

# Prospective study of incident injuries among southeastern United States commercial fishermen

Kristen L Kucera,<sup>1,2</sup> Dana Loomis,<sup>2,3,4</sup> Hester Lipscomb,<sup>1</sup> Stephen W Marshall<sup>2,5,6</sup>

<sup>1</sup>Division of Occupational and Environmental Medicine, Duke University Medical Center, Durham, North Carolina, USA

<sup>2</sup>Department of Epidemiology, School of Public Health, The University of North Carolina, Chapel Hill, North Carolina, USA

<sup>3</sup>Department of Environmental and Occupational Health, School of Public Health, The University of Nevada, Reno, Nevada, USA

<sup>4</sup>Department of Environmental Sciences and Engineering, School of Public Health, The University of North Carolina, Chapel Hill, North Carolina, USA

<sup>5</sup>Injury Prevention Research Center, The University of North Carolina, Chapel Hill, North Carolina, USA

<sup>6</sup>Department of Orthopaedics, School of Medicine, The University of North Carolina, Chapel Hill, North Carolina, USA

## Correspondence to

Dr Kristen Kucera, Division of Occupational and Environmental Medicine, Duke University Medical Center, 2200 W Main St, Suite 700, Durham, NC 27705, USA; kristen.kucera@duke.edu

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## ABSTRACT

**Objective** The purpose of this study was to describe occupational exposures and the incidence of non-fatal injuries among a group of southeastern US small-scale fishermen.

**Methods** Participants (n=219) were enrolled in a prospective cohort study and followed from August 1999 to May 2002. Demographic information was obtained at baseline, and weekly and biweekly telephone interviews elicited information on number of days worked, fishery, fishing gear used, maintenance work, glove use and any work-related injury events. Incidence rate ratios (IRR) and 95% CIs were calculated with Poisson regression for each factor and multivariate models controlled for potential confounders.

**Results** Over a third of participants (81/217) reported 125 injury events over 46 153 work-days for rate of 2.74 per 1000 work-days (95% CI 2.19 to 3.41). The majority of injuries were penetrating wounds to the hand, thumb and finger (35%) or back sprains and strains (8%); most required no medical care or time off work (67%). Injury rates were similar for on and off the water work (1.9 per 1000 work-days). Injury rates differed by fishery, water location and month. Factors associated with an increased injury rate included working on someone else's boat and maintenance work. Glove use was protective.

**Conclusion** Similar injury characteristics were observed in small-scale fishing as compared to large-scale. For small-scale fishermen, off and on the water work locations, and particularly maintenance work, were important predictors of injury. Despite the protective association for glove use, penetrating wounds to the hand, thumb and finger were common.

## INTRODUCTION

Fishing has been known as a hazardous occupation since early times. Ramazzini's 1713 textbook on occupational medicine describes fishing as "a very toilsome and exacting calling" that required workers to "endure the cruel buffets of the winds, freezing cold in winter, and in summer scorching heat".<sup>1</sup> Contemporary research demonstrates that fishing continues to be a dangerous occupation. In 1966, Schilling described deep-sea trawler fishing as an "extreme occupation" in an address before the Royal Society of Medicine and called for action to reduce the risk of death and injury in the industry.<sup>2</sup> Despite modernisation, the work of fishing is still carried out under changeable, often adverse, environmental conditions, using a wide range of equipment and work processes. Fishing is associated with high rates of fatal and non-fatal occupational injury worldwide.<sup>3 4</sup> Most research has been focused on fatalities, large-scale operations and deep waters with fewer studies of small-scale,

## What this paper adds

- ▶ Prospective studies of non-fatal injuries, particularly among small-scale commercial fishermen, are priority research areas.
- ▶ In this prospective cohort study, fishermen sought medical care and/or took time off work for 33% of 125 reported injuries.
- ▶ Working on someone else's boat and weekly maintenance work were associated with increased rates of injury and weekly glove use revealed a protective association.
- ▶ Severe injuries (medical care or time off work) may result in a greater financial burden for the small-scale, independent fisherman.
- ▶ Changes in the fishing industry may increase hazardous exposures and injury risk, and future interventions need to take account of this.

independent fishermen. Small-scale fishing operations have been identified by national and international organisations as a priority research area.<sup>5 6</sup>

Studies of non-fatal injuries have been primarily retrospective or cross-sectional and have been conducted in Europe, Scandinavia, Alaska, New Zealand and Australia. Information sources for these studies included accident and injury reports to insurance or workers' compensation agencies,<sup>7–10</sup> hospital records<sup>11–15</sup> and cross-sectional surveys.<sup>16 17</sup> One prospective study, conducted over a 6-month period in Scotland, described the characteristics of hospital injuries.<sup>13</sup> Work history, job exposures and a number of health outcomes, including lifetime history of accident/injury, were collected via dock-side surveys in a cross-sectional study among Spanish small-scale fishermen.<sup>17</sup> Data sources such as injury reports filed with insurance companies and hospital records capture the most severe injuries requiring medical care or time off work. Likewise with retrospective and cross-sectional surveys, which also may be subject to recall bias. Fishermen are well known for their toughness, independence and reluctance to seek medical care.<sup>18 19</sup> These characteristics combined with the above investigative methodologies do not provide a full picture of the exposures and injury risks for small-scale commercial fishermen.

Enumerating non-fatal injuries and the population at risk are especially challenging in the United States without universal healthcare coverage or unions for fishermen. In 2001, the NIOSH field station in Alaska initiated a hospital-based trauma registry and surveillance system to track non-fatal

injuries.<sup>14</sup> However, systematic surveillance for non-fatal injuries does not exist elsewhere in the USA. Surveillance serves several important functions: characterisation of the problem, identification of preventive measures and evaluation of efforts to reduce hazardous exposures and risk of injury. North Carolina is an important fishery state with fishing being a major industry and a traditional family-based occupation. The work is performed in shallow, protected waters as well as offshore. The purpose of this study was to: (1) characterise work processes, working conditions and exposures; (2) measure the incidence of occupational non-fatal traumatic injuries; (3) describe injury characteristics (type, mechanism and severity); and (4) determine the association between injury and occupational risk factors (eg, fishery, glove use).

## METHODS

### Study setting

The study was carried out in North Carolina, a major fishery state in the southeastern United States. Small-scale commercial crews of one to three fishermen making daily trips on boats up to 36 feet (10 m) in length retain an important presence here. In 1998 North Carolina had ~7000 licensed commercial fishermen, who landed approximately 180 million pounds of fish and shellfish worth US\$101 million dollars.<sup>20</sup> The number of workers actively engaged in the industry is larger, however, because licences are not required of crew members or workers who perform support functions without trading in fish. North Carolina's coastal area includes the Atlantic Ocean and a large estuarine zone lying between the mainland and a chain of barrier islands. The estuarine zone consists of a series of broad, shallow bodies of salt water, the largest of them being the Pamlico and Albemarle Sounds. The sounds and the rivers that feed them are an important habitat for marine life and support diverse commercial fisheries.

### Cohort recruitment and follow-up

All protocols involving human subjects were approved by the Institutional Review Board of The University of North Carolina School of Public Health. A volunteer cohort of water workers was recruited for a study originally designed to investigate possible estuary-associated syndrome (PEAS) hypothesised to arise from exposure to a toxic marine organism. Full details of recruitment and the protocol of that study have been presented previously.<sup>21</sup> Recruitment began in April 1999 and ended in May 2000. The target population included men and women 18–65 years of age who lived in North Carolina and worked on estuaries or the Atlantic Ocean for > 20 h per week for at least 6 months of the year. Efforts were focused on the recruitment of fishermen in the 13 counties around Albemarle Sound, Pamlico River and Neuse River where the potential for exposure to the organism implicated in PEAS was thought to be greatest. Fishermen who worked the Atlantic Ocean off North Carolina's upper coast were also sought as a group without exposure to the organism.

Potential participants were sought beginning with a list of licenced commercial fishermen obtained from the state Division of Marine Fisheries. Recruitment letters were sent to fishermen and brochures describing the study were distributed. Screening telephone calls were made to determine the interest and eligibility of potential study subjects. Of the 3268 individuals to whom calls were attempted, 2011 could not be reached or were unwilling to participate, 902 did not meet the inclusion criteria, and 117 initially agreed to participate but withdrew before their

initial interview. A total of 238 subjects were enrolled in the original cohort study. Demographic information about the participants and a description of their usual work activities, including the type of boats they used for fishing, the catch species they pursued, the fishing gear they used, and the areas in which they fished, was obtained in a baseline clinical interview. Members of the original cohort assembled for the study of PEAS were invited to join a companion study of occupational injuries that began in August 1999 and continued through May 2002. The follow-up study included 219 members of the cohort who were commercial fishermen and had completed at least one telephone follow-up interview (eight fishermen did not participate in the injury study and 11 participants were not commercial fishermen).

### Prospective assessment of exposure and outcomes

Participants were followed prospectively through telephone interviews scheduled weekly from April to October and biweekly from November to March. The period covered by the interviews averaged 7 days for April–October and 10 days for November–March, but the length could vary by several days depending on when participants were available. Some interviews were missed because participants could not be contacted, so the data for an individual fisherman could include gaps when neither injuries nor exposure information were observed.

In each interview, fishermen were asked to report the amount of time spent at work on and off the water, the catch species pursued and the gear used, the geographical areas fished since the previous interview, maintenance work and glove use. Incident injuries during each interview period were assessed by asking participants to report any damage to the body that required first aid, medical care or time away from work. Multiple injuries could be reported and details of the type of injury and the body part affected were requested for up to three injuries per interview period. Injured participants were also asked to describe the incidents that led to their injuries. Information was elicited on the fisherman's location and activities prior to injury and about the circumstances in which the injury occurred. The use of medical care and time off work after the injury were also described.

### Missing data

When the parent study (PEAS) ended early in October of 2001, the questionnaire was shortened for the duration of the injury study ending in May 2002. As a result, participants were no longer asked about weekly/biweekly maintenance work and glove use. Data were missing for 87 individuals (nine injury events) for these two variables. Since data were missing due to the logistics of data collection (missing by design) and were not dependent on the probability of exposure to either maintenance work or glove use, missing at random (MAR) was a reasonable assumption for the missing data pattern in these analyses. Assuming MAR and a monotone missing data pattern, values were imputed for these two variables (539 observations) using SAS PROC MI and MIANALYZE. The variables used to impute values over five iterations included: maintenance work, glove use, season, interview month, number of days worked off the water, age, gender, working on someone else's boat, previous history of injury and fishery (crab, finfish, clam, shrimp, oyster and other). Imputation models achieved >99% efficiency.

### Statistical data analysis

Descriptive analyses of the data were carried out using frequencies and means to describe the participants and the

incident injuries they sustained during follow-up. Work-days at risk were estimated from the information provided in the telephone interviews and injury incidence rates per 1000 work-days and their 95% CIs were calculated by standard methods.<sup>22</sup> Poisson regression models<sup>23</sup> were fit to the data to estimate incidence rate ratios (IRRs) and for the contributions of specific factors to injury rates. The factors considered included the fishery, location, maintenance work, glove use, working on or off the water and working on someone else's boat. Known confounders such as age, gender, season and previous history of time off work injury, were included in the final multivariate models as were risk factors with  $IRR \geq 1.20$  or  $IRR \leq 0.80$ . Because participants could have multiple injuries over the course of the study, the generalised estimating equations approach<sup>24</sup> was used to adjust the 95% CIs of the IRRs for serial correlation. Subset analyses were conducted for injuries resulting in time off work.

## RESULTS

The 219 fishermen ranged in age from 18 to 65 years (mean 44, SD 12). Nearly 90% were male and all but one were white (table 1). Years of education ranged from 7 to 18 years (median 13), with most fishermen having completed high school (table 1). At enrolment, 90% (n=196) reported working full-time, with two thirds (n=141) fishing year-round. The majority owned their own boat, ranging in size from 14 to 62 feet (4.3 to 18.9 m) and 27% regularly worked on someone else's boat. Almost half of the fishermen reported having a second non-commercial fishing job (n=99). Only 6% (13/219) reported a history of time off work-related injury at baseline. During follow-up many participants engaged in several types of fishing, but crab was the primary catch for almost half of the participants, followed by finfish and shrimp; other types of fishing were less common (table 1). The most common fishing gear used during follow-up included crab pots and gill nets.

Analysis includes 217 fishermen engaged in fishing work on or off the water (two fishermen did not fish during the study). Participants contributed 46 153 person-days at risk, an average of 213 days per fisherman. Eighty one fishermen reported a total of 142 incident injuries while working; the injuries resulted from 125 separate events (rate 2.74 per 1000 work-days, 95% CI 2.19 to 3.41). Twelve events resulted in two injuries each, one resulted in three injuries, one resulted in four injuries, and the remaining resulted in one injury each (n=111).

### Details about the injury event and injuries by part and type

At the time of the injury, fishermen were predominantly working with nets, pots or lines, performing maintenance work, working with catch or loading and unloading (table 2). Most injuries were caused by contact with knives, hooks or other sharp objects, followed by lifting or moving a heavy object, contact with the catch, falling on a hard surface or contact with fishing gear. Compared to on the water injuries, off the water injuries were due to maintenance work and contact with a knife, hook or sharp object (table 2).

The hand, wrist, thumb or finger was the most common injured body part (57%) followed by the back (9%), arm (9%), lower extremity (10%), trunk (not back) (8%), head or neck (5%) and shoulder (2%). Penetrating wounds were the most common type of injury (40%), followed by sprains or strains (18%), scrapes (14%), contusions (12%), bites or stings (6%), blisters or burns (5%) and other (4%). Fractures (1%) and concussions (1%) were rare. The most common part and type

**Table 1** Characteristics of North Carolina commercial fishermen, 1999–2001 (n=219)

	n	%
<b>Gender</b>		
Men	190	87
Women	29	13
<b>Race</b>		
White	218	99
Black	1	<1
<b>Age at enrolment (years)</b>		
<20	7	3
20–29	25	11
30–39	51	23
40–49	67	31
50–59	50	23
60+	19	9
<b>Education (years)</b>		
<12	70	32
12	86	39
>12	63	29
<b>Own a boat</b>	204	93
<b>Work regularly on other person's boat</b>	60	27
<b>Primary fishing performed during follow-up*</b>		
Crab	102	47
Finfish	72	33
Shrimp	24	11
Clam	16	7
Oyster	2	1
Other	1	<1
<b>Gear used during follow-up†</b>		
Crab pot	143	65.3
Crab other	31	14.2
Finfish gill net	133	60.7
Finfish net hauler	5	2.3
Finfish hook and line	43	19.6
Finfish pound net	19	8.7
Finfish other	49	22.4
Shrimp all	78	35.6
Clam all	45	20.5
Oyster all	41	18.7
Other all	51	23.3

\*n=2 did not fish during follow-up.

†Fishermen utilised more than one gear during follow-up, so percentages add to >100.

combinations were penetrating wounds (35%) or scrapes (9%) to the hand, wrist, thumb or finger and back strain or sprain (8%). Twelve per cent (7/57) of penetrating wounds became infected and all infected injuries were to the hand, wrist, thumb or finger (n=10).

The majority of injuries required no medical care or first aid from another person (67%, n=84). Eight per cent required an ambulance or trip to the emergency room, 10% required care from a medical practitioner and 15% required care from a co-worker, friend or relative. Most injuries required no time off work (77%). Twenty per cent resulted in less than a week off work and only 3% in a week or more off work. These off-work injuries most often were characterised by penetrating wounds to the hand, wrist, thumb or finger (29%) or back sprain/strain

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**Table 2** Circumstances of the injury events (n=125) among North Carolina commercial fishermen, 1999–2001

On the water (n=67)	n	%	Off the water (n=58)	n	%
Activity before injury event					
Working with nets, pots or lines	20	30	Maintenance	20	34
Working with catch	18	27	Working with nets, pots or lines	14	24
Maintenance	13	19	Non-specific activities while commercial fishing	11	19
Non-specific activities while commercial fishing	10	15	Loading or unloading boat or truck	7	12
Loading or unloading boat or truck	4	6	Docking, casting-off and trailering the boat	5	9
Docking, casting-off and trailering the boat	2	3	Working with catch	1	2
Injury contact					
Finfish, shellfish or other sea animals	18	27	Knife, hook or other sharp object	21	36
Other	11	16	Other	11	19
Lifting/moving heavy object	11	16	Lifting/moving heavy object	8	14
Falling on a hard surface	10	15	Falling on a hard surface	7	12
Fishing gear	8	12	Tools or equipment	6	10
Tools or equipment	5	7	Fishing gear	5	9
Knife, hook or other sharp object	4	6	—	—	—
Location					
Pamlico Sound	19	28	At home, doing fishing work	34	59
Other water location	18	27	Boat ramp, ditch bank or near water	15	26
Neuse river	8	12	Other	4	7
Pamlico river	8	12	On dock	2	3
Albemarle Sound	6	9	On road or highway	2	3
Ocean	5	7	At fish house	1	2
In boat, docked	2	3	—	—	—
Other	1	1	—	—	—

(13%). Rates of injuries requiring external care (0.89 per 1000 work-days) or time off work (0.61 per 1000 work-days) were considerably less than the overall injury rate (table 3).

Crude injury rates were similar for on and off the water work (table 3). For injury events due to a specific fishery, the highest

injury rates were observed for finfish followed by other, shrimp, clam and crab. Crude injury rates were highest in January and April and lowest July through October (figure 1). Injury rates were higher for the Atlantic and Pamlico Sound and lower for rivers, Albemarle Sound and other sounds (table 3).

**Table 3** Stratified incident injury rates per 1000 work-days and 95% CIs for North Carolina commercial fishermen, 1999–2001 (n=217)

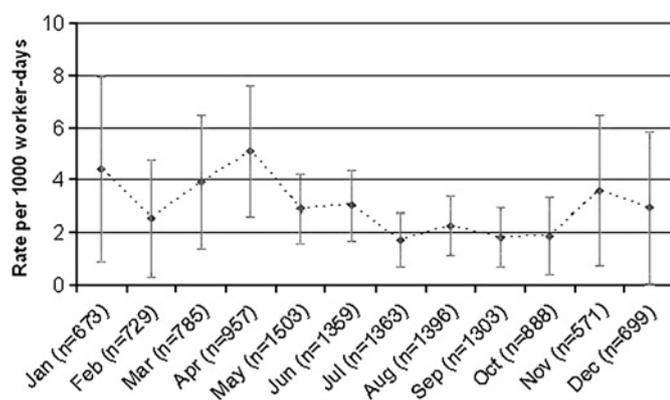
	Work-days	Injury events*	Crude rate per 1000 work-days	95% CI†
All fishing work	46153	125	2.74	2.19 to 3.41
Working on the water	36239	67	1.88	1.40 to 2.52
Working off the water	31424	58	1.93	1.44 to 2.58
By fishery‡				
Crab	16908	26	1.54	1.04 to 2.29
Finfish	10520	41	4.00	2.72 to 5.87
Clam	3727	9	2.16	1.01 to 4.61
Shrimp	2715	8	2.94	1.70 to 5.07
Oyster	429	0	—	—
Other‡	283	1	3.53	0.5 to 25.0
By location on the water				
Ocean	2917	11	3.77	1.54 to 6.00
River	13763	29	2.11	1.34 to 2.87
Albemarle Sound	6979	12	1.72	0.75 to 2.69
Pamlico Sound	10618	29	2.73	1.74 to 3.73
Other water area	8305	21	2.53	1.45 to 3.61
Injury severity				
Required external care§	46153	41	0.89	0.64 to 1.25
Required time off work	46153	29	0.61	0.37 to 0.98
Required medical care or time off work	46153	41	0.89	0.59 to 1.34

\*n=125 injury events, for a total of 142 injuries.

†n=40 injury events not attributed to a specific fishery.

‡Cell sizes too small for generalised estimating equations (GEE).

§External care includes any medical care or care from a co-worker, family or friend.



**Figure 1** Unadjusted monthly incident injury rates per 1000 work-days and 95% CIs, North Carolina commercial fishermen, 1999–2001 (n=217).

### Risk factors for injury

#### All injuries

After adjusting for age, season and history of time off work injury at baseline, results from multivariate analyses indicated that working on someone else's boat and maintenance work during the interview period were associated with an increased rate of injury (table 4). Glove use during the interview period was associated with a decreased rate of injury.

#### Injuries with time off work

For only 29 of the 125 injury events did fishermen lose a day or more of work. Controlling for season, age, gender and history of time off work injury at baseline, we observed increased rates for time loss injuries for working on someone else's boat (table 4). Glove use was a strong protective factor for these more severe injuries. We did not observe an association for maintenance work.

## DISCUSSION

In this cohort of North Carolina fishermen, the majority of injuries were penetrating wounds to the hand, wrist, thumb or

finger and back sprains or strains. For most of their injuries fishermen did not seek medical care or take time off work. Work exposures and injury risk varied by month/season with notable differences by fishery. The highest injury rate was observed for finfishing, while crabbing had the lowest rate. We also observed variability in the injury rate between fisheries and location. Overall, working on someone else's boat and weekly maintenance work were associated with increased rates of injury, and weekly glove use revealed a protective association.

This study described and characterised injury risks, regardless of severity, in a southeastern US small-scale fishing sector. Prospective weekly follow-up of fishermen resulted in more complete capture of events and person-time at risk—a difficult thing to achieve in any fishing population—enabling the calculation of injury rates by fishery, gear and location. Multivariate models controlled for confounders such as season, age and previous injury history.

It is difficult to directly compare these results to previous studies which reported hospitalised and/or compensated non-fatal injuries; however, the injury characteristics described here are comparable with previous studies of self-reported injuries. Hand and finger injuries<sup>8 16</sup> and back strains<sup>16</sup> were most common. A majority of injuries were due to working with fishing gear, a finding which is also supported in other studies.<sup>8 16</sup>

Our observed injury rate of 2.74 per 1000 work-days was higher than the 1.41 per 1000 man-days at sea observed in a retrospective cross-sectional study of Danish union fishermen.<sup>16</sup> While the injury definitions were similar between studies—both self-reported time loss and medical care injuries—the recall period from the Danish study was different from the one we used. Injuries and work days in the previous year were collected in a cross-sectional survey from Danish fishermen. As a result, some injuries may not have been reported and rates may represent more severe (and memorable) injuries. In the current study, rates for injuries requiring either medical care or time off work were lower (0.89 per 1000 work-days). Irrespective of recall period or injury severity, these rates are from different groups of fishermen; therefore, rates may represent exposure differences between the groups (eg, large vs small-scale, fishing method, fishing location).

**Table 4** Incidence rate ratios (IRR) and 95% CIs for North Carolina commercial fishermen, 1999–2001 (n=217)

	Any injury (125 events)				Injury with one or more days off work (29 events)			
	Unadjusted IRR (95% CI)	CLR	Adjusted IRR* (95% CI)	CLR	Unadjusted IRR (95% CI)	CLR	Adjusted IRR* (95% CI)	CLR
Sex								
Male (ref)	1.0	—			1.0		1.0	
Female	1.0 (0.6 to 1.8)	3.1	—		1.8 (0.7 to 4.8)	7.1	2.2 (0.9 to 5.6)	6.6
Age (years)								
<40 (ref)	1.0		1.0		1.0		1.0	
40+	1.6 (1.0 to 2.5)	2.5	1.7 (1.0 to 2.8)	2.9	2.5 (0.8 to 8.0)	10.1	2.8 (0.9 to 8.9)	10.2
History of time off work injury at baseline versus no history (ref)	2.0 (0.7 to 5.7)	8.3	1.5 (0.5 to 4.1)	7.7	5.0 (1.1 to 21.6)	18.9	3.8 (0.9 to 15.6)	17.3
Work on someone else's boat versus no work (ref)	1.3 (0.8 to 2.3)	2.9	1.4 (0.9 to 2.2)	2.6	1.6 (0.5 to 4.9)	9.8	1.2 (0.5 to 3.4)	7.4
Glove use during interview period versus none (ref)	0.6 (0.3 to 0.9)	2.7	0.7 (0.4 to 1.1)	2.6	0.2 (0.1 to 0.5)	5.5	0.3 (0.1 to 0.5)	4.1
Maintenance work during the interview period versus none (ref)	2.4 (1.6 to 3.7)	2.3	2.2 (1.4 to 3.5)	2.4	1.2 (0.4 to 3.2)	7.7	0.9 (0.3 to 2.7)	8.2
Season: April–October versus November–March (ref)	0.7 (0.5 to 1.0)	2.0	0.8 (0.6 to 1.1)	2.0	0.7 (0.3 to 1.5)	5.0	0.7 (0.3 to 1.6)	4.8

CLR, confidence limit ratio calculated by the upper confidence limit divided by the lower confidence limit.<sup>25</sup>  
\*Adjusted for all other variables in the column.

Repair work or work by the wharf was the second most common activity at the time of the accident after hauling the trawl among Swedish fishermen.<sup>10</sup> Injury rates were similar for work on and off the water, emphasising the importance of focussing injury prevention efforts on work in both locations. The proportion of injuries due to lifting and moving heavy objects and falling on a hard surface were also similar across locations. Off the water, a greater proportion of injuries were due to maintenance work compared to on the water (34% off vs 19% on water). Despite this absolute difference, injury rate ratios for maintenance work stratified by on and off the water were similar (RR 3.2, RR 2.3). Maintenance work for any injury was a risk factor, but not for time-loss injuries.

Roles of the crew—captain versus mate<sup>26</sup> and captain versus non-family or family crew member<sup>19</sup>—are important in determining the distribution of work tasks and risk of injury or musculoskeletal disorder. Differences in musculoskeletal symptoms and perceptions of work strain by job (skipper versus deck-hand) were identified among Swedish professional fishermen.<sup>27</sup> In this study, working on someone else's boat was associated with an increased risk of injury. This variable may serve as an indicator of crew status and/or the ability to customise the work environment. Fishermen who work on a boat that they do not own may need to work longer and harder, taking more risks, to cover use of the boat or pay shares to the owner. It may also indicate the tendency to work alone and with no crew member to share work tasks.

This study demonstrated a clear and consistent protective association between injury, regardless of severity, and any glove use during the week. We observed this effect in a previous case–crossover study examining triggers for hand injury.<sup>28</sup> Despite this protective association, penetrating injuries to the hand were the most common injury observed, many necessitating time off work, indicating that these injuries occur when gloves are removed or that current glove materials or practices do not provide sufficient protection. A survey of Spanish fishermen revealed that of the 57% who owned gloves, only 24% wore them regularly and 26% wore them when handling the catch.<sup>29</sup> We did not ask if participants were wearing gloves at the time of the injury, but we know from ethnographic interviews with commercial fishermen that gloves worn on the boats are comprised of thin latex and the occasional spine, pinch or bite penetrates the glove.<sup>18</sup> Since these injuries often result in infection and are a source of lost work time, they constitute a priority for future intervention. A study of French fishermen noted that the percentage of hand injuries decreased from 40% to 28% over a 17-year period and attributed this to better glove use and improved safety efforts in catch processing.<sup>3</sup> Clearly there is still room for improvement such as more resistant glove materials and better technology to decrease direct contact with the catch.

Previous time loss injury was strongly associated with subsequent time loss injury, and we controlled for this variable in our multivariate models. What does previous time loss injury mean for this population of fishermen? It could represent continuous, dangerous exposures or it could indicate the severity of the event. Fishermen are known for not taking time off or seeking medical care after injury.<sup>18 30</sup> As such, taking time off, when many can ill afford to, will only be considered in serious cases and increases the likelihood that fishermen will return to work before they should. Over-compensation or incomplete recovery could put the individual at risk for another similar injury to the same part or an injury to a different part. It is also likely that this variable represents the likelihood (or ability) of a particular fisherman to take time off. Previous time loss

injuries could also serve as a marker of exposure (eg, hours, pace, tasks, role on crew). Those with this history at baseline were less likely to be female (7.7% vs 13.6%) and more likely to be less than 40 years old (46.1% vs 37.4%). Beyond these demographic attributes, it is difficult to identify relevant baseline 'markers' of exposure since the both injury history and exposure variables were measured at the same time.

Worldwide, changes in the fishing industry have caused increased pressure for fishermen.<sup>31 32</sup> Changes in the North Carolina fishing industry since this study was conducted include: fish house closures, loss of water front access through sale and development (tourism), decreased landings and prices for some species, inflation in operation costs and regulation.<sup>33 34</sup> These changes have the potential to increase the frequency of high risk tasks such as manual materials handling. With access to the fish house from the water, fishermen had help loading and unloading. Without access to the waterfront, fishermen have to load bait and supplies into their truck, drive to their boat and transfer their supplies from truck to boat—and vice versa at the end of the day. Swedish fishermen perceived unloading as a high risk yet highly manageable activity.<sup>35</sup> Changes such as these greatly influence the degree to which such risks are manageable.

Changes in regulations also may have an impact on injury risk. For example, a new regulation in North Carolina prohibited the harvest of female crabs under 6.75 inches from September to April. Depending on the location of the fishing grounds and the number of female crabs, this increased the time handling the catch, increasing the potential risk for penetrating wounds to the hand. An efficiency study reported that more than 2 h were added to the average work day to comply with this regulation.<sup>36</sup>

### Strengths

The primary strength of this study lies in the prospective design enabling longitudinal ascertainment of outcomes and work-days at risk for calculation of injury rates. Cross-sectional surveys are subject to memory decay and assume uniformity of exposures over the time period of interest. Fishermen in this study provided injury and exposure details from a 7–10-day period, thus limiting recall bias.<sup>37</sup> Repeated assessment of time-varying exposures accounted for some exposure variability during the study period for fishery, gear, glove use and the performance of particular tasks such as maintenance work.

Detailed characterisation of all injuries, regardless of severity, was important in this population with limited access and propensity to seek medical care or take time off work. Data on work practices and equipment enabled us to relate a specific event and person-time at risk to the fishery or gear type used. Last, we were able to construct multivariate regression models controlling for the effects of important confounders.

### Limitations

Participant demographic characteristics are comparable to unpublished surveys of North Carolina commercial fishermen.<sup>34 38</sup> However, this study was conducted from 1999 to 2002 and may not account for subsequent changes in the industry such as decreased landings, fish house closures, new regulations or attrition of workers. This study comprised a small population, representing 3% of an estimated 7000+ fishing licence holders. It is not representative of crew members who do not have to be licenced. Previous studies have documented differences in occupational exposure and injury risks by crew status.<sup>19 27</sup>

This represents a volunteer cohort and there is a possibility of selection (volunteer) bias. Since participants were originally

enrolled for the PEAS study and not an injury study, we feel it unlikely to be biased towards injured fishermen. It is important to note, however, that the commercial fishermen who did participate were those able to commit significant time to attending clinic appointments and completing weekly telephone interviews.

Fishermen in this study completed an average of 56 telephone interviews (range 3–83) capturing an average of 66.1% of the eligible person-time (range 16.5% to 82.6%). Injured fishermen completed on average more interviews than uninjured fishermen (mean 60.8 vs 52.9), suggesting better follow-up for the injured. However, there was no difference in the percentage of eligible person-time captured by the interviews between injured and uninjured fishermen (67.3% vs 65.4%). It is possible that we may have missed some injury events due to incomplete follow-up, and therefore the absolute frequency of injury observed in this study may be underestimated. However, since time at risk would also be missed, the reported injury rates are less likely to be biased.

With only 217 fishermen and 125 injury events, we had limited power for our analyses as demonstrated by the wide confidence intervals. The unit of analysis was the interview week and some exposures overlapped (eg, fishery) or were assumed to be constant (eg, glove use) over the week. The rate ratios presented for fishery and fishing gear may not account for the effects of performing more than one type of work during the week.

Finally, we did not have weekly information on factors known to be associated with exposure and injury such as the presence of crew members, frequency of specific work tasks performed, measures of work intensity such as number of pots or nets pulled or pounds caught, weather or water conditions, and alcohol or drug use. We know from previous studies that weather and water conditions can increase risk for injury events through altered ship motions.<sup>39 40</sup>

## CONCLUSION

Similar types of injuries and risks were observed in small-scale independent fishermen as compared to large-scale fishermen, including penetrating wounds to the hand, wrist, fingers or thumb and back sprain or strain. For small-scale fishermen, off the water work locations were equally as important as on the water work locations. Current protective gear (gloves) may not be sufficient protection for certain activities. Changes in the industry may increase hazardous exposures and injury risk, and may need to be taken into account in interventions focused on proximal causes of injury.

Developing surveillance methods that capture non-fatal injury is a challenge, especially in the USA without universal healthcare coverage or unions or workers' compensation for small-scale, independent fishermen in particular. Even if there were, they would not capture the work and injury experiences for small-scale, independent fishermen. Although prospective cohort studies provide valuable and reliable information, they can be cost and time prohibitive and difficult to conduct. Therefore, cooperation between agencies, researchers and fishermen is especially important when conducting injury research in the small-scale sector.

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Kristen L Kucera, Dana Loomis, Hester Lipscomb, et al.

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