U.S. Coast Guard Research and Development Center
1082 Shennecossett Road, Groton, CT 06340-6096

Report No. CG-D-20-00

SKILL AND KNOWLEDGE LIMITATIONS IN MARINE CASUALTIES

FINAL REPORT
JUNE 2000

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National Technical Information Service, Springfield, VA 22161

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Marine Safety and Environmental Protection (G-M)
Washington, DC 20593-0001

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Marc B. Mandler, Ph.D.
Technical Director
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

Technical Report Documentation Page

1. Report No.	2. Government Accession Number	3. Recipient's Catalog No.
CG-D-20-00	ADA416477	

4. Title and Subtitle	5. Report Date
Skill And Knowledge Limitations In Marine Casualties	June 2000
	6. Performing Organization Code Project No. 3302.1.3

7. Author(s)	8. Performing Organization Report No.
Marvin C. McCallum, Alice M. Forsythe, Mireille Raby, Alice E. Barnes, Anita M. Rothblum, and Myriam W. Smith	R&DC 479

9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
Battelle Seattle Research Center 4500 Sand Point Way NE Seattle, WA 98105-3900	U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096	11. Contract or Grant No. Contract DTCG39-94-D-E00777, Delivery Order No. 96-F-E00258

12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
U.S. Department of Transportation United States Coast Guard Marine Safety and Environmental Protection (G-M) Washington, DC 20593-0001	Final
	14. Sponsoring Agency Code Commandant (G-MOA) U.S. Coast Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

The R&D Center's technical point of contact is Anita Rothblum, 860-441-2847, email: arothblum@rdc.uscg.mil.

16. Abstract (MAXIMUM 200 WORDS)

The present study addressed the applicability of investigation, reporting, and analysis procedures that focus on the role of mariner skill and knowledge limitations in marine casualties. An initial set of procedures was used during a trial implementation by Coast Guard Investigating Officers in their investigation of 389 marine casualties. The procedures were found to be effective. Analysis of the resulting casualty reports provided a basis for determining the prevalence and characteristics of skill and knowledge limitations in marine casualties, as well as the identification of investigator recommendations corresponding to specific causes. Skill and knowledge limitations were found to contribute to 22% of critical casualties, with errors in bridge operations being the predominant cause. The investigation tools allowed for the identification of the specific operational activities which were performed incorrectly and led to the casualty. This information provides the maritime community with specific areas in which improvements are needed in mariner education and shipboard operating procedures. Following the assessment of the initial procedures and analysis of the casualty data, a set of revised investigation tools was developed.

17. Key Words		18. Distribution Statement
accident investigations ship and boat accidents ship personnel performance (human)	casualties proficiency skills	This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.

19. Security Class (This Report)	20. Security Class (This Page)	21. No of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	94	

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

ACKNOWLEDGEMENTS

The authors would like to thank several key people at U.S. Coast Guard Headquarters Investigations Division (G-MOA-1) for their help and support on this study. Mr. Doug Rabe served as the sponsor for the study, providing useful insights and suggestions. LCDR Gordon Loebl was an able liaison in identifying appropriate Marine Safety Offices and coordinating schedules for investigation and reporting with those offices. Mr. James Law provided detailed analyses of Marine Safety Information System data in support of this work.

We are most grateful to the Senior Investigating Officers and the Investigating Officers from the U.S. Coast Guard Marine Safety Offices at Seattle, Washington; San Francisco, California; Galveston, Texas; and Miami, Florida. These individuals provided useful comments regarding the investigation and reporting procedures, and substantial time and effort to investigate and report casualties.

We obtained reviews of draft investigation procedures from several individuals, including Ms. Leslie Hughes of North Pacific Fishing Vessels Owner Association, Mr. Bob Diaz of Holland America Line Westours, Inc., Mr. Mike Godbey of Crowley Maritime, Captain George Sandberg of the U.S. Merchant Marine Academy, and Captain Joseph Murphy of Massachusetts Maritime Academy.

Dr. Alvah Bittner provided valuable comments and recommendations during our development of the revised investigation tools.

Ms. Susan Czarny provided able support in preparing forms and training materials during the early stages of this study. Ms. Judy Panjeti provided very capable support in data entry, data management, and documentation during the later stages of this study.

EXECUTIVE SUMMARY

It is estimated that human error directly contributes to between 75 and 96 percent of marine casualties (U.S. Coast Guard, 1995A). Gaining a better understanding of the nature and causes of casualties with human factors contributions will help in identifying strategies to reduce future marine casualty rates. The U.S. Coast Guard (USCG) routinely investigates marine accidents for cause, providing the potential for significantly reducing marine casualty rates. Two recent USCG Research and Development Center studies demonstrated the value of conducting marine casualty investigations that focus on individual human factors causal areas. These studies, which focused on mariner fatigue (McCallum, Raby, & Rothblum, 1996) and communications problems (McCallum, Raby, Forsythe, Slavich, Rothblum, & Smith, 2000), involved the investigation of a limited sample of marine casualties, yielding an initial characterization of the nature of human factors contributions to casualties in these two areas. In addition, the studies provided investigation tools for application by USCG Investigating Officers (IOs).

The present study focused on the role of skill and knowledge limitations in marine casualties, using the basic approach of the two earlier studies. This study had two objectives:

- Develop a method and tools that can be applied to investigate and report casualties involving skill and knowledge limitations.
- Provide an initial characterization of mariner skill and knowledge limitations that contribute to marine casualties.

We developed an initial set of procedures used to investigate and report on the contribution of skill and knowledge limitations to marine casualties. The procedures were then applied by IOs from four USCG Marine Safety Offices (MSOs) to collect a sample of casualty reports and identify issues. Our analysis of a sample of 389 casualties provided a number of insights into the specific skill and knowledge limitations that most commonly contribute to critical marine casualties. Finally, the investigation and reporting procedures used in the present study were reviewed and a set of revised procedures were produced, suitable for application by USCG IOs to investigate the contributions of skill and knowledge limitations to marine casualties.

Extensive time and effort were invested in the initial development of the procedures used in this study. During development of the procedures, a comprehensive list of activities associated with bridge, deck, engineering, and safety and emergency operations was defined and incorporated into the procedures. The definition and classification of operational activities represents the combined efforts of human factors and maritime experts. These efforts focused on developing easy-to-use forms that would maintain sufficient detail to address specific skill and knowledge limitations.

Our experience applying these procedures has demonstrated that significant time must be allocated for in-depth investigation of human factors causes. One of the current objectives of the USCG Office of Investigations and Analysis (G-MOA) is to expand the breadth and depth of human factors data available for analysis of cause. The systematic investigation of human factors causal information requires personal contact with the individuals directly involved in the

casualty and the application of detailed standardized procedures, requiring substantial investigator time. This conclusion is consistent with the two earlier studies in this series (McCallum et al., 1996; McCallum et al., 2000).

The Office of Investigations and Analysis has made significant progress recently in improving the quality of investigations into human factors causal areas. Recent additions to investigator training have increased the general level of awareness concerning human factors among the IOs. Additionally, G-MOA's guidance to focus on critical casualties has allowed IOs to spend more time on casualties representing significant risks to property and personnel safety. However, further development and implementation is required to establish a comprehensive process for the investigation and reporting of human factors causes. A systematic set of investigation tools that is integrated with standardized reporting procedures is required to successfully implement this approach. In addition, because of the extensive time required to investigate human factors causes, guidance must be provided regarding when it is appropriate to conduct such in-depth investigations.

Although the present study was limited to a sample of 389 casualties, it helped to characterize and quantify the extent to which mariner skill and knowledge limitations contribute to marine casualties. The incidence of skill and knowledge limitation contributions to critical casualties was determined to be approximately 22 percent, indicating that this area is a significant contributor to marine casualties and is worthy of government and industry attention and remedial action. The current procedures provided data that were useful in identifying the mariner activities associated with skill and knowledge limitations that contributed to the sample casualties. However, further investigation will be necessary to identify the specific skill and knowledge areas requiring remedial action.

The research procedures required IOs to investigate all casualties resulting from unsafe acts by mariners. Following the trial implementation of these procedures, a tool was developed that researchers used to classify unsafe mariner acts. This tool was further refined so that it could be used to reliably classify unsafe acts into the five categories of violations, rule-based mistakes, knowledge-based mistakes, slips, and lapses. This tool could be used by IOs to analyze casualties and identify those cases that were a result of mariner skill and knowledge limitations (i.e., those resulting from rule-based and knowledge-based mistakes).

The in-depth procedures used to investigate skill and knowledge limitations in the present study were based on subsets of a detailed list of operational activities. These procedures were found to be useful in characterizing mariner skill and knowledge limitations, as well as in providing IOs with a focus for developing recommendations for reducing future casualties. Streamlined investigation forms based on these procedures have been prepared to provide a common structure for the future in-depth investigation and reporting of skill and knowledge limitation contributions to casualties. It is recommended that these tools be implemented to obtain additional information regarding specific skill and knowledge limitations, potential underlying contributing factors, and remedial actions.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ACRONYMS

ARPA	Automated Radar Plotting Aid
COLREGS	Collision Avoidance Regulations
IO	Investigating Officer
G-MOA-1	USCG Headquarters Investigations Division
GRT	Gross Tons
MINMOD	Marine Investigations Module
MSIS	Marine Safety Information System
MSO	Marine Safety Office
PTP	Prevention Through People
QAT	Quality Action Team
USCG	United States Coast Guard

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1 INTRODUCTION

It is estimated that human error contributes to between 75 and 96 percent of marine casualties (U.S. Coast Guard, 1995A). Gaining a better understanding of the nature and causes of casualties with a human factors contribution will help in identifying strategies to reduce future marine casualty rates. The U.S. Coast Guard (USCG) routinely investigates marine accidents for cause, providing the potential for significantly reducing marine casualty rates. However, the investigation, reporting, and analysis of human factors causes is a more recent initiative that is still undergoing development within the USCG. Two recent USCG Research and Development Center studies have demonstrated the value of conducting marine casualty investigations that focus on individual human factors causal areas. These studies, which focused on mariner fatigue (McCallum, Raby, & Rothblum, 1996) and communications problems (McCallum, Raby, Forsythe, Slavich, Rothblum, & Smith, 2000), involved the investigation of a limited sample of marine casualties, yielding an initial characterization of the nature of human factors contributions to casualties in these two areas. In addition, the studies provided the basis for developing investigation tools that can be applied by USCG Investigating Officers (IOs).

The present study continued this programmatic effort, addressing the area of mariner skill and knowledge limitations. This study involved the development of procedures for trial application by IOs to investigate and report the contribution of mariner skill and knowledge limitations to marine casualties. The investigation and reporting procedures were implemented for a period of six to nine months at four USCG Marine Safety Offices (MSOs). Casualty reports were then reviewed by human factors researchers to ensure consistency and to identify procedural issues. Next, analyses were conducted to assess how well the resulting data could support the characterization of mariner skill and knowledge limitations in marine casualties. This report documents the development and implementation of these investigation and reporting procedures, presents findings that address how skill and knowledge limitations contributed to the investigated casualties, and provides a revised set of investigation tools that focus on mariner skill and knowledge limitations.

1.1 CURRENT USCG CASUALTY INVESTIGATION AND REPORTING PROCESS

Investigating and reporting marine casualties is the responsibility of approximately 160 full-time, 50 part-time, and 70 reservist IOs working out of 85 MSOs and affiliated units. Most full-time IOs are Coast Guard military personnel. The majority of these IOs have completed the two-week Investigation Department course taught at the USCG Reserve Training Center in Yorktown, Virginia. An increasing number of the full-time IOs have also taken the three-week course on advanced topics in investigation, including human factors in marine casualties. The average time on the job of an IO is 21 months (U.S. Coast Guard, 1995B). Few IOs have had any investigation experience prior to their assignment to the Investigation Department at an MSO (Byers, Hill, & Rothblum, 1994). However, a substantial number of IOs have served as Marine Inspectors.

Investigating Officers are assigned casualty cases that are identified through a Report of Accident, Injury, or Death (CG 2692); communications with other USCG departments; or via the

media. According to Byers, Hill, and Rothblum (1994), an IO opens approximately three cases per week, with the investigation load varying among MSOs and IOs. Investigations are conducted predominantly via telephone at most MSOs, although some MSOs send a staff member to the vessel or scene of the casualty whenever possible.[1]

Based on our observations and discussions at MSOs, the majority of an IO's day is spent investigating casualties and entering the results of these investigations into the Marine Investigations Module (MINMOD) of the Marine Safety Information System (MSIS). Recent upgrades to computer hardware and MSIS software have reduced the time required to enter investigation results, freeing more time for investigations. However, other IO duties, including collateral responsibilities, training, and participating in personnel action hearings, tend to reduce the amount of time available for investigations.

Two past Coast Guard Headquarters initiatives, the Prevention Through People (PTP) Quality Action Team (QAT) study (USCG, 1995A) and the Marine Safety Investigations QAT study (USCG, 1995B), focused on improving the USCG's ability to reduce human-related marine casualties. The PTP QAT found that the Coast Guard did not have access to sufficient information to assess the extent and nature of human factors contributions to marine casualties. Specific problems identified by the PTP QAT included inadequate human error causal data and a lack of any standard human error taxonomy or root cause investigation method for human causes. Two of the major reasons cited by this QAT for the persistence of marine casualties were that specific human errors that cause casualties are not identified and that high-risk operations are not identified or systematically analyzed.

The Marine Safety Investigations QAT (U.S. Coast Guard, 1995B) had the more focused objective of identifying areas for improvements in marine casualty investigation, reporting, and analysis. This QAT identified limitations in the value of the current MINMOD database to support human factors investigation and analysis. The team's recommendations included updating the marine casualty investigation process and providing human factors training to IOs. Another recommendation was to reduce or eliminate the investigation of minor casualties, thereby providing more time and focus to the investigation of critical marine casualties.

In the time that has intervened between the publication of the two QAT studies and the preparation of this report, several improvements to the marine casualty investigation, reporting, and analysis process have either been implemented or initiated. A one-day human factors training course (part of the advanced topics in investigation course) has been developed and presented to a number of IOs, providing them a survey of human factors contributions to casualties. A method for screening the criticality of casualties has been implemented, resulting in the reduction of staff time spent investigating minor casualties, and, thus, freeing additional time for a more in-depth investigation of critical casualties. In addition, steps are being taken to

[1] On-site investigation is often not possible when the USCG receives notice of a casualty after the vessel has already resumed its voyage.

implement an integrated investigation process that is modeled after the International Maritime Organization's report on the role of the human element in maritime casualties (International Maritime Organization, 1998).

1.2 STUDY OBJECTIVES

The current study had two objectives:

- Develop a method and tools that can be applied to investigate and report casualties involving skill and knowledge limitations.
- Provide an initial characterization of mariner skill and knowledge limitations that contribute to marine casualties.

1.3 STUDY APPROACH

The basic study approach was to develop tools and procedures for investigating and reporting mariner skill and knowledge limitations, test these tools and procedures in a small-scale study with a sample of MSOs, analyze the resulting casualty reports, and then develop a final set of investigation tools for broader application. We relied on the success of our earlier research studies (McCallum et al., 1996; McCallum et al., 2000), and employed the same basic strategy in developing and implementing the investigation and reporting procedures. This strategy included the following:

- Limiting IOs' investigation and reporting to well-defined issues.
- Training participating IOs in the use of the procedures.
- Employing stand-alone reporting forms that did not require the use of MINMOD or MSIS, thus keeping the research independent from the operational reporting of casualties.

The scope of this study dictated that we limit the type and number of casualties investigated and analyzed. First, only cases involving vessel or personnel injury casualties were included. Second, only those casualties associated with significant risk to property or injury to individuals were fully investigated and reported. Third, MSO participation was limited to four offices. Finally, based on our preliminary estimates of the contribution of mariner skill and knowledge limitations to casualties, we determined that we would need approximately 500 cases to adequately assess the value of the casualty data in these investigation reports. This led to the investigation of casualties at each participating MSO for a period of six to nine months.

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2 TECHNICAL APPROACH

2.1 OVERVIEW

This study began with the consideration of two factors required for investigating how mariner skill and knowledge limitations might contribute to a casualty: (1) the operational activity being performed by the mariner, and (2) the identification of the nature of the skill and knowledge limitation. Following the consideration of these two factors, researchers developed investigation and reporting procedures with the support of USCG IOs. Then, IOs at the four participating MSOs were trained and began implementing the procedures. Marine Safety Offices sent completed casualty reports to the researchers for review. The researchers reviewed the reports and resolved any questions prior to data entry and analysis. At the end of the implementation period, IOs assessed the procedures. Following data analysis and interpretation, a revised set of investigation tools was developed for future use by IOs.

2.2 IDENTIFYING SKILL AND KNOWLEDGE LIMITATIONS

The present study focused on a subset of human factors that is limited to unsafe acts that immediately precede a casualty. An unsafe act is generally defined as an action or decision that directly contributes to either the occurrence or the severity of a casualty. This focus limits the range of general human factors contributions identified in this study, as well as the range of skill and knowledge limitations investigated. Figure 1 is an adaptation of Reason's conceptualization (Reason, 1990) of the five human factors that typically contribute to a casualty. These factors are: (1) shipboard and shore-based management; (2) preconditions and contributing factors; (3) unsafe acts; (4) procedural and design defenses; and (5) circumstances and unusual conditions.

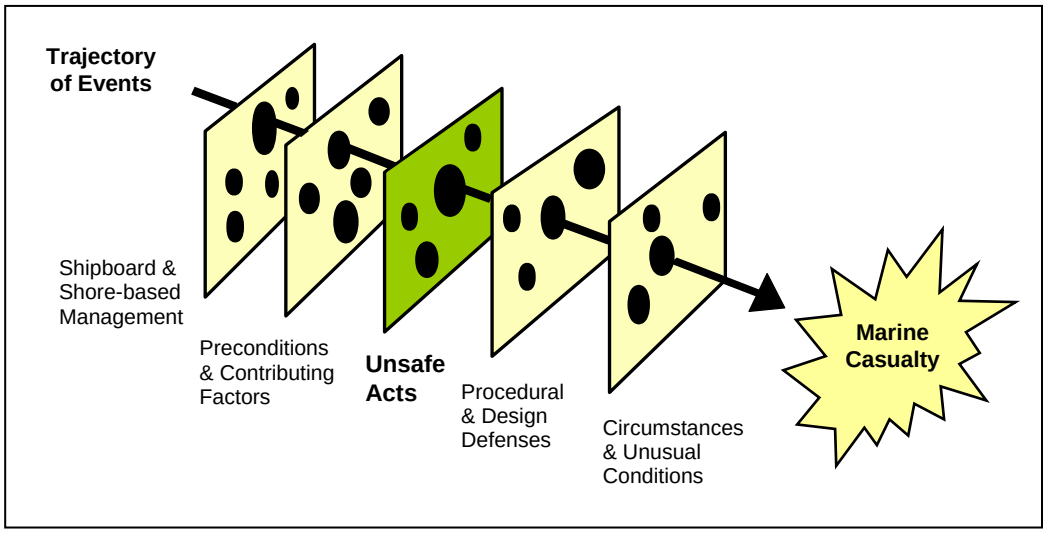

Figure 1. Adaptation of Reason's model of accident causation (Reason, 1990).

Figure 1 shows that the occurrence of a marine casualty requires the co-occurrence of conditions within each of these five factors. It should be noted that people's actions can influence the nature of any of these factors, and that many of these actions could reasonably be attributed to skill and knowledge limitations. However, the present study has focused exclusively upon skill and knowledge limitations that lead to unsafe acts, the highlighted factor in Figure 1.

It is also important to recognize that not every unsafe act is the result of skill and knowledge limitations. A person may have the skill and knowledge to act safely, but may deliberately choose not to do so, thereby violating an applicable rule, policy, or procedure. Moreover, a person may be momentarily distracted, resulting in a slip; or he or she may momentarily forget critical information, resulting in a lapse in memory. Conceptual efforts by Rasmussen (1987) and Reason (1990) have provided a useful structure for considering the nature of unsafe acts and distinguishing skill and knowledge limitations from other types of unsafe acts. Figure 2 is an adaptation of Reason's (1990) classification of unsafe acts. The flowchart in this figure was developed and used by the research team to help in defining those unsafe acts that were within the scope of the study. In the present application, only those unsafe acts judged to have resulted from either a rule-based mistake or a knowledge-based mistake, highlighted in Figure 2, were classified as a skill and knowledge limitation.

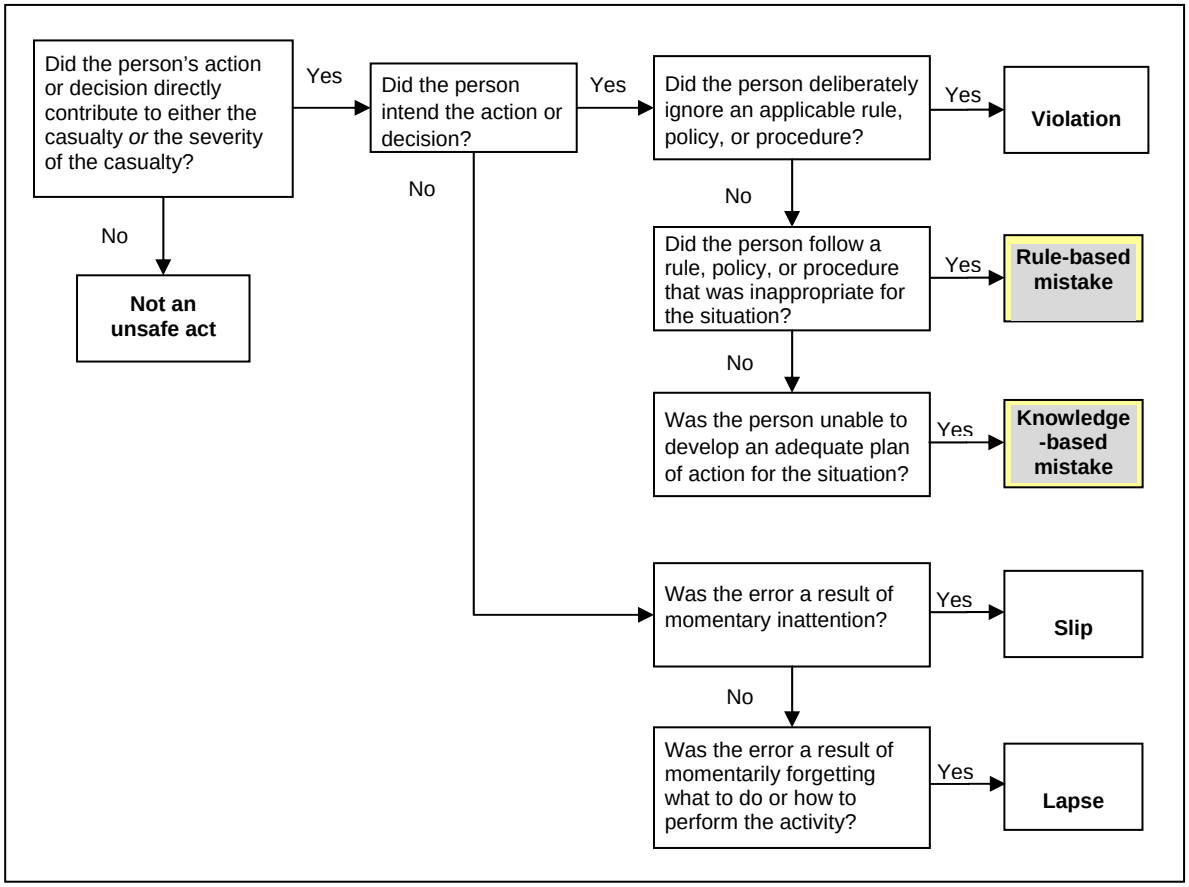

Figure 2. Unsafe acts classification procedure applied in the present analysis of marine casualties.

The purpose of the present study was to identify those unsafe acts that resulted from limitations in mariner skills and knowledge, rather than violations, slips, or lapses. In making these distinctions during the course of the research, we came to appreciate the interactions between skill and knowledge limitations and many of the other forms of unsafe acts. One could argue that almost every unsafe act has, at its root, a skill and knowledge limitation. For example, if a mariner cuts across the bow of an oncoming vessel to shorten his or her travel time, it could be argued that the mariner had inadequate knowledge of the risks involved in such an action and had limited skills in recognizing a dangerous situation. However, when the mariner involved has a lifetime of operational experience, it is more reasonable to classify such an act as a deliberate violation of navigation rules.

Similarly, it could be argued that slips of attention are often the result of an inadequate knowledge of appropriate procedures. For example, if a mariner leaves the pilothouse window open in rough weather, resulting in partial flooding when a large wave strikes the boat, it could be argued that this individual did not have an adequate understanding of the risks involved in such an action. If this individual is generally skilled as a mariner, however, it can be assumed that he or she understood the consequences of such an act, but was momentarily distracted from attending to and recognizing the danger. During the review of cases in the present study, the researchers determined that cases such as those outlined above were not the result of skill and knowledge limitations. This required a certain degree of judgment regarding the mariner's capabilities. However, the intent was to identify those casualties where better training and more experience could clearly result in improved operational safety.

Among the factors that may contribute to skill and knowledge limitations are procedures onboard vessels, training courses and curricula, and specific mariner training and experience. It is important to consider all of these levels of contribution when identifying casualties with skill and knowledge limitations and subsequently addressing ways of reducing such casualties.

2.3 IDENTIFYING RELEVANT OPERATIONAL ACTIVITIES

When the present procedures were being developed, it was recognized that any investigation of skill and knowledge limitations should involve identifying the mariner activity that directly contributed to the casualty. With this in mind, we used several sources to define a list of maritime operational areas and activities. Our primary sources were the *U.S. Code of Federal Regulations, 46-Shipping* (U.S. Office of the Federal Register, 1997); the *Seafarer's Training, Certification, and Watchkeeping (STCW) Code* (International Maritime Organization, 1996); and a current list of USCG-approved courses. Our secondary sources included a sample of approximately 50 National Transportation Safety Board casualty reports; task lists developed for a crew size modeling project sponsored by the USCG (Lee, McCallum, Maloney, & Jamieson, 1997); and selected maritime academy curricula. Based on these sources, a preliminary list of operational areas, activity areas, and specific activities was developed. During structured interviews, this preliminary list was reviewed by selected maritime educators; representatives from the towing, cruise, and fishing industries; and IOs from MSOs in New Orleans, New York, and Portland, Oregon. On the basis of these reviews, the list was refined to address a broad cross-section of the maritime industry.

The above process resulted in a list of operational areas, mariner activity areas, and specific activities that IOs could use to identify the mariner activity that contributed to a casualty under investigation. Table 1 lists the four operational areas (bridge operations, deck operations, engineering operations, and safety and emergency operations) and the 31 individual activity areas that were defined. In addition to the two levels of definitions shown in Table 1, a third level of specific activities was defined for each activity area. These specific activities were incorporated into casualty reporting forms that corresponded to each operational area. The categories in Table 1 were intended to provide a comprehensive list of the operational and activity areas that could contribute to a casualty. However, it was recognized that our review of casualty reports for this study would likely provide additional information that could be used to refine the definition of specific activities. Appendix A contains copies of the revised forms (see A-7 for bridge operations; A-9 for deck operations; A-11 for engineering operations; and A-13 for safety and emergency operations).

Table 1. Operational areas and activity areas used in the investigation and reporting procedures.

Bridge Operations	Deck Operations	Engineering Operations	Safety and Emergency Operations
1. Changing watch	1. Vessel stability and integrity management	1. Changing watch	1. General crew safety
2. Visual monitoring and lookout	2. Deck equipment operations	2. Engineering systems operation	2. Safety equipment inspection and service
3. Collision avoidance	3. Container cargo operations	3. Engineering systems inspection & testing	3. Controlling and fighting fires
4. Grounding avoidance and navigation	4. Bulk cargo operations	4. Routine, scheduled, and preventive maintenance	4. Confined space rescue
5. Shiphandling	5. Petroleum cargo operations	5. Unscheduled corrective maintenance	5. Person overboard procedures
6. Bridge communications	6. Towing and fleeting operations	6. Engineering communications	6. Abandon vessel operations
7. Port or anchor watch	7. Fishing operations		7. Emergency medical and lifesaving procedures
	8. Deck communications		8. Emergency communications
	9. Deck maintenance		
	10. Passenger safety		

2.4 INVESTIGATION AND REPORTING PROCEDURES

In developing the skill and knowledge investigation and reporting procedures, we adopted the basic approach that had been successful in the earlier casualty studies (McCallum et al., 1996; McCallum et al., 2000). Investigating Officers first conducted an initial *Screening and Background* process to collect general casualty information and to identify cases that met established criteria for further investigation of skill and knowledge issues. If the criteria for further investigation were met, an in-depth investigation of mariner background and operational activities was then conducted.

Figure 3 depicts the logic of the screening and investigation process. After determining whether the casualty was reportable, the criteria that defined critical casualties were considered to identify

those cases where there was a significant property loss or personnel injury. Cases that did not meet the criticality screening criteria were excluded from further investigation for the purposes of this study. Next, if the criticality criteria were met, those cases in which an individual's action or inaction directly contributed to the casualty were identified and selected for further consideration. For these human factors cases, IOs then reviewed the casualty to determine which of the four operational areas pertained to the case. Finally, for each applicable operational area, the case was further investigated to determine the mariner's training and experience, identify the specific activities that contributed to the casualty, and ascertain whether skill and knowledge limitations contributed to the casualty.

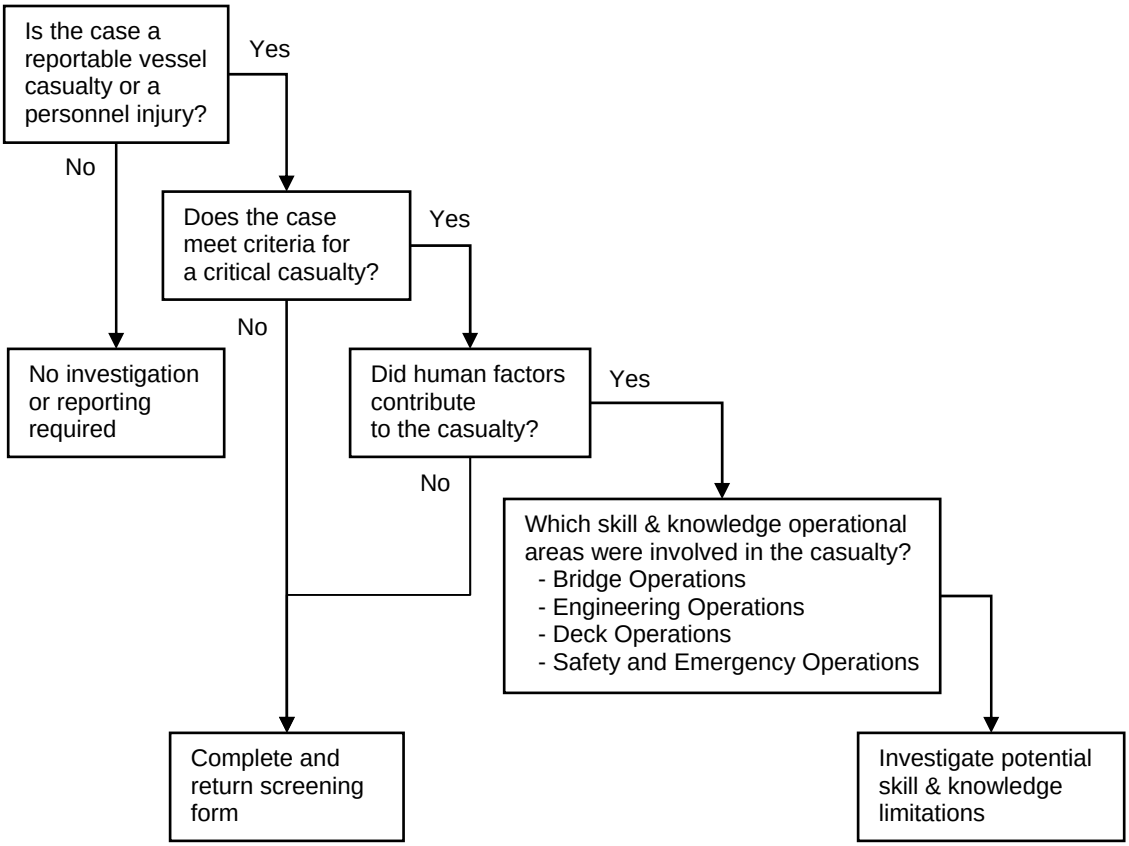

Figure 3. Summary of casualty screening and investigation process.

2.5 INVESTIGATING OFFICER TRAINING

Investigating Officers at each participating MSO received one day of initial training on the use of the investigation and reporting procedures and forms. The training had three main objectives:

- Introduce the purpose of the study and its objectives.
- Develop a general overview of some basic human factors and skill and knowledge limitations.

- Familiarize IOs with the investigation and reporting procedures to be used in the study.

Given the short duration of training and the need to ensure IOs' proficiency with the investigation and reporting procedures, the amount of time spent on human factors concepts was limited. The majority of time was spent introducing the concepts related to skill and knowledge contributions to casualties and acquainting IOs with the investigation and reporting procedures and forms.

As part of the training, a series of practical demonstrations in using the forms was provided. Three case studies that involved marine casualties with different skill and knowledge limitations were presented. Each case was summarized, investigation requirements were identified, and sample completed reporting forms were presented and discussed. Each IO received copies of the training slides, skill and knowledge limitations reporting forms, and a set of instructions for completing the forms. Appendix B contains a copy of the slides used during the training session.

2.6 REVIEW OF CASUALTY REPORTS BY RESEARCH STAFF

Investigating Officers at participating MSOs completed the applicable skill and knowledge limitations reporting forms for casualties that occurred during the nine-month period between October 1, 1998, and June 30, 1999.[2] These forms and supporting materials (CG 2692 and selected portions of the MINMOD report) were sent to the research team for review and data entry. Two researchers independently reviewed the forms submitted for each case. The researcher reviews provided independent judgments concerning casualty criticality, human factors contribution, appropriate operational activities to investigate, the activity-specific contribution of skill and knowledge limitations to the casualty, and appropriate recommendations for addressing any identified skill and knowledge limitations. In addition to reviewing the IO's conclusions and recommendations, the two researchers conducted a separate independent review of each case to classify mariner unsafe acts in accordance with the five categories presented in Figure 2.

Following the completion of these independent reviews, the judgments of the two researchers were compared and any disagreements were identified and discussed until agreement regarding each of the above factors was reached. If the researchers' decision differed from that of the IO, then the IO was contacted to resolve the difference of opinion and revise the report, as necessary.

2.7 PROCEDURE ASSESSMENTS

An initial assessment of the skill and knowledge investigation and reporting procedures was completed approximately 60 days following initial training. Fifteen IOs participated in half-day assessment sessions that were conducted at the four participating MSOs. A group discussion addressing the adequacy of the investigation process and reporting forms was conducted, as well as individual meetings with IOs to review ongoing and completed cases. The group discussion

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[2] MSO Miami began the study on December 28, 1998, and continued for six months. Due to a turnover in staff, MSO San Francisco Bay only reported casualties through April 30, 1999.

addressed the investigation process, investigation strategies and difficulties, and problems encountered in completing the reporting forms. Based on information gathered during the initial assessment, minor modifications were made to the *Screening and Background Form*.

Approximately six weeks after the end of the scheduled period for casualty investigation, researchers visited each MSO for one day to obtain feedback about the study and discuss unresolved questions concerning specific cases. Sixteen IOs participated in these final reviews. During this visit, IOs were presented with a summary of preliminary findings and asked to complete a survey addressing the training sessions, support materials, and casualty reporting forms. Group discussions then addressed perceived benefits of the study, and ways to improve the investigation, reporting, and research methods. Appendix C contains a copy of the final assessment survey and results of analyses for selected survey questions.

2.8 REVISION OF INVESTIGATION AND REPORTING PROCEDURES

A revised set of investigation tools for addressing the contribution of mariner skill and knowledge limitations to casualties was developed following the completion of procedure assessments, data analysis, and results interpretation. The resulting tools consist of a screening tool, a series of in-depth investigation forms, and instructions. The screening tool provides a means of identifying those unsafe mariner acts that are likely to have resulted from rule-based mistakes and knowledge-based mistakes. In-depth investigations of mariner skill and knowledge limitations are to be limited to those casualties involving unsafe acts that have been classified as either rule-based mistakes or knowledge-based mistakes.

The in-depth investigation forms are based upon the bridge, deck, engineering, and safety and emergency operations forms used by IOs in the present study. These forms have been streamlined to eliminate any information redundancies with other forms used for casualty investigation. In addition, the forms require IOs to identify specific activities associated with rule-based and knowledge-based mistakes, any weaknesses in mariner training and experience that may have contributed to the skill and knowledge limitations, and recommendations for reducing similar casualties in the future. The instructions for these investigation tools guide the investigator through the screening of casualties for likely skill and knowledge limitations and the subsequent specification of operational activities, as well as relevant training and procedures. The instructions also provide additional assistance with regard to collecting information relevant to casualties with a skill and knowledge contribution. The revised set of investigation tools for addressing mariner skill and knowledge limitations is provided in Appendix A.

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3 FINDINGS

This section presents the findings from our analyses of the casualty reports submitted by the IOs from the four participating MSOs and also findings from our assessment of the time demands and perceived benefits of using these procedures. The discussion of the findings is divided into five major topics. The first topic is an overview of the study sample which describes the prevalence of casualties by vessel type and by human factors contribution. The second topic in this section addresses general aspects of skill and knowledge contributions to casualties in the study sample. The third topic addresses specific skill and knowledge limitations within the bridge, deck, engineering, and safety and emergency operational areas. Fourth is a discussion of potential contributing factors to the casualties. This section addresses general issues and factors that may be related to casualties resulting from skill and knowledge limitations. The fifth and final topic concerns the perceived benefits and time demands reported by IOs in investigating casualties for potential skill and knowledge limitations. These issues are critical to the future use of the tools and procedures developed as part of this study.

An additional set of analyses was conducted to determine if specific training and experience factors could be used to identify mariners at risk for being involved in casualties resulting from skill and knowledge limitations. However, due to our limited sample of mariner training and experience information, we were unable to identify any significant trends in the data. Therefore, this topic will not be addressed further.

3.1 OVERVIEW OF THE STUDY SAMPLE

This discussion characterizes the study sample in terms of casualty types and vessel types. The study sample is then compared to a nationwide sample and the casualty screening results are summarized.

3.1.1 Prevalence of Casualty Types and Vessel Types

Figure 4 presents the frequency of casualty type (vessel casualty, personnel injury, or both) across the type of vessel involved for all 389 reportable casualties.[3] The figure shows that vessel casualties were by far the most prevalent type of casualty, accounting for 340 (87 percent) of the study sample of casualties. Personnel injury casualties were far less prevalent, accounting for a total of 37 casualties (10 percent); casualties involving both a vessel casualty and a personnel injury occurred in just 12 of the cases (3 percent). This trend is relatively consistent across vessel types. Figure 4 also allows a comparison of the prevalence of different vessel types. Five types of vessels account for 376 of the cases (97 percent). The frequency of casualties for these most-frequent vessel types was, in order of prevalence: towing vessels – 144 casualties (37 percent of the total cases), passenger vessels – 77 casualties (20 percent), fishing vessels – 76

[3] Throughout this report, a single vessel type is associated with each casualty. If more than one vessel was involved in a casualty, the vessel that was the primary focus of the investigation for cause is used to determine vessel type.

casualties (20 percent), freighters – 48 casualties (12 percent), and tanker vessels – 31 casualties (8 percent).

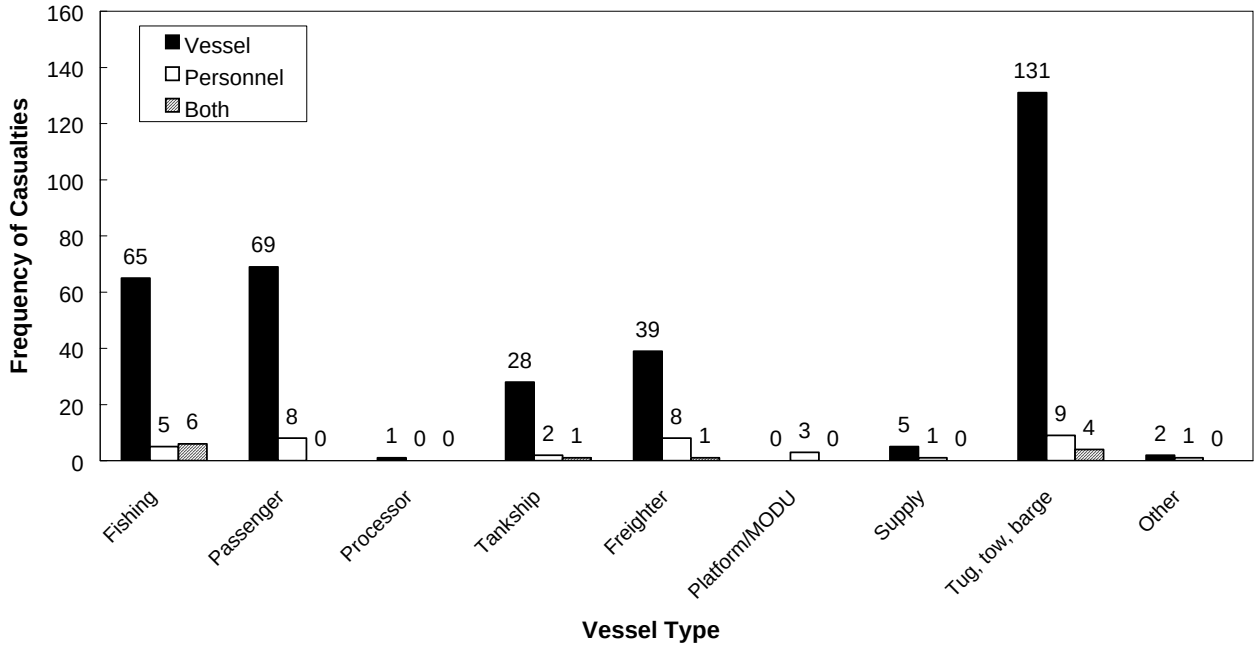

Figure 4. Frequency of vessel types in all reportable casualties (N=389).

3.1.2 Comparison of Study Sample to Nationwide Sample

Table 2 shows a comparison between the study sample and a nationwide sample of 4,275 casualties (completed cases) from roughly the same time period.[4] The most notable difference is for the tug, barge, and towing vessels, which made up 37 percent of the study sample versus 57 percent of the national sample. The lower representation of tug and towing vessels in the current sample may have correspondingly led to higher percentages, compared to the national sample, for the next highest categories of vessels—namely, 20 percent fishing vessels in the current sample compared with 13 percent in the national sample, and 20 percent passenger vessels in this sample compared with 10 percent in the national sample. Percentages of all other vessel categories were quite comparable for the two samples. In summary, the study sample contains an under-representation of tug, towing, and barge vessels and a slight over-representation of fishing and passenger vessels, compared to a nationwide sample.

[4] Note that the vessel type of "processor" from Figure 4, containing only one casualty, has been combined with the category of "other" in this table. The national sample did not distinguish this vessel type.

Table 2. Comparison of vessel types between the current study and a national sample.

	Study Sample		National Sample	
Primary Vessel Type	**Number**	**Percent**	**Number**	**Percent**
Fishing	76	20%	560	13%
Passenger	77	20%	433	10%
Tankship	31	8%	170	4%
Freighter	48	12%	392	9%
Platform/MODU	3	1%	27	1%
Supply Vessel	6	2%	58	1%
Tug, Barge, Tow	144	37%	2432	57%
Other	4	1%	203	5%
Totals	**389**		**4275**	

3.1.3 Summary of Casualty Screening Results

Figure 5 presents the results of screening the casualties in the study sample for criticality and human factors involvement. Screening for criticality resulted in sorting the casualties into three categories: non-critical, minor, and critical. In the present study, *non-critical casualties* were those in which there was no significant loss of property, no personnel injury, or no temporary loss of vessel steering or propulsion. *Minor casualties* involved a temporary loss of steering or propulsion that was judged not to adversely affect vessel seaworthiness. *Critical casualties* involved significant vessel damage or personnel injury, as defined in the reporting instructions and forms (see Appendix A).

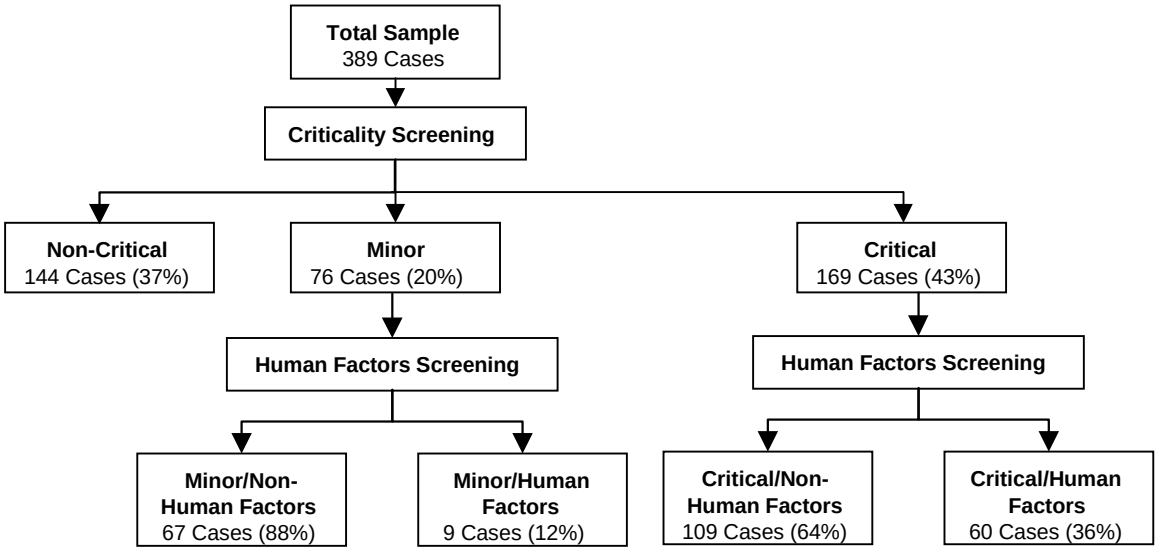

Figure 5. Results of screening the study sample of casualties for criticality and human factors involvement.

Review of Figure 5 indicates that there were 144 non-critical casualties (37 percent), 76 minor casualties (20 percent), and 169 critical casualties (43 percent). All minor and critical casualties were screened for a direct human factors contribution, defined as involving any action or inaction that directly and immediately contributed to either the casualty or the severity of the casualty.[5] Human factors contributions were relatively rare in the case of minor casualties, accounting for only nine of the 76 minor casualties (12 percent). Human factors contributions were relatively more prevalent among the critical casualties, accounting for 60 of those casualties (36 percent). Appendix D provides a summary of the analysis of the 76 minor casualties.

It is noteworthy that the percentage of critical casualties judged to have a direct human factors contribution is less than in the recently completed communications study, which used identical screening procedures with four different MSOs (McCallum et al., 2000). The communications study reported 49 percent of 200 critical casualties to have a direct human factors contribution, which is significantly greater than the 36 percent observed in the present study. A detailed review of casualties in the present study failed to reveal any cause for this discrepancy, except for a substantially lower percentage of casualties with a human factors contribution from one MSO. For that one MSO, only 24 percent of critical casualties were determined to have a direct human factors contribution, compared with a combined 42 percent for the remaining three

[5] Note that by screening for a "direct" human factors contribution, we are ignoring the majority of human errors that may have been latent contributors to the casualties, such as management policies, standard operating procedures, maintenance procedures, equipment design, etc.

MSOs. All casualty reports were independently screened by two researchers. Therefore, it is most likely that both the overall lower percentage of human factors cases and the lower level for the one MSO represent differences in the characteristics of the cases involved, rather than any systematic differences in the way in which human factors contributions to casualties were classified.

3.2 GENERAL ASPECTS OF SKILL AND KNOWLEDGE LIMITATION CONTRIBUTIONS TO CASUALTIES IN THE STUDY SAMPLE

The following discussion addresses four general aspects of skill and knowledge limitation contributions to casualties:

- The results of classifying the identified unsafe acts into the five categories of slip, lapse, violation, rule-based mistake, and knowledge-based mistake.
- The prevalence of skill and knowledge limitation contributions to critical vessel casualties and personnel injuries.
- The prevalence of skill and knowledge limitation contributions across vessel types.
- The frequency of skill and knowledge limitation contributions within the bridge, deck, engineering, and safety and emergency operational areas.

3.2.1 Classification of unsafe acts into the slip, lapse, violation, rule-based mistake, and knowledge-based mistake categories

Direct human factors contributions to casualties are those where an unsafe act has contributed to the casualty. As discussed in the *Technical Approach* section of this report, unsafe acts were independently categorized by two study researchers, and any disagreements were identified and resolved. Figure 6 presents the frequency with which unsafe acts were classified into the five unsafe act categories and the unknown category for the 60 critical casualties determined to have a direct human factors contribution.[6] The frequency and percentage of critical unsafe acts in each category was: violation – 6 (10 percent), slip – 12 (20 percent), lapse – 2 (3 percent), rule-based mistake – 15 (25 percent), knowledge-based mistake – 22 (37 percent), and unknown – 3 (5 percent). Rule-based and knowledge-based mistakes, the focus of the present study, account for the unsafe acts in 37 of the 60 critical casualties (62 percent). Appendix E describes the results of this classification process in more detail.

[6] Casualties were classified as "unknown" when insufficient information was available to make a judgment on this classification.

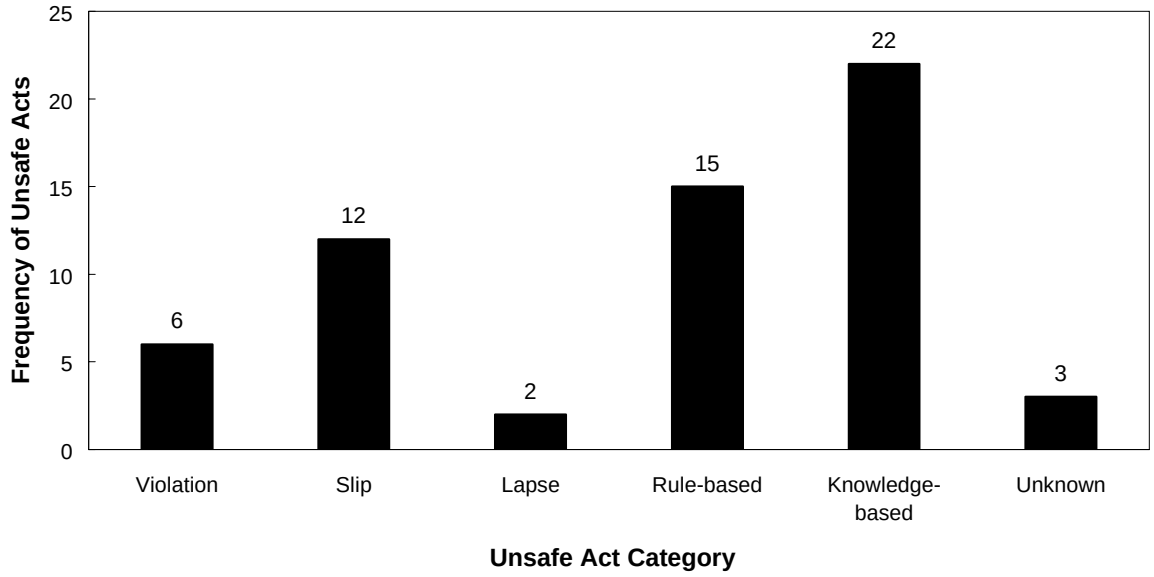

Figure 6. Results of classifying unsafe acts into the slip, lapse, violation, rule-based mistake, and knowledge-based mistake categories (N=60).

3.2.2 Prevalence of skill and knowledge limitation contributions to critical vessel and personnel injury casualties

The 37 rule-based and knowledge-based mistakes shown in Figure 6 represent the set of casualties with unsafe acts judged to have resulted from skill and knowledge limitations in this study. Figure 7 presents the frequency of the casualties with or without a skill and knowledge contribution for three types of casualties: vessel casualty, personnel injury, and those involving both a vessel casualty and personnel injury. In order to determine the incidence of skill and knowledge limitations in vessel casualties, "vessel casualties" and "both" must be combined from Figure 7. Thus, of the total 145 critical vessel casualties, 32 (22 percent) were determined to have a skill and knowledge limitation that contributed to the casualty. Combining data from "personnel injuries" and "both," 11 of the total 34 critical personnel injuries (32 percent) had a skill and knowledge limitation contribution. Overall, 37 of the 169 critical casualties (22 percent) were determined to have a skill and knowledge limitation contributing to the casualty. These overall rates provide strong support for the value of understanding how skill and knowledge limitations contribute to casualties.

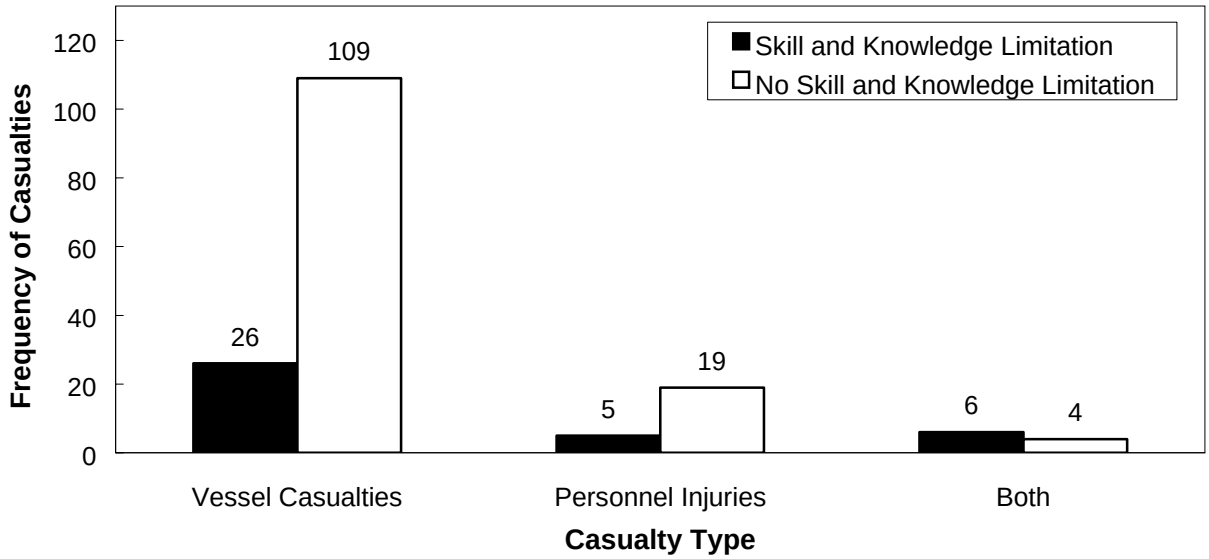

Figure 7. Frequency of skill and knowledge limitation contributions to critical casualties (N=169, of which 37 had a skill and knowledge contribution).

3.2.3 Prevalence of skill and knowledge limitation contributions across vessel types

One topic of interest is whether different vessel types have different incidences of skill and knowledge-related casualties. Figure 8 presents the frequency of critical casualties that were determined to have a skill and knowledge limitation contribution. The sample sizes are too small to warrant conclusions regarding specific vessel types being over- or under-represented in critical casualties with skill and knowledge limitation contributions.

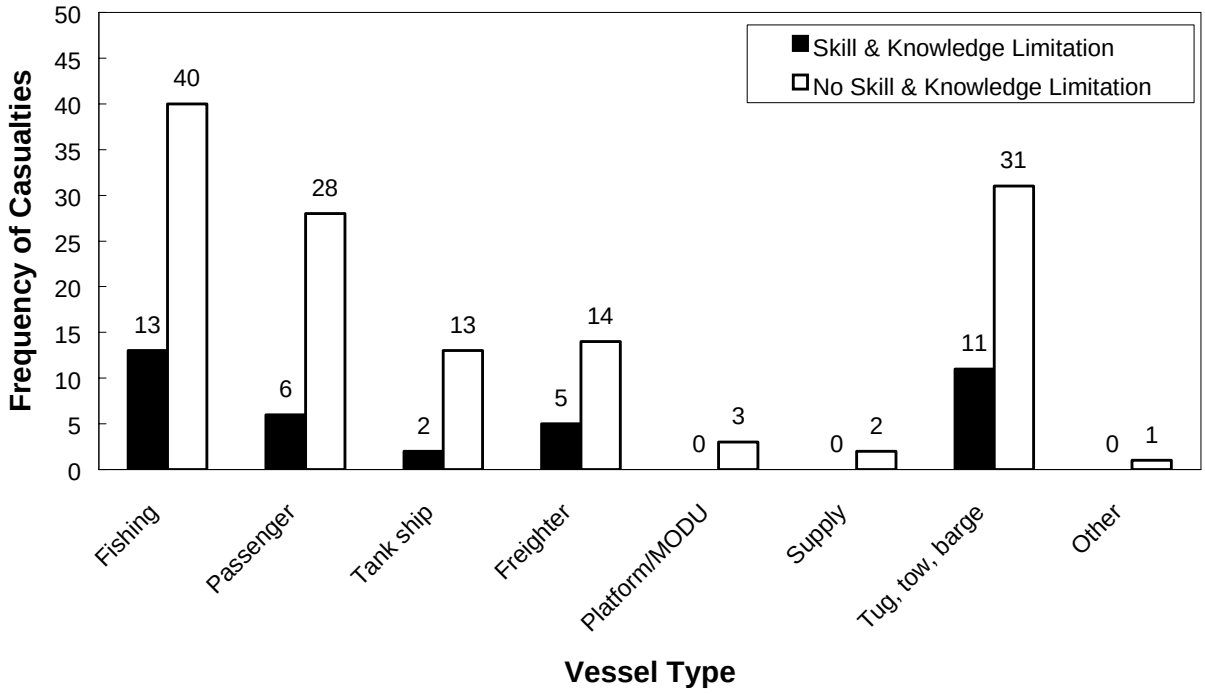

Figure 8. Frequency of vessel types involved in critical casualties, with or without a skill and knowledge limitation contribution (N=169, of which 37 had a skill and knowledge contribution).

3.2.4 Frequency of skill and knowledge contributions across the four operational areas

An initial step in characterizing the nature of skill and knowledge limitation contributions to critical casualties involves consideration of the general operational area involved. As noted above, 37 critical casualties were determined to have a skill and knowledge limitation.[7]

Figure 9 presents the frequency of casualties with skill and knowledge limitations across the four operational areas of bridge operations, deck operations, engineering operations, and safety and emergency operations. Nineteen of the casualties (51 percent) involved bridge operations, 11

[7] In six of these casualties, more than one individual or operational area was identified as contributing to the casualty due to a skill and knowledge limitation. The data for these cases were considered as a single record so that all problems were counted but no casualties or problems were double counted. For the two casualties that had skill and knowledge contributions from more than one operational area, only the primarily contributing area was counted. In one, the problem was in engineering operations and bridge operations were implicated only in being the other half of a failed communication. In the second, the same individual—an operator on a fishing vessel—made errors involving both deck and bridge operations. The primary error involved deck operations, with errors in bridge operations following only from that error. For consistency, clarity, and technical accuracy, only the primary errors are reported for these two casualties.

occurrences (30 percent) concerned deck operations, six (16 percent) involved engineering operations, and one occurrence (3 percent) concerned safety and emergency operations. Examining both the type of casualty and operational area together helps to characterize the general nature of skill and knowledge limitations. Skill and knowledge limitations in bridge and engineering operations occurred almost exclusively in vessel casualties, with 24 of the total 25 occurrences in these two groups involving a vessel casualty. Skill and knowledge limitations in deck operations occurred almost equally in vessel casualties (7 occurrences) and personnel injuries (6 occurrences). Finally, the single occurrence of a skill and knowledge limitation in safety and emergency operations contributed to a casualty that involved both a vessel casualty (total vessel loss) and a personnel injury (death of two mariners).

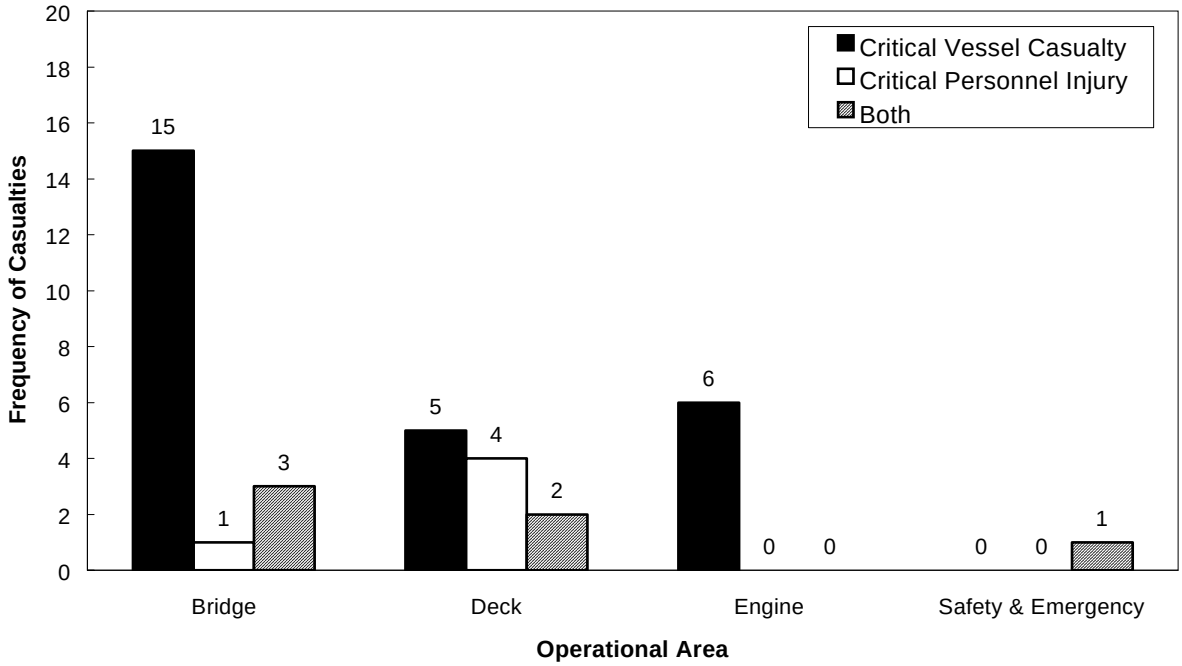

Figure 9. Frequency of casualties with skill and knowledge limitations in bridge, deck, engineering, and safety and emergency operations (N=37 casualties).

3.3 SPECIFIC SKILL AND KNOWLEDGE LIMITATION CONTRIBUTIONS TO CRITICAL CASUALTIES WITHIN THE BRIDGE, DECK, ENGINEERING, AND SAFETY AND EMERGENCY OPERATIONAL AREAS

The following discussions characterize the skill and knowledge limitations cited by IOs within each of the four operational areas studied. For each operational area, the prevalence of skill and knowledge limitations is first discussed according to general problem areas. Next, one or more brief descriptions of casualties that illustrate a major skill and knowledge limitation in the operational area are presented. Finally, a detailed review of the specific activities and problems associated with skill and knowledge limitations is provided.

Figure 10 presents the number of casualties and instances of problems for each of these levels, in order to facilitate the following discussion. Among the 60 critical casualties with a human factors contribution, 37 of these were determined to have a skill and knowledge limitation contribution, and these were categorized into the four operational areas (bridge, deck, engineering, and safety and emergency), as previously discussed. Within each operational area, a number of general problem areas could be cited, and within each general problem area, several specific problem activities could be noted. For example, the 19 casualties that had a bridge skill and knowledge contribution resulted in a total of 39 instances of contributing problem areas (i.e., more than one problem area was frequently cited as contributing to a particular bridge skill and knowledge limitation). At the next level, a total of 63 instances of specific problems were noted within bridge operations (i.e., more than one specific problem was frequently cited within a general problem area).

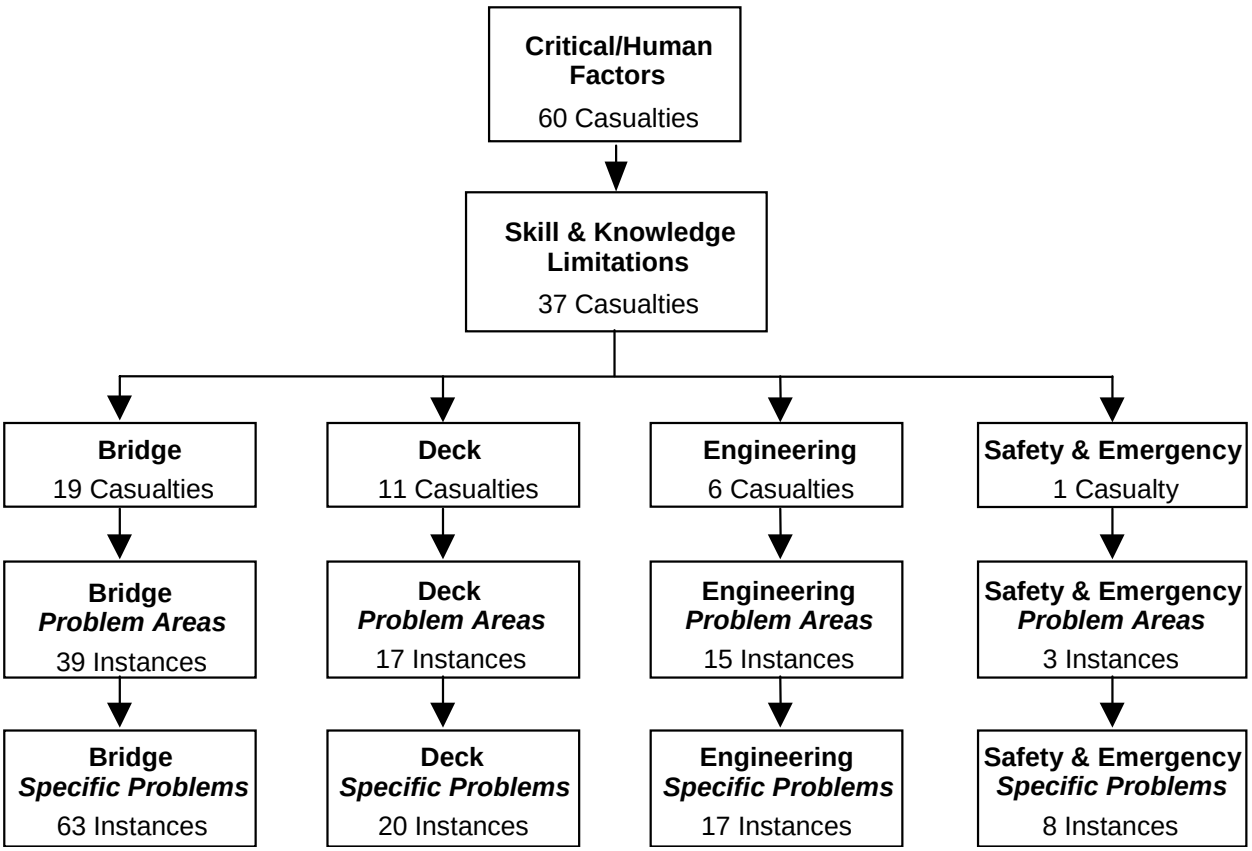

Figure 10. Frequency of skill and knowledge limitations, problem areas, and specific problems, by operational area.

3.3.1 Skill and Knowledge Limitations in Bridge Operations

Prevalence of skill and knowledge problem areas. Figure 11 presents the frequency with which skill and knowledge limitations in bridge activity areas were cited as contributing to the occurrence of critical casualties. Multiple skill and knowledge limitations corresponding to specific activities (e.g., maintain lookout or determine type and aspect of other vessels) that fall under a more general bridge activity area (e.g., visual monitoring) could be identified by IOs for a single casualty. Multiple problem areas were commonly cited within casualties, resulting in 39 instances of problem areas being noted for the 19 critical casualties with bridge skill and knowledge limitations. The four most commonly cited areas with skill and knowledge limitations were visual monitoring and lookout, collision avoidance, shiphandling, and bridge communications.

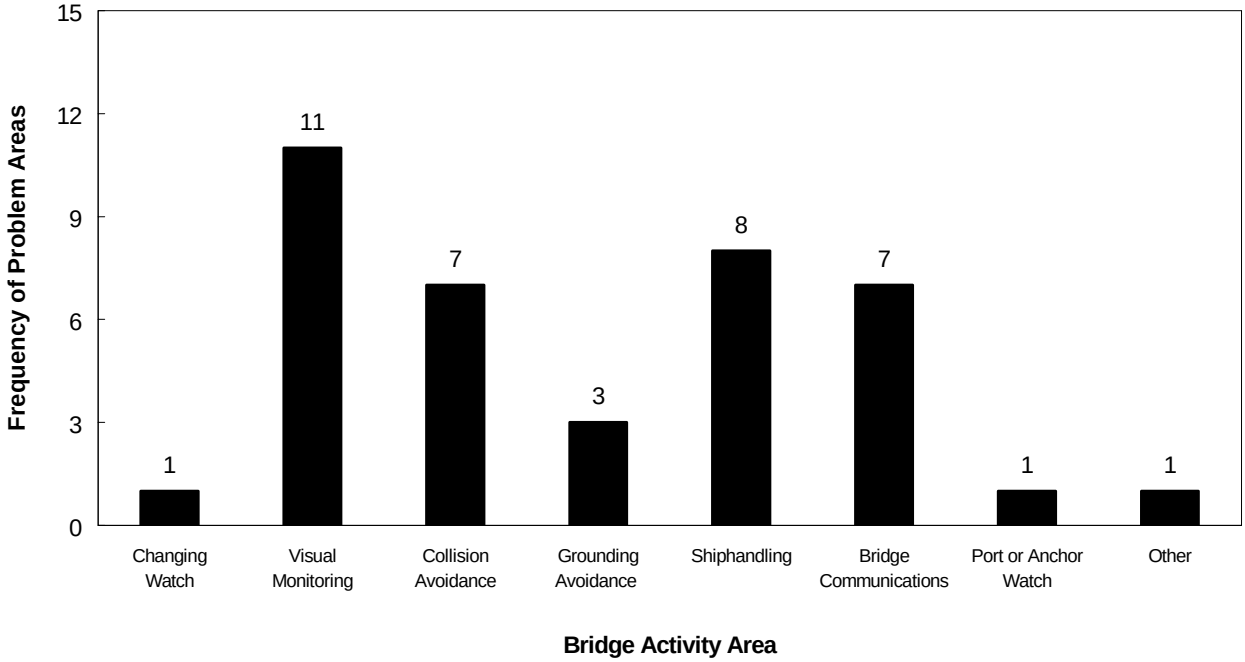

Figure 11. Frequency of bridge skill and knowledge problem areas within casualties (N=39 instances within 19 casualties).

Selected casualties. Below are brief descriptions of two casualties that represent bridge activity areas commonly cited as contributing to casualties. The two casualties provide examples of how skill and knowledge limitations in visual monitoring and lookout activities and shiphandling activities contribute to casualties.

Casualty Example: Bridge Operations, Visual Monitoring and Lookout

Synopsis: A 52-foot uninspected towing vessel pushing three loaded barges started outbound on the Old Brazos River, Texas at 0630 in October. The master was in the wheelhouse and his relief pilot was sleeping. Upon departure, the master broadcast his location, load, and intentions on VHF channel 16. The deckhand was working on the barges. At 0830, weather and visibility were good as they approached Surfside Bridge and the master once again broadcast his position and intentions on VHF channel 16. Shortly after passing under the bridge, a supply vessel came alongside the towing vessel and informed the master that he had run over a recreational fishing boat with his lead barge. The pilot contacted his deckhand and ordered him to the bow of the lead barge to search for the victim while he backed down on the tow. The victim was recovered after he surfaced at the stern of the lead barge, but was pronounced dead shortly afterward.

Specific Skill and Knowledge Limitations Contributing to the Casualty: Maintain lookout to detect objects, traffic, or navigational aids and assess visibility. Monitor radar or Automated Radar Plotting Aid (ARPA) and monitor radar contacts.

Comment: This was an experienced towboat pilot of 20 years. It appears he had let his skills and the application of his knowledge erode over time by lax standard operating procedures including not calling a deckhand as an additional lookout when the situation warranted.

Casualty Example: Bridge Operations, Shiphandling

Synopsis: Towing vessel #1 was being piloted out of the Houston ship channel by a Houston pilot. Towing vessel #1 was pushing two loaded oil barges, was traveling against a 1-2 knot current, and had limited maneuverability. Towing vessel #2 had been waiting for traffic before entering the channel and commenced to enter after agreeing to a "one-whistle" (port-to-port) passage with towing vessel #1. Towing vessel #2 began crossing the channel from the green to red side as towing vessel #1 continued to close. However, due to the incoming current and the initial vessel position, towing vessel #2 was unable to make the turn and collided with the port side of towing vessel #1's lead oil barge, resulting in an 80-foot gouge one foot above the waterline. Damage was extensive, but there was no pollution.

Specific Skill and Knowledge Limitations Contributing to the Casualty: Towing vessel #2 – assess threat of collision and determine collision avoidance maneuver, and maneuver in accordance with sea/river/weather conditions.

Prevalence of specific skill and knowledge problems. Table 3 presents the frequency with which skill and knowledge limitations in specific bridge activities were cited as contributing to critical casualties. Investigating Officers could identify skill and knowledge limitations corresponding to more than one specific activity within a more general bridge activity area and these are reported in Table 3. Among the 19 critical casualties involving skill and knowledge limitations in bridge operations, a total of 63 specific problems were cited by IOs.

Table 3. Frequency with which specific bridge skill and knowledge problems contributed to critical casualties.

Bridge Activity Area	Specific Activity	Frequency
Changing Watch	Check and acknowledge passage plan	1
Visual Monitoring	Maintain lookout	9
	Determine type and aspect of other vessels	5
	Receive and verify reports of visual contact	3
	Instruct lookout and ensure he or she is prepared	2
Collision Avoidance	Assess threat of collision	6
	Monitor radar or ARPA	3
	Determine vessel position	3
	Recognize and apply Collision Avoidance Regulations (COLREGS)	2
	Adjust and operate radar or ARPA	1
Grounding Avoidance	Calculate course changes	2
	Check and update navigation charts	1
Shiphandling	Maneuver IAW sea/river/weather	6
	Maneuver IAW with handling characteristics	3
	Communicate among bridge crew	2
	Dock, anchor, or moor vessel	2
	Manage and coordinate assist vessels	1
Bridge Communications	Communicate between bridge crew and pilot	4
	Communicate between vessels	4
	Interpret and reply to signals	1
Port or Anchor Watch	Monitor vessel to determine if anchor is dragging	1
Other	Moor vessel in proper location	1

3.3.2 Skill and Knowledge Limitations in Deck Operations

Prevalence of skill and knowledge problem areas. Figure 12 presents the frequency with which skill and knowledge limitations in deck activity areas were cited as contributing to the occurrence or severity of critical casualties. The frequencies in Figure 12 represent the number of casualties with one or more specific skill and knowledge limitations identified within each of the general deck activity areas. Limitations in multiple activity areas were cited for some casualties, resulting in 17 instances of problem areas for the 11 critical casualties with deck skill and knowledge limitations. The two most commonly cited areas with skill and knowledge limitations were vessel stability and integrity management, and fishing operations.

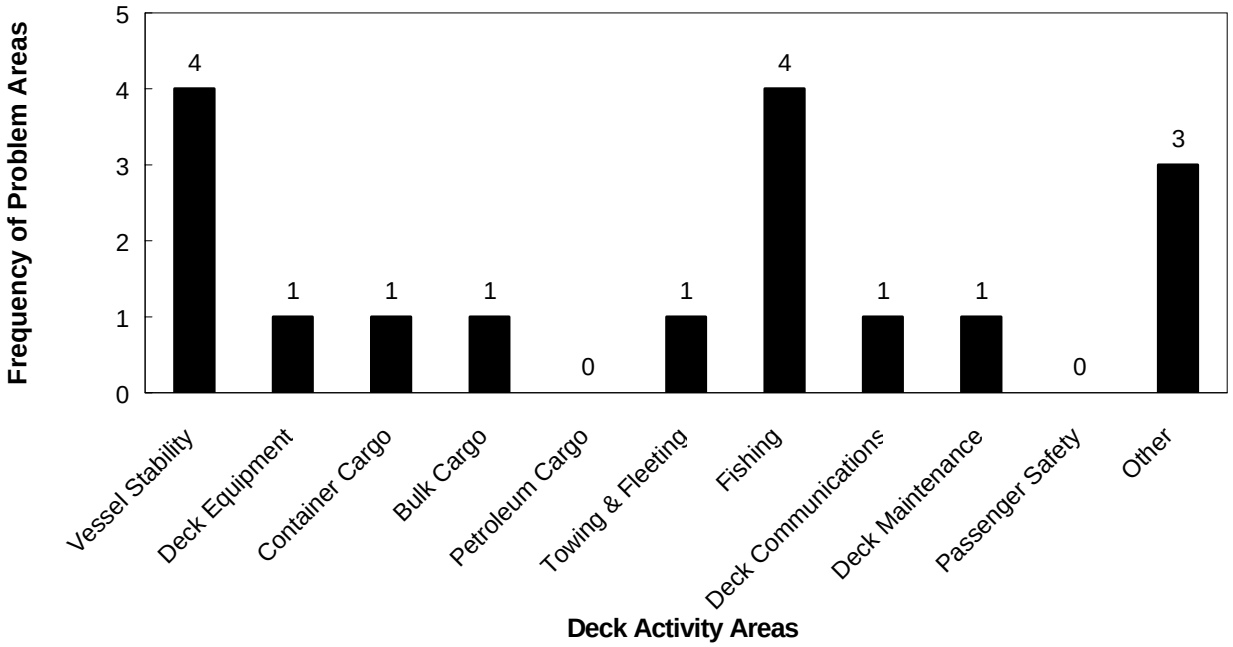

Figure 12. Frequency of deck skill and knowledge problem areas within casualties (N=17 instances within 11 casualties).

Selected casualty. Below is a brief description of a casualty that represents a deck operation activity area commonly cited as contributing to casualties. The casualty provides an example of how skill and knowledge limitations in vessel stability and integrity management contributed to casualties.

Casualty Example: Deck Operations, Vessel Stability and Integrity Management

Synopsis: A 38-foot fishing vessel left Bodega Bay, California at 0200 early in November to set Dungeness crab pots at nearby fishing grounds. The captain and two crew members had loaded 75 crab pots aboard the vessel. The weather was flat calm. The two crew members were on deck baiting the crab pots. About 30 minutes out of the harbor, the vessel, traveling on a Southwesterly heading, was struck by a single wave and immediately capsized. The captain was able to kick out a window in the pilothouse and escape. He was soon rescued by another vessel. The two crew members became entangled in the fishing gear and drowned.

Specific Skill and Knowledge Limitation Contributing to the Casualty: Load and unload a vessel taking into account load lines, stability, trim, and stress principles and calculations.

Prevalence of specific skill and knowledge problems. Table 4 presents the frequency with which skill and knowledge limitations in specific deck activities were cited as contributing to critical casualties. Investigating Officers could identify skill and knowledge limitations corresponding to more than one specific activity within a more general deck activity area and these are reported in Table 4. Among the 11 critical casualties involving skill and knowledge limitations in deck operations, a total of 20 specific problems were cited by IOs. Three of the specific problems identified by IOs did not correspond to a pre-defined specific activity and have been assigned to the "Other" category in Table 4. These have been incorporated into an additional deck activity area, general activities on deck, in the revised investigation tools (see page A-9).

Table 4. Frequency with which specific deck skill and knowledge problems contributed to critical casualties.

Deck Activity Area	Specific Activity	Frequency
Vessel Stability	Manage stability during cargo loading/unloading	3
	Adjust ballast	1
	Ensure water tight integrity	1
Deck Equipment	Prepare and stow cargo handling equipment	1
Container Cargo	Lash containers	1
Bulk Cargo	Secure bulk cargo	1
Towing and Fleeting	Make up and check tow	1
Fishing	Bring aboard and load catch	3
	Set, retrieve, and handle fishing gear	2
Deck Communications	Communicate among deck crew	1
Deck Maintenance	Work in confined spaces	1
	Perform hot work	1
Other	Perform general off-duty activities onboard vessel	1
	Personal movement onto or around the vessel	2

3.3.3 Skill and Knowledge Limitations in Engineering Operations

Prevalence of skill and knowledge problem areas. Figure 13 presents the frequency with which skill and knowledge limitations in engineering activity areas were cited as contributing to the occurrence of critical casualties. The frequencies in Figure 13 represent the number of casualties with one or more specific skill and knowledge limitations identified within each of the general engineering activity areas. Multiple problem areas were commonly cited for each casualty, resulting in 15 instances of problem areas for the six critical casualties with engineering skill and knowledge limitations. The three most commonly cited areas with skill and knowledge limitations were systems operations, engineering communications, and systems inspection.

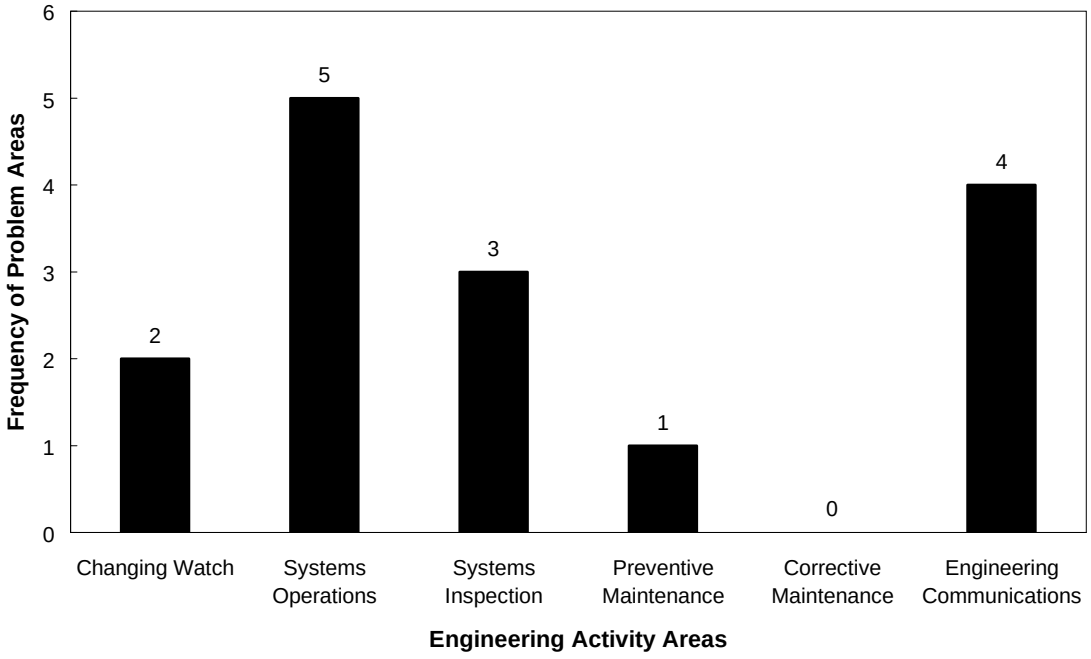

Figure 13. Frequency of engineering skill and knowledge problem areas within casualties (N=15 instances within 6 casualties).

Selected casualty. Below is a brief description of a selected casualty that represents an engineering operation activity area cited as contributing to casualties. The casualty provides an example of how skill and knowledge limitations in systems operations contributed to casualties.

Casualty Example: Engineering Operations, Systems Operation

Synopsis: A crude oil tanker was transiting from Valdez, AK, to San Francisco, CA, when it lost propulsion. The Third Assistant Engineer, who had been on the vessel for only one month and lacked sufficient familiarity with the steam plant, had inadvertently caused the problem by not switching on the feed pumps to the boilers. The boilers had lost pressure due to the lack of water.

Specific Skill and Knowledge Limitations Contributing to the Casualty: Operate main propulsion system (engines, boilers, fuel and steering).

Prevalence of specific skill and knowledge problems. Table 5 presents the frequency with which skill and knowledge limitations in specific engineering activities were cited as contributing to critical casualties. Investigating Officers could identify skill and knowledge limitations corresponding to more than one specific activity within a more general engineering activity area and these are reported in Table 5. Among the six critical casualties involving skill and knowledge limitations in engineering operations, a total of 17 specific problems were cited by IOs.

Table 5. Frequency with which specific engineering skill and knowledge problems contributed to critical casualties.

Engineering Activity Area	Specific Activity	Frequency
Changing Watch	Check status of ship equipment	2
Systems Operations	Operate motors, pumps, and lubrication systems	3
	Operate main propulsion system	2
Systems Inspection	Inspect/test main propulsion system	3
	Inspect/test generating/electrical systems	1
Preventive Maintenance	Maintain main propulsion system	1
Engineering Communications	Communicate between bridge crew and engine crew	3
	Communicate between engine crew	2

3.3.4 Skill and Knowledge Limitations in Safety and Emergency Operations

A single critical casualty in the present sample was cited as having safety and emergency operations as a contributing factor.

Safety and emergency operations casualty. Below is a brief description of the one casualty that was cited as having safety and emergency operations activities contributing to the casualty. The casualty provides an example of how skill and knowledge limitations in controlling and fighting fires can contribute to casualties.

Casualty Example: Safety & Emergency Operations, Controlling and Fighting Fires

Synopsis: A Cypriot freighter was anchored outside of Galveston, Texas, early one morning in late December. At approximately 0425, an engine room fire was discovered by the Third Engineer, who unsuccessfully attempted to extinguish the fire with two portable carbon dioxide extinguishers and one semi-portable foam extinguisher. He then notified the Chief Engineer and sounded the general alarm. The Chief Engineer, Third Engineer, and Second Engineer entered the engine room separately at different points. At 0435, the Chief Officer went to the entrance of the main engine room. He saw a quantity of white smoke, but felt little heat. At about this time, an explosion in the engine room was heard. The ship's service power then failed and the emergency power came on immediately and remained operational until approximately 0500. At 0440, the Chief Officer informed the Master that the fire was out of control. At 0450, the crew took muster and discovered that the Chief Engineer and Third Engineer were missing. A detail went into the ship's superstructure, but heavy smoke prevented an extensive search. The ship was abandoned shortly thereafter and continued to burn for several days.

Specific Skill and Knowledge Limitation Contributing to the Casualty: Establish and maintain a fire safety plan. Organize and conduct fire drills. Inspect and service fire-extinguishing equipment. Use fire fighting equipment and procedures. Maintain escape routes. Use breathing apparatus. Establish and maintain communications among crew.

Prevalence of specific skill and knowledge problems. A total of eight specific skill and knowledge limitations in safety and emergency operations were cited for the one critical casualty in this category. Table 6 lists these specific problems.

Table 6. Specific safety and emergency skill and knowledge problems cited by IOs.

Engineering Activity Area	Specific Activity
Controlling and Fighting Fires	Establish and maintain a fire safety plan
	Organize and conduct fire drills
	Inspect and service fire extinguishing equipment
	Use fire fighting equipment and procedures
	Maintain escape routes
Confined Space Rescue	Use breathing apparatus
	Maintain back-up escape routes
Emergency Communications	Establish and maintain communications with crew

3.4 CONTRIBUTING FACTORS ASSOCIATED WITH SKILL AND KNOWLEDGE LIMITATIONS

A number of contributing factors are worth noting with regard to skill and knowledge limitations. Training and job experience are issues of particular interest in this regard. For casualties with a skill and knowledge limitation, it may frequently be the case that either training curricula or specific mariner training and experience are inadequate. As part of the process of reporting on casualties with skill and knowledge limitations, IOs provided recommendations for improving mariner skill and knowledge and reducing the likelihood of similar casualties. Over 90 percent of their recommendations involved either additional or enhanced training, or increased job experience.

In other cases, vessel standard operating procedures may be inadequate. It would be worth identifying trends within this area to attempt to address this problem. Training itself will not be very useful in cases where a vessel's operating procedures are incomplete or problematic. In addition, there will always be the issue of the time and resources available for training, as well as unanticipated occurrences that are outside the realm of specific training. This research begins to suggest areas that may particularly merit the time and resources involved in training, when such decisions must be made. Further investigation is warranted in these areas, which are addressed more comprehensively in the revised investigation procedures.

3.5 PERCEIVED BENEFITS AND COSTS OF THE STUDY

3.5.1 Perceived Benefits of Study

During a group discussion with researchers at the end of the investigation period, IOs were asked to evaluate the benefits of this study. Several IOs noted that participation in the study increased their awareness of general human factors issues, and also increased the likelihood that they would ask questions about mariner training and experience levels during future investigations. Furthermore, some IOs noted that the investigator school at the USCG Reserve Training Center in Yorktown could benefit from the inclusion of a training session on how to investigate skill and knowledge limitations. Lastly, IOs suggested the reporting forms be refined and incorporated in the next generation of MSIS now being developed by the USCG.

3.5.2 Time Demands of Study

As part of the reporting process, IOs were asked to indicate the time spent investigating potential skill and knowledge limitations and completing the reporting forms. Estimates of the additional time required for the procedures used in this study are based on the median (50^{th} percentiles) of the IO estimates. Across all 389 cases in the study sample, the median investigation time was 15 minutes and the form completion time was also 15 minutes. Thus, our best estimate of the additional time spent by IOs in meeting the investigation and reporting requirements associated with this study is 30 minutes per case (representing the sum of the medians of 15 minutes for additional investigation and 15 minutes for additional form completion).

For the 60 casualties in which skill and knowledge limitations were investigated, the median investigation time was 45 minutes and the form completion time was 30 minutes, representing a total of 75 minutes. Compared to earlier studies of human factors in marine casualties, this total is less than the median of 90 minutes required to investigate and report communications (McCallum, et al. 2000) and more than the median total time of 40 minutes required for fatigue (McCallum, et al. 1996).

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4 CONCLUSIONS

The current study continued an ongoing effort to pursue ways in which the investigation and reporting of human factors contributions to marine casualties can be further improved within the USCG. This study focused on the role of skill and knowledge limitations in marine casualties and addressed two objectives:

- Develop a method and tools that can be applied to investigate and report casualties involving skill and knowledge limitations.
- Provide an initial characterization of mariner skill and knowledge limitations that contribute to marine casualties.

We were successful in meeting the study objectives. We developed an initial set of procedures used in the trial application to investigate and report on the contribution of skill and knowledge limitations to marine casualties. Our analysis of the sample of 389 casualties provided a number of insights into the specific skill and knowledge limitations that most commonly contribute to critical marine casualties. Finally, based on feedback from the IOs and on the results of our analysis, we revised the tools for investigating skill and knowledge limitations for application by USCG IOs. The remainder of this section discusses our conclusions.

4.1 DEVELOP A METHOD AND TOOLS THAT CAN BE APPLIED TO INVESTIGATE AND REPORT CASUALTIES INVOLVING SKILL AND KNOWLEDGE LIMITATIONS

Extensive time and effort were invested in the development of the initial procedures used in this study. During their development, efforts focused on creating easy-to-use forms that maintained sufficient detail to address specific skill and knowledge limitations. Our experience in the trial application of these procedures has demonstrated that significant time must be allocated for in-depth investigation of this type. In the current study, IOs required an additional 75 minutes to investigate and report those cases with a potential skill and knowledge limitation. One of the current objectives of the USCG Office of Investigations and Analysis is to expand the breadth and depth of human factors data available for analysis of cause. The investigation of causal information related to unsafe acts by mariners requires personal contact with the individuals directly involved in the casualty and the application of detailed standardized procedures, requiring substantial investigator time. This conclusion is consistent with the two earlier studies in this series (McCallum et al., 1996; McCallum et al., 2000).

The research procedures required IOs to investigate all casualties resulting from unsafe acts by mariners. Following the trial implementation of these procedures, a tool was developed that researchers used to classify unsafe mariner acts. This tool was further refined so that it could be used to reliably classify unsafe acts into the five categories of violations, rule-based mistakes, knowledge-based mistakes, slips, and lapses. This tool could be used by IOs to analyze casualties and identify those cases that were the result of mariner skill and knowledge limitations (i.e., those resulting from rule-based and knowledge-based mistakes).

The in-depth forms used in the present study were based on subsets of the operational activity list. These forms were found to be useful in characterizing mariner skill and knowledge limitations, as well as in providing IOs with a focus for developing recommendations for reducing future casualties. Revised versions of these forms have been prepared to provide a common structure for the future in-depth investigation and reporting of skill and knowledge limitation contributions to casualties.

4.2 PROVIDE AN INITIAL CHARACTERIZATION OF MARINER SKILL AND KNOWLEDGE LIMITATIONS THAT CONTRIBUTE TO MARINE CASUALTIES

Although a limited sample of cases was obtained, the present study helped to characterize and quantify the extent to which mariner skill and knowledge limitations contribute to marine casualties. The incidence of skill and knowledge limitations contributing to critical casualties was determined to be approximately 22 percent, indicating that this is a significant contributor to marine casualties and is worthy of USCG and industry attention and remedial action. The current procedures provided data that were useful in identifying the mariner activities associated with skill and knowledge limitations that contributed to the sample casualties. However, substantially larger samples of casualties will be required to identify those skill and knowledge areas that pose the greatest safety risks. In addition, the current study did not include investigation into the underlying factors contributing to inadequate skill and knowledge.

The Office of Investigations and Analysis has made significant progress recently in improving the quality of investigations into human factors causal areas. Recent training has increased the general level of awareness concerning human factors among many of the IOs. Additionally, the Office's guidance to focus on critical casualties has allowed IOs to spend more time on casualties representing significant risks to property and personnel safety. However, further development and implementation is required to establish a comprehensive process for the investigation and reporting of human factors causes. A systematic set of investigation tools that is integrated with standardized reporting procedures, along with guidance on when to apply these tools, is required to successfully implement this approach. With the collection of sufficient detailed data in the future, it will be possible to identify specific skill and knowledge areas requiring remedial action, as well as the underlying contributing factors to these problems.

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APPENDIX A

Revised Investigation Tools

This appendix provides revised tools for the investigation of skill and knowledge limitations. The appendix includes the following documents:

- *Instructions for Investigating Skill and Knowledge Limitations in Marine Casualties.*
- *Mariner Skill & Knowledge Limitations Investigation Screening.*
- *Bridge Operations – Mariner Skill & Knowledge Limitations.*
- *Deck Operations – Mariner Skill & Knowledge Limitations.*
- *Engineering Operations – Mariner Skill & Knowledge Limitations.*
- *Safety & Emergency Operations – Mariner Skill & Knowledge Limitations.*

INSTRUCTIONS FOR INVESTIGATING SKILL AND KNOWLEDGE LIMITATIONS IN MARINE CASUALTIES

INTRODUCTION

These forms are to be used to investigate the role of mariner skill and knowledge limitations in those casualties selected for in-depth investigation by your office. The forms allow you, the Investigating Officer, to screen casualties for their human factors involvement and the probable contribution of mariner skill and knowledge limitations. For the casualties that qualify, the forms specify the additional information to collect about the operational activities performed by mariners, mariner training and experience, and shipboard procedures.

In the context of marine casualty investigations, a *skill limitation* is indicated when a mariner's performance of a job activity does not meet standards typically required for that activity. A *knowledge limitation* is indicated when a mariner's theoretical understanding or practical knowledge of rules and procedures does not meet job demands.

A recent study sponsored by the USCG Office of Investigations and Analysis found that mariner skill and knowledge limitations were a contributing factor in 22 percent of critical casualties. This finding indicates the importance of investigating the contribution of skill and knowledge limitations in marine casualties and reporting your findings.

Your investigation of mariner skill and knowledge limitations will involve completing one or more of the following forms: *Skill & Knowledge Limitations Screening, Bridge Operations, Deck Operations, Engineering Operations, and Safety & Emergency Operations.*

USING THE FORMS

The *Skill & Knowledge Limitations Screening* form may be used to screen all casualties for their human factors involvement and the probable contribution of mariner skill and knowledge limitations. For casualties with a probable skill and knowledge limitation contribution, use the appropriate operations-related reporting form(s) (bridge, deck, engineering, and/or safety & emergency operations).

These forms should be filled out as completely and accurately as possible. Here are some general instructions for completing the forms:

- Print clearly
- Fill in all blanks
- If a question does not apply, write N/A
- If an answer is unknown, and/or cannot be obtained, write UNKNOWN
- If the answer to a question is "none," write or check NONE
- Record additional information or explanations in the space provided, on the reverse side, or on a separate piece of paper

SKILL AND KNOWLEDGE LIMITATIONS SCREENING FORM

Complete this form to determine whether to investigate the casualty for skill and knowledge limitations.

Below are some guidelines for using the screening form.

Step 1. Human Factors Involvement

Determine whether a person's actions, inaction, or decisions directly contributed to the casualty (or its severity). Continue with the form *only if* you answer YES to this question.

In answering this question, you may find it helpful to consider the following:

- Did any individual play an active, direct, and immediate role in the sequence of events leading up to the casualty?
- Were the mariner's actions, given the circumstances, ineffective or inappropriate? These actions might not have been the most immediate to the casualty, but might have contributed directly to the sequence of events or the severity of the casualty.
- Were there actions that were *not* taken, but which would be expected to be taken by most proficient mariners?
- Did a mariner's decisions result in actions, by the decision-maker or others, that contributed directly to the sequence of events or the severity of the casualty?

By identifying actions, inaction, or decisions, you are not necessarily identifying the root cause of the casualty or attributing blame. You are simply pointing to the presence of a human factors contribution.

Step 2. Contributing Individuals

Identify up to three individuals who, through their actions, inaction, or decisions, contributed most directly to the outcome or severity of the casualty. In responding to this question, you may find it helpful to consider the following individuals:

- Individual who committed the last action or decision prior to the casualty
- Individual who was injured
- Individual mentioned in the "Description of Casualty" on Form 2692
- Individual in charge of vessel activities

For each involved individual, indicate his or her name, job position, and the operational area (i.e., bridge, deck, engineering, and/or safety & emergency operations) involved.

Step 3. Contributing Activities

Provide a brief description of the relevant activities of each individual identified in Step 2. Your description of activities should include all actions, inaction, and decisions that contributed significantly to the casualty.

Follow the same, numbered, order of contributing individuals as in Step 2 (i.e., Mariner 1, Mariner 2, and Mariner 3).

Step 4. Potential for Skill & Knowledge Limitations

Answer the two questions on the form with regard to the actions, inaction, or decisions for each of the mariners listed in Step 2. These two questions determine whether a skill and knowledge limitation was a probable contributor to the casualty. If either 4a or 4b is answered YES, then the mariner either knowingly violated a rule or had successfully demonstrated the activity many times before. In either case, the YES answer indicates that a skill and knowledge limitation did **not** contribute to the casualty, and you do not need to go further.

If the answer to both of the questions in Step 4 is NO for any mariner, that mariner probably has a skill and knowledge limitation that contributed to the casualty. Complete the applicable operational area form(s) for that mariner (Step 5).

OPERATIONS FORMS

Step 5. Completion of Operations Form(s)

There are four different operations forms. Each one represents a different area of shipboard operations – Bridge, *Deck*, *Engineering*, and *Safety & Emergency Operations*. Except for their titles and Step 5.2, they are identical to one another.

Complete the applicable form(s) for each mariner for whom both questions in Step 4 were answered NO.

The purpose of the operations forms is to identify the specific activities that were not performed up to a level of skill and knowledge that would normally be expected of a proficient mariner. In addition, you are asked to identify the training and experience of the mariner(s) involved in the casualty, as well as current procedures that are available to guide mariner performance. Remember that you only need to fill out the operations forms applicable to the casualty.

Use the following guidelines when selecting the form(s) to complete:

BRIDGE OPERATIONS - Select this form when one or more of the following activities directly contributed to the casualty:

- Changing bridge watch
- Visual monitoring and lookout
- Collision avoidance
- Grounding avoidance and navigation
- Shiphandling
- Bridge communications
- Port or anchor watch

Consider completing this form when one or more of the following individuals are involved: master, pilot, operator, mate, helmsman, lookout, or any other crewmember standing watch on the bridge.

DECK OPERATIONS - Select this form when one or more of the following activities directly contributed to the casualty:

- Vessel stability and integrity management
- Deck equipment operations
- Container cargo operations
- Bulk cargo operations

- Petroleum cargo operations
- Towing and fleeting operations
- Fishing operations
- Deck communications
- Deck maintenance
- General activities on deck
- Passenger safety

Consider completing this form when one or more of the following individuals are involved: mate, boatswain, able-bodied seaman, pumpman, tankerman, dockworker, unlicensed deck worker, master, or operator.

ENGINEERING OPERATIONS - Select this form when one or more of the following activities directly contributed to the casualty:

- Changing engineering watch
- Engineering systems operations
- Engineering systems inspection and testing
- Routine, scheduled, and preventive maintenance
- Unscheduled, corrective repair
- Engineering communications

Consider completing this form when one or more of the following individuals are involved: chief engineer, assistant engineer, qualified member of the engineering department, unlicensed engineering worker, or any other crewmember working in the engineering space.

SAFETY AND EMERGENCY OPERATIONS - Select this form when one or more of the following activities directly contributed to the casualty:

- General safety
- Safety equipment inspection and service
- Controlling and fighting fires
- Confined space rescue
- Person overboard procedures
- Abandon vessel operations
- Emergency medical and life-saving procedures
- Emergency communications

Here are guidelines for completing some of the items on the operations forms:

Step 5.1. Maritime Work History of Contributing Mariner

Item 1. Indicate the mariner's name. *If there is more than one contributing individual, complete a separate form for each person.*

Item 2. Indicate the job position of the mariner at the time of the casualty.

Items 3-7. Complete each statement by indicating the number of years and/or months the individual has worked in his or her industry, company, present position, present vessel or facility, and route.

Item 8. Be as specific as possible in stating the individual's license (e.g., "Master of 1600 Ton Vessels" instead of "Master").

Step 5.2. Mariner's Actions, Inaction, and Decisions Contributing to the Casualty

This section is different for each of the operations forms because the activities relevant to each area are different. Here are some guidelines for completing this section:

Item 9. Describe how the involved mariner's actions, inaction, or decisions *directly and immediately* contributed to the casualty.

For the rest of the items in this section (the number of items varies depending on the operations form), read each question and check either YES or NO to indicate if the particular type of activity contributed to the casualty. For all YES responses, continue by checking the box next to each of the specific task(s) that contributed to the casualty.

Each operations form should have at least one YES checked in Step 5.2. Otherwise, that particular operational area is not relevant to the casualty.

As an example, assume that the casualty is a fire in the engine room, and the second assistant engineer and two unlicensed engineers are on watch. In an interview with the chief engineer, you learn that the fire occurred because one of the unlicensed engineers did not correctly light the boiler upon departure when asked to do so by the second assistant engineer. Detailed written procedures for lighting the boiler were not available and the unlicensed engineer had not received adequate on-the-job training on the procedures for this boiler.

In addition to completing the *Skill & Knowledge Limitations Screening* form, for this case you would complete the *Engineering Operations* form, because engineering operations are directly related to the casualty.

In your interview with the chief engineer, you would review the questions in Step 5.2 of the *Engineering Operations* form. Given the above description of the casualty, in Step 5.2 you would check YES for Item 11, "Did engineering systems operations activities contribute to this casualty?" Since lighting the boiler was the activity directly involved in the fire, you would also check the box next to activity 11a, "Operate main propulsion system (engines, boilers, fuel and steering)." Carefully consider each activity and its relevance to the casualty, as you will use this information when completing Steps 5.3 and 5.4.

Step 5.3. Training and Procedures

Note that the item numbers in this section vary depending on the operations form. In all other respects, Step 5.3 is identical on all operations forms.

In the top row in this step, list up to three activities from Step 5.2 that contributed most to the mariner's role in the casualty. Write the activity numbers (e.g., "10a") in the relevant spaces.

The next three items in each column ask you to describe the mariner's training relevant to the listed activity. Specifically:

- Check the types of training that apply to the activity.
- Briefly describe the most relevant training for the activity.
- State the time since the most relevant training for the activity.

The final row in each column of this step asks you to identify procedures (written or otherwise), regulations, or common practices that are available as a guide to performance of the activity under consideration. If there is a relevant procedure, regulation, or common practice, you should identify it and briefly describe its applicability. In responding to this step, you may find it helpful to consider the following:

- Standing orders
- Company procedures
- Vessel procedures
- Technical manuals
- Code of Federal Regulations
- Coast Guard regulations
- International regulations
- Rules of the Road

After describing any relevant procedures, you should indicate whether they are adequate to guide mariner performance by checking either YES or NO.

Step 5.4. Conclusions and Recommendations

Note that the item numbers in this section vary depending on the operations form.

Indicate whether you believe the mariner lacks skill and/or knowledge in each of the three contributing activities from Step 5.3. If you check TRUE to any of the statements in this section, then complete the last item on the form.

For the last item in this section (and on the form), describe what actions or steps you believe could be taken to improve the mariner's level of skill and knowledge, or to improve established procedures, in the activities identified as having a skill and/or knowledge limitation. Describe both the *minimum* efforts required to improve the mariner's skill and knowledge and the *ideal* efforts.

Questions to consider when completing this item are:

- Would the mariner benefit from additional shore-based or on-the-job training?
- Should the mariner's skills and knowledge relating to this activity be reassessed following additional training?
- What policies, regulations, or standard operating procedures should be developed or modified to be more appropriate in this situation?

When responding, try to make your recommendations as clear and specific as possible.

When the investigation and Step 5 have been completed, the results of your investigation and analysis can be incorporated into your MCDD, MCNS, and MCHF.

Mariner Skill & Knowledge Limitations Investigation Screening

*Please refer to the **Instructions for Investigating Skill & Knowledge Limitations in Marine Casualties** for general information about how to use this screening tool.*

Step 1: Human Factors Involvement

Did at least one person's actions, inaction, or decisions directly contributed to the casualty or its severity?

YES – Go to Step 2.

NO – Human factors are likely not involved and further investigation of mariner skill and knowledge limitations is unwarranted.

Step 2: Contributing Individuals

List the names and job positions of up to three persons whose actions, inaction, or decisions most directly contributed to the casualty. For each person, identify the general area(s) of vessel operations that contributed to the casualty, then go to Step 3.

Mariner's Name	**Job Position**	**Vessel Operations Contributing to Casualty** *(Bridge, Deck, Engineering, Safety & Emergency)*
1.		
2.		
3.		

Step 3: **Contributing Activities**

Briefly describe each person's actions, inaction, and/or decisions that contributed to the casualty.

Mariner 1:
Mariner 2:
Mariner 3:

Step 4: Potential for Skill and Knowledge Limitations

For each mariner, respond to the following questions. If possible,** interview **the mariner(s) in-person or by telephone to address these questions.	**Mariner 1**	**Mariner 2**	**Mariner 3**
a. Did this person's action or inaction result in their **knowing** violation of an applicable law, rule, policy or standard operating procedure? ***If NO for any involved mariner, go to b.*** *If YES for all involved mariners, end report. This casualty is likely a **violation**, not the result of skill and knowledge limitations.*	YES NO	YES NO	YES NO
b. Has each person successfully demonstrated the contributing activities many times before under similar circumstances and within the last five years? ***If NO for any involved mariner, go to Step 5.*** *If YES for all involved mariners, end report. This casualty is likely either a **slip** or a **lapse**, not the result of skill and knowledge limitations.*	YES NO	YES NO	YES NO

Step 5: Completion of Operations Form(s)

*Complete applicable operational area investigation form(s) for **Bridge, Deck, Engineering, and/or Safety & Emergency Operations, for each mariner with NO** answers to Questions 4a and 4b.*

Bridge Operations – Mariner Skill & Knowledge Limitations

Please complete a separate copy of this form for each person whose bridge activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **bridge** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all bridge activities (10-17) that directly contributed to the casualty.

10. Did **changing bridge watch** activities contribute? YES *Check all activities that apply.* NO *Go to 11.*
- ❑ a. Check and acknowledge passage plan, orders, and special information
- ❑ b. Assess traffic and weather conditions
- ❑ c. Check status of ship's equipment
- ❑ d. Ensure that watch is relieved

11. Did **visual monitoring and lookout** activities contribute? YES *Check all activities that apply.* NO *Go to 12.*
- ❑ a. Instruct Lookout as to duties and ensure Lookout is prepared to assume the watch
- ❑ b. Maintain lookout to detect objects, traffic, or navigational aids and assess visibility
- ❑ c. Determine type, aspect, and relative motion of other vessels
- ❑ d. Receive and verify reports of visual contact

12. Did **collision avoidance** activities contribute? YES *Check all activities that apply.* NO *Go to 13.*
- ❑ a. Adjust and operate radar/ARPA
- ❑ b. Monitor radar/ARPA and radar contacts
- ❑ c. Assess collision threat and determine avoidance maneuver
- ❑ d. Recognize and apply COLREGS

13. Did **grounding avoidance and navigation** contribute? YES *Check all activities that apply.* NO *Go to 14.*
- ❑ a. Establish a passage plan based on navigation information and knowledge of are
- ❑ b Determine vessel position using available systems
- ❑ c. Calculate course changes based on navigation information, local conditions, and local regulation
- ❑ d. Check and update navigation charts and publications

14. Did **shiphandling** activities contribute? YES *Check all activities that apply.* NO *Go to 15.*
- ❑ a. Maneuver in accordance with sea/river/weather conditions
- ❑ b. Maneuver in accordance with vessel and/or tow handling characteristics
- ❑ c. Maneuver vessel in accordance with conning orders
- ❑ d. Maneuver vessel during docking, anchoring, and mooring
- ❑ e. Manage and coordinate assist vessels

15. Did **bridge communications** contribute? YES *Check all activities that apply.* NO *Go to 16.*
- ❑ a. Communicate and coordinate effectively among the vessel's crew (Bridge, Engine, and Deck)
- ❑ b. Communicate and coordinate between the bridge watch team and the federal/state pilot
- ❑ c. Interpret and reply to signals (flag signals, flashing light, and ship's whistle)
- ❑ d. Establish and maintain VHF radio communications with other vessels and appropriate shore authorities

16. Did **port or anchor watch** activities contribute? YES *Check all activities that apply.* NO *Go to 17.*
- ❑ a. Inspect for leaks, loose or weak mooring lines, and smoke or fire
- ❑ b. Monitor vessel position to determine if anchor is dragging

17. Did a **bridge activity not listed above** contribute? YES *Briefly describe activity below.* NO *Go to 18.*

Step 5.3: Training and Procedures

Write the identification numbers of up to three bridge activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

18. Activity 1:	23. Activity 2:	28. Activity 3:
19. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	24. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	29. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
20. Briefly describe the mariner's most relevant training for **Activity 1**.	25. Briefly describe the mariner's most relevant training for **Activity 2**.	30. Briefly describe the mariner's most relevant training for **Activity 3**.
21. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	26. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	31. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
22. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? YES NO	27. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? YES NO	32. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? YES NO

Step 5.4: Conclusions and Recommendations

*Respond to items 33-34 **after** completing Step 5.3.*

33. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *33* and *34*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
b. The mariner most likely lacks **knowledge** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
34. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties? *Minimum:*			
Ideal:			

Deck Operations – Mariner Skill & Knowledge Limitations

Please complete this form separately for each person whose deck activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **deck** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all deck activities (10-21)) that directly contributed to the casualty.

10. Did **vessel stability and integrity management** activities contribute?	YES *Check all activities that apply.*	NO *Go to 11.*
❑ a. Load and unload a vessel taking into account load lines, stability, trim, and stress principles and calculations	❑ b. Adjust ballast as required to maintain stability ❑ c. Operate vessel in compliance with Stability Letter ❑ d. Ensure vessel's water tight integrity	
11. Did **deck equipment operations** activities contribute?	YES *Check all activities that apply.*	NO *Go to 12.*
❑ a. Board pilot	❑ c. Assist in tug/escort vessel tie-up operations	
❑ b. Conduct docking, anchoring, and mooring operations	❑ d. Prepare and stow cargo handling equipment	
12. Did **container cargo operations** activities contribute?	YES *Check all activities that apply.*	NO *Go to 13.*
❑ a. Establish container stowage plan	❑ c. Lash all containers	
❑ b. Load and unload containers	❑ d. Monitor and maintain cargo security	
13. Did **bulk cargo operations** contribute?	YES *Check all activities that apply.*	NO *Go to 14.*
❑ a. Establish bulk cargo loading plan	❑ c. Monitor and maintain cargo security	
❑ b. Load and unload bulk cargo	❑ d. Handle dangerous and hazardous cargo	
14. Did **petroleum cargo** activities contribute?	YES *Check all activities that apply.*	NO *Go to 15.*
❑ a. Operate pumping equipment	❑ c. Clean petroleum cargo tanks	
❑ b. Monitor piping and pumping systems	❑ d. Conduct inert gas and gas-free operations	
15. Did **towing and fleeting operations** contribute?	YES *Check all activities that apply.*	NO *Go to 16.*
❑ a. Establish a tow diagram	❑ c. Check tow for water and pump barges	
❑ b. Make up, check, and tighten towlines and headwires	❑ d. Conduct locking and lock assist operations	
16. Did **fishing operations** activities contribute?	YES *Check all activities that apply.*	NO *Go to 17.*
❑ a. Set, retrieve, and handle fishing gear	❑ c. Unload or transfer catch	
❑ b. Bring aboard and load catch	❑ d. Process catch	
17. Did **deck communications** activities contribute?	YES *Check all activities that apply.*	NO *Go to 18.*
❑ a. Communicate effectively between deck and bridge	❑ c. Coordinate between deck and assist vessels	
❑ b. Communicate effectively among deck crew	❑ d. Coordinate between deck and dock crew	
18. Did **deck maintenance** activities contribute?	YES *Check all activities that apply.*	NO *Go to 19.*
❑ a. Perform deck, hull, and surface chipping, painting	❑ c. Work in confined spaces	
❑ b. Maintain deck equipment	❑ d. Perform hot work	
19. Did **general activities on deck** activities contribute?	YES *Check all activities that apply.*	NO *Go to 20.*
❑ a. Embarking or disembarking vessel	❑ c. General off-duty activities onboard vessel	
❑ b. Moving around the vessel		
20. Did **passenger safety** activities contribute?	YES *Check all activities that apply.*	NO *Go to 21.*
❑ a. Ensure the safety of passengers during embarkation and disembarkation	❑ c. Inspect passenger spaces for hazards and take appropriate action	
❑ b. Ensure the safety of passengers when underway and during ship operations	❑ d. Confine passenger access to safe vessel spaces only	
21. Did a **deck activity not listed above** contribute?	YES *Briefly describe activity below.*	NO *Go to 22.*

Step 5.3: Training and Procedures

Write the identification numbers of up to three deck activities checked in Step 5.2 that most contributed to the casualty. (Example: *Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.)* Then, complete the remaining items under each listed activity.

22. Activity 1:	27. Activity 2:	32. Activity 3:
23. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	28. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	33. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
24. Briefly describe the mariner's most relevant training for **Activity 1**.	29. Briefly describe the mariner's most relevant training for **Activity 2**.	34. Briefly describe the mariner's most relevant training for **Activity 3**.
25. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	30. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	35. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
26. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? YES NO	31. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? YES NO	36. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? YES NO

Step 5.4: Conclusions and Recommendations

*Respond to items 37-38 **after** completing Step 5.3.*

37. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *37* and *38*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
b. The mariner most likely lacks **knowledge** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE

38. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties?

Minimum:

Ideal:

Engineering Operations – Mariner Skill & Knowledge Limitations

Please complete this form separately for each person whose engineering activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **engineering** actions, inaction, or decisions contributed to the casualty:
Now, check ☑ all engineering activities (10-16)) that directly contributed to the casualty.

10. Did **changing engineering watch** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 11.*

- ❑ a. Check and acknowledge standing orders, night orders, and special information
- ❑ b. Check status of ship's equipment
- ❑ c. Assess traffic and weather conditions
- ❑ d. Ensure that watch is relieved

11. Did **engineering systems operations** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 12.*

- ❑ a. Operate main propulsion system (engines, boilers, fuel and steering
- ❑ b. Operate generating and electrical systems
- ❑ c. Operate motors, pumps, and lubrication systems
- ❑ d. Operate service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)
- ❑ e. Load, discharge, or transfer fuel between tanks

12. Did **engineering systems inspection and testing** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 13.*

- ❑ a. Inspect and test main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Inspect and test generating and electrical systems
- ❑ c. Inspect and test motors, pumps, and lubrication systems
- ❑ d. Inspect and test service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

13. Did **routine, scheduled, and preventive maintenance** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 14.*

- ❑ a. Maintain main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Maintain generating and electrical systems
- ❑ c. Maintain motors, pumps, and lubrication systems
- ❑ d. Maintain service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

14. Did **unscheduled, corrective repair** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 15.*

- ❑ a. Repair main propulsion system (engines, boilers, fuel, and steering)
- ❑ b. Repair generating and electrical systems
- ❑ c. Repair motors, pumps, and lubrication systems
- ❑ d. Repair service equipment (evaporators, refrigeration, heating, AC, sewage, and garbage treatment)

15. Did **engineering communications** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 16.*

- ❑ a. Communicate and coordinate effectively among the vessel's crew (Bridge, Engine, and Deck)
- ❑ b. Communicate and coordinate effectively among the engineering crew

16. Did **engineering activity not listed above** contribute to casualty? YES *Briefly describe activity below.* NO *Go to 17.*

Step 5.3: Training and Procedures

Write the identification numbers of up to three engineering activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

17. Activity 1:	22. Activity 2:	27. Activity 3:
18. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	23. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	28. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
19. Briefly describe the mariner's most relevant training for **Activity 1**.	24. Briefly describe the mariner's most relevant training for **Activity 2**.	29. Briefly describe the mariner's most relevant training for **Activity 3**.
20. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	25. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	30. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
21. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? YES NO	26. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? YES NO	31. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? YES NO

Step 5.4: Conclusions and Recommendations

*Respond to items 32-33 **after** completing Step 5.3.*

32. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *32* and *33*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
b. The mariner most likely lacks **knowledge** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
33. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties? *Minimum:*			
Ideal:			

Safety & Emergency Operations – Mariner Skill & Knowledge Limitations

Please complete this form separately for each person whose safety and emergency activities contributed to the casualty.

Step 5.1: Maritime Work History of Contributing Mariner

1. Mariner's name:	2. Job position at time of casualty:
3. _____ years _____ months in this industry.	4. _____ years _____ months with this company.
5. _____ years _____ months in present position.	6. _____ years _____ months on present vessel or facility.
7. _____ years _____ months on present route.	8. Current licenses/documents (N/A if not applicable):

Step 5.2: Mariner's Actions, Inaction, or Decisions Contributing to the Casualty

9. Briefly describe how this person's specific **safety and emergency** actions, inaction, or decisions contributed to the casualty:

Now, check ☑ all safety and emergency activities (10-18)) that directly contributed to the casualty.

10. Did **general safety** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 11.*
- ❑ a. Embark and disembark vessel safely
- ❑ b. Walk about vessel safely
- ❑ c. Perform off-duty activities safely

11. Did **safety equipment inspection and service** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 12.*
- ❑ a. Inspect and service fire detection equipment
- ❑ b. Inspect and service fire extinguishing equipment
- ❑ c. Inspect and service lifesaving equipment, locating devices, and flotation devices
- ❑ d. Inspect and service survival craft
- ❑ e. Inspect and service emergency generator, batteries, etc.

12. Did **controlling and fighting fires** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 13.*
- ❑ a. Establish and maintain a Fire Safety Plan
- ❑ b. Organize and conduct fire drills
- ❑ c. Identify the type of fire
- ❑ d. Use fire-fighting equipment and procedures
- ❑ e. Maintain escape routes

13. Did **confined space rescue** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 14.*
- ❑ a. Locate individual(s)
- ❑ b. Establish a rescue plan
- ❑ c. Use breathing apparatus and other required equipment
- ❑ d. Maintain back-up personnel and escape routes

14. Did **person overboard procedures** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 15.*
- ❑ a. Initiate warning
- ❑ b. Locate person overboard
- ❑ c. Maneuver vessel
- ❑ d. Bring person aboard

15. Did **abandon vessel operations** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 16.*
- ❑ a. Don survival suits and personal flotation devices
- ❑ b. Launch, load, and maneuver lifeboats and life rafts
- ❑ c. Employ locating devices properly

16. Did **emergency medical and life-saving procedures** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 17.*
- ❑ a. Use medical chest and first aid items
- ❑ b. Apply First Aid/CPR

17. Did **emergency communications** activities contribute to casualty? YES *Check all activities that apply.* NO *Go to 18.*
- ❑ a. Establish and maintain communications with crew
- ❑ b. Establish and maintain communications with passengers
- ❑ c. Establish and maintain emergency communications with other vessels
- ❑ d. Establish emergency communications with shore authorities
- ❑ e. Monitor GMDSS and other emergency frequencies as required

18. Did **safety and emergency activity not listed above** contribute to casualty? YES *Briefly describe activity below.* NO *Go to 19.*

Step 5.3: Training and Procedures

Write the identification numbers of up to three safety and emergency activities checked in Step 5.2 that most contributed to the casualty. (Example: Activity 1: 10a, Activity 2: 13b, Activity 3: 16a.) Then, complete the remaining items under each listed activity.

19. Activity 1:	24. Activity 2:	29. Activity 3:
20. What training has the mariner had to prepare for **Activity 1**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	25. What training has the mariner had to prepare for **Activity 2**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training	30. What training has the mariner had to prepare for **Activity 3**? *(Check all that apply.)* ❑ No training of any kind ❑ Informal on-the-job training ❑ Formal, structured on-the-job training and supervision ❑ Coast Guard-approved course ❑ Maritime trade school training ❑ Maritime college or academy training ❑ Other training
21. Briefly describe the mariner's most relevant training for **Activity 1**.	26. Briefly describe the mariner's most relevant training for **Activity 2**.	31. Briefly describe the mariner's most relevant training for **Activity 3**.
22. How long has it been since the mariner received this **Activity 1** training? _____ years and _____ months	27. How long has it been since the mariner received this **Activity 2** training? _____ years and _____ months	32. How long has it been since the mariner received this **Activity 3** training? _____ years and _____ months
23. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 1**. Are procedures adequate? YES NO	28. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 2**. Are procedures adequate? YES NO	33. Briefly describe established vessel procedures, regulations, or common practices that guide mariner performance of **Activity 3**. Are procedures adequate? YES NO

Step 5.4: Conclusions and Recommendations

*Respond to items 34-35 **after** completing Step 5.3.*

34. If the mariner lacks skill or knowledge in any activity (1 to 3), complete *34* and *35*; otherwise, end this report (NOT skill or knowledge related).	**Activity 1**	**Activity 2**	**Activity 3**
a. The mariner most likely lacks **skill** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE
b. The mariner most likely lacks **knowledge** in this activity.	TRUE FALSE	TRUE FALSE	TRUE FALSE

35. What could be done to improve this mariner's skill and/or knowledge, or to improve established procedures and reduce casualties?

Minimum:

Ideal:

APPENDIX B

Training Materials

This appendix includes most of the 104 slides presented in the one-day Investigating Officer training conducted at participating Marine Safety Offices. The slides that showed completed forms are omitted.

SLIDES ARE PROVIDED IN A SEPARATE FILE.

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APPENDIX C

Procedure Assessment

This appendix summarizes the results of the assessment questionnaire that was administered at the end of the data collection period to all available participating Investigating Officers. A copy of the questionnaire follows the discussion of the assessment results.

Value of Training

Of the 10 Investigating Officers surveyed, 6 indicated they had taken part in the initial full-day training session. Using a scale of 1 (poor) to 5 (excellent), these IOs were asked to rate the project training on three factors: (1) explaining the purpose of the forms; (2) describing what information to collect; and (3) describing how to complete the forms. Average ratings for each of the factors ranged between 4.5 and 4.75, suggesting that the initial training was highly useful to the respondents. Among those who could not attend the initial full-day training session, four IOs indicated they received some form of training from colleagues at their MSO. The average IO ratings for that training, using the same three factors as above, were exactly the same, ranging between 4.5 and 4.75. Thus, it appears the initial full-day training adequately prepared IOs for their responsibilities in this study, including the training of colleagues who were unable to attend the initial session.

Usability of the Investigation and Reporting Procedures

The usability of material supporting the investigation and reporting procedures was assessed for (1) the *Instructions for Completing and Sending of All Forms;* (2) the *Screening and Background Form;* and (3) the *Operations Reporting Forms.*

During their initial training, all respondents received a copy of the instructions. The instructions appeared to be more useful to IOs during reporting than during investigation. Eighty percent of IOs stated they used the instructions more than half the time when filling out forms, but only 40 percent referred to the instructions when investigating a case. When asked to rate the instructions on their ease of use and value in the investigating and reporting process on a scale of 1 (poor) to 5 (excellent), IOs gave them moderately high average ratings of 4.1 (ease of use), 3.7 (value in investigation), and 4.1 (value in reporting).

Using the same 5-point scale, the screening form was rated on its ease of use and the value of its contribution to the quality of the investigation. This form received moderately high average ratings: 4.3 (ease of use) and 4.0 (value). The operations forms were also rated on the same two dimensions, using the same 5-point scale. This category of forms received average ratings similar to those for the screening form: 4.3 (ease of use) and 3.9 (value).

Usefulness of Present Investigation and Reporting Approach

The present method for investigation and reporting casualties involved a three-step process: (1) screening all cases for casualty criticality; (2) screening critical cases for human factors involvement; and (3) for critical/human factors cases, identifying whether skill and knowledge limitations contributed to the casualty. When asked to rate the usefulness of this approach using a five-point scale from Not Useful to Extremely Useful, 9 of the 10 IOs (90 percent) rated it as Useful or Very Useful. IOs were also asked to rate how participation in this project changed the quality of their investigations and reporting during the period of study. Using a five-point scale from Much Worse to Much Better, 70 percent of IOs said the quality was somewhat better or much better than it would have been otherwise.

In explaining their responses, most IOs noted that the systematic nature of this approach helped them to focus their investigations on the contributing individual's training, experience, and skill level. Several IOs mentioned this aided them in separating the "routine excuses," such as high wind and fast current, from the skill and knowledge limitations that contributed to a casualty.

Potential Future Implementation of Present Investigation and Reporting Procedures and Skill and Knowledge Limitations Training

Investigating Officers were asked to judge whether and to what degree the present investigation and reporting procedures should be implemented across all MSOs. Fifty percent of the respondents said the present procedures should be implemented across all MSOs, but with slight modifications, and 30 percent thought only limited portions of the procedures should be implemented. IOs who advocated continued use of the approach suggested it should be implemented in a streamlined format, perhaps by incorporating portions of the screening process and operations forms into MSIS.

Respondents were also asked to judge whether and to what degree skill and knowledge limitations training should be incorporated into the IO human factors training. One hundred percent of the respondents said that at least some skill and knowledge limitations training should be incorporated into the IO human factors training offered at the USCG Reserve Training Center in Yorktown.

FINAL ASSESSMENT SURVEY

This questionnaire is designed to provide you with an opportunity to comment on the recent USCG Skill & Knowledge Limitations Casualty Investigations Research Project. We would appreciate your feedback on the project training, data collection forms and written instructions. Please answer the following questions and contact us if you have any questions. Thank you!

Section 1. Background Information

1. Investigating Officer	2. Marine Safety Office θ GALMS θ SEAMS θ MIAMS θ SFCMS	3. Approximately when were you assigned to this IO shop? (mm/dd/yy)

Section 2. Project Training

4. Did you receive the full-day training provided by project staff at your office? θ Yes θ No
If NO, skip to #6. If YES, continue.

5. How would you rate this training on the following dimensions?

	Poor				***Excellent***
	1	**2**	**3**	**4**	**5**
a) Explaining why you were completing forms	θ	θ	θ	θ	θ
b) Describing what information you needed to collect	θ	θ	θ	θ	θ
c) Describing how to complete the forms	θ	θ	θ	θ	θ

Please skip to #9.

6. If you *did not* receive the initial training from project staff, did you receive any training from co-workers or supervisors at your office? θ Yes θ No *If NO, skip to #8. If YES, please continue.*

7. How would you rate this training on the following dimensions?

	Poor				***Excellent***
	1	**2**	**3**	**4**	**5**
a) Explaining why you were completing forms	θ	θ	θ	θ	θ
b) Describing what information you needed to collect	θ	θ	θ	θ	θ
c) Describing how to complete the forms	θ	θ	θ	θ	θ

Please skip to #9.

8. If you received neither training from project staff nor training from your co-workers or supervisors, how did you acquire the information necessary to complete the project requirements?

Section 3. Project Instructions & Forms

9. Did you receive a copy of the instructions for completing the forms? θ Yes θ No

If NO, skip to #10. If YES, please continue.

	Never	***Sometimes***	***About half of the time***	***Usually***	***Always***
a) How frequently do you use the instructions during your investigations?	θ	θ	θ	θ	θ
b) How frequently do you use the instructions during the preparation of the reporting forms?	θ	θ	θ	θ	θ

If you responded NEVER to both 9a and 9b, skip to #11. Otherwise, please continue.

10. How would you rate the instructions on their:

	Poor				***Excellent***
	1	**2**	**3**	**4**	**5**
a) Ease of use	θ	θ	θ	θ	θ
b) Value in conducting the investigation	θ	θ	θ	θ	θ
c) Value in completing the forms	θ	θ	θ	θ	θ

11. How would you rate the *Screening & Background Form* on its:

	Poor				***Excellent***
	1	**2**	**3**	**4**	**5**
a) Ease of use	θ	θ	θ	θ	θ
b) Contribution to the quality of the investigation	θ	θ	θ	θ	θ

12. How would you rate the *Operations Forms* on their:

	Poor				***Excellent***
	1	**2**	**3**	**4**	**5**
a) Ease of use	θ	θ	θ	θ	θ
b) Contribution to the quality of the investigation	θ	θ	θ	θ	θ

Section 4. Investigations

13. When it was required for an investigation, approximately what percentage of the time were you able to contact the individual(s) directly involved in the casualty? _____%

14. On average, how many phone calls did you make in order to reach the individuals directly involved in a casualty? _____

15. Overall, what do you think of this approach to the investigation of skill & knowledge limitations-related information?

Not Useful	***Somewhat Useful***	***Useful***	***Very Useful***	***Extremely Useful***
❑	❑	❑	❑	❑

Why?

16. How did participation in this project change the quality of your investigations and reporting?

Much Worse	*Somewhat Worse*	*No Change*	*Somewhat Better*	*Much Better*
❑	❑	❑	❑	❑

17. What suggestions do you have for improving the investigation procedures, the forms, or both?

18. Which of the following best reflects your opinion regarding implementation of the project's investigation and reporting procedures across all Marine Safety Offices?

- ❑ Do not implement the procedures
- ❑ Implement limited portions of the procedures
- ❑ Implement all of the procedures with slight modifications
- ❑ Implement the procedures as they are now

19. Which of the following best reflects your opinion regarding incorporation of the skill & knowledge limitations training into the IO human factors training?

- ❑ Do not incorporate the training
- ❑ Incorporate limited portions of the training
- ❑ Incorporate all of the training with slight modifications
- ❑ Incorporate the training as it is now

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APPENDIX D

Selected Findings for Minor Casualties

Although considered "critical" in current USCG policy, loss of propulsion-only and steering failure-only cases were considered minor casualties in the present study. These casualties neither resulted in significant damage to the vessel or other property, nor involved significant risk to the crew. The 76 minor casualties investigated and reported in this study were excluded from the main findings presented in Section 3 of this report. For the purpose of comparison, however, selected findings for these casualties are provided below. Due to the limited number of casualties in this subset of the study sample, no firm conclusions can be drawn from any of the following results.

Overview of the Minor Casualties

All of the minor casualties in the study sample were vessel casualties; none were personnel injuries. Of the minor casualties, only nine of 76 (12 percent) were determined to have a direct human factors contribution. The nine cases were classified into six knowledge-based mistakes, two rule-based mistakes, and one slip. As this classification indicates, eight of the nine minor casualties (89 percent) were determined to have a skill and knowledge limitation contribution. In these eight cases, four vessel types (fishing, passenger, tank ship, and towing) and three operational areas (bridge, deck, and engineering) were represented. Four cases concerned bridge operations, two cases involved deck operations, and two cases concerned engineering operations.

Mariner Activities Associated with Skill and Knowledge Limitations in Minor Casualties

In the eight minor casualties with a skill and knowledge limitation contribution, there were 16 separate occurrences of mariner activities cited. Table D-1 shows the frequency of each specific activity cited in bridge, deck, and engineering operations. In this subset, IOs cited 10 bridge activities, two deck activities, and four engineering activities. Shiphandling was the single most commonly cited activity area, with six total occurrences. Among the minor casualties, maneuvering in accordance with vessel handling characteristics was the most commonly cited specific activity involving skill and knowledge limitations.

Table D-1. Frequency of specific activities in minor casualties involving skill and knowledge limitations.

Operational Area / Activity Area / Specific Activity	Frequency
Bridge Operations	
Shiphandling	
Maneuver IAW vessel handling characteristics	3
Maneuver IAW sea/river/weather conditions	2
Docking, anchoring, mooring	1
Changing Bridge Watch	
Assess traffic and weather conditions	1
Check status of ship's equipment	1
Grounding Avoidance and Navigation	
Establish a passage plan	1
Bridge Communications	
Communicate effectively among bridge crew	1
Deck Operations	
Towing and Fleeting Operations	
Make up and check tow	1
Fishing Operations	
Set, retrieve, and handle fishing gear	1
Engineering Operations	
Engineering Systems Operations	
Operate main propulsion system	1
Load, discharge, and transfer fuel	1
Engineering Systems Inspection and Testing	
Inspect and test main propulsion equipment	1
Engineering Communications	
Communicate effectively among engineering crew	1

APPENDIX E

Initial Classification of Unsafe Acts

Study researchers independently classified the unsafe acts for the 60 critical human factors casualties into five categories: violation, slip, lapse, knowledge-based mistake, and rule-based mistake. The two researchers then met to discuss their differences of opinion, review and refine the definitions of each category, and reach agreement on the final outcome of the classification. Section 2.2 of this report details the criteria that were used to classify the unsafe acts. This appendix summarizes the results of the researchers' initial classification of the unsafe acts.

Table E-1 shows the results of the initial classification in the five main categories, plus the unknown category.[8] As shown in the table, the researchers initially agreed on 47 out of the 60 cases (78 percent), representing a moderate level of agreement. For the 13 cases in which they did not agree, the researchers discussed the reasons for their individual choices, revised category definitions, and eventually reached agreement on the classification of all 60 critical casualties with unsafe acts.

Table E-1. Classification of unsafe acts by human factors researchers.

		Researcher B						
		Violation	**Slip**	**Lapse**	**Rule-based mistake**	**Knowledge-based mistake**	**Unknown**	**Total**
Researcher A	**Violation**	3		1				**4**
	Slip	1	10		1			**12**
	Lapse			1				**1**
	Rule-based mistake	3	1		14	1		**19**
	Knowledge-based mistake	1			3	16	1	**21**
	Unknown						3	**3**
	Total	**8**	**11**	**2**	**18**	**17**	**4**	**60**

[8] Casualties were classified as "unknown" when insufficient information was available to make a judgment on the unsafe act classification.

Figure E-1 shows the frequency of each unsafe act category for the researchers' initial judgment, as well as their final consensus. Compared to the consensus, Researcher A slightly over-represented both violations and lapses and Researcher B slightly under-represented those categories. During the discussion following their independent reviews of the cases, the researchers came to appreciate the subtle differences among the various types of unsafe acts. This discussion led to the refinement of some of the categories – in particular, violations, knowledge-based mistakes, and rule-based mistakes. This refinement subsequently led to the final classification of fewer rule-based mistakes and more knowledge-based mistakes than either researcher had originally classified.

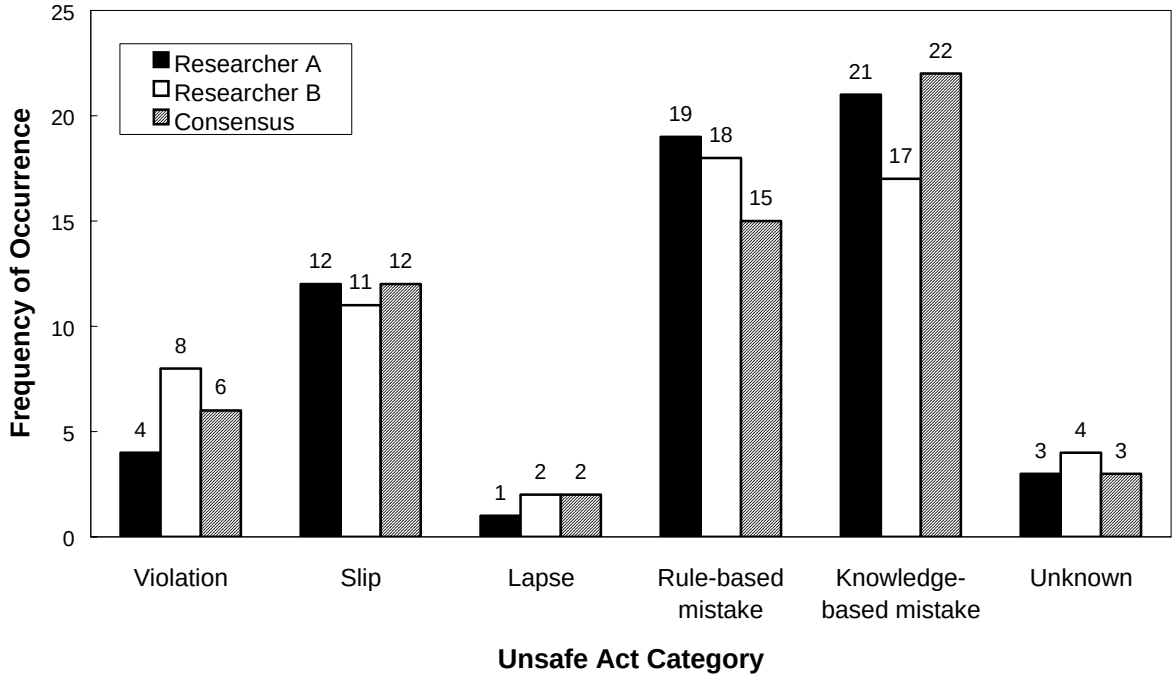

Figure E-1. Frequency of unsafe acts by each researcher and their consensus.

The differences between researchers in the initial classification results point to the difficulty in classifying unsafe acts consistently when casualty reports have somewhat limited firsthand information about a contributing individual's experience and level of skill and knowledge. Distinguishing a violation from either a knowledge- or rule-based mistake, for example, involves a thorough understanding of the contributing individual's experience level in the activity directly contributing to the casualty. Although the reporting forms in the present study contained questions regarding the contributing individual's training and experience, the investigations would have benefited from additional first-hand interview data from mariners about their knowledge and skill levels in the specific activities contributing to a given casualty. Obtaining this type of information may have required investigators to spend additional time, or to have better access to the individuals involved, but it would have resulted in a more reliable determination of skill and knowledge limitations.