



Preventing fatal winch entanglements in the US southern shrimp fleet: A research to practice approach



Jennifer M. Lincoln, * Chelsea C. Woodward, Grant W. King, Samantha L. Case, Devin L. Lucas, Theodore D. Teske

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

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ABSTRACT

Introduction: During 2000–2011, 35 injuries (8 fatal) involving winches were reported to the Coast Guard in the Southern shrimp fleet. Injuries involving the main winch drums had a higher risk for fatal outcomes compared to injuries involving the winch cathead (RR = 7.5; 1.1–53.7). The objective of this study was to design effective solutions to protect deckhands from entanglement hazards posed by winches found on the vessels in the Southern shrimp fleet. **Methods:** Based on injury characteristics, site visit observations, and input from vessel owners, NIOSH determined that the design and implementation of effective main-winch guarding was a feasible first-step in mitigating the entanglement hazard. Design considerations for stationary guards favor systems that are simple, affordable, durable, unobtrusive, and will not interfere with normal fishing operations. In addition, an auxiliary-stop method was tested to prevent entanglements in try-net winches. **Results:** Standardized passive guards were designed for three commonly found main winch models. Initial prototype guards have been sea-tested. The design of six additional guards is underway, for a total of three iterations for each winch model identified. These will incorporate features found to be valued by fishermen, will be more efficient, and will reduce the overall cost of fabrication and maintenance. Sea testing of these iterations continues. The auxiliary-stop circuit control prototype system was designed to prevent entanglements in the try-net winch and is currently being sea tested. **Discussion:** NIOSH has completed initial designs for stationary-winch guards. Through collaborations with shrimper associations and safety groups, the successfully tested winch guard and auxiliary stop designs will be made available to qualified welders and craftsmen to use. This approach has proven effective in preventing other types of winch injuries. **Practical applications:** Injury epidemiologic methods and industry input are an effective way to identify workplace hazards and to design effective safety interventions to control hazards.

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1. Problem

In August 2012, a 15 year old boy died when his clothing became caught in a rotating deck winch on a shrimp vessel in the Gulf of Mexico. This fatality received widespread press coverage and led to an epidemiologic investigation of winch hazards on shrimp vessels by the National Institute for Occupational Safety and Health (NIOSH) Commercial Fishing Safety Research and Design Program. NIOSH found that during 2000–2011, 35 injuries (8 fatal) involving winches in the southern shrimp fleet were reported to the United States Coast Guard (USCG). Injuries involving the main winch drums had a higher risk for fatal outcomes compared to injuries involving the winch cathead (RR = 7.5; 1.1–53.7). Fatal outcomes were also associated with being alone on the vessel (RR = 5.8; 2.1–15.9) (Centers for Disease Control and

Prevention [CDC], 2013). The findings highlighted the need for action to reduce the risk of entanglement on board fishing vessels.

Workers in the commercial fishing industry continue to have one of the highest occupational fatality rates in the United States, nearly 25 times higher in 2014 than the rate for all U.S. workers (Bureau of Labor Statistics [BLS], 2015). During 2000–2014, 693 fishermen were killed in the U.S. fishing industry, most commonly by drowning as a result of vessels sinking (344, 50%) and falls overboard (210, 30%). Another 12% of fatalities (81 deaths) were caused by injuries sustained onboard vessels, such as entanglement in machinery. Entanglement fatalities of deckhands in the United States occurred most often in the Gulf of Mexico (Commercial Fishing Incident Database [CFID], 2016). Additionally, NIOSH has shown that most (67%) severe nonfatal injuries occur on deck during the deployment and retrieval of fishing gear (Thomas, Lincoln, Husberg, & Conway, 2001).

Commercial fishing vessels are uninspected vessels. The U.S. Coast Guard (USCG) has authority over the safety of employees onboard these vessels. The Occupational Safety and Health Administration

* Corresponding author at: 4230 University Drive, Grace Hall – Suite 310, Anchorage, AK 99508, USA.

E-mail address: jxw7@cdc.gov (J.M. Lincoln).

(OSHA) only has jurisdiction out to three miles from shore and is precluded from enforcement with respect to working conditions regulated by other federal agencies. The USCG does have regulations requiring machine guarding (footnote), but the extent to which these are enforced is limited as evidenced by the lack of guarding on most deck equipment found on commercial fishing vessels.

The Southern shrimping fleet operates in the Gulf of Mexico and off the South Atlantic coast from Florida to North Carolina. A review of the literature found one other study that described entanglement injuries in the shrimp fleet. The study reviewed 19 patients who had been treated at a Texas hospital during 1986–2006, with injuries involving shrimp winches (Schroeder, Viegas, & Carmichael, 2008). All of the injuries were nonfatal, ranging in severity from crushed fingers to transhumeral amputations, and 17 of the 19 injuries were to the upper extremities.

To prevent these types of injuries, experts have recommended that vessel machinery be redesigned or retrofitted with safety features (Burgess, 2001; Husberg, Lincoln, & Conway, 2001). In 2005, NIOSH collaborated with the Northwest fishing industry to address the hazard of winch-related entanglements on fishing vessels that use a purse seine and a hydraulic capstan winch (Lincoln, Lucas, McKibbin, Woodward, & Bevan, 2008). An emergency-stop button located strategically on the winch was determined to be the most effective means for reducing the risk of winch entanglements posed by hydraulic capstan winches. The “e-stop” device was developed, tested, and licensed to a manufacturer for installation on new winches and for retrofitting on existing winches. A similar approach appears to be needed to develop viable prevention solutions to the hazards winches present on shrimp vessels.

The emergency-stop device created for capstan winches typically used in purse-seine fisheries, controls oil flow to and from a hydraulic winch motor (Lincoln et al., 2008). The emergency-stop circuitry when activated, arrests the oil flow which locks the capstan drums and prevents them from turning. However, hydraulically driven main winches for the shrimp fisheries are not widely adopted in the fleet due to cost limitations. NIOSH determined that this proven safety intervention for the Northwest capstan winches was not suitable for the mechanically-driven winches in use in the Gulf of Mexico shrimp fishery.

The objective of this study was to design effective solutions to protect deckhands from entanglement hazards posed by winches found on the vessels in the Southern shrimp fleet.

2. Background information on winches

There are two types of winches commonly used on commercial side-trawl shrimp boats to deploy and retrieve the nets; the main winch, and a try-net winch. To better understand the entanglement hazards associated with winch use, the following operation and physical descriptions are provided.

Side-trawl shrimp vessels typically employ multi-drum main winches mounted in the same frame located on the aft deck (see supplement, Fig. 1). These winch drums each wind a single wire rope that is bridled to multiple strands of wire cable that attach to the main trawl nets. The main winch drums are typically connected mechanically and are driven through a single power-take-off linkage system from the vessel's main engine. To engage or disengage the power to the main winch, one of two winch operators swings a bar or pushes a knobbed control cable. A cathead spool mounted on the end of each winch shaft spins when the power-take-off mechanism is engaged. Each winch operator is required to manually guide the retrieved cable evenly onto the drum with a pivoting lever. Guiding the cable requires the operator to exert considerable force pushing and pulling the pivoting lever. Typically, inadequate or no machine guards are present to prevent the worker from falling into or becoming entangled in moving machinery or the cable.

A smaller winch, the try-net winch, is similarly located on the aft deck under the house roof and adjacent to the main-winches. The try-net winch spools a lighter wire rope that drags a small net used to sample the expected catch of the main trawls (see supplement, Fig. 2). Unlike the longer retrieval frequency interval of the main winches, the try-net winch is used to check the small trawl net every 20 to 30 min while the larger trawl nets are out. The catch in the small net provides an estimate of what the larger trawl nets may contain. A try-net winch is commonly driven by an electric motor, whereas the main winch drums are mechanically driven. The electric motor start/stop controls for the smaller winch are ordinarily mounted above the winch on the house roof (see supplement, Fig. 3). The main shaft of the try-net winch also has a cathead solidly mounted. The operator stands near the winch and reaches up to the winch motor controls mounted on the house roof to switch the electric motor on. The try-net main shaft and cathead spin whenever the motor is energized. The operator partially rotates a clutch arm to engage the try-net winch spool to the spinning shaft and starts the wire rope to be retrieved. While the clutch arm is maintained engaged, the operator pivots a bar that has captured the wire rope to wind the line evenly onto the spool. The clutch and level-winding operation is similarly used in the operation of the main-drum winches. To turn off the power to the try-net winch, the operator again stands near the spinning cathead to reach the control switch mounted on the house roof.

3. Methods

This study identified ways to reduce the risk posed by these two types of winches commonly used on commercial side-trawl shrimp boats, the main winch and a try-net winch.

3.1. Design for stationary guards for the main deck winches

Since the main deck winches are associated with fatal injuries, the initial focus of the project was to design effective guarding for the main deck winches. Utilization of machine guarding, similar to that used in other industries, would reduce the risk of worker entanglement. Design considerations for stationary guards favor systems that are simple, affordable, durable, unobtrusive, applicable to various winch models, will not disable other vessel functions, nor interfere with normal fishing operations.

In the Fall of 2013, NIOSH awarded a contract to Tool Inc. of Marblehead, MA to conduct a dockside survey of side-trawl shrimp vessels to identify the three most common main winch types and to design standardized passive guards for each type.

The first iteration of the passive guard designs for each of the three models were then built and tested at sea. These sea trials were performed on working commercial shrimp boats. Owners and crewmen working on these subject vessels provided ongoing evaluations of design features that they saw as beneficial, as well as those features that proved to be cumbersome, non-robust, or interfered with fishing or maintenance operations. The information collected during sea trials was then used to improve the second design iterations of prototype guarding.

3.2. Design for auxiliary stop for the try-net winch

NIOSH engineers considered multiple safety interventions to prevent entanglements, and to reduce the severity of injuries while operating a try-net winch. The try-net winch motor start/stop controls are mounted on the house roof so workers cannot reach the controls to shut down power to the winch if entangled. The severity of injury to an entangled worker would be reduced if the power to the winch could be readily turned off. The development of an emergency-stop device required retrofitting an electric braking system on the winch motor

and placing an alternative control switch on the winch frame within reach of the victim.

4. Results

4.1. Design for stationary guards for the main deck winches

A survey of 103 boats was conducted in Louisiana and Mississippi. The three most common main winch models were the McElroy-Catchot models 505 and 503 and the Stroudsburg model 515 1/2T. Neither manufacturing company is currently in business (see supplement, Figs. 4, 5, 6).

With assistance from the USCG, NIOSH identified vessel owners to test the first three guard designs, one for each type of winch. Three working side-trawl shrimp vessels were chosen as test vessels operating out of Dulac, LA, Port Arthur, TX, and Chauvin, LA.

The guard designs were refined using structural analysis software. The structural material choice was marine grade aluminum chosen for its strength and lightness. Expanded metal grating was incorporated into the design to protect the worker from the spinning winch drums, yet allow viewing of the winding wire rope. Cast aluminum connectors were used in the design to reduce fabrication costs. Mounting gaskets of high-density polyethylene (HDPE) were used to separate the aluminum guard from the mild steel winch frame and from expanded metal grating.

The first guard prototype for the Stroudsburg 515 1/2T winch was fabricated and installed in July 2014 (see supplement, Fig. 7). The second prototype guard was installed on a McElroy-Catchot 505 winch in October (see supplement, Fig. 8). The third guard installation was completed on a McElroy-Catchot 503 winch in late November (see supplement, Fig. 9). The installations were organized as not to interfere with the fishing schedules of the working test vessels. This requirement added a burden to the coordination of the fabrication and installation schedules.

The captains and crews evaluated the performance of the first set of guards. Consistently, complaints were received that the cast aluminum connectors were quickly failing. Upon inspection, NIOSH engineers found that the set-screws used to clamp the connectors to the aluminum pipe were corroding. Though specified to be stainless steel and coated with an anti-seize compound, the set screws used were made from hardened alloy steel. The galvanic corrosion from the contact of dissimilar metals, saltwater environment, and warm temperatures accelerated the joint failures. The captains and crews also did not like the added maintenance required for the expanded metal top grate used in two of the first designs. The top-mounted fiberglass grate used on the McElroy-Catchot 503 winch was a desired feature. The arched guard rails over the catheads on this winch received praise, as they provided a sturdy place to grab onto when the deck was pitching from heavy seas.

Due to the specificity of the winch models, the single guard prototype for each model proved inadequate to refine the individual guard plans. A new contract was awarded in 2015 for the design of six additional guards, for a total of three iterations for each winch model identified. The following designs incorporated features valued by the fishermen, maintained the efficiency of the guard, and reduced the overall cost of fabrication and ongoing maintenance.

For the second design iteration of guarding, 304 stainless tubing and 18-8 stainless mounting hardware were specified as they cause minimal galvanic corrosion. The wall thickness of the tubing was reduced to make bending the framework components easier during fabrication. Fiberglass grating is readily found in use in fish holds in the fleet. The metal grating from the first design was replaced with the low maintenance fiberglass grates. Gaskets of HDPE were still used as a barrier between the mild steel winch frame mounts and the stainless steel guards.

In March 2016, the second design iteration guard designs for the McElroy-Catchot 505 and the Stroudsburg 515 1/2T winches were

installed. These guard designs were influenced significantly by the first version of the McElroy-Catchot 503. A metal plate located between the drums and cathead spools had restricted maintenance access and was replaced by arched rails on the McElroy-Catchot 505, and the expanded metal top was replaced with fiberglass grating (see supplement, Fig. 10). The Stroudsburg 515 1/2T winch guard also incorporated a modified arched rail placed between the catheads and main drums. This design eliminated acute angles on the guard that the workers may grab. Fiberglass grating also replaced the open top (see supplement, Fig. 11). Improvements have been made to the second design of the McElroy-Catchot 503 winch, but to date, a partner boat has not been identified to participate in sea testing.

Sea testing of the guards for the second and third designs is presently underway (at publication date), as additional partners and vessels are solicited. NIOSH will continue to seek collaborations with partners widely dispersed throughout the Gulf of Mexico and the southern Atlantic coast to test the guarding.

4.2. Try-net auxiliary-stop

This prototype system was designed to allow a victim of a try-net winch entanglement to shut off electrical power even if they are caught in the retrieving line. The system consists of one or two bumper-type switches mounted on the winch frame, and a circuit box that interfaces with the existing winch motor-controls (see supplement, Fig. 12). The prototype is not an emergency-stop device that will arrest the momentum of the drum, but an auxiliary-stop device used to de-energize the winch motor. As stated, try-net winch controls are commonly mounted to the house roof out of reach of a victim. A switch mounted on the winch frame provides an entangled victim closer proximity and accessibility to the means to stop winch power. The bumper switch can be struck with a nominal 10 lb (44 N) of force anywhere along its length to shut off power to the winch motor (see supplement, Fig. 13). Switches can be configured in multiple lengths. Considering the winch frame size, NIOSH engineers chose 10 in. and 12 in. models to test for reliability in the harsh environment. Configurations of one and two bumper switches were tested on three separate try-net winches (see supplement, Fig. 14). The auxiliary stop circuitry interrupts the existing electro-magnetic motor circuit controlling the breakers. It functions the same way as the motor-controller stop switch and once the bumper switch is struck, winch power can only be turned on through the existing motor-controller start switch. During the testing phase, a temporary means to by-pass the prototype auxiliary-stop circuit was implemented. A failure in the prototype would not prevent the crew to continue fishing. This by-pass was added as assurance to the vessel owner that if the prototype circuit failed during shrimping operations, the crew could readily by-pass the prototype circuit being evaluated. Fishing crews have not reported a circuit failure that necessitated the use of this feature.

Try-net winch auxiliary-stop circuits have been installed on boats in Chauvin LA, Port Arthur TX, and in Brownsville TX. The first installation was in December 2013, the next in April 2014, and the last in March 2015. Prior to installing the auxiliary-stop device on the boats, upgrades to their existing winch motor-controls were needed. The harsh saltwater environment and heavy use of the winches contributed to the wear on electrical components. The auxiliary-stop device circuit has worked as intended.

Bumper switches designed for industrial use were chosen to test proof-of-concept of the prototype circuit, after confirming their resistance to deterioration from ultra-violet light and their water-tightness. Initially, powder coated mild steel angle iron brackets were used to mount the auxiliary stop bumper switches. Due to the harsh marine environment and extreme working conditions, the powder coating would get chipped and corrosion would begin immediately. This mounting bracket material was changed to 304 stainless steel angle iron, which eliminated the noticeable corrosion.

Switch components tested have met with some apparent failures. It is unclear without further testing if intermittent reliability can be attributed to the salt water environment or switch manufacturing quality control. The condition of the try-net winch prior to the installation and testing of the prototype circuit has been a contributing factor for intermittent failures. Further testing on additional vessels will help determine the reliability of the components and if the failures are due to introduced factors or existing system wear and deterioration. Refinements to the auxiliary-stop prototypes will be made based on the feedback from the fishing crews.

5. Discussion

Installing robust stationary guarding and an auxiliary-stop system are effective solutions to reduce the risk of entanglement injuries. Both safety interventions should be implemented in the future to reduce the chance of entanglement and to reduce the severity of injuries if an entanglement occurs.

Winch entanglements cause traumatic brain injuries, amputations, and death each year in the commercial fishing industry (CFID, 2016). There are at least 80,000 U.S. commercial fishing vessels with exposed machinery posing hazards to deckhands (National Research Council, 1991). The target population of this study is the Southern shrimp fleet comprised of an estimated 5,237 vessels (National Marine Fisheries Service, 2013).

Our study has identified effective ways to control the hazards that main deck and try-net winches pose to deckhands on-board shrimp vessels by stationary guards and auxiliary-stop switches. The owners of shrimp vessels typically repair deck machinery rather than replace it. We discovered that manufacturers of commonly used winches are no longer in business. Though some aftermarket replacement components are available, salvaged parts from decommissioned vessels are frequently used.

The completion of guard design section of the winch safety study will end after the third iteration is vetted in the field.

This project will provide engineered drawings, fabrication plans, and installation guides for engineered stationary guards for main deck winches as well as auxiliary-stop designs for try-net winches to be installed in shipyards by welders and craftsmen qualified to make safety modifications to reduce hazards posed by deck winches. The guards will either replace less effective and substandard guarding, or be the first guards installed on the winches. The auxiliary-stops will be the first sort of control applied to try-net winches. The next phase of this project will focus on incentives for adoption and installation.

6. Summary

After identifying deck winches as hazards on shrimp vessels in the southern United States, NIOSH completed initial designs for stationary guards for the three most commonly used main deck winches in the Southern shrimp fleet. An auxiliary-stop device has also been designed and tested as an alternate means to shut off power to the try-net winch. Through collaborations and partnerships with shrimper associations and safety groups, the successfully tested stationary guard and auxiliary stop designs, including material specifications and estimated building costs, will be made available to be used in the shipyard. This information will be available in English, Spanish, and Vietnamese to better reach this culturally diverse fishing fleet.

7. Practical applications

Injury epidemiologic methods and industry input are an effective way to identify workplace hazards and to design effective safety interventions to control hazards. This approach has consistently proven effective in providing tools to prevent winch injuries on commercial fishing vessels.

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Jennifer M. Lincoln is the Associate Director for Science for the Western States Division, National Institute for Occupational Safety and Health (NIOSH). She is also the Director of the NIOSH Center for Maritime Safety and Health Studies. Dr. Lincoln received her PhD from Johns Hopkins University, is a CAPT in the US Public Health Service and a Certified Safety Professional (CSP). She is an advocate for providing strong science to improve safety in the work-place. She has authored numerous journal articles and is regularly consulted regarding marine safety issues.

Chelsea C. Woodward studied at Wenatchee Valley College and at Gonzaga University. He has worked as an electrical engineering contractor for the U.S. Bureau of Mines at the Spokane Research Center, and presently with the National Institute for Occupational Safety and Health, Western States Division. His professional emphasis at NIOSH has been in developing mechatronic safety systems, motion control and semi-autonomous system designs and applications, hydrogen-fueled vehicle safety systems and gas monitors, data acquisition controls and sensor networking formally focusing on the mining sector and currently designing safety interventions to serve commercial fishermen.

Grant W. King attended Colorado School of Mines and graduated with a BS in Mechanical Engineering. He has been doing health and safety research for the last 24 years at the Spokane Research Laboratory focusing on innovative guarding methods, wirelessly monitored guarding, and automated safety interventions. He has been with the NIOSH Commercial Fishing Safety Research and Design Program for the last three years. Currently, he is working on stationary guarding for commercial shrimping winches, auxiliary-stop systems for electric try-net winches, lazarette and slack-tank monitoring, and winch cathead guarding interventions.

Samantha L. Case is an epidemiologist at the National Institute for Occupational Safety and Health, Western States Division in Anchorage, AK. She received her Master's in Public Health from the University of Alaska Anchorage. Ms. Case works in the commercial fishing safety program and conducts surveillance of fatalities and vessel losses in the U.S. fishing industry. She is also the Assistant Coordinator for the Center for Maritime Safety and Health Studies.

Devin L. Lucas is an epidemiologist at the National Institute for Occupational Safety and Health, Western States Division, Alaska Office. He has worked for 10 years on research applying epidemiologic methods to identify and characterize occupational hazards in the U.S. fishing industry and to develop, test, and promote injury prevention solutions. Dr. Lucas earned his doctorate degree in public health from Oregon State University.

Theodore D. Teske is a health communication specialist for the NIOSH Western States Division. He began his career at NIOSH in 1999, developing safety training videos for the mining industry while earning his BA in Broadcasting from Gonzaga University. He received his MA in Communication and Leadership from Gonzaga in 2008. Ted is focused on improving the research to practice efforts and looks for innovative ways to engage workers to participate in and adopt the results of NIOSH research. His research interests include technology transfer and adoption, qualitative research methods for field research, and organizational and cultural communication.