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Situational awareness in the marine towing industry

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Thesis:

Situational Awareness in the Marine Towing Industry

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Abstract

Loss of situational awareness has been cited as the most common cause of accidents in the maritime industry. However, current research has not proven beneficial in determining the factors that underpin situational awareness. This study examined situational awareness among licensed captains and pilots of the inland towing industry. Twenty towboat captains, who operate on the Gulf Intracoastal Waterway (GIWW) from New Orleans, LA to Houston, TX and who represented 16 towing vessel companies, were interviewed and participated in an integrated survey that explored fatigue, communication, dangerous drugs and alcohol, social stress, and mental workload. These factors were believed to have a direct influence on situational awareness among towing vessel captains. These factors were compared and resulted in the identification of mental workload as the predominant factor affecting situational awareness. Upon further examination of mental workload, it was found that loss of situational awareness is likely to occur when a towing vessel captain is distracted by a cell phone conversation with their company or steers his or her tow in the vicinity of recreational vessels. In addition, the results also indicated complacency potential, a function of attitude toward automation and perception of mental workload. It was concluded that outreach and education to recreational boaters, establishing procedures for business conversations, navigation simulators, drills, and strategic thinking could be effective counter-measures against the loss of situational awareness induced by mental workload. Further research that measures the impact of those distractions or examines the effectiveness of such counter-measures in reducing the potential for loss of situational awareness is needed.

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Chapter 1

Introduction

1.1 Topic

Accidents involving towing vessels and barges have resulted in unacceptable deaths, injuries, and property damage. On September 15, 2001, the towing vessel BROWN WATER V, which was pushing four barges, struck one of the support columns of the Queen Isabella Causeway Bridge that connects Port Isabel to South Padre Island, TX, causing two sections of the bridge to collapse. As a result, several automobiles fell 85 feet into the water and eight people died. The U.S. Coast Guard concluded that the captain's negligence was a causal factor in the incident.

On May 26, 2002, approximately eight months later, the towing vessel ROBERT Y. LOVE, pushing two empty asphalt barges, struck the I-40 Bridge crossing the Arkansas River near Webber Falls, Oklahoma. This allision, which resulted in the collapse of two sections of the bridge, subsequently caused automobiles and tractor-trailer trucks to fall into the water killing 14 people. The National Transportation Safety Board (NTSB) concluded that a combination of fatigue and medical conditions had impaired the captain's ability to operate the vessel safely and were causal factors in this incident (NTSB 61). These two cases highlight the need to understand the role of human factors in towing vessel accidents, specifically the loss of situational awareness, which accounts for 71% of human error in the maritime industry (Grech and Horberry 3).

1.2 Problem Statement

Current studies of towing vessel accidents have not proven useful in terms of identifying the factors that affect situational awareness. This is evident when one looks at the September 7, 2006 report by the Towing Safety Advisory Committee (TSAC), who found that loss of situational awareness accounted for only 36% of human error in the towing vessel industry (TSAC 6). However, this figure should be higher considering that situational awareness accounts for 71% of human error (Grech and Horberry 3) in other sectors of the maritime industry.

A logical explanation for the lack of data on towing accidents can be derived from the accident pyramid in Pascal Dennis' book <u>Quality, Safety, and Environment</u> (106). Looking at the accident pyramid, one can conclude that when studying accidents, one only studies the "tip of the iceberg." Dennis implies that there are many near-miss situations involving loss of situational awareness and thousands of unsafe acts affecting situational awareness that cannot be ascertained by simply studying accident reports. This calls for a study that draws upon the experiences of licensed captains and pilots in the marine towing industry in order to determine the underlying factors affecting situational awareness.

1.3 Purpose

This study gathers contemporary data and defines the factors that influence situational awareness in towing vessel accidents and near-miss situations. The factors are compared in order to determine the most predominant factor that causes loss of situational awareness. This information will be used to create a foundation for root-cause analysis, to provide recommendations for addressing the predominant factor, and to suggest areas for future research in the towing industry.

Terminology

Allision – According to Black's Law Dictionary, an allision is an incident in which a vessel strikes a fixed object (e.g., a bridge, a navigational aid, or a moored ship). This should not be confused with the term collision, which refers to a vessel striking a moving object (e.g., another moving vessel).

American Bureau of Shipping (ABS) – ABS is a "classification society" headquartered in Houston, TX. A classification society is a non-governmental organization composed of ship surveyors and engineers who promote the safety of life at sea. All nations require that a ship's structure, design, and purpose be approved by a classification society. ABS is one of the "big three" classification societies in the maritime industry, along with Lloyds Register and Det Norske Veritas ("American Bureau of Shipping").

The American Waterways Operators – The American Waterways Operators, according to the organization's website, represents the owners and operators of a majority of towing vessels and barges operating in the United States.

Automatic Identification System (AIS) – AIS is used by ships and Vessel Traffic Services (VTS) to identify and locate vessels. This method of communication resolves the difficulty of identifying ships that are not in sight of one another due to fog, distance, line of sight, etc. AIS automatically broadcasts and allows vessels to exchange information pertaining to position, course, speed, and other ship data as a means of preventing collisions between vessels ("Automatic Identification System").

Barge – A barge is a flat-bottomed vessel built mainly to transport products on rivers and canals. Most barges are not self-propelled, requiring the assistance of towboats to push them or tugboats to pull them ("Barge"). Figs. 1.1 through 1.4 show four common barge types.

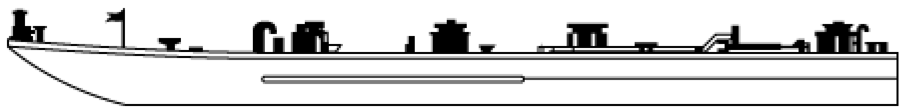

Fig. 1.1. Tank barge. Designed to carry petroleum products, petroleum, fertilizer, and chemicals. 297 ft. long, 1,000,000-gallon capacity.

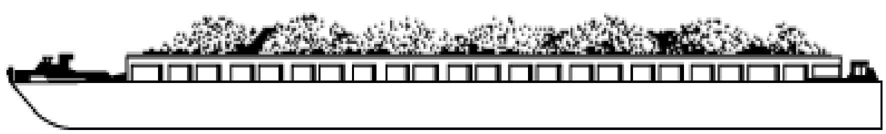

Fig. 1.2. Dry cargo barge. Designed to carry coal, steel, ore, sand, gravel, and lumber. 195 ft. long, 1,530-ton capacity.

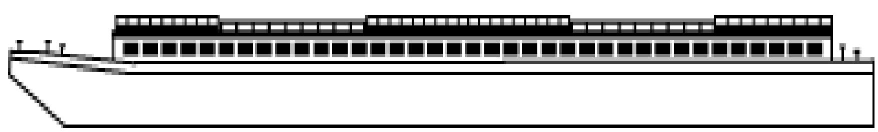

Fig. 1.3. Covered dry cargo barge. Designed to carry grain, soybeans, coffee, salt, sugar, paper products, and packaged goods that must be protected from the weather. 195 ft. long, 1,500-ton capacity.

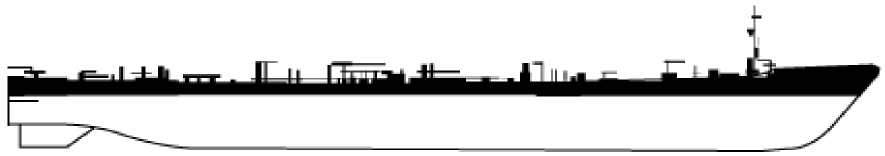

Fig. 1.4. Coastal ocean tank barge. Designed to carry petroleum products. 550 ft. long, 225,000-barrel capacity (1 barrel = 42 gallons).

Crew-member / Deckhand – An individual performing deck equipment maintenance, line handling and lookout duties onboard a towing vessel or other vessel. The deckhand is also responsible for ensuring the security of the barges, including checking void spaces and the wiring layout of the navigation lights. The deckhand assists the officer on watch by calling out clearance distances and pointing out hazards to navigation. The deckhand is supervised by the officer on watch.

Marine Casualty – An accident involving a vessel (46 CFR 4.03-1).

Master – An individual in charge of the towing vessel and its crew. Also known informally as the "captain." The captain also stands watch to steer the vessel. Captains operating towing vessels more than 26ft in length are required to be licensed by the U.S. Coast Guard.

Oversize Tow – As stated in 33 CFR 162.75 (b)(5)(i) and (b)(5)(ii), an oversize tow is a towboat or tug and barge unit that exceeds 1,180ft in length and/or 55ft wide if transiting the GIWW west of the Harvey Locks. Oversize tows require permits to transit the waterway. Permits for the GIWW are issued by the U.S. Coast Guard for tows between 55 to 72 feet wide, but no longer than 750ft long, which is the standard dimension for a towboat pushing six barges (two barges wide and three barges long).

Pilot (aka Relief Captain) – Second officer in charge of a towing vessel and its crew. The pilot is also known as the "mate" in coastal towing and in some river and inland waters. The pilot stands watch to steer the vessel. Pilots operating towing vessels more than 26ft in length are required to be licensed by the U.S. Coast Guard.

Port – Left. Often used during passing arrangements with other vessels (e.g., port-to-port passing).

Rules of the Road – This is a set of regulations developed by the U.S. Coast Guard and International Maritime Organization that regulates safe operation of vessels on the navigable waterways. They are also known as the navigation rules or "NavRules." The NavRules are categorized as either Inland Rules, which apply in most inland waters of the United States, or International Rules, which apply in international waters beyond COLREGS line of demarcation. The most important sections of the Rules of the Road describe "right of way" between two vessels in a meeting, crossing, or overtaking situation; actions taken to avoid collision; navigational light configuration for different types of vessels; and sound signals in restricted visibility and in other specific situations.

Starboard – Right. Often used during passing arrangements with other vessels (e.g., starboard-to-starboard passing).

Towing Vessel – There are two basic types of towing vessels: towboats and tugboats. Towboats are flat-bottomed boats of various sizes characterized by a square bow (front) and are designed to push barges (Blank 41). Towboats are most often seen on inland waterways and are classified by horsepower, ranging in size from 200 horsepower to over 10,000 horsepower (Blank 41). Towboats are often referred to as "push-boats" (Blank 3). *See fig. 1.5*. A tugboat is a vessel designed to push other vessels with its characteristic pointed or "model" bow or to pull disabled vessels or barges with a long steel or soft fiber rope (hawser) attached to its towing winch (Blank 69). Tugboats may be divided into three categories: harbor/ship assist, coastwise, and ocean (Blank 41). See fig. 1.5.

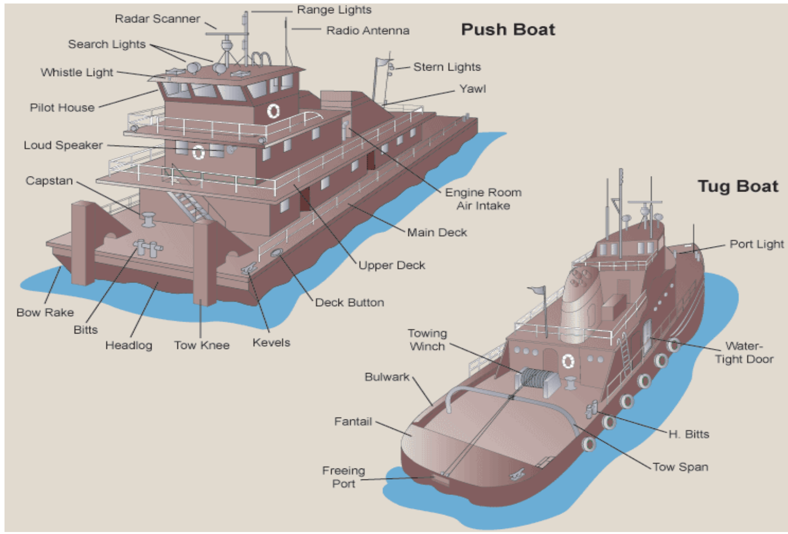

Fig. 1.5. Towboat and tugboat. Courtesy of McDonough Marine Services, Towing Services, 7 Jan. 2007 <http://www.mcdonoughmarine.com/towing.htm>.

Towing Safety Advisory Committee (TSAC) – TSAC is committee representing members from the barge and towing industry; the mineral and oil supply vessel industry; port districts, authorities or terminal operators; maritime labor; shippers; and the general public and makes recommendations to the Secretary of Homeland Security via the U.S. Coast Guard on matters relating to towing safety.

U.S. Coast Guard – For the purposes of this study, the U.S. Coast Guard is tasked by Congress to investigate marine casualties (other than major marine casualties) involving towing vessels and other types of vessels (46 CFR 4.03-30). In section 415 of the Coast Guard and Maritime Transportation Security Act, Congress directed the Coast Guard to develop safety inspection regulations for towing vessels.

Vessel Traffic Service (VTS) – VTS is a system that is used to advise vessels of the presence of other vessels and was established in order to regulate and help maintain a steady flow of vessel traffic in rivers and harbors worldwide. VTS is similar to air traffic control for aircraft. VTS is typically implemented by the local port authority and uses radar, AIS, and video cameras along portions of the river to obtain the position, course, speed, destination, and type of vessel. Most VTS systems in the United States are operated by the U.S. Coast Guard and regulate vessel traffic in the busiest waterways (i.e., New York City, NY; New Orleans, LA; or Houston, TX.) in order to maintain safety (Blank 432). See fig. 1.6.

Fig. 1.6. Vessel Traffic Service. Courtesy of Wikipedia Online Encyclopedia, 2007, 6 Aug. 2007 <http://en.wikipedia.org/wiki/Vessel_Traffic_Service>.

Whistle Passing – Towing vessel captains often communicate passing arrangements over the VHF-FM radio. Alternatively, it is common to communicate these passing arrangements using a whistle. One-whistle passing means that two vessels in a meeting situation will pass each other on their left side or port-to-port. Two-whistle passing means that two vessels in a meeting situation will pass each other on their right side or starboard-to-starboard. The 1- and 2-whistle are derived from the U.S. Coast Guard Rules of the Road (aka NavRules). Other whistle signals also are used in overtaking situations and as a danger signal.

1.5 Research Focus

What are human factors and how do they relate to situational awareness?

What factors affect situational awareness?

How do these factors impair navigation and mariner performance/decision making?

What's the predominant factor affecting situational awareness?

How can the predominant factor be addressed to mitigate its effect on situational awareness?

Chapter 2

Background

2.1 History of Towing Vessels

The first towing vessel, the CHARLOTTE DUNDAS, was a steam-powered paddlewheeler invented and engineered in 1803 by William Symington, a Scottish engineer and a native of Leadhills, Lanarkshire, Scotland. Symington patented the steam engine for a boat in 1787 and used this design in the CHARLOTTE DUNDAS ("William Symington"). The CHARLOTTE DUNDAS was developed because the Governor of the Forth and Clyde Canal Company, Lord Dundas of Kerse, wanted to tow coal barges on the canal. The CHARLOTTE DUNDAS successfully towed two 70-ton barges through 18 miles of the canal in approximately 10 hours (Baird 11).

Following the success of the CHARLOTTE DUNDAS, Lord Dundas ordered the construction of eight more of these steamboats, but canal authorities feared that damage would be caused to the canal banks by the vessels' paddlewheels and ordered the discontinuation of the towing vessel (Baird 11).

The towing vessel concept was continued by American engineer Robert Fulton, who introduced the steam powered passenger boat NORTH RIVER FERRY (aka CLERMONT) to North America in 1807. Fulton's towing vessel, based on Symington's idea, was utilized to carry passengers and freight, offering an alternative to travel on often crude and sometimes nonexistent roads (Baird 19). By 1825, Fulton's steam-driven passenger vessels had become a highly profitable business. At the time, steam-powered ferryboats operating in the harbors of New York, Boston, and Philadelphia were used to assist sailing ships in and out of the harbors (Baird 24).

By 1860, towing vessels were able to travel farther out to sea. This ability was exemplified by the British, who utilized their towing vessels to venture out to sea in search of incoming sailing ships and crippled steamships to tow back to London (Baird 45). By 1905, barge operations were established because sailing vessels that carried bulk cargoes could not manage the intricacies of navigating the narrow channels and inlets (Baird 226). The early barges, built of wood, offered a distinct advantage: they could be left at the dock for loading and unloading, which enabled the towing vessels that pushed them to accept other job offers (Baird 228). By WWI, tugs were recognized for their tough hulls and maneuverability, attributes that also made them well-suited for firefighting, salvage, and general errand running in a busy harbor (Baird 89).

2.2 Modern Towing

Today, the towing industry has become a diverse and economically vital area of trade and commerce. The current towing fleet, composed of approximately 5,200 towing vessels and 27,000 barges, transports over 800 million tons of raw materials along U.S. inland waterways. Petroleum products, chemicals, coal, wood products, metals, and grain are among the commodities most often shipped by barge. As noted by the American Waterways Operators, one of the advantages of open-deck barges is that they may be employed to ship cumbersome cargoes (i.e., nuclear reactors, drilling platforms, space shuttles, etc.) that cannot be transported by other means. In addition, deck barges can be outfitted with a crane to facilitate waterway construction.

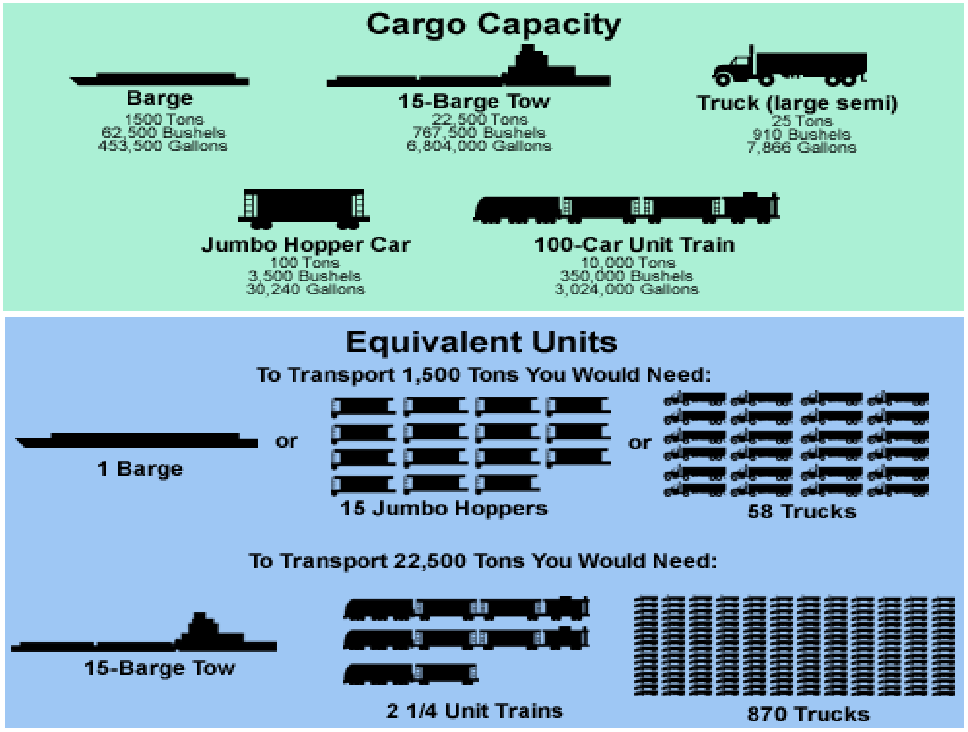

Fig. 2.1. Advantages of barge transport. Courtesy of The American Waterways Operators, Homepage page, 2007, 1 Jan. 2007 <http://www.americanwaterways.com>.

2.3 How Towing Vessels Communicate

Several regulations regarding communication between vessels can be found in the U.S. Coast Guard International-Inland navigation rules and 33 CFR Part 26. In general, communication between two vessels can be categorized as verbal and non-verbal. Verbal communication is accomplished via vessel-to-vessel or vessel-to-VTS through very high frequency (VHF-FM) radio. As 33 CFR 26 (a)(3) and 33 CFR 26 (a)(f) state, every towing vessel of 26 ft or greater is required to have a radiotelephone that is capable of transmitting and receiving VHF-FM frequencies. Verbal communication between two vessels is important with regard to collision avoidance and passing arrangements (Koester 6).

Fig. 2.2. Maritime VHF-FM radio. Courtesy of the Piplers of Poole Homepage, 2007, 13 Aug. 2007 <http://www.piplers.co.uk/products/small/md284400.jpg>

Non-verbal communication is often accomplished through the use of navigational lights (Blank 171, 327) and whistle signals, spotlight, day signals, Automatic Identification System (AIS), and radar. Per rule 24, towing vessels must adhere to the following navigational light configurations while operating on inland waters.

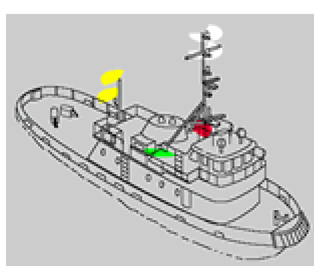

Fig. 2.3. NavRule 24, towing vessel pushing barges, less than 50 meters in length. Courtesy of U.S. Coast Guard, Navigation Center Homepage, 2007, 6 Aug. 2007 <http://www.navcen.uscg.gov/mwv/navrules/rules/Rule24.htm>

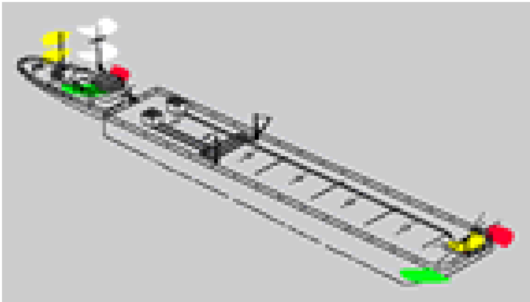

Fig. 2.4. NavRule 24, light configuration of a towing vessel pushing barges on the Mississippi River below Huey P. Long Bridge. Courtesy of U.S. Coast Guard, Navigation Center Homepage, 2007, 6 Aug. 2007 <http://www.navcen.uscg.gov/mwv/navrules/rules/Rule24.htm>

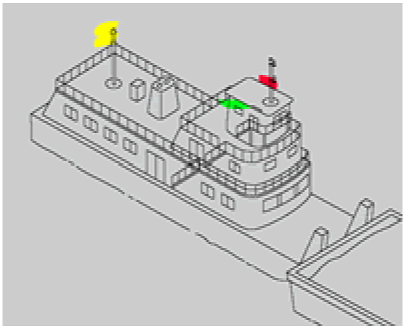

Fig. 2.5. NavRule 24, typical light configuration of a towing vessel pushing barges on the Mississippi River above Huey P. Long Bridge. Courtesy of U.S. Coast Guard, Navigation Center Homepage, 2007, 6 Aug. 2007 <http://www.navcen.uscg.gov/mwv/navrules/rules/Rule24.htm>

Day signals and ship's whistle are another form of communication between two vessels. For example, according to rule 24 (a)(v), a diamond day shape is required for tows that exceed 200 meters.

Per rule 34, communication via ship's whistle, a flashing spotlight can be used as a supplement to the verbal passing arrangements on VHF-FM, especially during periods of restricted visibility. For use as a danger signal, five short blasts or five spotlight flashes can be used to indicate danger or misunderstanding.

AIS and radar are other forms of communication between two vessels. Specifically, AIS is used by ships and Vessel Traffic Services (VTS) to identify and locate vessels. This method of communication resolves the difficulty of identifying ships that are not in sight of one another due to fog, distance, line of sight, etc. AIS automatically broadcasts and allows vessels to exchange information pertaining to position, course, speed, and other ship data as a means of preventing collisions between vessels ("Automatic Identification System"). Radar is a system that utilizes electromagnetic waves to identify the range, course, and speed of other vessels. In addition to vessel detection, radar can also be used to detect meteorological precipitation ("Radar").

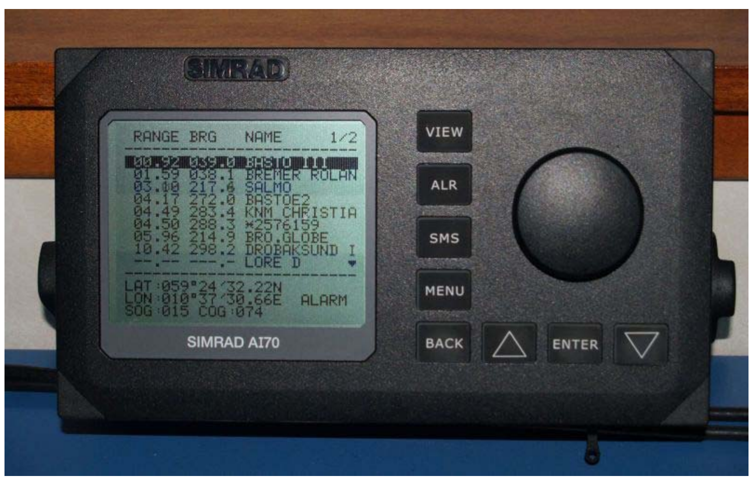

Fig. 2.6. AIS transponder. Courtesy of Wikipedia Online Encyclopedia, 2007, 6 Aug. 2007 <http://en.wikipedia.org/wiki/Automatic_Identification_System>.

Fig. 2.7. Marine radar. Courtesy of Prime Marine Services Homepage, 2007, 13 Aug. 2007 < http://www.boat-servicing.co.uk/boat-servicing-images/Marine%20Radar%20Installation.jpg >.

2.4 Drug and Alcohol Testing Regulations

There are numerous drug and alcohol testing regulations that apply to both the marine employer and operator of a towing vessel. Specifically, random, pre-employment, and reasonable-cause chemical testing has identified most towing vessel operators who were operating under the influence of dangerous drugs. Under random testing procedures (defined in 46 CFR 16.230), the marine employer is responsible for the annual testing of 50% of towing vessel crewmembers for dangerous drugs. This is normally done by “drawing names out of a hat.” The easiest and most efficient means of random testing is for the marine employer to randomly test their vessels instead of individual crewmembers. For example, if a company owns 10 towing vessels, the names of those vessels are written on 10 separate pieces of paper and randomly selected. When vessel A is selected, then the company waits until vessel A arrives at a dock. Crew-members are notified by the port captain[1] that they will be tested and are not allowed to depart the vessel until a urine specimen is provided. The marine employer hires a certified collector to collect the urine samples of each crewmember, which are sealed, packaged and shipped to a Substance Abuse and Mental Health Services Administration approved laboratory and tested for dangerous drugs. The test results are reported to a Medical Review Officer (MRO). The MRO is the final authority as to whether or not an individual is a user of dangerous drugs. If an individual is a user of dangerous drugs, then a report is made to the Coast Guard and the Coast Guard imposes "suspension and revocation"[2] proceedings against the individual's credentials. Additional regulations that address the drug testing program, certified collector, laboratory, and MRO can be found in 49 CFR 40.

The regulations given in 46 CFR 4.06-3 require mandatory drug and alcohol testing of crewmembers involved in a serious marine incident. Per 46 CFR 4.06-3 (a), alcohol testing must be conducted within two hours following a serious marine incident. Per 46 CFR 4.06-3 (b), drug testing must be conducted within 32 hours following a serious marine incident. Testing procedures are to be conducted within the allotted time frame unless precluded by safety concerns. For example, if a towing vessel collides with another vessel, which puts a hole in a barge and results in the barge taking on water, then chemical testing would not take place until the hole is patched or dewatering pumps are used to stabilize the barge.

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[1] A port captain is a representative of the towing vessel company and acts as a liaison between the towing vessel and company management.

[2] Suspension and revocation is commonly referred to as "S&R." It is the administrative consequence for licensed mariners who test positive for dangerous drugs or alcohol.

33 CFR Part 95 contains the regulations that prevent the operation of a vessel while intoxicated. Specifically, 33 CFR 95.020(b) states that .04 blood alcohol concentration from a chemical test is considered the standard for intoxication. 33 CFR 95.035 is the standard for reasonable cause and gives the marine employer with reasonable cause the right to order a chemical test.

Chapter 3

Literature Review

3.1 Situational Awareness and Human Factors

Situational awareness is one element of a much broader concept known as human factors. To understand the impact of situational awareness on the towing vessel industry, a definition of human factors must first be given. Given that research findings in this field typically lead to more questions than answers, the study of human factors is a daunting task. This is obvious in the endless variables that fall under the concept of human factors, as well as the lack of a commonly accepted definition. Moreover, the term is often used synonymously with human element and human error, which have distinct meanings.

This study draws upon the definition of human factors given by David Meister, who many consider the father of human factors research. In his book, The History of Human Factors and Ergonomics, human factors are discussed as synonymous with ergonomics and are concerned with the relationship between humans and technology. According to Meister, human factors can be categorized using three variables: the characteristics of the human, the environment in which humans function, and the type of technology with which the human interacts (Meister 6).

3.2 Situational Awareness and the Human Element

The term human element is very similar to the term human factors but is largely focused on human characteristics instead of the relationship between humans and technology. According to Meister, the human element can be categorized through the use of three variables: physical, mental, and motivational (Meister 8). The physical element is concerned with physical strength, human measurement, and the threshold limitations of human senses and perception. For example, most humans are incapable of lifting 500 pounds without mechanical assistance because of strength limitations and are incapable of reaching 20 feet in height because of human measurement limitations. Threshold limitations are further illustrated by the fact that it would be unreasonable to ask a person to read literature printed in font size smaller than 8 point because human vision without the aid of corrective lenses is overly stressed by such small type. The physical element is easy to understand and accommodate.

In contrast, the mental element poses a much greater challenge (Meister 8), because the mental requirements of technology are much more complex, less obvious, and more difficult to satisfy. For example, given human memory limitations, it would be unreasonable to ask a human to perform complex numerical calculations without a calculator or to process thousands of pages of literature without the aid of a computer (Meister 9). Finally, the motivational element is concerned with the impact of technology on human behavior, motivation, and alertness (Meister 10). For example, it would be unreasonable to expect an individual to maintain a high level of alertness and motivation without mental stimulation.

3.3 Situational Awareness and Human Error

James Reason, a Professor of Psychology at the University of Manchester in the United Kingdom, has written numerous articles on human error. In his book, Managing the Risks of Organizational Accidents, Reason defines human error as "the failure of planned actions to achieve their desired ends without the intervention of some unforeseeable event" (Reason 71).

Reason also concludes that actions may fail to achieve their goals in two conditions. In the first, the plan is adequate but the actions fail to go as planned, creating a situation also known as a *slip* or *lapse*. Slips are associated with attention or perception failures, while lapses involve failures of memory. In the second condition, the actions concur with the plan, but the plan is inadequate to achieve the intended outcome, creating a situation known as a *mistake*. Mistakes are further divided into two subcategories: *rule-based mistakes* and *knowledge-based mistakes*. Rule-based mistakes involve the misapplication of normally good rules, the application of bad rules, or failure to apply a good rule. Knowledge-based mistakes occur when an individual reaches his or her knowledge limitations, has run out of solutions, and must improvise solutions (Reason 71). Reason's theory implies that slips, lapses, mistakes, and loss of situational awareness are codependent.

3.4 Defining Situational Awareness

Over the last 40 years, it has become increasingly evident that human errors are responsible for most of the precursors that lead to accidents in the towing vessel industry. In this industry, human error is responsible for 56% percent of all towing vessel accidents and situational awareness accounts for 36% of human error (TSAC 6). *Situational awareness* is defined by Endsley as "being aware of your surroundings" and can be organized into three levels. Level 1 is the ability to perceive, be aware, or be alert to elements in the current situation, and level 2 is the ability to comprehend the current situation. Level 3 is the ability to make projections of future events and is the main precursor to decision making (Endsley 3).

Endsley's theory of situational awareness levels was tested in the maritime domain by Michelle Grech and Tim Horberry in 2002. Grech and Horberry conducted a study that focused on the lack of situational awareness among mariners using the Leximancer software system.[3] An analysis of 177 accident reports between the years 1987 and 2001 revealed that 71% of human errors were associated with lack of situational awareness. Of the situational errors, 58% were associated with level 1 (failure to correctly perceive information, detect information and failure to monitor data), 32.7% were associated with level 2 (failure to comprehend information), and 8.8% were associated with level 3 (failure to project future actions or over-projection of current trends; Grech and Horberry 3).

3.5 Situational Awareness and Marine Casualties

An early study of situational awareness was administered in 1976 by Barry Margetts, the chairman of the U.S. Marine Transportation Research Board. The study, aimed at defining human factors associated with accidents in the maritime industry, was conducted at a time when the seriousness of human error had not been fully realized. Margetts believed that "marine casualties are a result of a number of factors and human error is a contributing, if not fundamental factor" (Margetts 2). Drawing from his interviews with maritime industry experts, Margetts developed a questionnaire of 192

[3] The Leximancer software system is a tool used to analyze large amounts of data based on keywords and concepts.

questions and surveyed 254 merchant mariners, including 26 towing vessel captains and crew-members. The results of the study identified 14 human factors that contribute to accidents in the maritime industry. Of the 14 human factors, situational awareness was cited by 29% of those surveyed as the most common cause of marine casualties (Margetts 74). Margetts' findings have been supported by the ABS.

In an effort to understand the role of humans in vessel accident causation, the ABS conducted a survey of 14 maritime accident databases from 1991 to 2002 and found a high level of consistency among four of the databases: those maintained by Australia, Canada, the United Kingdom and the U.S. Coast Guard. In these four databases, the survey revealed that 80% to 85% of the accidents involved human error (ABS 10). A review of 109 accident reports from the Australian Transportation database showed 16 cases where task omission was the leading accident causation factor followed by 15 cases for loss of situational awareness and 13 cases due to lack of knowledge, skills, and abilities (ABS 10).

In a review of 198 accident reports from the Canadian Transportation database, situational awareness was the leading accident causation factor, accounting for 29 cases, followed by bridge communications, which accounted for 18 cases (ABS 13). A review of 88 accident reports from the United Kingdom database showed that situational awareness was the leading accident causation factor, followed by lack of bridge communications[4] (ABS 16). The U.S. Coast Guard database of marine accidents from 1991 to 2001 showed that 55% of accidents were caused by loss of situational awareness

[4] The bridge is where vessel movement is controlled. The captain gives maneuvering orders to bridge watchstanders. The number of watchstanders on a bridge varies depending on vessel type and size. The captain may be the only watchstander on a towing vessel bridge.

(ABS 18). This finding is consistent with the study of crew-member fatalities conducted by Cooper and Frasher of the U.S. Coast Guard and the American Waterways Operators.

Cooper and Frasher observed that lack of situational awareness was the leading cause of crew fatalities onboard towing vessels. In their 1995 study, the U.S. Coast Guard and American Waterways Operators set out to determine the leading cause of crew fatalities onboard towing vessels operating along the Mississippi and Ohio River systems and the Gulf Intracoastal Waterway (GIWW) from Brownsville, TX to St. Marks, FL between the years 1985 and 1994. Of the 136 accident reports, 106 were attributed to human factors. In these 106 accidents, 83% of the fatalities occurred from to crew-members falling overboard off the towing vessel or barge (Cooper and Frasher 12). Lack of situational awareness was the leading factor that contributed to those casualties. It was also determined that lack of training, role ambiguity, poor communication among crew-members, shortcuts, and failure to use safety equipment contributed to the loss of situational awareness (Cooper and Frasher 32).

In 2003, the U.S. Coast Guard and American Waterways Operators formed a work group to investigate the cause of bridge allisions involving barges and towing vessels. The group extracted data on 2,692 bridge allisions from the Coast Guard database dating from 1992 to 2001. The work group concluded that 90% of towing vessel allisions were related to human factors (Allegretti and Pluta 19) and that decision-making error accounted for 68% of the factors (Allegretti and Pluta 16). Subsequent analysis showed that 99% of decision-making errors were caused by an incorrect maneuver by the towing vessel captain. Further analysis also revealed that 92% of the incorrect maneuvering errors were caused by the towing vessel making an improper approach to the bridge[5] and an improper course prior to passing underneath the bridge. Most of the improper bridge approaches and improper courses were caused by faulty situational assessment and faulty decision making (Allegretti and Pluta 17). The results of this study prompted the Coast Guard to investigate the leverage points that influence decision making. It was noted that physical and psychological condition, as well as mental stress, were the top factors that influenced decision making (Allegretti and Pluta 23).

3.6 Fatigue and Situational Awareness

Some of the most important fatigue studies in the maritime industry were conducted by Thomas Sanquist and Mirelle Raby. In 1996, Sanquist and Raby posited that there was a relationship between fatigue and alertness and that they were interested in exploring the nature and extent of sleep disruption-induced fatigue and the impact of watch duration on personnel fatigue and alertness onboard commercial tankers[6] and cargo ships.[7] Their study, which surveyed 141 mariners over a period of three weeks, was conducted during a period when very little documentation existed regarding the nature and extent of fatigue among mariners. Sanquist and Raby developed a mariner logbook to obtain data on sleep episodes and alertness during the workday for a period of three weeks. The study also made use of a Background Information Inventory survey that contained 72 questions on sleep behavior on the ship and at home, questions related to chronic fatigue, various personality scales, health, work habits, and means used to

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[5] It is common practice for the towing vessel captain to “line up” the towing vessel and barge approach to the bridge in order to navigate safely under the bridge.
[6] Tankers are large ships that transport oil or petroleum products.
[7] Cargo ships are ships designed to carry various cargos.

reduce fatigue. The Retrospective Alertness Inventory was used to gather alertness ratings over a 24-hour period based on a scale of 1 (very alert) to 9 (very sleepy) with 0 signifying "asleep." This instrument compared alertness levels at home, at sea, at the beginning of a sea voyage, and at the end of a sea voyage. A significant number of mariners indicated that they experienced fatigue and decreased and inconsistent alertness during their watchstanding period (Sanquist and Raby 26). A substantial drop in alertness was noted on the 8:00 p.m. to midnight watch. The 4:00 a.m. to 8:00 a.m. watch also showed a significant decline in personnel alertness (Sanquist and Raby 33). Sanquist and Raby thus concluded that fatigue was a problem in the U.S. maritime industry (Sanquist and Raby iii).

In 1998, a similar fatigue study was conducted by Stuart Baulk and Louise Reyner who sought to investigate the extent to which poor-quality sleep occurs and to identify the factors contributing to poor sleep quality among crew-members employed on ferry boats.[8] This study investigated the sleep patterns of 12 crew-members from two ferry boats for a two-week period, with one week at sea and one week at home. Background information on the subjects was gathered through a questionnaire and data on sleep quality and duration were collected through the use of wrist-worn actimeters[9] and self-report sleep logs. Alertness was measured using the Karolinska Sleepiness Scale, which ranges from 1 (extremely alert) to 9 (very sleepy). The results of this study indicate that crew-members had significantly less sleep at sea than at home (Baulk and Reyner 26). In addition, crew-members who worked split shifts of six hours on watch, six hours off watch, six hours on watch, and six hours off watch experienced greater sleep disturbance

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[8] Ferry boats are public transport vessels used to convoy passengers and vehicles across waterways.
[9] Actimeters are devices that measure human movement.

and shorter sleep periods than members who worked a single shift of 12 hours on watch and 12 hours off watch (Baulk and Reyner 1). Despite the shorter sleep periods, Baulk and Reyner did not find evidence of reduced alertness or performance among the ferry crew and concluded that fatigue was not a problem onboard the ferry boats studied (Baulk and Reyner 27).

It seems as though Baulk and Reyner's conclusion contradicts those of Sanquist and Raby (Sanquist and Raby iii). Sanquist and Raby focused on tankers and cargo ships, which are vessels that operate offshore, whereas Baulk and Reyner focused on ferry boats, which operate on inland waterways. Like ferry boats, towing vessels operate on inland waterways. Does this imply that fatigue is only a problem for vessels that operate offshore and does not apply to towing vessels or ferry boats?

This would appear to be the case when one looks back on the 1995 study conducted by Cooper and Frasher of the U.S. Coast Guard and American Waterways Operators. Further investigation by Cooper and Frasher showed minimal correlation between fatality and time of day, time of year, vessel type, and weather. Most of the fatalities occurred during routine operations, while the vessel was underway, and in good weather, and fatalities were distributed fairly uniformly by time of day and year (Cooper and Frasher 14). This indicates that that fatigue was not a factor in the crew fatalities on towing vessels, which would support the findings of Baulk and Reyner. However, Sanquist and Raby's prediction about a fatigue problem in the maritime industry is supported by a number of fatigue studies, including the research of A. W. Parker of the Australian Maritime Safety Authority.

A. W. Parker conducted a survey of fatigue, stress, and occupational health and gathered data on the health and lifestyle behaviors of 36.5% of the entire Australian seafaring population, including towing vessel operators. Parker believed that automation, reduced crew sizes, and the influence of multi-skilling had exerted an impact on the physical and mental health of seafarers and had also contributed to increased fatigue under certain working conditions (Parker 22). In 1997, Parker found that 70% of seafarers reported fair to poor to very poor quality of sleep at sea, while 50% reported less than six hours of daily sleep at sea. A large portion of seafarers expressed continual concern about sleep quality at sea (Parker 3). Parker's results concur with Sanquist and Raby's statement about the existence of a fatigue problem in the maritime industry.

In April 2002, the U.S. Coast Guard and American Waterways Operators conducted another study to explore the relationship between fatigue and work-hour regulations. The U.S. Coast Guard believed that fatigue, work hours, and conflicts between company policy and work-hour regulations were factors in crew alertness. A survey of 17 towing companies revealed that alertness problems were caused by heavy weather, watchstanding schedule, and heavy vessel traffic, which were the most common issues cited by mariners. Contributing to these factors were sleep environment, time of day, work environment, energy consumed by the task, fitness for duty, and the captain's responsibilities (Quality Action Team 15).

On May 26, 2002, one month after the 2002 Coast Guard and American Waterways Operators study, the towing vessel *ROBERT Y. LOVE* allided with the Interstate 40 Highway Bridge near Webbers Falls, Oklahoma. The allision, which caused eight vehicles and three tractor-trailer trucks to fall into the river, resulted in 14 fatalities and $30.1 million in damage to the bridge (NTSB vii). The NTSB discovered that the captain, 60 years of age, had lost consciousness and had suffered an abnormal heart rhythm. It was later discovered that the captain was taking prescribed medication and had slept just 23 hours in the five days prior to the accident (NTSB 14). This suggests that fatigue impaired the captain's situational assessment and was a contributing factor to the accident.

3.6.1 Fatigue Issues in the Towing Vessel Industry

It is believed that one of the main fatigue concerns within the towing industry is travel time to the vessel. The licensed officer may be called by the company at a moment's notice and be assigned to a towing vessel to act in the capacity of the captain or pilot. In many cases, this requires last minute travel by automobile or airplane. The time of travel can induce fatigue or jet-lag,[10] especially if the individual is required to fly across several time zones.

As stated by Reilly, Atkinson and Waterhouse, "The symptoms of jet-lag include periodic fatigue during the day and the inability to sleep at night, difficulty in concentrating, mental confusion and disorientation, increased irritability and loss of vigor" (Reilly, Atkinson, and Waterhouse 366). Reilly and Waterhouse also conducted another jet-lag study in 2004. This study involved 11 subjects, ranging in age from 20-39, who recorded their jet-lag and differences in alertness, concentration, motivation, and irritability on a simulated flight from the United Kingdom to Hong Kong. Significant

[10] Jet-lag is a term that applies to a symptom or group of symptoms after a rapid time zone transition. A common symptom often associated with jet-lag is fatigue.

correlations were found between jet-lag and alertness, concentration, and motivation (Waterhouse et al. 128).

In addition to flying to meet their vessel, a captain/pilot may also be required to drive across hundreds of miles of monotonous roads or through the night in order to reach the vessel. The effects of driver fatigue were highlighted in a 1996 study conducted by the Federal Highway Administration. This comprehensive study investigated the factors leading to driver fatigue and loss of alertness. The routes of several tractor-trailers were video recorded under certain driving times and conditions. The results of this 16-week study found that driver fatigue and alertness were strongly influenced by time of day because of circadian rhythms. Drowsiness, which was observed with a face camera, was found to be greater for night-time driving than day-time driving (Wylie et al. 42).

The effects of monotonous road conditions and driver fatigue were analyzed by Pierre Thiffault and Jaques Bergeron in 2003. In this study, 56 university students, average age 24, participated in two 40-minute driving simulators using two road scenarios. The first scenery contained pairs of pine trees at intervals. The second scenery contained a rural setting with occasional houses, farms, and trees. The simulated road was a straight two-lane rural highway. Participants were asked to stay in the center of the right lane. The simulated light wind conditions and natural curved banking of the road created a tendency for the vehicle to deviate toward the right shoulder. The theory was that an alert driver will detect these road deviations early and correct with small steering wheel movements. Steering wheel movements were one of the measures that the Federal Highway Administration used to conduct its study on driver fatigue. A fatigued driver will not detect the small deviations and will have to adjust with larger steering wheel movements to correct road deviations. The results of this study showed a significant increase in fatigue and, thus, steering wheel movements, which were induced by a road environment lacking in sensory stimulation for the driver (Thiffault and Bergeron 389).

Engine noise and vibration are believed to be two common causes of sleep disruption in the towing vessel industry. The engines, generators, and machinery are loud and this noise can disrupt sleep, especially if the towing vessel is small. In 1995, Tamura, Kawada, and Sasazawa conducted a study on the effects of noise from a diesel engine on nocturnal sleep in three healthy males ages 29 to 33. Subjects were exposed to five nights of a steady noise level of 65dB(A) through loudspeakers, which simulated the noise level in the crew quarters onboard a Japanese training ship GINGA-MARU at underway speed. Subject were also exposed to five nights of controlled noise ranging from 35-50dB(A). Electrodes were applied to the individuals, who went to bed at 11:00 p.m. and were awakened at 7:00 a.m. by an alarm clock. On the following morning, these individuals were instructed to answer a sleep questionnaire. The results of that questionnaire showed that sleepiness, sleep maintenance, worry, integrated sleep feeling, and sleep initiation was significantly worse on the noise exposure nights as compared to the noise controlled nights (Tamura, Kawada, and Sasazawa 423-424).

Based on the number of studies that correlate fatigue, alertness, and decision making, one can conclude that fatigue can potentially induce a significant loss of situational awareness.

3.7 Communication and Situational Awareness

As noted by Cooper and Frasher, poor communication among crew-members contributes to the loss of situational awareness (Cooper and Frasher 32). In addition, a study conducted by the U.S. Coast Guard explored communication problems and marine casualties. The purpose of this study was to analyze the most prevalent communications problems associated with 589 marine casualties over a seven-month period. The study procedure analyzed communication in terms of four communication processes: prepare and send message, message transmission, receive and interpret message, and act on message (McCallum et al. 6). The results showed that 87% of communication problems were associated with the prepare and send message process; specifically, the inability of mariners to initiate communication when it would have been appropriate. In almost every marine casualty, at least one mariner did not perceive that a dangerous situation was developing, which is characteristic of situational awareness level 1, and did not communicate the information because he or she did not realize the need. The other reason for the lack of communication is that some mariners did perceive a dangerous situation, but assumed that other persons knew about it and would take action to avoid it (McCallum et al. 28).

In 2003, Koester conducted another study to compare the relationship between behavior and communication. Koester maintained that situational awareness could not be observed in “real-time” environments but could be measured by assessing how crew-members communicate. In a manner similar to his 2001 study, Koester observed bridge communication onboard ferry boats in a navigation simulator; however, unlike the previous study, which focused on mental workload, this study categorized communication into three types: actual, relevant, and general. *Actual communication* refers to a situation related to anti-collision maneuvers, alarms, and management of critical situations. *Relevant communication* is not important to the given situation, but is relevant to the overall safe navigation of the vessel. *General communication* is important neither to the situation nor to the safe navigation of the vessel, but enhances mental workload in order to increase the attention levels of the bridge crew. The results of Koester's study showed that communication levels rose as the situation changed. General communication decreased as actual and relevant communication increased, suggesting that crew-members were attentive to situations that jeopardized the safe navigation of the ferry boat and communicated their concerns to resolve the situation. This pattern indicated situational awareness on levels 1, 2 and 3 as defined by Endsley (Koester 6).

3.8 Drugs and Situational Awareness

There is very little argument concerning the effect of dangerous drugs on behavior and emotion. In fact, most if not all dangerous drugs are regulated by the U.S. Controlled Substances Act (CSA). Controlled substances include both illegal drugs and prescription medication. The CSA places all controlled substances into one of five categories or schedules according to the drug's potential for abuse, physical and psychological dependence, and accepted medical use. Schedule 1 drugs are substances that have a high potential for abuse and no medical use in the United States. Schedule 2 drugs are substances that have a high potential for abuse, but also have an accepted medical use in the United States. However, abuse of a schedule 2 substance can result in a high psychological and physical dependence. Schedule 3 substances have the potential for abuse, but this potential is lower than schedule 1 or 2. Schedule 4 substances have a lower potential for abuse than schedule 3 and have an accepted medical use in the United States. Abuse of a schedule 4 substance has a lower physical or psychological dependence than schedule 3. Schedule 5 substances have a lower potential for abuse than schedule 4 and have an accepted medical use in the United States. Abuse of a schedule 5 substance has a lower physical or psychological dependence than schedule 4 (Drug Information Bible 2).

3.8.1 Characteristics of Controlled Substances

In accordance with 46 CFR Part 16, marine employers are required to conduct drug testing of their mariners. Specifically, under 46 CFR 16.113, urine samples provided by each mariner are tested for the following controlled substances: marijuana, cocaine, opiates, phencyclidine, and amphetamines.

Marijuana is a schedule 1 controlled substance. Delta-9-tetrahydrocannabinol (THC) is responsible for virtually all of marijuana's psychoactive effects (Drug Information Bible 355). Surprisingly, however, there is little scientific knowledge of how marijuana affects the body and the brain. There is no doubt that a high level of THC can induce the common psychological effects of anxiety, panic and hallucinations, reduced ability to concentrate, and impaired short term memory (Drug Information Bible 365). The effects of marijuana on human behavior has been the subject of much controversy.

In November 1985, a study was conducted that examined the effects of THC on aircraft pilots 24 hours after they smoked one 19mg THC cigarette. Ten licensed private pilots participated in the study and were directed to perform a flight simulated landing task. Twenty-four hours after smoking one THC cigarette, the results of the study show that the pilots had difficulty aligning and landing in the center of the runway, including one pilot who landed off the runway. This study demonstrated the behavioral and cognitive difficulties associated with marijuana use (Yesavage et al. 1328).

A 1990 study analyzed the acute and residual effects of THC on performance measures. In this study, three experienced marijuana smokers participated in a series of two-day experimental sessions in which they smoked zero, one, or two marijuana cigarettes. Afterwards, they were tasked to conduct a computerized assessment of cognitive performance, which involved two-letter search, logical reasoning, digit recall, and serial addition/subtraction. Psychromotor performance was measured using a circular lights task. The results indicated that acute marijuana inhalation impairs performance on addition/subtraction tasks and digit recall tasks (Heishman et al. 562).

A 1991 study analyzed the long-term effects of marijuana use on selective attention. In this study, nine long-term cannabis users participated in a complex auditory selective attention task and their results were compared with nine non-users. Subjects were tasked to respond to audible tones of varying pitch and duration. The cannabis users performed worse than the non-users. The results indicated that long term cannabis use may impair the ability to efficiently process information (Solowij, Michie, and Fox 686).

Cocaine is a schedule 2 controlled substance. The common psychological effects of cocaine are anxiety, confusion, depression, hallucinations, suicidal behavior, paranoia, and obsessive/compulsive behavior (Drug Information Bible 331).

Opiates are derived from opium. The main opiates are morphine, codeine, thebaine, and papaverine. Heroin is also an opiate. The pharmacology of heroin and morphine is almost identical. Morphine is a schedule 2 controlled substance that acts on the central nervous system to relieve pain and is highly addictive when compared to other substances and has been known to induce dangerous physical and psychological dependencies. Morphine has also been known to cause visual hallucinations and nightmares. Codeine is a schedule 2 controlled substance for pain relief. Codeine is often obtained from cough syrups that contain codeine and are often taken by drinking the syrup from the bottle (Codeine). Thebaine (aka paramorphine) is a schedule 2 controlled substance and similar to both morphine and codeine, but is known to have stimulatory effects. Papaverine is a schedule 3 controlled substance and is used to treat spasms of the gastrointestinal tract and bile ducts. Heroin is a schedule 1 controlled substance and is used as a pain killer, but also has a high potential for abuse. Heroin is often used as an illegal drug because of its euphoric effects.

Phenylcyclohexyl (PCP) is a schedule 2 controlled substance that is used as a general anesthetic. The main chemical associated with the manufacture of PCP is piperidine. The drug was first introduced as an anesthetic for surgery, but it produced a number of post-operative problems such as feelings of delirium, delusions, visual disturbances, and varying degrees of psychotic behavior. The physical and mental effects of PCP are blurred vision, dizziness, confusion, delirium, loss of concept of size and distance, and out of body sensations (Drug Information Bible 375).

Amphetamine refers to a class of drugs with the suffix amphetamine, such as dextroamphetamine, methamphetamine and other less well-known drugs. Amphetamines or methamphetamines are schedule 2 controlled substances used as stimulants of the central nervous system and have many legitimate medical applications. Nearly all of the illicit amphetamine is methamphetamine. Methamphetamine has a stronger and more pronounced effect on the body and central nervous system than amphetamine. Amphetamines relieve fatigue, reduce the need for sleep, increase energy and confidence, and bring about physical and psychological exhilaration. This drug can also cause delusions, visual and auditory hallucinations, and can lead users to exhibit violent behavior. From the explanations provided by the Drug Identification Bible along with various case studies, it is clear that the acute and long-term effects of the five controlled substances can induce a loss of situational awareness among mariners in the towing vessel industry.

3.9 Alcohol and Situational Awareness

In addition to his situational awareness findings, Margetts identified drunkenness of a crew-member among the factors that induce loss of situational awareness. Fifty-three percent of those surveyed cited alcohol use and nine percent cited drug use as a factor that contributes to marine casualties and near-misses (Margetts 72). During the course of several interviews, one crew-member recalled that “the second officer would take over the watch gassed up and couldn’t evaluate the evasive action necessary to avoid vessels visible less than 5 miles away" (Margetts 72). It is obvious that fatigue and alcohol impair a mariner's ability to judge situations correctly, as was observed and confirmed by Dawson and Lamond.

In 1997, Drew Dawson and Nicole Lamond conducted a study comparing the performance impairment caused by fatigue with that due to alcohol intoxication. Forty subjects participated in two counterbalanced experiments. In one experiment, participants were kept awake for 28 hours and, in the other, participants were asked to consume 10 to 15 grams of alcohol at 30-minute intervals until their mean blood alcohol concentration reached .1 percent. Psychomotor performance was measured at half-hourly intervals using a computer-animated test of hand-eye coordination. Performance decreased significantly under both conditions. Between the tenth and twenty-sixth hours of wakefulness, mean relative performance decreased by .74 percent per hour. For each .01 percent increase in blood alcohol concentration, performance decreased by 1.16 percent. It was ultimately concluded that the effects of moderate sleep loss on performance are greater than the effects of moderate alcohol intoxication (Dawson and Reid 1997, p. 235). Similar findings emerged from a subsequent study in 1999 (Dawson and Lamond 1999, p. 261). A comparison of the 1997 and 1999 studies showed that moderate levels of fatigue produce higher levels of impairment than the proscribed level of alcohol intoxication (Dawson and Reid 1999, p. 261).

In 2000, Graham Marsden and John Leach investigated the effects of caffeine and alcohol consumption on maritime navigation skills. Twelve male subjects experienced in navigation and aged 35 to 52 years participated in the study. The subjects were moderate social drinkers and consumed coffee on a daily basis. Alcohol was administered in the form of 75 milliliters of whiskey at 40% strength, while caffeine was supplied in the form of black coffee without sugar. The researchers administered three tests: a visual search of different targets and backgrounds in a booklet; a chart search, in which each subject was required to locate as many different objects on a chart as he could within 30 or 60 seconds; and a navigation problem solving task, in which each subject was required to convert compass courses and plot a ship's position using compass bearings, longitude, and latitude, and then plan a voyage taking into account time, tidal range, currents, and wind. The results indicated that alcohol impaired participants' ability to perform visual search and significantly impaired their ability to perform navigation problem solving, but it did not affect their chart-search abilities. Caffeine was found to improve visual search but not chart search (Marsden and Leach 23). Combining alcohol and caffeine did not produce significant differences in performance, which may suggest that alcohol and caffeine cancel each other out. Regardless, one can conclude that alcohol and fatigue negatively affect decision making and can prove highly detrimental to situational awareness.

3.10 Social Stress and Situational Awareness

The 1997 findings of A. W. Parker within the Australian seafaring community show not only that 58.2 percent of seafarers consume alcohol at sea at a rate of three drinks per day (Parker 50), but also that negative lifestyle practices, such as smoking, poor nutrition, and excessive consumption of alcohol, are associated with health problems among seafarers (Parker 2). Parker's study also examined levels of stress reported by seafarers and investigated the most common factors that contribute to stress in the maritime industry. Stress was measured using the occupational stress indicator questionnaire. The results show that 80% of mariners reported occasional to frequent stress at sea, with 60% indicating that their stress levels were in the moderate to high category (Parker 52). The greatest source of stress cited by participants was the home/work interface "missing home, being away for long periods, and difficulties associated with the transition between ship and shore were common elements of concern" (Parker 78). Stress levels increased when family members were ill, especially when it was difficult to contact family by telephone (Parker 80, 87). This suggests that seafaring life contributes heavily to marriage breakdown and family stress. This might also explain a concern expressed by Barry Margetts, who found that 27% of respondents in his study felt there was a correlation between emotional stability and vessel accidents (Margetts 71). Parker's study implies that social stress associated with lifestyle behaviors and family problems can induce loss of situational awareness among seafarers.

The impact of social stress on situational awareness cannot be underestimated and offers a logical explanation for Cooper and Frasher's discovery in their 1995 study of towing vessel fatalities that unlicensed crew-members experienced the highest number of fatalities from falls overboard of any other crew position onboard the towing vessel. In the accident reports, crew-members were under the age of 25, had less than one year of experience, and incurred the highest fatality rate relative to all other age and experience categories (Cooper and Frasher 20). Cooper and Frasher concluded that "fatalities are strongly correlated by age, experience level, crew position and crew-member activity at the time of fatality" (Cooper and Frasher 8). This conclusion supports a theory articulated by John Mirowsky and Catherine Ross whose book <u>Social Causes of</u>

Psychological Distress argues that marital status, education, age, job, and income status are related to an individual's level of distress. Mirowsky and Ross also go on to say that married people raising children experience more stress than people who are not raising children, and that young adults experience more stress and depression associated with "getting established" and raising children as compared to middle-aged adults (Mirowsky and Ross 75).

3.11 Mental Workload and Situational Awareness

Meister's theory regarding the effect of mental stimulation on motivation is supported by a 2001 study conducted by Thomas Koester of the Danish Maritime Institute. Koester believed that attention was a function of mental workload and that traditional human factor studies did not adequately capture the relationship between attention and mental workload. Koester was able to measure attention by measuring the levels of communication among bridge watchstanders. This implied that increases in attention level were a function of increases in workload level and communication. To measure communication, Koester used a navigation simulator that offered the advantage of permitting audio and video recordings, the analysis of movements, and behavior and the controlling of environmental factors. In the simulator, Koester devised four scenarios onboard ferry boats, varying the voyages based on mental workload. In this case, workload was represented as variations in the amount of vessel traffic that approached the ferry. The more vessel traffic that was entered into the simulator, the higher the mental workload because of the information processing demands associated with situational awareness levels 1, 2, and 3. Observing the level of communication among bridge watchstanders, Koester determined that watchstander communication about an approaching vessel indicates that attention is paid to it (Koester 7). Koester found that communication increased as other vessels approached the ferry boat and that communication decreased during scenarios of minimal vessel traffic. Based on this information, Koester concluded that low mental workload levels could result in low attention levels and that high workload levels could result in high attention levels (Koester 10). This would support Endsley's theory that situational awareness is at risk when workload demands exceed human capacity or when workload is low (Endsley 19).

Although few studies have been conducted relating workload levels and attention in the maritime industry, one critical study was conducted in the aviation industry in 1997 by Mica Endsley and Mark Rodgers. Although the mode of transportation is different, pilots in the aviation industry operate in a similar manner to that of a towing vessel captain or pilot. In addition, the mental workload associated with tracking other aircraft versus tracking other vessels can significantly influence attention levels. This particular study was conducted to investigate the factors that cause operator error in air traffic control. The study involved 12 air controllers who had their watches monitored by computer video and audio recordings. The controllers were asked to report on their situational awareness during re-creations of their errors. The results of this study found that the workload associated with tracking numerous aircraft was linked to their inability to report situational awareness information. Specifically, workload was found to be high during times of operational error. During high workload, the operators paid less attention to the aircraft and other critical variables needed to maintain situational awareness. Further, as the number of aircraft increased, there were more errors in providing correct location information (Endsley and Rodgers 13). Endsley and Rodgers concluded that the number of aircraft and perceived workload significantly impacted situational awareness (Endsley and Rodgers 19).

Interestingly, this study also found that operational errors occurred during periods of low workload. This implies that passive air traffic monitoring also creates problems with maintaining situational awareness, especially if the automation of air traffic control systems is introduced (Endsley and Rodgers 20). Comparing and contrasting these two studies, the number of vessels that had to be tracked in Koester's study ranged from one to three (Koester 5). In Endsley and Rodgers' study, the average number of aircraft was 12.8 (Endsley and Rodgers 6). One can conclude that mental capacity and ultimately the effect of mental workload on situational awareness depends upon an individuals' perception of workload.

3.12 Redefining Situational Awareness

There seems to be no doubt that situational awareness is the predominant human factor in a majority of accidents in the maritime industry. Although there are very few studies in this area that relate strictly to towing vessels, the majority of situational awareness studies pertaining to the maritime industry can be applied to towing vessels. Researchers have focused on the study of towing vessel accidents as a way of identifying human error types. The accident studies have provided a general breakdown of human error types, but have proven insufficient for conducting further root cause analysis of loss of situational awareness. If situational awareness is the predominant human factor in the towing vessel industry, then why hasn't anyone statistically verified the factors that influence it?

Chapter 4

Methodology

4.1 Theory

In the marine towing industry, situational awareness can be affected by fatigue, lack of communication, drugs, alcohol, social stress and mental workload. Not only do these factors influence situational awareness, but they can also induce marine casualties and near-miss situations. Although most companies in the industry have programs in place that consider the contribution of human error to accidents, these programs examine human error in a superficial way by looking at the mistakes made by towing vessel operators. Simply identifying the mistake an operator made without studying the underlying causes of the error will not prevent recurrence of that marine casualty. Only by analyzing the factors that underpin situational awareness can substantial progress be made in reducing the frequency of towing vessel accidents. Thus, this research ultimately seeks to determine the predominant factor affecting situational awareness and to recommend actions that can be taken to address this factor.

4.2 The Problem With Accident Studies

Traditional methods of identifying human error and loss of situational awareness involve the analysis of prior marine casualties. While these accident reports have produced an expansive breakdown of human error, they have not proven useful for subsequent analysis. In fact, a number of human factor case studies identified in the literature review cite inaccuracies from the accident database, particularly in the area of human factors. Grech and Horberry noted this problem in their study of situational awareness levels in the maritime industry and acknowledged that “confining our analyses to accident reports only and not to incident and near-miss reports or even to normal operations might have resulted in other loss of situational awareness not being captured” (Grech and Horberry 4).

This problem was further highlighted by the U.S. Coast Guard and American Waterways Operators in two case studies. The first, which sought to determine the cause of towing vessel fatalities, the parties noted that they were not able to obtain causal factors from the Coast Guard database and mentioned that “the database does a good job of outlining what happened and is useful for generating fatality profiles, but it does not explain why an event happened” (Cooper and Frasher 7). In the second case study, which investigated towing vessel bridge allisions, the U.S. Coast Guard noted that the details necessary to determine causal factors were not available in the database and that the members of the work group therefore had to rely on their own judgment, operational experience, and knowledge of a particular waterway when interpreting the limited information from the casualty reports (Allegretti and Pluta 15). Similar findings were noted by Margetts (1976) and the American Bureau of Shipping (2004). These studies highlight a major disadvantage of the accident database: accident reports neither address near-miss situations nor reflect the expertise of highly experienced towing vessel operators, who might be able to provide substantial clarification of factors affecting situational awareness.

4.3 Preliminary Research

Preliminary research was conducted from February 2007 to June 2007. The purpose of this research was to gather knowledge of towing vessel operations. A basic questionnaire was developed that solicited opinions and perceptions of situational awareness in the towing vessel industry. However, this questionnaire was, at best, basic and the data was insufficient to support research findings. A more detailed questionnaire was needed in order to provide enough evidence to support research findings. Preliminary research included mailed surveys and personal interviews with licensed captains and pilots onboard towing vessels operating on the Lower Mississippi River, GIWW, and the Atchafalaya River. Further research was conducted with licensed captains and pilots at the U.S. Coast Guard Regional Exam Center. Interviews were also held with towing company officials, specifically the safety and health manager.

From June 4, 2007 to June 8, 2007 the author was invited as a guest onboard the towing vessel A. The towing vessel A transited downbound on the Lower Mississippi River from Memphis, TN to New Orleans, LA and initially pushed 25 hopper barges before taking on an additional 10 hopper barges. The purpose of the transit was to observe the daily operations onboard a towing vessel and provide clarification of the preliminary interviews.

4.4 Integrated Survey and Interviews

The survey portion of the interview consisted of six sections and was developed and revised based on studies of situational awareness in the maritime domain and interviews with towing vessel captains and pilots. The final survey was revised several times prior to interview (see appendix A). Section one of the survey solicits background information; responses in this section were used to determine the experience levels of the participants and help ensure accuracy of the data. Section two highlighted connections between fatigue and situational awareness. Section three identified the relationship between communication and situational awareness. Section four addressed the relationship between dangerous drugs, alcohol, and situational awareness. Section five highlighted the relationship between social stress and situational awareness. Section six of the survey identified connections between mental workload and situational awareness.

Telephone interviews were conducted with 20 towboat captains and pilots representing 16 towing vessel companies. Phone numbers were obtained from the U.S. Coast Guard oversize tow permit application and through personal interviews. A comparison of the situational awareness factors was conducted and the predominant factor was identified.

4.5 Research Limitations

The scope of this research is limited to towing vessel captains and pilots who operate towing vessels on the Gulf Intracoastal Waterway (GIWW). Specifically, towing vessels that push at least six or more barges or the equivalent of six barges (70ft x 750ft) and operate on the GIWW (west of the Harvey Locks or west of Algiers Locks). Research does not include interviews of other crewmembers such as deckhands, engineers, or cooks.

The limitations of the waterway in which these vessels operate were necessary because of the different environmental factors, for example, the difference in currents and sedimentation between the Lower Mississippi River and the GIWW might have skewed the data for mental workload. Further, captains operating in the vicinity of New Orleans or Baton Rouge on the Lower Mississippi River might have reported higher mental workload levels due to the amount of vessel traffic in the area.

Limitations to the type of towing vessel were also necessary to ensure consistent data. For example, fatigue or stress data between a fleet boat and a trip boat might have been different because fleet boats usually operate for only 12 hours. A trip boat usually operates over the course of several days and the captain must live on the vessel. Thus, the social stress levels and fatigue levels could be different.

4.6 Expected Results

The findings identified the predominant factor affecting situational awareness and demonstrated how this factor can contribute to virtually every marine casualty in the towing vessel industry. This study was also expected to highlight trends in the relationship between the participants' background and situational awareness. Interviews of towing vessel operators were expected to reveal new variables that affected situational awareness, but that have not yet been verified in the maritime industry. The results would suggest areas for future research.

Chapter 5

Findings

5.1 Background of Participants

Twenty towing vessel captains representing 16 towing vessel companies participated in this study. Their ages ranged from 33 to 61 years with an average age of 47.6 years. All participants held U.S. Coast Guard licenses with valid towing endorsements. Experience as a licensed towing vessel operator ranged from 8 to 37 years with an average experience of 23.3 years and a median of 20 years. Time spent underway ranged from 14 days to 60 days per tour of duty with an average underway time of 24.8 days per tour and a median time of 20 days per tour. When asked to describe their current health, nine participants stated that they were in excellent health, while seven stated they were in good health and 4 stated they were in fair health.

5.2 Fatigue

During the interviews, fatigue was described as a state of exhaustion that affects concentration and induces feelings of concern about having a towing vessel accident.

Table 5.1. Methods to address fatigue.

NOISE and VIBRATION INSULATION	**10**
ENFORCEMENT OF 12 HOUR RULE	**20**
TRAVEL ARRANGEMENTS	**17**

Table 5.1 is a breakdown of methods employed by towing vessel employers to address fatigue. This table is also a measure of company awareness of fatigue. The results of this study show that ten vessels on which captains are currently employed (50%) have installed noise and vibration absorbing barriers onboard their vessels. Noise and vibration barriers include those engineering modifications that absorb and reduce the effects of engine noise and vibration in the vessel's crew quarters and include insulation within the flooring and bulkheads as well as soundproof doors. This does not include muffler systems, which only reduce engine noise, but not engine vibration.

Under 46 CFR 15.705 (c), an operator steering a towing vessel greater than 26ft cannot work more than 12 hours in a 24-hour period. The results from Table 5.1 show that all companies enforce the "12 hour rule" by implementing a six-hour split watch schedule among their captains.

Seventeen companies (85%) either make or accommodate travel arrangements for their captains as a way of preventing fatigue caused by travel to the vessel. This also allows the captain to sleep for a minimum of six hours prior to relieving the watch instead of relieving the watch upon arrival to the vessel. This is regulated by 46 USC 8104(a), which requires 6 hours "off duty" for the officer relieving the watch.

Table 5.2. Crew endurance training.

OFTEN	**8**
SELDOM	**7**
NEVER	**5**

Table 5.2 measures how many companies take measures to conduct fatigue or crew endurance training. Table 5.2 shows that 40% of companies who employ the

licensed officers interviewed, conduct this training on a regular basis, while 35% conduct this training on an occasional basis and 25% of companies never conduct this training.

Table 5.3. Fatigue from travel.

OFTEN	**1**
SELDOM	**1**
NEVER	**18**

Table 5.3 measures whether travel by automobile or airplane from home to the vessel assignment induces fatigue. This question simulates a captain receiving an assignment from the company and being tasked to meet the towing vessel at a certain location for crew change. This table also measures the effectiveness of company arranged transport to and from the vessel (Table 5.1, travel arrangements). According to Table 5.3, 90% of participants did not report any feelings of exhaustion upon arrival to the vessel.

Table 5.4. Fatigue from engine noise.

OFTEN	**0**
SELDOM	**5**
NEVER	**15**

Table 5.5. Fatigue from engine vibration.

OFTEN	**0**
SELDOM	**5**
NEVER	**15**

Tables 5.4 and 5.5 measure whether engine noise and vibration prevent the captain from falling asleep. According to Tables 5.4 and 5.5, 75% of participants did not

express any feelings of fatigue due to engine noise and vibration. Twenty-five percent of participants occasionally experience fatigue due to engine noise and vibration.

Table 5.6. Fatigue during single tour.

OFTEN	**1**
SELDOM	**5**
NEVER	**14**

Table 5.6 measures whether fatigue occurs at the end of one tour. Table 5.6 may also be a good indicator of the effectiveness of company actions to prevent fatigue (Table 5.1). Table 5.6 shows that 70% of participants did not experience fatigue at the end of a single tour, while 25% occasionally experience fatigue at the end of a tour.

Table 5.7. Sleep quality.

GOOD	**15**
FAIR	**4**
POOR	**1**

Table 5.7 compares sleep quality underway compared to sleep quality at home. Seventy-five percent of participants reported good sleep conditions while underway, while 20% reported fair sleep conditions.

Table 5.8. Hours slept.

LESS THAN 4	**0**
4 TO 8	**4**
8 TO 10	**15**
OVER 10	**1**
AVERAGE	**8.5**

Table 5.8 measures how many hours a captain sleeps in a 24-hour period while underway. Seventy-five percent of participants slept at least 8 to 10 hours per day. Twenty percent of participants slept at least four to eight hours per day. The average hours of sleep in a 24-hour period, was 8.5 hours.

Table 5.9. Shift preference.

MULTI	**16**
12 HOUR	**2**
NO DIFFERENCE	**2**

Table 5.9 compares preferences between one 12-hour shift and multi-shifts in a 24-hour period. Table 5.9 shows that 80% of participants prefer the multi-shift, specifically the six hours on followed by six hours off, and believe they experience less fatigue during this watch schedule as opposed to a single 12-hour shift.

5.3 Communication

Communication was described as communication with crewmembers, other vessels, or VTS and how much this helps them in attaining situational awareness.

Table 5.10. Deckhands report the results of rounds.

OFTEN	**19**
SELDOM	**0**
NEVER	**1**

Table 5.11. Deckhands report hazards to navigation at night.

OFTEN	**19**
SELDOM	**0**
NEVER	**1**

Table 5.12. Deckhands call out distances from barge to pier.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.13. Deckhands call out distances from barge to lock wall.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.14 Deckhands call out distances from barge to bridge fender.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

The purpose of Tables 5.10, 5.11, 5.12, 5.13, and 5.14 is to measure the level of communication between the captain and his or her deckhands. The results from these tables show that 95% of captains have excellent communication with their deckhands and the deckhands can be trusted to report the results of their scheduled rounds and be trusted to report hazards to navigation at night. Further, deckhands can be relied upon to act as a lookout and call out distances between the barge and a pier when the towboat is mooring, a barge and lock wall or bridge fender when the towboat is transiting through these structures.

Table 5.15. Understanding of wind and current upon watch relief.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Table 5.16. Understanding of location of other vessels and hazards to navigation upon watch relief.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Tables 5.15 and 5.16 were used to measure the level of communication between the captain and the pilot/relief captain during watch relief. Specifically, Tables 5.15 and 5.16 measure the quality of communication between captain and pilot during watch relief through an understanding of the weather and location of other vessels. The results from Tables 5.15 and 5.16 indicate that all captains and relief captains are highly confident in the quality of communication and have a firm grasp of the winds, tides, currents, and vessel locations prior to watch relief.

Table 5.17. Understanding of my navigational light configuration.

HIGHLY	**20**
SELDOM	**0**
NEVER	**0**

The purpose of Table 5.17 is to measure the captain's understanding of his or her vessel's navigational lights. As stated in Chapter 2, navigational lights represent a means of non-verbal communication between two vessels. Table 5.17 is also a measure of the captain's understanding of the Navigational Rules (specifically rule 24) as they apply to his or her vessel. The results from Table 5.17 indicate that all captains are highly confident in their understanding of navigational light configuration.

Table 5.18. Communication of passing arrangements via VHF-FM radio with other commercial vessels.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Table 5.19. Other commercial vessels respond via VHF-FM radio.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.20. Other commercial vessel understanding of 1 and 2 whistle.

HIGHLY	**20**
SELDOM	**0**
NEVER	**0**

Table 5.21. Commercial vessel understanding my navigational light configuration.

HIGHLY	**20**
SELDOM	**0**
NEVER	**0**

The purpose of Tables 5.18, 5.19, 5.20, and 5.21 is to measure the communication between the captain of the towboat and the captain of another commercial vessel through VHF-FM radio and non-verbal communication (whistle signal and navigational lights). A commercial vessel was defined as another towing vessel, crew boat, or offshore supply vessel. These vessels are the most common to the GIWW, Atchafalaya River, and Port Allen Alternate Route. Table 5.18 shows that all of the participants frequently communicate passing arrangements with captains onboard other commercial vessels.

Table 5.19 shows that 95% of other commercial vessels reply to the initial passing arrangement via VHF-FM radio. Table 5.20 shows that all participants feel highly confident that the other captain understands the meaning of “1-whistle” and “2-whistle” passing. One (1) whistle passing means that two vessels in a meeting situation, pass each other on their port (left) side. Two (2) whistle passing means that two vessels in a meeting situation, pass each other on their starboard (right) side. Table 5.21 shows that all participants feel highly confident that the captain onboard the other commercial vessel understands the navigational light configuration of the other towboat.

Table 5.22. Communication of passing arrangements via VHF-FM radio with other recreational vessels.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Table 5.23. Recreational vessel respond via VHF-FM radio.

OFTEN	**1**
SELDOM	**12**
NEVER	**7**

Table 5.24. Recreational vessel understanding of 1 and 2 whistle signals.

HIGHLY	**1**
SELDOM	**9**
NEVER	**10**

Table 5.25. Recreational vessel understanding of my navigational lights.

HIGHLY	**1**
SELDOM	**9**
NEVER	**10**

The purpose of Tables 5.22, 5.23, 5.24, and 5.25 are to measure the communication between the captain of the towboat and the operator of recreational vessels through VHF-FM radio and non-verbal communication (whistle signals and navigational lights). A recreational vessel was defined as a privately owned vessel operated solely for pleasure and not for profit.

Table 5.22 shows that all participants attempt to initiate passing arrangements with recreational vessels via VHF-FM radio. However, Table 5.23 shows that recreational vessel operators frequently respond to the towboat captain via VHF-FM radio only 5% of the time, while 60% of recreational vessel operators occasionally respond and 35% of recreational vessel operators never respond to the initial passing arrangement on VHF-FM radio.

Tables 5.24 and 5.25 show that 50% of towboat captains are neither confident that the recreational vessel operator understands the meaning of “1 whistle” and “2 whistle” passing, nor that the recreational vessel understands the navigational light configuration of the towboat. Forty-five percent of captains are seldom confident that the recreational vessel understands the meaning of “1 whistle” and “2 whistle” passing and seldom confident that the recreational vessel understands the navigational light configuration of the towboat.

Table 5.26. Use of whistle or spotlight to attract attention.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Table 5.27. Maneuvering response from recreational vessel.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

The purpose of Tables 5.26 and 5.27 are to measure the communication between the captain of the towboat and the operator of another recreational vessel through use of the vessel's whistle or spotlight. Furthermore, Tables 5.26 and 5.27 measure how often a captain uses the whistle or spotlight to attract the attention of other recreational vessels if no response is made on VHF-FM radio. The results from Table 5.26 indicate that all participants often resort to the whistle or spotlight to attract the attention of the recreational vessel. Upon hearing the whistle blast or seeing the spotlight, the recreational vessel often takes action to avoid collision.

Table 5.28. Spotlight use.

OFTEN	**1**
SELDOM	**17**
NEVER	**2**

Table 5.28 measures how often the captain uses the spotlight as a means of communication with other commercial vessels. The purpose of this table is to measure how often alternate means of communication are utilized in addition to the VHF-FM radio. The results from Table 5.28 indicate that 85% of the participants seldom use their spotlight or whistle when making passing arrangements with other commercial vessels.

Table 5.29. Usefulness of radar.

VERY	**20**
SELDOM	**0**
NEVER	**0**

Table 5.30. Usefulness of AIS/electronic charts.

VERY	**20**
SELDOM	**0**
NEVER	**0**

Tables 5.29 and 5.30 measure the usefulness of pilothouse navigational equipment as a means of non-verbal communication and avoiding potential collisions with other vessels. The results from both tables indicate that all participants find both radar and electronic charts/AIS to be a very useful means of collision avoidance with other vessels.

Table 5.31. Usefulness of VTS.

VERY	**20**
SELDOM	**0**
NEVER	**0**

Table 5.31 measures the usefulness of VHF-FM radio communication with VTS as a means of avoiding potential collisions with other vessels. The results from Table 5.31 indicate that all participants find communication with VTS to be a very useful means of collision avoidance with other vessels.

5.4 Drugs and Alcohol

Drugs were defined as any illegal drug and prescription medication that impair situational awareness. Alcohol was defined as any substance that can cause symptoms of drunkenness.

Table 5.32. Last drug test.

LAST 3 MOS	**14**
BTWN 3 - 6 MOS	**4**
BTWN 6 – 12 MOS	**2**
OVER 1 YEAR	**0**
NEVER	**0**

Table 5.32 measures the last time the captain was tested for use of dangerous drugs by their employer. This is also a measure of whether a company enforces the U.S. Coast Guard/ Department of Transportation drug testing procedures. Table 5.32 shows that 70% of participants were drug tested within the last three months, while 20% were drug tested within the last six months and 10% were drug tested within the last year.

Table 5.33. Alcohol testing kits onboard.

YES	**15**
NO	**5**

Table 5.34. Alcohol testing conducted within 2 hours.

AWARE	**11**
NOT AWARE	**9**

Tables 5.33 and 5.34 measure whether a company takes proactive measures to enforce alcohol-testing regulations through the use of onboard alcohol testing kits. Table 5.33 shows that 75% of the towing vessels in this study have alcohol testing kits onboard and 25% do not. Table 5.34 shows that 55% of the participants are aware that they are supposed to conduct alcohol testing within two hours following a serious marine incident (a marine casualty meeting the criteria of 46 CFR 4.03-2).

Table 5.35. Aware of consequences of positive test.

AWARE	**20**
NOT AWARE	**0**

Table 5.36. Consequences versus prevention.

PREVENT	**19**
NOT PREVENT	**1**

Tables 5.35 and 5.36 measure whether the captain is aware of the U.S. Coast Guard Suspension and Revocation (S&R) proceedings against their license if found positive for use of dangerous drugs and alcohol. These tables also measure the effectiveness of the Coast Guard's S&R proceedings in prevention of drug and alcohol use among towing vessel captains. Table 5.35 shows that all captains are aware of the consequences of a positive drug and alcohol test. Table 5.36 shows that 95% of captains believe these consequences are a significant deterrent to the use of dangerous drugs and alcohol.

Table 5.37. Introduction of drugs/alcohol onboard vessel.

OFTEN	**1**
SELDOM	**3**
NEVER	**16**

Table 5.37 measures the effectiveness of a company's drug and alcohol program. According to the results from Table 5.37, 80% of captains stated that drugs and/or alcohol were never introduced onboard any of the company vessels without the company's knowledge. Fifteen percent of captains stated that drugs and/or alcohol were occasionally introduced onboard the company vessels without the company's knowledge, and 5% stated that drugs and/or alcohol were frequently introduced onboard the company vessels without the company's knowledge.

Table 5.38. Types of prescription drugs taken.

BLOOD PRESSURE	**5**
TYPE 1 DIABETES	**2**
ACID REFLUX	**2**
CHOLESTEROL	**3**
NONE	**11**

Table 5.39. Effect of prescription drugs.

MAJOR	**0**
LITTLE	**0**
NONE	**20**

Tables 5.38 and 5.39 measure the effect of prescription drugs. Participants were asked to state the type of prescription drugs taken. Twenty-five percent of participants were taking medication to control blood pressure. Ten percent were taking medication to

control type 1 diabetes. Ten percent were taking medication to control acid reflux, and 15% were taking medication to lower cholesterol. Table 5.39 shows that these prescription medications have no effect on the ability of these participants to operate a towboat.

5.5 Social Stress

Social stress is a physical or psychological response to events from society that can lead to loss of situational awareness.

Table 5.40. Yearly salary.

$60,000 - $80,000	**4**
$80,000 - $100,000	**6**
Over $100,000	**10**

Table 5.40 is a breakdown of the yearly earnings for 2006. It is also a measure of socio-economic status. Approximately 50% of captains earn over $100,000 per year. Thirty percent of captains earn between $80,000 to $100,000, and 20% earn between $60,000 and $80,000.

Table 5.41. Education level.

9^{th} GRADE	**2**
10^{th} GRADE	**3**
11^{th} GRADE	**2**
12^{th} GRADE	**12**
13^{th} GRADE	**1**
AVERAGE	**11**

Table 5.41 is a breakdown of the highest education completed. It is also a measure of socio-economic status. Sixty percent of participants have completed high school. Ten percent completed 9th grade, 15% completed 10th grade, 10% completed 11th grade, and 5% completed their freshman year at college.

Table 5.42. Worry about losing job.

OFTEN	**1**
SELDOM	**3**
NEVER	**16**

Table 5.42 measures social stress associated with worry about losing one's job. It is also an indicator of socio-economic status. Eighty percent of participants do not worry about losing their job, while 15% occasionally worry about losing their job and 5% frequently worry about losing their job.

Table 5.43. Marital status.

MARRIED	**16**
SINGLE	**4**

Table 5.43 is a breakdown of marital status among the participants. Table 5.43 could also be a measure of family stress potential. According to Mirowski and Ross, married people in supportive relationships are not as likely to suffer from feelings of social stress compared to single people (Mirowski and Ross 85). However, married people raising children are more likely to suffer from feelings of social stress (Mirowski and Ross 90). Table 5.42 shows that 80% of captains are married and 20% are single.

Table 5.44. Worry about relationship with family.

<u>OFTEN</u>	**2**
<u>SELDOM</u>	**2**
<u>NEVER</u>	**12**
<u>NOT APPLICABLE</u>	**4**

Table 5.45. Worry about supporting family/paying bills.

<u>OFTEN</u>	**0**
<u>SELDOM</u>	**2**
<u>NEVER</u>	**14**
<u>NOT APPLICABLE</u>	**4**

Table 5.46. Usefulness of email/cell phone for relationship.

<u>VERY</u>	**16**
<u>SELDOM</u>	**0**
<u>NEVER</u>	**0**
<u>NOT APPLICABLE</u>	**4**

Tables 5.44, 5.45, and 5.46 measure social stress associated with family. The results from Table 5.44 indicate that 75% of the married participants never worry about the stability of the relationship with their family when underway and away from their family. However, 25% of the married participants worry about their relationship stability. Table 5.45 shows that 87.5% of participants do not worry about their ability to pay the bills and only 12.5% worry about being able to support their family and pay the bills. Table 5.46 shows that all married participants find e-mail and cell phones to be very helpful in maintaining the stability of the relationship with their family.

Table 5.47. Tension with crew-members.

OFTEN	**1**
SELDOM	**7**
NEVER	**12**

Table 5.47 measures social stress associated with unsupportive relations with the vessel's crew. Sixty percent of captains have supportive relations with their crew and did not report any signs of crew tension. Thirty-five percent seldom have tension with their crew, and 5% have frequent tension with the vessel's crew.

5.6 Mental Workload

Mental workload was defined as the amount of mental work associated with information processing while steering a towing vessel, communicating with other vessels, and using electronic charts and radar.

Table 5.48. Worry about other towing vessels.

OFTEN	**4**
SELDOM	**10**
NEVER	**6**

Table 5.48 compares the captain's concern when navigating in the vicinity of other towing vessels. These results would be an indicator of attention distraction associated with mental workload. Table 5.48 indicates that 50% of participants have occasional worries about the abilities of the other captain on another towing vessel, while 20% do not worry about the abilities of the other captain on another towing vessel. Only

30% had frequent worries about the abilities of the other captain on another towing vessel.

Table 5.49. Worry about recreational vessels.

OFTEN	**17**
SELDOM	**3**
NEVER	**0**

Table 5.49 presents the captain's level of concern when navigating in the vicinity of other recreational vessels. These results would be an indicator of attention distraction associated with mental workload. Table 5.49 indicates that 85% of participants have frequent worries about the abilities of the operator on another recreational vessel to act in a predictable and responsible manner, while 15% have occasional worries about the abilities of the other captain on another recreational vessel.

Table 5.50. Boredom proneness when navigating in areas with little to no vessel traffic.

OFTEN	**5**
SELDOM	**9**
NEVER	**6**

Table 5.50 measures boredom proneness when navigating in areas with little-to-no vessel traffic. This table is also an indicator of both low workload and complacency potential. Twenty-five percent of participants experience frequent boredom when navigating in non-busy traffic areas, while 45% experience occasional boredom and 30% do not feel bored when operating in non-busy traffic areas.

Table 5.51. Cell phone calls distraction in busy area.

OFTEN	**6**
SELDOM	**9**
NEVER	**5**

Table 5.52. Cell phone calls distraction in non-busy area.

OFTEN	**1**
SELDOM	**12**
NEVER	**7**

Tables 5.51 and 5.52 compare distractions associated with cell phone calls from the company when navigating around other vessels or busy traffic areas compared to non-busy areas. These results would be an indicator of attention distraction associated with workload levels. Table 5.51 indicates that 30% of captains experience frequent distractions from cell phone calls from the company in busy traffic areas. Forty-five percent of captains experience occasional distraction from cell phone calls from the company in busy traffic areas. Twenty-five percent of captains experience frequent distractions from cell phone calls from the company in busy traffic areas.

Table 5.52 indicates that 5% of captains experience frequent distractions from cell phone calls from the company in areas with little vessel traffic. Sixty percent of captains experience occasional distractions from cell phone calls from the company in areas with little vessel traffic. Thirty-five percent of captains experience frequent distractions from cell phone calls from the company in areas with little vessel traffic.

Table 5.53. Most common navigation tool for locating navigational aids.

ELECTRONIC CHART	**19**
PAPER CHARTS	**20**
RADAR	**20**
PUBLICATIONS / NTM	**20**

Table 5.54. Most common navigation tool for vessel locations.

AIS	**20**
RADAR	**20**
VHF-FM	**20**

Table 5.55. Comparison of radar with AIS.

MORE RELIABLE	**15**
AS RELIABLE	**4**
NOT AS RELIABLE	**1**

Table 5.56. Comparison of electronic chart with paper chart.

MORE RELIABLE	**6**
AS RELIABLE	**8**
NOT AS RELIABLE	**6**

The purpose of Tables 5.53, 5.54, 5.55, and 5.56 is to measure the captain's reliance on electronic charts for navigational data as compared to paper charts and radar. These tables would also be an indicator of complacency potential. The results from Table 5.53 show that all captains rely equally on the electronic chart, paper charts, radar, publications, and notice to mariners for obtaining information on navigational aids. In one interview, the electronic chart was not onboard the towing vessel. Table 5.54 shows that captains rely equally on AIS, radar, and VHF-FM radio for knowing the locations of other vessels in the area when not in visual sight of each other.

Table 5.55 shows that 75% of the participants feel that radar is more reliable than AIS for knowing the location of other vessels, while 20% of the participants feel that radar is as reliable as AIS for knowing the location of other vessels and 5% feel that radar is not as reliable as AIS for knowing the location of other vessels.

Table 5.56 shows that 30% of the participants feel that paper charts are more reliable than electronic charts for obtaining information on navigational aids and landmarks. Forty percent of the participants feel that paper charts are as reliable as electronic charts for obtaining information on navigational aids and landmarks. Thirty percent of the participants feel that paper charts are not as reliable as electronic charts for obtaining information on navigational aids and landmarks.

Table 5.57. Difficulty using electronic charts.

OFTEN	**3**
SELDOM	**2**
NEVER	**14**
NOT ONBOARD	**1**

Table 5.58. Difficulty using AIS transponder.

OFTEN	**3**
SELDOM	**1**
NEVER	**16**

Tables 5.57 and 5.58 compare distractions associated operating the electronic charts and the AIS device. These results would be an indicator of attention distraction

associated with mental workload. The results from Table 5.57 show that 73.7% of participants stated that they do not have difficulty operating the electronic chart system. Sixteen percent (3 out of 19) of participants stated they experience frequent difficulty operating the electronic chart system. Eleven percent (2 out of 19) of participants stated they experience occasional difficulty operating the electronic chart system.

The results from Table 5.58 show that 80% of participants stated that they do not have difficulty operating the electronic chart system. Fifteen percent of participants stated they experience frequent difficulty operating the electronic chart system. Five percent of participants stated they experience occasional difficulty operating the electronic chart system.

Table 5.59. Reliance on engine alarms.

OFTEN	**0**
SELDOM	**20**
NEVER	**0**

Table 5.60. Confidence in engines.

HIGHLY	**19**
SELDOM	**1**
NEVER	**0**

Tables 5.59 and 5.60 measure the captain's reliance on engine gauges and alarms as a means of determining a potential engine casualty. A common marine casualty associated with towing vessels involves the loss of propulsion. The results would be an indicator of complacency potential. Table 5.59 shows that all participants seldom rely on the alarms and gauges in the pilothouse as an indicator of engine trouble. However,

Table 5.60 shows that 95% of participants are highly confident that the engines are running at optimal performance and 5% are sometimes confident that the engines are running at optimal performance.

Table 5.61. Number of GIWW transits.

MORE THAN 100	**18**
LESS THAN 100	**2**

Table 5.62. Same lock routine.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.63. Same bridge routine.

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.64. Same vessel(s) encountered (commercial vessels).

OFTEN	**19**
SELDOM	**1**
NEVER	**0**

Table 5.65. Same passing arrangements (commercial vessels).

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Tables 5.61, 5.62, 5.63, 5.64, and 5.65 measure the captain's complacency potential with respect to the routine and automation of course and speed through the Gulf Intracoastal Waterway (GIWW). The results would be an indicator of complacency potential. Table 5.61 shows that 90% of the participants have pushed barges on the GIWW more than 100 times. Tables 5.62 and 5.63 show that 95% of captains often steer the same course and speed through a lock and bridge. Further, Table 5.64 shows that 95% of captains often encounter the same commercial vessels on subsequent transits on the GIWW. Table 5.65 shows that these captains often make the same passing arrangements with other commercial vessels on the GIWW.

Table 5.66. Reliability on wind and current instruments.

OFTEN	**20**
SELDOM	**0**
NEVER	**0**

Table 5.67. Caught by surprise from wind or current.

OFTEN	**0**
SELDOM	**20**
NEVER	**0**

The purpose of Table 5.66 is to measure the captain's opinion of the reliability of wind and current gathering instruments such as the barge's jackstaff, information from the VTS or other vessels, tide tables, etc. Table 5.67 is an indicator of complacency potential with regard to reliance on wind and current instrumentation. Table 5.66 shows that wind and current gathering instrumentation is often highly reliable. However, Table

5.67 shows that the captain occasionally encounters situations where he or she is caught by surprise by the winds and currents.

Chapter 6

Discussion of Findings

6.1 Fatigue Analysis

The impact of fatigue on situational awareness was minimal for the participants. These results can be attributed to company awareness of fatigue issues, as well as the integration of crew endurance management systems (CEMS) as a part of normal business. In addition, companies have taken action to install engine noise and vibration insulation, as well as to ensure captains do not operate more than 12 hours in any 24-hour period and to provide travel arrangements to and from the vessel to prevent operator fatigue upon arrival to the vessel. These actions have resulted in reduced fatigue levels (see Tables 5.6, 5.7, and 5.8).

However, as encouraging as these results are the inability of many companies to ensure protection from hazardous noise and vibration from the vessel's engine room also increases the potential for fatigue. In other words, the effects of hazardous noise and vibration in the crew quarters from the engine room are still present, but captains are not fatigued because they are forced to adapt to the noise and whole body vibration.

The success of addressing fatigue among towing vessel captains is heavily dependent upon a company's awareness of the fatigue problem and its actions to address it. However, the overall trend appears to be favorable. Over the course of several years, we have seen more and more companies jump on the bandwagon and take initiative to address fatigue, including the integration of noise reduction insulation.

6.1.1 Company Awareness of Fatigue Issues

The majority of towing vessel companies were aware of the fatigue issues facing the industry and many companies have proactively sought out administrative and engineering solutions to address the problem (Table 5.1). In fact, some companies have addressed crew endurance and fatigue by installing noise and vibration insulation in decks, bulkheads, and doors to reduce and prevent the spread of engine-room noise and vibration to the crew quarters (Table 5.1).

Many participant companies have programs in place to accommodate travel arrangements for their captains (Table 5.1). These administrative measures allow captains to obtain sufficient rest prior to arrival to the vessel and an additional rest period of at least five hours once the captain arrives to the vessel and prior to relieving the watch (Table 5.3). In other words, these accommodations prevent the captain from having to drive or fly several hours to meet the vessel and then assume a six-hour watch immediately upon arrival to the vessel.

The results of this study show that all participant companies have programs in place to prevent a captain from operating more than 12 hours in a 24-hour period (Table 5.1). Under 46 CFR 15.705 (c), an operator steering a towing vessel greater than 26ft cannot work more than 12 hours in a 24-hour period. The implementation of split watch schedules (i.e., six hours on, six hours off) have not only prevented captains from operating more than 12 hours in a 24-hour period, but captains feel more energetic on a split watch schedule as opposed to one 12-hour shift (Table 5.9).

Seventy-five percent of captains reported good sleep conditions while underway (Table 5.7) with an average of 8.5 hours of sleep in a 24-hour period (Table 5.8).

Furthermore, 70% of participants did not experience fatigue at the end of the tour (Table 5.6). These are good indicators that the company's administrative and engineering enforcement of fatigue regulations are effective.

6.1.2 Crew Endurance Management

According to table 5.2, at least 75% of companies that employ the respondents offer crew endurance or fatigue training to their captains either on an occasional or regular basis (Table 5.2). In fact, the industry awareness of fatigue issues can be attributed to the U.S. Coast Guard's Crew Endurance Management System (CEMS). CEMS is a voluntary program that was formed as part of a joint industry-government partnership in January 2003. The concept of crew endurance was spearheaded by Carlos A. Comperatore and Pik Kwan Rivera. The central theme of this report was that crewmember endurance is not only a function of lack of sleep, but also a function of erratic work schedules, extreme temperature, frequent separation from loved ones, and heavy workload (Comperatore and Rivera 3). The report goes into detail on instructions for implementing a program of practices for controlling risk factors that affect crewmember endurance in the commercial maritime industry.

In December 2005, the Coast Guard demonstrated the success of the CEMS by applying it to the towing vessel industry. Seven companies and 419 vessels participated in the six-month project. The five components of the CEMS implementation involved: education of vessel crewmembers and company employees about risk factors related to endurance; changes to the work and sleep environments; light management (tinting windows and installing shutters and keep sunlight from penetrating sleeping quarters);

employing a trained coach to monitor and reinforce crew endurance and provide scientific information about CEMS, including diet, exercise, caffeine use, environmental stressors, psychological conditions, sleep, and body clock management; and changing the watch schedule to support light management and allow crewmembers sufficient quality and quantity of sleep (Department of Homeland Security and U.S. Coast Guard 6). The purpose of light management is the use of ocular light input to keep the body awake and alert during watch. This is especially critical for captains who stand night watch, sleep during the day and need light management as a tool for shifting their biological clocks so their alertness will peak during work periods and their fatigue levels occur during rest periods. This is done by tinting windows and installing shutters to prevent daylight from entering the captain's quarters, allowing a night watch captain adequate rest during the day, while preventing fatigue at night. The effectiveness of the fifth component is supported by Table 5.9, which suggests that 80% of the participants were less fatigued when on a six-hour split schedule as opposed to a 12-hour schedule. Six-months after initial implementation, the project demonstrated that CEMS, when implemented properly, was effective at reducing fatigue and fatigue-related risk.

6.1.3 Fatigue Potential

Though no correlation could be found between fatigue and loss of situational awareness, the potential for fatigue from engine noise and vibration is still significant. While a majority of the captains interviewed did not express concern with fatigue, those assigned to towing vessels not equipped with engine noise and/or vibration insulation devices (Table 5.1) are forced to adapt and have adapted to the hazardous noise and vibration levels.

In 2002, Tamura et al. conducted a sleep study on four students in a laboratory that simulated diesel engine noise onboard the Japanese training ship GINGA-MARU. Each subject slept 15 consecutive nights composed of four nights of quiet environment, followed by eight nights of noise exposure at 60 dB(A), followed by three nights of quiet environment. The results from the subsequent questionnaire indicated the habituation of sleep to ship's noise (Tamura et al. 111).

It would seem that the concern with fatigue is not its impact on loss of situational awareness, but that exposure to high levels of noise due to adaptation to engine noise and vibration in the crew quarters. Hazardous noise levels have been known to be associated with hearing loss (Plog and Quinlan 217).

6.2 Communication Analysis

No correlation could be found between lack of communication and loss of situational awareness. In fact, it would appear that lack of communication associated with the prepare and send message process between a captain and deckhand as identified by McCallum et al. or lack of communication between the captain and another vessel's captain has been addressed in the towing industry. The main issue with communication appears to be associated with the lack of verbal communication between the towing vessel and a recreational vessel, resulting in the increased use of the vessel's whistle or spotlight as an alternate means to verbal communication. Regardless of the communication preference, the results strongly show the utilization of the four communication processes (prepare and send message, message transmission, receive and interpret message, and act on message) as well as situational awareness levels 1, 2 and 3 (Endsley 3) and actual communication, suggesting that an approaching vessel is seen as important and communication is initiated with this vessel in order to avoid collision (Koester 6). The use of radar, AIS, and VTS as a non-verbal communication method has proven to be an enhancement to collision avoidance and situational awareness.

6.2.1 Communication With Vessel Crew

Vessel crew includes all crewmembers onboard a towing vessel, but, for the purposes of this study, the term refers specifically to deckhands and the pilot/relief captain. In general, the deckhand serves as the eyes and ears of the captain while they are on watch in the pilothouse. The captain is confined to the pilothouse and may not be aware of events happening throughout the vessel or to the vessel's tow. With deckhands, communication is accomplished with the use of a handheld device (one for the deckhand and one for the captain) or use of the vessel's telephone system. A captain or pilot pushing tows must be able to communicate with the deckhand on watch. The results show that 95% of captains have excellent communication with their deckhands and utilize them as lookouts while underway, during mooring evolutions, or when transiting a lock or bridge. While underway, situational awareness is gained as the deckhand makes rounds[11] of the tow; checking for wiring layout; upkeep of towing, fire, and rescue equipment; sounding voids;[12] checking the depth sounder and navigational lights; and then communicating any abnormalities back to the captain on watch (Blank 462; Tables

[11] "Rounds" are a nautical term for equipment and material checks for hazards onboard a towing vessel or anything unusual.
[12] A void space is also a confined space. To sound a void means to check the void space for flooding.

5.10 and 5.11). Communication with the deckhand also provides the captain with the ability to take preventative action, such as placing a portable dewatering pump to pump out a void space taking on water.

During mooring evolutions, the deckhand throws the towing vessel's deck line to a shoreside bitt or cleat in order to secure the towing vessel to the dock (Blank 464). In addition, the deckhand also communicates distances between the pier and vessel, relaying this information to the captain so they can adjust course and speed to safely moor the vessel (Table 5.12). During evolutions where a vessel is transiting through a lock or bridge, deckhands are used to communicate distances between the barge and the lock wall or bridge fender and relay this information to the captain, enabling the captain (Tables 5.13 and 5.14) to safely steer the towing vessel. This communication is important because each lock and bridge has its own peculiarities associated with it when a towing vessel approaches from either the downstream[13] or upstream[14] side and the towing vessel must maneuver with great care when transiting through these areas (Blank 247, 372).

The results also show excellent verbal communication between the captain and relief captain during watch relief (Tables 5.15 and 5.16). In fact, all the captains that participated in this study felt highly confident in their ability to understand the winds and current factors upon watch relief. In addition, all the captains felt highly confident in their understanding of other hazards to navigation, including the locations of other vessels. The effectiveness of the verbal watch relief is an indicator of situational awareness levels 1 and 2 (Endsley 3).

[13] Downstream means to travel in the direction of the current
[14] Upstream means to travel in the direction opposite the current.

6.2.2 Communication With Other Commercial Vessels

There seems to be no doubt that communication between a towing vessel captain and a captain onboard another commercial vessel is not only effective, but also a boon to situational awareness. In fact, the results indicate a high degree of verbal communication between the towing vessels in this study and other commercial vessels (Tables 5.18 and 5.19). This degree of communication is not only an example of *actual* communication (Koester 6), but is also indicative of the four communication processes (prepare and send message, message transmission, receive and interpret message, and act on message) as described by McCallum et al. The communication loop is demonstrated by Tables 5.18 and 5.19, where 95% of the towing captains interviewed were frequently able to conduct two-way passing arrangements with other commercial vessels (Table 5.19) on VHF-FM radio. Further, not only were all captains highly confident in their knowledge of their own navigational light configuration (Table 5.17), but they also felt highly confident in the competencies of the other captain to understand their methods of non-verbal communication, namely the interpretation of whistle signals (Table 5.20) and navigational light configuration (Table 5.21). Radar and AIS (especially with electronic chart integration) were used as additional methods of non-verbal communication, and they further enhanced overall situational awareness among towing vessel captains (Tables 5.29 and 5.30).

6.2.3 Communication With VTS

The use and value of information obtained from VTS cannot be overemphasized. In general, VTS is useful for managing traffic on the waterway and maintains the ultimate “big picture” with respect to their area of responsibility. In terms of situational awareness, the VTS watchstander can communicate the location, course, and speed of another vessel transiting the river. This information allows the captain to adjust course and speed in order to facilitate and accommodate passing arrangements. VTS is not only a useful tool for vessel information, but is also a very useful for safety zone broadcasts and for managing one-way traffic. Safety marine information broadcasts,[15] which are usually done by the local U.S. Coast Guard station, can also be conducted by the VTS. In the case of vessel accidents that impede traffic on inland waterways, VTS can be used to broadcast the location of the casualty and any pertinent safety zone information to ensure other vessels steer clear of the waterway hazard. Table 5.31 is an excellent measure of the effectiveness of VTS. Specifically, all the captains found information from VTS to be both highly reliable and useful for avoiding collisions with other vessels.

6.2.4 Communication With Recreational Vessels

The main issue with communication appears to be the lack of verbal communication between the towing vessel and recreational vessel (Tables 5.22 and 5.23) and the increased use of non-verbal communication on behalf of the towing vessel captain, utilizing the vessel’s whistle or spotlight (Tables 5.26 and 5.27). This suggests that recreational vessels are more responsive to non-verbal communication because of lack of radio equipment, inattentiveness on behalf of the recreational vessel operator, or

[15] Safety Marine Information Broadcasts (SMIB) are broadcasts made over VHF-FM radio announcing waterway hazards, bridge closures, and local weather to all vessels operating in a particular waterway.

language barriers. However, the preference for verbal versus non-verbal communication does not have an adverse impact on situational awareness because the initiation of verbal or non-verbal communication on behalf of the towing vessel captain indicates situational awareness levels 1, 2 and 3 and supports Koester's theory of *actual communication*, where an approaching vessel is seen as important and communication is initiated to this vessel in order to avoid collision (Koester 6).

6.3 Drug and Alcohol Analysis

Though there is no doubt that dangerous drugs and alcohol can induce loss of situational awareness, no substantial evidence could be found that correlates loss of situational awareness and use of dangerous drugs, prescription drugs, and/or alcohol among towing vessel captains. These encouraging results are mainly due to the success of drug and alcohol prevention within the industry, the enforcement of the Department of Transportation regulations, the knowledge of consequences of violating those regulations, and U.S. Coast Guard audits.

6.3.1 Drug and Alcohol Awareness

Much of the success of dangerous drug and alcohol prevention of towing vessel captains can be credited to both the U.S. Coast Guard and Department of Transportation regulations and company's awareness and enforcement of the regulations. In fact, most towing vessel companies have drug and alcohol policies that mirror the Department of Transportation regulations. The majority of captains are randomly tested for use of dangerous drugs at least semi-annually (Table 5.32). Further, at least 55% of captains are aware of the two-hour alcohol testing requirement following a marine casualty (Table 5.34) and 75% of the towing vessels in this study have alcohol testing kits onboard (Table 5.33).

In addition to the regulations, the U.S. Coast Guard conducts Drug and Alcohol Program Inspector (DAPI) audits of towing companies. DAPI audits are conducted to ensure a company has a drug and alcohol testing program in accordance with 46 CFR Part 16. During a DAPI audit, Coast Guard auditors inspect a company's drug and alcohol policy, their drug testing records (as per 46 CFR 16.260), random testing procedures, employee assistance programs, and management information system. The management information system is a computerized annual log of a company's drug and alcohol testing activity and is a requirement of 46 CFR 16.500. One can conclude that DAPI audits help the company enforce drug and alcohol testing regulations.

No evidence could be found that showed a loss of situational awareness from prescription drug use. The most common prescription drugs are those taken for high blood pressure, type I diabetes, acid reflux, and cholesterol (Table 5.38). These do not appear to pose a threat to situational awareness or to the captain's ability to steer a towing vessel (Table 5.39).

6.3.2 Consequences of Violation of Regulations

All the captains who participated in this study are aware of the Coast Guard's suspension and revocation proceedings (Table 5.35). Moreover, the suspension and revocation proceedings imposed by the Coast Guard are a significant deterrent to drug and alcohol use for a licensed captain or pilot (Table 5.36). If a captain or pilot is found to be a user of dangerous drugs and this is a first time offense, then 46 CFR 16.201 requires that the individual be denied employment as a crewmember or must be removed from duties that directly affect the safe operation of the vessel. The individual must submit their license to the U.S. Coast Guard and enter into a settlement agreement (a Sweeney cure).[16] Furthermore, before the individual can return to work, the Sweeney cure must be completed and an MRO must determine that the individual is drug-free and that the risk of subsequent use of dangerous drugs by that person is sufficiently low to justify their return. The MRO must provide a "back to work" letter as a condition of the Sweeney cure. On average, it takes 1.5 years for an individual to receive an MRO back-to-work letter. Failure to receive a back-to-work letter from the MRO usually results in permanent revocation of the individual's license pending administrative clemency. Subsequent offenses usually result in permanent revocation unless administrative clemency is applied for.

Additionally, any subsequent or previous alcohol test also results in unemployment for the towing vessel captain. Specifically, 49 CFR 40.23 (c) states:

> "As an employer who receives an alcohol test result of 0.04 or higher, you must immediately remove the employee involved from performing safety-sensitive functions. If you receive an alcohol test result of 0.02-0.039, you must temporarily remove the employee involved from performing safety-sensitive functions, as provided in applicable Department of Transportation agency regulations. Do not wait to receive the written report of the result of the test."
>
> "As an employer who receives a verified positive drug test result, you must

[16] The Sweeney cure or settlement agreement is a contract agreement between the Coast Guard and the captain that the captain's license will be suspended instead of revoked if the captain takes certain measures.

> immediately remove the employee involved from performing safety-sensitive functions. You must take this action upon receiving the initial report of the verified positive test result. Do not wait to receive the written report or the result of a split specimen test."

These regulations are effective deterrents against use of dangerous drugs and alcohol and it would be easy to understand the impact on livelihood when these regulations are violated.

6.3.3 Introduction of Drugs and Alcohol Onboard Towing Vessels

One concern communicated by some of the towing vessel captains was the introduction of drugs and alcohol onboard the towing vessel without the company's knowledge (Table 5.37). However, this was only reported in a few cases and companies were quick to respond and conduct reasonable-cause drug testing once the information was reported to them.

6.4 Social Stress Analysis

Social stress was not determined to be a significant factor in loss of situational awareness. This result can be credited to the captain's socio-economic status and supportive relationships among family and vessel crew.

6.4.1 Socio-Economic Status

According to Mirowsky and Ross, socioeconomic status is measured by education, occupational status, work conditions, and economic well-being, such as income and freedom from economic hardships (Mirowsky and Ross 78). In fact, "the higher one's socioeconomic status (education, job, and income), the lower one's level of distress" (Mirowsky and Ross 75). Onboard a towing vessel, the job title of captain can be considered a position of high socio-economic status. While the majority of captains only had a high school level of education or below (Table 5.41), the average underway experience of the participants in this study was 23.3 years. In addition, the annual income for 80% of participants ranged between $80,000 to over $100,000 (Table 5.40). A comparison of these two factors, combined with the fact that 80% of participants don't worry about losing their job (Table 5.42), as well as the high demand for licensed towboat captains, and lack of desire for younger individuals to enter the industry, as indicated by the age range (33-61 years old), is an excellent measure of job security. One can conclude that job security helps mitigate social stress (Mirowsky and Ross 75).

6.4.2 Supportive Relationships

In contrast to Parker, who ultimately discovered that social stress, especially family stress, was the greatest source of underway stress, a large majority of the married participants do not appear to be affected by family stress (Tables 5.43, 5.44, and 5.45). One of the main reasons for the different results is the nature of operations between an inland towing vessel and a merchant vessel. Specifically, towing vessels in this study operate on inland waterways (aka "brown water" operations) in contrast to the majority of merchant vessels in Parker's study, which operate in open ocean (aka "blue water" operations). A captain has better communication capabilities with family members while operating on an inland waterway through e-mail and cell phone (Table 5.46). These small, yet considerable changes enhance crew morale and help lessen social stress. According to Comperatore and Rivera, the use of cell phones, Internet, and email onboard a towing vessel are morale boosters that can have an enormous benefit to the emotional well-being of the vessel crew (Comperatore and Rivera 59). While underway, the captain also relies upon the relationship among his or her crew to diminish social stress. In fact, 95% of participants experience very little if any tension with their crew (Table 5.47).

6.5 Mental Workload Analysis

The results strongly suggest that mental workload is the predominant factor affecting situational awareness. In fact, a further breakdown of mental workload reveals that loss of situational awareness is likely to occur when a captain of a towboat is operating in or near an area of other recreational vessels or distractions from cell phone calls from the company and must devote constant attention to the recreational vessel or the phone conversation. In addition, a further analysis of mental workload also reveals areas of complacency potential due to routine operations, which can also induce a loss of situational awareness. However, the results indicate loss of awareness and complacency in some areas of inland navigation, but not all areas. This might suggest that these factors are based on individual characteristics. Furthermore, the results show an awareness of prudent seamanship, especially of the use of electronic navigation combined with operator recognition of the limitations of automated devices.

6.5.1 Distraction and Loss of Situational Awareness

The potential for loss of situational awareness is higher for a towing vessel captain operating in the vicinity of other recreational vessels versus other towing vessels, offshore supply vessels, or crew boats (Tables 5.48 and 5.49). This is due to lack of confidence in the competencies or predictability of the recreational vessel operator, especially in regards to the operator's lack of understanding of the meaning of whistle signals and navigational light configuration and lack of understanding about the maneuverability of the tow (Tables 5.24 and 5.25). The lack of confidence in the competency of the recreational vessel operator would suggest increased worry, attention, and distraction on behalf of the towing vessel captain (Table 5.49). A majority of captains expressed concern about the safety of navigating inland waterways in the vicinity of other recreational vessels.

The potential for loss of situational awareness is also higher for a towing vessel captain when having to answer the cell phone calls from the company; especially when operating in busy traffic areas (Tables 5.51 and 5.52). This is due to problems associated with division of attention and it is likely the captain will focus their attention on the conversation instead of on the safe navigation of the vessel. According to Endsley, the way in which a person deploys his or her attention has a fundamental impact on situational awareness, especially in complex environments where numerous sources of information compete for attention (Endsley 18). Thus, based on Tables 5.24, 5.25, 5.49, 5.51 and 5.52 it is highly likely that a captain will focus most if not all attention on recreational vessels or a phone conversation.

6.5.2 Mental Workload and Complacency Potential

A further breakdown of the mental workload results also highlights areas of complacency potential. In general, complacency can occur under both high and low workload extremes (Prinzel et al. 32). Unfortunately, not much is known about the effects of complacency on human performance or the best method for measuring it. Currently, no research exists within the maritime industry suggesting that complacency has ever been a causal factor for accidents. However, complacency has been researched in the aviation industry as a causal factor for accidents. Both aviation and towing vessels fall under the transportation industry, and it is highly likely that factors inducing complacency in one industry will closely parallel the other. The central theme of the aviation studies is that complacency is a combination of two factors: the crew’s attitude toward automation and toward a particular situation (Singh, Molloy, and Parasuraman 112). Before attempting to explain complacency in towing vessel captains, we must first understand the factors that shape a person’s attitude toward automation.

Factors that contribute to automation-induced complacency were revealed in a 1993 study conducted by Indramani Singh, Robert Molloy, and Raja Parasuraman. In this study, a Complacency Potential Rating Scale (CPRS) was developed that measured an individual’s attitude toward automated systems and complacency potential. A questionnaire was developed that was designed to assess attitudes toward automation. The results from the questionnaire identified attitudes that have the potential to create automation-induced complacency. These factors were: confidence in automation, perception of reliability of automation and subsequent reliance on automation, trust in automation, and safety afforded by automation. These four factors formed the basis of individual attitude toward automation in subsequent complacency studies (Singh, Molloy, and Parasuraman 118).

In the same year, Parasuraman, Molloy, and Singh conducted a secondary study to test the operator detection of automation failures during flight simulations. Forty subjects participated in the study and were required to monitor three separate systems (manual tracking, fuel management, and system monitoring), which were under automated control. They believed that complacency was measured by how well operators detected system malfunctions. The results of their study revealed that complacency was high for a group of subjects encountering automation with constant, unchanging reliability because this group developed a premature cognitive commitment regarding the nature of automation and its efficiency. Likewise, they found that inconsistent reliability resulted in less complacency, that trust and reliance on an automated systems waned immediately after a failure, and that these theories only held in a multi task/high workload environments (Parasuraman, Molloy, Singh 14).

What can be concluded about these two studies conducted by Parasuraman, Molloy, and Singh is that complacency is a function of attitude toward automation and a specific event. Attitude is formed by confidence, reliability, trust, and safety afforded by automation. Attitude towards automation, combined with specific events such as high mental workload strongly suggest the potential for complacency. However, more recent studies have significantly deepened our understanding of complacency and have demonstrated that it is not just a function of attitude toward automation and a specific event.

In 2001, Prinzel et al. conducted a study that examined the relationship between complacency potential, boredom proneness, and cognitive failure and whether people who have high scores on these factors experience automated-induced complacency under conditions of high and low workload extremes. Complacency potential was measured using the Complacency Potential Rating Scale (CPRS). Boredom proneness was measured using the Boredom Proneness Scale (BPS) and cognitive failure was measured using the Cognitive Failure Questionnaire (CFQ). Forty students from Old Dominion University participated in the study.

This first theory of this study was that an individual in a constant-reliability condition would experience complacency because he or she would experience premature cognitive failure and not be able to efficiently monitor systems (Prinzel et al. 10). Prinzel et al. defined premature cognitive failure as a function of premature cognitive commitment. As they wrote:

> “Premature cognitive commitment occurs when a person initially encounters a stimulus, device, or event in a particular context; the attitude or perception is reinforced when the stimulus is re-encountered in the same way. (Prinzel et al. 5) The context is described as a routine event, recurring event, high workload condition, or low workload condition (Prinzel et al. 5). This suggests that premature cognitive failure occurs when premature cognitive commitment desensitizes an individual’s ability to think critically.”

The second theory was that an individual with a high score on the CPRS would perform worse in a system monitoring task under constant-reliability as compared to participants with low CPRS scores. In addition, when an automated system had variable-reliability, no differences were expected (Prinzel et al. 10).

The third theory was that complacency potential, boredom proneness, and cognitive failure have an effect as to whether an individual will experience automated induced complacency (Prinzel et al. 10).

The results of the study show that complacency potential, boredom proneness, and cognitive failure significantly correlate with one another (Prinzel et al. 23). However, not all individuals trust automation and not all succumb to automation-induced complacency because individual differences in personality (i.e., experience and perception of workload and boredom) predispose them to behaving in certain ways in certain situations (Prinzel et al. 30). What was also discovered was that automation-induced complacency can occur under both high and low workload conditions, which contrasts with the work of Parasuraman, Molloy, and Singh, who argued that complacency only occurs under high workload conditions (Prinzel et al. 32). These three studies, however, are highly applicable to the towing vessel industry.

6.5.3 Applying Complacency Theories to Towing Vessels

The results from this study suggest that complacency is likely to occur while a captain is steering the towboat under routine environmental conditions or while transiting under or through bridges (swing bridges and fixed bridges) or through lock systems. This conclusion is derived from the combination of the physical reliability of the inland route, consistency in passing arrangements with other commercial vessels, consistency and reliability of wind and current forecasts, boredom proneness (Table 5.50) and operator experience. In fact, one can reasonably conclude that the physical characteristics and reliability of the inland route can represent a form of automation.

The physical characteristics of the inland route are fixed; this means that if a towboat were to transit from New Orleans, LA to Houston, TX via the GIWW, the captain would encounter the same number of bends, bridges, locks, and check-in points. As indicated by the results, 90% of the participants have transited the GIWW more than 100 times (Table 5.61) and often make the same approach through a lock or a bridge on the GIWW (Tables 5.62 and 5.63). In addition, 95% of these captains often encounter the same type of commercial vessels on subsequent transits (Table 5.64) on the GIWW and often make the same passing arrangements via VHF-FM or port-to-port passing (Table 5.65). Further, all participants attested to the consistency and reliability of wind and current forecasts from pilothouse instrumentation (Table 5.66). In general, this attitude of trust, reliability, and confidence in the characteristics of the automation of the inland route can form the basis of complacency potential (Singh, Molloy, and Parasuraman 118), as well as premature cognitive failure (Prinzel et al. 5).

As described by Singh, Molloy, and Parasuraman, the perception of workload is a second factor that would determine complacent behavior (Singh, Molloy, and Parasuraman 112). The participant's level of experience and their ability to become more versatile and handle more work can lead to perceptions of low workload. This concept is supported by a 2006 study that explored mental workload levels between experienced and inexperienced drivers.

In 2006, a study was conducted that evaluated the effect of driver experience on workload demands. The belief was that an inexperienced driver would experience higher levels of mental workload as compared with an experienced driver. Seventy-nine participants (40 in the high-mileage experienced group, 39 in the low-mileage inexperienced group) with an age range from 22 to 59 years participated in the driving simulation. The results indicated a significant difference in mental workload between the two groups. It was concluded that increased experience reduces the driver's mental workload (Patten et al. 893).

6.5.4 The Dangers of Complacent Behavior

Wind and currents can represent both constant and variable reliability. The direction and force of wind varies daily and can shift unexpectedly, especially after the passing of a cold front (Bowditch 529). The direction and force of currents vary depending on the season. The variation of the wind and currents may not always be factored by captains because of their consistency during a certain time frame. For example, the Lower Mississippi River and the Atchafalaya River are subjected to periods of "high water" and "low water" during the spring season. This means that during a portion of the year, it is highly likely that the currents will act the same, but they will behave differently during another portion of the year. Portions of the GIWW may not be affected by wind because of the trees; however, certain portions of the GIWW (such as in the vicinity of Houston, TX) are exposed to the force of the wind.

Wind and currents have a major effect on how a towing vessel approaches a bridge or lock because there is often cross-current or crosswind (Crenshaw 190). A slight change in current may mean a significant change in approach vector by the vessel (Crenshaw 37, 38). Although all captains attested that they seldom encounter situations where the wind and current act differently than what they anticipated, the importance of Table 5.67 was to demonstrate that there are occasional situations where the wind and current behave differently than forecasted by the vessel's onboard instrumentation (Table 5.66). The most important thing to keep in mind is that regardless of advances in instrumentation for forecasting of weather, these new advances are subject to limitations and occasional failures. The most reliable source of weather data is the captain of the towboat (Bowditch 532).

Over-familiarity on the inland route is also a problem. Canals such as the GIWW are manmade and are only as wide as necessary to achieve their intended purpose (Crenshaw 187). This poses a particular problem for large tows, especially oversize tows because of maneuvering limitations and navigating in areas with sharp turns or bends. The GIWW averages 125ft in width and the majority of oversize tows are 70ft wide.

In addition, tows can be subjected to a "bank suction" and "bank cushion" effect, both of which occur when the tow is transiting closer to one bank than the other. Bank suction occurs when the distance between the tow and nearer bank causes a suction effect because the water velocity on that side of the bank is faster and the water level near the bank is lowered, which can cause the tow to veer into the bank (Crenshaw 188). Bank cushion occurs when the water pressure between the bank and near channel pushes the bow back into the center of the channel (Crenshaw 188). Another problem occurs in sections of the GIWW where the bank has been cut out to form docks for mooring vessels. The absence of the bank can cause the vessel's bow to veer into the cut out and collide with these docks or moored vessels (Crenshaw 189).

Bank erosion and sedimentation are other environmental factors that could cause variance in the reliability of the inland route (Randle et al. 354). This erosion often results in the reduction of available water depth along the banks, which could force towing vessels to favor one side of the waterway and cause narrowing of the navigable waterway. The reduction in water depth creates the potential for vessel groundings. In addition, the narrowing of the waterways is especially troublesome for passing arrangements between oversize tows.

6.5.5 Indicators of Prudent Seamanship

The results show that not all towboat captains are subjected to loss of situational awareness due to mental workload or complacency. It was also believed that complacency would occur as a result of over-reliance on electronic navigation systems and the engine gauges. None of these beliefs were supported. As shown by Tables 5.53, 5.54, 5.55, and 5.56 electronic charts, paper charts, radar, nautical publications, and notice to mariners were used equally by the majority of participants to determine information about navigational aids (Table 5.53). Interestingly, radar is not relied upon as the primary means of safe navigation, although it was considered to be more reliable than AIS for locating vessels (Table 5.54 and 5.55). Much like AIS combined with electronic charts, radar can be used both during the day and night to track other vessels, especially during periods of reduced visibility. It is often considered more reliable than AIS because it can pick up floating debris, buoys, as well as storms and other vessels not equipped with AIS. However, radar does have limitations with its line of position (LOP) in that the signal can be distorted by land, which is a critical limitation when navigating a vessel around a river bend and trying to locate another vessel on the other side of that bend (Hobbs 176). AIS is not limited by land because it is based on a vessel's global positioning system. However, AIS only picks up vessels equipped with an AIS transponder (See fig. 2.6). In addition, the AIS does not pick up floating debris or buoys in the water. The skillfulness of using the Electronic Charting System (Table 5.57) and use of the AIS transponder (Table 5.58), both of which are complex systems, is believed to prevent loss of attention among the participants.

It was believed that complacency would occur as a result of over-reliance on the engine alarms in the pilothouse. Most towboats have automated engine rooms where the engine gauges are monitored by alarms. It is possible for these alarms to fail and the combination of over-reliance on alarms and an unmanned engine room can be catastrophic, resulting in loss of engines, fires, overheating, etc. (Blank 123). Tables 5.59 and 5.60 indicate that the captains seldom rely on these alarm systems and use alternate means of checking engine status, including distinguishing optimal engine noise by ear and use of deckhands, engineers, or "deckineers"[17] to assist with checking the engines. In general, the overall recognition of the limitations of automated devices, electronic navigation, and alarm systems prevents complacency among the captains and is an indicator of prudent seamanship.

[17] Combination of deckhand and engineer duties.

Chapter 7

Recommendations

7.1 Management Support

The first and most important step toward addressing loss of situational awareness is management support and commitment to safety. Without management support, it is highly likely that any attempts to address loss of situational awareness in a safety management system will be ineffective. In order to gain their support, management will need assurance that the safety investment is affordable, simple, can change mariner behavior, and, most importantly, will have a positive impact on the company's profits by reducing its risk of loss.

Once management support is secured, it is the responsibility of management to upgrade their ways of thinking from traditional ideas of "safety" to an actual safety management system. This is the responsibility of upper management and not the company's safety department. As explained by Dennis Pascal, a professional engineer and quality specialist at a Toyota manufacturing plant in Cambridge, Ontario, the safety department does not have the power to change things and is often used as a shield between upper management and the stakeholder (Pascal 13). Further, traditional safety systems focus on "end of pipe" measures, such as accidents and near-misses, instead of "upstream" measures, such as at-risk behaviors and safety audits. In addition, these companies tend to blame the mariner for accidents and tend to have a reactive approach instead of a preventative approach to safety (Pascal 62).

7.2 Identifying Cost

In general, accident costs can be categorized according to direct and indirect costs. Direct costs are associated with the cost of vessel repair and with worker compensation costs. Specifically, direct costs of injuries and illnesses included medical expenses for hospitals, physicians, drugs, and health insurance administration costs (Leigh et al. 8, 9, 10).

Indirect costs are associated with hidden costs such as contingent costs (i.e., environmental damage, pollution claims, etc.) and image costs. In addition, accidents resulting in injury or illness have indirect costs associated with loss of wages, employer retraining, and workplace disruption. The good news here is that both direct and indirect costs can be controlled by management. The company's human resource manager, the environmental, health and safety manager, workers compensation representative, accountants, and medical representatives can help obtain these numbers.

7.3 Safety Management Systems

As a basic rule, the key to a good safety management system is clarity and simplicity (Pascal 83). The American Waterways Operators' Responsible Carrier Program is a gold-standard safety management system. Unfortunately, not all towing vessel companies are signatories to American Waterways Operators. However, a towing vessel company does not need to be a member of American Waterways Operators in order to have an effective safety management system. The key to an effective safety management system is a commitment to safety, upstream measures, and management enforcement of policies. A safety management system is comprised by the following elements (Pascal 83):

1) **<u>Policy</u>** – The policy lays out the company's goals, values, and beliefs and is used in order to not only attain the company's goals, but provide both structure and consistency to decisions. The goals should be simple, measurable, achievable, reasonable, and trackable. Goals that are too high create mistrust, and goals that are not measurable invite criticism. Ultimately, the policy should be kept to one page or less. The policy also identifies safety management as a management responsibility instead of a department responsibility. The policy should be signed by the highest ranking official and union representative, which would represent an agreement between labor and management.

2) **<u>Principles</u>** – Principles and policies are interrelated. It is the principles that describe the details of the policy. Hence, the principles section help keep the policy section to one page.

3) **<u>Organizational Arrangements</u>** – Organizational arrangements set out responsibilities, authority, and accountability. Specifically, organizational arrangements define the responsibility and accountability of each person.

4) **<u>Programs</u>** – The program is a sequence of steps or activities to accomplish the objectives under a management system. In other words, how you will do it, who will be responsible, and when it will be done.

5) **<u>System Maintenance and Improvement</u>** – System maintenance and improvement is accomplished through the use of measures. Through the use of a survey,

a company can take a baseline measurement of where it stands and then do another round of surveys to measure improvement.

7.4 Measuring Lagging and Leading Indicators

A critical component toward shifting from the traditional safety management concepts is the implementation of measures; specifically, the identification and measurement of both “lagging indicators” and “leading indicators.”

In terms of safety, lagging indicators are most often linked to accident data or near-miss data (Toellner 42). Accident data is easy to collect because it is widely published and easy for management to understand. However, near-miss data is more difficult to collect. Although accident data does provide some insight into a company’s safety performance, the main problem with these data is that they do not prevent the accident from reoccurring (Budworth 24; Toellner 47). Furthermore, they cannot be used for root cause analysis and are often demoralizing to management (Budworth 24).

Leading indicators (or upstream measures) are often linked to preventative actions and are predictors of accidents. The most common leading indicators are safety audits and unsafe behavior (Toellner 44; Budworth 25, 26). Safety audits commonly measure safety performance against a standard that is outlined in a survey. The results of the audit not only allow a company to take preventative action but can be used to appraise a company’s safety performance (Budworth 25). The measurement of unsafe behavior can be used as another predictor of accidents. Further, it can be easily integrated into a safety audit and can be used to facilitate a change in attitude (Budworth 26). The main disadvantage of these leading indicators is that they often require a large investment of time and commitment from management; however, the long-term benefits of accident prevention far outweigh the costs.

Both lagging and leading indicators are needed to measure overall safety performance. Specifically, leading indicators are used to manage performance and lagging indicators are used to show the outcome of that performance.

7.5 Applying Measurements to Preventative Tasks

The following is a small list of recommendations for the company to begin the process of measuring safety performance and unsafe behaviors. This list is not all inclusive, but provides a realistic start for most, if not all towing vessel companies. The availability and enforcement of these tasks is largely dependent on management support.

Recreational Boating Safety Outreach – This would be a joint undertaking between the towing vessel company and the U.S. Coast Guard Auxiliary. The U.S. Coast Guard Auxiliary hosts boating safety courses for recreational boaters. However, the concerns expressed by towing vessel captains with regards to the competencies of the recreational boater, are not addressed at these courses. Towing vessel companies should express their concern and frustration over recreational boaters in writing to the local Coast Guard Auxiliary and request education and training to the recreational boating public. This public needs to be educated about the maneuvering limitations of towing vessels, right of way, navigational light configuration, and verbal and non-verbal communication systems. Perhaps the U.S. Coast Guard and American Waterways Operators could partner on this and provide a video to demonstrate the maneuvering limitations of a towing vessel. Company management should conduct periodic measurement of their captains' mental workload through surveys as a way of measuring the effectiveness of this training.

<u>Establishing Procedures for Business Conversations</u> – Recommend company management establish procedures for their captains to check cell phone messages or contact the company prior to assuming the watch. This could significantly prevent distractions associated with division of attention and ensure that any pertinent information is passed between the relief captain and the company. The use of surveys as a measurement can ensure loss of situational awareness is reduced.

<u>Drills</u> – Although drills are conducted by the captain, they should be enforced at the company management level. Random unannounced drills should be conducted by the company when the vessel moors. This will ensure that the vessel is conducting drills and not just signing the drill sheet. Drills can also be used to measure unsafe behaviors such as complacency and can do so at a minimal cost.

<u>Strategic Thinking</u> – Strategic thinking is another term for "thinking ahead," and it can help towing vessel captains avoid dangerous situations and detect errors before they occur (Rogers 114). Strategic thinking must be enforced and encouraged at the company management level and not at the mariner level. This can help to avoid complacency-inducing situations and to provide the tools to assist a young and inexperienced captain to think ahead like an experienced one. One of the best methods of strategic thinking that was mentioned by one of the companies is the solicitation of real-time wind and current information from other captains during passing arrangements. This information gives the captain time to anticipate and adjust course and speed when passing under or through bridges or locks.

Navigation Simulators – Navigation simulators offer a wide variety of advantages, especially with prevention of complacency as well as monitoring as well as measuring distractions associated with use of cell phones or other personal electronic equipment such as personal radio for music or portable television. The simulator can be adjusted to simulate the number of vessels, the number of hazards to navigation, and the effect of currents. Further, and most importantly, because the simulator is monitored and recorded, they can be used to measure unsafe behavior and pinpoint the levels of situational awareness.

Chapter 8

Conclusion

8.1 Summary

This study examined the effects of fatigue, communication, drugs and alcohol, stress, social stress, and mental workload on situational awareness. It was believed that these factors influence situational awareness in towing vessel accidents and near-miss situations and that a close study would reveal that one factor would predominate in such situations. These factors were compared and mental workload was identified as the most predominant factor that caused loss of situational awareness. A further examination of mental workload revealed that loss of situational awareness is likely to occur during situations where the towing vessel captain is discussing business matters with the company on cell phone or steering in the vicinity of recreational vessels. The results also revealed signs of complacency potential, which is a function of a captain's attitude toward automation and mental workload. Complacency potential had not been previously verified in studies of towing vessel accidents or accidents in the maritime industry.

It was determined that prevention of loss of situational awareness from mental workload is the responsibility of the towing company management and not the company safety and health representative or the towing vessel captain. Prevention of loss of situational awareness begins with company awareness and management support of safety management systems that measure unsafe behaviors, introduce variation, and avoid routine operations. Education and outreach to the recreational boating public can lead to improved understanding of towing vessel limitations and can possibly reduce the potential for loss of situational awareness among towing vessel captains. However, the towing vessel company must take the lead in expressing their concern and frustration to their local U.S. Coast Guard Auxiliary and request such training for the recreational boating public. Discussing business matters with company officials prior to assuming the watch can help prevent distractions from cell phone calls while on watch. Variation and avoidance of routine operations can be an effective tool for addressing complacency potential.

8.2 Areas of Further Research

Further research is needed that examines the effects of mental workload on situational awareness. Specifically, research is needed that measures the impact of onboard cell phones or other personal electronic devices on situational awareness as well as the effectiveness of counter-measures such as set times or procedures for conducting business calls with the company. In addition, research is needed that measures the impact of recreational vessels on situational awareness and the effectiveness of educational outreach. Complacency potential is another area of research. Specifically, more research is needed that examines the effectiveness of navigational simulators, drills, and strategic thinking in the reduction of complacency potential. These studies would be beneficial for towing vessel companies and captains in terms of accident prevention and would increase both tangible and intangible profits.

8.3 Coda: Understanding “Brown Water” Operations

Although this research focused on the human element associated with loss of situational awareness, I have also come to understand the difference between inland towing vessel operations (aka “brown water”) and offshore vessel operations (aka “blue water”). My experience as a Deck Watch Officer is limited to four years as a cadet studying the different facets of maritime navigation and application of those principles onboard the U.S. Coast Guard Cutter EAGLE, U.S. Coast Guard Cutter SUNDEW and two years as a commissioned officer onboard the U.S. Coast Guard Cutter CONFIDENCE. A majority of those underway operations were conducted offshore with occasional opportunities for inland navigation. As an observer onboard a “line haul” I am grateful for being able to experience the nature of inland towing vessel operations and have come to admire and respect the competencies and precision required and demonstrated by all crew-members. In particular, I was astonished by the level of precision during night-time navigation in a relatively confined waterway, limited visibility and conducted solely by radar. In the end, I remain hopeful that more and more companies will take measures to ensure their own sustainability by enhancing the safety of their mariners, which will not only attract the best candidates to be licensed captains, but ultimately ensure the stability of our economy.

Endnotes

1. The 14 human factors identified by Margetts are:
    a. Inattention
    b. Ambiguous Pilot-Master Relationship
    c. Inefficient Bridge Design
    d. Poor Operational Procedures
    e. Poor Physical Fitness
    f. Poor Eyesight
    g. Excessive Fatigue
    h. Excessive Alcohol Use
    i. Excessive Personnel Turnover
    j. High Level of Calculated Risk
    k. Inadequate Lights and Markers
    l. Misuse of Radar
    m. Uncertain Use of Sound Signals
    n. Inadequacies of the Rules of the Road

2. The 14 accident databases reviewed by the American Bureau of Shipping are:
    a. American Bureau of Shipping
    b. United States Coast Guard
    c. Port State Authorities
    d. Vessel owners and operators
    e. Occupational Safety and Health Administration
    f. U.S. Minerals Management Service
    g. U.S. Environmental Protection Agency
    h. International Maritime Organization
    i. U.S. National Transportation Safety Board
    j. United Kingdom Marine Accident Investigation Board
    k. Protection and Indemnity clubs
    l. International Association of Oil and Gas Procedures
    m. Transportation Safety Board of Canada
    n. Regulatory bodies in other countries

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APPENDIX A. INTREGRATED SURVEY AND INTERVIEW

SECTION ONE: BACKGROUND

1. Please state your current position towing vessel industry.

   ☐ Captain ☐ Pilot / Relief Captain

2. How old are you? ______________________________

3. How long have you been licensed to steer towing vessels? ____________________

4. How many days per trip are you underway? __________________________________

5. Do you hold a valid Coast Guard license with towing endorsement? ☐ Yes ☐ No

6. How would you describe your physical health?

   ☐ Excellent ☐ Good ☐ Fair ☐ Poor

SECTION TWO: FATIGUE

Fatigue means being so tired that you cannot concentrate and are fearful of having a towing vessel accident.

1. How does your company address fatigue issues / regulations?

   ☐ Noise / Vibration Insulation
   ☐ 12 Hour Enforcement
   ☐ Travel Arrangements

2. My company ________________ trains its crew-members on crew endurance management.

   ☐ Often ☐ Seldom ☐ Never

3. I am ________________ exhausted from having to drive or fly to meet the boat?

   ☐ Often ☐ Seldom ☐ Never

4. Noise from the engine room _________________ keeps me awake?

   ☐ Often ☐ Seldom ☐ Never

5. Vibration from the engine room _________________ keeps me awake?

   ☐ Often ☐ Seldom ☐ Never

6. I am __________________ exhausted toward the end of one patrol?

☐ Often ☐ Seldom ☐ Never

7. How would you describe your usual sleep while underway (compared to sleep at home)?

☐ Good ☐ Fair ☐ Poor

8. How many hours do you sleep in a 24 hour period while underway? ___________

9. Do multi-shifts (i.e. 6 on, 6 off / 7755) make you more or less fatigued?

☐ More fatigued (I prefer one 12 hour shift)
☐ Less fatigued (I prefer multi-shifts)
☐ No difference

SECTION THREE: COMMUNICATION

Communication is communication with crewmembers, other vessels, or VTS and how much they help you in attaining situational awareness.

1. My deckhands ___________ report the results of their rounds of the vessel and barges?

   ☐ Often ☐ Seldom ☐ Never

2. My deckhands ___________ can be counted on to report hazards to navigation at night?

   ☐ Often ☐ Seldom ☐ Never

3. My deckhands ____________ call out distances from the barge to the pier when the vessel is mooring?

   ☐ Often ☐ Seldom ☐ Never

4. My deckhands ____________ call out distances from the barge to the lock wall?

   ☐ Often ☐ Seldom ☐ Never

5. My deckhands ____________ call out distances from the barge to the bridge fender?

☐ Often ☐ Seldom ☐ Never

6. I am _____________ satisfied that I understand wind and current when I relieve the watch?

   ☐ Often ☐ Seldom ☐ Never

7. I am _____________ satisfied that I understand the location of other vessels and hazards to navigation when I relieve the watch?

   ☐ Often ☐ Seldom ☐ Never

8. I am _____________ confident that I understand my vessel's navigation light configuration and change it whenever required by the rules to do so.

   ☐ Highly ☐ Seldom ☐ Never

9. I ____________ communicate passing arrangements to other towing vessels via VHF-FM radio?

   ☐ Often ☐ Seldom ☐ Never

10. Other towing vessels ____________ respond to me via VHF-FM radio?

    ☐ Often ☐ Seldom ☐ Never

11. I am _____________ confident that other towing vessels understand the meaning of 1 and 2 whistle signal?

    ☐ Highly ☐ Seldom ☐ Never

12. I am _____________ confident that other towing vessels understand my nav. light configuration?

    ☐ Highly ☐ Seldom ☐ Never

13. I ____________ communicate passing arrangements to other recreational vessels via VHF-FM radio?

    ☐ Often ☐ Seldom ☐ Never

14. Other recreational vessels ____________ respond to me via VHF-FM radio or other signal device?

☐ Often ☐ Seldom ☐ Never

15. I am _____________ confident that recreational vessels understand the meaning of 1 and 2 whistle signal?

☐ Highly ☐ Seldom ☐ Never

16. I am _____________ confident that recreational vessels understand my nav. light configuration?

☐ Highly ☐ Seldom ☐ Never

17. I _______________ use my whistle or spotlight to attract the attention of other recreational vessels?

☐ Often ☐ Seldom ☐ Never

18. The recreational vessel _____________ maneuvers out of the way upon hearing my whistle or seeing my spotlight?

☐ Often ☐ Seldom ☐ Never

19. I ____________ flash my spotlight or use my whistle when making passing arrangements with other commercial vessels?

☐ Often ☐ Seldom ☐ Never

20. I find that information on vessel characteristics from Radar is ___________ critical to being able to plan ahead and avoid potential collisions with other vessels

☐ Very ☐ Seldom ☐ Not

21. I find that information on vessel characteristics from AIS / Electronic Chart is ___________ critical to being able to plan ahead and avoid potential collisions with other vessels

☐ Very ☐ Seldom ☐ Not

22. I find that information from VTS is __________ critical to being able to plan ahead and avoid potential collisions with other vessels

☐ Very ☐ Seldom ☐ Not

SECTION FOUR: DRUGS AND ALCOHOL

Drugs include illegal drugs and prescription medication that impair situational awareness. **Alcohol** refers to any substance that can cause symptoms of drunkenness.

1. When was the last time you were randomly tested for drug use? ______________

2. Alcohol testing kits _______ kept onboard?

   ☐ Are ☐ Are not

3. I am ____________ of the 2 hour alcohol testing regulations that went into effect last year?

   ☐ Aware ☐ Not Aware

4. I am ________ of the consequences to my license if found positive for drugs/alcohol?

   ☐ Aware ☐ Not Aware

5. The consequences __________ me from using drugs / alcohol underway?

   ☐ Prevent ☐ Do not prevent

6. Drugs and/or alcohol _____________ introduced onboard a towing vessel without the company's knowledge?

   ☐ Often ☐ Seldom ☐ Never

7. What prescription drugs do you take? ____________________

8. These prescription drugs have a __________ effect on my situational awareness.

   ☐ Major ☐ Little ☐ No

SECTION FIVE: SOCIAL STRESS

Social Stress is a physical or psychological response to events from society that can lead to loss of situational awareness.

1. How much do you earn per year?

   ☐ $10,000 - $20,000 ☐ $20,000 - $30,000 ☐ $30,000 - $40,000 ☐ $40,000 - $50,000

   ☐ $50,000 - $60,000 ☐ $60,000 - $80,000 ☐ $80,000 - $100,000 ☐ $100,000 +

2. What is the highest level of education you have completed (1-16)? ________

3. I ___________________ worry about losing my job?

   ☐ Often ☐ Seldom ☐ Never

4. What is your current marital status?

   ☐ Married ☐ Single

5. When underway, I _____________ worry about the stability of my relationship with my family?

   ☐ Often ☐ Seldom ☐ Never

6. I _______________ worry about being able to support my family and pay the bills?

   ☐ Often ☐ Seldom ☐ Never

7. E-mail / Cell phones are _______________ helpful for the stability of my relationship?

   ☐ Very ☐ Seldom ☐ Never

8. I _______________ have tense relations with other crew-members?

   ☐ Often ☐ Seldom ☐ Never

SECTION SIX: MENTAL WORKLOAD

Mental Workload is the amount of mental work associated with information processing from steering a towing vessel, time spent communicating with other vessels, using electronic charts and radar.

1. When steering a towing vessel in the presence of other towing vessels, I _______________ worry about the other Captain's understanding of my vessel's maneuvering limitations.

   ☐ Often ☐ Seldom ☐ Never

2. When steering a towing vessel in the presence of other recreational vessels or fishing vessels, I _______________ worry about the other Operator's understanding of my vessel's maneuvering limitations.

   ☐ Often ☐ Seldom ☐ Never

3. I ___________ feel bored when steering on long straight-aways or areas with little to non vessel traffic.

   ☐ Often ☐ Seldom ☐ Never

4. I find that cell phone calls I receive in a busy section of the waterway are ______________ distracting.

   ☐ Often ☐ Seldom ☐ Never

5. I find that cell phone calls I receive in a non-busy section of the waterway are ______________ distracting.

   ☐ Often ☐ Seldom ☐ Never

6. I rely heavily on ___________________ for information regarding navigational aids and landmarks (check all that apply).

   ☐ Electronic Charts
   ☐ Paper Charts
   ☐ Radar
   ☐ Publications / Notice to Mariners

7. During the day, I rely heavily on ___________________ for knowing vessel locations when not in visual sight (check all that apply).

☐ AIS ☐ Radar ☐ VHF-FM Radio

8. At night, Radar is ___________________ AIS for knowing vessel locations.

☐ More reliable than
☐ As reliable as
☐ Not as reliable as

9. Paper charts are ____________________ Electronic Charts for information of navigational aids and landmarks.

☐ More reliable than
☐ As reliable as
☐ Not as reliable as

10. I ______________ have a difficult time trying to operate the Electronic Chart.

☐ Often ☐ Seldom ☐ Never

11. I ______________ have a difficult time trying to operate the AIS transponder.

☐ Often ☐ Seldom ☐ Never

12. I ______________ rely on the pilothouse alarms to inform me of problems with the vessel's engines.

☐ Often ☐ Seldom ☐ Never

13. I am _______________ confident that the vessel's engines are running at optimal performance.

☐ Highly ☐ Seldom ☐ Never

14. I have safely pushed barges on the Gulf Intracoastal Waterway ________________.

☐ More than 100 times ☐ Less than 100 times

15. I _______________ steer the same course through a lock.

☐ Often ☐ Seldom ☐ Never

16. I _______________ steer the same course through a bridge.

☐ Often ☐ Seldom ☐ Never

17. I _______________ encounter the same commercial vessels on subsequent transits.

☐ Often ☐ Seldom ☐ Never

18. I _______________ encounter the same passing arrangements with commercial vessels.

☐ Often ☐ Seldom ☐ Never

19. This data is _____________ reliable for wind/ tide and current data.

☐ Often ☐ Seldom ☐ Never

20. I ____________ encounter situations where the wind / tide/ currents catch me by surprise.

☐ Often ☐ Seldom ☐ Never