HAZARD AND RISK IN THE NEW ENGLAND FISHING FLEET

Presented to the New England Section of the Society of Naval Architects and Marine Engineers
October 29, 1998

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ABSTRACT

The United States Coast Guard and the Volpe National Transportation Systems Center studied the 102 serious fishing vessel accidents (1993-1997) in Coast Guard District 1 (New England and Long Island, New York), U.S national fleet accident data, and international fishing vessel safety programs for the purpose of establishing risk factors and formulating options for future action by the Coast Guard to enhance fleet safety.

The 102 regional accidents involved total vessel losses and/or death(s), excluding strictly occupational cases. Each accident was studied in detail to determine causality among human and organizational, fishery and operational, and preventive safety factors. Causality in each case was assigned among the factors, summing to 1.0 and weighted according to the outcome of the accident, i.e., numbers of deaths and injuries.

The results quantify: 1) the aggregate “significance” of the causal factors; 2) the average weighted outcome of accidents by type (e.g., capsize, collision); and 3) the sensitivity of 1) and 2) to varied relative weightings of vessel losses and deaths.

1. INTRODUCTION

The fishing industry is one of the most dangerous in the United States, when measured by fatality and injury rates[1]. It is, in addition, when measured by fleet size and seamen at risk, the largest by segment by far in the American commercial marine sector. Yet serious and persistent safety problems have proven resistant to solution or mitigation. The small (L < 79’) fleet makes up the overwhelming majority of over 100,000 boats, but the relevant State and Federal safety regulations are scant outside of requirements for lifesaving, communications, and portable firefighting equipment. In short, they address the aftermath of an accident rather than its prevention.

The deck of a working fishing vessel combines the classical hazards of the sea (e.g., capsize, foundering, fire) with the occupational hazards of harvesting fish and marine animals. The work is often performed under conditions of duress and fatigue, and sometimes with obsolete or dangerous gear. Neither the United States Occupational Safety and Health Administration nor the Coast Guard effectively addresses the occupational hazards of fishing.

While it is common for multiple factors to be causal to an accident, the fishing industry combines those classical vessel hazards with the industrial hazards of taking, sorting, and storing fish. The synergistic effects of these hazards are not in any way covered by the marine or occupational safety regulations. The hazards of working a fishing vessel at sea are conceptually illustrated in Figure 1. This paper will show 1) evidentiary examples of multiple hazards, their combinations unique to the fishing industry in general and their fisheries in particular, and 2) the development of hazard data and risk analysis based upon a reliable and statistically significant set of reports investigating serious accidents.

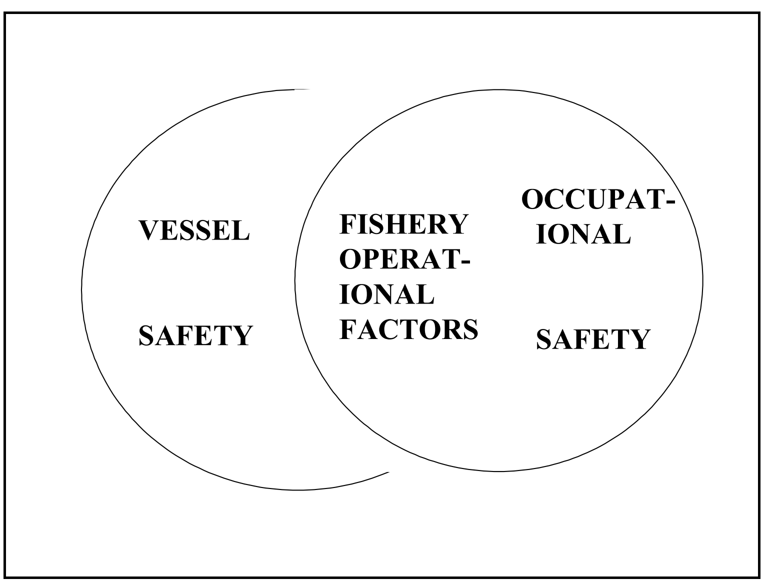
1.1 Program history

This fishing vessel safety project was funded at the Volpe Center by the Coast Guard Prevention Through People (PTP) program through the Headquarters Naval Architecture Division (G-MSE-2). While its original goal was to evaluate the state of stability and structural integrity (the most obvious gaps in the small fishing vessels safety regulations), re-evaluation of the project led to a new approach including a generalized risk assessment followed by development of recommended new safety measures. In the initial stage of the project, the Volpe Center found that, while stability remains a problem in some sectors of the small fishing vessels fleet, there is a troubling picture in which safety generally may be deteriorating as many fishermen face very difficult times

The results of the first phase form the basis for most of this paper and include the acquisition and analysis of a targeted set of safety and casualty data, gathering of information from the industry and the relevant regulatory and enforcement elements of the Coast Guard, and a hazard and risk analysis focused on the New England fishing fleet. The Coast Guard was given an array of program options for future action, from which the objectives and means of new safety initiatives can be developed.

The desired outcome of this work is an improvement in the Coast Guard's hazard and safety data acquisition and management, ongoing risk assessment of the fishing fleet, and in their risk communication to the industry. The Volpe Center project is one piece of an active effort by Coast Guard Headquarters and field units to understand hazard and safety in a diverse industry and to share that understanding with the affected people.

Figure 1
Fishing Industry Causality Diagram



2. A PICTURE OF THE INDUSTRY AND A STATEMENT OF THE PROBLEM

2.1 The United States Fishing Fleet

While there is little in the literature in the way of written history on the United States fishing industry, oral interviews have yielded a picture of its post-war development and the Coast Guard's response to safety issues. The fishing fleet at the beginning of this era was predominately wooden bottomed, "Eastern" rig vessels with the pilot house aft. The designs were often driven by the desire for efficient working conditions for the fishing gear then predominately in use, i.e., low freeboards and tender vessel motion for the men working at the sides hauling and setting tackle.

By the 1960s, the age of this fleet and the tendency towards lack of maintenance were resulting in high death and loss rates. The 1970s saw a shift to steel construction (and the "western" rig with the pilot house forward) and new infusions of capital after declaration by the United States of the 200 mile Economic Exclusion Zone.

Today, the United States has one of the largest domestic fishing fleets in the world, numbering over 100,000 fishing vessels. Of these, the vast majority (reported at over 99% by the NRC in 1991[1]) are under 79' long, the limiting length for regulation as small fishing vessels. Only 29% of the under 79' fleet are documented by the Coast Guard; the remainder are state registered or unregistered. The fleet operates in a number of unique regional fisheries, each with its own unique sectors. As examples, Gulf shrimpers, Alaska crab boats, New England trawlers and lobster boats, and Chesapeake crabbers all have unique operational, engineering, and environmental aspects.

Fishermen today face far more challenging circumstances than seen a generation ago. Depleted fish populations and stringent fisheries management plans aimed at stock recovery (licenses, quotas, and/or limitations of days at sea in most important fisheries) place greater strain on the their daily and annual operations. As a result, many now fish part-time, or frequently switch fisheries, holding as many as ten individual commercial licenses. These factors can, in some instances, contribute to questionable management and operational practices, including:

- <u>Lack of re-investment</u>, resulting in aging and more poorly maintained vessels.
- <u>Frequent service shifts</u> (e.g., lobster to scallop dragging) with no check on vessel safety implications. This may be particularly so for inshore fleet with its lower capital requirements.
- <u>Reduced manning</u>. Some vessels may operate with smaller crew complements than formerly, potentially exacerbating the hazard of fatigue.
- <u>"Junk" fisheries.</u> Harvesting "alternative" species requires big hauls to make trips economically feasible (e.g., herring boats with decks awash).

In this environment, the undertaking of new regulatory authority and other safety initiatives are very difficult. Yet, concerns over safety persist, with several Governmental and private sector bodies calling for new measures to reduce risk to fishermen at sea.

The industry has a majority of conscientious owners and operators. They lack, however, design and construction standards and, for the “small” vessels, regulatory strictures except for communications, emergency, and portable firefighting equipment; the best intentioned owner can initiate faulty design “upgrades”. Vessel modifications meant to enhance occupational safety have been seen to degrade vessel safety parameters. Maintenance and repair, in some cases neglected, are often diligently carried out with substandard parts and materials, as are systems changes directly affecting human safety.

As an example, there are multiple cases in the Maine scallop fishery of fatal injuries where a person has been crushed beneath a scallop drag. The towing wire suspends the laden drag over the working area while men work the gear. The wire holds upwards of a ton over the men, and may be connected to the drag by a store-bought screw clamp rather than a proper socket. In another case, the owners compromised his boat’s stability by raising mechanical equipment to a “whaleback” deck and enclosing a portion of the working deck with bulwarks, both with the laudable intent of improving the safety and comfort of men working on deck.

The industry then may be characterized by fishing vessels in good condition and bad going to sea, where they operate uniquely relative to the rest of the maritime world. The crews are nearly constantly on deck, in all but the worst weather, using complex and sometimes dangerous deck machinery, and hauling, sorting, and storing cargo from the sea, in vessels lacking elementary design and maintenance standards. The risks are clearly high, but not so clearly understood.

2.2 The Safety Picture

The modern phase of fishing vessel safety regulation began in 1977, when the IMO completed work on the Torremolinos Fishing Vessel Convention, aimed at vessels longer than 79’. The United States has not ratified Torremolinos, but many of the regulations for large fishing vessels are based thereon. Safety problems persisted in the fleet of smaller fishing vessels and, in 1988, the Congress responded with the Commercial Fishing Industry Vessel Safety Act (CFVSA). The Act conferred new regulatory authority to the Coast Guard, mostly for emergency response measures, rather than accident prevention. The Act also directed the Secretary of Transportation to conduct a fishing vessel safety study, which was carried out by the National Research Council (NRC) of the National Academy of Sciences and Engineering.

The NRC found that the fishing industry is among the most hazardous in the United States, with a fatality rate of 47 per 100,000 (equal to the mining industry)[1]. NRC noted that reported injury rates are very high and probably represent only a fraction of the real total. Their report recommended improved training, skills, and qualifications for fishermen, safer operating practices, and better inspection and maintenance of vessels and equipment. New regulatory authority in these areas (also recommended in National Transportation Safety Board recommendations attached to several fishing vessel casualty investigations) has not been requested by the Coast Guard or enacted by the Congress. The NRC further concluded that the United States regulations generally lack the formal measures found in some other industrialized nations for professional competence and vessel design and condition; rather, reliance has been placed on a patchwork of voluntary measures and programs.

At present, the Coast Guard's fishing vessel (L<79') safety program consists, in the main, of the following elements:

- 46 CFR Part 28 Subchapters A-E, consisting mainly of post-emergency equipment requirements and lacking preventive measures, such as qualifications for small fishing vessel masters, stability, vessel condition and watertight integrity. Presently, Subchapter E, "Stability", applies only to vessels whose length is 79' or over.
- National policy and international regulatory activities by Coast Guard Headquarters.
- Shoreside inspection and investigation program, carried out mainly by Fishing Vessel Examiners assigned to Marine Safety Offices (MSO). The Examiners implement the voluntary shoreside inspection program, investigate some casualties, and conduct a variety of outreach and education programs in the industry.
- Fishing Vessel Coordinators at Coast Guard District Headquarters offices, responsible for data management and coordination of each district's MSO activities.
- Enforcement at sea by boarding officers from Coast Guard cutters. These activities are often concurrent with fisheries enforcement carried out by the Coast Guard for the National Marine Fisheries Service (NMFS).

There are indications that the organizational split between Coast Guard marine safety ("m") personnel (generally in shoreside billets) and operations ("o") personnel (cutter crewmen carrying out at sea enforcement) has, at times, resulted in management and consistency problems. The boarding officers are often uncomfortable boarding fishing vessels at work, and interacting with operators who equate the Coast Guard with fisheries management policies they regard as onerous. Coordination and setting of priorities between the M and O elements is difficult, as is achieving consistency of safety inspection outcomes.

2.3 The Safety Horizon

The larger perspective on the United States fishing vessel safety regime is a comparison to that in other leading fishing nations with modern economies, such as Great Britain, Canada, Japan, and the Scandinavian countries. The NRC commented that the United States has relied on a patchwork of "voluntary, piecemeal safety measures" lacking coordination and the needed resources, while other nations as mentioned "use formal measures to improve professional competence among fishermen and the material condition of their vessels".

There is now the recognition that the safety regime in place since the 1988 Commercial Fishing Vessel Safety Act, while having some positive effect in the sense of lifesaving, is still not as effective as it can or should be. The Coast Guard must consider what mix of regulatory and voluntary initiatives can achieve the desired result of a safer industry.

As for voluntary programs, the Coast Guard's PTP program puts emphasis on fishing vessels to encourage safe practices by owners and operators without new regulations. A scan of the industry reveals several voluntary codes, including the North Pacific Fishing Vessels Owners' Association (NPFVOA) "Vessel Safety Manual"[2] and the Canadian Coast Guard "Manual of Safety and Health for Fishermen"[3]. A similar voluntary code was developed in the United Kingdom for vessels less than 36' in length and was rejected by industry as too costly and burdensome.

The voluntary codes cover, in differing degrees, management, operational, emergency, and health and safety issues. Their availability in the United States is not by any means universal, likely due in part to the geographic and economic diversity of the fishing industry. In addition, these codes do not address most vessel engineering issues such as structures, materials, propulsions plants, and the like.

There is presently one regulatory initiative, the 46 CFR Part 28, Subchapters E (Stability) and F (Subdivision and Watertight Integrity) now under development by the Fishing Vessel Safety Advisory Committee. The 1988 CFVS Act conferred authority in these areas to the Coast Guard, but the regulatory projects were deferred until after the lifesaving, firefighting, communications, and navigation rulemakings were completed, and their effect known. There is no schedule at present for a formal rulemaking process.

The proposed Subchapter E specifies intact stability requirements for all new vessels over 50' in length, both at delivery and when major modifications occur. Subchapter F specifies basic subdivision (watertight collision and engine room bulkheads) and a suite of watertight requirements similar to many of the conditions of assignment found in the International Load Lines Convention.

2.4 Comparison of United States and Overseas Regulations

The following is a brief comparison of United States fishing vessel safety regulations to those from overseas available to Volpe Center at the time of writing the report. These are: Canada, Iceland, and the United Kingdom.

- **Canada**

The Canadian fishing fleet numbers over 21,000. Vessel inspection is for those 15 gross tons and above and crew certification for 100 gross tons and above. Ayeko reports that 238 fishing vessels of less than 150 gross tons capsized, foundered, or sunk during 1987-1997, two thirds of which were less than 15 gross tons. Human elements, unchecked vessel modifications, and severe operating conditions contributed most often to these accidents[4].

While the Canadian regulatory regime is most similar to that of the U.S. among those reviewed, there are, unlike the U.S., intact stability standards for small fishing vessels, including initial metacentric height, righting energy, and ice accumulation requirements. The standard includes specific weight data of most types of loaded fish as an aid to the operator.

- **Iceland**

Iceland has adopted the Torremolinos Convention stability provisions for all fishing vessels 6 meters in length or longer (these are statutorily divided at the breakpoint of L = 15 meters). Those provisions are: righting energy ≥ 0.055 m-radians up to 30° heel; and righting arm ≥= 0.20 meters at 30° heel. The Icelandic Maritime Administration has studied its fleet and found that many small vessels (L < 15 meters) built prior to implementation of the rule failed to comply. The reasons given were 1) insufficient freeboard; 2) conversions and added weight, particularly in the form of powered fishing gear; and 3) on-deck catch stowage practices by some boats[5].

The remaining portions of the Icelandic fishing vessel regulations were not available. The stability requirement for all boats above 6 meters long is, alone, a dramatic contrast to United States regulations.

- **United Kingdom**

The United Kingdom's fishing fleet of 8,096 includes 6,569 under 12 meters in length, 1,099 between 12 and 24 meters in length, and 396 over 24 meters long[6]. While Torremolinos standards apply for the small number of fishing vessels over 24 meters long, the remainder of the fleet are regulated by statute[7], providing regulations for a comprehensive safety regime, including:

• Hull structure	• Fire protection and detection

• Watertight integrity, particularly the deck	• Protection of crew
• Freeboard	• Nautical equipment
• Intact stability (energy, GZ, GM)	• Lifesaving appliances
• Machinery and electrical	• Musters and drills
• Pumping arrangements	• Surveys, certificates, and schedules

Most of the statutory provisions apply to all boats over 12 meters in length. Of special note are the watertight integrity chapter, which reads like the International Load Lines Convention conditions of assignment, and the fire protection chapter (applicable down to L = 9 meters), which requires fire detection and fixed suppression systems in all machinery spaces as well as portable extinguishers for topside fires.

United Kingdom requires periodical surveys and issuance of certificates, primarily in matters of lifesaving, communications, and fire protection. They also license fishing vessel masters ("Deck Officer Certificate of Competency (Fishing Vessel)). The certifiation document lacks provisions for:

- Periodical surveys for seaworthiness and other items of the regulations.
- Provision for changes of services and rigging.

The United Kingdom also developed and attempted to put in place the "Code of Safe Practice for Registered Fishing Vessels Less than 12 Meters Length". The Code has a similar scope to the rules for larger vessels, generally with scaled down requirements. It was soundly rejected by the industry and has been shelved for the time being by Marine Safety Agency.

2.5 NTSB, NRC, and CFIVSC

The previous section indicates a gap, to varying degrees, between the United States and other leading maritime nations in the matter of small fishing vessel safety regulation. The nature of the gap has been explored in three (at least) fora in the United States. The following are brief summations of their activities and findings.

➢ **<u>NTSB</u>**

The NTSB has investigated a number of fishing vessel accidents over the last twenty years, each of which has resulted in recommendations to the Coast Guard for enhancements to either regulations, enforcement, or other approaches to provide for industry safety. Many of these have been incorporated in the regulations since passage of the 1988 CFIVS Act. The most currently relevant of the recommendations are the following (parenthetically, the term "reiteration" indicates that NTSB has repeated the recommendation in at least two accident reports):

- M-85-68 (several reiterations): Seek legislative authority to license captains.
- M-80-27: Develop list of unsafe practices and vessel arrangements.
- M-86-11 (reiteration): Seek legislative authority to require stability tests and information for the master.
- M-87-52 (reiteration): Seek legislative authority for requiring training.
- M-87-51 (reiteration): Develop minimum safety training standards for all commercial fishermen.
- M-87-64 (reiteration): Seek legislative authority for periodic inspections.

The list is informative for several reasons. The Board clearly feels that certification and training are serious issues; they have each surfaced in many of the fatal accidents they've investigated. In addition, they see a need for periodic inspections of the fishing vessels. Voluntary dockside inspections provide in some measure for both these items, but fall well short of the requirements seen in some other countries, e.g., the United Kingdom.

The Board has not focused its recommendations specifically on stability or watertight integrity, although the listing of unsafe practices would certainly cover the scenarios leading to the sinkings and capsizings seen in the accidents they've investigated. M-86-11 asks for stability tests and information for the master, an apparent emphasis on the human element. The effectiveness of such tests would depend on keeping them up with configuration and service of the vessel and on the master's capability to understand the documentation.

The NTSB has not issued a fishing vessel accident investigation report since 1991. Coincidentally or not, this was the same year the National Research Council (NRC) issued its report "Fishing Vessel Safety" per the direction of the 1988 CFIVS Act.

- **National Research Council**

The 1991 findings of the NRC Committee on Fishing Vessel Safety differentiated somewhat between the sectors of the fishing fleet, pointing out that casualties and fatalities occur at a higher rate in the larger boats. Their break point was not necessarily at the length of 79', although the report's Figure 3-18 showed the most dramatic increase at just that point. The fatality rate on the largest fishing vessels exceeded that for the other most dangerous industries, largely due to the increased incidence of occupational deaths, e.g., from moving machinery.

Nonetheless, the fatality rates for the smaller vessels (the focus of this study) more likely to operate inshore were comparable to high-risk industries. The Committee's recommendations tracked very closely with the thrust of the NTSB's recommendations to the Coast Guard over the years, i.e., safety and survival training, skills development and certification of masters, and inspection program to ensure the vessels' fitness for service. NRC did not specifically call for new regulations, but their attitude toward "voluntary, piecemeal" measures, by comparison with those formal licensing and inspection regimes in place in some other countries, was unmistakably skeptical.

- **Commercial Fishing Industry Vessel Safety Committee (CFIVSC)**

The Committee has drafted new regulations (per authority of the CFIVS Act of 1988) for stability (46 CFR Part 28, Subpart E) and Subdivision and Watertight Integrity (46 CFR Part 28, Subpart F). Subpart E would apply to all vessels (built or modified since 1991(/)) greater than 50' in length, requiring regular periodic surveys, and re-calculation of stability in the case of a conversion or substantial modification. Minima are proposed for GM, GZ, positive range, and righting energy, including the worst conditions of heel associated with lifting gear and of icing. The draft requires stability information to be provided for the master in an easily accessible format and specifies requirements for freeing ports.

The proposed Subpart F addresses, firstly, basic subdivision requirements, including watertight collision bulkhead for vessels greater than 50' in length, and watertight machinery space bulkheads for, apparently, all fishing vessels. Watertight or weathertight integrity of the deck would be required, depending on which side of the 50' breakpoint the vessel falls. A general requirement for weathertight closures for all weather deck hatches and enclosed space openings is proposed for vessels less than 50 feet in length. All decked vessels 50 ft or more would have watertight/weathertight integrity to prevent water entry into the hull, closed superstructure and deckhouse, through specified construction of sills, hatches, coamings, and miscellaneous scuppers, air pipes, etc.

The Committee appears to be addressing the riskiest—most deadly-- subset of accidents: capsizings from all causes (weather and/or operational error) and founderings/sinkings resulting from severe weather, more specifically, downflooding. The new Subpart F addresses ingress of water through the hull in a general way only and does not specify particulars for through hull mechanical penetrations, sea cocks, etc.

3. APPROACH AND METHODOLOGY

3.1 General

The risk assessment consists essentially of: 1) identification and classification of hazards; 2) acquisition of a set of reliable causality data for serious fishing vessel accidents; 3) apportionment of causality for each accident; 4) development of an analytical method to weight hazards in accordance with accident outcomes; and 5) identification of the most important aggregated risk factors. The underpinning of the entire exercise is its focus on reliable data for a clearly defined accident set, described as follows:

- Serious accidents, that is, those vessel accidents involving deaths and/or total vessel losses. Purely occupational fatalities were excluded, but accidents where fisheries operational practices were causal are part of the data set, i.e., those factors belonging in the intersection of the two “hazard circles” in Figure 1. Occupational safety is a critical matter, but is extremely complex, especially given the great number of fisheries, and is nearly exclusively a matter of crew experience and diligence, and fishing gear design. For now, it lies beyond the Coast Guard’s purview, but its importance must not be forgotten.
- The accidents in the analysis population must have sufficient investigative data and narrative to form an accurate picture of causality in each case. For this reason, Volpe Center focused on a set of pilot data from one District, while validating that result with less intensively analyzed national data sets. A detailed study of national fleet accidents was seen as an intractable approach.
- The choice of the District 1 fishing fleet is sensible for several reasons. It is a large and diverse group, including many fisheries, both inshore and offshore, and operates in a great variety of weather and seasonal conditions. On the practical side, District 1 Headquarters was a subway ride from the Volpe Center; they have also been perhaps the most successful among the Coast Guard Districts in compiling and organizing fleet safety data.
- The data covers the last five years, roughly the period of time since publication of the NRC report and also since the startup of the current version of the Coast Guard Marine Safety Information System (MSIS).

The findings of the regional hazard assessment include both causality trends and a five year history. The accident history will be compared to fleet exposure, i.e., the amount of time spent at sea, to ascertain whether level of effort is an influence. In addition, the causality and history will be compared at the national level, through data to be obtained from the Coast Guard Headquarters MSIS manager. National economic fishing data will be used to validate the safety history here as well.

3.2 Data

Volpe Center commenced work by conducting a data search, both in the United States and overseas, to support the Phase 1 approach described above. The main points of the search are the following:

- District 1 log books and MSO records yielded a sufficient number of adequately detailed serious accident reports for the hazard analysis. These data were scrubbed and sorted for the analysis of regional casualties and risk.
- MSIS data requests (filled by Coast Guard Headquarters staff) provided the basis to compare the last five years with the findings of the NRC study, as well as a national counterpoint to the District 1 regional trends.
- NFMS catch, fleet, and days at sea data are used as a basis for comparing recent safety trends with activity of fishing fleet. The days at sea data consisted of yearly vessel data ("Vdot") gathered from port departure and arrival calls from the boats to NMFS and from vessel trip data reported by dealers.
- No other sources of significant national fishing fleet data are to be found outside of the Coast Guard. It is worthy of note that the Marine Bureau, mandated by the 1988 CFVSA to collect accident data, had no available accident data which could be used for this study.
- Inquiries with other national administrations (e.g., Canada, United Kingdom) as to casualty data were not fruitful. It was found that overseas data lack the numbers and specificity to complement this work.

➢ **<u>Data Issues</u>**

Every risk assessment requires reliable data for arriving at valid, quantified results. In this instance, the only available data were from the Coast Guard, both at District 1 and the MSIS at Headquarters. The following points are the difficulties encountered in their collection and analysis:

- In the national MSIS data base, the fishing fleet is but one sector of all marine industries covered. For this reason, not all data of interest for this analysis were available as they do not fit the data base structure. For instance, fishery/gear specific analysis not possible because these data are not collected.
- The District 1 casualty data, in electronic form (Excel) and paper (collated monthly log books), are a very good start toward the data management required of each district. Even so, there are gaps attributable to several factors:
    - ⇒ The District coordinator gets SAR and "multi-unit" cases, but misses some incidents known only at the local level; e.g., the *Mary Lane* sinking in Maine in which there was no SAR and the crew were picked up by a nearby fishing vessel.

⇒ The quality of narrative supplements ranges from excellent to very poor, and is in some cases nonexistent. The priorities for MSO fishing vessel examiners are not consistent over time or among units. Training and internal standards would improve quality and should focus efforts on the causal aspects of every casualty, not the SAR effort or pollution event.

3.3 Hazard Analysis Methodology

The intent of the hazard analysis is to assess, in depth, the causality of the selected population of serious vessel accidents by review of investigation reports, to collate and weight the results in a matrix, and to correlate the results with national MSIS data. The main features of this method are the taxonomy of causality factors and the weighting of the accident elements of death, injury, and total loss. The weighting of accidents according to their outcomes adds the component of consequence defining a risk analysis.

- **Hazard taxonomy**

The taxonomy categorizes and defines the hazards of the complex of vessels and activities in the fishing industry. The idea is to build a “mental model” which fishermen and regulatory and enforcement personnel can understand. Again, the focus of this analysis is vessel casualties and losses, including those where fisheries practices are contributing factors, and their attendant deaths and injuries.

The operations of fishing vessels create a unique working environment and a challenging analytical problem. Fishermen working on deck to extract a living from the sea are subject to 1) vessel safety hazards such as capsizing, ingress of water, and fire as are all commercial vessels, and 2) occupational hazards from working on deck with dangerous equipment in exposed and often dangerous conditions. As previously suggested, there is a third hazard category resulting from the interaction of the first two, i.e., the influence that vessel characteristics have on deck operations and the effect of fishery operations on vessel performance (see Figure 1).

This model categorizes hazards from the top down into categories (vessel safety and fisheries/operational), factors, and sub-factors within the factors categories. The analysis makes a careful distinction between occupational and “environmental” factors; the latter are those aspects of climate, fishery, season, and location, which have a direct effect on the safety of the vessel. The development of this taxonomy is from examination of the CFR fishing vessel regulations (which deal mainly with emergency procedures and equipment), conversations with Coast Guard and industry people, and examination of the accident records.

Table 1 shows the detailed hazard taxonomy, with specific factors (capitalized terms) and sub-factors. Vessel safety is divided into the two categories of “Preventive Safety Factors” and “Emergency Equipment and Procedures”. The Preventive Factors are those which indicate engineering and human features of safe operations. “Structural integrity” covers the design and maintenance of the hull envelope as a watertight/weathertight entity. “Vessel condition” is a catch-all for other systems onboard affecting safe operations, e.g., propulsion plant, piping, or fishing gear. “Crew preparedness” includes human factors of experience and training; safety drills and awareness are included as most closely a human training and response issue. “Stability” includes the intact and damage modes. “Damage stability” is a measure of the intended subdivision of the vessel, whereas “Structural Integrity—Subdivision bulkheads” deals with compromised bulkheads and the resulting progressive flooding. Therefore, a vessel with insufficient or non-existent subdivision is treated distinctly from one with weepholes or non-tight penetrations through subdivision bulkheads.

“Emergency Equipment and Procedures” are obvious: those human and engineering elements designed for response to, rather than prevention of, emergency situations. “Fishery and Operational Factors” are those owner/operator practices which influence either the prevention or outcome of accidents. These are primarily fishing operations aspects, but include, in “Vessel history” engineering items such as configuration, service, and rigging changes. The distinction lies in whether the configuration caused an accident by failing as designed (e.g., a modified towing rig) or through improper use (e.g., stern drag exerting excessive transverse force). Manning issues are within the purview of the owner/operator decision on how to fish and are therefore included as operational sub-factors. The influence of when and where a boat fishes, and what it fishes for, is accounted here in sub-factors of catch loading and weather and sea conditions.

The development of this approach was nicely anticipated by the MSO Portland Fishing Vessel Safety Index, developed there for improved management and execution of their Voluntary Dockside Inspection program. MSO Portland categorized and weighted all inspection checkpoints, largely on the lines of CFR fishing vessel regulations, but also including a detailed treatment of watertight integrity items. The taxonomy here is more broadly based, including the regulated aspects of safety (in a less detailed manner), but also addressing gap areas such as stability and subdivision, fisheries characteristics such as seasons, and changes of service.

- **Weighting of results**

Each accident is weighted by assigning values for 1) deaths, 2) injuries, and 3) total loss of the vessel, thus numerically accounting for the severity of consequences of each. The initial values chosen are [5] for the total loss of the vessel, [5] for each death associated with the casualty, and [1] for each injury associated with the casualty. The initial results reflect these values; a separate analysis will test the sensitivity of altering the weights, specifically the value assigned to a death.

Table 1
Hazard Taxonomy

	HAZARD CATEGORY	FACTOR	Sub-factor	FACTOR	Sub-factor
	FISHERY AND OPERATIONAL FACTORS	VESSEL HISTORY		FISHERY/OPS ASPECTS	
			Reported casualties		Exposure to WX extremes
			Change of service		Water temp.
			Unchecked weight/rig mods		Seasonal factor
		FISHERY/OPS			Unchecked/dangerous
			Catch loading		Undermanned
			Water in cargo		Operating alone
			Rig type (IS or hull integ.)		Fatigue
			Rig type (safety on deck)		
VESSEL SAFETY	PREVENTIVE SAFETY FACTORS	CREW PREPAREDNESS		STRUCTURAL INTEGRITY	
			Training, knowledge of FV		Shell plate/stiffs.
			Safety drills/awareness		Subdiv. blkhds.
			Situational awareness		Mech. seals, thru fittings
			Experience of master		Bilge pumps
		VESSEL CONDITION			High water alarms
		NAVIGATION/COMMS			Deck openings
			Radio		Damage control kit
			Radar	STABILIT	
			Reflectors		Intact stability
			GPS/SATNAV		Damage stability
			Navigation books/lights/		
	EMERGENCY EQUIPMENT & PROCEDURES	LIFESAVING EQPT/PROCEDURES		FIRE	
			Lifesaving eqpt.	SAFETY	Suppression/extinguishment
			Immersion suits		Back flame control
			EPIRB		Engine rm. vent'l't'n
			First aid eqpt/training		SCBA
					Fire detection (voluntary)

- **Case population**

The author conducted an in-depth study of narrative accident investigation reports, focused on Coast Guard District 1 (New England and Long Island), from 1993 to the present. District 1 is a complex and diverse regional fleet, with lobster, scallops, groundfish, herring, shellfish, urchins, and many other fisheries. All cases selected belong to either the “vessel safety” or “fishery/operational practices” categories; purely occupational events are not included here.

The case population includes five man overboard deaths. These are considered to be “fishery and operational aspects” casualties, because the victims were each operating alone and thus responsible for control of the vessel and working of the fishing gear. Interaction of the boat, fishing gear, and environmental conditions is seen as a factor in these accidents. Other purely occupational deaths are not included.

Sinkings and other total losses without death or injury are included for the following reasons: 1) serious loss of property; 2) the potential inherent in any sinking for death(s); and 3) the indications that any such loss can provide relative to serious hazards onboard. These do not include sinkings at the pier, which, though indicative of certain hazards, lack the operational element and which may skew the results toward one particular type of hazard (i.e., water ingress and flooding).

There were 102 cases found with sufficient narrative data for determination of causality. Many candidate cases were not used because of insufficient investigative data, or because it was not possible for investigators to determine the cause.

- **Determination of causality**

Each of the 102 cases selected was reviewed in detail, by reading of the MSIS entries, MSIS Marine Casualty Supplemental Narrative (MCSN), and other investigative reports. In each case, the review resulted in a distribution of causality totaling 1.0. The variance in quality of the investigations meant that some cases lack the detail of others; in all cases, the maximum number of valid contributory factors was sought. Most accidents therefore were found to have from three to five contributing causalities.

The author strove to limit the band width of assigned causality values (e.g. 0.3 + 0.3 + 0.2 + 0.2), subject to the nature of the accident and the available information. In many founderings and sinkings where multiple causes contributed to a slowly developing loss, such an approach is valid. In a rapid capsize, however, it may be clear that a single factor is largely or wholly the cause. Limited narrative data also resulted, in a small number of instances, in a similar divergence.

The results of this review track well with the factors appearing in the MSIS accident records. The latter do not appear in the same detail as the case-by-case review, but correspond generally, e.g., situational awareness = “human factor”. The detail is available in the underlying layers of the Coast Guard’s data base. Regional and national accident data obtained from MSIS through a request to data base managers at Coast Guard Headquarters are the subject of a detailed comparison in a later section.

4. HAZARD ANALYSIS

The results of the hazard analysis are presented "top-down"; that is, causality distributions are found in successively more detailed fashion, starting with the broadly defined "categories". Case briefs are an important part of the presentation, giving insight into the multi-causal and synergistic hazards at work, and a view of the application of the weighting and scoring approach used in the analysis.

4.1 General

The initial sort of District 1 data for small fishing vessels indicated that 52% of deaths during 1993-97 were purely of an occupational nature, as were 97% of the reported injuries. The 102 cases selected involving non-occupational deaths or total vessel losses are sorted in Table 2 and the distribution of casualty types is depicted in Figure 2.

Sinkings are by far the most common scenario for both total vessel losses and fatalities. The second, also in both instances, is capsize. Groundings have resulted in very few total vessel losses and no deaths, while only one collision met the specification of a serious accident (the collision of the *Heather Lynn* with a tug/barge tow rope, and her subsequent capsize, causing three deaths). Fires resulted in seven total losses, one injury, and no deaths.

<u>Table 2</u>
District 1 Case Population

	Deaths		Injuries		Other	Total
Accident Type	#accidents	#deaths	#accidents	#injuries	accidents	Accidents
Sinking	7	9	3	3	43	53
Capsize	8	14	6	12	8	22
Collision	1	3	0	0	0	1
Fire	0	0	1	1	14	15
Grounding	0	0	0	0	6	6
Man overboard/ operating alone	5	5	0	0	0	5
TOTAL	**21**	**31**	**10**	**16**	**71**	**102**

Figure 2
All cases by casualty type

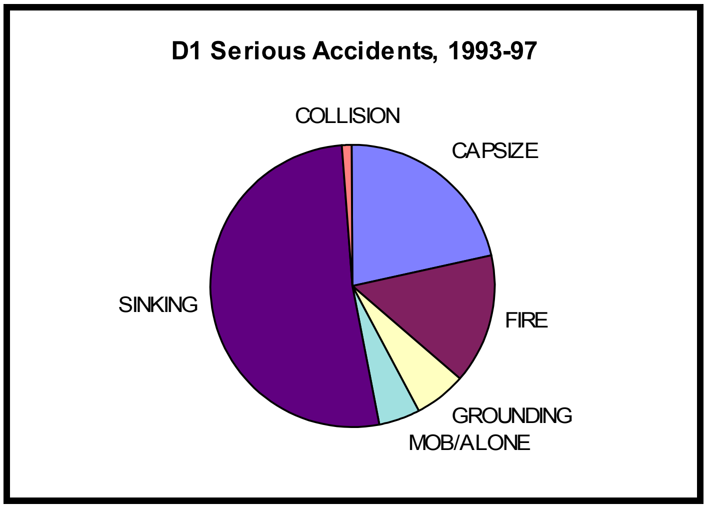


Figure 3

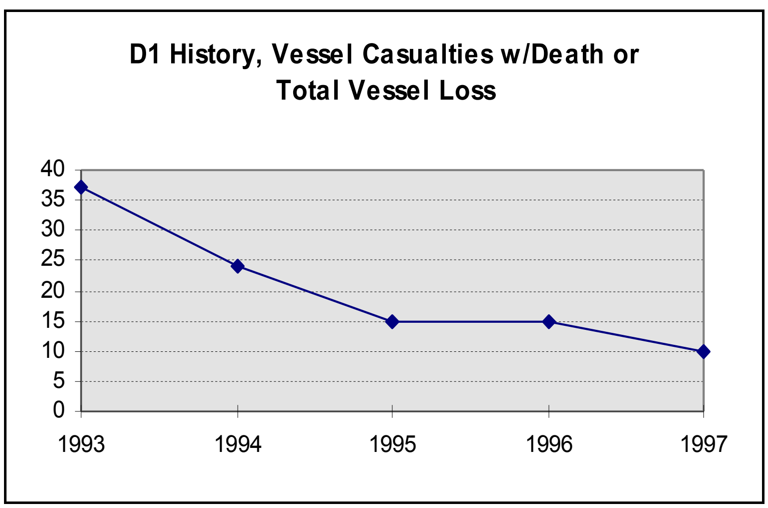


Figure 4

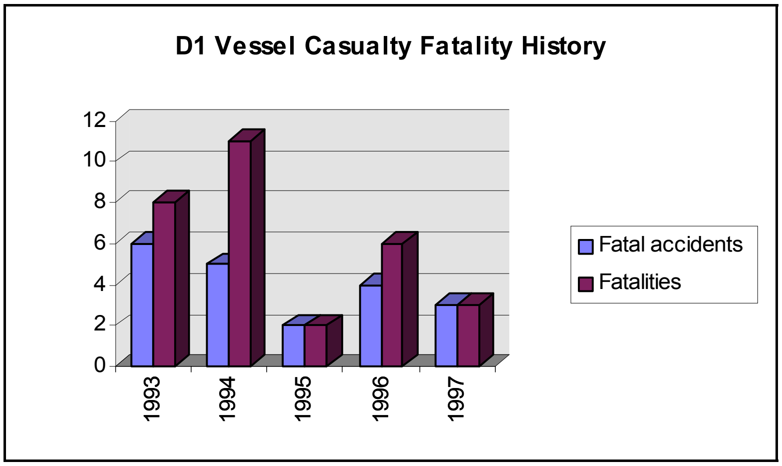


Figure 3 indicates a significant downward trend from 1993 to the present in serious fishing vessel accidents in District 1. A similar general trend appears in Figure 4 for fatal accidents and fatalities. It is not possible in the scope of this study to account for all the factors that could influence these decreasing rates (weather, shifting locations and types of fishing operations, market economics). The exposure of the New England fishing fleet, in terms of days at sea, is the topic of a later section.

4.2 Causality by Category

The detailed assessments of the accident cases resulted in a distribution of causality, summing to 1.0 for each case, and totaling 102.0 for the whole population. Figure 5, the un-weighted distribution by causality category, shows that deficiencies in preventive measures are the dominant component, followed by fishery and operational aspects. A similar sort with weighted values yields nearly identical relative numbers (Figure 6). The relative influence of the three causality categories in fatality accidents appears in Figure 7. Emergency equipment factors are the least significant in every data sort, and especially so in fatal accidents, because there were no deaths associated with total losses due to fire (fire detection and suppression equipment not causal).

It is clear that attention to preventive safety measures is the primary issue; this includes vessel engineering and maintenance and human factors of training, vigilance, and experience. Fishery and operational aspects are clearly a contributing factor in many accidents. Examination of these factors shows a clear element of human influence, as in decisions leading to exposure to severe weather, and manning issues.

Post-emergency procedures and equipment figure in comparatively few cases, where deficiencies are seen to exacerbate—not cause—bad situations. The detailed analysis of causal factors following shows that fire safety issues are the majority factor in this category. It is perhaps a measure of the effectiveness of the current regulations on lifesaving that it is a factor in so few of the serious accidents analyzed, accidents where the vessel, the crew, or both are in extremis.

Section 7.3 is a detailed analysis of the causal factors in each category, with individual examples of accidents added to illustrate the major points.

Figure 5

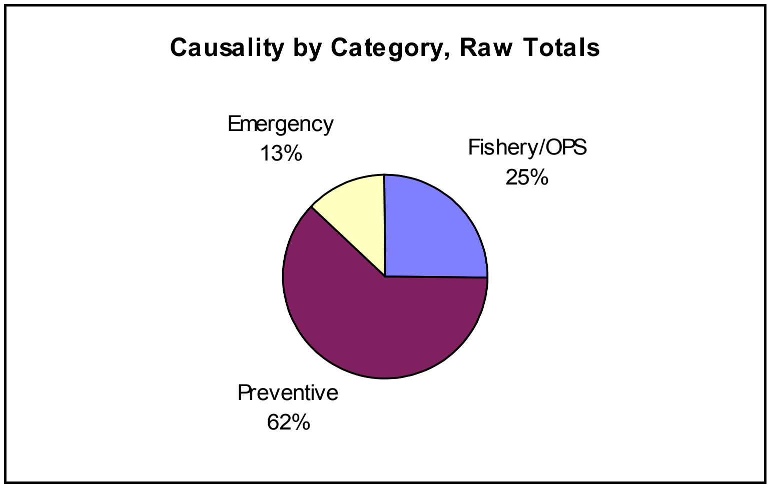


Figure 6

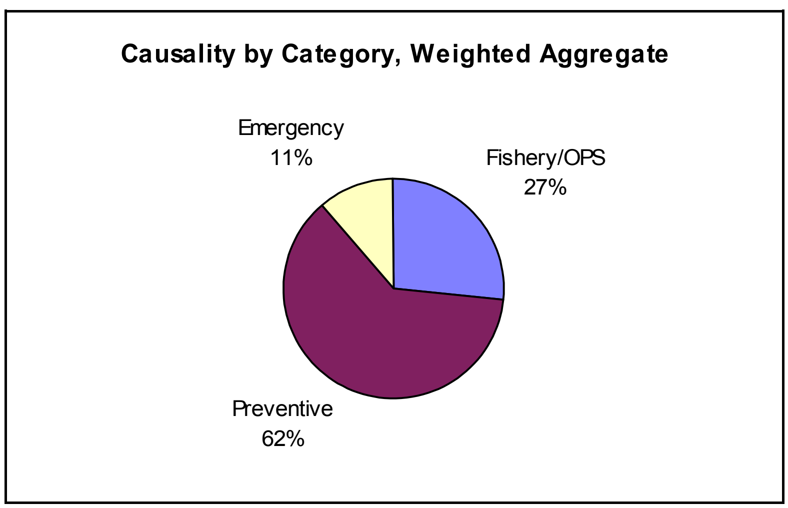
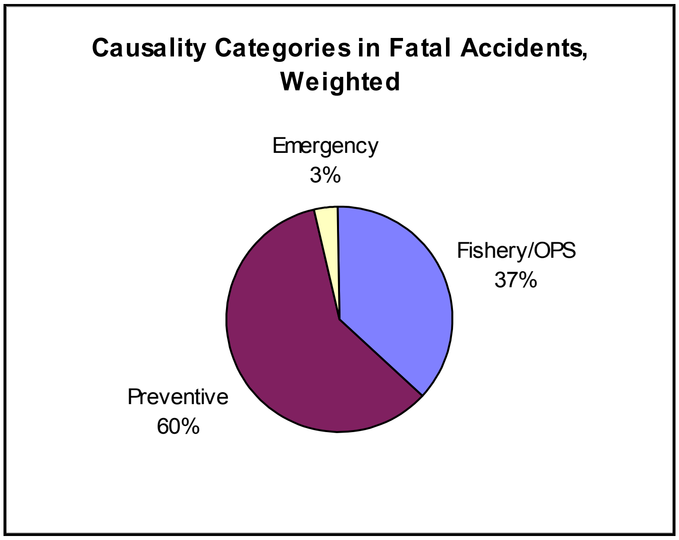


Figure 7



4.3 Causality by Factor

The heart of the hazard analysis lies in the more detailed de-aggregation of causality found in this section, to be approached as follows:

- Discussion of each hazard factor in detail, including how different factors and sub-factors were seen to influence each other and the hazard "scoring" for each accident. The logic for the hazard scoring emerged from the accident accounts themselves, in which event chains revealed several repetitive patterns.
- Illustration of the results by specific accidents. Each account will include the weighted value of the accident ("VALUE"), as specified by the methodology, and the causal factor distribution ("CAUSALITY") adding to1.0.
- Graphic displays of the aggregate weighted totals of the causal factors.

Figures 8 and 9 show the aggregation of weighted causal factor scoring for fatal accidents only, and for the entire accident population, respectively. They tell much the same story: operational and crew preparation factors, along with compromised watertight integrity, are clearly the primary hazard factors found in this study. It is impossible to ignore the overlying theme of "human factors" in the three primary hazard categories which emerged. Each factor will be discussed in detail following.

➢ **Fishery and operational aspects**

Figure 10 depicts the relevant weighted sub-factors. Only "WX" (weather), water temperature (affecting survival of persons in the water), and seasonal considerations (other than those affecting stability) are essentially environmental factors, although the argument could be advanced that a human decision to operate in rigorous conditions is also at work. Those remaining sub-factors have in common human decisions, e.g., amount and manner of catch loading or manning levels and working hours.