Primary prevention of fishing vessel disasters: Evaluation of a United States Coast Guard policy intervention

Citation	Lucas, D. L., Kincl, L. D., Bovbjerg, V. E., Branscum, A. J., & Lincoln, J. M. (2014). Primary prevention of fishing vessel disasters: Evaluation of a United States Coast Guard policy intervention. Marine Policy, 50, 67-73. doi:10.1016/j.marpol.2014.05.017
DOI	10.1016/j.marpol.2014.05.017
Publisher	Elsevier
Version	Version of Record
Terms of Use	http://cdss.library.oregonstate.edu/sa-termsofuse

Marine Policy 50 (2014) 67–73

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Primary prevention of fishing vessel disasters: Evaluation of a United States Coast Guard policy intervention

Devin L. Lucas [a,b,*], Laurel D. Kincl [a], Viktor E. Bovbjerg [a], Adam J. Branscum [a], Jennifer M. Lincoln [b]

[a] College of Public Health and Human Sciences, School of Biological and Population Health Sciences, Oregon State University, 123 Women's Building, Corvallis, OR 97331, USA

[b] National Institute for Occupational Safety and Health, Alaska Pacific Office, 4230 University Drive Ste 310, Anchorage, AK 99508, USA

ARTICLE INFO

Article history:
Received 12 March 2014
Received in revised form
12 May 2014
Accepted 13 May 2014
Available online 2 June 2014

Keywords:
Fishing vessel disasters
Marine safety
Injury prevention
Occupational epidemiology

ABSTRACT

Primary injury prevention strategies are needed to improve worker safety in the fishing industry by reducing the occurrence of vessel disasters. In 2006, the United States Coast Guard (USCG) implemented a novel safety policy intervention for two fleets of freezer-trawlers and freezer-longliners in Alaska. The *Alternate Compliance and Safety Agreement* (ACSA) set standards for vessel stability, watertight integrity, hull condition, and other critical vessel components. To determine if ACSA has been an effective primary prevention intervention for improving safety in the fishing industry, a longitudinal study was conducted using retrospective data on vessel casualties during 2003–2012. On both types of vessels, reported rates of serious vessel casualties decreased after the vessels reached compliance with ACSA requirements, suggesting that ACSA has had a positive effect on vessel safety in the freezer-trawl and freezer-longline fleets. These results support the premise that primary prevention policies can contribute to worker safety by reducing the occurrence of vessel disasters. Future USCG safety policies should be patterned after ACSA and improved by following the recommendations outlined in this study.

Published by Elsevier Ltd.

1. Introduction

Vessel disasters (e.g., vessels capsizing, sinking, grounding, or burning) are the leading contributor to occupational fatalities in the U.S. commercial fishing industry [1], which has consistently been one of the most hazardous industries nationwide [2]. During 2000–2009, 148 separate vessel disasters resulted in 261 fatalities in U.S. fisheries, representing 52% of all fishing industry fatalities [1]. Studies in other nations, including Australia, Poland, Denmark and England have also found that vessel disasters are the cause of the majority of deaths at sea among fishing industry workers [3–6]. In the U.S. fishing industry during 2000–2009, Lincoln and Lucas [1] found that fishing vessel disasters were the end result in a sequence of events that culminated with a final catastrophic event, such as the vessel sinking. The most frequent initiating events (the first problems to arise) for vessel disasters were flooding (28%), instability (18%), struck by a large wave (18%), collision (10%), and fire/explosion (5%).

In April 2001, the 92 foot (28 m) freezer-trawl (FT) vessel *Arctic Rose* was fishing in the Alaska Bering Sea when it flooded and sank, killing all 15 workers onboard [7]. One year later, the 180 foot (55 m) freezer-longline (FL) vessel *Galaxy* caught fire and sank in the Bering Sea with three worker fatalities out of 26 workers onboard [8]. The FT fleet suffered another vessel disaster in 2008 when the *Alaska Ranger* flooded and sank, killing five of the 47 crewmembers [9]. The *Arctic Rose, Galaxy,* and *Alaska Ranger* were part of two fleets of FT and FL vessels that operate in the Bering Sea/Aleutian Islands and the Gulf of Alaska. The distinction between FT and FL vessels and other trawlers and longliners is that the freezer vessels are outfitted with factories and freezers onboard, which are used to process and freeze the catch, while other trawlers and longliners catch and deliver fish whole to onshore processing plants [10]. FT vessels are also known as non-Pollock catcher-processors, factory-trawlers, and amendment 80 vessels. An FT vessel catches fish by towing a large, bag-shaped net along the ocean floor. As the net fills, fish are pushed to the far end of the net, called the “cod-end,” where they accumulate. When the trawl net is full, it is brought to the surface with winches and the fish are transferred into holds until being moved into the factory for processing [11]. After processing, the fish products are packaged and frozen. The average crew size for FT vessels is 36 workers

* Corresponding author at: National Institute for Occupational Safety and Health, Alaska Pacific Office, 4230 University Drive Suite 310, Anchorage, AK 99508, USA. Tel.: +1 907 271 2382.
E-mail address: dlucas@cdc.gov (D.L. Lucas).

http://dx.doi.org/10.1016/j.marpol.2014.05.017
0308-597X/Published by Elsevier Ltd.

[12], with jobs including captain, mate, engineer, deckhand, fish processor, and cook [13]. An FL vessel catches fish by setting a line of baited hooks along the ocean floor. Fish are brought onboard one at a time as the line of hooks is retrieved [11]. Fish are then unhooked and moved to the factory where processing and freezing take place. The average crew size for FL vessels is 20 workers [12], with similar jobs as found in the FT fleet [14].

According to the United States Coast Guard (USCG), the FT and FL fleets operating in Alaska are at high risk for worker injuries:

> [FT and FL] operations require a sizeable crew, processing and freezing machinery, hazardous gases (anhydrous ammonia or Freon), and large amounts of packaging materials on board. Additionally, because of their ability to freeze, package and store frozen catch, these vessels can operate in the most remote areas of the Bering Sea, far from search and rescue support. These factors combine to significantly increase safety and operational risks to this fleet. [15]

An empirical study of work-related injuries onboard FT and FL vessels supported the USCG assessment. Specifically, from 2003 to 2012, the annual risk of fatal injuries in the FT fleet was 130 deaths per 100,000 full-time equivalent workers (FTEs), and the annual risk of non-fatal injuries was 44 per 1000 FTEs [12]. The annual risk of fatal injuries in the FL fleet during the same period was 65 deaths per 100,000 FTEs, and the annual risk of non-fatal injuries was 36 per 1000 FTEs [12].

The first attempts to create safety standards for fishing vessels through federal legislation began in 1930s, but were not successful until the Commercial Fishing Industry Vessel Safety Act of 1988 was signed into law [16]. The law requires most fishing vessels to carry survival equipment, such as personal flotation devices, immersion suits, life-rafts, throwable flotation devices, distress signals, emergency position indicating radio beacons, and fire extinguishers [17]. The safety standards of the 1988 vessel safety act were implemented during the early 1990s and had a measurable positive effect on worker fatalities caused by vessel disasters. The case-survivor rate for vessel disasters in Alaska increased from 78% in 1991–1993, to 92% in 1994–1996, to 94% in 1997–1999 [18] because crewmembers had access to these newly required life-saving devices, which increased their survival prospects after abandoning ship. However, the frequency of vessel disasters did not decrease during that decade because the 1988 vessel safety act focuses almost entirely on secondary prevention of death; that is, keeping workers alive in the water until rescue aid arrives [18].

Primary prevention strategies can contribute to worker safety by reducing the occurrence of vessel disasters. During 2004–2005, the USCG engaged the owners and operators of FT and FL vessels to discuss safety problems and to generate solutions [19]. A new set of safety rules was formed for the FT and FL fleets under a special policy, the *Alternate Compliance and Safety Agreement* (ACSA) (for a detailed account of the development of ACSA, refer to [10,19]). The emphasis of ACSA was placed on the primary prevention of vessel disasters; it included rules for vessel stability, watertight integrity, and the material condition of the hull, tail shaft, rudder, and machinery. Alongside the standards for primary prevention, ACSA also included requirements aimed at secondary prevention of fatalities, such as having life-saving equipment, fire-fighting equipment, emergency communications and navigation equipment, and conducting emergency drills [10].

As the administrator of ACSA, the USCG was responsible for examining and certifying the vessels in the program. After vessels corrected deficiencies and reached full compliance with ACSA standards, they were issued an ACSA compliance letter. The overarching hallmark and objective of ACSA was to work "closely with industry stakeholders in developing elements of this alternate and voluntary program in order to save lives" [10]. ACSA was signed into policy in 2006, with a deadline of January 1, 2008 for vessels to reach full compliance with the new rules [19].

By focusing on primary prevention of vessel disasters, ACSA aimed to improve safety in the FT and FL fleets. However, plans for evaluating the efficacy of the program were not included in its design. Consequently, the impact of ACSA on safety in these fleets has been unknown. The purpose of this research was to evaluate the efficacy of ACSA as a primary prevention intervention for vessel disasters.

2. Material and methods

2.1. Study design

To determine if ACSA has been an effective intervention for improving safety in the fishing industry, a longitudinal study was conducted using historical data on vessel casualties during 2003–2012. The goal was to compare the rate of vessel casualties before and after implementation of ACSA. The year 2003 was chosen as the beginning of the study period because it was the first year that exposure data (vessel-days at sea) were available.

The study group consisted of all FT and FL vessels that operated in the Bering Sea/Aleutian Islands and Gulf of Alaska regions during the study time period and were in full compliance with ACSA standards during 2012. Full compliance with ACSA standards was achieved only for vessels that were (i) enrolled in the ACSA program, (ii) inspected for all deficiencies listed in the ACSA requirements, and (iii) issued an ACSA compliance letter by the USCG or recognized third party, which occurred only after correction of any identified deficiencies. There were 17 FT vessels and 20 FL vessels that met the criteria and were included in the study group.

2.2. Data

The outcome used to assess the efficacy of ACSA was the count of vessel casualties on each vessel during each year in the study period. Vessel casualties were defined as failures of vessel components or systems that resulted in problems such as the loss of electrical power, loss of propulsion, loss of steering, flooding, and fire. This outcome was selected through a process of informal interviews with ACSA stakeholders (USCG & vessel owners), a review of the literature, and application of a theoretical framework (theory of man-made disasters) that is described in Section 4. Five USCG personnel and four fishing industry representatives participated in informal interviews and independently provided their expert opinions on the metrics (quantifiable measures of performance) that should be used to evaluate ACSA. All nine informants listed vessel casualties as the primary and most relevant metric for assessing the efficacy of ACSA.

During the design of this study, some marine safety experts conveyed the opinion that because ACSA was designed to prevent vessel disasters (which are the most severe type of vessel casualty), there may not be an effect of ACSA on reducing minor casualties. To address that issue, two forms of the outcome variable were analyzed. Outcome A was the count of *all* vessel casualties (minor, moderate and serious) and outcome B was the count of *serious* vessel casualties. Casualty severity was determined based on how the casualty was resolved. Casualties were coded as minor if they were resolved permanently by the crew at sea and did not require any outside assistance or a return of the vessel to port for repairs. Moderate casualties were either resolved at sea with outside assistance, or the vessel returned to port without assistance for permanent repairs. Serious casualties required the vessel to be towed or otherwise assisted to port for repairs.

Individual vessels operate at sea for different lengths of time during the year. Vessels that operate for longer periods have more exposure to hazards than vessels that operate less. Therefore, the measure of exposure used in this study to adjust risk estimates was *vessel days at sea*, obtained for each vessel in the study group for each year during 2003–2012.

2.3. Data sources

Vessel casualties were identified through two sources, the USCG Marine Information for Safety and Law Enforcement (MISLE) database and the National Marine Fisheries Service (NMFS) Observer Vessel Survey. Data security and use agreements were established to access data from each agency. MISLE is used to record information reported by fishing companies to the USCG on vessel casualties. Federal law requires companies that operate fishing vessels to report vessel casualties to the USCG [20]. USCG investigators enter data into MISLE from a number of sources depending on the seriousness of the casualty. For instance, some records in MISLE concerning minor casualties may only have a single source of data such as a standard USCG reporting form completed by the company, or standard documentation of a telephone call to the USCG. More serious casualties in MISLE may have additional data sources such as witness statements, damage assessments, and repair logs collected by a USCG investigator.

In an attempt to identify casualties that were not reported by companies to the USCG, the NMFS Observer Vessel Survey was utilized. NMFS is the federal government agency responsible for the management of the nation's fisheries to ensure their sustainability [21]. NMFS places observers on vessels that operate in federal fisheries to monitor catch volume, by catch, and other fishing operations [22]. Fishery observers also record safety related events, such as injuries to workers and vessel casualties that come to their attention while on the vessel. The events are initially recorded by the observers in their logbooks and reported to NMFS staff. When observers finish their assignments on the vessels, they are debriefed and provide additional information into the Observer Vessel Survey. Observer coverage (the amount of time a vessel must carry an observer onboard) depends on several factors, including vessel length, fishing gear, and species targeted. Based on those factors, observer coverage during the study period ranged from approximately 30–100% for FT and FL vessels [23].

2.4. Statistical analysis

Data on vessel casualties were extracted from MISLE and the NMFS Observer Vessel Survey and entered into a dataset. Data were matched to identify and remove duplicate records. An exploratory data analysis was completed to examine the distribution of the outcome variable and covariates. Individual vessels reached compliance with ACSA at different times during the implementation period. The earliest ACSA compliance letter was issued in 2006 and the latest in 2010. To control for this variation in calendar years, a new variable, *ACSA years*, was created to indicate the number of years before and after the ACSA compliance letter issuance for each vessel. Year zero was the year that each vessel received its compliance letter; years before the compliance letter issuance were coded with consecutive negative numbers and years after the compliance letter issuance were coded with consecutive positive numbers. Incidence rates of the outcome were calculated for each *ACSA year* using *vessel days at sea* as the denominator.

The count of casualties on each vessel was repeatedly measured at 10 different times (years 2003–2012), introducing correlation of measurements within the same vessel. A second source of correlation, clustering of vessels within the same company, was also expected. To account for correlated longitudinal measurements and clustering of vessels by company, a mixed-effects model was selected to allow for the inclusion of random effects for vessel and company.

An exploratory data analysis revealed that the variances of both outcomes were larger than the means (i.e., overdispersion in Poisson regression). In addition, the Bayesian information criterion (BIC) supported negative binomial regression over Poisson regression due to its inclusion of a dispersion parameter that allows for greater data variability over a Poisson model. Therefore, a multilevel mixed-effects negative binomial regression model was used for data analysis. The outcome variable, y_{ijk}, was the count of casualties (or serious casualties for outcome B) on vessel i from company j during year k that occurred during M_{ijk} days at sea. The corresponding empirical casualty rate was calculated as y_{ijk}/M_{ijk}.

In addition to the primary predictor variable, which was a binary indicator of ACSA compliance letter issuance, the model contained fixed effects for vessel type (FT or FL), vessel length (feet), vessel age (year built), and a random effect for company with a nested random effect for vessel within company. The offset (exposure) was vessel-days at sea. An interaction term was added to allow the effect of ACSA to vary according to vessel type. The random effects were assumed to be normally distributed.

Rate ratios were calculated to compare rates of vessel casualties before and after ACSA for FT and FL vessels. Specifically, the estimated rate ratio and 95% confidence interval (CI) comparing pre to post ACSA compliance letter issuance for FT vessels of the same age and length was calculated, along with the corresponding rate ratio comparing pre to post ACSA for FL vessels. In addition to comparing casualty rates before and after ACSA, the probability of having no casualties was calculated and compared.

Data analysis was performed using Stata 13 [24]. Descriptive statistics were calculated using means, medians, and standard deviation (SD). Model fit was assessed graphically by plotting the residuals and the predicted versus observed mean casualty rates. In addition, BIC was used for model selection.

3. Results

The study group was comprised of 17 FT vessels owned by six companies and 20 FL vessels owned by eight companies. The FT vessels had a median length of 143 ft (mean = 143; SD = 42), a median age of 32 years in 2012 (mean = 32; SD = 4), and had a median crewsize of 34 workers (mean = 34; SD = 12). The FL vessels had a median length of 117 ft (mean = 126; SD = 23), a median age of 32 years in 2012 (mean = 37; SD = 18), and had a median crewsize of 20 workers (mean = 18; SD = 5). Most FT vessels (11, 65%) reached compliance with ACSA during 2008. The earliest ACSA compliance letter was issued in 2006 and the latest in 2009. Among FL vessels, 13 (65%) reached compliance during 2008 with the earliest in 2007 and latest in 2010.

During 2003–2012, FT vessels in the study group operated 39,888 days at sea, an average of 235 days at sea per vessel per year. The FL vessels logged 44,326 days at sea, an average of 222 days at sea per vessel per year. There were 387 vessel casualties reported to the USCG and/or documented by NMFS observers during the study period; 205 occurred onboard FT vessels and 182 occurred onboard FL vessels (Table 1). Overall, 56% of casualties on FT vessels and 43% of casualties on FL vessels were reported by the companies to the USCG.

The most common types of casualties on FT vessels were loss of electrical power (74, 36%), loss of propulsion (65, 32%), and fire (27, 13%). FL vessels had similar casualties: loss of propulsion (63, 35%),

Table 1
Sources of data on vessel casualties involving FT and FL vessels during 2003–2012.

	Total casualties	Data source			% Reported to USCG	% Observed by NMFS
		USCG only	NMFS only	USCG & NMFS		
FT vessels (n=17)						
2003	12	1	9	2	25.0	91.7
2004	11	1	9	1	18.2	90.9
2005	20	8	8	4	60.0	60.0
2006	16	3	8	5	50.0	81.3
2007	10	5	4	1	60.0	50.0
2008	24	5	12	7	50.0	79.2
2009	26	9	11	6	57.7	65.4
2010	30	8	8	14	73.3	73.3
2011	33	12	12	9	63.6	63.6
2012	23	11	9	3	60.9	52.2
Total	205	63	90	52	56.1	69.3
FL vessels (n=20)						
2003	21	1	15	5	28.6	95.2
2004	33	5	21	7	36.4	84.8
2005	16	0	13	3	18.8	100.0
2006	17	1	11	5	35.3	94.1
2007	18	6	11	1	38.9	66.7
2008	10	3	4	3	60.0	70.0
2009	19	6	9	4	52.6	68.4
2010	16	9	6	1	62.5	43.8
2011	16	4	6	6	62.5	75.0
2012	16	6	8	2	50.0	62.5
Total	182	41	104	37	42.9	77.5

Table 2
Vessel casualty type and severity for FT and FL vessels during 2003–2012.

	Minor		Moderate		Serious		Total[a]
	No.	%	No.	%	No.	%	No.
FT vessels (n=17)							
Loss of electrical power	66	89.2	8	10.8	0	0.0	74
Loss of propulsion	33	50.8	14	21.5	18	27.7	65
Fire	25	92.6	2	7.4	0	0.0	27
Flooding	6	31.6	12	63.2	1	5.3	19
Loss of steering	4	57.1	2	28.6	1	14.3	7
Other[b]	3	30.0	7	70.0	0	0.0	10
Total	137	67.8	45	22.3	20	9.9	202
FL vessels (n=20)							
Loss of electrical power	49	86.0	7	12.3	1	1.8	57
Loss of propulsion	27	45.8	25	42.4	7	11.9	59
Fire	16	76.2	4	19.0	1	4.8	21
Flooding	14	77.8	4	22.2	0	0.0	18
Loss of steering	13	72.2	4	22.2	1	5.6	18
Other[c]	1	25.0	2	50.0	1	25.0	4
Total	120	67.8	46	26.0	11	6.2	177

[a] The grand total in this table is 379 casualties due to missing data on severity for 8 casualties.
[b] Groundings, collisions, hull breaches w/o flooding.
[c] Groundings, bilge pump failures w/o flooding.

loss of electrical power (57, 31%), and fire (21, 12%). For all types of casualties combined, 257 (66%) were minor, 91 (24%) were moderate, and 31 (8%) were serious (Table 2). On FT vessels, 68% of flooding (13/19) and 49% of loss of propulsion (32/65) casualties were greater than minor severity, while only 7% of fires (2/27) and 11% of loss of power (8/74) casualties were greater than minor severity (Table 2). On FL vessels, 54% of loss of propulsion (32/59) and 28% of loss of steering (5/18) casualties were greater than minor (Table 2).

Estimates from multilevel mixed-effects negative binomial regression models for outcome A (the count of all vessel casualties) and outcome B (the count of serious vessel casualties) are presented in Table 3. On FT vessels of average age and length, the estimated rate of all casualties from pre to post ACSA rose 52% from 3.05 to 4.62 per 1000 vessel-days (RR=1.52, 95% CI 1.07, 2.15) (Table 4). The probability of an FT vessel having no casualties during a year decreased 38% from pre to post ACSA (Table 5). However, when restricting the analysis to serious casualties only (outcome B), the rate of serious casualties decreased 8% pre to post ACSA (RR=0.92, 95% CI 0.34, 2.46) and the probability of having no serious casualties remained approximately the same.

On FL vessels of average age and length, the estimated rate of all casualties (outcome A) from pre to post ACSA decreased 11% from 4.25 to 3.80 per 1000 vessel-days (RR=0.89, 95% CI 0.61, 1.31) (Table 4). The probability of an FL vessel having no casualties

Table 3
Multilevel mixed-effects[a] negative binomial regression models for two vessel casualty outcomes involving FT and FL vessels during 2003–2012.

	Outcome A: all vessel casualties[b]			Outcome B: serious vessel casualties[c]		
	Coeff.	SE	95% CI	Coeff.	SE	95% CI
ACSA time period						
Pre-ACSA (ref)	–	–	–	–	–	–
Post-ACSA	0.42	0.18	0.06, 0.77	−0.09	0.50	−1.07, 0.90
Vessel type						
Freezer-trawler (ref)	–	–	–	–	–	–
Freezer-longliner	0.33	0.42	−0.49,1.16	10.72	0.59	−1.88, 0.43
ACSA × vessel type	−0.53	0.26	−1.04, −0.01	−1.71	1.19	−4.04, 0.62
Vessel length	0.01	0.01	−0.01, 0.02	0.01	0.01	−0.01, 0.01
Vessel year built	0.01	0.01	−0.02, 0.03	−0.03	0.02	−0.07, 0.004
Intercept	−18.53	23.72	−65.03, 27.97	59.97	38.90	−16.28, 136.22

[a] Random effects of vessels nested within companies were included in models, with days at sea serving as an offset.
[b] Sum of counts = 387 total vessel casualties.
[c] Sum of counts = 31 serious vessel casualties.

Table 4
Observed[a] and predicted[b] rates[c] of vessel casualties involving FT and FL vessels during 2003–2012.

Outcome	Observed/predicted	Pre-ACSA rate	Post-ACSA rate	Pre/post RR	95% CI
FT vessels (*n* = 17)					
All casualties	Observed	4.40	6.30	1.43	–
All casualties	Predicted	3.05	4.62	1.52	1.07, 2.15
Serious casualties	Observed	0.59	0.51	0.86	–
Serious casualties	Predicted	0.52	0.48	0.92	0.34, 2.46
FL vessels (*n* = 20)					
All casualties	Observed	4.71	3.86	0.82	–
All casualties	Predicted	4.25	3.80	0.89	0.61, 1.31
Serious casualties	Observed	0.37	0.05	0.14	–
Serious casualties	Predicted	0.25	0.04	0.17	0.02, 1.37

[a] Empirical rates observed in sample data.
[b] Predicted rates calculated from regression models (Table 3), which were adjusted for covariates and correlated data.
[c] Number of casualties per 1000 vessel days.

Table 5
Predicted probabilities of experiencing zero vessel casualties on FT and FL vessels[a] before and after ACSA compliance.

Outcome	Pre-ACSA	Post-ACSA	% Change
FT vessels (*n* = 17)			
All casualties	0.54	0.39	−38.46
Serious casualties	0.90	0.90	0.00
FL vessels (*n* = 20)			
All casualties	0.46	0.48	4.17
Serious casualties	0.95	0.99	4.04

[a] For an average length, average age vessel exposed to average days at sea.

during a year improved 4% from pre to post ACSA (Table 5). The decrease in the rate was greater for serious casualties (outcome B), with an 83% decrease in the rate pre to post ACSA (RR = 0.17, 95% CI 0.02, 1.37) and a 4% increase in the probability of having no serious casualties (Table 5).

4. Discussion

This study found indications of a positive effect of ACSA on vessel safety in the FT and FL fleets. On both types of vessels, reported rates of serious vessel casualties decreased after the vessels reached compliance with ACSA requirements. Serious casualties are the most important to prevent since they have the most immediate potential to develop into vessel disasters under certain circumstances (such as severe weather conditions or prolonged time until rescuers arrive) leading to fatal injuries. The negative binomial regression analysis did not identify statistically significant variables, in part because serious casualties were rare events, with only 31 in the study group during 2003–2012. However, the empirical rates and model-based point estimates of rate ratios suggest that the current ACSA policy has had a positive effect on safety for those FT and FL vessels participating in it.

ACSA appears to have been more effective on FL vessels than on FT vessels. The rate of all casualties on FL vessels decreased after ACSA compliance, while on FT vessels the rate increased. Also, the decline in serious casualties was much steeper on FL vessels than on FT vessels. There is not a clear explanation for the difference in ACSA effect on the two vessel types. Apart from fishing gear, the vessels are quite similar, as are the types of casualties that occurred on them. ACSA requirements are the same for both types of vessels. Although the reported rate of all casualties increased substantially on FT vessels after ACSA, there is no reason to think that ACSA was responsible for the increase since there are no provisions of ACSA that would conceivably cause an actual increase in the risk of casualties.

The increase in all casualties on FT vessels is probably not representative of an actual increase in the risk of casualties. Instead, the increase was likely caused by a combination of increased documentation of casualties by NMFS observers, increased reporting of casualties by vessel companies to the USCG, and fluctuations common to trends involving small numbers of rare events. On January 1, 2008 a new fisheries management regulation for FT vessels was implemented, which included a doubling of the number of NMFS observers on FT vessels from one observer to two observers [25]. The implementation of this regulation coincides with the large increase in the number of casualties recorded by NMFS observers in 2008 (Table 1). The increased NMFS observer coverage may have also had an indirect influence on the associated increase in casualty reports by companies to the USCG. The increased documentation and reporting of casualties that occurred in the same year as ACSA implementation may have obscured the effect of ACSA that would have otherwise been identified. The finding that serious casualties on FT vessels decreased even in the face of greater reporting is consistent with this explanation and with ACSA efficacy.

Vessel casualties may be indicators for larger problems with the vessel that could trigger a future vessel disaster. This supposition is supported by the theory of man-made disasters developed by Turner [26], which states that disasters involving complex man-made systems (such as fishing vessels) are not chance events or 'Acts of God' [27]. Instead, a sequence of events, often starting years prior to the disaster, occurs and escalates to the eventual disaster [26]. In the sequence of events, a disaster incubation period exists in which unnoticed or misunderstood events accumulate. Instead of recognizing these precursor events as warning signs of an impending disaster, workers fail to perceive the warning events as such or fail to adequately assess the risk [26].

Vessel casualties may represent misunderstood warning signs of a future vessel disaster. If so, then reducing vessel casualties should in turn reduce vessel disasters and the accompanying loss of life. ACSA standards for the material condition of the hull, internal structure, tail shaft(s), rudder(s), machinery, watertight integrity, safety training and safety equipment attempt to address the causes of vessel casualties and vessel disasters. This study analyzed casualties on each vessel in the study group over time to determine if ACSA has been effective at reducing these events at sea.

A major objective of ACSA was to reduce worker fatalities in the FT and FL fleets through primary prevention of vessel disasters. The decline in serious vessel casualties on both FT and FL vessels in the post-ACSA period is an indication that ACSA is having the desired effect on vessel safety. By employing a primary prevention approach, ACSA represents a shift in conceptualizing vessel safety in the fishing industry. Regulations for fishing vessel safety in the U.S. have historically taken a reactive approach, focusing on saving lives after a vessel disaster has occurred, and omitting requirements that would promote the primary prevention of vessel disasters. ACSA was developed to be a mixed strategy of primary, secondary and tertiary prevention efforts, all of which are needed to make meaningful progress in improving worker safety in the fishing industry.

At the national level, recent U.S. legislation on fishing vessel safety has included components that focus on primary prevention. The "Coast Guard Authorization Act of 2010" was signed into law in October 2010 [28] and contains safety requirements for commercial fishing vessels [29]. In the 2010 Coast Guard Authorization Act, the new safety regulations emphasize primary prevention of vessel disasters, but in the near-term they only apply to newly constructed vessels. After 2020 certain older vessels (>25 years old) will be required to participate in "alternate safety compliance (ASC) programs" to improve vessel safety. As with the current ACSA program for the FT and FL fleets, these new policies represent a positive shift towards a strategy that includes primary prevention efforts.

Like ACSA, the forthcoming ASC programs will be targeted at specific fleets of fishing vessels. The results of this study suggest that if the new ASC programs are patterned after ACSA, they can be successful at reducing vessel casualties. Two key recommendations from this study may further strengthen the future ASC programs. First, a quantitative risk assessment for each targeted fleet should be carried out prior to drafting the specific provisions of each ASC program. The ASC programs should then be tailored to address the highest risk and most severe types of safety problems experienced by the different fleets. A well-planned, empirical approach to assessing hazards will make the programs more effective at improving safety because they will be focused on resolving the true causes of the worst problems. The data gathered during quantitative risk assessments can also be used as baseline data for evaluating the ASC programs after their implementation.

The second recommendation for future ASC programs is to include an evaluation plan in the design phase. One of the challenges encountered in this study of ACSA effectiveness was the retrospective nature of the data collection, including selecting the outcome within the constraints of existing data. As an ASC program is developed, the metrics for evaluation (such as vessel casualties and crewmember injuries) should be selected during the design of the program, and initial measurements of the metrics should be conducted to establish baseline levels. The selected metrics should encompass the hazards identified in the fleet risk assessment, but may also include other measurable outcomes. Surveillance of the metrics should continue after implementation of the ASC programs to obtain the necessary evaluation data.

5. Limitations

ACSA was initiated many years prior to this study and lacked a plan for evaluating program efficacy, which necessitated using historical data. Because ACSA was applied to almost the entire FT and FL fleets, there were no non-ACSA vessels to form a comparison group. This research used a retrospective longitudinal study design, which did not control for factors outside ACSA that could have affected the outcome measures. Although the study used all available data on ACSA to date, the small sample size of 37 vessels may have decreased the ability of statistical tests to detect significant effects of ACSA.

The selection of an outcome was limited to existing data that had been consistently collected annually by NMFS and USCG staff. Vessel casualties were an appropriate outcome to use for this analysis, however there may have been other types of outcomes that could also be used to evaluate ACSA that were not considered due to the absence of existing data. Vessel casualties were underreported to the Coast Guard (as shown in Table 1), and although the addition of NMFS observer data filled the gap to some extent, there were likely still some casualties that were missed. As a result, the casualty rates measured in this study were likely conservative estimates, meaning that the true risk of casualties was probably higher.

If the amount of underreporting fluctuated during the study period in a way that was correlated with the implementation of ACSA, then those changes in reporting could be responsible for the decreases in casualty rates instead of ACSA. Given the decrease in serious casualties on both types of vessels (which are less likely to be underreported than minor or moderate casualties), even with higher NMFS observer presence on FT vessels after ACSA, it seems unlikely that the effect of ACSA on casualty rates is a spurious relationship.

6. Conclusions

ACSA was designed as a primary prevention intervention for the FT and FL fleets operating in Alaska. Declines in the rates of all casualties on FL vessels and serious casualties on both FT and FL vessels suggest that ACSA has improved safety in those targeted fleets. These results support the premise that primary prevention strategies can contribute to worker safety by reducing the occurrence of vessel disasters. Future ASC programs should be patterned after ACSA and improved by following the recommendations outlined in this study regarding quantitative risk assessment and evaluation planning.

Conflict of interest statement

The authors report no conflicts of interest.

Acknowledgments

The authors express sincere gratitude to personnel at the USCG and in the NMFS observer program who provided access to data for this study. This study did not receive any external funding.

References

[1] Lincoln JM, Lucas DL. Occupational fatalities in the United States commercial fishing industry, 2000–2009. J Agromed 2010;15:343–50.
[2] Bureau of Labor Statistics (BLS). National census of fatal occupational injuries in 2012 (preliminary results). Washington, DC: Bureau of Labor Statistics; 2013.
[3] Jaremin B, Kotulak E. Mortality in the Polish small-scale fishing industry. Occup Med (Lond) 2004;54:258–60.
[4] Laursen LH, Hansen HL, Jensen OC. Fatal occupational accidents in Danish fishing vessels 1989–2005. Int J Inj Contr Saf Promot 2008;15:109–17.
[5] Mitchell R, Driscoll T, Healey S, Hull B, Mandryk J, Hendrie L. Work-related fatal injuries in the fishing industry in Australia, 1989 to 1992. J Occup Health Saf – Aust NZ 2001;17:375–86.
[6] Roberts SE. Britain's most hazardous occupation: commercial fishing. Accid Anal Prev 2010;42:44–9.
[7] United States Coast Guard (USCG). Investigation into the circumstances surrounding the sinking of the uninspected fishing vessel Arctic Rose. Washington, DC: United States Coast Guard; 2003.
[8] United States Coast Guard (USCG). Investigation into the circumstances surrounding the explosion, fire, and sinking of the uninspected fish processing vessel Galaxy. Washington, DC: United States Coast Guard; 2005.
[9] National Transportation Safety Board (NTSB). Sinking of U.S. fish processing vessel Alaska Ranger: Bering Sea. Washington, DC: National Transportation Safety Board; 2009 (March 23, 2008).
[10] United States Coast Guard (USCG). Guidance for the Alternate Compliance and Safety Agreement program (ACSA). Washington, DC: United States Coast Guard; 2012.
[11] Alaska Seafood Marketing Institute. Harvesting Alaska Whitefish. ⟨http://www.alaskaseafood.org/ information/fisheries/pages/harvest-whitefish.html⟩; 14 April 2012.
[12] Lucas DL, Kincl LD, Bovbjerg VE, Lincoln JM, Branscum AJ. Work-related traumatic injuries onboard freezer-trawlers and freezer-longliners operating in Alaskan waters during 2001-2012. Am J Ind Med 2014.
[13] United States Seafoods. United States seafoods job descriptions. ⟨http://unitedstatesseafoods.com⟩; 15 April 2012.
[14] Alaskan Leader Fisheries. Alaskan leader fisheries: employment. ⟨http://www.alaskanleaderfisheries.com⟩; 15 April 2012.
[15] United States Coast Guard (USCG). Alternative compliance and safety agreement (ACSA) for the Bering Sea/Aleutian Island and Gulf of Alaska freezer longliner and freezer trawler fishing fleets. Washington, DC: United States Coast Guard; 2006.
[16] Hiscock RC. Fishing vessel safety in the United States: the tragedy of missed oppertunities. In: Lincoln JM, Hudson DS, Conway GA, Pescatore R, editors. International fishing industry safety and health conference. Woods Hole, MA: National Institute for Occupational Safety and Health; 2002.
[17] United States Coast Guard (USCG). Federal requirements for commercial fishing industry vessels. Washington, DC: United States Coast Guard; 2009.
[18] National Institute for Occupational Safety and Health (NIOSH). Surveillance and prevention of occupational injuries in Alaska: a decade of progress. . Cincinnati, OH: National Institute for Occupational Safety and Health; 2002.
[19] United States Coast Guard (USCG). The Alternate Compliance and Safety Agreement (ACSA) historical timeline. ⟨http://www.uscg.mil/d13/cfvs/Acsa/pdfs/ACSA%20Timeline.pdf⟩; 17 April 2012.
[20] United States Coast Guard (USCG). Report of marine casualty (CG-2692). Washington, DC: United States Coast Guard; 2013.
[21] National Marine Fisheries Service (NMFS). About national marine fisheries service. ⟨http://www.nmfs.noaa.gov/aboutus/aboutus.html⟩; 16 September 2013.
[22] National Marine Fisheries Service (NMFS). North Pacific groundfish and halibut fisheries observer program. ⟨http://www.alaskafisheries.noaa.gov/sustainablefisheries/observers⟩; 16 September 2013.
[23] National Marine Fisheries Service (NMFS). Fisheries monitoring and analysis. ⟨http://www.afsc.noaa.gov/FMA/default.htm⟩; 16 September 2013.
[24] StataCorp. Stata statistical software. 13 ed.. College Station, TX: StataCorp LP; 2013.
[25] McIlwain K, Hill J. Catch shares in action: United States Bering Sea and Aleutian Islands non-pollock (Amendment 80) cooperative program. Environmental Defense Fund; 2013.
[26] Turner BA. Man-made disasters. London: Wykeham Publications; 1978.
[27] Pidgeon N, O'Leary M. Man-made disasters: why technology and organizations (sometimes) fail. Saf Sci 2000;34:15–30.
[28] Hiscock RC. A brief history of fishing vessel safety legislation. Washington, DC: National Transportation Safety Board Fishing Vessel Safety Forum; 2010.
[29] United States Coast Guard (USCG). New requirements for commercial fishing industry vessels. Washington, DC: United States Coast Guard; 2012.