Supporting Information Appendix for: The effect of rights-based fisheries management on risk-taking and fishing safety

Lisa Pfeiffer[a] and Trevor Gratz

[a]Corresponding author; E-mail: lisa.pfeiffer@noaa.gov.

S1 Fishery background

The West Coast sablefish fixed gear fishery targets sablefish (*Anoplopoma fimbria*) off the coasts of California, Oregon, and Washington. The fixed gear sector (which includes pots and long-lines) is allocated nearly 50 percent of the total annual catch limit of West Coast sablefish. The species range extends through Canada, the Gulf of Alaska, the Aleutian Islands, and the Bering Sea, although those stocks are managed separately by the Canada's Department of Fisheries and Oceans and the United States' North Pacific Fisheries Management Council and National Oceanic and Atmospheric Administration.

The West Coast sablefish fixed gear "primary" fishery is the sector of interest for this analysis because of an individual tradeable quota (ITQ) program that was instituted in the fishery in 2001. In this section, we detail the management measures in place before and after the 2001 ITQ program (Fig. S1).

Our dataset begins in 1994, the first year in which data of quality comparable to the present are available on the West Coast. A license limitation program for the sector began in 1994, which changed the fishery from open access to one in which a vessel must have a permit to be able to participate. About 240 permits were issued, and the fishery remained extremely overcapitalized, necessitating a season length of only a few days to constrain catches to the allocated limit (*1*).

Although the fishery was not a particularly dangerous, high incident-rate, or high mortality rate fishery compared to many other fisheries, safety concerns were an important driver of the rationalization (transition from limited access to individual fishing quota) process that began in the late 1990s. In addition to the classic derby fishery type problems of over-capitalization, an extremely short season (5-10 days in 1995-2000), and a lack of financial viability of many vessels in the fleet, both the industry and regulators recognized the dangerous situations in which harvesters were being forced to fish. The timing of the derby fishery was shifted to later in the year when West Coast weather is typically better, 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. However, the seasons continued to condense and, correspondingly, safety concerns escalated (Amendment 14 of the Pacific Coast Groundfish Fishery Management Plan).

Individual fishing quotas (IFQs) were being discussed as a solution to the problems plaguing the fishery, but the 1996 Magnuson-Stevens Fishery Conservation and Management Act (MSA, PL 94-264) re-authorization included a moratorium on new IFQ programs, which was interpreted to include any program that would allow sufficient fishing time and opportunity that each vessel in the fleet could be reasonably expected to catch the amount of the limit allocated specifically to each vessel.[1] In 1997, equal individual catch limits were imposed on all fixed gear permit holders. However, in order for these equal limits not to be interpreted as an IFQ, the season length was shortened so that the fleet had no chance of catching the total catch limit.[2] A "mop-up" season was held later in the year to catch the remainder of the total allowable catch (TAC), with it again equally allocated. It was recognized that this system was extremely reallocative and did nothing to address the derby nature of the fishery, but was seen as the only option available and a first step toward IFQs.

In 1998 a "three tier" system was established, in which each vessel's equal limit was replaced with one of three limit amounts, based on the vessel's historical catch. Thus, vessels with larger historical catches were allocated a higher "tier", or percentage of the annual catch

[1]The moratorium was intended as a research period to study the effects of the Alaska Halibut and Sablefish Rationalization program, which was implemented in 1995. The program was generally considered extremely successful by the fishermen involved, but other fisheries, particularly on the East Coast, called for the moratorium to consider the longer-term consequences.

[2]In practice, the season length was set so that the sum of the individual limits was at least 25 percent greater than the expected fleet catch.

limit.[3] Again, however, the season length was determined such that the projected fleet catch was well below the sum of the individual limits, and the regular season was followed by a mop-up season. The regular seasons continued to be characterized by over-capitalization, extremely short seasons, and nearly constant fishing effort while open (*1*). This system continued until 2001.

In 2001, the fishery was granted an exemption to the extension of the MSA moratorium on new IFQ programs. The "permit stacking program" was implemented, which extended the three-tier system by allowing vessels to register up to three permits on a single vessel (to allow capacity reduction) and the fishing season was progressively lengthened over the next few years. Permits could be stacked through leasing or purchase arrangements. In 2001, the season was 2.5 months long, in 2002-2003 it was 6 months long, and in 2004-2012 the fishing season was 7 months long. The permit stacking program is still in place today, and we refer to the program as an individual tradeable quota (ITQ) management system, although trading, and thus consolidation, is restricted by limiting the number of permits that can be attached to a vessel to three.[4]

The management history of the fishery allows us to compare the behavior of fishermen before and after ITQs were implemented in the fishery. The mop-up seasons constitute an interesting comparison as well. While different from the fully implemented tier stacking program, the mop-up seasons constituted a pseudo-catch shares program because the leftover quota was individually allocated to permitted vessels and although the mop-up season openings were short, the quota quantities were small, meaning that vessels had enough time fish their quota as they saw fit.

[3]In practice, these tier assignments were made on the basis of the "permit's" catch history, not the vessel's, and the benefits accrued to the permit owner, not the vessel owner. In many cases they were the same, but not always, particularly in cases where permits had been transferred.

[4]Technically, trading is also restricted by the original number of permits in each tier and the percentages of the fleet's allocation that are used to calculate annual catch limits within each tier.

In addition, there are two other sectors in which sablefish can be landed on the West Coast with fixed gear. Both the "daily" and "open access" sectors have been managed with restrictive trip limits (maximum daily, weekly, monthly, and/or bi-monthly catches) for the entire time period. These limits are subject to adjustments by fisheries managers throughout the year. Managers may lower the limits if they determine that the the sector is fishing "faster" than in previous years (approaching the annual limits at a faster rate). Most adjustments are small. Participants in the "daily" sector must have a limited entry permit to fish, while anyone can participate in the "open access" sector. An average of 60% of primary sector vessels participate in the daily or open access fishery in a given year (Table 2).[5] The annual catch limit is much lower for the daily and open access fisheries; the daily sector is allocated approximately 6% of total commercial sablefish catch limit, the open access fishery is allocated approximately 9%, and the primary sector is allocated approximately 32%. The gear, target species, fishing methods, geographical distribution of fishing, and participants in these three fisheries are similar (and in some cases the same). Management has remained stable over time in the daily and open access sectors. Together, this "trip-limit" sector of the West Coast sablefish fixed gear fishery provides an ideal comparison fishery for the primary sector fishery.

S2 Data

This section contains the methodology, tables, and figures referred to in the Methods: Data section of the main article.

[5]Limited-entry vessels can only fish in the open access sector if their limited-entry fishery closes, they remove their permit from the vessel, or they use a non-endorsed gear.

S2.1 Estimation of trip start dates

Trip starts (location and date) were determined from West Coast Groundfish Observer Program data. In the sablefish fishery, approximately 20 percent of trips had federal observers on board for the time period 2002-2012.[6] For unobserved trips, trip length was modeled using the Observer data (results in Table S1; in-sample R^2=0.84, RMSE=0.43). Estimated trip length was adjusted if the predicted trip length overlapped with the previous landing.[7]The Observer program data collection began in 2002, so estimates of all trip lengths from prior to 2002 are out-of-sample estimates. Ninety-eight percent of observed trips departed and landed in the same port, so departure locations for unobserved trips were assumed to be the same as the location of landing designated in the fish ticket.

S2.2 Estimation of expected revenue

Expected revenue is the product of dockside sablefish prices and the expected sablefish catch per fishing trip ($E(C_{mit})$), which are assumed to be independent. Prices are estimated using a 15-day moving average of past prices received by all vessels in the primary fleet by the state of delivery. Prices are typically obtained by the vessel via pre-trip communication with the processing plant to which they will deliver. Prices may decrease as a result of delivery gluts (especially in the pre-ITQ period), but processors are aware of the deliveries they expect and would take this into account when they quote a price to a vessel. Purchased fish are headed, gutted, frozen and mainly exported to Japan. Processing and marketing have not remarkably changed over the time period used in this analysis.

Expected catch per trip is modeled parametrically:

[6]More information available at http://www.nwfsc.noaa.gov/research/divisions/fram/observation/index.cfm.

[7]Predicted trip length overlapped with the previous landing for 2% of trips. Predicted trip length was adjusted to be 1 day shorter in these cases.

$$E(C_{mit}) = \alpha + \gamma' \mathbf{x_{it}} + \varepsilon_{it} \tag{S1}$$

Vessel capacity is a key component of catch per trip, but is not observable. It is proxied by a function of vessel length.[8] It also varies by month, management regime, gear, and the vessel's remaining quota. The results for the expected catch regression are shown in Table S2.

S2.3 Weather data

Fishing in poor weather conditions has been shown to contribute to the probability of accidents and safety incidents (*2–6*). Wind speed is the most appropriate indicator of weather conditions that is attainable for the entirety of the time series (daily observations from 1994-2012) and at a meaningful spatial scale. Wind speed was estimated using reanalysis surface fluxes generated by the National Center for Environmental Protection (NCEP).[9] Reanalysis wind speed data is available in 2-degree grids in 6-hour intervals. We calculated the maximum daily 6-hour average wind speed at each grid cell, then calculated the inverse distance weighted average from the four cells nearest to the port of departure of each fishing trip in our dataset.[10] The NCEP reanalysis under-estimates actual wind speeds at the coast, because generally, two of the nearest four grid locations are at least partially over land. We designated 7.5 meters/second (14.6 knots) as "high wind" conditions. Based on spot-checks of historical wind advisories (data that is not widely available), days that were over 7.5 m/s were often designated as small craft advisory conditions ($>$22 knots or > 11.18 m/s) by the National Weather Service. In

[8] Net tonnage is observed for about 80 percent of the vessels in the fleet. The relationship between net tonnage and length was estimated to be $net\,tonnage = length^{2.8}$.

[9] National Center for Environmental Protection NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/

[10] Shepard's method, or inverse distance weighting, is used to interpolate the maximum 6-hour average wind speed at each possible port of departure from buoy data. With this method, the weight assigned to each grid point decreases as the distance from the interpolated point decreases. We use p=3; p is the parameter that assigns how quickly the weight decreases with distance.

addition, the four-grid average of the daily max of 7.5 m/s corresponded to an average wind speed at the nearest ocean-based grid point of 11.4 m/s (22.4 knots), which is just greater than the small craft advisory designation. Finally, we calculated the maximum daily wind speed at each port with a functioning weather buoy within 50 km, using data from the National Oceanic and Atmospheric Administration National Data Buoy Center. This measurement is more likely to accurately reflect maximum wind speeds at each port than the four-grid spatial average of the daily maximum wind speeds from the reanalysis data, but is not available at all ports for the entire time period. We compare these "actual" buoy wind speeds (which we assume would be highly correlated with actual small craft warnings) to the reanalysis data wind speeds to determine what level (X) of reanalysis data wind speed minimizes the "misdesignation" as a small craft advisory. Misdesignation is defined as either "actual" (buoy) wind speed greater than 11.18 m/s and reanalysis wind speed less than X, or "actual" (buoy) wind speed less than 11.18 m/s and reanalysis wind speed greater than X. We find that misdesignation is minimized at a reanalysis data wind speed of X=7.5 m/s (Fig. S2).

As such, our "high wind" indicators may not correspond exactly to actual National Weather Service advisories, but should be representative of weather conditions. High winds occur most often during the winter when the sablefish season is closed (November-March). High winds occur least often in April-May and August-October (Table S3).

S3 Results tables

This section includes the full results tables that are used to calculate the summary tables included in the main manuscript. The first column of Table S4 contains the results of the difference-in-differences regression of the rate of fishing on high wind days (equation 2) for all vessels that participated in the fishery. These results are presented in graphical form in the main paper (Figure 1). The second column of Table S4 contains the results of the difference-in-differences regression of the rate of fishing on high wind days (equation 2) for vessels that fished in the primary fishery both pre- and post-ITQ. The average treatment effect is slightly larger for this set of vessels, supporting the proposition that the pattern of consolidation after the ITQ program (the exit of more risk-averse vessels) results in a downward bias of our estimate. Had the vessels that exited the fishery remained, the estimated treatmentment effect may have been even larger.

Table S5 contains the results of the fixed effects logit model of the individual daily probability of fishing (equation 3, coefficients presented as odds ratios) for all vessels. Table S6 contains the fulls results of the comparisons between vessels less than and greater than or equal to 43 feet in length, vessels that fished in California versus those that did not, and vessels that exited the fishery versus those that remained.

Table S7 further splits the participants into four size categories: less than 30 feet, 30-43 feet, 43-50 feet, and greater than 50 feet. It shows a consistent relationship between the coefficients and vessels size as in Table S6, which is used in the manuscript. Finally, Table S8 contains the results of equation 3 excluding the vessel fixed effects but including a continuous interaction between vessel length and each independent variable in the regression. Fig. S3 shows the predicted probabilities resulting from this model of beginning a fishing trip (at expected revenue equal to the mean) for the pre-ITQ period and the post-ITQ period, on a day with high winds and a day without high winds. In the pre-ITQ period, there was no significant difference in the probability of taking a fishing trip on a day with high winds compared to a day without. Post-ITQ, the difference is significant for all but the very largest vessels. On a high wind day, the probability of taking a fishing trip is very low for all sizes of vessels in the post-ITQ period. The difference, which is the effect of the ITQ program on the probability of fishing on a high wind day, is largest for small vessels. Again, these results are consistent with those in Tables S5, S6, and S7.

S4 Robustness tests

In this section we report the results of several analyses that examine the robustness of the estimates in Tables 1 and 3 in the main article to several assumptions and potential concerns.

S4.1 Annual effects in the fixed effects logit model

The pooled-years-management regime specification defined in equation 3 gives an easily interpretable estimate of the average effect of management. We also estimate the model with individual year effects to affirm that no one year or trend is driving the results (Table S9).

S4.2 Restricted data estimates of the fixed effects logit model

High wind days are distributed non-uniformly over the year; they occur most frequently at the beginning and end of the calendar year (Table S3). Because the primary fishing season now lasts for seven months, it is possible that the estimates in Table S5 could be driven by harvesters shifting their fishing to times of the year with a remarkably different distribution of high wind days from the pre-ITQ period, for example, only fishing during the summer months when the weather is good and completely avoiding months when the weather has a chance of being poor. While this would still technically be an estimate of the effect of ITQs on the probability of fishing in windy weather, it would be more supportive of a story of shifting seasonal effort. To test whether a seasonal shift in fishing effort is driving the estimated effect, we restrict the post-ITQ data to the month of August. Most of the pre-ITQ seasons occurred in or around August. The results (Table S10) are similar to those from the full sample, meaning that the results are not driven by avoidance of fishing at the extremes of the season. Table S11 translates these results to the changes in probability and marginal rates of substitution shown in the main text, which again, are similar to those from the full sample.

S4.3 Inclusion of "mop-up" seasons

The "mop-up" seasons, which were held weeks to months after the conclusion of the primary season prior to the institution of ITQs, provide an additional opportunity to identify the mechanism causing the decrease in the probability of beginning a fishing trip in poor weather. The primary season was shortened to ensure that no vessel could catch its portion of the quota, so as to not take on the aspects of an individual fishing quota (IFQ) program (further details above, in the "Fishery background" section S1). Several months after the primary season, the leftover quota was then individually allocated to permitted vessels and fished in the mop-up season. Although the mop-up season openings were short, the quota quantities were small, meaning that vessels had enough time to fish the quota as they saw fit. Thus, while different from the fully implemented tier stacking program, the mop-up seasons constituted a pseudo-IFQ program because quota was indeed individually allocated.

Table S12 provides additional evidence that the causal mechanism behind the reduction in the probability of beginning a fishing trip in poor weather (modeled as equation 3 in the main article) is the individual allocation of quota. The effect of high winds in the mop-up season (odds ratio of 0.314, $p<0.001$) is more similar to the effect in the post-ITQ period (0.251, $p<0.001$) than it is to the pre-ITQ regime (0.752, $p<0.01$), despite the mop-up seasons occurring in the years prior to ITQs (and thus experiencing the same unobservable effects).

S4.4 Test of the common trend assumption

The difference-in-differences estimation (equation 2) relies on the assumption that the trends in the pre-treatment time period are the same for the treatment and control groups, and without the treatment, the trend in the treated group would have followed the trend in the control group. Fig. S4 shows graphically that while the average fishing rate on high wind days was consistently higher in the primary fishery, the trends were similar. The rates in both fisheries increased from

1994 to 1996 and 1997, and then decreased to a level slightly higher than the rate in 1994. To test the assumption, we perform “placebo” tests on years (Table S13). In each column we assume that the ITQ was introduced in a different year and estimate equation 2. If the treatment effect (the interaction between the post-placebo year and the primary sector) is significant, then the common trend assumption is violated and the difference-in-differences estimate may be biased. Using the pre-ITQ data, the placebo treatment effect is insignificant in all tests except the placebo year set as 1995. Note that there is only one year of pre-placebo year data to support the regression for the 1995 placebo year.

S4.5 Placebo test of the effect of the ITQ on untreated fisheries

Most of the vessels that participate in the primary sablefish fishery also participate in other fisheries (Table 2 of the main article). An additional test of the validity of the difference-in-differences estimate involves estimating equation 2 using a placebo treatment effect, or estimating the effect of the introduction of the ITQ on a fishery that did not actually receive the ITQ. The most common additional fisheries that primary sablefish vessels participated in were the Dungeness crab, rockfish, and salmon fisheries. Table S14 provides the estimated treatment effect of ITQs in 2001 (a placebo treatment) on the average annual rate of fishing on high wind days in each of these fisheries, as well as all other fisheries (except primary sablefish) combined. The control group in each regression is the daily and open access sablefish fixed gear fishery. The estimated placebo treatment effect is insignificant in each regression, providing support for the specification of the model.

References

1. Hastie JD (2001) *Permit Stacking As An Approach To Implementing Harvest Rights That Can Be Transferred And Accumulated*.

2. Ayeko M (2002) *Causes and Contributing Factors-Analysis of Accidents Involving Fishing Vessels in Canada* eds Lincoln JM, Hudson DS, Conway GA, Pescatore R (Publications Dissemination, EID, Cincinnati OH).

3. Lang JS (2002) *Fishing Vessel Safety-A Marine Accident Investigator's Perspective* eds Lincoln JM, Hudson DS, Conway GA, Pescatore R.

4. Page E (2002) *Ready for Sea The Seventeenth Coast Guard District's Safety Program* eds Lincoln JM, Hudson DS, Conway GA, Pescatore R.

5. Scully A (2002) *Challenge and Opportunity: Occupational Health and Safety "On the Edge"* eds Lincoln JM, Hudson DS, Conway GA, Pescatore R.

6. Jin D, Thunberg E (2005) An analysis of fishing vessel accidents in fishing areas off the northeastern united states. *Safety Science* 43:523–540.

Table S1: Log-linear model of the length of observed trips. Estimated trip length is used to identify the day in which a trip began.

	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 S2: Log-linear model of expected catch (mt) per trip

	Ln of expected catch per trip	
Spawning biomass (thousands of mt)	0.0129	(0.010)
Spawning biomass squared	-0.0001	(0.000)
Longline gear	ref.	
Other gears	-0.8004***	(0.078)
Pot gear	0.0733**	(0.028)
Remaining quota (mt)	0.1038***	(0.002)
Remaining quota squared	-0.0013***	(0.000)
Post-ITQ	ref.	
Pre-ITQ	1.8745***	(0.141)
Vessel net tonnage squared	0.0000***	(0.000)
capacity2	-0.0000***	(0.000)
Apr	ref.	
May	0.1588**	(0.052)
June	-0.0239	(0.050)
July	-0.0890	(0.050)
August	0.1940***	(0.049)
September	0.2480***	(0.048)
October	0.2845***	(0.052)
PreITQ_May	-0.5707***	(0.115)
PreITQ_Aug	-0.4600***	(0.119)
PreITQ_Sept	-0.4508***	(0.119)
Constant	5.9315***	(0.388)
Observations	13521	
R^2	0.324	

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

Table S3: Percentage of high wind days, by month, in the 15 most often-used U.S. West Coast ports.

Month	Percent of high wind days
Jan	19.2
Feb	16.7
Mar	14.1
Apr	8.1
May	9.6
Jun	14.6
Jul	12.1
Aug	9.0
Sept	6.7
Oct	9.4
Nov	16.6
Dec	23.0

Table S4: Difference-in-differences regression of the average annual rate of fishing on high wind days

	All vessels	Vessels fishing both pre and post ITQ
Post-ITQ	-0.019**	-0.014**
	(0.005)	(0.005)
Primary Sector	0.510***	0.540***
	(0.026)	(0.035)
Post-ITQ X Primary Sector	-0.428***	-0.459***
	(0.029)	(0.037)
Constant	0.033***	0.026***
	(0.005)	(0.004)
N	5396	4240
R^2	0.50	0.53

Note: * p < 0.05, ** p < 0.01, *** p < 0.001. Standard errors in parentheses. The constant gives the pre-ITQ average annual rate of fishing on high wind days in the trip-limit fishery. The coefficient on the interaction between the post-ITQ and primary fishery variable gives the treatment effect of the ITQ program on the rate of fishing on high wind days.

Table S5: Fixed effects logit model of the probability of fishing, for all vessels in the primary fishery.

	All vessels
Post-ITQ	0.080***
	(0.006)
Expected revenue, Pre-ITQ	0.998
	(0.006)
Expected revenue, Post-ITQ	1.043***
	(0.001)
High winds, Pre-ITQ	0.687***
	(0.067)
High winds, Post-ITQ	0.250***
	(0.018)
Observations	223976

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S6: Fixed effects logit model of the probability of fishing, by vessel size, state, and whether or not the vessel remained in the fishery after ITQs.

	Vessels<43 ft	Vessels>43 ft	CA fishing	Non-CA fishing	Vessels that exited	Vessels that stayed
Post-ITQ	0.037***	0.153***	0.072***	0.090***		0.080***
	(0.005)	(0.020)	(0.011)	(0.008)		(0.006)
Expected revenue, Pre-ITQ	0.998	1.020**	1.001	1.003	1.029	0.997
	(0.013)	(0.008)	(0.016)	(0.006)	(0.029)	(0.006)
Expected revenue, Post-ITQ	1.173***	1.036***	1.052***	1.041***		1.043***
	(0.006)	(0.001)	(0.004)	(0.001)		(0.001)
High winds, Pre-ITQ	0.636***	0.639*	0.630***	0.662*	0.362***	0.750**
	(0.073)	(0.125)	(0.079)	(0.111)	(0.109)	(0.078)
High winds, Post-ITQ	0.180***	0.381***	0.237***	0.264***		0.250***
	(0.019)	(0.038)	(0.023)	(0.029)		(0.018)
Observations	100898	123078	54603	168228	1689	222287

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S7: Fixed effects logit model of the probability of fishing, by vessel size categories.

	Vessels < 35 ft	Vessels 35-43 ft	Vessels 43-50 ft	Vessels > 50 ft
Post-ITQ	0.019***	0.061***	0.109***	0.153***
	(0.004)	(0.010)	(0.026)	(0.029)
Expected revenue, Pre-ITQ	0.968	1.024	1.034	1.015
	(0.024)	(0.017)	(0.018)	(0.009)
Expected revenue, Post-ITQ	1.232***	1.157***	1.116***	1.031***
	(0.013)	(0.006)	(0.004)	(0.001)
High winds, Pre-ITQ	0.611**	0.654**	0.582	0.597
	(0.105)	(0.101)	(0.169)	(0.161)
High winds, Post-ITQ	0.149***	0.209***	0.391***	0.381***
	(0.025)	(0.029)	(0.054)	(0.054)
Observations	36853	64045	50837	72234

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S8: Logit model of the probability of fishing, including vessel length as a continuous variable

	Change in the odds of beginning a fishing trip
Pre-ITQ (ref.)	
Post-ITQ	0.114***
	(0.022)
Pre-ITQ*Vessel length	0.970***
	(0.004)
Post-ITQ*Vessel length	0.963***
	(0.001)
Expected revenue, Pre-ITQ	1.001
	(0.019)
Expected revenue, Pre-ITQ*Vessel length	1.000
	(0.000)
Expected revenue, Post-ITQ	1.125***
	(0.006)
Expected revenue, Post-ITQ*Vessel length	0.999***
	(0.000)
High winds, Pre-ITQ	0.625
	(0.243)
High winds, Pre-ITQ*Vessel length	1.011
	(0.010)
High winds, Post-ITQ	0.069***
	(0.020)
High winds, Post-ITQ*Vessel length	1.036***
	(0.007)
Observations	224282

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S9: Fixed effects logit model of the probability of fishing with annual effects

	Change in odds of beginning fishing trip	
1994 (ref.)		
1995	1.205	(0.29)
1996	2.137**	(0.62)
1997	0.734	(0.17)
1998	0.726	(0.19)
1999	0.706	(0.15)
2000	1.009	(0.24)
2001	0.169***	(0.03)
2002	0.072***	(0.01)
2003	0.073***	(0.01)
2004	0.060***	(0.01)
2005	0.064***	(0.01)
2006	0.058***	(0.01)
2007	0.055***	(0.01)
2008	0.066***	(0.01)
2009	0.088***	(0.01)
2010	0.106***	(0.02)
2011	0.096***	(0.01)
2012	0.079***	(0.01)
Expected revenue, 1994	1.040*	(0.02)
Expected revenue, 1995	1.005	(0.02)
Expected revenue, 1996	0.967	(0.02)
Expected revenue, 1997	1.026*	(0.01)
Expected revenue, 1998	1.043	(0.03)
Expected revenue, 1999	1.040*	(0.02)
Expected revenue, 2000	1.018	(0.01)
Expected revenue, 2001	1.071***	(0.00)
Expected revenue, 2002	1.087***	(0.01)
Expected revenue, 2003	1.082***	(0.00)

Expected revenue, 2004	1.104***	(0.00)
Expected revenue, 2005	1.076***	(0.00)
Expected revenue, 2006	1.077***	(0.00)
Expected revenue, 2007	1.079***	(0.00)
Expected revenue, 2008	1.062***	(0.00)
Expected revenue, 2009	1.052***	(0.00)
Expected revenue, 2010	1.044***	(0.00)
Expected revenue, 2011	1.031***	(0.00)
Expected revenue, 2012	1.041***	(0.00)
High winds, 1994	0.217***	(0.06)
High winds, 1995	0.674	(0.14)
High winds, 1996	0.250***	(0.09)
High winds, 1997	0.582	(0.41)
High winds, 1998	1.040	(0.28)
High winds, 1999	1.579	(0.43)
High winds, 2000	1.022	(0.19)
High winds, 2001	0.542**	(0.12)
High winds, 2002	0.293***	(0.08)
High winds, 2003	0.207***	(0.07)
High winds, 2004	0.423***	(0.10)
High winds, 2005	0.376***	(0.11)
High winds, 2006	0.369***	(0.10)
High winds, 2007	0.370***	(0.09)
High winds, 2008	0.197***	(0.05)
High winds, 2009	0.174***	(0.05)
High winds, 2010	0.223***	(0.04)
High winds, 2011	0.139***	(0.03)
High winds, 2012	0.190***	(0.05)
Observations	223976	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S10: Fixed effects logit model of the probability of fishing, post-ITQ data restricted to **August only**

	Change in odds of beginning a fishing trip
Post-ITQ	0.099***
	(0.012)
Expected revenue, Pre-ITQ	0.994
	(0.009)
Expected revenue, Post-ITQ	1.034***
	(0.003)
High winds, Pre-ITQ	1.013
	(0.121)
High winds, Post-ITQ	0.370***
	(0.061)
Observations	35596

Note: * p < 0.05, ** p < 0.01, *** p < 0.001. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S11: Changes in the probability of taking a fishing trip resulting from the fixed effect logit model of the probability of fishing, post-ITQ data restricted to August only

	Mean probability of taking a trip	Effect of $1000 increase in expected revenue		Effect of a high wind day		Marginal rate of substitution	Mean revenue per trip ($2012)
		Change in probability	Estimated coefficient	Change in probability	Estimated coefficient		
Pre-ITQ	24.1%	-	-0.005	-	0.013	-	15.9
Post-ITQ	4.2%	3.4%	0.033***	-63.0%	-0.995***	30.2	12.3
Percentage change	-82.6%						

Note: Post-ITQ data restricted to trips in the month of August. Number of observations: 35,596. Vessel fixed effects included. Marginal rate of substitution and mean revenue are in thousands of dollars. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table S12: Fixed effects logit model of the probability of fishing, including mop-up seasons

	Fished in the primary sector
Pre-ITQ (ref.)	
Mop-up seasons	0.279***
	(0.02)
Post-ITQ	0.089***
	(0.01)
Expected revenue, Pre-ITQ	1.006
	(0.00)
Expected revenue, Mop-up seasons	1.040**
	(0.01)
Expected revenue, Post-ITQ	1.047***
	(0.00)
High winds, Pre-ITQ	0.752**
	(0.07)
High winds, Mop-up seasons	0.314***
	(0.05)
High winds, Post-ITQ	0.251***
	(0.02)
Observations	240851

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimates are presented as odds ratios. Expected revenue is in thousands of US dollars. Standard errors in parentheses.

Table S13: Placebo tests on years of the difference-in-differences regression of the rate of fishing on high wind days

	1995	1996	1997	1998	1999
Post-placebo year	0.021*	0.002	-0.017	-0.017	-0.016
	(0.006)	(0.014)	(0.011)	(0.010)	(0.009)
Primary Sector	0.396***	0.461***	0.492***	0.496***	0.512***
	(0.009)	(0.033)	(0.038)	(0.039)	(0.032)
Post-placebo year X Primary Sector	0.140**	0.089	0.049	0.047	0.022
	(0.026)	(0.048)	(0.053)	(0.054)	(0.053)
Constant	0.016**	0.032*	0.043**	0.041**	0.038**
	(0.003)	(0.011)	(0.010)	(0.008)	(0.007)
N	1954	1954	1954	1954	1954
R^2	0.593	0.591	0.589	0.589	0.589

Note: Column headings indicate the "placebo" introduction of the ITQ. Data is restricted to 1994-2000. * p < 0.05, ** p < 0.01, *** p < 0.001. Standard errors in parentheses. The coefficient on the interaction between the post-placebo year and primary fishery variable gives the treatment effect of the placebo program on the rate of fishing on high wind days.

Table S14: Placebo tests on fisheries of the difference-in-differences regression of the rate of fishing on high wind days

	Crab	Rockfish	Salmon	All other fisheries
Post-ITQ	-0.003*	-0.003*	-0.003*	-0.001
	(0.001)	(0.001)	(0.001)	(0.003)
Placebo fishery	0.017***	0.012***	0.021***	-0.020***
	(0.003)	(0.002)	(0.002)	(0.003)
Post-ITQ X Placebo fishery	0.005	0.001	-0.002	0.000
	(0.003)	(0.002)	(0.003)	(0.004)
Constant	0.007***	0.008***	0.008***	0.021***
	(0.001)	(0.001)	(0.001)	(0.003)
N	5404.	4543	4655	4611
R^2	0.220	0.166	0.194	0.276

Note: Column headings indicate the "placebo" introduction of the ITQ. "All other fisheries" includes all fisheries except the primary sablefish fishery. * p < 0.05, ** p < 0.01, *** p < 0.001. Standard errors in parentheses. The coefficient on the interaction between the post-ITQ period and placebo fishery variable gives the treatment effect of the placebo program on the rate of fishing on high wind days.

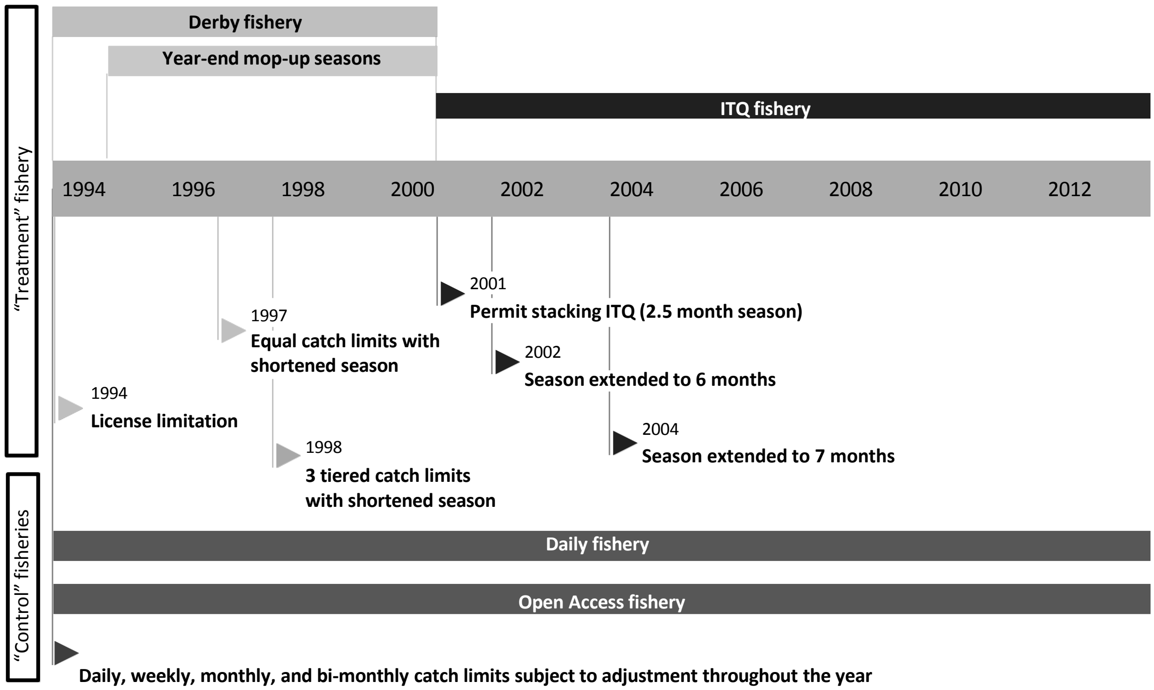

Figure S1: Time-line of major management actions in the West Coast sablefish fixed gear fishing sectors.

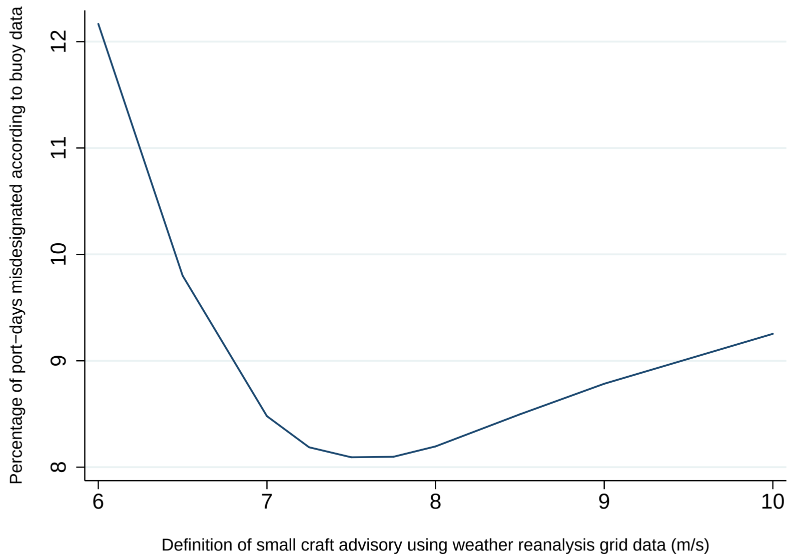

Figure S2: Percentage of port-days misdesignated as small craft advisories by the gridded reanalysis data, as compared to maximum wind speeds at the closest buoy. Misdesignation is minimized at a wind speed of 7.5 m/s in the reanalysis data.

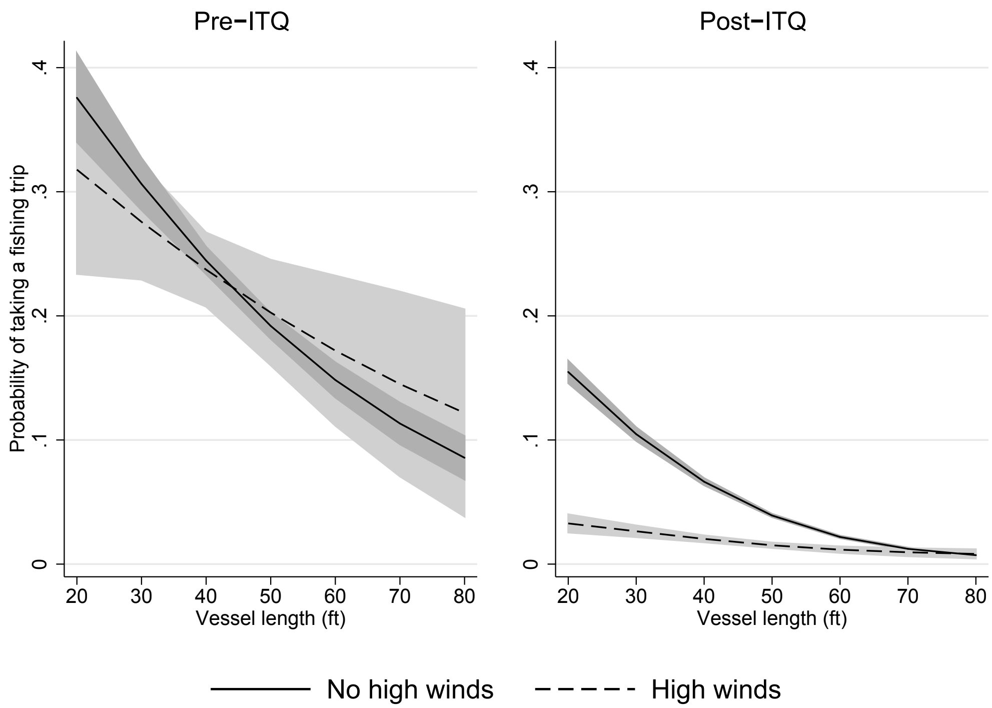

Figure S3: Probability of taking a trip on a day with high winds and a day without high winds, pre-ITQ and post-ITQ, by vessel length. Model includes vessel length as a continuous interaction with expected revenue and high winds, but does not include vessel fixed effects. Expected revenue held equal to the mean. Shaded area is the 95% confidence interval.

Figure S4: Comparison of pre-treatment trends in the average annual fishing rate in high winds of the treatment and comparison groups.