Tuesday, October 24, 2000

INNOVATIVE APPROACHES TO INVESTIGATING AND PREVENTING FISHING VESSEL CASUALTIES

Photograph and caption by Earl Dotter

A fisherman dons layers of insulated clothing topped with hooded rain gear, rubber boots and gloves, and releases the massive chain-linked dredge into the sea. Entanglement of hands and clothing in unguarded winches is always a possibility, especially when fishermen are working in wet, slippery conditions on the shifting work platform.

PROMOTING IMPLEMENTATION OF SAFETY MEASURES

Marianne Törner,
National Institute for Working Life/West,
Göteborg, Sweden
E-mail: Marianne.Torner@niwl.se

Mats Cagner, Bertil Nilsson
Feelgood OHS Services, Boras & Falkenberg,
Sweden

Per-Olov Nordling
Lindholmen Development, Goteburg
Sweden

Marianne Törner, PhD, is an associate professor at the Department of Human Factors Engineering, Chalmers University of Technology. She is also a researcher at the National Institute for Working Life/West in Göteborg, Sweden. Her research areas include risks for injuries and accidents in occupational life, with special focus on risk management and development of methodology to promote change processes towards improved safety. Dr. Törner has been active in ergonomics and risk research in fishery since 1981.

INTRODUCTION

Fishing is a high-risk occupation. Much effort has been put on safety education to fishermen and on developing and presenting technical solutions to reduce the hazards. In spite of this, the general experience of many experts in the field is that the degree of implementation of safety measures in fishing is low [Hughes 1994; Aasjord and Silseth 1995]. The experience of the present project team is that fishermen often reject the evidence of accidents in fishing. Also, technical measures to reduce the hazards are often considered to cost too much money. The purpose of the present study was to develop, apply and evaluate the results of a method to promote implementation of safety measures in fishing. The approach was based upon demonstrating the high frequency of accidents in commercial fishing, identifying the direct causes, coupling these to technical shortcomings on board specific vessels, presenting suitable technical countermeasures and the potential of such measures for reducing costs. Substantial participation of the fishermen themselves was considered essential to obtain the goal of adequate selection, acceptance and actual implementation of technical solutions.

METHODS

The method consisted of the following elements:

> Analysis of serious accidents in fishing for 12 years retrospectively. Determining the frequency of such events was based on statistics reported to the Swedish Labor Market No-fault Liability Insurance. Case definitions were comprised of events leading to more than 30 days of sick listing, permanent disability or death. Hearing injuries and injuries while commuting to and from work were excluded;
>
> Analysis of the monetary costs to victim and entire crew of serious accidents due to each such direct cause. This analysis was based on median time of sick listing as a result of different categories of direct causes. It was also based on economics data typical of three common types of fishing;
>
> Inventory of suitable technical measures to reduce the risks;
>
> Participatory safety inspection of 101 fishing vessels giving a list of urgent technical safety measures on each vessel;
>
> Short-term follow-up of degree of implementation and of satisfaction with undertaken measures, performed through telephone interviews; and
>
> Long-term follow-up of continued use of measures taken as well as of further safety measures and plans for such measures, performed through telephone interviews.

RESULTS

The t-analysis showed that approximately 12 serious injuries per 1000 fishermen were reported each year. The yearly rate of reported fatalities was 0.7 per 1000 fishermen. The most common activity at the instant of the accident was hauling of the trawl. The direct causes of the events fell into 17 different categories, the most common being falls in 28 percent of the cases studied.

The cost analysis of the 17 direct causes of injuries and death showed substantial costs for the victim and, under most circumstances, also for the rest of the crew. The safety inspection was performed following a checklist and on the 101 vessels as many as 1300 safety deficiencies and 130 ergonomics deficiencies were identified. Twenty of the vessels performed fishing with only one man on board a substantial part of the year. Twenty-two had a crew of four or more.

Six months after the safety inspection 80 percent of the vessels had taken measures against on average two of the identified risks. Forty-nine of the 160 measures taken concerned acquiring or taking up the use of safety glasses or hearing protections. The rest of the measures were rather evenly distributed over the entire range of items on the checklist. Forty men held the opinion that safety measures had a potential for reducing costs in fishing. Twenty-seven men felt unable to take a standpoint in this matter. They indicated that life and health was a matter of ethics and money should not or at least had not until then been considered in this context. Ninety-three of the fishermen appreciated the visit and safety inspection. One benefit of substance was considered to be the opportunity to discuss safety problems with a knowledgeable person from outside the fishing community.

Two and a half years after the inspection, 78 vessels were available for follow-up. Ninety-six percent of the measures taken previously aboard these ships were still in use and in all but one case the fishermen were satisfied with their function. Forty-five of the 78 vessels had corrected further hazards identified at the inspection. In all, 85 corrective/preventative actions were taken. Also, 49 measures to improve safety or ergonomics on board, not listed at the inspection, had been taken. All together 60 vessels had taken further such measures. The measures taken were distributed over most of the items on the checklist. Thirty-nine fishermen were considering plans for still additional measures and 14 men stated that other crews had shown interest in safety measures taken on board. When asked why identified hazards had not been eliminated, the most common answers were that the remaining measures were not considered necessary (18 men), strained economy (8 men), that they had not got around to it (5 men) or that they felt that no acceptable solutions were at hand (3 men). On the question “What do you consider necessary for you personally to take further safety measures on board?” most common answers were that the economy must be improved (24 respondents) or that it would take an accident to occur (13 respondents.) Seventy-four of the 78 fishermen wished to maintain continuous contact with the OHS in the manner practiced in the present study. Results of the present study are presented in further detail in Törner and Nordling [2000], Törner et al [2000a] and Törner et al [2000b].

DISCUSSION

A shortcoming of the method used in the present study was the absence of a control group of fishing vessels. This was, however, not considered possible to obtain in a reliable and ethical manner. It is therefore difficult to state how many of the safety measures would have been taken without the intervention of the present project. At the six-month follow-up the participating fishermen stated that 68 of the 160 measures taken were a direct consequence of the safety inspection within the project. It is not unlikely that concerning a portion of the remaining items implementation was, if not initiated, at least precipitated by participation in the project. Authorities and the fishermen's organizations carry a large responsibility for continuously keeping safety on the agenda and for developing strategies to support safety work economically. There is, in the opinion of the research team, room for improvement in this context.

CONCLUSIONS

The methodology used, based on direct contact and visits to specific vessels, is resource demanding but the results of the present study indicate that it is cost effective, since a substantial number of hazards were eliminated and the measures taken remained in long-term use. The results also indicate that activity in safety work may to a certain extent be self-generating.

More efforts should be placed on developing improved technical solutions to known safety problems in fishing and on demonstrating the benefits of such devices.

OHS services in fishing should develop strategies to satisfy the fishermen's interest in continued direct contact with safety experts, without significant costs for the individual fisherman.

ACKNOWLEDGEMENTS

Financial support was given by the Swedish Labor Market No-fault Liability Insurance Fund for Research, which is hereby gratefully acknowledged.

REFERENCES

Aasjord H, Silseth A [1995]. Tiltakspakke for ökt sikkerhet i fiskerflåten. Report Number MT40 F95-0124. Trondeim, Norway: Marintek, Sintef-gruppen.Trondheim, Norway.

Hughes LJ [1994]. Vessel safety program. Proc. National Fishing Industry Safety and Health Workshop, Anchorage, Alaska, Oct 1992. Washington DC, NIOSH: publ no 94-109, pp 180-188.

Törner M, Nordling, P-O [2000]. Occupational injury in Swedish fishing. Part 1: Analysis of injury statistics. Occ Ergo *2* (2): 91-104.

Törner M, Cagner M, Nilsson B, Nordling P-O [2000a]. Occupational injury in Swedish fishing. Part 2: Promoting implementation of safety measures. Occ Ergo *2*: (2): 81-89.

Törner M., Cagner M, Nilsson B, Nordling, P-O [2000b]. Follow-up of long-term effects of method for promoting prevention of occupational accidents. Arbete och Hälsa, 3. (Work and Health), Sweden: National Institute for Working Life.

QUOTA-BASED FISHERY MANAGMENT REGIMES

LT Christopher Woodley
Fishing Vessel Safety Coordinator
13th U.S. Coast Guard District
Seattle, Washington, U.S.A.
E-mail: CWoodley@pacnorwest.uscg.mil

LT Chris Woodley was commissioned in the Coast Guard in 1990 and has been directly involved the Coast Guard's Fishing Vessel Safety Program since 1993. He is qualified as a fishing vessel examiner, an investigating officer, and a senior marine inspector. He has been assigned at Coast Guard Marine Safety Office (MSO) Pittsburgh, MSO Anchorage, served as the marine safety detachment supervisor in Dutch Harbor, Alaska, and is currently based in Seattle as the Fishing Vessel Safety Coordinator for the 13th Coast Guard District. LT Woodley recently completed his Master's Degree in Port and Transportation Management at the University of Washington, where his thesis topic was titled "Developing Regional Strategies in Fishing Vessel Safety: An Integration of Vessel Safety and Fisheries Management." He has also just been selected by the Coast Guard to attend a six month program specializing in maritime accident investigations. LT Woodley hails from Anchorage, Alaska and is just crazy enough to move back there.

INTRODUCTION

Fishery management practices can impact vessel safety in a variety of ways.[1] By establishing the framework and rules under which fishing vessel operators compete against each other, fishery managers dictate the spatial and temporal aspects of the fishing season, as well as who participates. Fishery managers also dictate specific input controls into fishing vessel operations such as limits on vessel size, limits on crew size, and limits on the amount or type of harvest gear utilized. These assorted controls are specifically designed to manage fishery effort, by limiting the catching power of a fleet of vessels. Under open access regimes, for example, fishery managers often have difficulty matching harvesting capacity (number of vessels or catching power) with biological productivity of the fishery resource/population. There is no separate limit to how much an individual vessel or company can harvest within the constraints of total allowable catch. This leads to a highly competitive operating environment in which individual fishermen attempt to maximize their catch for increased economic gain. This competition is known as "the race for fish" and is particularly fierce in open access fisheries characterized by overcapacity, seasons of short duration, and a high value/low volume resource [U.S. Congress, Senate 1999].

In certain fisheries (but not all), this race for fish strongly influences the safe operation of fishing vessels. This race encourages fishermen to operate in all weather and sea conditions, to operate without rest, and encourages risk-taking behaviors. None of these safety concerns can be readily addressed by the narrow confines of the vessel-based and crew-based regulatory approach provided in the Commercial Fishing Industry Vessel Safety Act (CFIVSA). These safety concerns, however, can be partially or even fully addressed within the context of changes in fishery management. National Standard Ten of the Sustainable Fisheries Act of 1996 requires that regional fishery management councils “promote the safety of human life at sea” when developing fishery conservation and management measures [Sustainable Fisheries Act 1996].

This paper explores the connection between fishery resource management and the safe operation of fishing vessels by focusing primarily on safety problems found in the Bering Sea/Aleutian Island (BSAI) King and Tanner crab fishery off the coast of Alaska. The paper then compares and contrasts the different fishery management regimes that currently exist in the BSAI management areas. The purpose of this review is to consider how different management regimes influence safety and how changes in fishery management can potentially improve safety.

SAFETY/ECONOMIC PROBLEMS IN THE BSAI CRAB FLEET

The fatality rate in the Bering Sea/Aleutian Island crab fisheries has approximately doubled in the past five years from an average rate of 127 fatalities per 100,000 Full Time Equivalent (FTE) workers from 1990 to 1994, to an average rate of 272 fatalities per 100,000 FTE workers during the 1995 to 1999 period [Woodley 2000].[2] This extraordinary jump has occurred despite this fleet’s extremely high participation in the Coast Guard voluntary dockside exam program [Woodley 1999] and has also occurred despite a substantial increase in Coast Guard search and rescue (SAR) assets in the Bering Sea since 1995. The most common causes identified as leading to fatalities have been operating in poor weather, vessel overloading, crew fatigue, and combinations of the three.

A careful examination of the BSAI crab fleet, within the context of its existing fishery management regime and the fleet's economic performance, sheds some light upon the origin of safety problems within this fleet and also explains why current safety measures are not addressing the problem. The foremost problem with the Bering Sea crab fleet, from a fishery management perspective, is that despite efforts to limit overcapacity and fishery participants through a license limitation plan (LLP), the catching power within the fleet still far exceeds current available crab resources. This overcapacity is compounded by shrinking crab seasons and is further exacerbated by recent severe downturns in Bering Sea crab stocks.[3] As a result, the average vessel in the crab fleet is making less money. Since 1994, the annual ex-vessel value of the Bering Sea crab harvest from the four major crab fisheries has been well below the decade average, falling from U.S. $1.75 million per vessel in 1990 to U.S. $0.7 million per vessel from 1995 to 1998 [Natural Resources Consultants, Inc. 1999].

The outlook for the BSAI crab fisheries is not good. The Bering Sea opilio fishery, which is the staple fishery for the crab fleet, is in serious, albeit natural, decline. The guideline harvest level declined by 88 percent from 1999 to 2000, and it is expected that the 2001-2002 seasons will also be fished at a very low-level harvest strategy. This means that crab fishermen will have to maximize effort within the remaining crab fisheries to remain viable. These economic factors and limited options to participate in other fisheries, combined with the Olympic style derby type fishery, intensifies the race for fish in a fishery which already has one of the highest occupational fatality rates in the U.S.

MARRYING SAFETY AND ECONOMIC PERFORMANCE: A FUNCTION OF FISHERY MANAGEMENT

One of the major factors which has transformed the economic problems into a safety problems is the following relationship: to compete in a highly competitive open access fishing environment which is characterized by a short, intense season, a vessel with a greater catching power than its competitor has a better chance to catch more fish and obtain a greater economic reward. In the BSAI crab fleet, the catching power or capability of a vessel is related to a number of critical vessel and crew safety features: the number of pots a vessel is able to carry [Hermann et al 1998], how quickly gear is lifted, baited, and reset, and the willingness to work in all weather and sea conditions.

As more vessels have entered the fisheries and crab stocks have declined, there has been a proportional reduction in per vessel harvest and income. In an attempt to recapture this lost share, many vessel owners have increased their harvesting capability by investing in the ability to carry additional pots [Greenberg and Hermann 1994]. The safe carriage of additional pots often necessitates expanding the vessel dimensions by increasing the length or beam of the vessel [Poulson 1999]. Because such investments are extremely expensive and can cost literally a million dollars or more, not all owners can afford or are willing to take such measures, especially with the poor outlook for the fishery.

Another way to increase catching power is to carry additional pots beyond what the vessel can safely carry. A vessel that normally can carry 120 pots can theoretically increase its catching/earning power by 20 percent by adding 24 additional pots. Under the current regulatory regime, the number of pots that a vessel can carry is limited by the vessel's stability booklet/letter, or Alaska Department of Fish and Game (ADF&G) pot limits.[4] Adding pots beyond the vessel's stability requirements increases the center of gravity, decreases the freeboard of the vessel, and lessens the vessel's ability to right itself from external heeling forces such as wave or wind action, or internal forces such as free surface effect, improper loading, or tank management. These decreases in vessel stability make the vessel more prone to capsizing events. In heavy freezing spray and icing conditions, as is common in the winter months of the Bering Sea, vessels are even more susceptible to capsizing.

Despite the danger associated with overloading, operating in icing conditions, and operating with minimal crew rest, this is largely the normal operating conditions of the fleet [Woodley 1999]. These conditions are occurring not out of ignorance of safety regulations or lack of knowledge about vessel safety [Woodley 1999] but arguably, because of the extreme economic competitiveness within the open access crab fisheries. To be competitive, a vessel owner/ operator must maximize the harvesting capability of the vessel and maximize time spent fishing. This translates into maximizing pots carried, fishing in all conditions of weather, and fishing without rest.[5] Each of these factors influencing safety falls outside of the existing safety regime, and also falls outside of the changes proposed by the Coast Guard in its fishing vessel safety action plan. As will be demonstrated in the next section, changes to fishery management practices either by changing the fishery regime or by making changes in the fishery management plans would arguably be far more effective in addressing these safety problems than would additional vessel-based and crew-based safety regulations.

REVIEW OF FISHERY MANAGEMENT REGIMES

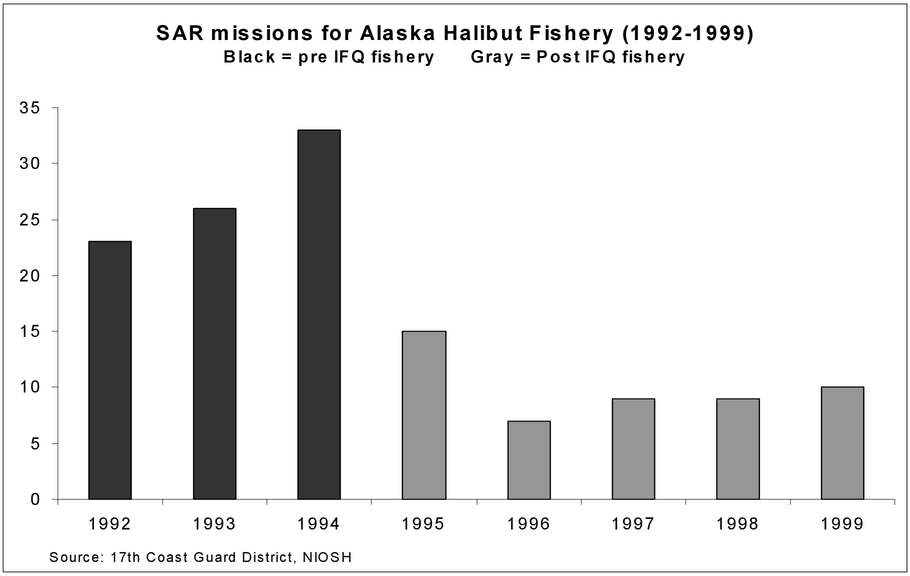
There are several different fishery management regimes currently practiced within the BSAI management area for both state and federal fisheries. These regimes include open access, Individual Fishery Quotas (IFQs), Community Development Quotas (CDQ), and American Fishery Act style fishery cooperatives. The following section will focus upon the four basic management systems, examining the safety features associated with each.

Open Access: The BSAI crab fleet provides just one example of how open access fishery management can impact safety. Another well-documented example of how an open access fishery can impact safety is the old halibut derbies in the State of Alaska. Prior to 1995, fishing for halibut in Alaska was an open access fishery. Over the years, the number of vessels participating in the fishery increased substantially, resulting in overcapacity [NRC 1999a]. As a result, seasons became shorter and shorter and the entire harvest was ultimately caught within a 24-hour, derby-style fishery. This race for fish "often forced participants. . .to fish in unsafe weather conditions, to work continuously for long periods without rest, and possibly overload their vessels due to limited openings" [NIOSH 1997]. As a result, these halibut openings had some of the highest search and rescue caseload and fatality rates of any given fishery in Alaska, with rates annually approaching 122 fatalities per 100,000 fishermen [NIOSH 1997].

Individual Fishing Quotas: Beginning in 1995, the North Pacific Fishery Management Council established a new fishery management regime called Individual Fishing Quotas (IFQs)[6] for halibut and sablefish. The implementation of IFQs rationalized the fishery in terms of the number of vessels participating and the speed at which the fishery progressed. The number of vessels dropped by approximately 50 percent and the number of days in the season increased from 24 hours to 245 days a year.[7] Instead of being forced to fish in less than optimal conditions or when the vessel or crew is not ready, fishermen can operate in a safer manner by harvesting their quota based upon their own schedule and can take into account weather and condition of the vessel and crew.

There is considerable evidence to suggest that IFQs have made this a much safer fishery. Search and rescue statistics from the Seventeenth Coast Guard District, show a sharp decline in the number of rescues in the halibut and sablefish fishery since the implementation of IFQs. (See Figure 1.) While there may be other factors involved which have influenced these numbers, it is widely believed that the IFQ program has had a positive impact on vessel safety in the halibut/sablefish fishery [NRC 1999a]. Additionally, surveys of Alaska halibut and sablefish IFQ holders from 1997 to 1998 indicate that 85 percent of those surveyed felt "IFQs have made fishing for halibut safer" [Knapp 1999]. This assessment is also verified by a recently completed study on fatality rates in the Alaskan halibut/ sablefish fishery, which indicates an average five-year decline of 15 percent in the fishery.

There is also evidence, however, that not all fisheries operating in an IFQ regime have enjoyed the same safety benefits as the halibut/sablefish fishery. Four surf clam/quahog vessels on the Mid-Atlantic in January 1999 were engaged in IFQ fisheries at the time they sank. It has been reported that in the surf clam fishery, because the quotas in the surf clam fishery are controlled by



Source: 17th Coast Guard District, NIOSH

Figure 1. Alaska Halibut Search and Rescue Missions

the clam processors, vessel operators have little choice when to fish or how much to catch [Hall 1992]. This reduction in flexibility can negatively impact safety.

Canadian experience with enterprise allocations (similar to IFQs) in the Nova Scotia offshore fishery have also produced mixed results; where some safety issues have remained the same or worsened, others have improved. Of particular interest within these fisheries, however, is the virtual elimination of overloading and capsizing events since the introduction of the enterprise allocation system [Binkley 1995]. This has been attributed to vessels being able to determine their catch prior to departing for the fishing grounds and not needing to load up or harvest beyond the vessel's carrying capacity.

Community Development Quotas (CDQs): The Community Development program is a recently instituted quota-based allocation system. The CDQ program allocates a specific quota of the total allowable catch of various fisheries (including king and tanner crab) directly to groups of villages in western Alaska [NRC 1999b]. These village coalitions, called CDQ groups, may contract out their quota to be fished by commercial fishing vessels. As in the IFQ program, each vessel participating in the CDQ program is allowed to fish a pre-designated quota. Returning to the 1994 analysis by Hermann and Greenberg that described competition and pace of the crab fishery in terms of pots fished and pots pulled, it is clear that fishing for crab in the CDQ regime offers many differences that may translate into safety-enhancing features. This can be seen in Table 1, which compares (between a CDQ and open access fishery) the number of pots registered per vessel (a measure of competitiveness) and the number of pots pulled per vessel per day (a measure of fishery pace) for the 1998 and 1999 Bristol Bay red king crab and Bering Sea opilio fisheries.

Under the CDQ regime, the fishery is less competitive and slower paced. While the number of registered pots between the two fisheries is only slightly different, there is a substantial reduction in the number of pot lifts per vessel per day (due to longer soak times). As a result, the fishery provides for increased opportunity for rest (from four hours a day to eight hours a day), reduces stability concerns due to fewer pots being carried, and provides increased choice in determining when it is too rough to fish [personal communication with Kevin Kaldestaed, President of Kaldestaed Fisheries, 4 Jan 2000].[8]

Pollock Conservation Cooperative & American Fishery Act Type Cooperatives: Following the enactment of the American Fisheries Act (AFA) of 1998, nine companies operating 20 qualified U.S. flag catcher processor vessels formed the Pollock Conservation Cooperative (PCC). Owners formed the PCC to end the race for fish that had previously existed under the open access regime in the BSAI pollock fishery. The problems associated with the race for fish within the pollock fishery were not primarily safety related. With an average fatality rate of approximately 28 fatalities per 100,000 FTE workers since 1990, the BSAI pollock fishery has enjoyed a relatively solid safety record for the past decade. Instead, the race for fish within the at-sea processor sector of the pollock fleet was characterized by severe overcapacity, an ever increasing need for investment in more capacity to maximize catch, under utilization of the pollock resource, and economic instability within the fleet [At-Sea Processors Association 1999]. Since the enactment of the PCC, significant changes have occurred within the at-sea processor pollock fleet that have rationalized and slowed down the fishery. The following statistics compare the pollock A season averages from 1995-1998 under the open access regime for the 16 qualifying vessels, and the 1999 season under the Pollock Conservation Cooperative (PCC) regime for the 16 qualifying vessels [At-Sea Processors Association 1999]:

Table 1. Open Access & CDQ BSAI Crab Fishery Comparisons (Source ADF&G)

	1998	1999
Bristol Bay red king crab		
% Reduction in Pots Lifted	76%	76%
% Reduction in Pots Fished	6%	12%
Bering Sea opilio crab		
% Reduction in Pots Lifted	53%	48%
% Reduction in Pots Fished	6%	4%

> Annual daily catch fell by 60 percent in 1999 compared to the 1995-1998 average.
>
> Average hauls per day fell by 45 percent from the 1995-1998 average.
>
> The season length increased from the 27.8 days average from 1995-1998 to 59 days under the PCC.[9]

While the slowing down of the fishery and the flexibility offered by the quota systems has not had an impact upon fatality rates (the fatality rate has remained at zero since 1995), vessel owners from several of the PCC companies have reported an approximately 50 percent reduction in processing crew injuries since the implementation of the cooperatives [personal communication with John Bundy, President for Glacier Fisheries, 25 March 1999]. This reduction in injuries has been attributed to a slower work pace and reduced fishing in poor weather conditions.

SUMMARY

Based upon the cursory assessments of the four principal fishery management system types being administered in the BSAI management areas, it appears that quota-based systems have several potential safety benefits over the current open access system. Not only can quota-based systems reduce overcapacity, they can also reduce the speed of the fishery, and reduce the emphasis on catching power. In terms of safety, this can translate into less fatigue, reduce the need to overload a vessel, and allow a master flexibility as to what type of weather in which he fishes. Each of these concerns have been identified as major problems within the BSAI crab fleet (as well as numerous other fishing fleets nationwide), and none of these safety improvements can be achieved within the existing framework of the CFIVSA. If advances in commercial fishing vessel safety are to be made beyond the existing national focus of vessel and crew-related safety remedies, changes in the fishery management regimes must be seriously considered.

REFERENCES

At –Sea Processors Association [1999]. "Preliminary assessment of the pollock conservation cooperative." Seattle: At-Sea Processors Association. Photocopied.

Binkley M [1995]. Risks , dangers, and rewards in the Nova Scotia offshore fishery. Montreal: McGill-Queen's University Press.

Greenberg J, Herrmann M [1994]. Allocative consequences of pot limits in the Bristol Bay red king crab fishery: An economic analysis. North Am J of Fisheries Mgmnt *14:* 307-317.

Hall A [1992]. ITQs-Solution to the 'tragedy of the commons' or tragedy for the common man? Nat Fisherman, November, 1-b.

Hermann M , Greenberg J, Criddle K [1998]. An economic analysis of pot limits for the Adak Brown king crab fishery: A distinction between open access and common property. Alaska: Alaska Fishery Research Bulletin *5:* 25-38.

Natural Resources Consultants, Inc. [1999]. "Status of Washington based commercial fisheries and the fleet's future utilization of Fishermen's Terminal" Seattle: Natural Resources Consultants, Inc. Photocopied.

National Institute for Occupational Safety and Health [1997]. Commercial fishing fatalities in Alaska: risk factors and prevention strategies. Current Intelligence Bulletin 58. Washington, D.C.: DHHS (NIOSH) Publication No. 97-163.

National Research Council [1999a]. Sharing the fish: toward a national policy on individual fishing quotas. Washington, D.C.: National Academy Press.

National Research Council [1999b]. The community development quota program in Alaska. Washington, D.C.: National Academy Press.

Poulsen E H [1999]. Economic feasibility of the industry funded license buyback for the Bering Sea crab fleet [Master's thesis]. Washington: University of Washington.

Sustainable Fisheries Act [1996]. Vol. 100., part 5, 3559.

U.S. Congress. Senate [1999]. Committee on Commerce, Science, and Transportation. Testimony of Dr. David Fluharty before the Committee Hearings on Magnuson-Stevens Fishery Conservation and Management Act. 106th Cong., 1st sess., 29 July.

Woodley C [1999]. "A Review of the 13th & 17th Coast Guard district at the dock stability and pot loading survey for the 1999 Bristol Bay red kingcrab season." Seattle, WA: 13th Coast Guard District. Photocopied.

Woodley C [2000]. Developing Regional Strategies in Fishing Vessel Safety: Integrating Vessel Safety and Fishery Management [Master's thesis]. Washington: University of Washington.

FOOTNOTES

1. Quota-based fishery management is a highly controversial subject. The thoughts expressed in this paper reflect only the opinion of the author, and not the U.S. Coast Guard.

2. The vast majority of the 67 fatalities in the BSAI crab fleet from 1990 to 1998 have been capsizing events (64 percent), man overboard (27 percent), and industrial type accidents(9 percent).

3. In 1999 these declines have resulted in closures of two major crab fisheries (St. Matthew blue king crab and Pribilof Island redking crab), a 50 percent harvest reduction in Bristol Bay red king crab, and an 88 percent reduction in Bering Sea opilio crab harvest.

4. As a conservation measure designed to curtail fishery speed and effort, ADF&G has limited the individual number of pots a vessel can fish. These pot limits are not a safety measure because the number of pots a vessel is allowed to fish under ADF&G rules is not based on individual vessel stability criteria.

5. As a safety measure, ADF&G provides wet storage areas so that vessels can store unbaited pots near the fishing grounds prior to the season. Ideally wet storage reduces the number of pots a vessel must carry at one time. Due to shrinking season lengths, many vessel operators feel there is not enough time to travel to the wet storage areas to retrieve their pots and instead opt to carry as many pots as possible.

6. An IFQ is defined as “a Federal permit under a limited access system to harvest a quantity of fish, expressed by a unit or units representing a percentage of the total allowable catch of a fishery, that may be received or held for exclusive use by a person” (NRC 1999).

7. Although the season is 245 days, most vessels do not fish the entire period, but fish until their individual quota is exhausted.

8. Kaldestaed Fisheries is a partner with the Bristol Bay Economic Development Corporation, a CDQ group.

9. This reduction is impressive considering the pollock quota available has been cut by 50 percent as a result of reallocation among sectors.

AN INNOVATIVE INVESTIGATION OF THE RELATIONSHIP BETWEEN FISHERIES EQUIPMENT DESIGN AND MARINE AND OCCUPATIONAL ACCIDENTS IN THE INSHORE SCALLOP FISHERY OF THE NORTHEASTERN UNITED STATES

Jeffrey R. Ciampa, B.S., Master Mariner (1600 GRT)
Visiting Scholar
Harvard School of Public Health
Boston, Massachusetts, U.S.A.
E-mail: Jrciampa@msn.com

Commander Vince Wilczynski, Ph.D.
United States Coast Guard Academy
New London, Connecticut, U.S.A.

Thomas J. Smith, S.C.D., C.I.H.
Harvard School of Public Health
Occupational Health Program
Boston, Massachusetts, U.S.A.

Ann S. Backus, M.S.
Harvard School of Public Health
Occupational Health Program
Boston, Massachusetts, U.S.A.

Jeff Ciampa is a 1983 graduate of the United States Merchant Marine Academy, and has sea experience serving onboard commercial vessels of the U.S. Merchant Marine. He served from 1993 through 1999 as the commercial fishing vessel safety coordinator at the U.S. Coast Guard Marine Safety Office in Portland, Maine. He was responsible for designing and implementing safety programs in the commercial fishing industry of the northern New England region of the United States. His design of the innovative small vessel damage control trainer was recognized with a United States Vice-Presidential award on government innovation, and was subsequently adopted nationwide by the U.S. Coast Guard. Jeff Ciampa is currently employed as the Manager of Safety, Training and Environmental Compliance for Sprague Energy of Portsmouth, New Hampshire, New England's largest independent marine terminal operating company.

BACKGROUND

This paper documents efforts to address safety problems affecting the inshore scallop fishery occurring in coastal waters of the State of Maine, United States of America. Comparison of analysis of safety problems and design of preventive interventions must include a review of the regulatory authority and controls governing the affected fishery. The regulatory structure of this fishery has the State (provincial) government responsible for resource management regulations and the Federal (national) government responsible for management of safety conditions within the fishery. Safety regulations in place for vessels of this size (typically between 8 to 15 meters in length) and operating area are limited to mandatory carriage of maritime survival equipment. There are no construction or design standards or controls in place for vessels of this size, and there is no authority for the vessels to be inspected for minimum standards of materiel condition. Agencies of the federal and state government lack the authority to require professional competency licensing for masters or crew members for fishing vessels of this size. Vessel owners are required to be licensed by the State government to participate in the fishery. This licensing authority requires no qualification of professional competency and is utilized for conservation control purposes only. Both federal and state government agencies require mandatory reporting of accidents affecting vessels in this fishery. The U.S. Coast Guard rarely enforced these regulations prior to establishment of a dedicated fisheries safety effort in 1993. Accident records maintained prior to 1993 did not record the fishery the vessel was engaged in or the equipment type in use. Therefore, records that do exist prior to 1993 are thought to be highly incomplete and difficult to incorporate into an historical analysis of safety trends within this fishery.

In the absence of authority to regulate design, construction, maintenance, and operating standards for vessels in this and other fisheries, the U.S. Coast Guard established in 1993 a safety program intended to identify accident trends and develop and initiate preventive interventions. Restricted by the absence of regulatory authority, participation of the fishery in this program is voluntary in nature, although regional Coast Guard commanders have bolstered this program by tasking safety program personnel to participate in accident investigation processes. The safety initiatives detailed in this paper are an evolutionary development of the voluntary safety program initiated in 1993.

DESCRIPTION OF THE FISHERY

The harvest of scallops from inshore waters of the State of Maine is by regulation limited to winter months. Regulations allow open access by fishing vessels owned by permitted individuals during the harvest season, which typically runs from November 1 through April 15. Vessels are not limited to individual or regional quotas. The design of harvest equipment is strictly regulated, as is a minimum shell size for retained scallops. Vessels are not subject to operating area restrictions. Harvest is limited to the hours between sunrise and sunset each day. There are no restrictions on vessel size, design, or crew size. Fisheries divers engaged in hand harvest of scallops comprise a small portion of the scallop fishery. The vessels and safety conditions of this hand harvest sector are not included in this paper.

Vessels utilized for scallop dragging are typically between 8 to 15 meters in length, with a few larger vessels utilized for offshore fisheries engaged in the fishery on a seasonal basis. Vessels are typically of fiberglass construction, although wood hulls and occasionally steel hulls are employed. Many of the vessels employed in the fishery are utilized seasonally in other fisheries, typically employing stationary gear. In 1998, 775 vessel owners were permitted to employ their vessels in this fishery. (The vast majority of these own a single vessel.) This number was the highest number of permitted individuals in this fishery in recent years. Vessels typically operate with two crew members. Many vessels will be operated by a single individual at some point during the fishing season. Crew sizes as high as six have been observed, although these crew sizes are generally limited to the highly competitive first few days of the fishing season.

Construction of the fishing apparatus, locally referred to as a “drag”, is highly regulated for conservation control purposes. These devices consist of a chain mail bag fixed to a steel frame designed to drag the device firmly against the seabed as the vessel tows the device across fishing banks. Heavy chains on the bottom of the drag behind the steel frame are installed to dig into the seabed and scrape scallops (and other bottom sediment) into the chain mail bag. Scallops and the larger chunks of sediment from the seabed are retained in the chain mail bag and recovered to the vessel, typically after 10 to 15 minutes of towing. The vessel tows the fishing apparatus by a single wire.

IDENTIFICATION OF ACCIDENT TYPES

Within two years of the establishment of a dedicated fisheries safety program by the U.S. Coast Guard a distinct pattern of serious worker injuries and adverse events involving vessels was identified in scallop vessels. Vessels in this fishery were observed to suffer a wide range of adverse events, although an alarming number of capsizes and serious injuries were recorded. In the investigation of these incidents, fisheries safety officers (trained as maritime transportation safety officers) observed a wide range of equipment handling systems in use on board vessels in the scallop fishery. This range of equipment design was unique to the scallop fishery. In most commercial fisheries of the northeast United States, fishing equipment and vessel handling systems have evolved to similar designs. The diversity of equipment in use in the scallop fishery, which appeared to be based on regional designs, is considered unique to this and related fisheries in the northeast United States.

HISTORICAL SAFETY APPROACH

Fishery safety efforts traditionally employed by the U.S. Coast Guard include the conduct of investigations to determine the causative factors of an adverse event, for the purpose of preventing similar accidents in the future. Historically, the findings of investigations would form the data employed in fisheries safety efforts. Sequences observed in the documentation of safety incidents would form the basis of preventive efforts, which would be conducted on a vessel-by-vessel basis. This process was effective in the identification of individual vessels in danger of repeating previously documented events, and once identified, in advising the vessel operator of the potential for the formation of a similar sequence.

This process is extractive in nature, with data being drawn from event sequences and opinions formulated into safety recommendations exclusively by safety personnel. By excluding the affected population from the identification of risk and the formation of safety recommendations the process is essentially an open loop, with the affected population receiving only the opinions and recommendations of others regarding risks they face. This results in three distinct problems in the proper identification of risk and formation of effective preventive solutions. First, the affected population does not participate in the identification of risk, and may hold different perceptions of risk or possess valuable experience outside of the observed patterns. Second, the process of advising vessel operators of conditions observed in sequences is effective at avoiding repetitive accidents, but is ineffective at evaluating problems on a fleet wide basis, when effective solutions may lie not in the maintenance of equipment, but in its very design. Third, the process of advising affected populations of safety recommendations formulated solely by safety personnel does not allow the population to comment on the perceived economic or efficiency aspects of proposed preventive solutions, which can affect acceptance of solutions otherwise considered effective.

DEVELOPMENT OF AN INNOVATIVE APPROACH

When the pattern of serious injuries and vessel damage was identified, a response to the safety problems in the inshore scallop fishery was initiated. The wide range in equipment types observed in this fishery created a problematic application of the historical safety approach. The wide range in patterns being experienced by the different equipment types did not lend for easy categorization of events. A poor understanding by safety personnel of the economic and regional conditions that resulted in a wide range in equipment types forced the development of a preventive strategy designed to maximize inclusion of the affected population.

EXCESS OF ACCIDENTS

Previous efforts to include the affected population in development of preventive solutions were complicated by the differing perceptions of risk held by fishermen and fisheries safety personnel. Historically, safety efforts were focused on the prevention of serious injuries, deaths, or vessel loss, with certain event sequences being especially important to address through safety programs. To effectively include the affected population in a discussion of risk, it is especially important that the population and the safety agency view the problem as one which creates an excess of injuries or loss, with safety incidents occurring above levels considered acceptable for the activity involved. In the inshore scallop fishery, the number of vessel capsizes being experienced constituted a significant percentage of the total number of capsizes experienced in all fisheries, with 9 of 13 recorded incidents occurring in the inshore scallop fishery. Serious acute injuries, including amputation and fatal injury resulting from “struck by” incidents were also recorded in this fishery sector while not being observed in any other sector of the commercial fishing industry. Historical documentation of these incidents was compelling evidence for members of the inshore scallop fishery that their fishery was experiencing excessive injuries.

INTERRELATIONSHIP OF MACHINERY DESIGN TO ACCIDENT FORMATION

Historically many incidents in the commercial fisheries are classified as human error in the operation of essentially hazardous machinery. In several of the capsize incidents experienced in the inshore scallop fishery, vessel operators involved in the incidents reported minor errors in judgment or vessel handling as the cause of the event. The practice of behavioral controls to prevent harm involving inherently dangerous equipment results in the perpetual need to conduct activities under all service conditions using the exact same behavioral controls. Elimination of a hazard through engineering design will allow for variance in behavior of operators, thereby creating an inherently safer environment for the crew of the vessel involved.

In the inshore scallop fishery, the use of behavioral controls to prevent serious safety incidents was widespread. In the investigation of both vessel capsizes and acute injuries incidents, fisheries safety personnel repeatedly encountered descriptions of vessel handling and work practices that could be employed to prevent injury and vessel loss. The widespread use of behavioral controls to prevent harm rather than the use of engineering controls indicated a good opportunity for introducing effective engineering solutions to mitigate safety problems.

CHARACTERIZATION OF EQUIPMENT HANDLING SYSTEM

Recognition of highly regionalized designs of hull-equipment design prompted an effort to identify and characterize the equipment systems in use. During the 1997-1998 inshore scallop fishery season, fisheries safety personnel were deployed on Coast Guard vessels and on commercial fishing vessels through out the season to identify every different type of vessel-equipment system in use. This effort resulted in the identification of nine distinct designs, all of which were photographed and video taped for analysis. An engineering analysis of these vessel-equipment designs resulted in the characterization of three basic types of vessel-equipment designs. These designs, and their use in various situations, are described in the following paragraphs.

Single wire systems: Five of the designs utilized a mast/boom system and a single hydraulic winch system. The crew utilizes this winch system to set the fisheries apparatus overboard to the seabed, to tow the apparatus through the water, and to recover the apparatus to the vessel and suspend it above the deck for access.

Two wire systems: Two of the designs utilized a towing frame and independent mast/boom system to handle the fisheries apparatus. One hydraulic winch system was used to set the fisheries apparatus to the seabed, to tow the apparatus across the seabed, and to recover the apparatus to the side of the hull. A second hydraulic winch system was used to recover the fisheries apparatus on board and suspend the equipment from the mast/boom system for access by the crew. These designs involved manual interaction with the equipment by the vessel crew to make and disconnect the connection of the second winch system at each cycle of the fishing operation.

Two wire, one wire on equipment systems: Two of the designs involved two hydraulic winch systems utilized to set, tow, recover and suspend the fisheries apparatus. In these designs only one of the hydraulic winch systems is connected to the fisheries apparatus. The second hydraulic winch system is utilized to cycle rigging systems to facilitate the suspension of the fisheries apparatus for access by the crew.

Washington County System, Design: Single wire system

Basic Description: This design uses a single wire, led directly from the drag winch through a towing block mounted at the head of a boom carried on the vessel's centerline. The arrangement allows for the drag to be suspended above the deck of the vessel for access by the crew, but results in a towing point very high in the rigging.

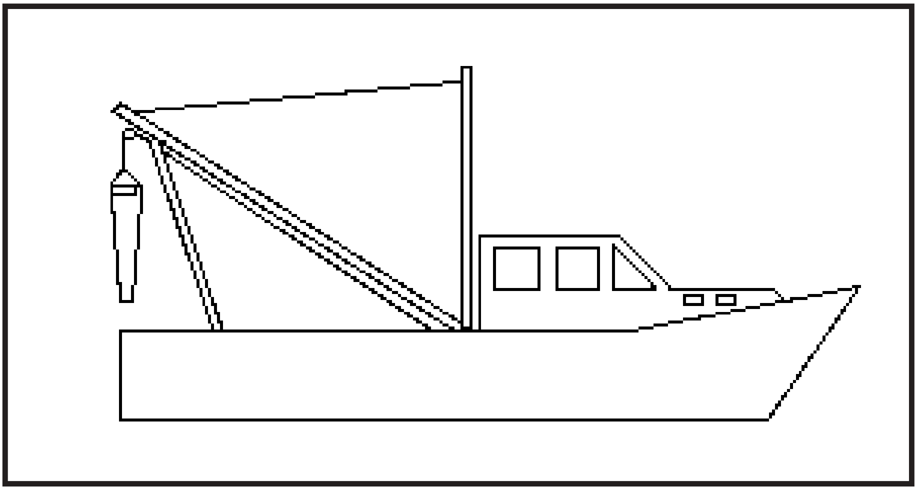


Figure 1: Washington County System, drag recovered.

Fixed A-Frame System, Design: Single wire system

Basic Description: In this design, towing and lifting are accomplished by a single block located on the vessel's centerline above the transom of the vessel. The towing block is suspended from a fixed A-Frame, typically supported by struts leading forward on the vessel. In some variants, the forward struts have been observed to be wire or chain, with a slight rake to the A-Frame.

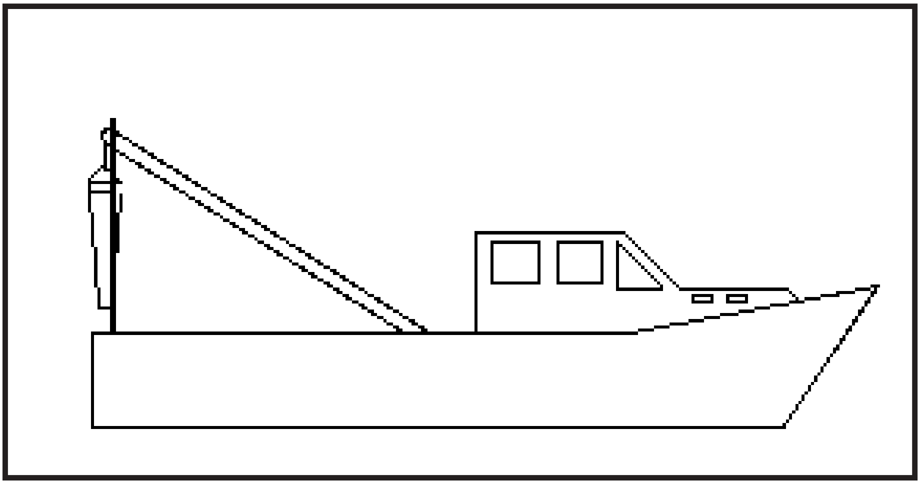


Figure 2: Fixed A-Frame system, drag recovered.

Harpswell System, Design: Single wire system.

Basic description: This design makes use of a single wire rigged to a block mounted on a frame at the after end of the vessel. The Harpswell rig frame resembles the frame used in Dropping Frame designs, and is mounted to the vessel on pins that allow it to pivot fore and aft. The frame of this design moves through a much smaller arc, and does not appreciably lower the height of the towing point. This design allows the vessel to recover and suspend the drag outboard of the transom, then use the frame to shift the laden drag forward, over the transom of the vessel.

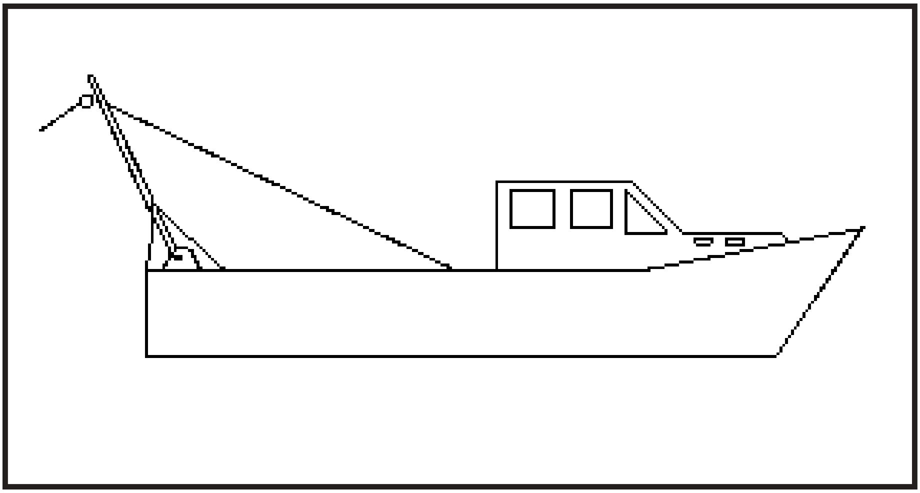


Figure 3: Harpswell system, drag deployed.

Rocket Launcher System, Design: Single wire system.

Basic description: The "rocket launcher" system is a single wire system, designed to tow the drag off the stern of the vessel. The scallop drag is contained in a pivoting cage, which allows the drag to be emptied through the jaw of the drag without the need for persons to stand beneath the suspended weight of the drag.

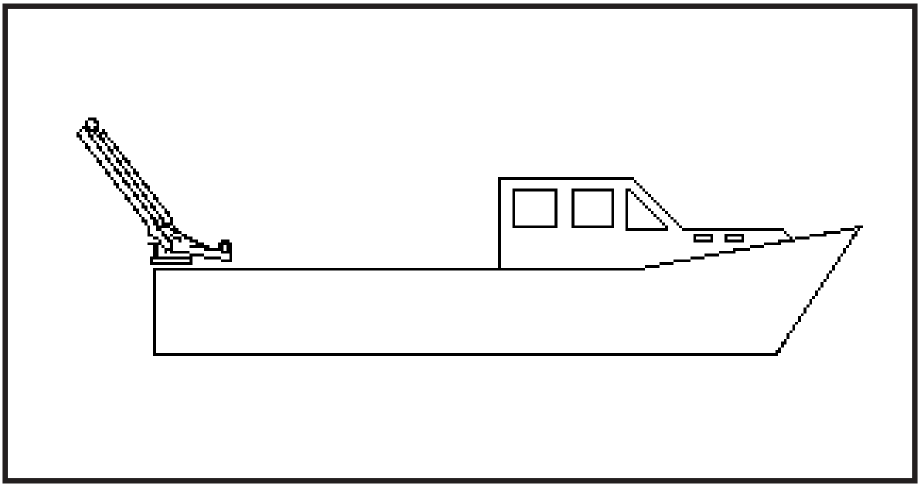


Figure 4: Rocket launcher system, drag recovered.

Single Point Side System, Design: Single wire system.

Basic description: This design makes use of a boom-mounted athwartships to set and recover the drag. The boom is positioned so that the height of the boom is sufficient to suspend the drag aloft without use of a second wire. As the height of the towing point at the head of the boom is sufficient to generate significant heeling moments, these vessels will use a lizard to lower the effective towing point when the vessel is engaged in dragging.

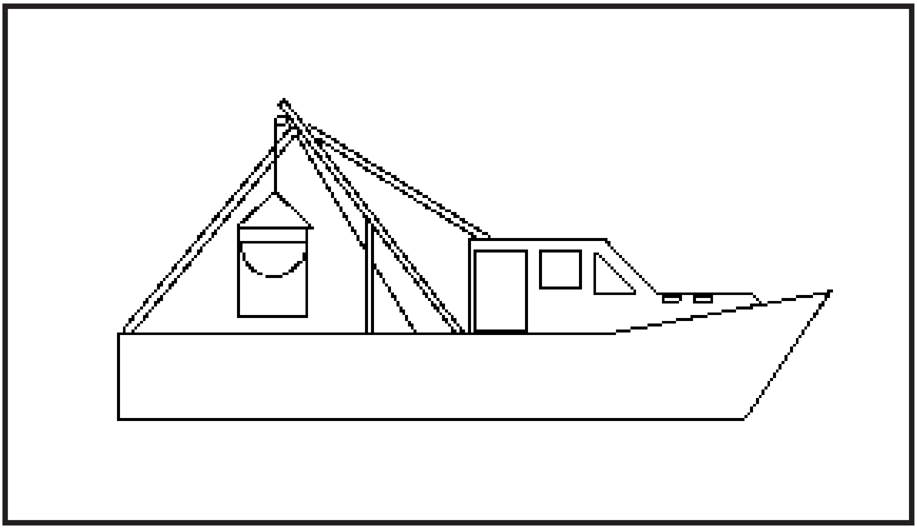


Figure 5: Single point side system, drag recovered.

Quarter Drag System, Design: Two-wire system.

Basic description: This design utilizes two wires. One wire is dedicated for towing purposes, typically rigged to a block suspended from a towing frame positioned at the quarter of the vessel. This wire is used to set, tow, and recover the drag. When the drag is recovered, the crew will make a second wire or fiber rope (called a cargo line) to the head of the drag by a hook. By slowly easing out on the towing wire and hauling in on the cargo line, the weight of the drag is shifted forward below the boom head block, and then hoisted aloft until the drag clears the gunwale of the vessel.

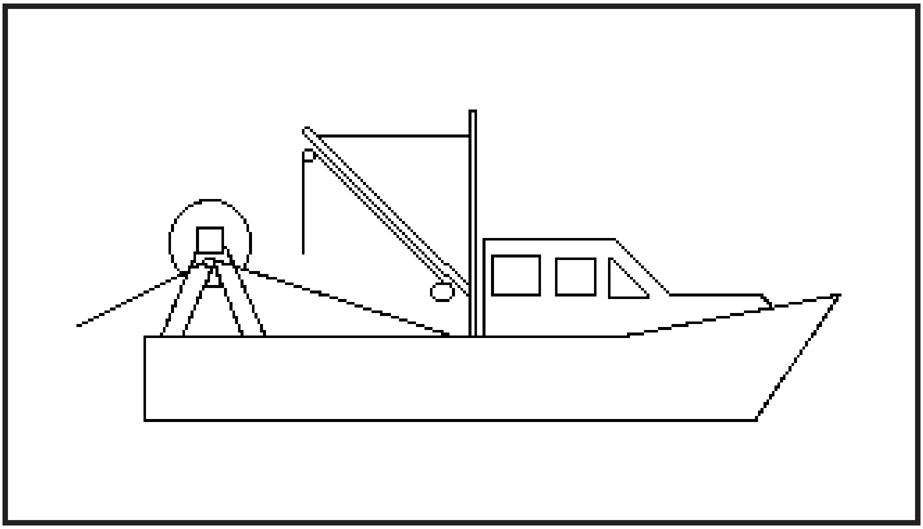


Figure 6: Quarter drag system, drag deployed.

Side Drag System, Design: Two-wire system.

Basic description: Two separate wires are used in this system. One wire is dedicated for towing purposes, typically rigged to a block suspended from a towing arm positioned amidships. This wire is used to set, tow, and recover the drag. When the drag is recovered, the crew will make a second wire or fiber rope (called a cargo line) to the head of the drag by a hook. By slowly easing out on the towing wire and hauling in on the cargo line, the weight of the drag is shifted aft below the boom head block, and then hoisted aloft until the drag clears the gunwale of the vessel.

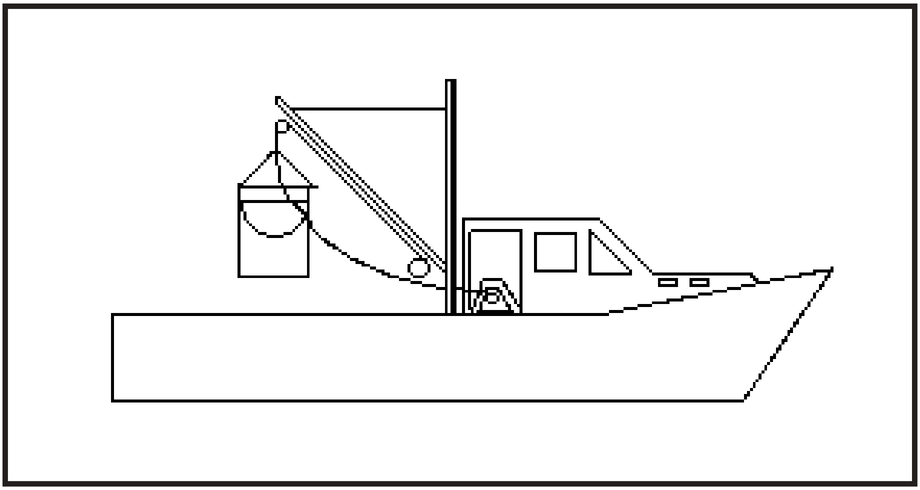


Figure 7: Side drag system, drag recovered.

Flying Block System, Design: Two-wire system (one wire on drag).

Basic description: This design is very similar to the Washington County design, except that towing block is fitted to a wire lead through a second block fitted to the boom head plate. This second block is used to lower the towing block when the vessel is towing.

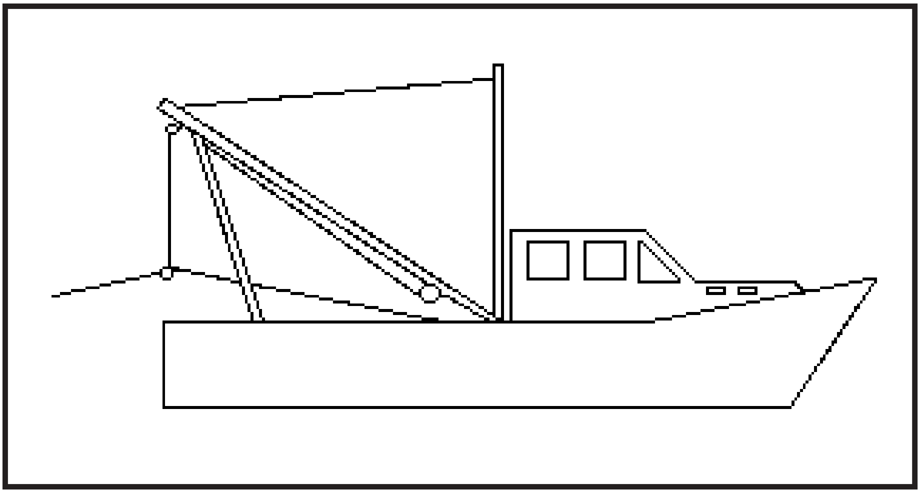


Figure 8: Flying block system, drag deployed.

Dropping Frame System, Design: Two-wire system (one wire on drag).

Basic description: This design involves a frame mounted over the work deck of the vessel, fitted to swivels mounted to the gunwales of the vessel. The drag wire is led to a towing block on the frame. A topping lift is led from a second winch to a block at the masthead, then to the top of the frame. This arrangement allows for the frame to be lowered from a position over the work deck of the vessel to a position roughly parallel with the gunwales of the vessel.

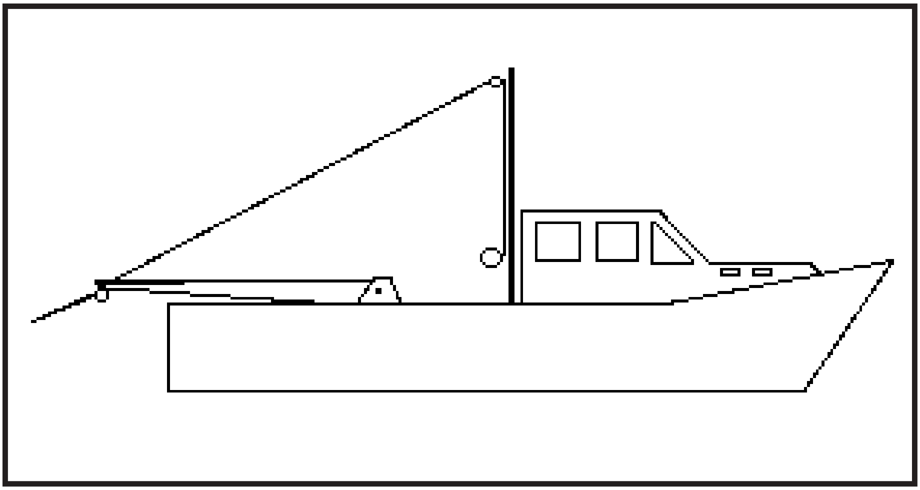


Figure 9: Dropping frame system, drag deployed.

LINK OF INJURY/ACCIDENT DATA TO MACHINE TYPE

Preliminary efforts to characterize the nature of accidents being experienced in the scallop fishery identified three basic types of circumstances responsible for the majority of known serious safety incidents. Two of the circumstances involved vessel stability, resulting in vessel capsizings. Some of the capsize incidents were suffered while towing fishing apparatus across the sea bed. These incidents are referred to as dynamic incidents, as energy of the vessel's propulsion system contributed to the forces involved in the capsizing. The remainder of the capsize incidents occurred while the vessels were engaged in lifting laden fishing apparatus from the water to recover catch. These incidents are referred to as static incidents; as forces from the vessel's propulsion equipment did not contribute to the heeling moment resulting in capsize. The remainder of the known serious incidents involved injury to crew members in what are best described as classic industrial injuries. In these incidents, persons were injured (in one instance fatally) by rigging failure or by entanglement in hydraulic winches during fishing equipment recovery operations.

A review of vessels involved in serious incidents appeared to reveal an interrelationship between equipment handling system design in use on a vessel and the types of accidents being suffered. Specifically, vessels towing from points aloft in their rigging appeared to be suffering the bulk of the dynamic stability incidents, while vessels towing and lifting equipment from the sides of the vessels appeared to be suffering the majority of the static stability incidents. The majority of serious occupational type incidents appeared to be occurring on vessels designed to handle equipment over the side of the hull.

By linking observed incident types to the taxonomy of vessel-equipment designs, a fishery specific terminology was developed that allowed fisheries safety personnel to achieve highly effective communications with the affected population. To explain the vessel-equipment designs and conduct effective demonstrations of accident sequences and operating parameters, tabletop models of the nine basic designs were constructed, and a 30-minute videotape detailing on board working conditions of each of the vessel-equipment designs was produced. Development of these tools allowed vessel operators to compare the characteristics of their vessels to unfamiliar designs.

Table 1: Dispersion of accident types by vessel-equipment classification

	Dynamic capsize	Static capsize	Serious acute injury
Single wire	3	1	0
Two wire	1	3	2
Two wire, one on gear	0	1	1

COMMUNITY BASED INVOLVEMENT

Equipped with tools to demonstrate and a taxonomy classifying the different vessel-equipment designs in use in the inshore scallop fishery, fisheries safety personnel began a process of involving the affected community in the identification of risk and the development of preventive solutions. This process was conducted by scheduling a series of town meetings, to which each vessel operator residing in the town was invited. The agenda for these meetings included presentation of the nine basic vessel-equipment designs and an explanation of the accident types that had occurred and were of concern to the Coast Guard. In an open comment type format, each of the nine vessel-equipment designs was then reviewed. The advantages and disadvantages of each vessel-equipment type, and the likelihood that each type could avoid causing specific actions leading to injury or vessel loss was identified and discussed by the groups of 10 to 20 vessel operators. The comments of each discussion were recorded so the product of all meetings could be reviewed and analyzed for common and disparate opinions and experiences. In this process, it was found that the models and fishery specific terminology were highly effective at prompting group analysis of safety incidents experienced within a given region, and in the identification of specific engineering controls that vessel operators considered crucial to avoiding injury or vessel loss.

At the start of this process it was recognized that the absence of accurate historical records severely limited the development of an accurate analysis of safety conditions affecting this fishery. The implementation of an interactive process of studying safety problems permitted the collection of data pertaining to basic safety parameters related to vessel-equipment design and injury/vessel loss history. These data were collected through a questionnaire administered to the participating individuals (vessel owners). An unexpected source of data was found in the open forum meetings conducted with fishermen. The dialogue between fishermen and between fishermen and safety personnel that was fostered by the open forum format allowed the fishermen to draw on their extensive experience and knowledge of historical safety problems and enabled them, as a group, to shed new light on safety problems and the interrelationship between occupational and marine safety incidents.

The relating of experiences and previously unrecorded history by seasoned vessel operators clearly documented the evolution of vessel-equipment designs in this fishery. Operating in an unregulated environment, vessel-equipment designs have been modified through the years as vessel owners attempted to evolve toward equipment that was profitable, efficient and safe. In open group discussions on the potential for design modifications, the experience of seasoned vessel operators proved very valuable for identifying problems that the fishery had previously evolved beyond. Historical input from seasoned fishermen proved exceptionally valuable for identifying the link between occupational injury risks and stability hazards, and documented that the evolution of vessel-machinery designs that minimized occupational injury tended to result in an increase in stability-related risk. This finding proved to be one of the more valuable elements of the closed loop, interactive research method.

Conventional safety investigation systems rely heavily on injury/fatality/vessel loss data as the basis for the design of preventive solutions. Upon finding an unresearched safety problem, the application of a conventional open loop, extractive process presumes that the problem will continue unabated until sufficient data is recorded from which to formulate preventive measures. On the other hand, unresearched safety problems addressed through an interactive method allows the affected population to participate in the identification of risk, and can recover historical data and previously unrecorded risk factors invaluable in the development of preventive solutions. Because the interactive methodology captures historical data, there is no need to observe unsafe conditions for years before formulating effective prevention strategies.

Inclusion of the affected population in the development of preventive strategies results in early consideration of economic and efficiency concerns of the fishery, which prevents energy and resources from being directed toward effective but inherently unacceptable preventive solutions. The identification of potential preventive measures within the scope of economic efficiency allows for engineering resources to be focused on measures defined by and acceptable to the community. Including the affected population in this manner ultimately improves the communication problems often encountered in the delivery of preventive measures developed in conventional open looped safety efforts.

COMMUNITY BASED INVESTIGATION MODEL

The techniques used to investigate injuries, fatalities, and vessel loss in the Maine inshore scallop industry can be generalized as a model for investigating other safety concerns within the maritime and occupational safety communities. The technique, called the Community Based Investigation Model (CBIM) is a sequence of five activities conducted by the investigator: Note excess, suspect a cause, classify, link, and use community-based involvement. When applied, the CBIM is a powerful approach that engages the actual members of the industry that are being examined in the investigation. This section presents the model, and fully describes the five sequential components of a Community Based Investigation.

As demonstrated with the inshore scallop industry, many occupational health investigations simply extract information from the industry with perhaps little or no feedback supplied to those who are studied. With the CBIM, the investigation process is interactive. The subjects of the study are engaged in all parts of the study, and in fact, help determine the direction and focus of the study.

In many ways, the CBIM is a consultative process more than an investigative technique with a high level of interaction between the study leader and the study participants. As such, recommendations for safety improvements reach the industry in a near real-time period, with many of the recommendations originating from the industry itself. The role of the government regulator shifts quite readily from investigation and enforcement to education and assistance. The five components of the CBIM illustrate and enforce this relationship.

NOTE AN EXCESS

The initial component of the CBIM is the identification of an excess of injury, fatality, and/or vessel loss/damage rates for a specific operation or industry. This step is crucial, for it identifies the reason for the investigation by the investigating agent and the community being investigated. Because the industry participants are partners in the investigation, the reason for the study must be clearly stated and readily understood by all participants. By adopting the "excess" orientation for the study, the investigation will be conducted on statistically significant occurrence rates that are abnormal for the industry.

SUSPECT A CAUSE

To determine the focus of the study, the second phase of the investigation must develop a hypothesis for the cause of the injuries, deaths, and or vessel loss/damage, with the hypothesis being very broad rather than being narrow and sharply focused. Using this broad view, causation should be hypothesized as behavioral, environmental, operational, or mechanical causes. The excess rates and a suspect cause for the excess establish the initial framework for the study. It is conceivable that multiple suspects could be identified as causes for the events and used in the community based investigation technique.

CLASSIFY

Using the suspect cause hypothesized to be responsible for the excess of accidents, the industry needs to classify the cause into a taxonomy of four steps. It is suggested to conduct these meetings within the industry's home community to increase participation rates of the industry subjects, provide context for the discussions, and as to show the participants that their participation is valued. The presentation focuses the industry on the study's methodology and frames their attention on the scope and interim findings of the study.

The goal of these meetings and any subsequent discussions is twofold: education of the community and focused analysis by the investigators. During the community discussions, the participants have the opportunity to review their industry from a unique perspective. They will see their individual platforms as one member of a class of platforms and realize these platform classes correlate with the occurrence of adverse events. Their observations and comments on the investigation's interim results and methodology will help correct any misconceptions made by the investigators. Also, the participant's presented solutions to problems benefit from the instant review and refinement by other members in the community discussion group. As the investigators conduct these discussions with various groups within the industry, they serve as a conduit within the industry to educate members about the findings. It is very likely that the community will begin to identify specific problems associated with the industry classification categories that did not surface during the investigation. This insight, combined with the review of the areas warranting additional investigation identified by the study directors, identify topics that require further analysis by the investigators. For example, the participants may highlight unique situations and practices that have not yet resulted in an excess of harm, but have the potential to do so. The investigators can then focus their resources on these specific areas that have been determined by the industry participants and the investigators themselves.

CONCLUSIONS

The analysis of the inshore scallop industry using an innovative investigation method was presented as a case study from which the CBIM was derived. The unique attribute of this investigation technique is the active involvement of the industry participants in the study. Rather than simply extracting study data from the participants, the participants are partners in (linear) feed-forward systems, the CBIM is multidimensional (iterative) and analogous to a closed loop system. The assessment of the study findings is done in near real time, with corrections to the study's assumptions, results, and industry practices initiated during the study.

The community-based investigation promotes increased dialogue between the investigators and the industry participants as they partner to correct unsafe industrial practices. This partnership establishes a new role for the investigators as they shift from regulators to educators. This also establishes a new role for industry and captures industry knowledge and experience not available through the usual accident reports, vessel inspections and emergency room reports. The model suggests that the solution to unsafe practices is not additional regulation and enforcement of the industry, but rather increased education and development of safe practices. The government officials conducting the investigation become partners with the industries, and provide the service of educating members about the potential for injuries or vessel loss, suggest best practice methods, and extract areas needing additional investigation. This paradigm shift is certainly one from which that all parties, the investigators and industry participants, immediately benefit.

The CBIM is a powerful technique to identify and resolve systematic safety problems within an industry. For the inshore scallop industry, the CBIM identified the necessity to view the vessel and harvesting equipment as a single machine, to analyze machine characteristics, and classify the machines into types. It brought scallop fishermen into the process and made their valuable input part of the knowledge base. As a result, these participants learned more about the systematic problems with their industry, and were able to offer solutions, and identify areas requiring additional investigation. This investigation methodology is a powerful tool that partners the safety perspective of government regulators with the economic efficiency perspective of industry participants. Together, this team can identify unsafe practices and design improvements to the industry that will be accepted.

CAUSES & CONTRIBUTING FACTORS – ANALYSIS OF ACCIDENTS INVOLVING FISHING VESSELS IN CANADA

Marcel Ayeko, M.S.C., C.Eng., M.R.I.N.A.
Chief, Marine Safety Analysis
Transportation Safety Board of Canada
Hull, Quebec, Canada
E-mail: marcel.ayeko@tsb.gc.ca

Until his recent appointment as the Manager — Quality, Planning and Performance at the Transportation Safety Board of Canada, the author has worked at the same organization for the last ten years as Chief of Marine Safety Analysis. Job highlights included investigation and safety analysis of marine transportation accidents; including the identification of safety deficiencies, risk analysis, risk control options, and the development of corrective safety actions. Past employments include the following: Naval Architect/Shipbuilding Engineer (Burma, Singapore, Japan), Project Manager (Saint John Marine Consultants, New Brunswick), Offshore Engineering Specialist (Petro-Canada, Calgary), Lecturer (Marine Institute, Newfoundland), Consultant - Offshore Naval Architect (Canada, England, Monaco), Marine Surveyor (Canadian Coast Guard).

Marcel Ayeko is a Chartered Engineer (Engineering Council — UK) with a M.Sc degree in Naval Architecture and Shipbuilding and is a Member of the Royal Institution of Naval Architects. He has delivered several papers on various subjects of marine transportation safety at conferences in Canada, Spain, Bulgaria, France, Croatia, and the United Kingdom.

The Canadian Transportation Accident Investigation and Safety Board, commonly known as TSB, is a Canadian federal government agency mandated to improve transportation safety by:

> Conducting independent investigations, including, when necessary, public inquiries, in order to make findings as to their causes and contributing factors;
>
> Identifying safety deficiencies as evidenced by transportation occurrences; and

Reporting publicly on its investigations and public inquiries and on the related findings.

The TSB's sole objective is to advance transportation safety, which is predicated upon the identification of safety deficiencies and associated risks. As such, the investigations are carried out with the prime purpose of identifying safety deficiencies in transportation occurrences and to propose corrective safety action designed to eliminate or minimize risks associated with any such deficiencies.

TSB is independent of other government departments that regulate or operate elements of the marine, rail, commodity pipeline, and air transportation systems. It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board does not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

TSB APPROACH TO ADVANCING TRANSPORTATION SAFETY

Generally, an investigation of any occurrence has three main objectives:

a. To find out "What happened?" (i.e. to satisfy curiosity);

b. To determine "Who did it?" for the purpose of apportioning blame, liability; and

c. To improve safety.

Traditional investigations placed more emphasis on objectives (a) and/or (b). Objective (a) will be met if the investigation can just determine the cause. In a traditional investigation, once the *immediate cause* of an accident is found, the process of investigation often stops at that point without further examining the information about cause such as underlying factors and contributory conditions. Determination of *immediate cause* is useful in identifying who had the last opportunity to intervene and prevent the accident. It does little in terms of understanding of the unsafe conditions, which lead to unsafe acts in the first place.

With objective (b), the investigation will be looking for who is to blame with a view to establishing damage compensation and punishment (civil/criminal liability.) For example, an investigation might conclude upon discovering the fact that a collision occurred because the master of the fishing vessel did not proceed at a safe speed. Possible underlying factors such as the requirement to maintain a tight sailing schedule, to take advantage of a per-trip fishing quota, or the need to work long hours resulting in fatigue due to a small complement, etc. were usually left undetermined. As such, cause determination or apportioning blame by itself would not do much to improve safety.

Today, more and more investigations are conducted to learn from the accidents and thus improve safety. As indicated above, the ultimate objective of TSB investigations is to *improve safety*, transportation *safety*. To that end, TSB investigations are conducted to identify inadequacies in the system, which could cause or contribute to the probability and/or severity of an accident or an incident.

WHAT IS "SAFETY" AND HOW TO IMPROVE IT?

The Oxford dictionary defines *"safety"* as "*freedom from danger or risks.*" Risk has two elements and is commonly defined as the product of the probability of an adverse outcome and the severity of that outcome.

$$\text{RISK} = \text{PROBABILITY} * \text{CONSEQUENCE}$$

To improve safety means to eliminate or reduce risks. Risk can be treated by reducing *probability* and/or minimizing the *consequences*. To do so, one must understand the causes and underlying factors that contribute to both elements of the RISK equation. If the focus of an investigation is only on the causal factors and on preventing "recurrence", it will limit the potential for safety improvement by not considering the second element of the risk equation. Many of us can think of an accident that had factors at play that were not causal, but that contributed to the severity of the outcome. An obvious example would be inadequate lifesaving equipment and inadequate competence and training in marine emergency duties. Another could be the design characteristic of the vessel that allowed a relatively minor incident to become a serious accident. Eliminating such deficiencies will do nothing to prevent a future accident, but it may significantly improve safety by reducing the severity of consequences.

DETERMINATION OF CAUSAL, CONTRIBUTING AND UNDERLYING FACTORS

Since its inception in 1990, TSB has systematically analyzed its investigative findings to arrive not only at the proximate causes but to understand the underlying factors that caused or contributed to the severity of accidents. Today, several models, analytical tools, and techniques exist to assist the investigator/ analyst in analyzing accident causation not only for the purpose of understanding "WHAT" happened but also "WHY" it happened, by establishing the root causes and contributing factors to the accident.

Dr. James Reason of the University of Manchester developed one such model. While some analysts refer to this as the "*Swiss Cheese Model*," it is much better known as *"Reason's Model*." (See Figure 1.) TSB safety analysts in all modes of transportation often use this model. The second layer represents unsafe act(s) committed by frontline operator. Fortunately, a well-designed system has built-in defenses (the first layer in the model), physical or administrative, to mitigate the circumstances of such unsafe acts. But the model requires us to look beyond the immediate circumstances of the accident. It will force the user to examine all the preconditions at the time of the occurrence, including such things as fatigue, stress, operating practices, etc. The fourth

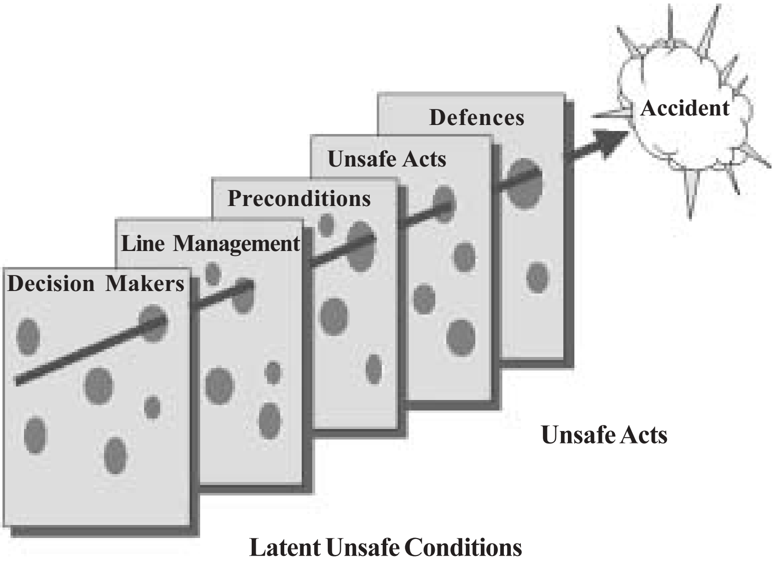


Figure 1: Reason's Model

layer represents the effects of line management in such areas as training, maintenance, operating procedures, etc. The fifth layer depicts all high-level decision-makers such as regulators, owners, the designers, manufacturers, and the unions, etc. Reason suggests that these decision-makers frequently make "fallible" decisions and these latent defects stay dormant waiting for someone to commit an unsafe act and thereby triggering a potential accident scenario. If the system's defences function as intended, benign outcomes result; if they do not, the result may be a tragedy. Reducing or eliminating safety deficiencies can be represented by a reduction in the size or number of holes, and thereby reducing the probability of an accident. The Reason Model is particularly useful in illustrating the concept of multiple causality.

The General Error Modeling System (GEMS) (see Figure 2), also proposed by Dr. Reason, is used by analysts to look beyond unsafe acts committed by front line operators. The GEMS framework is used to determine the origin of that particular act or causal condition. For the scope of this paper, it is sufficient to recognize that to uncover the underlying causes behind the decision of an individual or group, it is important to determine if there were any factors in the work system that may have facilitated the error and the unsafe act. Human performance analysts at TSB use this model to identify underlying human and organizational factors.

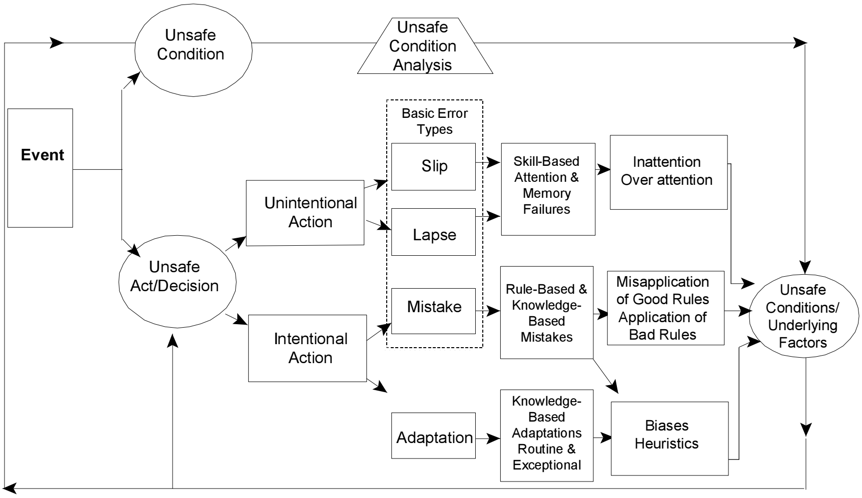


Figure 2: General Error Modeling System

OVERVIEW OF ACCIDENT STATISTICS on FISHING VESSELS

During the period 1975-1999, the TSB recorded a total of 19,000 shipping accidents involving 21,000 vessels. Approximately 50 percent (10,370) of them were Canadian fishing vessels. Of these vessels, more than half measured less than 15 gross tons. Since 1988, about half of the vessels involved in marine accidents have been fishing vessels.

In 1999, 532 shipping accidents, involving 577 vessels, were reported to TSB. About half of the vessels involved were fishing vessels; about 15 percent were foreign-flag vessels in Canadian waters and the remainder involved other types of Canadian-flag vessels. A total of 44 vessels were reported lost in the same period, of which 39 were fishing vessels. Note that there were approximately 26,000 federally licensed fishing vessels in Canada. The following table depicts a brief overview of the types of vessels involved in shipping accidents reported over the past ten years.

Table 1 - Vessels Involved in Shipping Accidents by Type of Vessel

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cargo	76	68	52	41	48	34	28	20	25	25
Bulk Carrier OBO	129	121	135	132	141	120	97	60	67	71
Tanker	49	32	27	25	26	15	24	13	18	14
Tug	82	68	48	43	57	52	46	38	43	42
Barge	98	97	41	34	42	51	43	31	24	35
Ferry	33	37	26	29	28	27	22	17	22	22
Passenger	24	26	34	20	17	20	18	15	27	19
Fishing	586	481	467	380	445	389	322	320	253	280
Service Vessel	59	52	50	31	44	36	24	30	27	35
Non-commercial	23	38	26	32	23	29	16	12	18	14
Other	13	10	9	11	11	3	15	18	8	20
Total	**1,172**	**1,030**	**915**	**778**	**882**	**776**	**655**	**574**	**532**	**577**

In 1999, the most frequent types of shipping accidents involving fishing vessels were grounding flooding, fire/explosion, and foundering/sinking in that order. While grounding and flooding accidents are the most frequent; foundering/ sinking and capsizing accidents generally result in more severe consequences in terms of lives lost or damage to vessels. Most fatalities reported under the "Other" types of accidents involved fishing vessels, which had gone missing. (See Table 2.)

Table 2 - Canadian Fishing Vessels by Type of Accident*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Fatalities**
Collision	38	31	18	23	38	17	8	12	8	21	11
Capsizing	19	16	8	11	7	14	9	10	8	3	40
Foundering/ Sinking	57	50	34	34	36	40	27	28	13	22	50
Fire/Explosion	92	68	68	57	62	54	52	48	33	37	2
Grounding	154	108	131	109	111	98	88	75	65	74	10
Striking	66	67	59	32	35	24	12	22	29	15	1
Ice Damage	16	4	17	8	10	8	14	16	9	6	0
Propeller/ Rudder/ Structural Damage	33	28	38	36	27	28	36	25	13	30	0
Flooding	84	65	55	41	77	69	51	58	51	55	0
Other	12	22	30	18	21	20	11	15	16	10	24
Totals	**571**	**459**	**458**	**369**	**424**	**372**	**308**	**309**	**245**	**273**	**138**

* This table excludes the few foreign-flag vessels involved in shipping accidents in Canadian waters.

** Number of fatalities is for the 10-year period.

SUMMARY ANALYSIS OF SAFETY DEFICIENCIES

Since 1992, the Board has systematically identified several safety deficiencies and made over 30 safety recommendations with a view to mitigating risks in the Canadian fishing industry. The most commonly found safety deficiencies identified in these recommendations are summarized in the following subsections:

INADEQUATE TRAINING AND AWARENESS

Lack of crew training and knowledge in survival techniques aboard Canadian fishing vessels has been found in many investigations as a factor attributable to both the frequencies of accidents as well as to the severity of consequences.

Until recently, there were no regulatory requirements in Canada for personnel operating small fishing vessels of less than 100 gross registered tons to be certificated for competency in navigation, seamanship, safety, vessel stability and survival skills. However, these vessels constitute over 95 percent of the registered Canadian fishing fleet. At present, the Certification and Safe Manning Regulations are being revised to require competency and training for officers on Canadian fishing vessels of 60 GRT and over.

Most fishermen do not have formal training in vessel stability and are unable to extrapolate the stability of their vessel under different conditions. (As of October 2000, there are no stability requirements for fishing vessels of less than 15 GRT in Canada unless they are engaged in herring and capelin fishery.)

TSB investigations consistently reveal that fishermen who were involved in serious occurrences often lacked adequate nautical skills and knowledge of safe operations. Many fishermen did not have formal training or knowledge to respond effectively to distress situations. Crews' failure to properly secure watertight openings, failure to wear survival suits, failure to carry and/or properly operate locating devices, such as electronic position indicating radio beacons (EPIRBs), and lack of familiarity with lifesaving equipment such as life rafts have contributed to the loss of lives in many occurrences.

In Canada, unqualified crew members with inadequate watchkeeping abilities have contributed, at least in part, to between 45 and 50 percent of all collisions, groundings, and strikings involving fishing vessels. Several collision and grounding occurrences investigated by the TSB suggest that lack of formal training in the use of radar, radar plotting, and other safe navigational procedures (e.g. reduce speed, sound fog horn, post dedicated lookout, etc.) have exacerbated the situation leading to such occurrences.

INADEQUATE SURVIVAL EQUIPMENT, SKILLS AND DRILLS

The survival of the crew when abandoning ship at sea depends largely on the capability and reliability of the survival equipment, as well as the crew's familiarity and skill in using that equipment. One person's knowledge of life raft deployment, distress signal use, or emergency response could easily save an entire vessel and crew.

In recent years, at least five fishing vessel occurrences were reported to the TSB in which problems regarding the use of life rafts were identified. In April 1995, a 44 ton fishing vessel sank; two of her crew drowned when the life raft capsized. In November 1995, a 27 GRT fishing vessel capsized and sank rapidly; the life raft had to be cut free from the securing lashings as none of the crew knew that the raft was outfitted with a knife. On the same day, another fishing vessel sank, taking the life raft with her before the crew had time to deploy it. A 1995 safety study, sponsored by the Alaska Marine Safety Education Association (AMSEA), that evaluated the effectiveness of AMSEA courses in emergency preparedness and survival training targeted at commercial fishermen in Alaska from January 1991, to December 1994 found that "*none of the 114 fishermen who died during the study period were graduated from the courses, and none of the 64 vessels on which a death occurred had a course-trained person on board*" [Perkins 1995]. Unfortunately, lives are still being lost due to crewmembers' unfamiliarity with the use of their lifesaving equipment or emergency procedures.

On the other hand, the TSB has also witnessed at least three occurrences where crews survived severe winter conditions in North Atlantic waters for several hours because they were able to deploy and use the life saving equipment as intended. In the January 1993 sinking of the scallop trawler *Cape Aspy*, ten of the survivors were rescued from their life raft after three hours, and one other was pulled alive from the frigid sea approximately six hours after the vessel sank. Immersion suits were credited for saving the lives of these survivors. The most recent example is the sinking of the 56-meter long 877 GRT shrimp fishing vessel *BCM Atlantic* off the coast of Labrador on March 18, 2000. While shooting a trawl at night, on shrimp fishing grounds off Labrador, the *BCM Atlantic* struck a piece of ice. The vessel was holed in the shell plating in the vicinity of a common bulkhead between the engine-room and the cargo hold; the vessel flooded and then sank. All 26 persons on board donned immersion suits and abandoned ship into three life rafts. After drifting in the life rafts over three hours in -11 °C, all 26 people were recovered. No serious injuries or pollution resulted from this occurrence. This rapid and successful abandonment was attributed to the crew being able to properly deploy and use the lifesaving equipment as a result of the recent boat drill.

DOWNFLOODING — UNSECURED HATCHES, DECK/ BULKHEAD OPENINGS

Since 1975, failure to secure openings on decks and below decks has contributed to the loss of at least 20 fishing vessels and 28 lives. Openings in watertight bulkheads are common on fishing vessels for the convenience of movement of crews, equipment, and cargo. All vessels are designed and equipped with means to secure such openings. However, leaving such accesses unsecured and/or open at sea has caused several occurrences of multiple compartment flooding in fishing vessels. TSB investigations have consistently found that many fishermen were not aware that breaches of watertight integrity provided by the bulkheads and hatches vitally affected the seaworthiness of the vessel and subsequently their safety. In a 1998 accident involving a 13-m long fishing vessel, the investigation attributed the downflooding through two unsecured fish hold hatches to the loss of the vessel. There was no permanent device for securing those covers. No trace of the wreck or of three of the five crewmembers was found.

VESSEL MODIFICATIONS, ADDITION OF WEIGHT ITEMS AFFECTING STABILITY

In Canada, fishing vessels over 15 GRT are subject to safety inspection every four years. (Vessels less than 15 GRT are not required to be inspected.) Between these inspections, many vessel owners make modifications to their vessels by adding various structures, heavy items, fishing gear, and equipment without being aware that such modifications can adversely affect the vessel’s stability, reduce the freeboard, and compromise crew safety in adverse weather conditions. Fishermen do not normally notify the authorities of such modifications to reassess vessel stability characteristics. There is currently no procedure for marine surveyors to systematically account for such modifications.

UNSAFE LOADING & OPERATIONAL PRACTICES

Often, accidents occurred when fishermen misuse or exceeds the ship's capability causing it to lose its inherent stability and/or allowing the ship to be overwhelmed by external environmental factors such as wind, waves, ice, and seas, etc. TSB investigations over the years indicated that many crews on fishing vessels do not fully appreciate that their day to day operating procedures and loading practices may be creating unsafe conditions. Unsafe loading practices such as improper penning of fish holds, improper handling and excessive stowage of fishing gear and lobster traps, have led to several accidents.

INADEQUATE DRAINAGE OF SHIPPED SEAS OFF DECKS, FREEING PORTS

Canadian regulations require fishing vessels to be fitted with freeing ports of adequate area to facilitate rapid and effective freeing of shipped water from the deck. It is not uncommon to find freeing ports welded or bolted shut on many fishing vessels to prevent the catch or equipment from slipping through. Apparently, the crews do not always realize the perilous effect of water retained on deck. One can see from the above that sometimes the adequacy of the "regulations" was not an issue but rather the issue is of compliant culture and enforcement.

STABILITY AND STABILITY INFORMATION

Approximately 75 percent of capsizing and foundering accidents are attributable to stability. Many stability-related accidents involving fishing vessels are largely attributable to human factors. In most instances, vessel operators were not familiar with stability, safe loading and operating practices, and guidelines or restrictions necessary to maintain the stability of their vessels under various operating conditions. Analysis of at least three fishing vessel accidents suggested that many fishermen and fishing vessel operators are not aware that modifications and the addition of items can adversely affect the stability of the vessel and, consequently, the safety of the crews.

In several cases, stability booklets containing information on stability characteristics and various loading conditions for fishing vessels are complex and the information is not user-friendly. Consequently, essential information is not being put to effective use.

HOURS OF REST FOR CREWS ON FISHING VESSELS

Today's competitive environment, with diminishing resources at sea such as in salmon and lobster fisheries, places pressure on fishermen to take undue risks and to operate in adverse weather conditions for frenzied stretches of hours and days with whatever crew is available, trained or otherwise, inducing fatigue and performance degradation.

In Canada, regulations affecting hours of rest do not apply to personnel employed on Canadian fishing vessels. The requirement for daily periods of rest for persons employed on a ship is addressed in the Safe Manning Regulations; however, these regulations specifically exclude fishing vessels. In its report on the investigation into the grounding of the stern trawler *Zagreb,* it was found that the officer of the watch on the *Zagreb* had worked 11.5 hours prior to the grounding, after 10 days of fishing on a six-hours-on/six-hours-off work schedule. The grounding resulted in the total loss of the vessel. As a result, the Board expressed its concern with the frequency of fishing vessel accidents in which issues related to crew fatigue were found to have contributed.

FIRE AND EXPLOSION

As previously depicted in Table 2, fire/explosion is the third most frequent type of event involving fishing vessels. While occurrences involving fire incurred more severe vessel damage than other accidents, they generally resulted in fewer fatalities or fewer serious injuries per accident than other types of small fishing vessel accidents. The TSB has not conducted an in-depth analysis of fires on fishing vessels; however, information gathered during investigations indicates that unsafe operating procedures and practices, inadequacy in housekeeping, improper installation and maintenance of electrical equipment, machinery, and piping contribute to most fires and explosions.

RISK CONTROL — PROBABILITY & CONSEQUENCE REDUCING FACTORS

Risk can usually be controlled through a combination of four approaches: terminate risk; transfer risk; treat risk; and tolerate risk.

It is obvious that preference should be given to developing safety measures that will completely eliminate the deficiencies to prevent similar adverse consequences in the future. Regrettably, such solutions are often the most expensive and are often times impossible. Since this is a safety conference, we are not interested in transferring risk. In most cases, where the risk associated with potential safety deficiencies cannot be eliminated in a complex system, such as fishing vessel operations, the system should be made more tolerant to risk by building one or more of the following defenses/barriers in the system:[1]

Designing for minimum hazards;

Installation of safety devices; provision of warning devices, signs, placards, etc;

Establishment of procedures and practices; and

Provision of training and awareness.

Our experience indicates that administrative interventions, such as rules, regulations, procedures, and training, etc., alone may not provide an effective hazard control in many circumstances, especially when the level of risk is very high. TSB believes that while rules compliance is necessary for accident prevention, it alone is not sufficient to advance safety. In a complex system such as transportation, even the most rigorous set of rules will not cover every contingency; interpretation by individuals will be required to cover unanticipated situations. Indeed, notwithstanding their knowledge of the rules, even the most motivated employees are subject to the normal slips, lapses, and mistakes that characterize human behavior. The TSB embraces the "defense in depth" philosophy which seeks multiple and diverse lines of defense to mitigate the risks of normal human errors.

CONCLUSION

It is evident that human and organizational factors play an important role in overall system safety. Acknowledging this fact is an important first step in accident prevention. Based on the information presented above, it is apparent that an increased awareness and training for fishermen in operational safety and survival skills will substantially improve the safety record of the fishing industry. A caveat, however: training is no substitute for poor design. Today's competitive environment places pressure on fishermen to maximize vessel utilization with minimum crew size inducing stress, fatigue, and resulting performance degradation. When stressed, fatigued, overworked, etc., skills and methods obtained through training usually fail.

I believe that the fishing industry's safety record can be improved, but this will require systematic attention to safety on the part of government agencies and the industry as a whole, namely owners, operators and most importantly, the fishermen themselves.

REFERENCES

Ayeko M [1992]. Safety Deficiency Analysis Approach to Fishing Vessel Safety. The Proceedings of 2nd International Symposium on Safety and Working Conditions Aboard Fishing Vessels. Villagarcia de Arosa, Galicia, Spain.

Ayeko M [1997]. In Search of Causal and Contributory Factors In Stability-Related Accidents. The Proceedings of 6th International Conference on Stability of Ships and Ocean Vehicles — STAB'97. Varna, Bulgaria.

Haile PG [1997]. Draft Manual for Safety Deficiency Analysis. Canada: Transportation Safety Board.

Perkins R [1995]. Evaluation of an Alaskan marine safety program. Pub Health Rprts, *10*:110.

FOOTNOTES

1. While there are some disagreements as to the order of effectiveness in intervention (known as "safety precedence sequence,") safety professionals are unanimous in proposing these barriers/interventions.

IMPROVING SAFETY IN THE ALASKAN COMMERCIAL FISHING INDUSTRY

Jennifer M. Lincoln, M.S.
Brad J. Husberg, M.S.P.H.
George A. Conway, M.D., M.P.H.
Alaska Field Station
Division of Safety Research
National Institute for Occupational Safety & Health
Centers for Disease Control & Prevention
Anchorage, Alaska, U.S.A.
E-mail: jlincoln@cdc.gov

LCDR Lincoln is an officer in the U.S. Public Health Service, working as an Injury Epidemiologist and Occupational Safety and Health Specialist for NIOSH in Anchorage, Alaska. For the past nine years, Jennifer has concentrated her research on commercial fishing safety and drowning prevention in Alaska. Since her start at NIOSH, Ms. Lincoln has collaborated in the design and pilot testing of the Alaska Occupational Injury Surveillance System, writing a special supplement for that database for the collection and analysis of commercial fishing and drowning injury risk factor data.

This paper was previously printed in the International Journal of Circumpolar Health vol. 60; no. 4, 2001

Objectives: Over 90 percent of deaths in Alaska's commercial fishing industry were due to drowning, following vessel sinkings. In the early 1990s, the U.S. Commercial Fishing Industry Vessel Safety Act required the implementation of safety measures for all fishing vessels. The purpose of our study was to examine the effectiveness of these measures in reducing the high fatality rate of Alaska's commercial fishermen.

Study Design: Alaska Occupational Injury Surveillance System and Alaska Trauma Registry data were used to examine fishing fatalities and injuries. Demographic, risk factor, and incident data were analyzed for trends.

Results: During 1991-1998, there was a significant ($p<0.001$) decrease in Alaskan commercial fishing deaths. Significant progress has been made in saving lives of fishermen involved in vessel sinkings. During 1991-1997, 536 fishermen suffered severe injuries (437/100,000/year). These injuries resulted from being entangled, struck or crushed by equipment (60 percent) and from falls (25 percent).

Conclusions: Vessel sinkings still continue to occur, placing fishermen at substantial risk. Efforts toward improving vessel stability and hull integrity and avoidance of harsh weather conditions must be made to further reduce the fatality rate. The nature of nonfatal injuries reflect that modern fishing vessels are complex industrial environments posing multiple hazards. Measures are needed to prevent falls and improve equipment handling and machinery guarding.

INTRODUCTION

For many years, commercial fishing has been well-known as a dangerous occupation. Numerous publications have been written about the hazards of commercial fishing in the U.S. and Alaska [Schnitzer 1993; NRC 1991; NTSB1987; Knapp 1991; Storch 1978]. More recent studies show a reduction in fatalities in Alaska since the implementation of the Commercial Fishing Industry Vessel Safety Act (CFIVSA), and has also shed light on continued problems that current regulations have not addressed, such as machine hazards on deck [NIOSH 1997; Husberg 1998; Lincoln 1999]. This more recent literature also recommended that the approach to improving safety in the fleet be augmented by concentrating on preventing vessel capsizings and sinkings from occurring in the first place, as well as continuing to prepare crew to react to them if they do occur [NIOSH 1997; Lincoln 1999].

The purpose of this paper is to update the information from previous studies to illustrate the continued progress in reducing fatalities in the commercial fishing industry in Alaska, as well as to address a more complete spectrum of injury by evaluating the nonfatal injuries on board fishing boats. Injury prevention programs are described that have been implemented as a result of our surveillance efforts to address the safety problems in the commercial fishing industry in Alaska.

MATERIALS AND METHODS

The Alaska Occupational Injury Surveillance System (AOISS) is a comprehensive surveillance system for fatal occupational traumatic injuries. It contains information on demographics, location, cause of injury, weather conditions, emergency gear, personal protective equipment, and work experience. Usually, press releases from the Alaska State Troopers, reports from news media, calls from the Alaska Occupational Injury Prevention Program (OIPP) Coordinator, or from jurisdictional agencies alert us to new cases. Data from other agency sources are entered to supplement the AOISS database. The National Institute for Occupational Safety and Health (NIOSH) Alaska Field Station (AFS) shares AOISS data and reconciles tabulations with the OIPP and the Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI) program within the Alaska Department of Labor and Workforce Development.

The Alaska Trauma Registry (ATR) is a population-based trauma registry that collects information from all 24 acute-care hospitals in Alaska. Information is abstracted from hospital medical records and added to the ATR database. The ATR consists of information on persons who are injured. Also, those injured have to either be admitted to a hospital, transferred from an emergency department to another hospital for admission, or declared dead after they arrive at the hospital. Trauma registries are a unique source of injury surveillance and prevention data. Demographics, geographic information, disability, medical cost, payment source, cause of injury, discharge diagnosis, and severity scoring are a few examples of data that are collected. The ATR is managed by the State of Alaska Department of Health and Social Services, Division of Public Health, Section of Community Health and Emergency Medical Services in Juneau, Alaska.

The AFS emphasizes non-regulatory collaborative responses in our intervention efforts. Strong working relationships have been established with many other federal, state, municipal, and nongovernmental agencies. These relationships have been formalized into the Alaska Interagency Working Group for the Prevention of Occupational Injuries (AIWG). Industry and workers are also asked to be full partners in planning and executing interventions and in providing ongoing surveillance data to track success or failure of these interventions. The NIOSH Alaska Field Station provides assistance to the AIWG in organizing, analyzing, and interpreting surveillance data. Based on this data and collaboration, several injury prevention strategies have been established and implemented.

RESULTS

FATALITIES

Commercial fishermen represented 217 (33 percent) of the 648 occupational fatalities that occurred in Alaska during 1990-1999. Given the mean full-time equivalent Alaska commercial fishing workforce of 17,500, this is equivalent to a fatality rate of 124/100,000 workers/year. This rate has decreased from the rate reported in 1991 through 1992 (200/100,000/year); however, it is still over five times as high as the overall occupational fatality rate for the state (22/100,000/year) (Alaska, 2000) and 28 times the overall U.S. occupational fatality rate of 4.4/100,000/year [CDC 1993].

The fatality rate among fishermen varied considerably by type of fishery: shellfish (primarily crab) had the highest (407/100,000/year), followed by herring (204/100,000/year), and halibut (119/100,000/year) (See Figure 1— Fishery-Specific Fatality Rates). Fisheries differ in geographic location of fishing grounds,

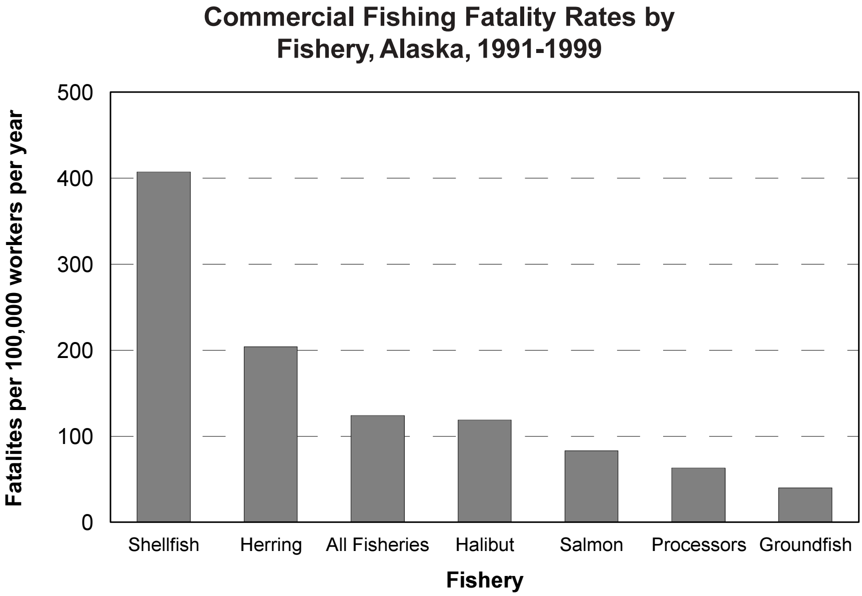
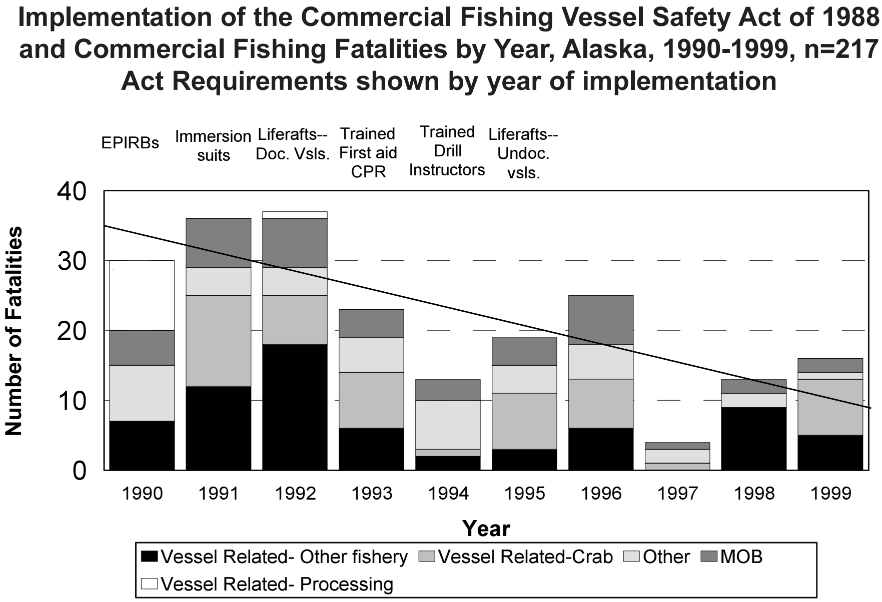


Figure 1: Fishery-Specific Fatality Rates

type of harvesting equipment and techniques, time of year, and duration of seasons. Crabbing, a shellfish fishery, is particularly hazardous because harvesting of crab species in Alaska generally takes place during the winter, which is often characterized by rough weather.

Most fishermen drowned and/or died from hypothermia (186, 86 percent), as the result of vessel-related events (vessel sinkings or capsizings) (133, 72 percent), falls overboard (43, 23 percent), diving incidents (5, 3 percent), or other drowning event (3 percent). Other fatalities were due to deck injuries (16, 7 percent), or some other event (15, 7 percent). Of 133 fatalities in vessel-related events, the largest number (61, 46 percent) of fishermen were participating in the shellfish fishery. Of those falling overboard (man overboard [MOB]) and drowning, 22 (51 percent) were also participating in the shellfish fishery. Fatalities from falling overboard were categorized by cause of immersion: entanglement in net or line (12, 27 percent), observed fall (12, 27 percent), unobserved fall (victim missing from vessel) (10, 23 percent), or being washed or blown into the water (10, 23 percent). None of these workers wore personal flotation devices (PFDs). Of the 71 fishermen who drowned in vessel-related events and for whom PFD/immersion suit usage was available, 54 (76 percent) were documented not to have been wearing any type of PFD or immersion suit, whereas 17 (24 percent) were wearing such devices. (For 62 fishermen in vessel-related events, it is unknown whether they were wearing any type of PFD or immersion suit.) On the other hand, among survivors of such casualties, 34 of 47 were wearing PFDs or immersion suits. Thus, odds ratio calculation shows that survivors of these vessel-related events in which at least one person drowned were 8.3 times (95 percent CI=3.59-19.24) more likely to have been wearing a PFD or immersion suits than were decedents.

The CFIVSA was implemented from 1990-1995. This act requires specific safety equipment (i.e. life rafts and immersion suits) and training (i.e. drill instructor training and first aid) for fishermen. From 1990-1999, Alaska experienced a 49 percent decline in all work-related deaths including a 67 percent decline in commercial fishing deaths (1990-1992 average compared to 1997-1999 average). By 1999, there had been a significant ($p<0.001$) decrease in the number of deaths in the Alaskan commercial fishing industry (See Figure 2).



Chi-square for linear trend= 18.0; p<0.001

Figure 2: Fatality Trend Line During and After CFVISA

AFS analysis of USCG vessel casualty statistics for 1991 through 1999 revealed that the number of vessels lost per year have remained relatively constant (mean 34, median 36), as have the number of workers on board (i.e., number of persons at risk) (mean and median 106), whereas remarkable progress has been made in the case-survivor rate (number survivors ÷ number on board) in this type of incident. The case-survivor rate has increased from an average of 78 percent in 1991-1993, to 92 percent in 1994-1996, and then to an average of 94 percent from 1997-1999 (See Table 1— Case Fatality Rate). (Information is not available for 1990.) These data only represent fatalities due to the loss of a vessel, therefore, MOBs, crushings, and fires are not represented.

NONFATAL INJURIES

From 1991 through 1997, commercial fishing had the highest number of injuries as recorded in the ATR. However, by 1998, the construction industry (621) had overtaken commercial fishing (587) as the industry with the highest number of hospitalized injuries from 1991-1998. Commercial fishing had an average

Table 1: Recent Decrease in Case Fatality Ragte, Alaska Commercial Fishing Industry, 1991-1999

Year	Number of Vessels Lost*	Workers on Board*	Worker Fatalities**	Case Fatality Rate***	Case Survivor Rate
1991	39	93	25	27%	73%
1992	44	113	26	23%	77%
1993	24	83	14	17%	83%
1994	36	131	4	3%	97%
1995	26	106	11	10%	90%
1996	39	114	13	11%	89%
1997	31	84	1	1%	99%
1998	37	124	9	7%	93%
1999	28	104	11	11%	89%

* Source: U.S. Coast Guard 17th District Fishing Vessel Safety Coordinator.

**Fatalities from capsized or lost commercial fishing vessels only.

***Case Fatality Rate: (number killed/number at risk) x 100 percent.

annual hospitalized injury rate of 4/1,000 workers, ranking third behind the logging (18/1,000) and construction industries (6/1,000). There has been a slight decline in the number of nonfatal injuries in the industry.

The three most common types of injuries were fractured bones (279), open wounds (73), and burns (29). Extremities were the body regions most often injured with 184 to the upper extremities and 171 to the lower extremity. The third most common body region mentioned was the spine (35).

Machinery (187) was the leading cause of nonfatal hospitalized injuries in the commercial fishing industry. Falls (149) ranked a close second, followed by being struck by an object (98). Narrative descriptions of injury events revealed that falls most often occurred into holds, through open hatchways, and as a result of slipping on ladders and gangways. Injuries from machinery often involved equipment unique to this industry. "Crab pots" (baited cages weighing up to 800 lbs. empty which are maneuvered by cranes on deck) and "crab pot launchers" were listed in the records as factors in a number of injuries. A crab pot launcher is a hydraulic lift which raises and tilts the pot over the top of the gunwale where the pot slides into the water. Bait choppers, powerblocks, cranes, and winches were also repeatedly mentioned as being factors in these injuries. It is not possible to do an analysis based on fishery using ATR data.

DISCUSSION

Contributing factors in commercial fishing deaths vary from those for nonfatal injuries to workers in this industry. As mentioned previously, most commercial fishing deaths result from the loss of a vessel due to capsizing or sinking. If commercial fishing is going to continually become safer, capsizings and sinkings must be prevented by concentrating on vessel stability and hull integrity. MOB prevention and successful retrieval from the water are also important to further improve safety in the fleet. ATR data show that most nonfatal injuries occur while working on the vessel (either on deck or below). Nonfatal injuries are more commonly caused by machinery on deck, falls, and/or being struck by objects with most of these injuries occurring in the crab fishery.

ALASKA INTERAGENCY WORKING GROUP- FISHING SUBCOMMITTEE

The focus areas that were identified from the AIWG to prevent fatalities include addressing the stability problems and MOB prevention and rescue on crabbing vessels. The focus areas identified for nonfatal injuries include examining the problems with deck layout and machinery and how this relates to deck injuries.

DOCKSIDE ENFORCEMENT PROJECT

The Fishing Subcommittee of the AIWG developed a project to address the issues of vessel stability in the Bering Sea crab fleet. Members of the committee (primarily in the USCG) developed and organized groups starting in October 1999, to board crab vessels in Dutch Harbor, King Cove, and Akutan, Alaska, in conjunction with Alaska Department of Fish and Game personnel during their tank inspections to check compliance with on board stability instructions. The USCG enforced stability instructions on overloaded vessels with Captain of the Port authority detaining overloaded vessels. There has been strong industry for this project. The subcommittee is also using this project as a way to collect information on MOB experiences and risk factor information among crab fishermen.

DECK SAFETY PROJECT

The subcommittee also determined that attention should be given to worker safety around deck machinery, an area that appears not to have been adequately addressed by current safety regulations. Efforts are needed to better define the relationship between the vessel, fishing equipment and the worker. The NIOSH Alaska Field Station started an engineering design project in October 2000 to address some of these issues. This project is first addressing safety concerns on board crab boats and plans to also look at other vessel types.

Many of the injuries in the ATR occurred while working in the proximity of a crab pot launcher while fishing for either crab or cod. Recommendations to fishermen for the prevention of these injuries could come from safety and machine guarding lessons learned in general industry. For example, installing a machine guard on the bait chopper to prevent hands from entering the blades, or painting a yellow line for a “safety zone” around the perimeter of the crab pot launcher to serve as a reminder for the fishermen to stand behind the line while the launcher is in motion. Painting the launcher itself a bright color and/or with reflective paint could help fishermen to see the launcher under low light conditions, to be aware of its location and movement. Such measures require further evaluation.

The NIOSH Alaska Field Station has initiated a project to examine the deck environment surrounding the deployment and retrieval systems (e.g. cranes, “power blocks”, pulleys, winches, lines, nets, crab pots, and crab pot launchers) of fishing equipment from a mechanical and safety engineering perspective.

Additional areas to focus on include machine guarding, separating workers and lines, and fall prevention.

The NIOSH Alaska Field Station is continuing to study the causes of these deck injuries, develop strategies to prevent them, and evaluate safety practices that some crews already have in place. This information is communicated to other fishermen, captains, and vessel owners to increase awareness of the problem to discuss potential solutions. These ideas could then be personalized and individually implemented with the intent of increasing safety awareness and preventing these types of injuries.

The NIOSH Alaska Field Station organizes, analyzes, and interprets data for action. Both successful safety regulations (CFIVSA) and non-regulatory collaborations resulting in intervention efforts have proven to be effective in reducing deaths in Alaskan commercial fishing industry. Fishery-specific approaches like the Dockside Enforcement Project and the Deck Safety Project can also be tailored to suit needs in other fisheries. The NIOSH Alaska Field Station is very interested in further collaboration, and invite individuals/groups interested in preventing injuries and fatalities in this industry to contact us.

REFERENCES

Centers for Disease Control and Prevention [1993]. Commercial fishing fatalities–Alaska, 1991-1992. MMWR, *42*(18):350-359.

Husberg BJ, Conway GA, Moore MA, et al. [1998]. Surveillance for nonfatal work-related injuries in Alaska, 1991-1995. Am J Industrial Med *34*:493-498

Knapp G and Ronan N [1991]. Fatality rates in the Alaska commercial fishing industry. Alaska Sea Grant College Program, Pub No. AK-SG-90-03. Anchorage, Alaska:University of Alaska, Institute of Social and Economic Research.

Lincoln JM**,** Conway, GA [1999]. Preventing commercial fishing deaths in Alaska. Occup Environ Med *56:* 691-695.

NIOSH[1997]. Current Intelligence Bulletin #58: Commercial fishing fatalities in Alaska, risk factors and prevention strategies. Cincinnati, Ohio: U.S. Department of Health and Human Services, Public Health Service, U.S. Public Health Service, Centers for Disease Control and Prevention, Natonal Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-163.

National Research Council, [1991]. Fishing vessel safety: blue print for a national program. Washington, D.C.: National Academy Press.

National Transportation Safety Board [1987]. Safety study, uninspected commercial fishing vessel safety. Washington, D.C.:PB87-917003.

Schnitzer PG, Landen DD, Russell JC [1993]. Occupational injury deaths in Alaska's fishing industry, 1980 through 1988. Am J Public Health *83*: 685-688

State of Alaska [2000]. Occupational-related fatalities in Alaska, 1990-1999. Alaska: Department of Health and Social Services Bulletin No. 16 .

Storch RL [1978]. Alaskan king boat casualties. Marine Technology *15*: 75-83.