Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

MARINE INVESTIGATION REPORT M16A0115

Deck crane failure and fatality

Unregistered aquaculture vessel
Milligan's Wharf, Prince Edward Island
29 April 2016

Canada

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Le présent rapport est également disponible en français.

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Summary

On 29 April 2016, at approximately 1035 Atlantic Daylight Time, a small vessel was engaged in aquaculture operations 1 nautical mile east of Milligan's Wharf, Prince Edward Island, when the operator was fatally injured by the vessel's crane. The operator was working below the elevated boom of the crane when its hydraulic cylinder piston rod fractured, causing the boom and attached rigging to fall and strike his head, resulting in immediate death.

Le présent rapport est également disponible en français.

Factual information

Particulars of the vessel

Name of vessel	Unregistered aquaculture vessel
Registry/License number	Unregistered
Type	Barge
Built	2016, Poplar Grove, Prince Edward Island
Length overall	8.5 m
Draft (at time of the occurrence)	15 cm
Propulsion	37.3 kW, gasoline outboard motor
Crew	2
Registered owner/manager	Five Star Shellfish Incorporated

Description of the vessel

The aquaculture vessel was a self-propelled aluminum barge with a shallow draft and an enclosed double-bottom void space (Figure 1). It was constructed at a local welding shop for the purpose of transporting oysters to and from lease sites and maintaining oyster-growing equipment. The main deck extended from the stern to approximately 50 cm aft of the bow. The controls for the steering, propulsion, and crane were located approximately 1 m aft of the bow on the starboard side. Propulsion power to the vessel was a gasoline 4-stroke outboard motor. There were 2 freeing ports[1] fitted in the transom.

Figure 1. Aquaculture vessel

A crane was fitted adjacent to the steering location on the centreline of the vessel. Its base was positioned approximately 1.2 m inboard from the steering, propulsion, and crane hydraulic controls. Hydraulic power to the crane was supplied via a hydraulic pump that was powered by a separate gasoline motor fitted on the stern. Hydraulic pipework under the port side gunwale, which powered the crane, ran from the pump to the hydraulic crane controls that were located just forward of the steering station. A gasoline-powered wash-down pump and attached hose were fitted on the port side gunwale approximately 2.5 m from the stern. The vessel and the attached crane had been in use for approximately 2 weeks prior to the occurrence.

[1] Freeing ports are designed to shed water that is shipped onto the main deck.

Design and construction of the vessel and crane

The crane and the vessel had been constructed at a local welding shop. The owners provided verbal instructions to the shop owner to design a crane-and-vessel package that was similar to the package they had purchased 2 years before from the same shop, but that was capable of lifting heavier equipment. The builder therefore used heavier components for the construction. The vessel was built without the use of a lines plan or engineered drawings and was not inspected during construction or assessed for stability. Following its construction, it was not inspected, certified, or registered with Transport Canada (TC). It was not fitted with any navigational lights.

The crane was constructed without the use of any plans, drawings, or other pre-set engineering specifications and was put into service without formal testing. The crane that was first built on the other vessel had been in service for 2 years without any known malfunctions.

The crane was capable of lifting oyster storage containers weighing between 500 and 1000 kg, as well as performing maintenance operations on oyster-growing equipment. It was a hydraulically powered knuckle boom–type crane with an articulated arm (Figure 2). The arm was attached to a vertical member (king post) that could rotate about its vertical axis at the base and 2 hydraulic cylinders (lower and upper) that provided the arm linkages with horizontal and vertical motion. The lower hydraulic cylinder was connected to the king post and the lower boom arm. The hydraulic cylinder was designed to lift 13 092 kg (28 863 lb) at 20.68 megapascals (MPa) (3000 pounds per square inch) maximum working pressure.

Figure 2. Crane on the aquaculture vessel (parts identified)

Legend
A King post
B Articulating arm, lower boom arm
C Hauler
D Location of the steering, engine, and hydraulics controls

History of the voyage

On 26 April, the aquaculture vessel departed from the processing plant at approximately 0815[2] with 2 crew members on board: the operator and the deckhand. The vessel travelled approximately 100 m to a company-leased aquaculture site to raise and load 2 submerged oyster storage containers, each weighing approximately 680 kg, using the crane, and transport them back to the processing plant (Figure 3).

After the containers at the plant were unloaded using the crane, the vessel travelled approximately 1 nautical mile to another company-leased aquaculture site. At this site, the crew conducted maintenance on submerged oyster cages and buoyancy devices. First they used the crane and its attached hauler to retrieve and raise the submerged cages (Figure 4).[3] The buoyancy devices were then drained, and plugs were installed to float the cages until the fall season (Figure 5).

Figure 1. Oyster storage container about to be transported to another company vessel

2 All times are Atlantic Daylight Time (Coordinated Universal Time minus 3 hours).

3 In the fall, the plugs on the buoyancy devices are removed to allow the oyster cages to sink to the sea bottom for the winter to prevent damage from ice.

Figure 4. Oyster cages being lifted

Figure 5. Oyster cage securing lines, including the attached unsubmerged main line (the main line is normally submerged, but is exposed when lifted during maintenance operations)

After the crew completed the maintenance and reached the end of 1 main line of cages, they became aware that the securing lines of 1 of the cages were tangled in the main line. The operator returned to the tangled cage and raised the boom of the crane (which was not suspending a load) up to its full elevation so the attached hauler would be out of the way, allowing the operator to work under it while untangling the lines. The operator reached over the side of the vessel to untangle the lines while explaining the procedure to the deckhand. At approximately 1035, before the operator could stand upright after completing his task, the

lower hydraulic cylinder piston rod fractured, causing the boom to free fall and the attached hauler to strike the operator's head, resulting in immediate death.

The deckhand operated the steering and propulsion controls to navigate the occurrence vessel toward another company vessel working nearby. Upon arrival at the other company vessel, a crew member from that vessel relieved the deckhand on the occurrence vessel and navigated it back to the processing facility. At that time, an emergency call was placed and the police were notified.

Meteorological conditions

The weather was clear and sunny, with winds from the north-northeast at 8 knots.

Damage to the vessel

There was no damage to the vessel. The on-board crane's lower hydraulic cylinder (Figure 6) failed when the extended piston rod fractured.

Owning company

The owning company had been in business for 16 years as a molluscan shellfish processing facility. They had a full-time staff of 10 to 12 people who process oysters, quahogs, and soft/hard shell clams located on a section of Milligan's Wharf in the Conway Narrows area of Prince County, PEI.

Vessel registration

Although the aquaculture vessel was a small commercial fishing vessel required to be registered with TC, it was not registered. As the vessel had a gross tonnage of less than 15, according to Part II of the *Small Fishing Vessel Inspection Regulations* (SFVIR), it would not have been required to undergo inspections by TC or be assessed for stability.[4]

Personnel certification

The operator of the crane and the occurrence vessel had 30 years of experience in the fishing industry, fishing lobster and oysters. For 16 years, the operator was part owner and manager of the owning company. He had Marine Emergency Duties training. The operator was exempt from the obligation to hold the Small Vessel Operator Proficiency training certificate because he had declared to have at least 7 fishing seasons as master of a fishing vessel of up to 15 gross tonnage or not more than 12 m in length overall.

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[4] Only large fishing vessels (less than 3% of all active fishing vessels in Canada), vessels fishing herring and capelin, or vessels that have made modifications or have changed their operation are required to undergo stability assessments. However, TC places the responsibility on all fishing masters to ensure their vessel has and maintains adequate stability.

The deckhand was new to the fishing industry, and it was his first fishing season employed with the company. He had no formal relevant training or any type of marine certification.

Neither the operator nor the deckhand was certified to operate a crane or had taken any formal crane operation training.

Failure of the hydraulic cylinder piston rod

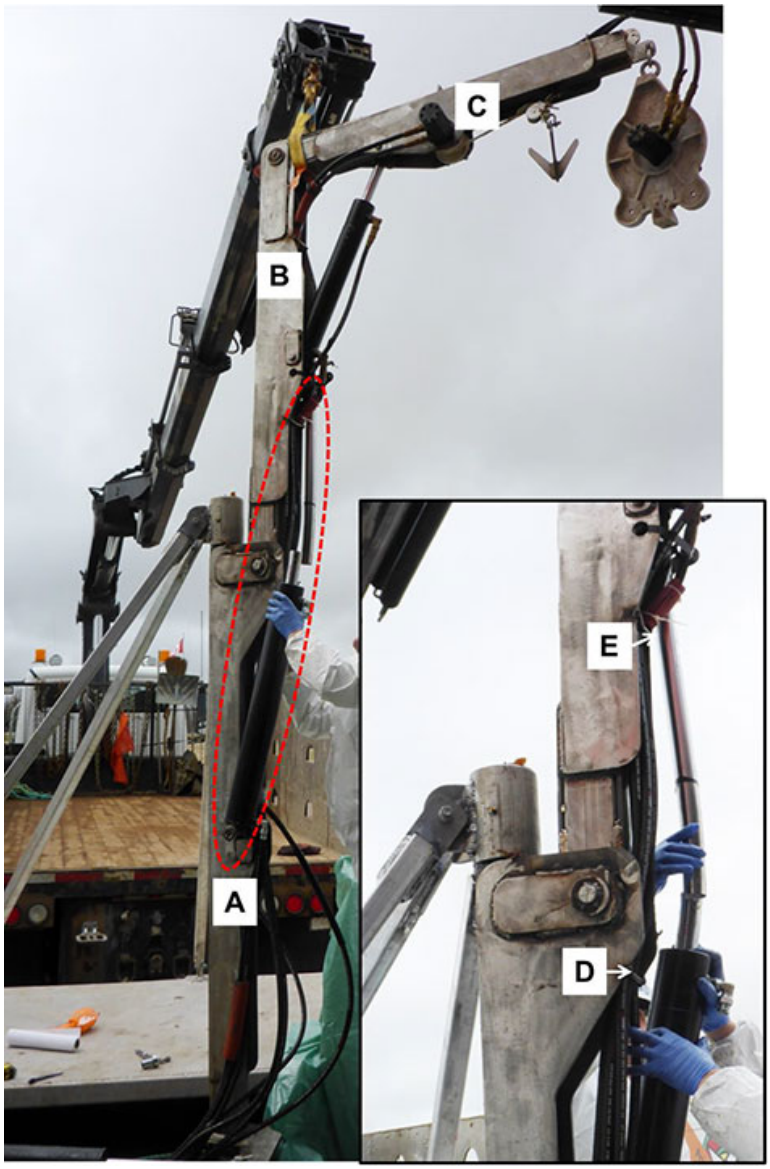
Laboratory testing indicated that the individual lower hydraulic cylinder and piston rod parts met the manufacturer's specifications.[5] The only exception was the hardened layer of the rod; the thickness of this layer was only slightly below the rod manufacturer's specifications and was determined not to be contributory to the piston rod failure.

The knuckle boom crane that was on board the vessel is pictured in Appendix A. The crane had a hollow metal U-shaped body, and the boom was raised and lowered by way of a hydraulic cylinder affixed to the lower segment of the crane body. The hydraulic cylinder consisted of an exterior casing with an interior piston and attached rod. The piston rod could extend and retract through a seal in the exterior casing. There were also 2 tie rods installed on the crane: 1 on the lower segment of the crane body and 1 on the first section of the knuckle boom. These tie rods were welded on to hold the hydraulic hoses within the crane body and increase its rigidity.

Further measuring and testing determined that when the boom of the crane was at its maximum height, the piston rod was prevented from fully extending because the fully extended rod was approximately 1 inch longer than the space available within the confines of the crane body: the mechanical stop within the piston did not limit the rod's extension to the available space. Additionally, the 2 tie rods (D and E in Figure 6) restricted the path that the hydraulic cylinder and rod could travel when the boom was being raised or lowered, resulting in side loading of a sufficient extent to cause the permanent bending of the piston rod into a half-moon shape. These 3 factors resulted in an overstress of the piston rod, causing it to buckle and eventually fracture.

5 TSB laboratory report LP112/2016, section A-3.5.6.

Figure 6. Crane and broken hydraulic cylinder shown in situ



Legend

A	King post
B	Lower boom arm
C	Upper boom arm
D and E	Tie rods

The fractured hydraulic cylinder piston rod had scoring and discoloration that indicated the rod had experienced bending on previous lifts when the crane boom was fully raised. Operation of the hydraulic cylinder with a bent piston rod resulted in damage to the piston rod's chrome plate and to the rod bearing.[6] Over time, surface cracks formed in the piston rod's chrome plate, some of which extended into the induction-hardened layer underneath. Loading analysis indicates that the bending stress applied to the bent piston rod is close to

[6] A rod bearing is a circular guide, commonly made of bronze, located within the cylinder body. The bearing is used to guide the piston rod as it extends.

the material's ultimate tensile strength.[7] Eventually, the combined effect of the applied bending stress and stress concentration from the previously formed surface cracks exceeded the fracture strength of the piston rod, and it broke in brittle bending overload.

The investigation determined that the bending of the rod would have been difficult to detect visually unless the crane was in its fully extended position.

Crane standards

Numerous certification standards are relevant to the cranes, hoisting, and rigging industry:[8] for example, CAN/CSA-Z150.3-11: *Safety code on articulating boom cranes*, which is not mentioned in the Workers Compensation Board of Prince Edward Island (WCB PEI) *Occupational Health and Safety Act General Regulations*, or CAN/CSA-Z150: *Safety code on mobile cranes*, which is mentioned in the WCB PEI *Occupational Health and Safety Act General Regulations* and specifies the requirements for the design, construction, installation, inspection, testing, maintenance, and operation of mobile cranes. However, neither of these standards, nor any other national standards, applies specifically to cranes, of the same type as in this occurrence, that are mounted on a vessel.

Prince Edward Island Occupational Health and Safety Act *and* General Regulations

WCB PEI is a Crown corporation[9] charged with overseeing the implementation and application of the Prince Edward Island *Occupational Health and Safety Act* (PEI OHS Act). WCB PEI's mission is to protect workers and employers through a sustainable, no-fault injury insurance program by caring for injured workers, promoting safe and healthy workplaces, and enforcing safety legislation.

The PEI OHS Act directs WCB PEI on the administration of workplace safety legislation. The PEI OHS Act, as well as the *General Regulations*, describes the minimum standard of occupational health and safety for workplaces in Prince Edward Island. Fishing vessels are recognized as workplaces under the PEI OHS Act as of 2000.

Cranes

Regarding cranes, or hoisting apparatuses, as they are called in the PEI OHS Act *General Regulations* and WCB PEI *Aquaculture Safety Code of Practice*, the responsibility for the inspection, safety, and maintenance of the apparatus in question rests with the employer.

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7 TSB laboratory report LP112/2016, section 3.4.3.

8 Standards Council of Canada, *Standards Referenced in Canadian Regulations for the Hoisting and Rigging Industry* (August 2014), at https://www.scc.ca/en/hoisting-rigging-report (last accessed on 02 August 2017).

9 G. Welton, "Workers Compensation Board of PEI staff structure," *The Employment Journey on PEI*, at http://employmentjourney.com/workers-compensation-board-of-pei-staff-structure (last accessed on 02 August 2017).

According to the *General Regulations*, the employer "shall ensure that hoisting apparatus is designed, installed, erected, checked, examined, inspected, operated and maintained in accordance with the appropriate C[anadian] S[tandards] A[ssociation] Standard."[10] However, none of the standards listed in the *General Regulations* applies specifically to cranes mounted on a vessel.

The *General Regulations* also specify that the employer

> shall designate a competent person to thoroughly inspect and test hoisting apparatus including safety devices
>
> (a) before it is first put into use;
>
> (b) once a month;
>
> (c) after any happening involving the hoisting apparatus which could have damaged some part of the apparatus.[11]

The employer must also ensure that "a log book recording inspections and repairs is maintained."[12] In terms of the worker's responsibility, the *General Regulations* specifically require that the operator [of the hoist]

> (a) visually inspect the hoisting apparatus before use to verify that it is in safe working order;
>
> (b) move a load only on a signal from a signaller (…);
>
> (c) raise a load vertically or, if necessary to raise a load obliquely, take precautions to avoid endangering employees;
>
> (d) avoid carrying a load over employees;
>
> (e) not leave a suspended load unattended.[13]

The crew did not visually inspect the crane before its use to verify that it was in safe working order.

Personal flotation devices

The *General Regulations* of the PEI OHS Act do not have specific requirements for work taking place on board fishing vessels: for example, the *General Regulations* do not require fishermen to wear personal flotation devices (PFDs) while working on deck. The Prince Edward Island *Fall Protection Regulations* require that

> [w]here a worker is exposed to the hazard of falling from a work area and there is a risk of drowning if the worker does fall, the employer shall

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10 Workers Compensation Board of Prince Edward Island, *Occupational Health and Safety Act General Regulations*, subsection 34.2(2).

11 Ibid., subsection 34.5(2).

12 Ibid., subsection 34.5(3).

13 Ibid., subsection 34.6(3).

> (a) provide to the worker a personal floatation [sic] device where the work area is less than 3 m above the surface of the water;
>
> (b) provide rescue equipment that includes
>
> (i) an adequate boat to ensure a safe and timely rescue,
>
> (ii) a life buoy attached with 15 m of rope that is at least 10 mm in diameter and that is made from polypropylene or other material that provides an equivalent level of protection,
>
> (iii) a boat hook,
>
> (iv) an audible alarm system to notify of an accident.[14]

These regulations are written with shore-based workplaces in mind and are not applied to fishing vessels in Prince Edward Island.

Transport Canada regulations

TC manages the registration and inspection of vessels in Canada and provides regulations to improve the safety of the vessels and operators. Inspections may be conducted by TC or a representative that TC has authorized. In this occurrence, the vessel was unregistered. The vessel was not required to be inspected by TC under the SFVIR, nor was the crane on board required to be inspected under the *Cargo, Fumigation and Tackle Regulations*.

Personal protective equipment

With the exception of gloves, the 2 crew members on board the vessel were not wearing any personal protective equipment (PPE), such as lifejackets, PFDs, or hard hats.

The PEI OHS Act *General Regulations* require the employer to ensure that workers exposed to a hazard wear appropriate PPE.[15]

The PEI OHS Act, PEI OHS Act *General Regulations*, and *Aquaculture Safety Code of Practice* refer to the duties of the employer and the worker regarding the wearing of personal protective equipment. The PEI OHS Act and *General Regulations* do not specifically identify PPE required for different activities, but refer to hazards at the workplace and state that the employer shall ensure "that workers and supervisors are familiar with occupational health or safety hazards at the workplace."[16]

The *Aquaculture Safety Code of Practice* is more specific about PPE, stating that the employer is to "[a]ssess the level of risk that each of the identified activities pose and then determine the

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14 Government of Prince Edward Island, *Fall Protection Regulations* (chapter O-1.01), section 10, at https://www.princeedwardisland.ca/en/legislation/occupational-health-and-safety-act/fall-protection-regulations (last accessed on 02 August 2017)

15 Ibid., section 45.

16 Workers Compensation Board of Prince Edward Island, *Occupational Health and Safety Act*, paragraph 12.(1)(d).

suitable personal protection [*sic*] equipment that will minimize the risk to the worker's health and safety."[17] The employer must also "[e]xplain to the worker any hazard, safe work procedures and any personal protective equipment that is required to complete the work task."[18]

In this occurrence, neither the crane operator nor the deckhand was wearing a hard hat.

Lifesaving and firefighting equipment

Vessels subject to Part II of the SFVIR and measuring less than 12.2 m in length, such as the occurrence vessel, are required to carry on board an approved lifejacket for each person, a lifebuoy, and a watertight can with 6 self-igniting flares.[19] Under firefighting equipment regulations, they are also required to carry a fire bucket on board.[20]

The occurrence vessel did not carry any lifesaving or firefighting equipment as required by regulation.

In July 2017, TC's *Fishing Vessel Safety Regulations* came into force; they apply to small fishing vessels up to 24.4 m in length and with a gross tonnage of no more than 150. These regulations state that

> No person shall operate, or permit another person to operate, a fishing vessel in environmental conditions or circumstances that could jeopardize the safety of persons on board unless a lifejacket required by this Part, or a personal flotation device that meets the requirements of section 3.21, is worn
>
> (a) by all persons on board, in the case of a fishing vessel that has no deck or deck structure; or
>
> (b) by all persons on the deck or in the cockpit, in the case of a fishing vessel that has a deck or deck structure.[21]

Thus, TC's minimum requirement for personal flotation is the carriage of standard lifejackets. There is no requirement to ensure that fishermen carry PFDs on board or wear them at all times. Although a fishing master can determine that a risk is present and decide to require the crew to wear PFDs, the assessment of risk is subjective. As such, many masters may not perceive the need to acquire PFDs. Also, even if PFDs are carried, if they are not worn at all times, crew members may not have adequate time to don them in an emergency.

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17 Workers Compensation Board of Prince Edward Island, *Aquaculture Safety Code of Practice*, section 17, p. 43.

18 Ibid., section 16, p. 41.

19 Transport Canada, SOR/2010-91, *Small Vessel Regulations* (last amended 6 December 2013), section 18 and subsection 54(1).

20 Ibid., subsections 53(2) and 54(1).

21 Government of Canada, *Canada Gazette,* Part II, Vol. 150, no. 14 (13 July 2016), Regulations Amending the *Small Fishing Vessel Inspection Regulations*, section 3.09, at http://gazette.gc.ca/rp-pr/p1/2016/2016-02-06/html/reg1-eng.php (last accessed on 02 August 2017).

Requirements for personal flotation devices

Fishermen often operate in harsh physical and environmental conditions. They harvest, load, transfer, and store their catch while the vessel is in various sea conditions, and the risk of going overboard is high. If a fisherman ends up in the water, the consequences can be fatal: among other things, cold shock, hypothermia, and exhaustion[22] can quickly lead to death, especially without the assistance of a PFD.

The TSB has determined that, in Canada, from 2006 to 2016, an average of 9 deaths per year occurred in the commercial fishing industry. Over the same period, approximately 46,000 commercial fishermen were employed per year. The TSB's *Safety Issues Investigation into Fishing Safety in Canada* (SII) identified drowning as the primary cause of death in Canada's fishing industry.[23]

In this occurrence, the crew members were not wearing PFDs or lifejackets, nor were any carried on board the vessel. Although the fishermen did not fall in the water, the risk remained that they could have fallen in at any time.

Several education and awareness programs and initiatives within the fishing community strive to change behaviours and promote the use of PFDs. In British Columbia, Fish Safe's "Real Fishermen" campaign uses promotional materials featuring fishermen wearing PFDs. In Nova Scotia, the Fisheries Safety Association of Nova Scotia has consulted with fishermen and suppliers to develop and implement initiatives such as wharf visits, family pledges, an elementary school poster contest, advertising, and design testing to increase awareness of the importance of wearing PFDs. In addition, the Nova Scotian Safe at Sea Alliance has collaborated with industry and government representatives to develop a plan for the province's fishing industry. The plan includes several recommendations to improve safety through education, awareness, and enforcement. One such recommendation is the development of an enhanced program that includes safety drills and demonstrates PFDs in action. Despite the aforementioned initiatives, there has not been a significant change in the behaviour of fishermen, and many continue to be resistant to wearing a PFD.

Apart from Quebec's Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST),[24] neither TC nor any other provincial workplace safety regulator has requirements to ensure that fishermen wear PFDs at all times. Despite risk-based regulations and industry initiatives to change behaviours and create awareness about the importance of wearing PFDs, as well as design improvements by PFD manufacturers to address

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22 C.J. Brooks, K.A. Howard and J. Jenkins, *Survival at Sea for Mariners, Aviators and Search and Rescue Personnel* (North Atlantic Treaty Organization and Research and Technology Organisation, February 2008), Chapter 10: Drowning is Not a Helpful Diagnosis Written on the Death Certificate, pp. 10-1–10-6, at http://www.dtic.mil/dtic/tr/fulltext/u2/a485550.pdf (last accessed on 02 August 2017).

23 TSB Marine Investigation Report M09Z0001, p. 31.

24 Formerly known as the Commission de la santé et de la sécurité du travail (CSST).

fishermen's concerns about comfort and constant wear, many fishermen continue to work on deck without wearing a PFD.

Because PFDs are lightweight and wearable, fishermen can wear them at all times on a vessel to ensure that they are wearing a PFD if they go overboard, which can often happen very suddenly.

Previous recommendations related to personal flotation devices

On 05 September 2015, the large fishing vessel *Caledonian* capsized 20 nautical miles west of Nootka Sound, British Columbia.[25] At the time, the vessel was trawling for hake with 4 crew members on board. The vessel sank, and 3 of the crew members lost their lives. The 1 crew member who survived had been wearing a PFD. The Board considered that implementing explicit requirements for fishermen to wear PFDs, along with appropriate education and enforcement measures, would significantly reduce the loss of life associated with going overboard. Therefore, in 2016, following the *Caledonian* occurrence, the Board issued the following 2 recommendations:

> WorkSafeBC require persons to wear suitable personal flotation devices at all times when on the deck of a commercial fishing vessel or when on board a commercial fishing vessel without a deck or deck structure and that WorkSafeBC ensure programs are developed to confirm compliance.
>
> **TSB Recommendation M16-04**

> The Department of Transport require persons to wear suitable personal flotation devices at all times when on the deck of a commercial fishing vessel or when on board a commercial fishing vessel without a deck or deck structure and that the Department of Transport ensure programs are developed to confirm compliance.
>
> **TSB Recommendation M16-05**

In June 2016, the small fishing vessel C19496NB was lobster fishing with 3 people on board about 0.5 nautical miles from Miller Brook Wharf, Salmon Beach, New Brunswick, when 1 of the traplines became entangled. The heavy strain on the line reduced the starboard aft freeboard of the vessel, which, in combination with the quartering seas that struck the same area, led to the vessel rapidly taking on water and capsizing. After the vessel was recovered by the fishing vessel *Marie Eliser 1*, 1 crew member received medical assistance for hypothermia, while the other 2 were pronounced dead by the paramedics.

It was determined that none of the crew members were wearing lifejackets or PFDs when the vessel capsized, and no PFDs were carried on board. Since the capsizing occurred quickly, there was no time for the crew members to access and don the lifejackets stowed on board.

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25 TSB Marine Investigation Report M15P0286.

The TSB considers that implementing explicit requirements for fishermen to wear PFDs would significantly reduce the loss of life associated with going overboard, and has already made similar recommendations to TC and WorkSafeBC.[26] Therefore, the Board recommended that

> The government of New Brunswick and WorkSafeNB require persons to wear suitable personal flotation devices at all times when on the deck of a commercial fishing vessel or on board a commercial fishing vessel without a deck or deck structure and that WorkSafeNB ensure that programs are developed to confirm compliance.
>
> **TSB Recommendation M17-04**

Management of risk

A risk assessment involves the identification of the hazards present in an operation, development of methods to eliminate or control those hazards, and a process by which these mitigation measures are reviewed and amended on an ongoing basis. Risk assessment includes analyzing both the probability and the severity of adverse consequences.

A risk management system on a vessel attempts to formalize how hazards are identified, assessed, and managed. Effective risk management requires organizations to be aware of the risks involved in their operations, competently manage those risks, and be committed to operating safely.

WCB PEI also publishes the *Aquaculture Safety Code of Practice,* which is intended to serve as general guidance to assist the industry to "identify and control situations or hazards that could cause harm."[27] The code emphasizes the importance of a "well thought-out risk management strategy."[28] The employer is required to assess the risks of activities and relay information to the worker regarding the hazards, procedures, and PPE required for work tasks.[29]

The company did not have a formalized risk management system, nor was it required by regulation. No safety drills or dedicated safety or toolbox meetings[30] were carried out.

As of 13 July 2017, the new *Fishing Vessel Safety Regulations* requires that the authorized representative provide written safety procedures for the crew and that drills be held to ensure that the crew is proficient at all times in carrying out those procedures.

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26 TSB Marine Investigation Report M15P0286, recommendations M16-04 and M16-05.

27 Workers Compensation Board of Prince Edward Island, *Aquaculture Safety Code of Practice*, Introduction, p. 4.

28 Ibid.

29 Ibid., section 16, p. 41.

30 A toolbox meeting is an impromptu safety meeting in which crew members make an effort to correct unsafe acts or conditions, relay safety-related rules or policies, or discuss recent accidents or incidents.

Safety Issues Investigation into Fishing Safety in Canada

In August 2009, the TSB undertook an in-depth safety issues investigation into fishing vessel safety in Canada. The SII report, released in June 2012, provides an overall, national view of safety issues in the fishing industry, revealing a complex relationship and interdependency among these issues. The Board identified the following safety significant issues requiring attention: stability, lifesaving appliances, fisheries resource management, the cost of safety, safety information, safe work practices, the regulatory approach to safety, fatigue, training, and fishing industry statistics.

TSB Watchlist

The TSB Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer.

Commercial fishing safety is a 2016 Watchlist issue. As this occurrence demonstrates, some commercial vessels may still not be carrying the required lifejackets on board or ensuring that crew members are wearing PFDs while the vessel is in operation.

Commercial fishing safety will remain on the TSB Watchlist until

- new regulations are implemented for commercial fishing vessels of all sizes;
- user-friendly guidelines regarding vessel stability are developed and implemented to reduce unsafe practices;
- there is evidence of behavioural changes among fishermen regarding the use of PFDs, EPIRBs, and survival suits, as well as of on-board safety drills and risk assessments being carried out; and
- there is concerted and coordinated action by federal and provincial authorities, leaders within the fishing community, and fishermen themselves to put in place strong regional initiatives and develop a sound safety culture in the fishing community.

TSB laboratory reports

The TSB completed the following laboratory report in support of this investigation:

- LP112/2016 – Examination of Crane and Hydraulic Cylinder

Analysis

The analysis will focus on the testing of cranes installed on vessels, the standards for the design and construction of cranes, inspections of cranes by Transport Canada (TC) or authorized representatives, on-board risk assessment systems, the wearing of personal flotation devices (PFDs) or lifejackets by crew, and the fishing community's recognition of the relationship among safety issues.

Factors leading to the crane failure and the fatality

During maintenance operations on oyster-growing equipment, the operator elevated the boom of the crane to work over the side of the aquaculture vessel to untangle a securing line attached to a floating oyster cage. In that position, the operator was directly underneath the elevated boom of the crane.

Although the crane could have been rotated laterally to enable the operator to work without the crane overhead, the operator did not rotate the crane, likely because he did not perceive a risk; the crane was not carrying a load at the time.

After a few seconds, the crane failed, causing the boom and attached rigging to fall and strike the operator's head, fatally injuring the operator.

The failure was caused by a design flaw in the construction of the crane itself: the attachment points for the hydraulic cylinder within the crane were not far enough apart to allow for the full extension of the piston rod when the crane was fully elevated. Also, the piston rod was subject to side loading due to contact with the hose guards. As a result, the piston rod was forced to bend. After it had bent on several occasions, the material was no longer able to sustain the bending stress, and the rod fractured fully at the time of the occurrence.

The design flaw that resulted in the bending of the hydraulic cylinder rod was not detected by the crew or the company within the few weeks that the crane was in service, nor was the crew visually inspecting the crane prior to each voyage.

Design and inspection of lifting appliances

Cranes or lifting appliances are complex machines requiring a design that, when in operation, does not create any forces that exceed the specified strength of its individual parts. This occurrence highlights the potential risk when lifting appliances are designed incorrectly and no testing or regulatory inspection requirements are in place.

Workers Compensation Board of Prince Edward Island

The Workers Compensation Board of Prince Edward Island (WCB PEI) develops and maintains standards for the protection of the occupational safety and health of workers and self-employed persons.

As of 2000, following a legislative amendment, fishing vessels were recognized as a workplace under the WCB PEI *Occupational Health and Safety Act* (PEI OHS Act). As of that update, the PEI OHS Act *General Regulations* applied to the occurrence vessel.

According to the *General Regulations,* the employer is responsible for designating a "competent person to thoroughly inspect and test hoisting apparatus" before it is first put into use, as well as on a monthly basis.[31] The operator or individual using the crane also has the responsibility to inspect the crane visually before each use to ensure that it will function as intended.[32] Records of inspections and repairs are to be kept in a log book.[33]

In this occurrence, it is possible that the crew would not have been able to detect the deficiency in the crane through visual examination: unless the crane was fully extended, it would have been difficult to detect the flaw in the crane's design. Nonetheless, the practice of performing regular inspections, especially before an apparatus is installed and first used, is an important measure to help to mitigate potential hazards.

If lifting appliances are not tested thoroughly before being put into service as well as inspected before each use, there is an increased risk that the appliances will not function as intended.

Canadian Standards Association

Lifting appliances on board vessels must be designed in a manner that ensures that they are safe and effective at carrying out the work required. Although the Canadian Standards Association has a standard[34] that covers articulating cranes like the crane in this occurrence, the standard does not apply to cranes installed on vessels.

In this occurrence, the crane was constructed in a similar manner to a smaller crane that had been designed and installed by the same builder for a previous vessel owned by the same owner. The smaller crane had been in use for about 2 years without any malfunctions. Because the owner needed a second vessel and crane that was capable of lifting heavier equipment, the builder used heavier components to satisfy that requirement. No formal engineering plans or calculations were used to construct the crane, nor were any formal engineering tests conducted on the crane to verify the limits of its operation.

If there are no standards for the design and construction of lifting appliances on small fishing vessels, there is an increased risk that unsafe lifting appliances will be constructed and installed.

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31 Workers Compensation Board of Prince Edward Island, *Occupational Health and Safety Act General Regulations*, subsection 34.5(2).

32 Ibid., subsection 34.6(3).

33 Ibid., subsection 34.5(3).

34 CAN/CSA-Z150.3-11: *Safety code on articulating boom cranes.*

Transport Canada

Transport Canada (TC) manages the registration and inspection of vessels in Canada and provides regulations to improve the safety of the vessels and operators.

While lifting appliances installed on commercial vessels in Canada are required to undergo a scheduled, detailed, rigorous inspection and a testing procedure found in the *Cargo, Fumigation and Tackle Regulations* of the *Canada Shipping Act, 2001*, lifting appliances on fishing vessels are exempt from that requirement.

No federal regulatory requirements for crane certification or testing apply to a crane installed on a vessel of the same class as the vessel in this occurrence. Of the 20,382[35] registered fishing vessels in Canada, many may have lifting appliances installed that are not being inspected or tested by TC or an authorized representative.

If lifting appliances installed on fishing vessels are not inspected by either TC or an authorized representative, defects in those appliances that pose a hazard may go undetected.

Risk assessment

Although fishermen are often aware of the risks present in their fishing operations, few undertake risk assessments to manage those risks on board their vessels. Risk assessments involve identifying the hazards present in an operation, developing methods to eliminate or control those hazards, and creating a process by which these methods are reviewed and amended on an ongoing basis. This can be a formal, documented system or can be achieved simply and effectively through regular safety or toolbox meetings led by the master/operator of the vessel. In each meeting, the master/operator would have the opportunity to review on-board risks with the crew, remind them of the means established to mitigate those risks, and discuss workplace hazards.

In this occurrence, the crane's base was positioned approximately 1.2 m inboard from the steering, propulsion, and crane hydraulic controls on the vessel. Given this arrangement as well as the size of the vessel, the operator would manoeuvre the crane, navigate the vessel, and untangle the cage attachment lines, all necessarily while situated at the vessel's gunwale, which was under the elevated crane boom.

When the boom is elevated without an attached load, there may be no perceived risk that it could fall. However, there are several different situations in which a crane boom can fall without a lifted load, including a mechanical malfunction or failure in 1 of the crane parts. When the operator was untangling the securing line, he could have been taking steps, such as rotating the crane laterally, to work without the crane overhead. The operator did not rotate the crane, likely because he did not perceive a risk in working underneath it; the crane

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35 Canadian Council of Professional Fish Harvesters, *Transport Canada Regulatory Training Needs Assessment – Final Report*, p. 16, at http://www.fishharvesterspecheurs.ca/product/transport-canada-regulatory-training-needs-assessment-final-report (last accessed on 02 August 2017).

was not carrying a load at the time. It is possible that the risk could have been identified through some type of safety meeting or other form of risk assessment. In this occurrence, there was no risk assessment process, and safety meetings were not held.

Furthermore, the use of personal protective equipment (PPE) may help to mitigate safety risks and hazards. Although the WCB PEI *Aquaculture Safety Code of Practice* does refer to the need to perform a risk assessment, it does not explain how such an assessment must be done. Also, the employer's responsibilities are set out under the assumption that the employer has already done some form of risk management and is aware of all the hazards involved in the work operation.

It is up to the employer to determine if a risk is present and if the PPE should be worn. Thus, it is crucial that employers conduct an adequate and thorough risk assessment. As the assessment of risk and determination of hazards is subjective, an inadequate assessment of risk may lead to a failure to require employees to wear PPE in appropriate situations.

If fishing vessel operations do not have an adequate system for on-board risk management, there is a risk that the crew may be exposed to unsafe conditions, such as working underneath a crane boom without PPE.

Lifesaving equipment

Not wearing flotation devices on a fishing vessel is an unsafe practice that the TSB has identified over the years. In the fishing community, the reasons fishermen give for their resistance to using PFDs include discomfort, the risk of entanglement, and the perception that it is not practical or normal to wear a PFD. Furthermore, risks such as falling overboard and drowning are perceived to be low, with the result that many fishermen see little benefit to protecting themselves from these risks while they focus on the day-to-day business of fishing.[36] As well, unsafe behaviours that are rooted in traditional values, attitudes, practices, and the perception of efficiency prove the most difficult to change.[37] Recently, research and safety efforts have focused on commercial fishing and the behaviours involved.[38] [39]

Various initiatives across Canada have been gaining traction to promote the use of wearing PFDs, and their use is starting to become more common. The fishing safety associations in conjunction with various fishing associations and nautical training schools across Canada heavily promote the wearing of PFDs through advertising, information campaigns, and regular promotional visits to ports. Despite these initiatives, many fishermen still choose not

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36 TSB Marine Investigation Report M09Z0001, pp. 63–66.

37 D.M. DeJoy, "Behaviour change versus culture change: divergent approaches to managing workplace safety," *Safety Science*, Vol. 43, Issue 2 (2005), p. 108.

38 M.E. Davis, "Perceptions of occupational risk by US commercial fishermen," *Marine Policy*, Vol. 36, Issue 1 (2012), pp. 28–33.

39 P.H. Lindoe, "Safe off shore workers and unsafe fishermen – a system failure?" *Policy and Practice in Health and Safety*, Vol. 5, Issue 2 (2007), pp. 25–39.

to wear a PFD while at sea. This is recognized as a widespread safety concern in the Canadian fishing community.[40]

Although it was not a causal or contributing factor in this occurrence, no lifejackets and no PFDs were carried or worn on board the occurrence vessel.

If fishermen do not wear PFDs or lifejackets while working on deck, despite the industry awareness initiatives promoting their use, there is an increased risk that fishermen will not survive in the event that they fall overboard.

Safety issues in the fishing industry

The *Safety Issues Investigation into Fishing Safety in Canada* (SII) categorized actions that impact safety into 10 significant safety issues and found that there are complex relationships and interdependencies among them. These safety significant issues are further analyzed in the SII. In this occurrence, at least 4 of these 10 safety significant issues were present. The following practices and procedures relating to these 4 safety significant issues identified in the SII were evident in this occurrence:

Lifesaving appliances

Safety issues investigation findings	**Relationship to this occurrence**
Fishermen resist wearing PFDs because many have accepted the risk.	The crew members of the aquaculture vessel were not wearing PFDs.
Fishermen may fit their vessels with lifesaving appliances only for regulatory compliance.	The owner did not purchase the minimum lifesaving appliances required by regulation.

Training

Safety issues investigation finding	**Relationship to this occurrence**
Fishermen assess and manage their risk based on experience.	The operator had not taken training on lifting appliances prior to operating a crane. The deckhand did not have any formal relevant training.

Cost of safety

Safety issues investigation findings	**Relationship to this occurrence**
Fishermen usually weigh the cost (time and money) of safety drills, training, and equipment against the likelihood of an accident happening.	The operator did not conduct safety drills.

40 TSB Marine Investigation Report M09Z0001.

Fishermen generally see the likelihood of an accident happening as very low.	The possibility of falling overboard or the crane boom falling was considered very unlikely on the unregistered aquaculture vessel.

Safe work practices

Safety issues investigation finding	Relationship to this occurrence
Fishermen do not always emphasize the importance of safety in work practices.	It was not a standard work practice to wear PFDs during fishing operations; likewise, hard hats and safety boots were not worn during crane operation work.

Interdependency of safety issues

The safety of fishermen is compromised by numerous issues that are interconnected. The following safety issues share a complex relationship and were identified in this occurrence:

- Lifesaving appliances – PFDs were not worn and there were no lifesaving appliances on board, as required by regulation.
- Training – the operator had a minimal amount of training on vessel operations.
- Cost of safety – the risk was deemed low enough to reject the purchase of lifesaving appliances or PPE (such as hard hats).
- Unsafe work practices – the risks of not wearing a PFD or a hard hat were accepted.

Past attempts to address these safety issues on an issue-by-issue basis have not led to the intended result: a safer environment for fishermen. The SII emphasizes that to obtain real and lasting improvement in fishing safety, change must address not just 1 of the safety issues involved in an accident, but all of them, recognizing that a complex relationship and interdependency exists among those issues. Removing a single unsafe condition may prevent an accident, but only slightly reduces the risk of other accidents.

The safety of fishermen will be compromised until the complex relationship and interdependency among safety issues is recognized and addressed by the fishing community.

Findings

Findings as to causes and contributing factors

1. The operator was working over the side of the aquaculture vessel, underneath the elevated boom of the crane, to untangle a securing line attached to a floating oyster cage.

2. The crane failed when the piston rod of the hydraulic cylinder that was used to drive the lower boom arm broke in a bending overload condition.

3. When the piston rod fractured, the boom and attached rigging struck and fatally injured the operator.

4. The design of the crane was flawed: there was insufficient space between the hydraulic cylinder's attachment points to allow for the full extension of the piston rod when the crane boom was fully raised.

5. As the piston rod was not able to fully extend without making contact with the hose guards, it was subject to side loading from that contact and was forced to bend. After bending on several occasions, the material was no longer able to sustain the bending stress and the rod fractured.

6. The crew or the company had not detected the design flaw within the few weeks that the crane was in service, nor was the crew visually inspecting the crane prior to each voyage.

Findings as to risk

1. If lifting appliances are not tested thoroughly before being put into service as well as inspected before each use, there is an increased risk that the appliances will not function as intended.

2. If there are no standards for the design and construction of lifting appliances on small fishing vessels, there is an increased risk that unsafe lifting appliances will be constructed and installed.

3. If lifting appliances installed on fishing vessels are not inspected by either Transport Canada or an authorized representative, defects in those appliances that pose a hazard may go undetected.

4. If fishing vessel operations do not have an adequate system for on-board risk management, there is a risk that crew may be exposed to unsafe conditions, such as working underneath a crane boom without personal protective equipment.

5. If fishermen do not wear personal flotation devices or lifejackets while working on deck, despite the industry awareness initiatives promoting their use, there is an increased risk that fishermen will not survive in the event that they fall overboard.

6. The safety of fishermen will be compromised until the complex relationship and interdependency among safety issues is recognized and addressed by the fishing community.

Other findings

1. The occurrence vessel was not inspected by Transport Canada, nor was it required to be by regulation.

2. The occurrence vessel was not fitted with any navigation lights or firefighting equipment, as required by regulation.

3. There were no lifejackets carried on board, as required by regulation.

Safety action

Safety action taken

Transportation Safety Board of Canada

On 05 October 2016, the Transportation Safety Board of Canada (TSB) issued marine safety information letters 09/16 and 10/16.

The first letter was sent to the company that built the crane, to inform the company of a safety issue concerning the design of the crane that was identified during the TSB investigation.

The second letter was sent to the owners of the occurrence vessel, to inform them of a safety issue regarding the importance of wearing proper personal protective equipment that had been identified in the course of the investigation.

Transport Canada

Transport Canada issued a detention order to the owner of the sister vessel and crane prohibiting the use of the crane until it was certified by an engineer.

Workers Compensation Board of Prince Edward Island

Following the completion of an investigation by Occupational Health and Safety (OHS) officers, a Hazard Alert entitled "Oyster Barge Crane Boom Failure" was developed and issued to stakeholders. As part of the Hazard Alert, OHS recommended that cranes used on oyster barges or similar marine vessels be

- designed using an engineered design;
- inspected and maintained on a regular basis to verify they are in safe working order; and
- positioned and designed so as to minimize overhead hazards for workers.[41]

OHS staffed a booth at the annual general meeting of the Prince Edward Island Fishermen's Association, speaking to stakeholders about safety issues and distributing safety materials, including the Hazard Alert related to the 29 April 2016 fatality.

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41 Workers Compensation Board of Prince Edward Island, "Hazard Alert: Oyster Barge Crane Boom Failure," at http://www.wcb.pe.ca/DocumentManagement/Document/pub_oysterbargehazardalert.pdf (last accessed on 02 August 2017)

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 02 August 2017. It was officially released on 09 August 2017.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

Appendices

Appendix A – Parts of the crane