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Linking Datasets to Characterize Injury and Illness in Alaska's Fishing Industry

Laura N. Syron, Samantha L. Case, Jennifer R. Lee, and Devin L. Lucas

Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Western States Division, National Institute for Occupational Safety and Health, Washington, D.C., USA

ABSTRACT
Limited research has characterized nonfatal injury/illness in Alaska's hazardous fishing industry. This study aimed to determine (a) the utility of linking datasets to conduct surveillance, and (b) injury/illness patterns during 2012–2016. Data were obtained from the Alaska Trauma Registry (ATR), Fishermen's Fund (FF), and US Coast Guard (USCG). Datasets were coded to identify patterns in injury/illness characteristics and circumstances. Probabilistic linkage methods were utilized to identify unique incidents that appeared in more than one dataset. After linking datasets, 3,014 unique injury/illness cases were identified. By dataset, 2,365 cases appeared only in FF, 486 only in USCG, 110 only in ATR, 25 in ATR and FF, 15 in ATR and USCG, 10 in USCG and FF, and 3 in all datasets. FF mainly captured claims submitted by small, independently-owned vessels in Southcentral and Southeastern Alaska. In contrast, USCG mainly captured reports from large, company-owned vessels in Western Alaska. By nature, cases were most frequently sprains, strain, and tears (27%), cuts (15%), and fractures (11%). Across fleets, injuries/illnesses most frequently resulted from contact with objects and equipment (41%), overexertion and bodily reaction (27%), and slips, trips, and falls (20%). Work processes associated with traumatic injuries were most frequently hauling gear (18%) and walking, climbing, and descending (18%). Half of all injuries were of moderate severity (53%). Linking datasets, which capture different segments of Alaska's fishing industry, provides the most comprehensive understanding of nonfatal injury/illness to date. These results, stratified by fleet and severity, will inform prevention strategies.

ARTICLE HISTORY

KEYWORDS
Probabilistic linkage; occupational safety and health

Introduction

Severe occupational injuries and illnesses are life-altering. Beyond economic costs, they cause acute and chronic pain, disability, and worsened family dynamics, community involvement, and mental health.[1–5] Work-related injury significantly raises the risk of suicide and opioid overdose death.[6] Recent qualitative studies in New England's fishing industry have found perceived associations between the industry's physical demands, high rates of injury and chronic pain, and opioid misuse among crewmembers.[7,8]

Alaska's fishing industry, including offshore seafood processing, is economically vital. In 2017, Alaskan fishermen harvested the majority of U.S. seafood (6 billion pounds), and generated the largest portion of national revenue ($1.8 billion), with processing adding economic value to the natural product.[9] Approximately 37,000 fishermen and offshore processors work in fleets across Alaska.[10,11] Fleets are groups of vessels that use the same gear to harvest and/or process certain seafood species within a region. Vessels differ widely in size and configuration, ranging from small, undecked vessels that are less than 25 feet (7.5 meters) in length and operated by a single crewmember, to large decked vessels that are greater than 300 feet (91 meters) in length with dozens of crewmembers.[12]

Alaska's fishing industry is highly hazardous. According to the Census of Fatal Occupational Injuries, 26 fishermen died on the job in Alaska during 2012–2016, accounting for 18% of the State's work-related fatalities.[13] The National Institute for Occupational Safety and Health (NIOSH) has studied fatalities among fishermen since the 1990s, including making safety recommendations and developing interventions.[14] Hazards and fatality rates vary between Alaskan fleets, and thus, interventions must be targeted to specific fleets.[15,16] Additionally, deaths among

CONTACT Laura N. Syron lsyron@cdc.gov Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Western States Division, National Institute for Occupational Safety and Health Washington, D.C., USA.

Alaskan fishermen due to drug overdose and suicide have increased in recent years.[16]

Limited research has characterized the burden, characteristics, and causes of nonfatal injury/illness in Alaska's fishing industry. Epidemiologic studies have focused mainly on fatal and nonfatal traumatic injuries in specific regions, fleets, and occupations, oftentimes utilizing data from the U.S. Coast Guard and Alaska Trauma Registry.[17–21] Few studies have explored illnesses and chronic health risks.[22,23]

The State of Alaska, in cooperation with the Bureau of Labor Statistics, conducts an annual Survey of Occupational Injuries and Illnesses (SOII). However, SOII does not include self-employed workers and therefore does not adequately capture fishermen, who are mostly self-employed.[24] Likewise, fishermen are not typically covered by traditional Workers' Compensation.[25–27] Rather, Alaskan fishermen can file claims with the State's Fishermen's Fund.[28] Therefore, the Fishermen's Fund, U.S. Coast Guard, and Alaska Trauma Registry can provide injury/illness data. No previous study has analyzed Fishermen's Funds data or linked these datasets for injury/illness surveillance.

This study aimed to (a) determine the utility of linking datasets for nonfatal injury/illness surveillance in Alaska's fishing industry and (b) characterize injury/illness patterns during 2012–2016. Furthermore, this study aimed to identify hazards to target for control by stratifying: (a) by fleet, and (b) by the most severe injuries industry-wide.

Methods

Case definition

This study included work-related, nonfatal injury/illness among all commercial fishermen and offshore seafood processors that occurred in Alaska during 2012–2016 and: (a) were treated at an acute care facility captured by the Alaska Trauma Registry; (b) were reported to the U.S. Coast Guard; and/or (c) for which claims were filed with Fishermen's Fund. Injury/illness was considered work-related if an event/exposure at work caused or contributed to a condition or significantly aggravated a pre-existing condition.[29]

Data sources

Alaska trauma registry

The Alaska Trauma Registry (ATR) is a statewide injury surveillance system that collects data from the State's 24 acute-care facilities.[30] Data include injury information and patients' treatments, outcomes, and demographics. For this study, the research team requested de-identified data in accordance with ATR's release of information policy. We utilized NIOSH's Industry and Occupational Computerized Coding System[31] to code industry within the full dataset and identify cases among fishermen and offshore seafood processors.

U.S. coast guard

The U.S. Coast Guard (USCG) shares regulatory jurisdiction over fishermen's safety with the Occupational Safety and Health Administration (OSHA).[32] Vessel owners/masters/operators are legally required to report to USCG any "injury that requires professional medical treatment (treatment beyond first aid) and, if the person is engaged or employed on board a vessel in commercial service, that renders the individual unfit to perform his or her routine duties" (CFR, Title 46, Section 4.05–1). A standardized form is used to document injury details.[33] Although crewmembers are only required to report injuries, they also report illnesses/conditions necessitating USCG support (e.g., medical evacuations). USCG and NIOSH have a memorandum of agreement allowing researchers to access and utilize reports. For this study, we manually reviewed reports (brief notifications and full investigations) to identify cases. We abstracted de-identified information from reports into a database, including: date; location; vessel characteristics; fishery; demographics; and injury/illness information.

Fishermen's fund

The State of Alaska established the Fishermen's Fund (FF) for the treatment and care of Alaska-licensed commercial fishermen who become injured/ill on the job.[28] However, offshore seafood processors may be covered under traditional Workers' Compensation and do not qualify for FF benefits. Fishermen file FF claims to cover transportation, medical care, prescriptions, and therapy costs. FF is an emergency fund payer of last resort. Benefits are only awarded after consideration of other coverage, such as private health or vessel insurance. Benefits from the Fund are financed from revenue received from each resident and nonresident commercial fisherman's license and permit fee.[28] We submitted a public records request for de-identified data. The dataset included information on the incident date, location, fishery, gear type, demographics, and injury/illness.

Measures

We standardized variables and classification systems across datasets. Based on narrative descriptions and existing variables, we used the Occupational Injury and Illness Classification System (OIICS) to manually code nature of injury/illness, body part affected, and event/exposure.[34] We utilized NIOSH's "source of injury/illness" codes, which are modelled after OIICS and developed specifically for the fishing industry.[20,23]

Two variables were coded only for traumatic injuries: work process and severity. We assigned a code from NIOSH's Work Process Classification System, which was developed specifically for the fishing industry.[19,20,21,35] To code severity (Appendix 1), we modified a scale used in USCG investigative reports. USCG investigators code severity using a scale adapted from the Abbreviated Injury Scale (AIS). This scale contains AIS levels and general definitions but has less stringent coding rules, to allow for coding cases lacking clinical diagnoses. For this study, we further modified the scale to remove criteria based on treatment (e.g., "no medical treatment required," "hospitalized 48+ hours within 5 days of injury"). By definition, FF and ATR cases involved in medical treatment. Additionally, FF and USCG did not regularly contain detailed information on treatment.

We standardized geographic regions as Southeast, Southcentral, or Western. For USCG, region was coded based on coordinates, with Southeast including locations east of 141°W, Western including locations west of 156.4°W, and Southcentral between those cut-offs. For FF, region was coded based on the district, as defined by Alaska Statute,[36] with Southeast including Districts 1 and 2, Southcentral District 3, and Western Districts 4 and 5. For ATR, region was manually coded based on city/town.

Fleet was determined based on targeted species, vessel/gear type, and region. For USCG reports, this involved reviewing the narrative, vessel-related fields, and vessel activity history, as well as searching state and federal fishing permit databases. For FF claims, fleet was determined by reviewing the fishery, gear type, and location fields, which are routinely collected. The ATR system does not routinely collect vessel or fishery information. Therefore, fleet could only be determined when narrative fields contained sufficient information.

Probabilistic linkage and analysis

The research team reasoned a priori that a unique case could appear in more than one dataset (i.e., appear as a "duplicate" case across datasets). For example, a fisherman could suffer an injury and: (1) the crew reports it to USCG; (2) it is treated at an acute care facility captured by ATR; and (3) the fisherman, if lacking other means to pay for medical care, submits a claim to FF. The datasets had to be linked in order to identify such duplicate cases.

When direct identifiers are unavailable, probabilistic linking methods outperform deterministic methods.[37–39] Therefore, we employed probabilistic linkage methods because the datasets lacked direct identifiers. Probabilistic linking methods assess the discriminatory power of each identifier and likelihood that two cases are a true match, based on whether they agree or disagree on various identifiers. Methods include "blocking" on certain variables, which reduces the comparison space to include only matched pairs that meet certain basic criteria (e.g., date, region).[37]

To identify duplicate cases, the lead author first manually reviewed each combination of datasets (i.e., ATR-FF, ATR-USCG, and FF-USCG) by blocking on month/year and matching on age, fleet, region, and narrative. Next, Link Plus™ software[40] was used to automatically link each combination of datasets. This probabilistic linkage program is based on Fellegi and Sunter's[41] theoretical framework and uses the EM algorithm to estimate model parameters.[42] Cases were blocked on month/year and matched on: age; sex; fleet; region; nature; body part; source; event/exposure; and work process. Link Plus calculates a score for each comparison pair, with a higher score indicating a higher likelihood of a true match. The lead author chose the lowest cut-off score for manual review, in order to identify and review all potential matches. After consolidating duplicates identified through both the manual and automatic reviews, the datasets were merged.

Descriptive statistics, including frequency, percent distributions, and cross-tabulations, were calculated in Stata 14.2.[43] The Institutional Review Board determined this study did not require a full review because its primary intent is surveillance for injury/illness control (IRB No. 17-WSD-04D).

Results

ATR included 153 cases, USCG included 514 cases, and FF included 2,403 cases (Figure 1). Reviewing each combination of datasets both manually and automatically using software was important for identifying all unique cases that appeared in more than one dataset (i.e., "duplicate" cases). Each method identified duplicate cases that the other method missed, when linking each combination of datasets. When linking ATR-USCG, manual review identified 89% of the duplicates and the software identified 61%. When linking ATR-FF, manual review identified 79% of the duplicates and the software identified 50%. When linking USCG-FF, both manual review and the software identified 54% of duplicates. Linking datasets identified 53 duplicates total, across the three datasets. In total, 3,014 unique cases were identified post-linking.

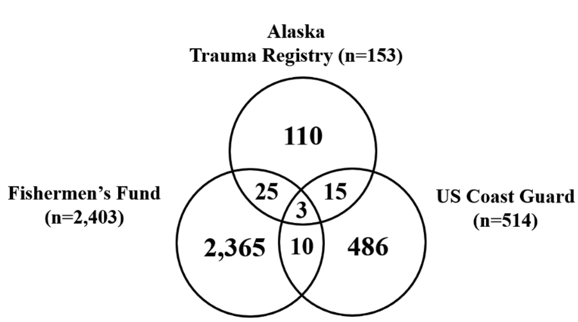

Figure 1. Nonfatal injury/illness cases in Alaska's fishingindustry, 2012–2016, by dataset and linked (3,014 unique cases).

Utility of datasets

In ATR (153 cases), all cases were traumatic injuries, as expected. Most were fractures (40%), crushing injuries (12%), cuts (10%), amputations (7%), and intracranial injuries (7%). By severity, 1% of injuries were minor, 31% moderate, 34% serious, 29% severe, and 5% critical. Injuries occurred most frequently in Western Alaska (47%), followed by Southcentral (37%) and Southeast (16%). Fleet was coded for only 62 cases (41%). Of the 17 fleets identified, most cases were in: salmon drift gillnet (10, 16%); salmon seine (9, 14.5%); Bering Sea/Aleutian Island (BSAI) crab (8, 13%); multi-species motherships (5, 8%); and salmon set gillnet (5, 8%). The number of cases generally declined each year, with a high of 41 cases in 2014 and a low of 17 in 2016.

In USCG (514 cases), most cases were traumatic injuries (92%), followed by disease and disorders (4%) and "symptoms" that could not otherwise be classified (4%). Most injuries were fractures (15%), cuts (10%), surface wounds/bruises (10%), and sprains/strains/tears (9%). By severity, 30% of injuries were minor, 39.5% moderate, 19% serious, 0.5% severe, and one case that was critical. The majority of cases occurred in Western Alaska (89%), followed by Southcentral (8.5%), and Southeast (2.5%). Fleet was coded for 488 cases (95%). Of the 15 fleets identified, most cases were in: BSAI pollock fleet (American Fisheries Act [AFA] fleet) (27%); non-pollock factory trawlers (Amendment 80) (25%); cod freezer longliners (15%); multi-species motherships (8%); and BSAI crab (6%). The number of cases reported each year remained fairly consistent, with a low of 94 cases in 2012 and high of 111 in 2016.

In FF (2,403 cases), most cases were traumatic injuries (93%), followed by diseases/disorders (6%), and symptoms (1%). Most injuries were sprains/strains/tears (32%), cuts (16%), surface wounds/bruises (10%), fractures (9%), and punctures (5%). By severity, 32% of injuries were minor, 58.5% moderate, 9% serious, and 0.5%

severe. The most common diseases/disorders were respiratory illness (52) and musculoskeletal disorders (35). The majority of cases occurred in Southcentral Alaska (42%), followed by Southeast (36%) and Western (22%). Fleet was coded for 2,140 cases (89%). Of the 20 fleets identified, most cases were in: salmon drift gillnet (29%); salmon seine (19%); halibut/sablefish longline (11%); salmon set gillnet (8%); and salmon troll (7%). The number of FF claims declined steadily each year, from a high of 603 cases in 2012 to a low of 380 in 2016.

ATR and FF contained injury cases that were not reported to USCG. ATR contained 135 unreported injuries, including: 1 minor, 43 moderate, 45 serious, 39 severe, and 7 critical. FF contained 2,202 unreported injuries, including: 708 minor, 1,296 moderate, 196 serious, and two severe.

Injury/illness patterns among all cases

The following sections present the analysis of unique cases, post-linking. Over the five-year study period, the number of injury/illness cases declined each year, with 723 cases in 2012, 693 in 2013, 567 in 2014, 529 in 2015, and 502 cases in 2016. Ages ranged from 82 years, with a mean of 38 years (SD: 14 years). Most crewmembers were male (2,774, 93%).

By nature, most cases were traumatic injuries (2,779, 92.5%), followed by diseases/disorders (165, 5.5%), and symptoms (43, 1.5%). The most common injuries included: sprains/strains/tears (819); cuts (452); fractures (343); surface wounds/bruises (299); and punctures (140). By injury severity, 891 (32%) were minor, 1,472 (53%) moderate; 363 (13%) serious, 45 (1.5%) severe, and 8 (0.5%) critical. Among all traumatic injuries, crewmembers sought medical care for 234 skin infections that resulted from an initial injury (e.g., cut, scratch). Of the 165 diseases/disorders, most were respiratory illnesses (52), musculoskeletal disorders (35), circulatory system diseases (20), carpal tunnel syndrome (15), and skin infections (15). Among the respiratory infections, the majority were acute respiratory infections, including the common cold (39), pneumonia (6), and influenza (3). By body part, most injury/illness affected crewmembers' upper extremities (1,129, 38%), trunk (743, 25%), lower extremities (474, 16%), and head (384, 13%). The most commonly-affected upper extremities were hands (716) – particularly fingers (452) – followed by arms (164) and shoulders (140). Most cases affecting the trunk involved the back (444), chest (128), abdomen (120), and pelvis (48). (Supplemental Table 1 presents a cross-tabulation of nature and body part for all cases.)

Event/exposure was coded for 90% of cases. Contact with objects/equipment occurred most frequently (1,101, 41%), followed by overexertion/bodily reaction (738, 27%), and slips/trips/falls (541, 20%). Other types included transportation incidents (167, 6%), exposure to harmful substances/environments (119, 4.5%), injuries from persons and animals (24, 1%), and fires/explosions (13, 0.5%). Source was coded for 85% of cases. The most common sources were fishing gear (670, 26%), vessel interior/exterior (646, 25%), bodily motion (226, 9%), and general tools and equipment (221, 9%). Fishing gear most frequently included: pots/traps (86); longline hook (53); drift gillnet (53); seine net (30); and power net reel (27). Among injuries involving the vessel, almost half were on deck (282). The work process associated with injury was coded for 80% of cases. In total, over one-third of injuries were associated with a work process involving gear (792, 36%). The most common specific work processes were hauling gear (397, 18%), walking/climbing/descending (386, 17%), and repair/maintenance/cleaning (317, 14%).

Injury/illness patterns by fleet

Of the 27 fleets identified post-linking, two had over 300 injury/illness cases: salmon drift gillnet (697) and salmon seine (451). In the salmon drift gillnet fleet, most cases were traumatic injuries (650, 93%), commonly sprains/strains/tears (240), cuts (125), fractures (71), and surface wounds/bruises (67). By severity, 32% of injuries were minor, 58% moderate, 10% serious, 0.3% severe and 0.2% critical. Table 1 presents injury/illness circumstances in the salmon drift gillnet fleet. Contact with objects/equipment (235, 38%) frequently involved being struck by (106), caught/compressed (49), and striking against (40). Overexertion/bodily reaction (163, 26%) primarily included overexertion involving outside

Table 1. Injury/illness in Alaska's salmon drift gillnet fleet, 2012–2016, by event/exposure, work process, and source.

	Event/Exposure						
Work Process	Contact Object/Equipment	Overexertion, Bodily Reaction	Slip, Trip, Fall	Transport Incident	Other*	Unknown	Total (%)
Source							
Repair, maintain, clean	47	12	19	2	8	9	97 (18.58)
Deck	0	0	13	0	0	0	
Deck knife	7	0	0	0	0	0	
Power grinder	6	0	0	0	0	0	
Power hand saw	5	0	0	0	0	0	
Other	29	12	6	2	8	9	
Walk, climb, descend	11	6	66	11	1	0	95 (18.20)
Deck	0	0	38	4	0	0	
Bodily motion	0	6	5	0	0	0	
Ladder	0	0	7	0	0	0	
Other	11	0	16	7	1	0	
Handle fresh catch	19	21	9	2	1	3	55 (10.54)
Fish	4	12	0	0	0	0	
Deck	1	0	9	0	0	0	
Bodily motion	0	7	0	0	0	0	
Other	14	2	0	2	1	3	
Haul gear	21	20	5	0	0	0	46 (8.81)
Prepare gear	21	8	5	1	0	1	36 (6.90)
Handle gear on deck	5	14	5	2	0	2	28 (5.36)
Set gear	19	2	6	1	0	0	28 (5.36)
Pull up anchor	13	6	1	0	0	0	20 (3.83)
Prepare vessel for sea	1	9	3	4	0	1	18 (3.45)
Off duty	8	0	1	3	3	1	16 (3.07)
Offload fish	3	4	8	0	0	1	16 (3.07)
Mooring	3	1	5	2	0	0	11 (2.11)
Process catch	8	3	0	0	0	0	11 (2.11)
Prepare vessel for storage	1	2	3	0	0	1	7 (1.34)
Watch	1	1	0	1	0	0	3 (0.57)
Other	19	4	6	2	3	1	35 (6.70)
Unknown/NA	35	50	3	7	21	59	175 (-)
Total (%)	235 (38.03)	163 (26.38)	145 (23.46)	38 (6.15)	48 (5.98)	79(-)	697 (100)

*"Other" event/exposure includes: exposure to harmful substances or environments (n = 27), fire (n = 6), violence (n = 3), and insect bite (1).

sources (95) and bodily conditions resulting in diseases/disorders/symptoms (28). Slips/trips/falls (145, 23%) mostly involved falls to the same level (65) and falls to a lower level (59). Transportation incidents (38, 6%) often involved collisions between vessels and objects (14), falls/jumps from water vehicle (9), water vehicle/propeller striking people (5), and collisions between water vehicles (5). In Table 1, the injury/illness source is listed below the work process. For example, of the 97 crewmembers injured while performing "repair/maintenance/cleaning," 47 were injured by contact with an object/equipment [deck knives (7), power grinders (6), power hand saws (5), and "other" sources (29)]; and 19 were injured by a slip/trip/fall [13 from deck and 6 from "other" surfaces]. While "walking/climbing/descending" (95, 18%), crewmembers frequently slipped/tripped/fell from the deck (38) and ladders (7). In total, 138 injuries involved gear (hauling, preparing, handling on deck, or setting) in the salmon drift gillnet fleet.

In the salmon seine fleet, most cases were traumatic injuries (423, 94%), commonly sprains/strains/tears (132), cuts (68), and surface wounds/bruises (54). By severity, 32% of injuries were minor, 56.5% moderate, 11% serious, and 0.5% severe. Table 2 presents injury/illness circumstances in the salmon seine fleet. Contact with objects/equipment (179, 46%) frequently included being struck by (101), caught or compressed (38), and striking against (18). Overexertion/bodily reaction (98, 25%) mainly involved overexertion involving outside sources (65) and bodily conditions (12). Slips/trips/falls (73, 19%) commonly involved falls to the same level (36), falls to a lower level (16), and slips/trips without falls (15). Transportation incidents

Table 2. Injury/illness in Alaska's salmon seine fleet, 2012–2016, by event/exposure, work process, and source.

	Event/Exposure						
Work Process	Contact Object/Equipment	Overexertion, Bodily Reaction	Slip, Trip, Fall	Transport Incident	*Other	Unknown	Total (%)
Source							
Haul gear	52	32	9	4	0	2	99 (31.03)
Seine net	4	10	0	0	0	0	
Tow line	8	2	0	0	0	0	
Purse ring	7	0	0	0	0	0	
Bodily motion	0	3	3	0	0	0	
Deck	0	0	5	0	0	0	
Winch	5	0	0	0	0	0	
Other	28	17	1	4	0	2	
Walk, climb, descend	7	7	40	7	0	1	62 (19.44)
Deck	0	0	19	5	0	0	
Bodily motion	0	7	8	0	0	0	
Other	7	0	13	2	0	1	
Repair, maintain, clean	30	3	7	2	2	0	44 (13.79)
Handle gear on deck	11	15	6	1	0	3	36 (11.29)
Prepare gear	11	5	3	1	0	0	20 (6.27)
Prepare vessel for sea	7	3	2	0	0	0	12 (3.76)
Handle fresh catch	4	2	1	0	1	0	8 (2.51)
Set gear	5	2	1	0	0	0	8 (2.51)
Off duty	2	0	0	0	3	0	5 (1.57)
Process catch	4	0	1	0	0	0	5 (1.57)
Mooring	0	2	0	1	0	0	3 (0.94)
Pull up anchor	3	0	0	0	0	0	3 (0.94)
Prepare vessel for storage	1	1	0	0	0	0	2 (0.63)
Offload fish	1	0	0	0	0	0	1 (0.31)
Watch	1	0	0	0	0	0	1 (0.31)
Other	6	2	1	1	0	0	10 (3.13)
Unknown/NA	34	24	2	2	14	56	132 (-)
Total (%)	179 (46.02)	98 (25.19)	73 (18.77)	19 (4.88)	20 (5.14)	62(-)	451 (100)

* "Other" event/exposure includes: exposure to harmful substance or environment (n = 11), violence (n = 3), insect bite (n = 3), injury from animal (n = 1).

(19, 5%) frequently involved falls/jumps from water vehicles (9) and vessels striking people (7). The most common work process was hauling gear (99, 31%), during which crewmembers experienced overexertion while hauling the net (10) and came into contact with the tow line (8), purse ring (7), and winch (5). In total, 79 injuries in the salmon seine fleet involved gear. (Supplemental Tables 2–4 present injury/illness circumstances in the halibut/sablefish longline [272], salmon set gillnet [189], and salmon troll [169] fleets.)

Severe injury patterns

Industry-wide (across all fleets), 416 injuries (15% of all injuries) were coded as serious, severe, or critical. Fleet was coded for 78% of these cases. Of the 18 fleets identified, most cases were in: salmon drift gillnet (68, 21%); salmon seine (48, 15%); BSAI pollock (35, 11%); halibut/sablefish longline (24, 7%); salmon troll (20, 6%); salmon set gillnet (19, 6%); non-pollock factory trawler (18; 5%); salmon and herring tender (16, 5%); and BSAI crab (15, 5%). Injuries were mostly fractures (209, 50%), hernias (73, 18%), intracranial injuries (48, 12%), and crushing injuries (31, 7.5%). Table 3 presents injury circumstances. Contact with objects/equipment (143, 36%) frequently involved being struck by (69) and caught/compressed (60). Slips/trips/falls (120, 30%) mostly involved falls to a lower level (54) and falls to the same level (53). Overexertion/bodily reaction (70, 18%) was primarily overexertion involving outside sources (64). Transportation

Table 3. Serious, severe, and critical traumatic injuries in Alaska's fishing industry, 2012–2016, by event/exposure and work process.

	Event/Exposure						
Work Process	Contact Object/Equipment	Slip, Trip, Fall	Overexertion, Bodily Reaction	Transport Incident	Other*	Unknown	Total (%)
Walk, climb, descend	2	64	3	22	0	0	91 (27.33)
Haul gear	35	10	22	3	0	0	70 (21.02)
Repair, maintain, clean	14	9	2	4	2	0	31 (9.31)
Set gear	10	3	7	0	0	0	20 (6.01)
Handle gear on deck	12	1	7	0	0	0	20 (6.01)
Handle fresh catch	6	2	4	0	0	0	12 (3.60)
Process catch	6	1	3	1	0	0	11 (3.30)
Mooring	2	3	1	5	0	0	11 (3.30)
Prepare vessel for sea	3	4	2	2	0	0	11 (3.30)
Prepare gear	4	2	4	0	0	0	10 (3.00)
Offload fish	6	3	0	0	0	0	9 (2.70)
Handle packaged frozen fish	5	2	1	0	0	0	8 (2.40)
Prepare vessel for storage	1	4	1	0	0	0	6 (1.80)
Pull up anchor	4	1	0	0	0	0	5 (1.50)
Diving	2	0	0	0	2	0	4 (1.20)
Off duty	0	0	0	1	2	0	3 (0.90)
Other	4	2	2	2	1	0	11 (3.30)
Unknown	27	9	11	9	6	21	83 (-)
Total (%)	143 (36.20)	120 (30.38)	70 (17.72)	49 (12.41)	13 (3.29)	21(-)	416 (100)

* "Other" event/exposure categories include: Violence (n = 5); exposure to hazardous environment and substances (n = 5); and fire/explosion (n = 3).

incidents (49, 12%) often involved falls/jumps from vessels (22) and collisions between vessels and objects (9). In total, almost one-third of injuries were associated with a work process involving gear (120, 29%). Leading specific work processes were walking/climbing/descending (91, 27%) and hauling gear (70, 21%).

Discussion

By linking ATR, USCG, and FF, this study identified 3,014 unique cases of work-related, nonfatal injury/illness among commercial fishermen and offshore seafood processors in Alaska during 2012–2016.

Utility of datasets

Linking datasets allowed for the most comprehensive understanding of nonfatal injury/illness in Alaska's fishing industry to date. The number and type of cases captured by each dataset varied greatly, with relatively few cases appearing in more than one dataset. As expected, ATR captured only traumatic injuries (predominantly fractures, crushing injuries, and cuts) which ranged from moderate to critical severity. Likewise, given reporting requirements, USCG mainly captured injuries (chiefly fractures, cuts, and surface wounds/bruises), but these ranged from minor to serious. FF mainly captured injuries (mostly sprains/strains/tears and cuts), which ranged from minor to serious. Unlike ATR and USCG, FF also captured many illnesses. Generally, occupational illnesses (including musculoskeletal illness) are less likely to be captured through passive surveillance methods.[44]

The fleets/regions captured by USCG and FF differed greatly. The vast majority of USCG reports were submitted by large, company-owned vessels operating in Western Alaska (e.g., AFA, Amendment 80, cod freezer-longliners, and motherships). Crewmembers in these fleets tend to be covered under corporate insurance plans and therefore would not submit FF claims. Crewmembers working on small, independently-owned vessels operating in Southcentral and Southeast Alaska (e.g., salmon fleets) mainly submitted FF claims. During 2015–2016, the majority of Alaska's fishing jobs were in the salmon fishery[45] and it is logical that the highest number of injuries/illnesses appeared in salmon fleets. For

ATR, fleet was coded for less than half of the cases, but cases spanned many fleets.

Previous research has noted that fishermen may underreport injuries to USCG.[19,23,35,46–49] Across fleets, crewmembers are required to report injuries necessitating treatment beyond first aid *and* resulting in an inability to perform typical duties. By definition, ATR and FF injury cases involved treatment beyond first aid. Although it is difficult/impossible to determine if minor and moderate injuries captured by ATR and FF resulted in crewmembers' inability to perform typical duties, it is very likely that serious, severe, and critical injuries met both reporting criteria. Therefore, at least 91 cases in ATR and 198 cases in FF should have been reported. The extent to which 1,296 moderate injuries captured by FF should have been reported is unclear. Fishermen working on smaller, independently-owned vessels likely underreport injuries that do not require USCG assistance. For example, a previous survey of West Coast Dungeness crab fishermen found that crewmembers only sought clinical or emergency care for 25% of injuries.[49] Across U.S. industries, underreporting of occupational injury/illness is common.[44,50,51]

Injury/illness patterns

Over one-third of injuries/illnesses affected crewmembers' upper extremities, mostly the hands and fingers, and a quarter affected the trunk, predominantly the back. One-third of injuries were sprains/strains/tears, followed by cuts, fractures, and surface wounds/bruises. Fishermen, who face a variety of skin problems,[52] sought medical care for over 230 skin infections that resulted from an initial injury. This study identified 35 musculoskeletal disorders and 15 carpal tunnel syndrome cases. Almost half of injuries resulted from contact with gear/equipment/machinery, followed by almost one-third from overexertion, and one-fifth from slips/trips/falls. These findings are similar to patterns identified in prior studies, some of which described exposures to ergonomic hazards, which can cause life-altering conditions.[17,22,48,53,54] Most concerning in terms of acute injury, this study identified over 415 serious/severe/critical injuries, commonly including fractures, hernias, intracranial, and crushing injuries.

Prevention strategies should be fleet-specific. Salmon drift gillnetters were most frequently injured performing repairs/maintenance/cleaning and walking/climbing/descending. In contrast, salmon seiners were most frequently injured while hauling gear. For purse-seine vessels, NIOSH developed an emergency-stop to prevent entanglement in capstan deck winches.[15] This study found that, industry-wide, over one-third of injuries involved fishing gear, which differs between fleets. Over 85 injuries involved pots/traps, which corresponds to previous research on the BSAI crab fleet.[20]

Safety management systems (SMS) could be utilized to prevent injury/illness, as has been proposed for commercial fishing fleets outside the U.S.[55,56] Although some company-owned, large vessels operating in Alaska may use SMS,[23] the extent to which smaller, independently-owned vessels use SMS is not clear. SMS could be scaled to meet crewmembers' needs onboard smaller vessels. Although interventions should be fleet-specific, certain hazards are ubiquitous.

When possible, ergonomic hazards should be addressed by redesigning the workplace to meet crewmembers' needs and abilities, rather than by modifying behavior, per the hierarchy of controls.[57] The fishing industry presents unique ergonomic challenges. Alaskan fishermen who participated in an ergonomics training course described how difficult it was to make major changes to on-deck equipment and explained that standard lifting guidance to "rotate with the feet, not the torso" when lifting could be dangerous on deck.[58] Participatory ergonomic research[59] should be conducted to develop and evaluate prevention strategies.[60,61]

To prevent slips/trips/falls, obstructions and substances/seafood should be removed from walkways as frequently as possible. Proper drainage should be maintained, with appropriate gratings, mats, or raised platforms, and surfaces designed to increase adhesion.[62] OSHA provides guidance on fall protection for the fishing industry.[63] Research in the Danish fishing industry found that wearing boots with anti-slipping soles helped to reduce slips/trips/falls and that boots should be replaced as soon as they are worn out.[64] Finally, although not addressed in this study, working hours and sleep deprivation are safety and health concerns in the U.S. fishing industry.[22,23,65–68] Community-based participatory research could determine if/how fatigue risk management systems[69] could be implemented.

Limitations

Injury/illness rates could not be calculated due to major differences in each dataset's inclusion criteria, as described earlier. Given that rates were not calculated, this study could not determine differences in injury/illness risk between fleets. Alaska's fishing industry is complex and there are many instances in which injuries/illnesses would not be captured by ATR, USCG, or FF. For example, an injury/illness could be treated at a clinic or emergency department not captured by ATR, paid for with personal health/vessel insurance, and go unreported to USCG. The steady decline in the number of FF cases over the study period could have been due to a number of potential factors, such as a true decline in the number of injuries/illnesses, a reduction in the size of the workforce, and/or an increase in the usage of other types of insurance (e.g., Affordable Care Act, personal health insurance, vessel insurance).

These surveillance data likely underrepresent the true burden of nonfatal conditions and likely are more representative of acute traumatic injuries than illnesses, including diseases, infections, and musculoskeletal illnesses/disorders caused by cumulative trauma.[44,49–51] Additionally, USCG and FF did not regularly contain clinical diagnosis and treatment information. This may have introduced misclassification bias in coding nature of injury/illness and injury severity. For example, it is possible that cumulative trauma might have contributed to some of the injuries that were described as acute traumatic sprains, strains, and tears in the narrative sections. Based solely on reviewing narrative descriptions (e.g., 'processor pulled muscle in lower back while picking up frozen cases of fish'), it was not always possible to determine the extent to which cumulative trauma might have been a factor. However, any misclassification would likely be minor and not affect the overall results/conclusions. Furthermore, implementing ergonomic hazard control measures would help to prevent musculoskeletal injuries and illnesses caused by acute trauma and cumulative trauma.

Conclusion

This study is the first to characterize nonfatal injury/illness across Alaska's fishing industry by linking ATR, USCG, and FF datasets. The datasets captured different industry segments. Large, company-owned vessels operating in Western Alaska mainly reported injuries to USCG, whereas small, independently-owned vessels in Southcentral and Southeast Alaska mainly submitted FF claims. By analyzing FF claims, this study was the first to present detailed injury/illness data for salmon fleets. It also provided detailed data on severe injuries industry-wide. Prevention strategies should be tailored by fleet, with efforts to control hazards related to gear/equipment/machinery, ergonomics, and slips/trips/falls.

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Disclaimer

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ORCID

Laura N. Syron http://orcid.org/0000-0003-1477-996X

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Appendix 1. Traumatic Injury Severity Scale

Severity	Examples
Minor	Minor/superficial scrapes (abrasions); minor bruises; minor cuts; first degree burn; digit sprain; minor strain/sprain.
Moderate	Broken fingers, toes, or nose; amputated fingers or toes; de-gloving of fingers or toes; dislocated joint; severe strain/sprain; second or third degree burn covering 10% or less of the body (if face is included move up one category); herniated disc.
Serious	Broken bones (other than fingers, toes, or nose) partial loss of limb (amputation below elbow/knee); de-gloving of the entire hand/arm or foot/leg; second or third degree burns covering 20–30% of the body (if face included move up one category); bruised organs; minor head trauma with headache or dizziness.
Severe	Internal hemorrhage; punctured organs; severed blood vessels; second/third degree burns covering 30–40% of the body (if face included, move up one category), loss of entire limb (amputation of whole arm/leg).
Critical	Spinal cord injury; extensive second- or third-degree burns; concussion with severe neurological signs; severe crushing injury; internal hemorrhage; second/third degree burns covering 40% or more of body; severe/multiple organ damage.