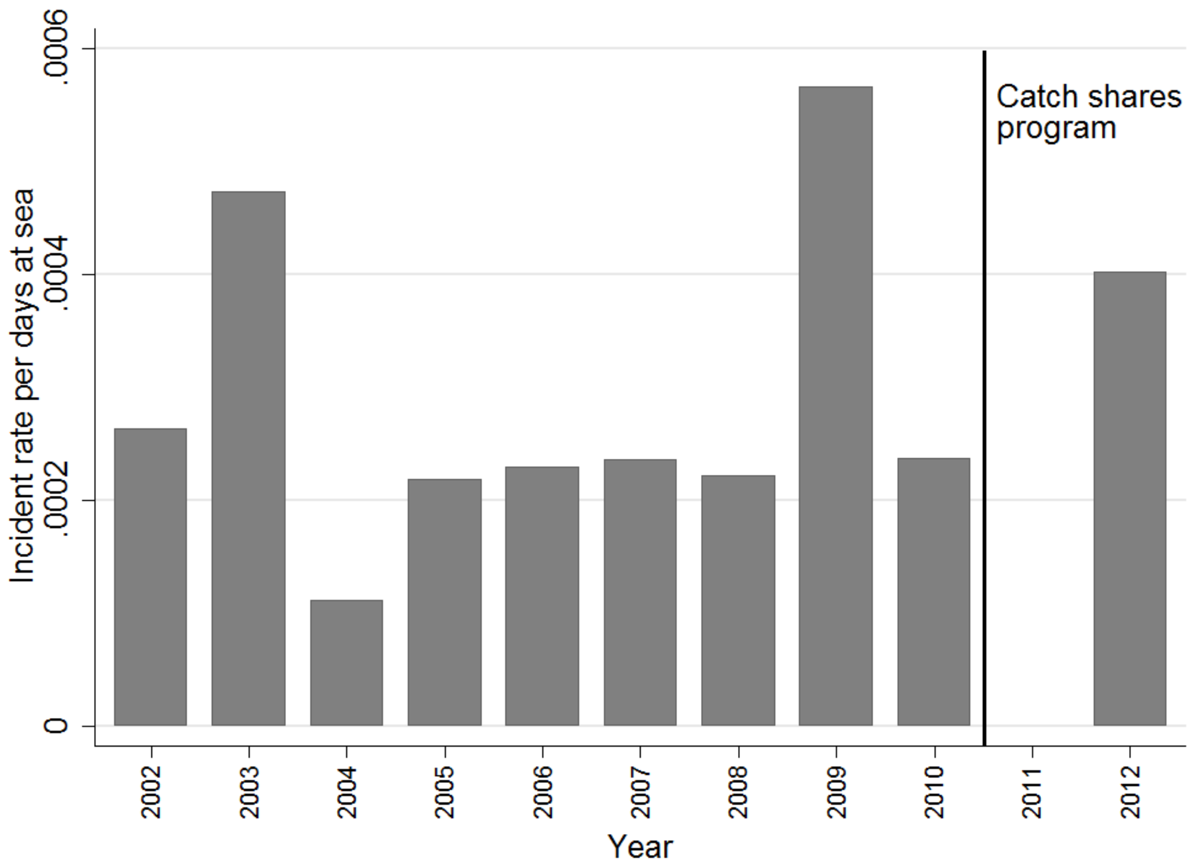

Figure 6. Incident rate (number of Coast Guard-reported incidents per predicted days at sea) in the West Coast limited entry groundfish trawl fishery (2002-2012).

Tables 1 - 4

Table 1: Log-linear model of the length of observed trips in the sablefish tier limit fishery.

	Log of trip length (hrs)
Vessel length (ft)	0.0750***
	(0.019)
Vessel length squared	-0.0006***
	(0.000)
Catch (mt)	0.1006***
	(0.013)
Catch squared	-0.0011**
	(0.000)
Days since last delivery	0.0013***
	(0.000)
Days since last delivery squared	-0.0000**
	(0.000)
TAC of LE fixed gear sablefish (mt)	-0.0002***
	(0.000)
Longline	ref.
Pot	-0.1965**
	(0.098)
Other fixed gear	0.0642
	(0.126)
Primary sector	ref.
Daily sector	-0.2430***
	(0.078)
Open access sector	-0.3270***
	(0.089)
Non-sablefish trip	-0.3147***
	(0.081)
Constant	0.9251*
	(0.480)
Port dummies	Yes
Observations	3191
R^2	0.840

Note: * p < 0.05, ** p < 0.01, *** p < 0.001. Standard errors in parentheses.

Table 2. Predicted total days at sea, incidents, and incident rate per day at sea in the sablefish tier limit fishery.

Year	Predicted days at sea	Incidents	Incident rate
1994	1489	1	0.0006716
1995	1534	3	0.0019557
1996	1296	1	0.0007716
1997	1467	0	0
1998	1260	0	0
1999	1222	2	0.0016367
2000	1418	1	0.0007052
2001	1419	0	0
2002	1679	1	0.0005956
2003	1751	0	0
2004	1786	0	0
2005	1646	1	0.0006075
2006	1513	0	0
2007	1461	0	0
2008	1479	0	0
2009	1791	0	0
2010	2069	0	0
2011	2047	0	0
2012	1905	0	0

Table 3: Log-linear model of the length of observed trips in the limited entry groundfish trawl fishery.

	Log of trip length (hrs)
Vessel length (ft)	0.017**
	(0.006)
Vessel length squared	-0.000**
	(0.0000)
Catch (mt)	0.014***
	(0.002)
Catch squared	0.000
	(0.0000)
Catch*DTS trawl	Ref.
Catch*Groundfish fixed gear	0.049**
	(0.015)
Catch*Non-whiting midwater trawl	-0.015***
	(0.002)
Catch*Non-whiting non-DTS	0.010**
	(0.003)
Catch*Shoreside whiting	-0.015***
	(0.002)
Days since last delivery	0.002***
	(0.000)
Days since last delivery squared	-0.000*
	(0.000)
First delivery of year	0.007
	(0.128)
DTS trawl	Ref.
Groundfish fixed gear	-0.363**
	(0.112)
Non-whiting midwater trawl	-0.351**
	(0.106)
Non-whiting non-DTS	-0.367***
	(0.058)
Shoreside whiting	-0.721***
	(0.058)
Constant	3.443***
	(0.226)
Port dummies	Yes
Observations	10,798
R^2	0.610

Note: * p < 0.05, ** p < 0.01, *** p < 0.001. Standard errors in parentheses.

Table 4. Predicted total days at sea, incidents, and incident rate per day at sea in the limited entry groundfish trawl fishery.

Year	Predicted days at sea	Incidents	Incident rate
2002	11384	3	0.0002635
2003	10566	5	0.0004732
2004	8980	1	0.0001114
2005	9137	2	0.0002189
2006	8715	2	0.0002295
2007	8457	2	0.0002365
2008	9000	2	0.0002222
2009	10599	6	0.0005661
2010	8423	2	0.0002374
2011	7654	0	0
2012	7458	3	0.0004023

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