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Factors associated with crewmember survival of cold water immersion due to commercial fishing vessel sinkings in Alaska

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A B S T R A C T

Occupational fatality surveillance has identified that fishing vessel disasters, such as sinkings and capsizings, continue to contribute to the most deaths among crewmembers in the US fishing industry. When a fishing vessel sinks at sea, crewmembers are at risk of immersion in water and subsequent drowning. This study examined survival factors for crewmembers following cold water immersion after the sinking of decked commercial fishing vessels in Alaskan waters during 2000–2014. Two immersion scenarios were considered separately: immersion for any length of time, and long-term immersion defined as immersion lasting over 30 min. Logistic regression was used to predict the odds of crewmember survival. Of the 617 crewmembers onboard 187 fishing vessels that sank in Alaska during 2000–2014, 557 (90.3%) survived and 60 died. For crewmembers immersed for any length of time, the significant adjusted predictors of survival were: entering a life-raft, sinking within three miles of shore, the sinking not being weather-related, and working as a deckhand. For crewmembers immersed for over 30 min, the significant adjusted predictors of survival were: wearing an immersion suit, entering a life-raft, working as a deckhand, and the sinking not being weather-related. The results of this analysis demonstrate that in situations where cold water immersion becomes inevitable, having access to well-maintained, serviceable lifesaving equipment and the knowledge and skills to use it properly are critical.

1. Introduction

Fishing vessel sinkings present extreme survival challenges to those involved. When a fishing vessel sinks at sea, crewmembers are at risk of immersion in water and subsequent traumatic injuries or death. Cold water immersion can cause hyperventilation, muscle tension, reduced cognitive function, and swimming failure; leading to death from drowning or hypothermia (Golden, 1973; Cooper et al., 1976; Hayward and Eckerson, 1984). Among the challenges of surviving a vessel sinking are psychological stressors, which have been shown to significantly affect decision making and response abilities, impairing chances of survival (Singer, 1982; Leach, 2004). To overcome these extreme environmental and psychological factors, crewmembers must be prepared with effective survival equipment, knowledge, and skills. High levels of emergency preparedness have not always been ubiquitous in the US fishing industry, which may have contributed to the long history of deadly vessel sinkings. During 1982–1987, an average of 108 commercial fishing fatalities occurred annually in the United States, the majority of which were due to vessel sinkings (National Research Council, 1991).

The US fishing industry is not alone in facing cold water survival challenges when vessels sink at sea. Commercial fishing is recognized as an extremely hazardous occupation worldwide (Jensen et al., 2014). In Arctic and Nordic countries, fishermen are regularly exposed to the threat of cold water immersion (Jensen et al., 2014; Kaustell et al., 2016). Reducing the risk of exposure to cold water is relevant to the fishing industries of all northern nations.

Attempts to create safety standards for fishing vessels through federal legislation began in the 1930s, but were not successful until 1988 when the Commercial Fishing Industry Vessel Safety Act of 1988 (CFIVSA) was signed into law (Hiscock, 2002). The law required the US Coast Guard (USCG) to issue and enforce regulations for safety equipment and operating procedures on fishing vessels (USCG, 2009). Compliance with specific requirements of the law depends on the characteristics and activities of the particular vessel, such as the type and length of the vessel, area of operation, seasonal conditions, number of people on board, whether the vessel is federally documented or state registered, and the date the vessel was constructed or converted (USCG, 2009).

While the specific requirements of the CFIVSA vary based on individual vessel characteristics, in general the law requires most fishing vessels to carry survival equipment such as personal flotation devices

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(PFDs), immersion suits, life-rafts, throwable flotation devices, distress signals, emergency position indicating radio beacons (EPIRBs), and fire extinguishers (USCG, 2009). The law also requires certain fishing vessels to be equipped with high water alarms and bilge systems, and to conduct monthly emergency drills (USCG, 2009). The safety standards of the 1988 CFIVSA were implemented during the early 1990s and had a measurable effect on worker fatalities caused by vessel sinkings. The case-survivor rate for vessel sinkings in Alaska increased from 78% in 1991–1993, to 92% in 1994–1996, to 94% in 1997–1999 (NIOSH, 2002).

Worker fatalities due to vessel sinkings decreased during the 1990s because crewmembers had access to and knowledge of the use of the newly required lifesaving equipment, which increased their survival time after abandoning ship. However, the frequency of vessel disasters did not decrease during that decade, nor did fatalities due to falls overboard and onboard injuries (NIOSH, 2002; Lucas and Lincoln, 2007). These are not unexpected findings, since the CFIVSA focuses almost entirely on secondary prevention of death; that is, keeping workers alive in the water until rescue aid arrives.

As the marine safety regulations mandated by the CFIVSA were being developed, marine safety training organizations were also being established. In 1985, the Alaska Marine Safety Education Association in Sitka, Alaska was created with the initial objective of creating a standardized, hands-on, skill-based training curriculum for marine safety trainers throughout Alaska (Dzugan, 2010). At approximately the same time, the North Pacific Fishing Vessel Owners Association funded a safety training program in Seattle, Washington. These two programs continue to offer hands-on training in emergency skills including issuing mayday calls, EPIRB deployment and maintenance, immersion suit/PFD use and care, life-raft use, and use of flares (Dzugan, 2010).

Aside from the 1988 safety legislation affecting the entire US fishing industry, other fleet-specific safety programs have been established by the US Coast Guard to target high-risk fleets and associated hazards. The *At-the-Dock Stability and Safety Compliance Check* program initiated in the Bering Sea and Aleutian Islands crab fleet in 1999 was designed to ensure vessels were loaded in accordance with their stability instructions. This program contributed to a significant decrease in the number and rate of vessel sinkings and fatalities in the fleet (NIOSH, 2016). In another US Coast Guard safety initiative, freezer-longliners and freezer-trawlers operating in Alaska were enrolled in the *Alternate Compliance and Safety Agreement* (ACSA) beginning in 2006. This program addressed a variety of vessel safety issues, including stability and condition of the hull. The rate of serious vessel casualties decreased in both fleets after complying with ACSA requirements (Lucas et al., 2014). One final example involved the Dungeness crab fleet operating off the West Coast of the US, which has been repeatedly identified as a high-risk fleet with a high proportion of fatalities from vessel disasters (Lincoln and Lucas, 2010; Case et al., 2015). A voluntary program called *Operation Safe Crab* was developed in 2000 to address this issue by evaluating stability, watertight integrity, and lifesaving equipment on board (Hardin and Lawrenson, 2010).

Another source of potential hazard reductions in the fishing industry has involved modifications to fishery management plans, which are unique to each fleet and are designed primarily to prevent the depletion of the fish stock. Several experts have hypothesized that fisheries management plans may affect worker safety (FAO, 2016). The need for safety improvement is mentioned frequently when there is a proposal to implement quota-based fisheries management plans. Since 1990, several fisheries in Alaska have changed to this type of system. NIOSH has provided safety assessments of two of the most notable, the halibut/sablefish fleet and the Bering Sea and Aleutian Islands crab fleet. However, it is difficult to assess exactly how much the management plan change affected safety vs. other policies and changes the fleet experiences. For instance, NIOSH noted that a combination of Coast Guard programs (mentioned above), industry initiatives, and fishery management changes have improved crewmember safety in the Bering Sea and Aleutian Islands crab fleet which has experienced one fatality since implementation of the quota system (NIOSH, 2016). When NIOSH initially evaluated Individual Fishing Quotas (IFQs) in the halibut/sablefish fleet (Lincoln et al., 2007), the findings revealed a significant decrease in the rate of all fatalities in the fleet. However, a more recent review of the rate of fatalities over a longer study period did not reveal the same decrease. This suggests that while fishery management policies may have influenced safety initially, other factors may be responsible for the persistent hazards observed in the fleet.

While the number and rate of fatalities among workers in the US fishing industry have decreased somewhat over time (Lincoln and Lucas, 2010), commercial fishing remains one of the highest risk occupations in the US (Bureau of Labor Statistics, 2016). Occupational fatality surveillance has identified that vessel disasters, such as sinkings and capsizings, continue to contribute to the most deaths among crewmembers nationwide. During 2000–2009, 52% of deaths in the industry occurred during vessel disasters, and several Alaskan fisheries were identified as having relatively high numbers of fatalities from vessel disaster events (Lincoln and Lucas, 2010).

Previous studies investigating the determinants of vessel sinkings have found several factors influencing the probability of a disaster occurring or the severity of the disaster (in terms of vessel damage or crewmember injury), including the type of disaster, wind speed and other environmental conditions, season, vessel age, and operating distance from shore (Jin et al., 2001; Jin et al., 2002; Jin and Thunberg, 2005; Jin, 2014). However, no studies have examined survival factors of crewmembers immersed after a vessel sinking. Also, the previous studies of determinants of vessel disasters were focused on the northeastern US, and may not be generalizable to fleets in Alaska. The purpose of this paper was to identify survival factors of crewmembers immersed in cold water after vessel sinkings.

2. Methods

2.1. Case definition

This study examined crewmembers who experienced cold water immersion after the sinking of decked commercial fishing vessels in Alaskan waters during 2000–2014. If crewmembers were not at risk of immersion, they were not included in the study. Two immersion scenarios were considered separately: immersion for any length of time, and long-term immersion defined as immersion lasting over 30 min. The 30 min cut-point was chosen based on the results of the exploratory data analysis which showed that mortality increased sharply for immersion lasting more than 30 min. Crewmember survival was categorized as a binary outcome: survived or died. For the purpose of these analyses, crewmembers who were lost at sea (body not recovered) were presumed to have died.

Sinking events of decked commercial fishing vessels were included when the vessel was lost at sea. In addition, a small number of events were included in which the vessels capsized, crews abandoned ship at sea, and the vessels remained afloat or eventually ran aground (unoccupied) instead of actually sinking. Open vessels, such as setnet or seine skiffs, were excluded due to the substantial physical and operational differences between open and decked vessels. For instance, skiffs are typically less than 24 feet and operate very close to shore. Skiff operations are short-term, often limited to a few hours at a time. Skiffs do not typically carry life-rafts, EPIRBs, or immersion suits.

Groundings and fires, where vessels remained afloat, were not included in the analysis because of the decreased risk of crewmember immersion. A fatal sinking was defined as a sinking in which at least one crewmember died. A nonfatal sinking was defined as a sinking in which the entire crew survived.