Work-Related Traumatic Injuries Onboard Freezer-Trawlers and Freezer-Longliners Operating in Alaskan Waters during 2001–2012

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Background *Workers onboard freezer-trawl (FT) and freezer-longline (FL) vessels in Alaska may be at high risk for fatal and non-fatal injuries.*
Methods *Traumatic occupational injuries onboard vessels in the FT and FL fleets were identified through two government data sources.*
Results *The annual risk of fatal injuries was 125 per 100,000 FTEs in the FT fleet, and 63 per 100,000 FTEs in the FL fleet. The annual risk of non-fatal injuries was 43 per 1,000 FTEs in the FT fleet and 35 per 1,000 FTEs in the FL fleet. The majority of injuries in the FT fleet occurred in the factories and freezer holds, whereas the most common injuries in the FL fleet occurred on deck while working the fishing gear.*
Conclusions *The findings confirmed that workers in those fleets were at high risk for work-related injuries. Injury prevention should focus on removing hazards in the work processes injuring the most workers.* Am. J. Ind. Med. 57:826–836, 2014. *© 2014 Wiley Periodicals, Inc.*

KEY WORDS: occupational safety; injuries; fishing industry; Alaska; work process

INTRODUCTION

In April 2001, the 92 foot (28 m) freezer-trawl (FT) vessel *Arctic Rose* was fishing in the Bering Sea when it flooded and sank, killing all 15 workers onboard [USCG, 2003]. 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) [USCG, 2005]. Commercial fishing is a high-risk occupation. In the U.S. fishing industry during 2000–2009, 504 workers were killed in work-related incidents [Lincoln and Lucas, 2010a]. The estimated occupational fatality rate for U.S. fishing industry workers in 2011 was 121 deaths per 100,000 full time equivalent workers (FTEs), the highest of any civilian occupation and 34 times higher than the rate for all U.S. workers [BLS, 2012a].

Within the broad U.S. fishing industry, vessels vary widely in terms of size, configuration, target species, method of catch, and operating area. Workplace hazards and injury risks also differ across the many fleets of vessels. For example, the annual risk of fatal injuries during 2000–2009 in the Alaska salmon fishery was 115 deaths per 100,000 FTEs, compared to 600 deaths per 100,000 FTEs in the Northeast U.S. multispecies groundfish fishery [Lincoln and Lucas, 2010b].

The *Arctic Rose* and *Galaxy* were part of two fleets of FT and FL vessels operating in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA). In contrast to other trawlers and longliners, FT and FL vessels are outfitted with factories and freezers onboard that process the catch into various fish products; other trawlers and longliners catch and deliver fish whole to onshore processing plants [USCG, 2012a]. FT vessels are also known as non-Pollock or non-AFA catcher processor trawl vessels, factory-trawlers,

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and amendment 80 vessels. A 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 and then moved into the factory for processing [Alaska Seafood Marketing Institute, 2012]. After processing, the fish products are packaged and frozen. The average crew size for FT vessels is estimated at 35 workers [USCG, 2006], with jobs including captain, mate, engineer, deckhand, fish processor, and cook [United States Seafoods, 2012].

A 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 [Alaska Seafood Marketing Institute, 2012]. 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 [USCG, 2006], with similar jobs as found in the FT fleet [Alaskan Leader Fisheries, 2012].

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 [USCG, 2006].

Workers on these vessels are considered by the USCG to be at high risk for worker injuries; however the actual risks and patterns of fatal and non-fatal injuries in these fleets have not been quantified and described. The purpose of this epidemiologic study was to estimate the risk of injuries to workers in the FT and FL fleets, to characterize the etiology of injuries, and to suggest injury prevention priorities based on empirical findings.

METHODS

Case Definition

All reported traumatic occupational injuries to workers onboard vessels in the FT and FL fleets operating in Alaska during 2001–2012 were included as cases in this study. A traumatic injury was defined as "any wound or damage to the body resulting from acute exposure to energy … caused by a specific event or incident within a single workday or shift" [BLS, 2013]. As such, musculoskeletal disorders of a cumulative nature (e.g., repetitive motion injuries) and noise induced hearing loss were excluded from this study. Injuries of all severity from minor to critical were included as cases.

An occupational injury was defined as a case of traumatic injury that met the criteria for an injury at work as specified by the Census of Fatal Occupational Injuries [BLS, 2013]. This definition included injuries to any worker (captain, deckhand, cook, fish processor, etc.) onboard the vessels. Because of the unique setting in which commercial fishing takes place (i.e., workers are exposed to work-related hazards even when off duty), workers in the fishing industry were considered "at work" the entire time they were at sea. Intentional (self-harm or assault) injuries at work were included as prescribed and defined by the Census of Fatal Occupational Injuries [BLS, 2013].

Data Sources

Cases of work-related injuries were identified through two sources, the USCG Marine Information for Safety and Law Enforcement (MISLE) 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 on injuries of crewmembers. The USCG requires companies that operate fishing vessels to report injuries sustained at sea that require treatment beyond first aid [USCG, 2013]. USCG investigators enter data into MISLE from a number of sources depending on the seriousness of the case. For instance, some records in MISLE concerning minor injuries may have only 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 cases in MISLE may have additional data sources, such as witness statements, medical records and death certificates collected by a USCG investigator.

There have been no published assessments of compliance with injury reporting in the fishing industry, thus the extent of underreporting is unknown. One factor that may have influenced the level of reporting of injuries to USCG authorities during the study period was a USCG initiative during 2005–2008 aimed at improving the level of reporting of injuries by fishing companies [C. Sears, personal communication, August 16, 2013]. Other factors that may have affected reporting are discussed in more detail in the Limitations section.

In an attempt to identify injuries 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 [NMFS, 2013a]. NMFS places observers on vessels that operate in federal fisheries (such as FT and FL vessels) to monitor catch limits, bycatch, and other fishery management rules [NMFS, 2013c]. Fishery observers also record safety related events, such as injuries, 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) is regulated by several factors, including but not limited to vessel length, fishing gear, and species targeted. Based on those factors, observer coverage during the study period ranged from approximately 30–100% for each of the FT and FL vessels [NMFS, 2013b].

This study was reviewed by the Oregon State University institutional review board and granted a waiver of informed consent because the study data were abstracted without any personally identifying information from existing data sources (study number 5374).

Measures

For each case of occupational injury identified in the two data sources, measures on the geographic location (latitude and longitude), weather conditions (wind speed, wave height, air temperature), vessel characteristics (fishing gear type, length, year built), injury characteristics (nature, body part, mechanism, source, severity), and victim demographics were collected. The Occupational Injury and Illness Classification System (OIICS) was used to code the nature of injury and body part [BLS, 2012b]. Injury severity was coded with an adaptation of the Abbreviated Injury Scale (AIS) used by USCG investigators in their case reports [USCG, 2012b]. The USCG injury severity scale contains the same levels and general definitions of severity as AIS (minor, moderate, serious, severe, critical), but has less stringent coding rules than AIS to allow for coding cases that lack clinical diagnosis information.

The activity or task being completed by the worker at the time of injury was coded using the Work Process Classification System [Jensen et al., 2003, 2005, 2006]. The system was originally crafted to describe the patterns of injuries on industrial trawlers in Denmark, and was subsequently adapted to other types of Danish fishing vessels. Jensen et al. [2003] expected that all of the main (highest level) work processes and some of the sub-processes would apply to all types of fishing vessels. Other sub-processes would need to be revised to fit the unique fishing methods of certain vessels. The work processes used in this study were constructed from the information on injuries found in the source databases. The full list of processes and sub-processes used in this study are available in the Supplementary Electronic Material (see Supplementary Tables SI and SII).

The denominator (exposure) estimate used to calculate incidence rates in this study was full-time equivalent workers (FTEs). Calculating rates of injuries using FTEs 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 same amount of exposure to risk as workers in other industries who work standard full-time schedules, thereby allowing comparisons of risk between industries. To calculate FTEs for each year, data from NMFS on the crew size and days at sea for each vessel in the FT and FL fleets for each year during 2003–2012 were collected. The year 2003 was the earliest for which NMFS data were available; therefore FTEs were not calculated for 2001–2002. The number of crewmembers was multiplied by the number of days at sea to generate “crew-days.” Crew-days was then divided by the number of regular work days in a year (250 days; 2,000 hr). This method of calculating FTEs in the fishing industry has been published previously [Thomas et al., 2001; NIOSH, 2002; Lincoln and Lucas, 2010b].

Analysis

Data on the cases of fatal and non-fatal injuries that met the criteria for inclusion in this study were extracted from MISLE and the NMFS Observer Vessel Survey and entered into a dataset. Data were matched to identify and remove duplicate records. When duplicate records were found, the information in each data source was combined, unless the two sources had contradictory information, in which case the data from MISLE were used. A descriptive analysis was completed to explore the patterns and characteristics of occupational injury cases in the FT and FL fleets in Alaska during 2001–2012. The frequency of fatal and non-fatal injuries was calculated for each year during the study period. Incidence rates were calculated for each year that FTEs were available (2003–2012). A trend analysis was not possible because of yearly fluctuations in the level of injury reporting by fishing companies (see Limitations section for additional details).

Descriptive statistics such as frequency and percent distributions, measures of central tendency and dispersion, and cross-tabulations were calculated in Stata version 12.1 [StataCorp, 2012] to explore and characterize the data. Rate ratios (RR) and 95% confidence intervals (CI) were calculated to compare injury rates in the FT and FL fleets. Spatial patterns of injuries were examined by mapping the location of each incident in ArcGIS software [ESRI, 2009] using latitude and longitude data.

RESULTS

During 2001–2012, 24 FT vessels and 42 FL vessels operated in Alaskan waters. The number of vessels varied from year to year as existing vessels were retired or sunk, and new vessels entered the fleet. The median length of FT vessels was 148 feet (91–267 feet) with a median of 35 crewmembers (11–77 crewmembers). The median length of FL vessels was 136 feet (92–172 feet) with a median of 19 crewmembers (7–26 crewmembers).

For the 12-year study period 2001–2012, a total of 712 work-related injuries on FT and FL vessels were recorded by USCG investigators and NMFS observers. The FT fleet had an average of 34 injuries per year (409 total), and the FL fleet had an average of 25 injuries per year (303 total). In the FT fleet, 306 (75%) of injury cases appeared in the USCG MISLE database, and 152 (37%) appeared in the NMFS Observer Vessel Survey. The overlapping 49 cases (12%) appeared in both data sources. In the FL fleet, 153 (51%) of injury cases appeared in the USCG MISLE database, and 196 (65%) appeared in the NMFS Observer Vessel Survey. The overlapping 46 cases (15%) appeared in both data sources.

Only 11 women were among the injured workers (six in the FT fleet and five in the FL fleet). The median age of injured workers in the FT fleet was 33 years (16–65 years) and 32 years (18–61 years) in the FL fleet. Data on race/ethnicity were missing in almost all case reports. The state of Washington was the residence for 138 workers (60%) injured in the FT fleet and 70 workers (57%) injured in the FL fleet. The median amount of work experience among injured workers in the FT fleet was 2 years (0–48 years) and 4 years in the FL fleet (0–30 years). Fish processors were the most frequently injured workers (268, 75%) in the FT fleet, followed by deckhands (61, 17%). In the FL fleet, deckhands were the most frequently injured (119, 48%) followed by fish processors (90, 37%).

Latitude and longitude were reported for 345 (48.5%) injury cases in the FT and FL fleets. Of those, the majority of injuries occurred throughout the fleets' main operating areas in the Bering Sea and along the entire Aleutian Island Chain (Fig. 1). Few (12, 3%) occurred in the Gulf of Alaska. The median distance from shore of an injury incident in the FT fleet was 29 miles (0–174 miles). In the FL fleet, the median distance from shore of injury incidents was 32 miles (0–189 miles).

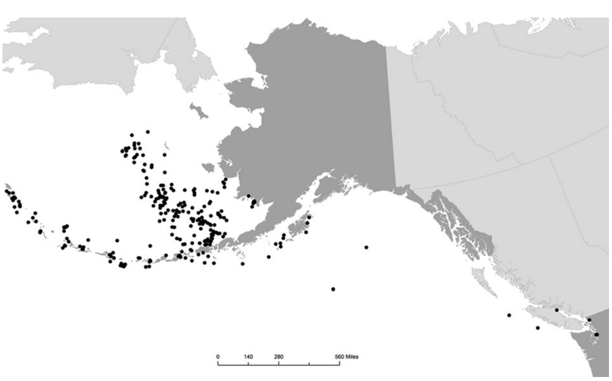

FIGURE 1. Location of fatal and non-fatal injuries onboard freezer-trawlers and freezer-longliners, 2001–2012 (n = 345).

Injury Characteristics Onboard Freezer-Trawlers

Of the 409 injuries in the FT fleet, 25 were fatal and 384 were non-fatal. Most of the fatal injuries occurred during two vessel disasters, the sinking of the *Arctic Rose* in 2001 (15 deaths) and the sinking of the *Alaska Ranger* in 2008 (5 deaths). The other five fatal injuries were caused by drowning after falling overboard (three deaths) and blunt force trauma due to being struck by a trawl cable and a hydraulic door (two deaths). The time period for which exposure estimates were available was 2003–2012. During that decade, the annual risk of fatal injuries in the FT fleet was 125 per 100,000 FTEs, and the annual risk of non-fatal injuries was 43 per 1,000 FTEs (Table I). The non-fatal injury rate appeared fairly stable during 2003–2005, and then increased sharply for 2 years before gradually declining to the level observed in the first 3 years of the time period (Fig. 2).

The fatal injury rate in the FT fleet was nearly twice that in the FL fleet (see next section), although not statistically significant (RR = 1.98, 95% CI 0.64–7.30). The non-fatal injury rate was 22% higher in the FT fleet than in the FL fleet (RR = 1.22, 95% CI 1.03–1.45).

Undiagnosed injuries exhibiting symptoms of acute pain/swelling were the most common type of injury in the FT fleet (68, 17%) followed by sprains/strains/tears (64, 16%) and open wounds such as lacerations, punctures, and avulsions (61, 15%). Upper extremities were the most frequently injured body part (Table II). Injury severity was usually minor (187, 47%) or moderate (153, 39%), with the remaining being serious (30, 8%), severe (1, 0.3%), or critical (25, 6%). All of the critical injuries were fatal.

Work process was coded for 342 (84%) injuries in the FT fleet (Supplementary Table SI). The remaining 16% of cases lacked information on work process and were coded as missing. The main work processes associated with the highest frequencies of injuries in the FT fleet were *handling frozen fish* (139, 41%), *processing the catch* (72, 21%), and *traffic onboard* (41, 12%; Table III). The sub-processes of *handling frozen fish* that were associated with the most injuries were *stacking blocks of fish* (in the freezer hold) and *offloading product*.

Handling frozen fish was the most common work process for undiagnosed pain/swelling, sprains/strains/tears, contusions, fractures, crushing injuries, and intracranial injuries (Table III). *Handling frozen fish* injuries were most often caused by being struck by a box of frozen fish (45, 32%) and by single episodes of overexertion (42, 30%). Almost all injuries sustained while handling frozen fish were minor (88, 64%) or moderate (45, 33%); four (3%) were serious (Table IV).

TABLE I. Frequency and Rate of Fatal and Non-Fatal Injuries Onboard Freezer-Trawlers and Freezer-Longliners, 2001–2012

	Freezer-trawler (N = 24)					Freezer-longliner (N = 42)				
	Fatal	Non-fatal	FTE	Fatal rate[a]	Non-fatal rate[b]	Fatal	Non-fatal	FTE	Fatal rate[a]	Non-fatal rate[b]
2001	15	19	—	—	—	0	23	—	—	—
2002	0	24	—	—	—	5	49	—	—	—
2003	0	19	779	0	24	1	27	743	135	36
2004	0	15	767	0	20	0	29	768	0	38
2005	0	18	784	0	23	0	19	744	0	26
2006	0	42	768	0	55	0	16	590	0	27
2007	1	63	785	127	80	0	15	525	0	29
2008	5	48	877	570	55	2	15	589	339	25
2009	2	34	715	280	48	0	32	503	0	64
2010	0	49	848	0	58	1	21	554	180	38
2011	1	28	842	119	33	0	30	665	0	45
2012	1	25	846	118	30	0	18	678	0	27
Period total	25	384	8,012[c]	125[c]	43[c]	9	294	6,359[c]	63[c]	35[c]

[a]Per 100,000 FTE.
[b]Per 1,000 FTE.
[c]Period is 2003–2012.

The work process of *processing the catch* in the FT fleet was responsible for most of the laceration/puncture/avulsion injuries, amputations, and poisonings (Table III). These injuries were most often caused by being caught in running equipment (28, 39%) and by slipping knives (11, 15%). The majority of injuries sustained while processing the catch were minor (29, 41%) or moderate (33, 47%). The remaining eight (11%) were serious (Table IV).

Injury Characteristics Onboard Freezer-Longliners

In the FL fleet, nine of the 303 injuries during 2001–2012 were fatal, of which three occurred in 2002 during the *Galaxy* disaster (the sole vessel disaster in the fleet during the study period). The other six fatal injuries were caused by drowning after falling overboard (three deaths), blunt force trauma due to being caught in conveyor belts (two deaths), and asphyxiation due to freon exposure in a confined space (one death). The annual risk of fatal injuries during 2003–2012 was 63 per 100,000 FTEs, and the annual risk of non-fatal injuries was 35 per 1,000 FTEs (Table I). The non-fatal injury rate was approximately constant for the first 6 years of the time period (Fig. 2). In 2009 the rate more than doubled, and then declined slowly to a level that in 2012 was similar to the first part of the decade.

Work process was coded for 231 (76%) injuries in the FL fleet (Supplementary Table SII). Information on work process was missing for the other 24% of injuries. In the FL fleet,

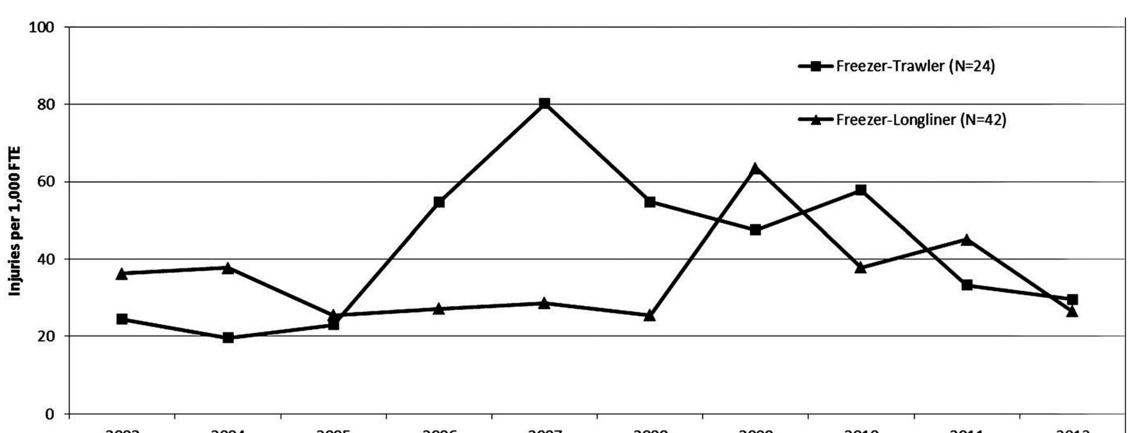

FIGURE 2. Non-fatal injury rates onboard freezer-trawlers and freezer-longliners, 2003–2012.

TABLE II. Nature and Body Part of Fatal and Non-Fatal Injuries Onboard Freezer-Trawlers and Freezer-Longliners, 2001–2012

	Body part															
	Head		Neck		Trunk		Upper extremities		Lower extremities		Body systems		Missing		Total	
Nature of injury	No.	%[a]	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Freezer-trawler																
Fracture	2	5	0	0	4	5	31	19	10	14	0	0	0	—	47	12
Laceration/puncture/avulsion	11	26	0	0	0	0	39	24	7	10	0	0	4	—	61	15
Amputation	0	0	0	0	0	0	18	11	1	1	0	0	0	—	19	5
Crushing	0	0	0	0	0	0	13	8	1	1	0	0	0	—	14	4
Contusion	6	14	0	0	5	6	28	17	14	20	0	0	3	—	56	14
Intracranial injury	19	44	0	0	0	0	0	0	0	0	0	0	0	—	19	5
Sprain/strain/tear	0	0	0	0	38	49	7	4	19	27	0	0	0	—	64	16
Drowning	0	0	0	0	0	0	0	0	0	0	19	61	0	—	19	5
Hypothermia	0	0	0	0	0	0	0	0	0	0	5	16	0	—	5	1
Poisoning	0	0	0	0	0	0	0	0	0	0	6	19	0	—	6	2
Undiagnosed pain/swelling	4	9	4	100	30	38	14	9	16	23	0	0	0	—	68	17
Other	1	2	0	0	1	1	12	7	3	4	1	3	0	—	18	5
Missing	1	—	0	—	1	—	5	—	3	—	0	—	3	—	13	—
Total	44	100	4	100	79	100	167	100	74	100	31	100	10	—	409	100
Freezer-longliner																
Fracture	2	5	0	0	1	3	28	23	6	21	0	0	0	—	37	13
Laceration/puncture/avulsion	22	50	0	0	0	0	52	43	6	21	0	0	17	—	97	34
Amputation	0	0	0	0	0	0	8	7	1	3	0	0	0	—	9	3
Crushing	0	0	0	0	0	0	7	6	0	0	0	0	0	—	7	2
Contusion	3	7	0	0	11	29	9	8	3	10	0	0	0	—	26	9
Intracranial injury	10	23	0	0	0	0	0	0	0	0	0	0	0	—	10	3
Sprain/strain/tear	0	0	0	0	9	24	3	3	7	24	0	0	4	—	23	8
Drowning	0	0	0	0	0	0	0	0	0	0	5	19	0	—	5	2
Hypothermia	0	0	0	0	0	0	0	0	0	0	10	37	0	—	10	3
Poisoning	0	0	0	0	0	0	0	0	0	0	5	19	7	—	12	4
Undiagnosed pain/swelling	5	11	1	100	15	39	8	7	6	21	0	0	1	—	36	12
Other	2	5	0	0	2	5	5	4	0	0	7	26	1	—	17	6
Missing	2	—	0	—	0	—	3	—	1	—	0	—	8	—	14	—
Total	46	100	1	100	38	100	123	100	30	100	27	100	38	—	303	100

[a]Valid percentages (which exclude missing values from the denominator) were used for all percent calculations.

injuries occurred most frequently during the main work processes of *hauling the gear* (61, 26%), *handling frozen fish* (51, 22%), and *traffic onboard* (30, 13%; Table III). Under the main work process of *hauling the gear*, *operating the longline roller* was the most common sub-process. The most frequent types of injuries (across all work processes) were lacerations/punctures/avulsions (97, 34%), fractures (37, 13%), and undiagnosed pain/swelling (36, 12%). Injury severity was distributed as: minor (112, 39%), moderate (136, 45%), serious (22, 8%), severe (4, 1%), and critical (10, 4%). Of the 10 critical injuries, nine were fatal.

The most common types of injuries that occurred while hauling the gear in the FL fleet were lacerations/punctures/avulsions (Table III). Of all injuries sustained while hauling the gear, the event that produced the highest number was being struck by a fish hook (26, 43%). Injuries were minor (23, 39%) or moderate (32, 54%), with four serious injuries (7%; Table IV).

Fractures, contusions, and poisonings in the FL fleet most frequently occurred during the work process of *handling frozen fish* (Table III). Injuries associated with handling frozen fish were usually caused by being struck by a box of frozen fish (20, 39%). Injuries were most often minor (21, 42%) or moderate (21, 42%); however six (12%) were serious and two (4%) were critical (Table IV).

DISCUSSION

Stakeholders such as fishing companies, USCG, government and academic researchers, and industry associations

TABLE III. Work Process and Nature of Fatal and Non-Fatal Injuries Onboard Freezer-Trawlers and Freezer-Longliners, 2001–2012

	Nature of injury													
Work process	**Fracture**	**Laceration/ puncture/ avulsion**	**Ampu- tation**	**Crushing**	**Contusion**	**Intra- cranial injury**	**Sprain/ strain/ tear**	**Drowning**	**Hypo- thermia**	**Poisoning**	**Undiagnosed pain/ swelling**	**Other**	**Missing**	**Total**
Freezer-trawler														
Traffic onboard	6	3	0	1	8	1	7	0	0	0	13	1	1	41
Watch on bridge	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Preparing fishing gear	1	1	0	0	1	0	0	0	0	0	0	1	0	4
Setting the gear	1	1	0	1	2	0	1	1	0	0	0	0	0	7
Hauling the gear	3	1	2	1	4	2	3	0	0	0	2	1	1	20
Handling gear on deck	3	1	0	1	4	2	0	1	0	0	1	1	0	14
Processing the catch	3	28	11	1	3	2	10	0	0	4	10	0	0	72
Other work with catch	0	0	0	0	2	1	0	0	0	0	0	0	0	3
Handling frozen fish	18	8	1	6	23	7	34	0	0	1	27	7	7	139
Preparing deck gear	0	0	0	0	2	1	0	0	0	0	2	0	0	5
Working in engine room	0	0	0	0	0	0	1	0	0	0	0	1	0	2
Working in the galley	1	2	0	0	0	0	0	0	0	0	0	0	0	3
Off duty	1	0	0	0	1	0	0	2	3	0	1	0	0	8
Other	2	5	1	0	4	0	4	0	0	0	2	3	2	23
Missing	8	11	4	3	2	3	4	15	1	1	10	3	2	67
Total	47	61	19	14	56	19	64	19	5	6	68	18	13	409
Freezer-longliner														
Traffic onboard	3	3	1	0	4	1	6	0	6	0	3	2	1	30
Watch on bridge	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Preparing fishing gear	1	5	0	0	1	0	0	0	0	0	4	0	1	12
Setting the gear	0	5	2	0	1	1	1	1	0	0	0	0	0	11
Hauling the gear	2	37	0	1	7	3	1	0	2	0	5	1	2	61
Handling gear on deck	0	4	1	0	0	0	0	1	0	1	0	0	0	7
Processing the catch	2	8	4	0	0	0	2	0	0	1	1	1	1	20
Other work with catch	0	5	0	1	1	0	1	0	0	0	0	0	0	8
Handling frozen fish	16	3	1	2	8	3	2	0	0	5	10	1	0	51
Preparing deck gear	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Working in engine room	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Working in the galley	0	0	0	0	0	0	0	1	0	1	0	0	0	2
Off duty	1	1	0	0	0	0	0	2	2	3	0	2	0	11
Other	1	3	0	0	2	1	1	0	0	0	2	4	0	14
Missing	11	22	0	3	2	1	9	0	0	1	10	4	9	72
Total	37	97	9	7	26	10	23	5	10	12	36	17	14	303

can use the results of this study to design interventions to eliminate the hazards responsible for the majority of injuries to workers onboard FT and FL vessels. Partnerships between these stakeholders could pave the way for practical and effective solutions.

This study used the Work Process Classification System developed by researchers in Denmark [Jensen et al., 2005]. All of the 18 main work processes were applicable to the FT and FL vessels in this study; however, many of the sub-processes needed to be modified or replaced in order to properly categorize the unique fishing procedures in the Bering Sea and Aleutian Islands. The Work Process Classification System, used in conjunction with OIICS coding for nature of injury and body part, was an effective method for identifying the specific circumstances producing the most injuries in each fleet. Having a high level of detail on injury-producing work processes will enable injury prevention tactics to be targeted directly at the specific fishing procedures causing the worst problems.

TABLE IV. Work Process and Severity of Fatal and Non-Fatal Injuries Onboard Freezer-Trawlers and Freezer-Longliners, 2001–2012

	Severity of injury						
Work process	**Minor**	**Moderate**	**Serious**	**Severe**	**Critical**	**Missing**	**Total**
Freezer-trawler							
Traffic onboard	26	12	3	0	0	0	41
Watch on bridge	0	0	0	0	1	0	1
Preparing fishing gear	2	1	1	0	0	0	4
Setting the gear	1	5	0	0	1	0	7
Hauling the gear	6	7	3	1	1	2	20
Handling gear on deck	4	8	1	0	1	0	14
Processing the catch	29	33	8	0	0	2	72
Other work with catch	1	1	0	0	1	0	3
Handling frozen fish	88	45	4	0	0	2	139
Preparing deck gear	4	0	1	0	0	0	5
Working in engine room	1	0	1	0	0	0	2
Working in the galley	1	2	0	0	0	0	3
Off duty	0	2	1	0	5	0	8
Other	7	9	4	0	0	3	23
Missing	17	28	3	0	15	4	67
Total	187	153	30	1	25	13	409
Freezer-longliner							
Traffic onboard	10	14	4	0	0	2	30
Watch on bridge	0	0	0	0	1	0	1
Preparing fishing gear	10	2	0	0	0	0	12
Setting the gear	3	7	0	0	1	0	11
Hauling the gear	23	32	4	0	0	2	61
Handling gear on deck	2	4	0	0	1	0	7
Processing the catch	5	14	1	0	0	0	20
Other work with catch	3	4	0	0	0	1	8
Handling frozen fish	21	21	6	0	2	1	51
Preparing deck gear	0	1	0	0	0	0	1
Working in engine room	1	1	0	0	0	0	2
Working in the galley	1	0	0	0	1	0	2
Off duty	4	1	0	3	3	0	11
Other	6	4	2	1	1	0	14
Missing	23	31	5	0	0	13	72
Total	112	136	22	4	10	19	303

Working With Fishing Gear

Although the majority of injuries in the FT fleet involved fish processors in the factories and freezer holds, the most common injuries in the FL fleet were to deckhands working directly with the longline fishing gear. In particular, operating the longline roller during the work process of hauling in the gear exposed workers to fish hooks moving by them at high speed causing lacerations, punctures, and avulsions. To prevent these types of injuries, engineering interventions should focus on reducing workers' proximity to the fish hooks as the longline is being hauled onboard. Personal protective equipment may also be investigated as a solution if complete removal of the hazard is not possible.

Processing Fish

The factories onboard FT and FL vessels are equipped with fish processing machinery and conveyor systems to move fish from one machine to the next. The machines have different levels of automation that either increase or decrease the need for worker contact. The injuries sustained while processing fish were different in nature than those sustained while handling frozen fish, suggesting that successful injury prevention efforts must also be different. Interventions to reduce injuries need to target the specific hazards encountered while processing fish that cause lacerations, punctures, avulsions, and amputations, which were the most frequent types of injuries associated with processing fish. Working with knives and running equipment are exposures of particular concern that need to be a high priority.

Handling Frozen Fish Products

Fish products manufactured in the factories onboard FT and FL vessels are frozen in plate freezers and then packaged in boxes and stored in freezer holds. Boxes of frozen fish products typically weigh 45 pounds (20 kg) and are moved around by a combination of conveyor systems, chutes and manual labor. The work process of handling frozen fish was responsible for nearly half of all injuries in the FT fleet and a quarter of all injuries in the FL fleet, and should be a priority area for injury prevention strategies. Interventions are needed to protect workers from being struck by boxes of frozen fish, especially while stacking boxes in the freezer holds and during offload. Ergonomic interventions are also needed to prevent injuries caused by single episodes of overexertion while manually moving boxes of fish. Future research should also investigate the contribution of vessel motion and fatigue to these types of contact injuries and the potential for engineering controls to secure fish products and prevent them from falling or shifting suddenly.

Risk Patterns of Injuries

The injury rates measured in the FT and FL fleets showed that workers on those vessels were at high risk for work-related injuries. Between the two fleets, the risks of both fatal and non-fatal injuries were higher in the FT fleet than the FL fleet. Compared to other fisheries in the U.S., the fatality rates in the FT and FL fleets were lower than many others, including the Northeast U.S. groundfish trawl fleet, Atlantic scallop fleet, and West coast Dungeness crab fleet [Lincoln and Lucas, 2010b]. The non-fatal injury rates calculated in this study are not comparable to rates reported in other fishing industry studies because of differences in the case definitions and exposure assessments. This study used FTEs as the measure of exposure, whereas other studies used number of workers [Norrish and Cryer, 1990; Marshall et al., 2004], work-days [Kucera et al., 2010], and man-days [Moore, 1969]. Four studies were identified that calculated FTEs similar to the current study, but they had substantially different case definitions (such as hospitalized injuries only) and data sources (such as state trauma registries) [Husberg et al., 1998; Lincoln et al., 2001; Thomas et al., 2001; Day et al., 2010]. The field of fishing industry safety would benefit from standardized methods for measuring and comparing risk.

The trends observed in the reported injury rates of the FT and FL fleets were most likely influenced by the fluctuating level of reporting of injuries to USCG authorities. The use of the NMFS Observer Vessel Survey proved to be an important method in this study because it identified 103 injuries in the FT fleet and 150 injuries in the FL fleet that were not reported by fishing companies to the USCG.

The demographic characteristics of injured workers (age and sex) in the FT and FL fleets were consistent with those of the larger population of workers employed in the Alaska fishing industry [Cannon and Warren, 2012].

Limitations

The findings in this study are subject to several limitations. Some injuries were unreported to the USCG, and NMFS observer data did not completely fill in the gap. One factor that may have influenced the level of reporting of injuries to USCG authorities during the study period was a USCG effort aimed at improving the level of reporting of injuries by fishing companies. According to C. Sears [personal communication, August 16, 2013], who was a USCG investigating officer stationed in Alaska during 2003–2008, in 2005 the USCG began several initiatives directed at improving the reporting of injuries by fishing companies. These initiatives included education on reporting directed at vessel captains and companies by way of posters, articles in fisheries publications, memos, and warning letters. USCG staff also concentrated heavily on obtaining reports from companies on incidents that were brought to the USCG's attention but had not been reported by the companies. The timeline of the USCG's heightened priority on injury reporting corresponds exactly to the sharp rise in the injury rate observed in the FT fleet during 2006–2007.

Underreporting of work-related injuries is a recognized problem across all industries in the U.S. [Azaroff et al., 2002]. Many of the barriers to reporting injuries found in other industries, such as fear of disciplinary action and failure to recognize work-relatedness of an injury, are likely present in the fishing industry as well (see Azaroff et al. [2002] for an in-depth discussion of the barriers to reporting occupational injuries).

Not all injuries were accounted for in this study, and thus the true risk of injury exceeds the amount measured in this study. Furthermore, the reporting bias may not have been consistent from year to year; causing trends over time to be more representative of changes in reporting rather than changes in the actual risk of injuries. While this bias did inhibit the analysis of trends over time, it did not impede the characterization of injuries to identify the common hazards and priority areas for interventions.

The FTEs used in this study estimated the overall exposure for the population as a whole, not an individual measure of exposure to workplace hazards. The injury rates then apply to the fleets as populations, not necessarily to individuals within the fleets. Individual risk may be higher or lower than the population average, depending on the unmeasured level of individual exposure.

The data available for this study did not regularly contain information on the clinical diagnosis and treatment of injured workers. The lack of clinical records may have introduced misclassification bias in the nature of injury and injury severity coding. This misclassification, if present, would likely be minor (such as misclassification into an adjacent injury severity level) and not affect the overall results and conclusions.

CONCLUSION

To suggest injury prevention priorities based on empirical findings, we estimated the risk of injuries to workers in the FT and FL fleets operating in the Bering Sea and Aleutian Islands, and characterized the etiology of those injuries. The findings confirmed that workers in those fleets were at high risk for work-related injuries, and that the risk was higher in the FT fleet than in the FL fleet during 2003–2012. Injuries in the FT fleet were most frequent among fish processors handling frozen fish and processing the catch, while injuries in the FL fleet were most frequent among deckhands hauling in the fishing gear and fish processors handling frozen fish. Injury prevention efforts should focus on the specific work processes injuring the most workers in each fleet, and concentrate on removing the hazards producing the most common and most severe types of injuries.

The FT and FL fleets should implement 100% incident reporting to provide valid data for targeting injury prevention efforts. Future research with the FT and FL fleets should involve multiple stakeholders (e.g., fishing companies, USCG, safety training organizations, and fisheries management agencies) and focus on investigating potential solutions to safety problems by developing, implementing, and evaluating interventions. The interventions should be designed to mitigate risk factors or promote protective factors and should be targeted at specific hazards. In addition to using the findings presented in this article, future projects could further analyze the dataset collected for this study to more accurately design and target interventions.

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