NORTH PACIFIC RESEARCH BOARD PROJECT FINAL REPORT

An Evaluation of Quota-based Management Systems in Alaska

NPRB Project 533 Final Report

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Abstract

Introduction
The objective of this study was to systematically assess whether safety improvements had occurred after quota-based management systems were established in the Alaskan halibut/sablefish and pollock fisheries.
Methods
Safety improvements were measured by identifying declines in fatalities and search and rescue missions for the halibut/sablefish fisheries and declines in non-fatal injuries in the Bering Sea Aleutian Island pollock fishery. Data were summarized in descriptive tables by year and fishery, and a multivariate model was used to examine the effect of management system change. A Poisson regression model was employed.
Results
Our results show a statistically significant decline in rates of fatalities and search and rescue missions for halibut/sablefish fishermen after implementation of Individual Fishing Quotas. We also found a significant decline in non-fatal injury rates among factory trawler vessels participating in the pollock fishery, however, this decline occurred pre-implementation of the American Fisheries Act.
Conclusions
The measurable safety effects of management system changes are provided as evidence to others considering management regime changes. Better data collection and coding is necessary to keep track of adverse events by type of fishery so that future evaluations can be done. A review of the safety effects of the new quota-based management system on the Bering Sea Aleutian Island crab fishery should also be completed.

Keywords

Alaska
Halibut
Pollock
Safety
Fatalities
Injuries
Management Systems
Individual Fishing Quota (IFQ)
American Fisheries Act (AFA)

Citation

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The findings and conclusions in this report have not been formally disseminated by NIOSH and should not be construed to represent any agency determination or policy.

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Study Chronology

Our project had no prior related projects. We did not change the title. Please find the two progress reports following.

Progress Report #1
Project #: 533
Title: Safety Evaluation of Fisheries Management
Principal Investigator and Recipient Organization:
Jennifer Lincoln, PhD
National Institute for Occupational Safety and Health
Alaska Field Station
Contract Period and Amount of Funding:
May 05- April 07
$45,269
Report Period: Through June 30, 2006
Lead Author of Report: Jennifer Lincoln

Project Summary:
This project will evaluate the impact of the changes in fishing management regimes on safety in the halibut/sablefish fleet and the Bering Sea Aleutian Island pollock fleet. Despite the assertion by fishery managers, industry leaders, and in academic circles that vessels operating in a quota based fishery are generally safer, there has been no systematic assessment to examine corresponding improvements in measures of safety. We aim to examine rates of injuries, fatalities, search and rescue missions, and vessel sinkings in fishing fleets both before and after changes in fishing management. This systematic assessment of the change in these rates will provide more scientific evidence to support policies made by fisheries and living resource managers. To limit the influence of confounding variables, and increase the degree to which we can asses the effect of IFQ and quota-based management systems on safety, we will apply a case-control design. Safety measures will be assessed over time, before and after the implementation of the new management systems, and compared between the fishery of interest and a comparable fishery. The inclusion of two controls will allow us to quantify the safety effects due to changes in fishery management.

Progress Summary:
Thus far we have been collecting data for the project and have conducted preliminary analyses to detect improvements in safety after changes in management regimes. Data for the analyses have been collected from several sources (Table 1).

Fatal events and vessels lost have been identified from the Alaska Occupational Injury Surveillance System and from the US Coast Guard.

Estimates of the number of vessels that operated, number of operational days and average number of crew for each year were obtained from 1990-2004 for all fishing fleets in Alaska. For the halibut/sablefish fleet this information was obtained for 1990-2004. This information is being used to calculate rates such as fatality rate per 100,000 workers; number of vessels lost per 100 vessels; number of SAR per 100 vessels; and numbers of nonfatal injuries per 10,000 workers.

Search and rescue information for the halibut/sablefish fleets from 1990-2004 has been requested from the US Coast Guard.

We have identified the vessels operating in the Pollock fleet before and after the implementation of the American Fisheries Act in 1999. Information on the number of reported non-fatal injuries for each vessel has been collected and we have conducted preliminary analyses on these data.

Table 1. Data Sources for Analyses

Data Type	Source	Years Available	Obtained
For Halibut/Sablefish Fleets			
Fatality data	AOISS and USCG	1990-2004	√
Number of fishermen	NRC	1990-2004	√
Number of vessels	NRC	1990-2004	√
Numbers of vessels lost	USCG	1990-2004	√
Search and Rescues (requested)	USCG	1990-2004	
Search and Rescues for comparison cod fleet	USCG	1990-2004	
For Pollock Fleets			
USCG Investigated nonfatal	USCG	1990-2004	√
USCG Investigated nonfatal for comparison cod fleet	USCG	1990-2004	
Number of fishermen	NRC	1990-2004	√
Number of vessels	NRC	1990-2004	√

AOISS: Alaska Occupational Injury Surveillance System
USCG: United States Coast Guard
NRC: Natural Resources Consultants, Inc. (contractor)

Progress Report #2
Project #: 533
Title: Safety Evaluation of Fisheries Management
Principal Investigator and Recipient Organization:
Jennifer Lincoln, PhD
National Institute for Occupational Safety and Health
Alaska Field Station
Contract Period and Amount of Funding:
May 05- April 07
$45,269
Report Period: Through December 31, 2006
Lead Author of Report: Jennifer Lincoln

Project Summary:
We are evaluating the impact of the changes in fishing management regimes on safety in the halibut/sablefish fleet and the Bering Sea Aleutian Island pollock fleet. Despite the assertion by fishery managers, industry leaders, and in academic circles that vessels operating in a quota based fishery are generally safer, there has been no systematic assessment to examine corresponding improvements in measures of safety. We are examining changes in the rates of injuries, fatalities, search and rescue missions, and vessel sinkings in fishing fleets both before and after changes in fishing management. This systematic assessment will provide more scientific evidence to support policies made by fisheries and living resource managers. To limit the influence of confounding variables, and increase the degree to which we can asses the effect of IFQ and quota-based management systems on safety, we will apply a case-control design.

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Search and rescue information for the halibut/sablefish fleets from 1990-2004 has been received from the US Coast Guard and we are reviewing the applicability of these data.

We have identified the vessels operating in the Pollock fleet before and after the implementation of the American Fisheries Act in 1999. Information on the number of reported non-fatal injuries for each vessel has been collected and we have conducted preliminary analyses on these data.

We will be conducting qualitative interviews with fishing vessel captains in Dutch Harbor from February 2-9 to supplement our findings by understanding how the changes in the management regimes affected things like crew size, days at sea, fatigue, and watchkeeping all of which may be proxies for safety changes.

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Number of fishermen	NRC	1990-2004	√
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USCG Investigated nonfatal	USCG	1990-2004	√
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Number of fishermen	NRC	1990-2004	√
Number of vessels	NRC	1990-2004	√

AOISS: Alaska Occupational Injury Surveillance System
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Introduction

Quota-based fisheries management systems have been utilized as a way to reduce overcapitalization, promote resource conservation, and enhance economic sustainability in the commercial fishing industry. Fishery managers in Alaska have adopted quota-based management systems over open access fishery management systems for several fisheries. In the past 12 years, the halibut and sablefish fisheries, Bering Sea and Aleutian Island (BSAI) pollock fishery, and the BSAI crab fisheries have all been converted to quota-based management systems. In addition to the previously mentioned benefits, it is argued that quota-based fishery management systems can also increase safety by removing the "race to fish." In each of the fisheries that have adopted quota-based management systems in Alaska, safety has been used as a primary or secondary justification for the need to change from a "race to fish" or derby-style fishery to a quota-based management system (Hughes & Woodley, 2007; NOAA, 2004).

Fishery managers, industry leaders, and academicians have claimed that safety may be improved in fisheries that adopt quota-based systems. The reasons for these claims include participants being able to choose the weather in which to fish, slowing the pace of the fishery, allowing the crew more rest, and providing more stability for the fishery which leads to a more professional and experienced crew. Despite these assertions that changing to a quota-based management system will result in a safer fishery, there has been little systematic assessment of safety measures in these fisheries after quota-based systems were implemented. This project evaluated the impact of fishery management changes on measures of safety in the Alaskan halibut/sablefish fleet and the BSAI pollock fleet. At the time of the project proposal, the BSAI crab fisheries had not yet changed to a quota-based management system; therefore, these fisheries were not reviewed in this study. We examined rates of serious non-fatal injuries, fatalities, and search and rescue (SAR) missions in these fleets before and after they changed to quota-based management systems. This systematic assessment to detect the change of these rates provides scientific evidence to support arguments that these management regime changes improve safety.

For background information, we have provided a short description of an open access fishery management system and the quota-based fishery management systems for halibut/sablefish and Pollock.

Open Access Fishery Management Systems

Fishery managers set an annual Total Allowable Catch (TAC) for a given fishery. In an open access fishery management system, there is no limit to how much an individual vessel or company can harvest within the constraints of the TAC. This leads to a highly competitive operating environment in which individual vessels attempt to maximize their catch for increased economic gain. This competition is known as the "race for fish" (Woodley 2000). In heavily overcapitalized fisheries which result in

progressively shorter seasons, fishing operations are characterized by intense "derby style" openings. These derby fisheries create intense working conditions often requiring participants to fish in unsafe weather conditions, work continuously for long periods without rest, and possibly overload their vessels. In contrast, the change to quota-based fishery management has been seen as an opportunity for improving vessel and crew safety.

Quota-Based Fishery Management for Halibut/Sablefish.

The Individual Fishing Quota (IFQ) program was developed by the North Pacific Fisheries Management Council for Alaska's halibut and sablefish fisheries and was implemented in 1995. Under the IFQ management system, TACs are set annually. However, the total TAC is allocated to individual quota share holders and quota share holders may only harvest their pounds of allocated quota share. Shares may also be transferred, leased, or sold under commercial contract. Because vessel operators are no longer engaged in a "race to fish" with other fishermen, they may have more options to fish in a safe manner. Operators may fish a greater number of days over a longer period of time and have the ability to choose when to fish to maximize safe weather and sea conditions. Longer seasons also provide more stable employment and opportunities for more professional and experienced crews. These management changes did result in a decline in the number of vessels and corresponding workforce. According to one report, the halibut fleet decreased by more than half over 12 years; from 3450 vessels in 1994 to 1279 vessels in 2005. Similarly, the sablefish fleet decreased in size from 1191 vessels in 1994 to 378 vessels in 2005 (Hughes & Woodley, 2007). In this paper, we accounted for these declines in the trend analyses to ensure that any decrease in adverse events is not simply a factor of fewer participants in the fishery.

Quota-Based Fishery Management for Pollock.

The BSAI pollock fishery is the largest fishery by volume in the United States. During the 1990's, the open access pollock fleet was becoming more competitive and season length was decreasing and slowly creating a "derby style" fishery. Annual harvest quotas and season opening dates were set, catch volumes were monitored throughout the season, and the season ended when the TAC was met (Hughes & Woodley, 2007). The American Fisheries Act (AFA) in 1999 changed the management system of this fishery to a quota-based system. Under the AFA, the TAC is allocated to the three sectors of the pollock fleet (motherships, factory trawlers, catcher vessels) through quota shares issued to vessel owners. Under fishery cooperatives allowed under the AFA, quota shares may be transferred to vessels within each sector. This practice allows more efficient vessels to harvest the quota and allows smaller, less capable vessels to remain in port. Instead of racing to fish, vessel operations and fishery pace are based upon carefully developed scheduling and delivery times, product quality, weather conditions and

markets. The AFA resulted in a 45% decline in the number of factory trawlers and a 15% decline in the number of catcher vessels participating in the fishery (Hughes & Woodley, 2007). Again, the decline in vessels and corresponding workforce was accounted for in the trend analyses to ensure that any decrease in adverse events is not simply a factor of fewer participants in the fishery.

Removing the "race to fish" and stretching the season over a longer time period has the potential to improve safety. These benefits come from the vessel operator's ability to harvest their allocated share on a schedule that optimizes the fishing operation, markets, and weather/sea conditions. Reports have shown that increased revenues have resulted in upgrades and better maintained vessels, and crews are better trained and more experienced (Hughes & Woodley, 2007). However, improvements in safety have not been examined or measured in a scientific manner.

Our hypotheses for this study were:

1. The safety of the halibut/sablefish fleet in Alaska has improved since the implementation of the IFQ management system in 1995 and can be measured by a decline in both fatalities and SAR missions.
2. The safety of the BSAI pollock fleet in Alaska has improved since the implementation of the American Fisheries Act (AFA) in 1999 and can be measured by a decline in non-fatal injuries.

Objectives

The objective of this study was to systematically assess whether safety improvements had occurred after quota-based management systems were established in the halibut/sablefish and pollock fisheries. Safety improvements were measured by identifying declines in fatalities and SAR missions for the halibut/sablefish fisheries and declines in non-fatal injuries in the BSAI pollock fishery. The measurable safety effects of management system changes are provided as evidence to others considering management regime changes.

Methods

Safety improvements were defined as a decline in fatalities, SARs, or non-fatal injuries. Safety improvements for the halibut/sablefish fishery were measured by changes in rates of fatalities and SARs. It was not possible to review declines in non-fatal injuries in the halibut/sablefish fisheries because many of those incidents either are not reported to the USCG or the records available did not indicate in which fishery the injury occurred. The pollock fishery, on the other hand, had relatively low rates of fatal injuries and SARs prior to the implementation of the AFA, so safety improvements for the pollock fleet were measured by declines in non-fatal injuries on factory trawlers. Due to the limited number of pollock

factory trawlers and the ability to link injury dates to fishery data for individual vessels, non-fatal injuries were easily attributed to the pollock fishery. We reviewed rates during a comparable time period pre and post implementation of the quota-based management system for each fishery. This allowed us to focus more specifically on the immediate effect the management change had on these fisheries. For the pollock fishery we were also able to compare factory trawlers to head & gut trawl catcher processors to assess the change to the AFA versus those unaffected by the law to control for changes in the industry overall.

Data

Fatalities: Commercial fishing fatality data came from the Alaska Occupational Injury Surveillance System (AOISS). AOISS is a comprehensive surveillance system for occupational fatalities from traumatic injuries in Alaska, maintained by the National Institute for Occupational Safety and Health (NIOSH), Alaska Field Station. One of the sources used by AOISS is USCG investigation reports. AOISS includes the fishery that the victim was participating in at the time of the fatality.

SAR missions: The number of SAR missions for the halibut/sablefish fisheries from 1992 to 2000 was gathered from the USCG who had published the information in two different reports. For the years 1992-1996, the information was found in the NIOSH Current Intelligence Bulletin (NIOSH, 1997). For 1999-2000, SAR data were published in the NOAA Pacific Halibut-Sablefish Report for fishing year 2005 (NOAA, 2007). Since these publications did not contain data for 1997-1998, these data were imputed using the rounded average of the nearest available data. We did not have a fishery available to use as a comparison group for the halibut/sablefish fishery analysis since SAR data available from the USCG are not accurately coded by fishery.

Non-fatal injuries: Non-fatal injuries for factory trawlers participating in the pollock fishery were identified in the Marine Information for Safety and Law Enforcement (MISLE) database and its predecessor the Marine Safety Information System (MSIS). We examined the casualty history of each factory trawler and the associated injuries that occurred on these vessels during 1995-2005. We focused on these vessels because of the probability that non-fatal injury events are reported to the USCG, since these are large corporate-owned vessels usually with human resource managers and safety professionals on staff. In 1999, the USCG changed the investigation requirement for non-fatal injuries. A higher level of injury severity had to be reached for the event to be recorded in MISLE. For consistency, all records prior to 1999 were reviewed by the authors and only those injury reports meeting the more restrictive investigative requirement were used in the analyses.

We were not able to use data from the Alaska Trauma Registry to review non-fatal injuries as originally proposed. Upon review of the ATR we determined that fishery could not be reliably or consistently identified for these records.

Denominators

Rates were calculated using specific measures of exposure as the denominators. To calculate fatality rates, the denominator was full-time equivalent (FTE) halibut/sablefish fishermen, calculated for each year from 1991 to 2000. Calculating rates using the FTE as the denominator was important in this study because the fishing industry does not operate on a regular full-time schedule. FTEs adjust the worker population to reflect the amount of time worked and allows comparison to rates of other industries.

To calculate the FTEs, data were collected for vessels participating in each fishery including the number of fishing vessels, average crew size, and length of the fishery (days) during the study period. Multiplying the number of fishing vessels by average crew size resulted in the number of fishermen working in that particular fishery. We took the product of the number of fishermen and days worked to calculate fisherman-days. Fisherman-days were divided by the number of regular work days in a year (260). Fisheries that had seasons fewer than 15 days were weighted by a factor of three to give credit for longer hours worked and increased time at risk per day. Seasons lasting between 16 and 50 days were weighted by a factor of two, and seasons lasting longer than 50 days were not weighted. The result was the number of full-time equivalent fishermen. This method of calculating the full-time equivalent has been used in other fishery studies (Thomas et al., 2001; NIOSH, 2002; Lucas and Lincoln, 2007).

Since the specific definition of the serious non-fatal injuries precludes comparison with published rates for other industries, a more general exposure measure representing time working at sea was used. Rates for non-fatal injuries used the exposure measure of vessel-weeks, available through the National Marine Fisheries Service, as the denominator. Vessel-weeks represent the number of weeks that each vessel was fishing. For example, 3 vessels fishing for 2 weeks represents 6 vessel-weeks.

SARs are events to vessels, not individuals, and thus the exposure measure needed to be vessel-specific. Both vessel-weeks and number of vessels (representing vessels per fishery) were used to determine the best model fit for explaining the differences in SARs over time.

Analysis

Data were summarized in descriptive tables by year and fishery, and a multivariate model was used to examine the effect of management system change. Descriptive tables include rates for fatalities, SARs, and non-fatal injuries. Rates were calculated as the number of events divided by the measure of exposure over the same time period multiplied by an appropriate scaling factor as noted in the tables (e.g., 100,000 for fatalities).

For each measure a multivariate model was built to examine the rate of death/SAR/non-fatal injury as it related to the implementation of the quota-based management system. Due to the low

frequency of the events under study and the changing level of exposure by year, a Poisson regression model was employed (Agresti 2002). The variables included in the model were the type of fishery and an indicator for before or after the change in management in the fishery of interest. These multivariate models assessed the significance of each predictor variable as it relates to the changes in rates over time similar to a more common simple regression analysis. Model fit was assessed by testing the deviance compared to its asymptotic Chi-square distribution with non-significant results indicating reasonable fit. The significance of the indicator variable for before or after management change is an assessment of the effect of the change on safety. Models were tested using PROC GENMOD in SAS version 9.1 (SAS Institute Inc., Cary, NC).

Results

Halibut/Sablefish

During 1991-2000 there were 17 fatalities in the Alaskan Halibut/Sablefish fishery, with most of these occurring during 5 vessel sinkings in 1991 (N=2) and 1992 (N=3) (Table 1). The rate of fatalities was 97 per 100,000 FTE for the entire period; 144 per 100,000 before IFQs were implemented and 28 per 100,000 after implementation. The Poisson regression model using FTE as the exposure variable found a significant effect for implementation of the IFQs starting in 1995 (p=0.009). This model provided a reasonable fit to the data, ($\chi^2_{(8)}$=11.3, p=0.19). As noted in the methods section, there were not data available to provide an appropriate comparison group during the same period.

Table 1: Halibut/Sablefish Fishermen Fatality Rate by Year

Year	# Fatalities	FTE	Rate per 100,000 FTEs
1991	6	2663	225
1992	7	3167	221
1993	1	2220	45
1994	1	2394	42
1995	0	1266	0
1996	0	1214	0
1997	0	1229	0
1998	1	1104	91
1999	1	1096	91
2000	0	1124	0

IFQs implemented in 1995

There were 104 SAR missions between 1992 and 1996 in the halibut/sablefish fishery, and another 9 during 1999-2000 (Table 2). Data for 1997 and 1998 were imputed using the rounded average

of the nearest available data. The estimated rate of SARs was 463 per 100,000 vessels during the entire time period; 602 before IFQs were implemented and 316 per 100,000 vessels after implementation. The Poisson regression model using number of vessels as the exposure variable had the best fit and showed a significant effect for implementation of the IFQs starting in 1995 (p=0.004; model fit $\chi^2_{(5)}$=8.19, p=0.15). As noted in the methods section, there were no data available to provide an appropriate comparison group during the same period.

Table 2: Halibut/Sablefish SAR case Rate by Vessels Fished

Year	# SARs	Vessels	Rate per 100,000 Vessels
1992	23	4618	498
1993	26	4362	596
1994	33	4641	711
1995	15	2673	561
1996	7	2527	277
1997	7*	2455	285
1998	7*	2078	337
1999	6	2076	289
2000	3	2018	149

IFQs implemented in 1995
*Imputed values for missing data

BSAI Pollock

During 1995-2005 there were 81 serious non-fatal injuries on factory trawlers operating in the pollock fishery, with a rate of 2.1 per 100 vessel-weeks. Before the management change the rate was 3.7 per 100 vessel-weeks, and from 1999-2005 the rate decreased to 0.9 per 100 vessel-weeks. The AFA vessels had a steep decline in injury rates leading to the AFA and then hit a plateau in 1999 when AFA was implemented. In order to assess the potential change in safety relative to changes in the industry overall, a comparison group was included in the model. The head and gut (H&G) trawl catcher processor vessels, which are not managed by a quota system, had a total of 21 serious non-fatal injuries during 1995-2005 with a rate of 0.5 non-fatal injuries per 100 vessel-weeks. These vessels utilize similar fishing gear, have similar operating seasons, and have similar crew organization (vessel operators, deck force, and processing workers). The comparison group had a fairly steady rate of non-fatal injuries over the entire period. The Poisson regression model using vessel-weeks as the exposure variable found a statistically significant effect for implementation of the AFA in 1999 (p<0.001). However consideration should be given to why the decline in the injury rate occurred before implementation of the AFA. The

model also found a statistically significant difference between the two fisheries ($p<0.001$) but only a marginally significant interaction ($p=0.06$) indicating the difference in rates before and after 1999 between the two fisheries. This model provided a good fit to the vessel-level injury and vessel information ($\chi^2_{(384)}=312.68$, $p=0.99$).

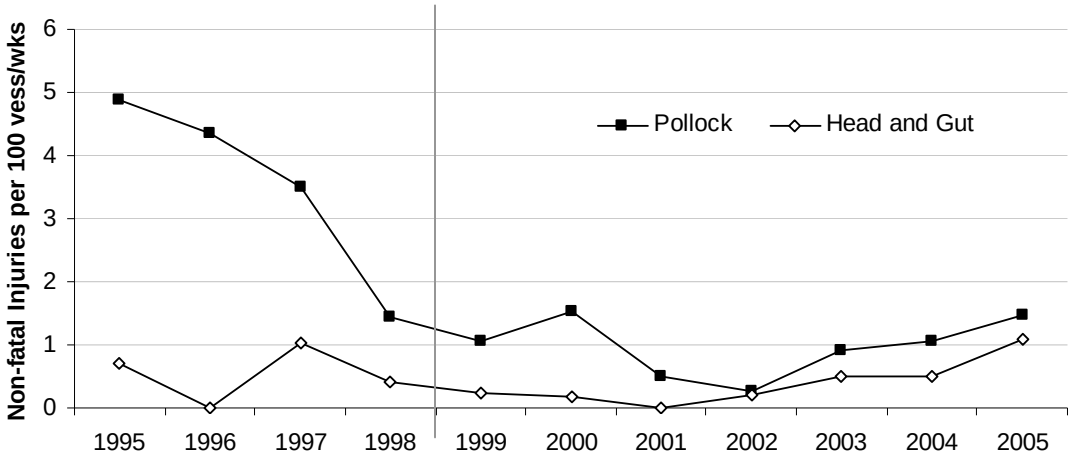

Figure 1. Rate of Non-fatal Serious Injuries per 100 Vessel-weeks for Pollock and Head and Gut Vessels in Alaska Before and After the American Fisheries Act in 1999

Discussion

We found evidence of an improvement in safety for each fishery and measure of safety we examined. Each fishery and safety measure is discussed below.

Halibut/Sablefish

The measurable effect of safety improvement for the halibut/sablefish fleets was a decline in the rate of both fatalities and SAR missions after IFQs were implemented. The fatality rate decreased by 81% and the SAR mission rate decreased by 47%. These results update the information NIOSH provided the National Research Council during the review of individual fishing quotas. We reported in 1997 that there had been 0 deaths in the halibut/sablefish fishery since implementation of IFQs and that the average annual number of SAR missions conducted had decreased significantly ($p=.009$) (NRC, 1999). This decrease continued through our study period of 2000. In addition, this significant decline is fatalities and SARS is greater than the decline in vessels participating in the fishery.

Other factors not related to management changes are present that could have contributed to the decline in the fatality rates. During 1991-2000 the overall commercial fishing fatality rate for all fisheries declined in Alaska. Equipment and training requirements of the Commercial Fishing Industry Vessel

Safety Act of 1988 were implemented in the 1990's. The impact of the CFIVSA on fishing fatalities has been discussed in numerous papers (NIOSH, 1997; Lincoln & Conway, 1999; NIOSH, 2002). In 1991, only 73 percent of commercial fishermen involved in vessel sinkings survived while in 1998, 93 percent of those involved survived. This is a result of keeping fishermen warm and afloat through the use of immersion suits and life rafts while awaiting rescue (Lincoln & Conway, 1999). Although the fatality rates decreased for the entire industry, the number of vessels that sank each year did not change. This suggests that people were using survival equipment and were surviving until being rescued (Lincoln & Conway, 1999). Our results showing a decline in SAR missions for the halibut/sablefish fleet suggest that fishermen participating in this fishery were having fewer emergencies at sea requiring a SAR mission to be launched.

We defined a "safety" improvement as a decline in the rate of an undesirable event such as non-fatal injuries, fatalities, or SAR missions. The term safety can also be broadened to mean something intangible and much harder to measure. Maurice et. al. 2001, defines safety as "a state in which hazards and conditions leading to physical injury… are controlled in order to preserve the health and well being of individuals and the community". Quota share fisheries potentially provide an environment where fishermen can choose not to fish in poor weather, lessen the pace at which they work, and rest more resulting in a "safer" environment.

The change in the "safety" environment for the halibut/sablefish fleet, was reviewed by the Institute of Social and Economic Research. They found that more than 85% of quota shareholders who responded to the survey answered "yes" to the question: "Do you think IFQs have made fishing for halibut safer?" (ISER, 1996)

BSAI Pollock

Results for the pollock fishery revealed a measurable improvement in safety. The pollock factory trawlers experienced a 76% decrease in the non-fatal injury rate when comparing the rate from 1995-1998 to the rate from 1999-2005. Injury data and information on the number of weeks fished pre-1995 is not available. Unlike the fatality and SAR rate differences in the halibut/sablefish fishery, the decline in the non-fatal injury rate for the pollock fleet started before implementation of the AFA (Figure 1). The model revealed a statistically significant difference in the rate of non-fatal injuries before and after 1999, however, the annual data suggest other influences besides the AFA . The decline of non-fatal injuries pre-1999 could be a result of vessels dropping out of the fishery prior to implementation of the AFA or because the fishing companies who owned these vessels started making corporate safety improvements prior to the AFA. These corporate owned vessels were developing safety programs at this time which were focused on preventing these types of injuries. In addition, the North Pacific Fishing Vessel Owners

Association, Vessel Safety Program had started offering classes in deck safety, factory safety, and OSHA regulations at this same time. Many of the people fishing on these vessels were taking these courses. The data in this report do not permit us to determine if the declines observed prior to 1999 were due to the AFA or other more general industry changes.

For this analysis, we used the H&G fleet as a comparison group in order to assess the potential change in safety relative to changes in the industry overall. The H&G fleet is not managed by a quota system. There was a significant difference between the non-fatal injury rates between the two groups of vessels and a marginally statistically significant interaction ($p=0.06$) indicating the difference in rates before and after 1999 between the two fisheries. However the decline in injury rates pre 1999 in the pollock fleet is not explained by this comparison group.

Anecdotally, several skippers in Dutch Harbor on pollock factory trawlers and catcher vessels mentioned several things that changed after AFA that may have made the fishery "safer". Skippers mentioned the benefit of being able to choose weather and maintain a more experienced crew (Lincoln, 2007a). Pollock fishermen also explained that there are still very real economic pressures present, such as delivery deadlines and harvesting the most fish during their prime stage of life (Lincoln, 2007a). We should not ignore the many pressures that influence fishermen's risk-taking behavior. A change in management systems removes some of these pressures, but there are still others present that encourage risky actions. Peer pressure, pressures of competition, productivity pressures and of course economic pressures cannot be completely removed from this industry. Quota-based management systems lessen some of these pressures by spreading out the length of the fishery and lessening the "race to fish".

Recommendations

The quota-based management system for the halibut/sablefish fishery revealed measurable improvements in safety indicated by declines in fatality rates and rates for SAR missions after implementation of the IFQ system. Although the pollock factory trawlers showed a measurable decline in non-fatal injury rates, it is unclear how much of this change may have been due to the implementation of the AFA.

Commercial fishing is the most dangerous occupation in the country (BLS, 2007) and a change in the management system of a fishery is not a panacea. Commercial fishing takes place in a dynamic environment and adverse events are caused by the culmination of risk factors. Many factors influence the safety of fishermen including vessel design, construction and stability; human factors including crew training, work methods, hours of work, and personal protection. Ensuring that the way the fishery is managed does not adversely affect safety is very important.

We have recommended other areas that should also be addressed when trying to improve fishing vessel safety. These areas include developing tailored interventions for particular fisheries that 1. prevent vessel loss; 2. identify effective strategies to prevent fatalities from falls overboard; 3. identify effective strategies to prevent severe injuries resulting from being caught in or struck by deck machinery or fishing gear; and 4. establish marine safety training and refresher training programs for all commercial fishermen (Lincoln, 2007b).

Based on our findings, we recommend that data collection and coding for adverse events such as fatalities, non-fatal injuries, SARs and vessel loss be improved. All of these events must be coded by the fishery in which the vessel was operating so that we can identify high-risk groups of vessels and also design and evaluate specific interventions such as management system changes for each fishery.

Our initial proposal did not include reviewing the impacts of the recent BSAI Crab rationalization on safety. We recommend this be done in future studies.

Strengths and limitations

Strengths of our study include multiple outcome measures controlling for changes in exposure such as fatalities per FTE, SAR missions per vessel, and non-fatal injuries per vessel-week. Being able to control for the effect of fleet consolidation is necessary if real safety improvements are to be measured after management regime changes.

Limitations to our study include restricted availability of safety measures due to incomplete or uncoded information on fishery. This was a problem when trying to identify a comparison group for the halibut/sablefish fleet. We were also dependent on companies reporting non-fatal injuries to the USCG. We did not examine reporting practices of each vessel; however, it is unlikely that there is a systematic bias that would significantly alter our findings.

Conclusions

In this study, we have presented evidence of how safety improves when quota-based management systems were implemented. We used multiple outcome measures to assess safety improvements. Our results show a statistically significant decline in rates of fatalities and SAR missions for halibut/sablefish fishermen after implementation of IFQs. Although the pollock factory trawlers showed a measurable decline in non-fatal injury rates, it is unclear how much of this change may have been due to the implementation of the AFA. Other positive changes in this fleet occurred in the mid-1990's including improved safety programs for the companies that owned these vessels. Safety climate change is an important factor when examining "safety improvement" as a result of these management system changes. However, continued monitoring of the change in risks is warranted. Better data

collection and coding is necessary to keep track of adverse events by type of fishery so that future evaluations can be done. A review of the safety effects of the new quota-based management system on the BSAI crab fishery should also be completed.

Publications

We plan to submit a scientific manuscript to "Marine Policy" once report is accepted by NPRB.

Outreach

The results of this project will be translated through a combination of NIOSH efforts and partnerships. Outputs will include: scientific support to show process of evaluating safety changes, information on safety changes in the halibut/sable fish and pollock fleet. Outputs will be disseminated through conferences, NIOSH reports of investigation, peer-reviewed journal articles, industry publications, and stakeholder meetings. Partnerships with fishing and marine safety organizations, universities, fishing vessel owners, and other government agencies will be crucial to the translation of results to the workplace.

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