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Many advances have been made to shipping and the maritime industry over the last century. Despite these advances, errors that lead to injuries, accidents, and catastrophes continue to occur. Fatigue has been identified as a major contributor to these incidents. The purpose of this study was to determine the leading causes of fatigue for mariners and specifically, for deck watch officers (DWO's). The maritime industry is unique in that mariners are required to live and work on ships for an extended period of time. Questionnaires and face-to-face interviews were used to study the relationship between sleep, the work environment and fatigue. The questionnaire addressed the occurrence and causes of fatigue, quality and quantity of sleep, electronics/automation and current regulations.

Through analysis of the data, the leading causes of fatigue for DWO's were found to be lack of sleep and sleeping at inconsistent times. Sleep environment, including darkness/lighting, temperature, noise, vibration, and ship motion were also studied and found to have little to no effect on sleep quality and subsequently fatigue. Today's ships are very sophisticated and well-equipped with navigation and communication aids. Contrary to previous studies, electronics and automation was found to be helpful during both routine and emergency situations. The current U. S. and international regulations were established in an effort to reduce fatigue by requiring minimum hours

of rest. These regulations seem to be adequate according to the participants in this study; however, these regulations are difficult to enforce and regulations alone will not increase safety.

In conclusion, this study found that advances in technology have reduced the number of personnel on the bridge and subsequently, increased the workload for DWO's. With the multitude of duties and responsibilities DWO's have, current staffing levels are not adequate for ensuring proper rest. Regulations that address hours of rest for mariners are adequate, however, they should also address dynamic schedules and human physiology.

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Factors that Contribute to Maritime Fatigue

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Vivianne W. Louie, Author

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1. INTRODUCTION AND SCOPE OF THE RESEARCH

1.1. Motivation for Research

Many changes have been made since the turn of the century as a result of vessel casualties like the Titanic where people died and valuable cargo was lost. Early steam engines driven by primitive boilers exploded frequently, causing large losses of life. In 1823 alone, 14 percent of all steam vessels in the United States were destroyed by explosions, resulting in more than 1,000 fatalities. (Shipwrecks and other Maritime Disasters, 2005) Vast improvements were made to the design of vessels and vessel components, including hull materials, lifesaving and fire protection equipment. In an effort to increase safety and protect the marine environment, the maritime community around the world came together to form the International Maritime Organization (IMO) (IMO, 2004). Regulations on lifesaving equipment and subdivision of the hull compartments to increase seaworthiness were established, and as a result, vessel safety has improved immensely over the last century. Specifically, U. S. regulations and International Conventions such as Loadline, Safety of Life at Sea, and International Convention on Standards of Training, Certification and Watchkeeping, (STCW), were established to set requirements and minimum standards for watertight integrity, vessel equipment and design, and seafarer training, certification and watchstanding among other things.

More recently, machinery performance and proper equipment on board vessels has been the main focus of safety inspections. With the introduction of steel, diesel engines, and electronics, many advances have been made towards vessel safety. No longer are vessels required to have wind and clear skies for propulsion under sail and navigation by the stars. There are fewer explosions and sinkings as ships have become more sophisticated. Maritime accidents continue to occur and while machinery and equipment are no longer the primary causes of human and vessel casualties, the human element has become more critical to vessel safety.

Human error resulting from fatigue has been identified as a major contributing factor to many maritime casualties, accidents, and injuries. International and U. S. regulations specify the number of hours of rest that mariners are required to have, yet mariners are still fatigued and causing catastrophic accidents. The economic losses related to lost productivity, personal injuries, medical expenses, property and environmental damage due to fatigue, sleep disorders and sleep deprivation are estimated to exceed $100 billion each year in the U.S. (Drobinich, 2002).

Research on human error has been conducted in the transportation industry, particularly in aviation; however, relatively little research has been done in the maritime industry. As shipping continues to thrive with today's global economy, casualties will continue to occur despite the best efforts of the mariner. Further research in the safety community must be conducted to find alternative ways of minimizing future casualties.

The timing could not be better for conducting research on human limitations and topics such as fatigue in the maritime industry. The U. S. Coast Guard, IMO and industry alike, have recognized that errors resulting from humans are a major concern that can and should be reduced. The Coast Guard conducted an analysis of the last thirty years of marine casualty data and found human error to be a significant problem. The Coast Guard has been seeking suggestions and recommendations from the maritime industry to gain insight on where processes can be improved to increase safety or efficiency. These efforts are part of the Coast Guard's Prevention Through People program (Federal Register, 1995).

In 1997, IMO adopted a resolution setting out its vision, principles and goals for the human element and publicly stated, "The human element is a complex multi-dimensional issue that affects maritime safety, security and marine environmental protection involving the entire spectrum of human activities performed by ships' crews, shore based management, regulatory bodies and others. All [stakeholders] need to co-operate to address human element issues effectively" (IMO, 2004).

The current laws for coastal and oceangoing merchant vessels of more than 100 gross tons that govern hours of rest and work are very antiquated, dating back to the early twentieth century. More recent laws only address tankers, towing vessels, and fishing vessels and still only limit the number of work hours. Limiting work hours is helpful, but other factors need to be considered to reduce fatigue and the subsequent opportunity for human error. The Coast Guard is working on updating hours of service requirements, but more information is needed before the new regulations are established. Title 46 United States Code (U.S.C.) §8104 is the section of the law that includes requirements for licensed officers to have work-hour limitations, an off-duty period before taking charge of the deck watch prior to departing port, and watch rotations on vessels. Specifically, 46 U.S.C. §8104(d) states that a mariner cannot be required to work for more than 8 hours in one day, however, there are exceptions to the work-hour limitations such as time necessary for docking/undocking, conducting emergency drills, actual emergency situations or overriding operational conditions. Under these and other conditions that may compromise the safety of the vessel and its passengers and crew, 46 U.S.C. §8104(f) states that a mariner can be required to work more than 8 hours in a day. The relevant portions of 46 U.S.C. §8104 and STCW '95 Section A-VIII/1 are included in Table 1.1. STCW '95 Section A-VIII/1 is the international convention that is applicable to the establishment of required hours of rest aboard certain foreign and U.S. vessels whose country is party to STCW. While these regulations provide a minimum amount of control over the hours of rest for mariners, regulations alone are not sufficient in minimizing fatigue. Other factors such as sleep environment and work conditions also need to be considered.

Table 1.1. Statutes and regulations on maritime work, rest and watchstanding.

46 U.S.C. §8104(a):	An owner, charterer, managing operator, master, individual in charge, or other person having authority may permit an officer to take charge of the deck watch on a vessel when leaving or immediately after leaving port only if the officer has been off duty for at least 6 hours within the 12 hours immediately before the time of leaving.
46 U.S.C. §8104(d):	"merchant vessels of more than 100 gross tons...shall be divided, when at sea...into at least 3 watches, and shall be kept on duty successively to perform ordinary work incident to the operation and management of the vessel...A licensed individual or seaman in the deck or engine department may not be required to work for more than eight hours in one day."
46 U.S.C. §8104(f):	"Subsections (d) and (e) of this section do not limit the authority of the master or other officer or the obedience of the seamen when, in the judgment of the master or other officer, any part of the crew is needed for – (1) maneuvering, shifting the berth of, mooring, or unmooring, the vessel; (2) performing work necessary for the safety of the vessel, or the vessel's passengers, crew, or cargo; (3) saving life on board another vessel in jeopardy; or (4) performing fire, lifeboat, or other drills in port or at sea."
STCW '95 Section A-VIII/1:	(1) All persons who are assigned duty as a officer in charge of a watch or as a rating forming part of a watch shall be provided a minimum of 10 hours of rest in any 24-hour period. (2) The hours of rest may be divided into no more than two periods, one of which shall be at least 6 hours in length. (3) The requirements for rest periods laid down in paragraphs 1 and 2 need not be maintained in the case of an emergency or drill or in other overriding operational condition. (4) Notwithstanding the provisions of paragraphs 1 and 2, the minimum period of ten hours may be reduced to not less than 6 consecutive hours provided that any such reduction shall not extend beyond two days and not less than 70 hour of rest are provided each seven-day period.

1.2. Research Questions

Fatigue has been identified as a major contributor to human error and maritime accidents. In order to improve safety and to increase the vigilance and performance of mariners, fatigue must be reduced. The National Safety Transportation Board (NTSB) has recognized that safety research must focus on uncovering the relationships between risk factors and accidents/incidents, "Monitoring the incidence and severity of transportation accidents and injuries does not, by itself, lead to the improvement of transportation safety. Safety improvement results from influencing the factors that affect the likelihood of harmful outcomes" (NTSB, 2002). Following this mandate, the primary purpose of this study is to identify those factors that result in fatigue for deck watch officers (DWO's) in the maritime industry. By identifying fatigue risk factors, it will then be possible to develop appropriate countermeasures to reduce the likelihood of fatigue leading to poor performance.

Mariners live a unique lifestyle that is unlike any other in the transportation industry. Shoreside workers go home after an eight or ten hour day, and in some jobs with "long days," after 24 hours. For mariners, the ship is the location of employment, home, and recreation for not only hours or days, but weeks and even months at a time. As a result, to understand the factors related to fatigue in the maritime industry, both the work and the living environment need to be investigated. Furthermore, even though DWO's stand navigational watches in shifts, their work is unlike other shift workers. Mariners rotate work hours, have long periods of vigilant watch keeping and work long hours in harsh environments. In this environment, deficits in performance can have catastrophic implications such as loss of lives, property and damage to the environment (Howarth, Pratt & Tepas, 1999).

Based on previous research on fatigue and studies on maritime safety, research questions were developed to guide this research. These research questions focused on the relationships between various factors and shipboard fatigue.

1. Are mariners fatigued and if so, what are the factors that cause fatigue for mariners?
2. Is the sleep environment on ships conducive to quality sleep?
3. The number of electronic devices that aid the mariner in navigation and communication in bridge or wheelhouse (where command and control functions are located) has dramatically increased over the last few decades. As a result, fewer mariners (i.e., radio officers and lookouts) are required to assist the DWO and less physical activity is required of the DWO. Have the conditions resulting from the use of electronics increased or decreased fatigue levels as a result?
4. Are the watchstanding regulations, established decades ago, still adequate for today's shipping environment?

Figure 1.2.1. illustrates the fatigue factors particular to the maritime industry included in this research. Mariners' fatigue levels maybe affected by the quantity and quality of sleep, work schedules, long hours, complex electronics/automation, ship motion, weather, and regulations. These factors can subsequently influence performance and vigilance leading to accidents, injuries, and even catastrophes.

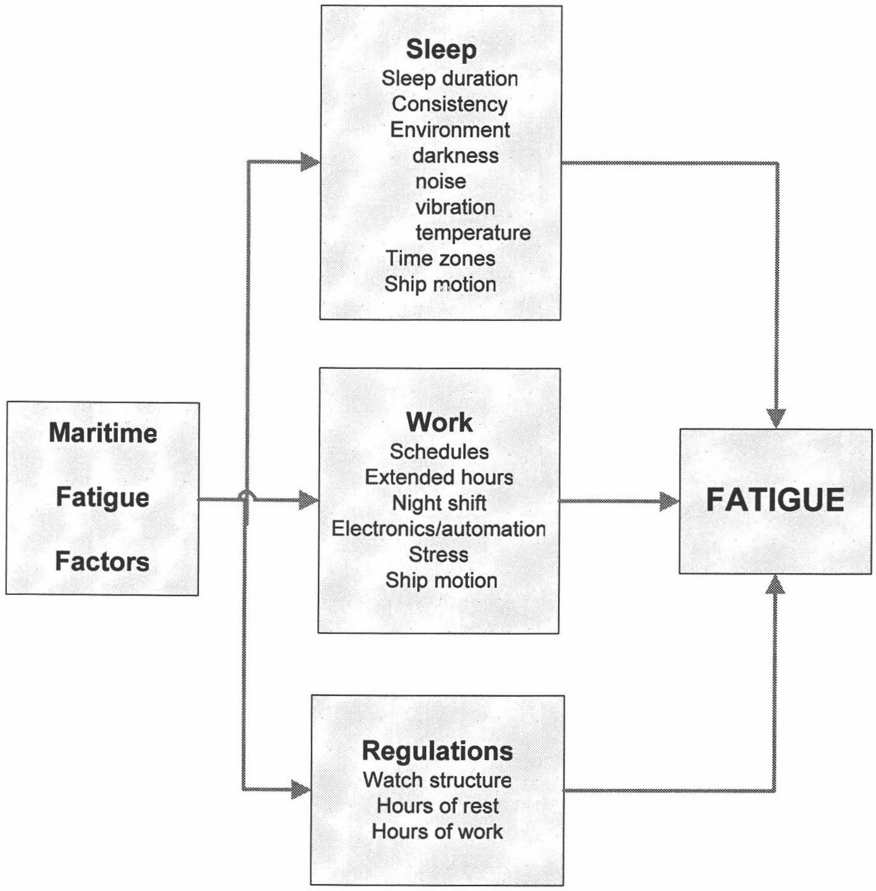

Figure 1.2.1. Maritime fatigue factors included in this study.

1.2.1. Fatigue

Given the rigorous and varied schedules that mariners work and live by, fatigue is a persistent issue faced by DWO's. DWO's are contracted to work at least eight hours per day, seven days per week for months at a time. They are also subjected to harsh working environments such as exposure to extreme temperatures, rough weather conditions, and confined spaces.

The first research question was established to investigate the prevalence of fatigue as well as the potential sources of fatigue and to identify a leading cause of fatigue. This study investigated the prevalence of fatigue while on watch and the time during the voyage when DWO's felt most fatigued. Lack of sleep, inconsistent sleep times, stress, temperature, and ship motion are all potential causes of fatigue. However, DWO's were interviewed to explore other factors that cause fatigue and to determine which of these factors, from the perspective of DWO's, were the most likely source of fatigue.

1.2.2. Fatigue and Sleep

The second research question was designed to investigate the impact of sleep quality on fatigue by studying the relationship between fatigue and the sleep environment for DWO's. Various aspects of the sleep environment, including noise, vibration, temperature and other factors particular to sleeping on board vessels were studied. The amount of sleep, consistency of sleep times, and differences in sleep patterns while in port and while at sea were also investigated.

Darkness and lighting, temperature appropriateness and ventilation are potentially significant sleep quality factors. With smaller crews in today's ships, mariners sleep in their own staterooms and have control over the room temperature and to some extent, the amount of ventilation they receive. Sources of unwanted light in most staterooms are mainly from windows which are installed with window covers such as thick curtains that can adhere to the wall. Mattress comfort and ship motion may also be a sleep quality factors.

Ship motion can also affect the quality of sleep. Excessive motion is not constant, and most mariners become acclimated to the constant movement of the vessel. Noise and vibration, however, can be constant when the vessel is underway, and therefore may also be a significant factor. Even in relatively calm seas, ships are constructed of steel and heavy machinery, which causes the vessel to reverberate noise and vibration.

1.2.3. Fatigue and Work

The third research question was designed to investigate how the shipboard working environment impacts fatigue. Specifically, the effect of electronics, stress levels and changing time zones were studied. Electronics such as global positioning systems (GPS), cell phones, and radars have reduced the amount of work for DWO's and have practically eliminated the need for radio officers and lookouts. The reduction in activity, however, can lead to boredom and decreased vigilance. Studies have shown that monotony and reduced stress levels can actually increase fatigue levels. Also, studies have shown that under routine situations, electronics may reduce workload, but other studies conclude that electronics can increase workload during stressful operations (Lee & Sanquist, 2000).

1.2.4. Fatigue and Regulations

The fourth research question was designed to investigate the role that current regulations play in mitigating fatigue. U.S. regulations require licensed personnel to be divided into at least three watches for large sea going ships. Traditionally, the chief mate, second mate, and third mate share the responsibility of the navigation watch and stand two four-hour watches per day. STCW '95 regulation A-VIII/1.1 requires that all DWO's are provided a minimum of 10 hours of rest in every 24-hour period. Furthermore, the hours of rest may not be divided into more than two periods, of which one rest period must be at least six hours long. *Rest,* as defined in STCW, is a period of time during which the person is off duty, not performing work (which includes administrative tasks such as chart corrections or preparation of port-entry documents), and is allowed to sleep without being interrupted. This research did not investigate fault and only investigated whether or not mariners were in compliance with the STCW hours of rest requirements.

1.3. Research Approach

Using previous research as a foundation, questionnaires and interviews of licensed deck officers on a variety of commercial vessels were conducted. Questionnaires are used by researchers to learn about important issues that cannot be easily studied through observations (Patton, 2002) and to quantify a particular phenomenon that is not otherwise easily measurable (DeVellis, 1991). Further, questionnaires can be used to understand a larger population by taking a representative sample (Salant & Dillman, 1994). It would be difficult to interview all mariners, especially since they are difficult to access and seldom in home port. However, by obtaining a significant sample of mariners, and DWO's in particular, a preliminary assessment can be completed to understand various aspects of living and working on board vessels. The focus of this study was to identify factors that may contribute to fatigue experienced by mariners. Questionnaires were administered to gain an understanding of the quality and quantity of sleep by DWO's on large seagoing vessels. The research instrument was also designed to collect information on the watch schedules being used (rotating, straight, two-four hour watches, etc.). Where possible, face-to-face interviews were used to solicit DWO's perspectives on the causes of fatigue, possible countermeasures, and the adequacy of current regulations. Interviews often provide important insights into a situation (Yin, 2003). By establishing rapport with the participants during the interview process, important insights on the issues of DWO fatigue and on possible ways to avert fatigue may be uncovered. Participants were also more willing to share sensitive/legal information during the face-to-face interviews rather than sharing such issues in writing.

This study used direct input from mariners living and working on large freight ships, public vessels, and ferries. To be a licensed mariner, such as a chief mate or master requires years and even decades of sea time. Because the participants of this study have many years of experience in this unique environment, documenting the challenges and soliciting the opinions of this population on factors that contribute to fatigue was appropriate for the research questions under study. In addition, suggestions of this same target population were gathered to identify potential countermeasures for the risk factors identified.

Using open-ended questions and interviews allowed the researcher to identify sources of fatigue, why fatigue occurs, and suggestions of design interventions or prevention ideas to minimize adverse consequences.

1.4. Research Contribution

Results of this study will increase the body of knowledge regarding the factors that affect shipboard fatigue and possibly contribute to the establishment of updated hours of service regulations. The key findings from this study are summarized in this section.

Lack of sleep and inconsistent sleep times were found to be the leading causes of fatigue. The rigorous and varied schedules along with the numerous time zone changes make it difficult to maintain consistent sleep and wake times. Furthermore, the traditional four-on and eight-off watch schedule does not enable DWO's an adequate amount of time off for sleep, meals, personal hygiene and other work requirements.

Electronic navigation and communication aids have drastically improved in accuracy and efficiency over the last few decades. As DWO's become more proficient with the use of electronic aids and as the interface designs continue to improve, these devices will continue to make the job easier for DWO's during both routine and emergency situations.

Theoretically, 10 hours of rest every 24 hours is reasonable, especially when transiting at sea. However, when the vessel has several port calls in a short time frame, the resulting duties that accompany loading and unloading at a port often do not enable all DWO's to receive ten hours of rest or even six hours of uninterrupted period of rest. Most participants agreed that the current regulations regarding hours of rest are adequate, however they are seldom followed. Therefore, regulations alone are not adequate in minimizing fatigue. Other considerations such as organizational policies and increases in personnel were suggested as potential countermeasures for reducing or eliminating fatigue.

2. LITERATURE REVIEW

This chapter will first define human error and fatigue. Using previous research as a foundation, common problems associated with fatigue in maritime and other transportation industries will be discussed. This is followed by a discussion of the regulations that govern work and rest periods in the maritime industry. Previous research related to the management of fatigue and the benefits and challenges of modern technology will also be discussed. A final section summarizing the duties and positions for DWO's of interest in this research is also included in this chapter.

2.1. Human Error

Human error has been defined as inappropriate human behavior that lowers levels of system effectiveness or safety, which may or may not result in accident or injury (Wickens, Gordon & Liu, 1998). It has also been defined by Reason (1990), as a planned sequence of mental or physical activities that fail to achieve the intended outcome in which the failures did not happen by chance. In an analysis of 100 accidents at sea, Wagenaar and Groeneweg (1988) found that cognitive problems accounted for 70% of human error and was present in 93% of the accidents. In order to reduce maritime casualties, more research is needed to identify potential risk factors related to human error and on developing ways to effectively minimize or eliminate these risk factors.

Previous research on the percentage of maritime accidents resulting from human error is not consistent. Human error has been shown to account for anywhere from 50% to 96% of maritime accidents. The percentage cited in various studies depends on the specific parameters of the study and on how human error was defined. The Norwegian Maritime Directorates database revealed that more than 50% of maritime accidents have human-related causes" (Havold, 2000). Another study on U. S. ship collisions that occurred between 1970 and 1979 found human error to account for 67% (Meurn, 1990) of these collisions. Atkinson, Stockel and Chudley (1993) reported that human error in the form of ignorance or negligence was estimated to be responsible for up to 77% of marine accidents in confined waters. According to Sanquist (1992), human error accounts for 65-80% of maritime casualties; whereas a Coast Guard report estimated that 75-96% of marine casualties were caused by some form of human error (Rothblum, n.d). While the exact percentage is not known, the risk is significant and more research is needed to reduce these errors.

2.2. Fatigue

Fatigue is a common issue for many transportation industries, including the maritime industry. The consequences of fatigue can be lethal and destructive (Jones, Dorrian & Dawson, 2003) especially in transportation where heavy vehicles and vessels carrying passengers and dangerous cargo are moving at high speeds with great momentum. A 1996 United States Coast Guard analysis of 279 incidents showed that fatigue contributed to 16 percent of critical vessel casualties and 33 percent of personal injuries (McCallum, Raby, & Rothblum, 1997). Fatigue is not only an undesirable state from an individual perspective, but also from a systems perspective. The safety of the crew, the vessel and cargo are all at an increased risk level for accident or injury when DWO's are fatigued. Fatigue affects performance as a result of reduced competence or as a result of not being able to maintain goal-directed behavior (Michielsen, de Vries, Van Heck, Van de Vijver & Sijtsma, 2004). Fatigue also impairs information processing which can diminish a worker's ability to respond effectively to any unusual circumstances or to emergency situations (Lal & Craig, 2001; NTSB, 1999). In order to reduce the fatigue levels for mariners, more research needs to be conducted to identify the causes of fatigue and develop methods to reduce the fatigue levels.

Fatigue is not simply "tiredness resulting from hard work or exercise" (Ehrlich, Flexner, Carruth, & Hawkins, 1980). There are many factors that affect fatigue, including the duration and quality of sleep, shiftwork and work schedules, irregular work hours, circadian rhythms, time of day, monotonous environments, and stress from demanding delivery schedules (NTSB, 2002, Lal & Craig, 2001). See Table 2.2.1. for a summary listing of previous research on various fatigue factors.

Table 2.2.1. Fatigue factors and references.

Fatigue Factor	References
Sleep duration	French, 2002 Jones, Dorian & Dawson, 2003 Sullivan, 2003
Sleep quality	National Sleep Foundation (NSF), 2004 Akerstedt, Fredlund, Gillberg & Jansson, 2002
Shiftwork	Salvendy, 1997 Baker & Morriseau, 1993
Work Schedules/ Long hours	Lal & Craig, 2004 Hakkanen & Summala, 2000 Goode, 2003 French, 2002 Jones, Dorian & Dawson, 2003 Crum & Morrow, 2002
Irregular work hours	Lal & Craig, 2004
Circadian rhythms/ Time of day	Salvendy, 1997 French, 2002 Sehgal, 2004 Rowe, French, Neville & Eddy, 1992
Electronics/automation/monotonous environments	Lal & Craig, 2004 Atkinson, Stockel & Chudley, 1993 Sauer et al, 2002
Stress	Lal & Craig, 2004
Temperature	Ellis, 1953
Ship motion	Stevens & Parson, 2002 Wertheim, 1998

Fatigue may also be categorized as either physical fatigue or as mental fatigue. Physical fatigue has been referred to as a symptom which emerges after prolonged physical exertion without sufficient rest (Michielsen, et al., 2004). Being confined to the ship, mariners experience physical fatigue on a regular basis from having to work and live on board the vessel. Fatigue can result from hours of standing on the bridge during a navigational watch, walking around various locations throughout the ship, climbing stairs or ladders between decks and cargo holds, and maintaining balance as a result of the constant vessel motion (Stevens & Parsons, 2002; Wertheim, 1998). DWO's regularly traverse the entire length of ship and traverse from top to bottom to carry out duties such as monitoring both the safety and seaworthiness of the vessel as well as checking on the cargo on board. Dimensions of ships vary but can easily extend beyond 200 yards in length and 100 feet from top to bottom. One of the vessels boarded for this study was 840 feet long and 118 feet wide. As a result of the duties assigned to DWO's, it is not uncommon for DWO's to walk significant distances each day.

Mental fatigue has been described as reduced psychological capacity and less willingness to act adequately due to earlier mental or physical effort (Michielsen, et al., 2004). Working onboard any vessel can be mentally fatiguing for a variety of reasons including stress as well as the lack of adequate rest from frequent port calls, irregular work hours, or monotonous watch situations. There are numerous factors that may result in creating a stressful work environment at sea. For example, demanding delivery schedules, maintaining proficiency in using complex equipment, inclement weather as well as absence from friends and family can all lead to psychological stress for DWO's.

2.3. Hours of Rest

Fatigue is most noticeable in industries that are heavily reliant on 24-hour operating systems such as shipping. One factor contributing to fatigue that is common among different transportation industries is the amount of rest workers receive. Results of studies in the trucking industry have shown the need for driving hour restrictions. These restrictions were established based on the increase in the level of accident risk experienced after prolonged driving (Hakkanen & Summala, 2000). Finland enacted a regulation that restricts truck drivers to no more than 10 hours of driving time. However, regulations alone are not adequate. Hakkanen and Summala (2000) found that 31% of all truck drivers had been regularly driving more than the maximum allowed time. One objective of this study was to determine whether or not mariners, like truck drivers, are routinely out of compliance. The regulations specifying hours of rest for mariners are established in Chapter VIII of STCW '95 and are described in detail in Section 2.4.

The aviation industry is also concerned with work schedules and fatigue. Unlike the maritime regulations, flight crews have strict limitations on work hours. Federal aviation regulations in the United States limit operations to 30 flight hours in any seven days, and pilots are given 24 consecutive hours of rest each week. In a study on the relationship between U.S. commercial aircraft pilot schedules and accidents, Goode (2003) found that there is a discernable pattern of an increased probability of an accident as the duty time increases. These results suggest that establishing limits on duty time for commercial pilots would reduce risk. Currently, the regulations for DWO's are much less stringent than those applied to pilots in aviation. In the maritime industry, DWO's are generally required to obtain only 10 hours of rest in any 24 hour period, and there are no other longer term (work) restrictions in place. Because ships operate 24 hours a day, seven days a week, deck officers are subject to night watches on a regular basis. Those working night operations or extended duty hours are at greater risk when fatigued, which can potentially result in grave consequences (French, 2002; Baker & Morriseau, 1993; Rowe, French, Neville, & Eddy, 1992).

Cognitive abilities become impaired as a result of sleep deprivation, demanding shift schedules, and/or night operations. As a result of fatigue, operators have a reduced ability to solve complex problems, lose motivation to find solutions and are less able to adequately assess risks. Operators also become lost in details and are less able to troubleshoot equipment malfunctions (French, 2002). These potential reductions in performance can be extremely dangerous for the deck officer who is surrounded by and heavily dependent on complex equipment such as radars, GPS's, fire detection and suppression systems and various alarm and warning systems.

Both short term and long term fatigue result from insufficient rest and impacts not only an individual's performance but also that of teams (fire fighting, lifeboats, anchor, etc), departments and the entire ship. Acute, or short term fatigue can occur following cargo operations, intense training (fire/lifesaving drill in extreme conditions), motion sickness and/or an arduous day but can be eliminated or reduced after a period of rest, or when tasks are switched (Bultmann, et al., 2000). Chronic, or long term fatigue, can occur near the end of a tour of duty with extensive sleep disruption. Unlike short term fatigue, long term fatigue is not easily reversible and can result in reduced concentration and motivation (Bultmann, et al., 2000). Most mariners have become accustomed to working while fatigued and accept the long and intense days or months as part of the job. Further research is needed to produce converging evidence concerning the nature of acute and chronic fatigue as determined by shift work requirements and sleep disruption induced by voyage factors such as time in port, weather, and duration of voyage (Sanquist, 1992).

Work-related fatigue is influenced by the amount of time an individual has been at work, the time of day, and the duration and timing of previous sleep periods. The probability of fatigue-related injury increases with the amount of time the person has been working. The risk increases exponentially after 9-12 hours (Jones, Dorrian & Dawson, 2003; Goode, 2003). After working eight hours of navigation watch, it is not difficult to exceed 9-12 hours of work for DWO's, particularly for those that stand a navigation watch before and after the normal working day such as the chief mate (Meurn, 1990). Navigation watches are carried out by the chief mate, second mate and third mate. DWO's typically stand watch for a total of eight hours per day and the navigation watches are divided in two four-hour periods as summarized in Table 2.3.1. Although the master assigns the watches, traditionally, the chief mate stands the *4-8*, watches " or from 0400-0800 and 1600-2000; the second mate stands the *mid's* or midnight to 4 a.m. and noon to 4 p.m; and the third mate stands watch from 8 a.m. to noon and again from 8 p.m. until midnight.

Table 2.3.1. Typical watchstanding schedule.

Watchstander	Watch schedule	Watch schedule name
Chief mate	0400-0800 1600-2000	Four to eight's
Second mate	0000-0400 1200-1600	Midwatch
Third mate	0800-1200 2000-2400	Eight to twelve's

2.4. Regulations

Hours of service regulations throughout the transportation industry have been a topic of debate over the last decade. When the hours of service regulations for the shipping industry were enacted in the early 1900's, they were thought to be a positive and necessary way to manage alertness and fatigue. These regulations were viewed as a means for avoiding danger to employees and to the public. The U. S. laws regarding hours of work and rest vary depending on the type (oil tanker, towing, fishing etc) and size or tonnage of the vessel. Aside from the Oil Pollution Act of 1990 (OPA '90) regulations that affect oil tankers and the STCW '95 regulations, maritime hours of service regulations are dated. In addition, laws such as OPA '90 were developed as a result of political pressures and are not scientifically based. Because of the technological innovations impacting the maritime industry in recent years, some experts believe that many of the current hours of service regulations in the United States are no longer valid or effective (Tepas, 1994). The specific requirements that limit hours of rest and hours of work for DWO's are summarized in Table 2.4.1.

Table 2.4 1. Summary of work and rest limitations and watchstanding requirements.

Regulation	Vessel Applicability	Details/Requirements
46 U.S.C. §8104(a)	U. S. vessels	DWO's may take charge of the deck watch on a vessel when leaving or immediately after leaving port only if the officer has been off duty for at least 6 hours within the 12 hours immediately before the time of leaving.
46 U.S.C. §8104(d)	U. S. vessels 100 gross tons and above	Licensed individuals, sailors, shall be divided into three watches when at sea.
		No more than 8 hours of work allowed per day for DWO's.
46 U.S.C. §8104(f)	U. S. vessels 100 gross tons and above	More than 8 hours of work allowed for docking/undocking, emergency drills, actual emergency situations or overriding operational considerations.
STCW '95 Chapter VIII/1. and 46 CFR 15.1111	CFR: U. S. Vessels that operate beyond the boundary line STCW: All vessels party to the convention including the U. S.	Navigational watch personnel shall receive a minimum of 10 hours rest in any 24-hour period.
		The hours of rest shall be divided into no more than two periods, of which one shall be at least six hours in length.
		The minimum period of 10 hours rest may be reduced to not less than six hours as long as the reduction does not exceed two days and the individual receives 70 hours of rest in each seven-day period.
46 U.S.C. §8104(n)	All U.S. tank vessels	On a tanker, a licensed individual or seaman may not be permitted to work more than 15 hours in any 24-hour period, or more than 36 hours in any 72-hour period, except in an emergency or a drill. In this subsection, "work" includes any administrative duties associated with the vessel whether performed on board the vessel or onshore.

There are currently international and U. S. regulations that address hours of rest. Under the international convention, STCW '95, Chapter VIII, all DWO's must be provided a minimum of 10 hours of rest in every 24-hour period and the hours of rest are divided into no more than two periods, of which one period must be at least six hours long (to enable a relatively longer sleep period). This international convention has also been adopted into U. S. Coast Guard regulation, Title 46 Code of Federal Regulations (46 CFR) 15.11111. Similarly, STCW and CFR have specific regulations for mariners that work on tank vessels. The OPA '90 enacted work-hour limitations for tank personnel of 15 hours per 24 hours and 36 hours per 72 hours . The U.S. law that requires DWO's a period of rest before leaving port is 46 U.S.C. §8104(a):

> An owner, charterer, managing operator, master, individual in charge, or other person having authority may permit an officer to take charge of the deck watch on a vessel when leaving or immediately after leaving port only if the officer has been off duty for at least 6 hours within the 12 hours immediately before the time of leaving.

The U. S. law that limits the number of hours mariners can work is stated in 46 U.S.C. §8104(d).

> On a merchant vessel of more than 100 gross tons ...the licensed individuals, sailors, coal passers, firemen, oilers, and water tenders shall be divided,when at sea, into at least 3 watches, and shall be kept on duty successively to perform ordinary work incident to the operation and management of the vessel...A licensed individual or seaman in the deck or engine department may not be required to work more than 8 hours in one day.

However, 46 U.S.C. §8104(f), allows mariners to work more than eight hours in one day under certain circumstances:

> Subsections (d) and (e) of this section do not limit the authority of the master or other officer or the obedience of the seamen when, in the judgment of the master or other officer, any part of the crew is needed for -
> (1) maneuvering, shifting the berth of, mooring, or unmooring the vessel;
> (2) performing work necessary for the safety of the vessel, or the vessel's passengers, crew, or cargo;
> (3) saving life on board another vessel in jeopardy; or
> (4) performing fire, lifeboat, or other drills in port or at sea.

These regulations are intended to prevent fatigue by prescribing limitations on work hours and a minimum number of watch officers. While at sea for days or even weeks at a time, these regulations may be adequate, however, for vessels that frequently pull into port, the DWO's need to be involved with mooring, unmooring, maneuvering, and tending to cargo operations, etc. in which there are no limits for the amount of time DWO's may work.

U. S. regulations stipulate specific limitations on hours of work and rest for tankers, merchant vessels and fishing vessels. However, there are a variety of different watch-standing schedules that crews use depending on variables such as the number of available watchstanders, the length of the trip, and what the captain or crew prefers. Some schedules permit a full eight hours of sleep but many do not. When working the traditional three person watch rotation with four hours on, eight hours off schedule, getting just six hours of sleep can be difficult when time off is taken for meals, personal hygiene, and/or relaxing before going to sleep.

2.5. Managing Fatigue

There are many factors that need to be considered in managing fatigue. Managing fatigue can be especially challenging for those in the maritime industry. Circadian rhythms, temperature, scheduling, extended hours, sleep hygiene, and modern technology have all been shown to be important factors to manage (Jones, Dorian & Dawson, 2003). Other considerations previously mentioned include the effects of motion due to sea and weather conditions. The next sections provide a brief overview of these factors based on previous research from a variety of domains.

2.5.1. Circadian Rhythms

Human circadian rhythms, such as sleep-wake cycles, brain function, and thermoregulation, are cycles that occur within a period of 24 hours (Sehgal, 2004). These rhythms can be synchronized or reset daily by environmental cues such as light. Circadian rhythms may explain in part why many nightshift workers experience problems with both staying awake during their work hours and sleeping during their off hours (day). Nightshift workers are working when they should be sleeping according to circadian rhythms, and sleeping when their biological clock tells them they should be awake (Salvendy, 1997). There are periods of peaks and troughs throughout a 24-hour day. Experiments were conducted that measured core body temperature, heart rate and cortisol excretion to identify these peaks and troughs. All three sets of measures clearly indicated troughs at around 4 a.m. and peaks between 12 p.m. and 6 p.m (Sehgal, 2004). As illustrated in Figure 2.5.1.1., the troughs has been defined as the daily period when energy and alertness are at their lowest levels, typically spanning from bedtime to sunrise, with the most-critical period spanning from 0300 to sunrise (Comperatore & Rivera, 2002). The troughs have been identified as zones of extra vulnerability in terms of human performance. As a result, peak performance is unlikely during troughs and poor performance in these periods may increase the risk of accident (Salvendy, 1997).

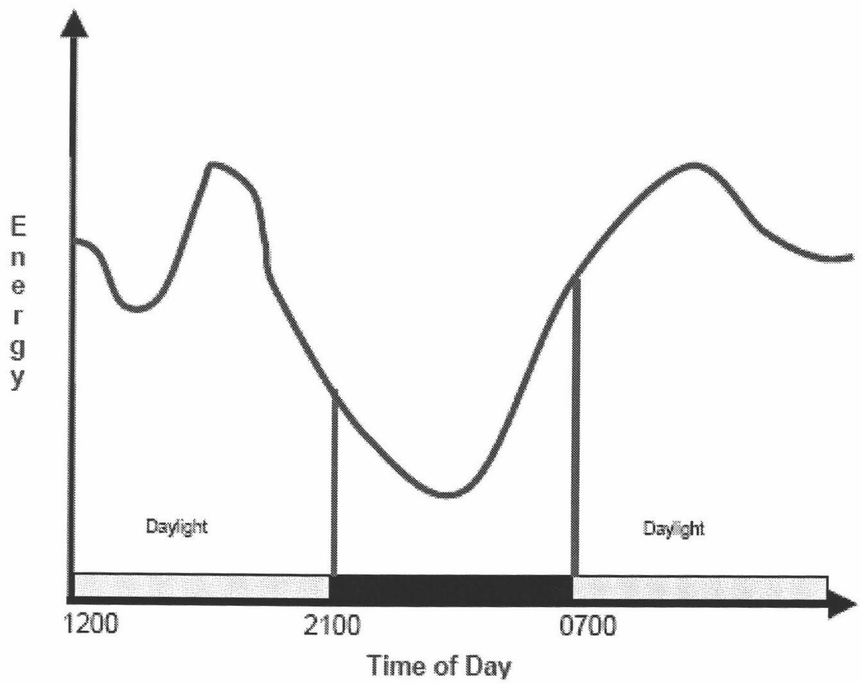

Figure 2.5.1.1. Periods of low and high energy in a typical 24-hour period. (Comperatore & Rivera, 2003).

Furthermore, night workers may experience cognitive impairment because circadian and homeostatic processes that regulate sleep are also critical for waking cognitive ability (Sehgal, 2004). Some options to compensate for lack of wakefulness at night include using bright lights and pharmacological countermeasures such as caffeine (Sehgal, 2004, Comperatore & Rivera, 2002).

2.5.2. Temperature

Temperature, particularly, hot environments, has also been identified to be a factor in causing fatigue and has been shown to impact human performance (Macdonald, 2003). In a study conducted by Ellis (1953) in the British Navy, over 80 percent of officers and crew felt less efficient in the tropics than in more temperate waters. Efficiency was affected by the warm temperature by inducing lethargy. As a result, reduced concentration, retardation, lowered responsibility, personality changes and memory failures were experienced by the sailors. Others, engaged in sedentary mental work, were unable to think after short periods in hot offices, felt drowsy, and made mistakes. An important finding of this study was that mistakes were made frequently in hot climates and were made without the knowledge of the person making the mistake (Ellis, 1953).

2.5.3. Scheduling

One of the most important workplace issues related to fatigue management is the interacting effects of working hours, shift systems, and workload levels (Macdonald, 2003). The watchstanding laws applicable to deck personnel, 46 U.S.C. § 8104 (d), has been mandated by statute since 1915. This statute requires merchant vessels of more than 100 gross tons to divide licensed individuals into at least three watches, which translates to at least three DWOs for watchstanding. For most ships, the three DWO's are the chief mate, second mate and third mate. A study conducted by the National Research Council (NRC) (1990), for the U.S. Coast Guard, found that the traditional watch schedule followed by most of the work's fleet, four hours on and eight hours off, interferes with normal sleep cycles, particularly for those that stand the night watch. A recommended schedule was to give the second and third mate full-length periods of sleep by assigning them to 12-hour watches followed by 12 hours of free time.

In a recent study that investigated truck driver fatigue, the single most important factor influencing truck driver fatigue was starting the work week tired. This finding highlights the importance of the role of scheduling. In particular, drivers must be given adequate recovery times between assignments (Crum & Morrow, 2002). It is also important for drivers to use the time between assignments to get adequate rest.

There are currently fatigue detection systems on the market that companies can use to assess work schedules and predict operator alertness and performance based on sleep interactions, circadian rhythms and other symptoms of fatigue. In a review of the existing fatigue detection systems, Horberry, Hartley, Krueger, and Mabbott (2001) concluded that these systems can potentially improve shiftwork rosters and can provide "useful advice to inexperienced supervisors," but future models will need to take into account individual differences such as susceptibility to fatigue, circadian physiology and job demands Horberry, et al. (2001).

2.5.4. Extended Hours

Extended work hours is another factor relevant to this research. Long working hours are common in the maritime industry and even desired by many union members because it can substantially increase their earnings (NRC, 1990). Although long hours are common and even desired, it is not recommended by safety practitioners. In a NIOSH study on overtime and extended work shifts, Caruso, Hitchcock, Dick, Russo and Schmit (2004) reported that the 9th to 12th hours of work were associated with feelings of decreased alertness, increased fatigue, lower cognitive function, declines in vigilance on task measures and increased injuries. When an individual's physical, physiological and psychological capacity is less than the required workload, the human being is overloaded and as such, cannot help but to err (Petersen, 2003).

DWO's work longs days, everyday, for months at a time. DWO's typically stand two four-hour navigational watches in the wheelhouse, where they are responsible for many duties including continuously tracking the ship's movements, monitoring the radar to detect other vessels and aids to navigation, and navigating the vessel (Meurn, 1990). In addition to these eight hours of watch standing, there are many other duties that each officer is responsible for completing in their office or at some other location on the ship. These duties include inventory and maintenance of safety and navigation equipment, administrative work, preparing for cargo operations, training etc. The long working days easily result in 80+ hour work weeks. Not only do mariners work excessive hours on a daily basis, but there are no weekends or days off in which they can recover from the long hours. They work every day that they are on the vessel for months at a time. These demanding working conditions result in higher fatigue levels and stress that can affect performance such as deteriorated verbal reasoning and alertness (Macdonald & Bendak, 2000), both of which are essential for standing a vigilant navigational watch.

2.5.5. Sleep Hygiene

Sleep hygiene is also relevant to a study of fatigue factors. Sleep deprivation and sleep disorders are estimated to cost Americans over $100 billion annually in lost productivity, medical expenses, sick leave, and property and environmental damage (NSF, 2004). Good fatigue management entails much more than prescribing the hours that an individual works, it also takes into account regulating, measuring, and managing the opportunity to obtain sufficient sleep (Sullivan, 2003). Sleep hygiene consists of seven components that are relevant to mariners (NSF, 2004). These seven components are summarized in Table 2.5.5.1.

Table 2.5.5.1. Components of sleep hygiene.

Component	Description
1. Duration	Individual requirements are unique, however, minimum 7-9 hours in a 24 hour period.
2. Consistency	Maintain the same sleep and wake times each day/night.
3. Environment	Create a sleep-conducive environment that is dark, quiet, comfortable, cool, well ventilated and free of interruptions. If possible, sleep on a comfortable mattress and pillow.
4. Diet	Avoid heavy meals and spicy foods close to bedtime. Finish eating at least 2-3 hours before regular bedtime.
5. Chemical substances	Avoid caffeine, nicotine, and alcohol close to bedtime.
6. Daily routine	Establish a regular, relaxing bedtime routine away from bright lights
7. Exercise	Exercise regularly and finish working out at least a few hours before bedtime. Exercising contributes to sounder sleep.

Ensuring proper sleep hygiene is often a challenge in the shipping industry. Sleep duration and consistency is often beyond the control of the individual mariner and is dictated by company policies and scheduling practices, and even regulations. A study on crew size and maritime safety by the NRC (1990) found that the four-on eight-off watch schedules affects crews by interfering with normal sleep cycles, upsetting circadian rhythms and depriving sleep. With only eight hours off between watches, it is difficult to obtain the recommended 7-9 hours of sleep. Additional time is taken for meals, personal hygiene and the watch relief process. The same study recommended a system in which each watch keeper has a 10 to 14-hour period of unbroken free time each day to permit unbroken sleep. Longer periods of free time would require a change in the traditional schedule or increased personnel.

Maintaining consistent sleep and wake times for shipboard personnel is easier when the vessel is in the open ocean, where the schedule is more regular than in or near ports. The date and time a ship pulls into port varies and is determined mainly by shoreside personnel but can be affected by weather conditions, dock availability, and operating condition of the vessel. These variations are beyond the control of the individual mariner, and can disrupt normal sleep and wake times. The NSF (2004) claims it is "important to keep a regular bed and wake-time" to allow the body to synchronize with the circadian clock.

Creating a sleep-conducive environment that is dark, quiet, comfortable, cool, well ventilated and free of interruptions is important for obtaining quality sleep. Most mariners have control over the sleep environment, particularly on more modern ships where there are smaller crews and mariners have individual staterooms. Most staterooms have a small window that can be darkened and thermostats to regulate the temperature. Noise can be difficult to control even though many ships are constructed with sound absorbing barriers on floors, ceilings and walls. This can be especially challenging for those that work at night and sleep during the day when there is a lot of activity both internal and external (cargo operations, maintenance) to the ship. NSF (2004) recommends the use of blackout curtains, eye shades, ear plugs, "white noise," humidifiers, fans and other devices to improve the sleep environment.

The motions of a vessel at sea can also create an undesirable sleep environment. In particular, vessel motion can lead to motion sickness and/or drowsiness. Performing physical tasks at sea with even the lightest of sea conditions is more difficult than performing tasks ashore. This is due to the extra effort required to maintain balance on a moving platform. This extra effort induces fatigue, increases the mental effort required to perform tasks and leads to decreased human performance (Stevens & Parson, 2002).

Diet, use of chemical substances, daily routine and exercise are individual lifestyle choices the mariner makes. Ships typically have one galley where all meals are prepared. The daily menu is determined by the chief steward and master, which can make it difficult for individuals to choose what and when they eat. To increase the quality of sleep, the NSF recommends avoiding heavy meals and spicy foods before bed time as well as avoiding the use of caffeine, nicotine and alcohol before bedtime. Furthermore, they recommend establishing a regular relaxing bedtime and exercise regimen well before bedtime.

2.6. Modern Technology – Benefits and Limitations

New and even older commercial vessels are required to be well-equipped with navigation systems, communication systems and advanced warning systems to aid the professional mariner. These systems are also used to aid other vessels that may be in distress. These systems include GPS, collision avoidance radars, electronic charts, global marine distress and safety systems, and global satellite communication systems. Compared to the days of celestial navigation and iceberg lookouts, these sophisticated systems have greatly enhanced the navigation capabilities of mariners, the safety of vessels and personnel, and have significantly reduced personnel requirements in the wheelhouse.

Mariners rely heavily on these technologically advanced systems to get from port to port safely and efficiently. Large shipping companies building new vessels are opting to increase the level of automation in vessels for various reasons. Technology-based advances and automation can increase productivity and reduce the number of personnel and their associated costs. Some experts also argue that automation is an effective means to reduce human error by taking the human element out of the picture (Wang & Zhang, 2000). Some studies even suggest that "under proper conditions, workload levels decline and performance rises with one-person operation" (Lee & Sanquist, 2000). These findings, however, are only true during routine conditions and do not necessarily hold true when conditions are not ideal. Automation has been defined as the execution by a machine agent of a function that was previously carried out by a human (Parasuraman, 1997). Many considerations need to be taken into account when deciding whether or not to use automation including over-reliance and individual differences. Complexities of the operational environment and individual human operators may cause automation to be used in different ways than intended. Designers, regulators and operators must be knowledgeable about how the automation works and when and where its use is appropriate (Parasuraman, 1997).

Recent studies have concluded that the misapplication of modern technologies in information and communication systems may actually degrade decision making effectiveness during emergencies and decrease workplace safety and productivity (Wheeler, Bolton, & Sanquist, 1990; Tepas, 1994). Other studies have suggested that poorly designed automation may reduce workload during routine operations, but can result in increased workloads during stressful operations (Lee & Sanquist, 2000).

Another issue associated with increased levels of automation is that DWO's and operators become less active during watchstanding duties and are subject to more monitoring activities. Previous research has shown humans are not particularly good at monitoring activities, especially when fatigued or less vigilant (Sauer et al., 2002). This can lead to boredom, loss of situational awareness, poor decision making and lack of action or delayed responses. Further, when automatic systems fail, operators may have difficulty regaining manual control because they need time to construct an up-to-date mental model of the current system state in order to effectively intervene (Sauer et al., 2002). To be beneficial to navigation safety, automation must reduce rather than increase the number of monotonous tasks to be performed by the lone watchkeeper where boredom and lack of mental stimulation can be problematic. If automation exacerbates these undesirable conditions, the risk of human error increases (Atkinson, Stockel & Chudley, 1993).

2.7. Information Overload

The wheelhouse or the bridge is typically where command and control functions are located. In newer ships, the bridge is the ship's operation center where essential vessel functions, including navigation, engine control and communications are controlled and monitored. As a result, the master or the crew can be overwhelmed with the amount of incoming information not only from navigation and communication aids, but also from warnings alarms, other crewmembers reporting back with assessments, and status reports from the engine room, galley, hospital etc. Sauer et al. (2002) conducted a study on the effects of ship navigation displays on performance and found that the interface design had a significant effect on fatigue. Furthermore, they found a "strong" increase in fatigue from monitoring multiple displays, especially as time passes over a 4-hour watch period. If a decision maker is fatigued, and is inundated with information, poor decisions will likely occur. Fatigue and sleep loss can lead to selective attention. In dual source vigilance tasks, subjects tend to monitor one source closer than the other, and focus on the expected even missing the unexpected when it happens (NRC, 1990). These poor decisions can result in injury or catastrophe. This was the case for the third mate during the Exxon Valdez grounding. Fatigue, stress from workload, and cognitive tunnel vision were in part responsible for the accident The third mate focused on the most salient information at the time, the location of the iceberg on the radar, but forgot about the submerged portions of Bligh Reef, resulting in the largest oil spill in U.S. history (Bookman, 1991).

Three types of information-related performance difficulties that fatigued DWO's may be affected by are: decision uncertainty, self-reinforcement and decision bias. These performance difficulties can contribute to error, accidents and even catastrophes. Decision uncertainty occurs when a decision maker has to make a decision but has difficulty resolving ambiguities in the information at hand and focuses on information he/she deems most salient (Macdonald, 2003). Self reinforcement occurs when the decision maker gives more (unwarranted) credence or attention to repeated or recycled information (Wheeler, Bolton, & Sanquist, 1990). Decisional bias occurs when the decision maker is subjected to information that has changed as it moves through the system such as receiving second or third hand information (Wheeler, Bolton, & Sanquist, 1990).

Fatigue is a persistent occupational hazard for drivers in all modes of transportation (Brown, 1997). Factors that cause fatigue in other industries, and in general, have been identified, but addressing fatigue in the maritime industry is complex. The maritime industry, from a global perspective, will benefit from more research on developing methods to reduce fatigue, particularly for DWO's.

3. RESEARCH METHODOLOGY

3.1. Participants

The rank structure for licensed deck personnel on most ships consists of the master, chief mate, second mate and third mate. The duties and responsibilities for each position differ as summarized in Table 2.5.3.1. Usually addressed as the captain, the master is in overall command of the ship and is effectively the general manager who is responsible for the safe navigation and operation of the ship (Marine Society, 2005). The master does not stand scheduled watches but is normally required by company policy to be on bridge when the ship is in pilotage waters (areas where a pilot is required by state or federal mandates to direct the vessel to port), close proximity to shore or navigational hazards, particularly bad weather or when other conditions dictate, he or she would closely oversee the navigation of the ship.

The chief mate is often addressed as the mate and is responsible for the day to day working of the deck. These responsibilities include overseeing daily work of the deck crew and for the stowage, loading, carriage and discharge of the cargo with particular attention to the ship's stability. The second mate is the ship's navigator and has primary responsibility for the upkeep of charts and passage planning. At sea, the second mate keeps both 12–4 watches and in port shares cargo watches with the third mate. The second mate is also frequently the ship's medical officer. The third mate assists both the mate and second mate, keeps both 8-12 watches at sea and shares cargo watches with the second mate in port. As the safety officer, the third mate is also responsible for the maintenance of the ship's lifesaving and firefighting (ff) equipment. The duties and watch schedule for licensed deck officers are summarized in Table 3.1.1.

Table 3.1.1. Duties and responsibilities of licensed deck personnel.

Position	Watch schedule	Primary Duties
Master	None assigned	overall in charge of the safe navigation & operation of the ship
Chief mate	0400-0800 1600-2000	Cargo operations & ship stability
Second mate	0000-0400 1200-1600	Navigation officer – maintains navigation publications & charts
Third mate	0800-1200 2000-2400	Safety officer – maintains lifesaving & ff equipment

A diverse range of ship drivers were solicited for inclusion in this study. In particular, DWO's from foreign freight ships, domestic freight ships, tank ships, Coast Guard cutters, and large passenger ferries were invited to participate. The majority of the participants were interviewed in the Puget Sound area. Puget Sound was chosen because it is a large, diverse port with a regular fleet of ferries, military vessels, and foreign and domestic freighters. Although the main focus was on U. S. vessels, it was important to include foreign vessels to provide a broader perspective and identify potential cultural aspects that would not otherwise be discovered.

DWO's from seagoing vessels that are subject to International Convention for the Safety of Life at Sea (SOLAS) requirements (primarily seagoing vessels over 500 gross tons) were targeted for this study. Participants were solicited and interviewed onboard vessels and ashore at the International Organization of Masters, Mates, & Pilots (MMP) union hall in Seattle, Washington. The majority of participants were from vessels that were on Pacific Rim routes including Asia, Alaska, and Hawaii, although participants from vessels working on the Atlantic coast, Gulf coast, Europe and Africa were also included.

To reach potential participants on actively working ships, the researcher worked closely with marine inspectors from the Coast Guard Marine Safety Office (MSO) in Seattle, Washington. Contacts at the MSO helped the researcher to identify vessels coming in to port, to identify vessels to be inspected and to coordinate visits to the vessel. The MSO receives an advance notice of arrival for all vessels greater than 300 gross tons (33 CFR 160) that are destined for Puget Sound. This notice includes vessel and crew details and the ship's itinerary. The ship's itinerary includes information such as the estimated time of arrival, the estimated time of departure, the location of the port, and other logistical information. Coordinating and boarding vessels in conjunction with the MSO greatly assisted with logistics such as scheduling visits, providing transportation, gaining access to the ship, the captain and other DWO's.

Initially, participants were approached unannounced on board the vessels. The commercial vessels were in port from 6-24 hours to load/unload cargo. Access to the vessel and the participants was fairly limited as a result of recent security restrictions and busy work schedules while in port. In some cases, prior arrangements were made with Coast Guard personnel or company management in order to gain access to the waterfront facility, the vessel, and ship personnel. Upon boarding each vessel, the researcher met with the master to briefly explain the study and to obtain permission to interview the other DWO's and to ascertain the availability of personnel to participate. Unlike being out at sea, shipboard personnel are typically most busy while in port overseeing cargo operations, conducting inspections and maintenance, receiving supplies, and seeing family. As a result, it was difficult for the DWO's to dedicate a significant amount of time for interviews.

A total of 43 DWO's participated in the study. Three methods were used to complete the research questionnaire: onboard interviews, shoreside interviews, and selfadministration of the questionnaire. The primary method used to solicit participants was to physically go onboard vessels and speak with DWO's directly. As shown in Table 3.1.2, the majority of the questionnaires were completed in this manner. This method was effective, but time consuming since vessels were not always readily accessible or in port. In addition, ship personnel were busy working, leaving little time for conducting interviews. In the interest of time and to increase participation, it was suggested by a licensed union member to go to the local MMP union hall to solicit DWO's while they were awaiting employment opportunities. Conducting interviews at the union hall was successful and 15 additional participants were interviewed for inclusion in the study. A packet of questionnaires with self-addressed stamped envelopes were also given to the office manager at the union hall for distribution to visiting DWO's. The same questionnaire was used but the questionnaire was self-administered without the researcher being present. Eight self-administered questionnaires were completed and either hand retrieved or mailed back to the researcher.

Table 3.1.2. Method and number of completed questionnaires.

Method	Number
Onboard interviews	20
Shoreside interviews	15
Self-administered questionnaires	8
Total	43

All participants were either licensed DWO's (masters, chief mates, second mates, third mates) or Coast Guard DWO's. At the time the questionnaires were completed, all participants were actively working or were between jobs. Of the 43 DWO's that participated in this study, the majority were second Mates, followed by masters, chief mates, and third mates as shown in Table 3.1.3. A total of five participants were DWO's from three different Coast Guard cutters. One Coast Guard DWO was also licensed as a third mate but was categorized as Coast Guard for the purpose of this study.

Table 3.1.3. Breakdown of participant type by position.

Position	Number
Master	9
Chief Mate	7
Second Mate	13
Third Mate	7
Coast Guard	5
Unknown	2
Total	43

There were 39 male and four female participants in this study. The mean age of the participants was 43 years and the mean experience level was 17 years.

Ferry vessels included public ships from the Alaska Marine Highway System (AMHS) and Washington State Ferries (WSF). The AMHS vessels carry passengers, vehicles, and freight between Washington State, British Columbia, Canada and Alaska. The WSF vessels primarily operate in Puget Sound, Washington, but also carry passengers and vehicles between the San Juan Islands in Washington and Victoria, Canada. Other vessel types included Roll-On/Roll-Off (Ro-Ro) from Totem Ocean Trailer Express, Inc., and containerized freight ships from Horizon, American President Lines, Matson and COSCO and others. Ro-Ro vessels typically carry many types of vehicles including automobiles, construction equipment, and tractor trailers. U. S. Coast Guard vessels include polar ice breakers and high endurance cutters.

3.2. Research Variables

The independent variables are variables or controls that are manipulated to examine their effect on some other variable (Muchinsky, 2003). Ten independent variables and five dependent variables were used in this study. These variables are summarized in Table 3.2.1. and are defined in the next section. The foundational basis for choosing these variables is also described.

Table 3.2.1. Description of research variables.

Research Variables		
Variable	**Type**	**Definition/example**
Position/Title	Independent	e.g Master, C/M, 2/M, 3/M
Experience as a licensed officer/DWO	Independent	# of years employed as a licensed DWO
Age	Independent	Participant's current age
Gender	Independent	Participant's gender (M/F)
Vessel Type	Independent	Tankship/ferry/RO-RO
Crew Size	Independent	Number of personnel on vessel
Route	Independent	Destination and port calls
Watch schedule	Independent	Hours worked while on watch (4-8)
Length of time on current shift	Independent	# of weeks/months on this shift
Length of time on current vessel	Independent	# of weeks/months on this vessel
Prevalence of fatigue	Dependent	Fatigue experienced on watch.
Leading causes of fatigue	Dependent	Lack of sleep, interrupted sleep.
The amount of sleep obtained	Dependent	e.g. 6-8 hours.
Sleep quality	Dependent	The quality of sleep based on the sleep environment and continuity
Work and Stress	Dependent	e.g. Standing a navigational watch

As licensed deck officers, DWO's were targeted for this study. Most merchant vessels have four licensed deck officers, comprising the master, chief mate, second mate and third mate. Each of these positions have different responsibilities and watch schedules as described in Table 2.5.3.1. Data from the different positions were compared to determine if the position had an affect on sleep quantity and quality. The age and experience level of the participants were also captured. Through the interviews and reviewing data, it was learned that age and experience have a strong correlation. Most DWO's become licensed mariners by attending merchant academies. Both experience and age differences between participants varied by over 35 years. Similar to job position/title, data was analyzed by age and experience levels to determine if there was a difference in fatigue levels. The data on sleep environment was analyzed to determine if there was a perceived difference between men and women.

Vessel particulars such as the vessel type, crew size and vessel route were also captured. Most participants were on seagoing merchant vessels such as freight and container ships. The crew sizes on most seagoing ships differ very slightly but usually consist of only four DWO's. Vessel routes include waters all over the world, however, since the interviews and questionnaires were completed in the Puget Sound area, most of the participants were on Pacific coast runs to Asia and Alaska. This data was initially captured to see if there was a difference in the results. After data collection was completed, the vessel type, crew size and routes were found to be fairly similar and the dependent variables were not further analyzed to see if there was a difference in regards to these three independent variables.

The length of time on the person has worked on the current shift and length of time on the person has worked on the vessel was initially captured to see if these factors had an affect on the dependent variables. Through the interviews and evaluation of the data, it was learned that most of the participants do not stay with one vessel for a very long period of time, usually for only months at a time. Therefore, the dependent variables were not analyzed using these two independent variables.

The prevalence fatigue was studied to see if fatigue was an issue in the maritime industry from the perspective of DWO's. The data was further analyzed to determine if there was a significant difference in the level of fatigue experienced by the DWO's when age and watch schedules were taken into account. Assuming fatigue was prevalent in the maritime industry, the leading causes of fatigue were studied to identify where potential improvements can be made. The quantity and quality of sleep are thought to be a factor in determining fatigue levels. Other work factors such as the use of electronics and stress levels may affect fatigue levels as well. These variables were studied to determine their impact on fatigue levels.

3.3. Pilot Study

A pilot study was conducted to evaluate the usability of the research questionnaire, to determine the amount of time required to obtain informed consent, and to determine the amount of time required to administer the questionnaire. Pilot study participants included one electrical engineer from Corvallis, Oregon and four personnel comprising coxswains and crew members from a Coast Guard small boat station located along the coast of Oregon. A total of five male personnel between the ages of 20 and 42 with work experience ranging from four to twenty years participated in the pilot study. Vessels at the small boat station are typically crewed with a boat coxswain and two crewmembers, one of which is often a boat engineer who is primarily responsible for ensuring the boat's machinery operates properly. Boat coxswains are much like the master or captain of a large vessel; they are responsible for the overall safety of the crew, the vessel and all operations. Crewmembers also stand navigational watches and perform duties similar to DWO's. These participants work irregular schedules, work long hours, have inconsistent sleep times and were selected because of their similarities with seagoing DWO's.

Each participant in the pilot study read and signed the consent form. Two participants completed the questionnaires on their own (self-administered) and three participants were interviewed using the questionnaire. Each participant required approximately 15-20 minutes to complete the informed consent and questionnaire. The participants commented that the questionnaires were easy to understand and follow. Consequently, no changes were made to the final version of the research instrument.

3.4. Data Collection Details

Before any interviews commenced, the researcher was introduced to potential participants as a Coast Guard member and a graduate student in the Department of Industrial and Manufacturing Engineering at Oregon State University. A brief synopsis of the purpose of the study and the length of time to complete the interview was conveyed to each participant. All participants read and signed the informed consent (Appendix A). Participants were also given a copy of the informed consent if requested. Each participant was asked every question on the questionnaire. Participants were not required to provide an answer to every question. Responses from all interviews were recorded with pen and paper. Interviews lasted between 20 and 60 minutes. Participants were not paid, and participation was completely voluntary. All data collected was treated as confidential to protect the individual and shipping company and to encourage candid responses.

Shoreside company management was not informed of employee participation. In one case, the vice president of operations assisted the researcher with scheduling a meeting with the ship's master. It is not very likely that the data was biased as a result of the interaction with the vice president because the interviews were conducted in individual offices on board the vessel without other persons present.

3.5. Research Instrument

The research instrument used for this study was a 24 item questionnaire (Appendix B). The questionnaire was designed as a tool to help the researcher investigate factors related to fatigue, specifically for DWO's on seagoing vessels. The questionnaire consisted of questions that addressed both the occurrence and causes of fatigue, quantity of sleep, sleep continuity and consistency, time zones, sleep environment, ship motion, stress, electronics/automation and current regulations. Information regarding the background of the participant (position, experience, age, gender, watch schedule, length of time on vessel and length of time on shift) and vessel details (vessel type, route, and crew size) were also captured. The first subsection, 3.5.1., describes the questionnaire items related to fatigue, and the following two sub-sections describe the questionnaire items related to sleep and work, respectively.

3.5.1. Fatigue

The first two questionnaire items were developed based on previous research on short and long-term fatigue and are shown in Figure 3.5.1. Both short term and long term fatigue result from insufficient rest and impact an individual's performance as well as team performance. For teams engaged in lifesaving activities such as fire fighting, lifeboat deployment or anchoring teams, individual performance and the performance of work teams are critical to personal safety as well as the safety of the entire crew. Short term fatigue can occur following cargo operations, intense training (fire/lifesaving drill in extreme conditions), the onset of motion sickness and/or an arduous day (Sanquist, 1992). Long term fatigue can occur near the end of a tour of duty where extensive sleep disruptions were experienced (Sanquist, 1992). Short term fatigue can be reduced through adequate sleep, however long term fatigue requires more than just one or two nights of sleep. The response choices provided in this study captured the participants' estimates of the prevalence of both short-term and long-term fatigue.

The next questionnaire item, also shown in Figure 3.5.1, addresses the causes of fatigue. Normal operations expose mariners to a variety of operational risk factors. Prior research has identified lack of sleep, irregular work periods, stress, temperature, and excessive motion to be risk factors that affect performance and safety (NSF, 2004; Lal & Craig, 2004; Comperatore & Rivera, 2003; Stevens & Parsons, 2002). The purpose of this questionnaire item was to identify causes of fatigue and rank them in order of risk from a DWO perspective. It is important to note that participants were asked if there were other causes of fatigue in addition to those listed.

How often do you feel fatigued while on watch?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

When do you feel most fatigued during the voyage? During the…

Beginning	*Midway*	*Towards the end*
1	2	3

What do you consider to be the (top 5) leading causes of fatigue while underway?

_____ lack of sleep
_____ inconsistent sleep times
_____ stress
_____ temperature heat, cold
_____ excessive motion
_____ or something else

Figure 3.5.1. Questionnaires items related to fatigue.

3.5.2. Sleep

Long and irregular work schedules that require operators to juggle work demands lead to reduced or disrupted sleep and consequently, fatigue (National Center on Sleep Disorders Research, 2003). According to the NSF, most adults need between seven and nine hours of sleep each night for optimum performance, health and safety (NSF, 2004). The amount of sleep DWO's receive depends heavily on the ship, work and watch schedules. A ship's schedule can change from day to day depending on whether the ship is at sea or in port. Since crews typically work long hours while in port, the amount of time available for DWO's to sleep may be reduced. As the ship approaches port, additional personnel are required to assist with navigation, mooring, and cargo operations. This may also contribute to reduced sleep. The purpose of the first two items related to sleep was to determine if DWO's were able to get sufficient sleep for optimum performance. These questionnaire items are shown in Figure 3.5.2.1.

How many hours of sleep per day do you receive on average?

While in port?

Less than5	*5-6*	*6-7*	*7-8*	*more than 8*
1	2	3	4	5

While at sea?

Less than5	*5-6*	*6-7*	*7-8*	*more than 8*
1	2	3	4	5

How often do you receive more than seven hours of sleep?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

Figure 3.5.2.1. Questionnaire items related to average quantity of sleep.

Consistency is another challenging aspect of the sleep environment of employees in the maritime industry. The NSF recommends maintaining a regular bed and wake-time because it allows the body to synchronize with the circadian clock (2004). A regular bed and wake time can be difficult to maintain and is not the norm for the shipping industry. It is a regular occurrence for ships to pull into each port at different times of the day. Due to the global nature of the shipping industry, vessel crews are also working in multiple time zones and are expected to perform duties at various times of the day and night. As a result, the effect of changing time zones on sleep was also felt to be relevant to this research. Three questionnaire items, shown in Figure

3.5.2.2., were developed to explore the various issues related to the consistency of the sleep and work periods experienced by the DWO's studied.

What hours do you normally sleep?

Is it continuous sleep? Yes No

How often do you sleep these hours (pulling into port, cargo ops) ?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

Do you take naps? Yes No

How many times do you get woken up during your sleep period (due to alarms, emergencies)?

4 or more	3	2	1	0

Are you affected by time zones? If so, how?

Figure 3.5.2.2. Questionnaire items related to the consistency and continuity of sleep.

Studies have indicated that insufficient sleep can be extremely dangerous, leading to serious or even fatal accidents (NSF, 2004). The sleep environment can affect the amount of time it takes to fall asleep and remain asleep. An environment conducive to sleep is cool, quiet, dark, comfortable and free of interruptions with a comfortable and supportive mattress and pillow (NSF, 2004). Due to the geographic location of the vessel, the physical location of the sleeping quarters, and the 24-hour watch rotation, DWO's are sometimes required to sleep during daylight hours and in other conditions detrimental to obtaining high quality sleep.

Motion sickness has also been shown to be a factor in maritime fatigue. Heavy seas can induce motion sickness and cause mariners to become incapacitated. As a result, the number of available personnel to work is decreased, creating more fatigue for those that are able to stand watch or work. Moderate seas can also increase fatigue by requiring extra effort to maintain balance on a moving platform. The extra effort has been found to induce fatigue, degrade mental capabilities and to decrease human performance (Stevens & Parson, 2002). Depending on the design of the hull and the sea conditions, mariners may also experience drowsiness from the constant rocking/motion of the vessel. The next questionnaire items related to sleep environment are shown in Figure 3.5.2.3. These items were developed to identify potential issues with the sleep environment.

How would you rate your sleep environment?

a. Darkness/Lighting

Very light	*Fairly light*	*Dark*	*Very dark*	*Completely darkened*
1	2	3	4	5

b. Mattress comfort

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

c. Temperature appropriateness/comfort

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

d. Noise: Noisy enough to disrupt/prevent sleep

Never	*Occasionally*	*Fairly often*	*Very often*	*Always*
1	2	3	4	5

e. Vibration: Enough vibration to disrupt/prevent sleep

Never	*Occasionally*	*Fairly often*	*Very often*	*Always*
1	2	3	4	5

f. Ventilation adequacy

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

g. Does ship motion affect your sleep?

In a bad way		*Doesn't affect your sleep*		*In a good way*
1	2	3	4	5

Figure 3.5.2.3. Questionnaire items related to the sleep environment.

3.5.3. Work

In addition to investigating the effects of sleep on fatigue, the DWO's were also asked about their work environment as it relates to stress and fatigue. Studies have suggested that "under proper conditions, workload declines and performance rises with one-person operation" (Lee & Sanquist, 2000) in the shipping industry. These findings are germane during routine operations. To the contrary, similar research has also found that poorly designed automation targeted at reducing workload during routine operations can actually increase workload during stressful operations (Lee & Sanquist, 2000). Other studies have concluded that the misapplication of modern technologies in information and communication systems may also degrade decision making effectiveness during emergencies and decrease workplace safety and productivity (Wheeler, Bolton & Sanquist, 1990; Tepas, 1994). Three questionnaire items were developed to explore mariners' evaluation of the working environment. One of the items specifically addressed the role of electronics. In particular, mariners were asked to assess the role of automation during routine situations and during emergencies. These three questionnaire items are shown in Figure 3.5.3.1.

Would you consider your job more *mentally* or *physically* challenging?

Is your job very stressful?

Very Stressful		*Average*		*Not at all*
1	2	3	4	5

Does automation/electronics make your job easier or more difficult ...

	easier	more difficult	about equal
during routine situations	1	2	3
during emergencies	1	2	3

Figure 3.5.3.1. Questionnaire items related to ship work levels.

The final questionnaire item, shown in Figure 3.5.3.2., was used to evaluate the application and effectiveness of current international regulations related to rest.

Current regulations addressing fatigue require employers to give licensed officers, such as DWO's, at least 10 hours of rest every 24 hours. Since the Coast Guard is currently in the process of updating hours of rest regulations, the information gathered from this questionnaire item may contribute to updated regulations. This assessment was also intended to identify other concerns that should be considered.

To reduce fatigue, STCW requires a minimum of 10 hours of rest every 24 hours. Do you think this is sufficient? Why or why not?

Figure 3.5.3.2. Questionnaire item related to hours of rest.

4. RESEARCH FINDINGS

The data collected was analyzed using Microsoft Excel 2000 and SPSS 10.0. The research findings are categorized into three subsections corresponding to the topics of fatigue, sleep, and work. The first sub-section addresses the occurrence and causes of fatigue. The second subsection addresses the quantity of sleep, sleep continuity and consistency, naps, time zones, sleep environment and the effect of ship motion. The third subsection addresses the issues of job requirements, stress, the affect of automation/electronics and current regulations.

4.1. Fatigue

The first questionnaire item assessed the frequency participants felt fatigued while on watch. With two four-hour navigational watches, there is an expectation that some degree of fatigue will occur. Long work hours, monotonous work, boredom, high workload, hours of standing, eye strain and other forms of physical and mental stress are typical factors contributing to fatigue (Maldonado, Mitchell, Taylor & Driver, 2002). When asked how often they felt fatigued while on watch, nearly half of participants in this study felt fatigued between zero and 20 percent of time. One third of the participants were fatigued 20-40 percent of the time, and a small remainder of the participants (19%) felt fatigued 40-100 percent of the time. The results are summarized in Table 4.1.1.

Table 4.1.1. Distribution of how often the participants felt fatigued while on watch.

Percent of Time	Number of Participants	Percentage of Participants
0-20%	20	48%
20%-40%	14	33%
> 40%	8	19%

The results were further analyzed to determine if there was a significant difference in the level of fatigue experienced by the DWO's when age and watch type were taken into account. The age of the participants ranged from 22-60 years. Two age categories were analyzed. DWO's between 20-40 and those older than 40 were compared. A non-parametric Mann-Whitney test was used for this comparison. The results, shown in Table 4.1.2, indicate no significant difference between the two age groups and fatigue levels (p=0.159).

Table 4.1.2. Statistical analysis for the frequency of experiencing fatigue by age.

Age	n	Mean Response	Standard Deviation	p-value*
20-40	15	1.867	0.743	0.159
41-60	26	1.654	1.164	

* Mann-Whitney test used.

A second analysis was conducted to compare levels of fatigue based on the watch schedule. DWO's in this study were classified under one of four different watch types. The DWO's typically stand two watches per day, either the 4-8's (0400-0800 and 1600-2000), 8-12's (0800-1200 and 2000-2400) or the mid-watch (0000-0400 and 1200-1600) based on their position. The chief mate typically stands the 4-8's, the second mate typically stands the mid-watch, and the third mate typically stands the 8-

12's. The master is not usually assigned a watch but will rotate in and stand a watch for a mate who has been awake for a significant amount of time, been working long hours or needs sleep. Participants that stood the 4-8 watch, primarily chief mates, might be expected to have a higher prevalence of fatigue as a result of the early wake up times that accompany that watch and the long (16 hour) work day as a result of standing a watch before and after the typical working day. Comments received during interviews also indicated that this group might have a higher prevalence of fatigue. It is commonly acknowledged in the industry, that the chief mate has the most demanding job on the ship due to workload, responsibilities, and the watch schedule. A Kruskal-Wallis test was completed for the level of fatigue based on watch type. As shown in Table 4.1.3, no significant difference between watch types and fatigue level was found (p=0.789).

Table 4.1.3. Statistical analysis for the frequency of experiencing fatigue by watch schedule.

Watch Schedule	n	Mean Response	Standard Deviation	p-value*
0400-0800 1600-2000	7	2.000	1.155	0.789
0800-1200 2000-2400	6	1.667	0.816	
0000-0400 1200-1600	9	1.444	0.527	
Rotating	12	1.583	1.084	

* Kruskal-Wallis test used to determine p-value.

The next questionnaire item relating to fatigue was focused on the time in which participants felt most fatigued during the voyage (beginning, midway or near the end). As shown in Figure 4.1.1, 86% of all participants chose either *midway* or *near the end,* and nearly half of the participants (20 out of 42), chose *towards the end* as the time in which they felt most fatigued. Only six participants felt most fatigued at the *beginning* of the voyage. One participant commented that he felt most fatigued near the beginning as a result of not being accustomed to the working schedule. For the participants interviewed, voyages lasted between 8-12 weeks. For those with permanent jobs (typical of the masters and chief mates), DWO's were off the ship as much as they were on the ship. In essence, they worked six months out of the year. After being away from work for 2-3 months, it is understandable that some DWO's are fatigued at the beginning of a trip and require extra time to become re-accustomed to the rigorous work schedule.

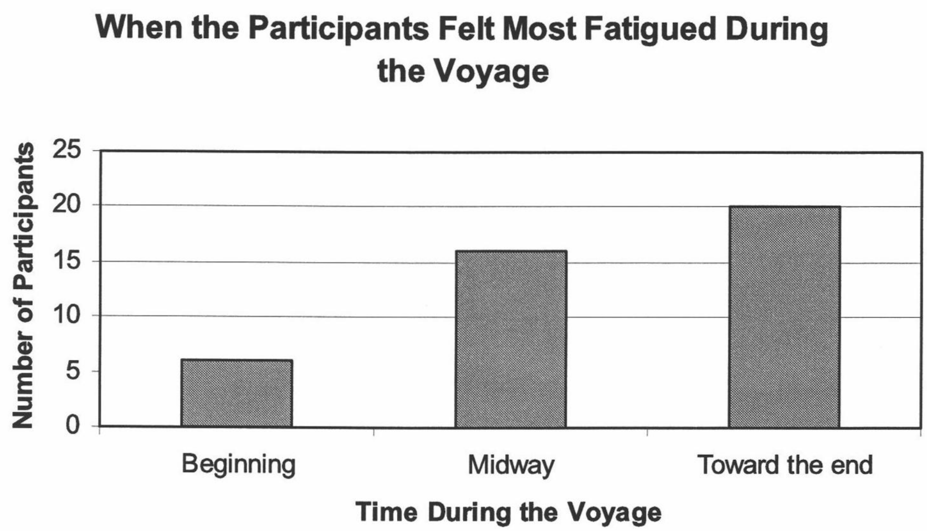

Figure 4.1.1. Distribution of when the participants felt most fatigued during the voyage.

Previous research has found that long term fatigue can occur near the end of a tour with extensive sleep disruption (Sanquist, 1992). Of these 20 participants, the vast majority identifying the highest fatigue level at the end of the voyage were masters and second mates, six and eight, respectively. As the person that is ultimately responsible for the ship and the crew, the master is frequently disrupted during sleep. It is typically the master whom official visitors such as executives, government agency personnel, incoming and outgoing company personnel come on board to see. In addition to the many meetings, the master is usually required by company policy to be in the wheelhouse during special operations including approaching port, departing port, and navigating challenging waters that require extra vigilance. Since second mates typically stand watch from midnight to 0400, their sleep period is also disrupted, and as a result, they seldom receive the recommended 7-8 hours of sleep. As documented in the questionnaires, most second mates typically have two sleep periods, a few hours before going on watch and a few hours after coming off watch. Given that the masters and second mates both have regular sleep disruption and experience fatigue near the end of the tour, these results provide an indication that masters and second mates are more prone to experiencing long term fatigue.

Participants were asked to evaluate what they considered to be the leading causes of fatigue when the vessel was underway and not in port. They were given five fixed choices and one open ended choice. They were asked to rate the top three causes of fatigue. The top three choices are summarized in Table 4.1.4. Twenty-four participants chose *inconsistent sleep time* as the leading cause of fatigue. Twenty participants chose *lack of sleep* as the second leading cause of fatigue. Other causes of fatigue not listed on the questionnaire but specified by participants, included monotony, boredom, diet/food choices available, weather, noise, and time changes.

Table 4.1.4. Distribution of the leading causes of fatigue.

Leading Causes of Fatigue				
Answer Choice	**Number 1 Choice**	**Number 2 Choice**	**Number 3 Choice**	**Total Responses**
Lack of Sleep	11	20	4	35
Inconsistent Sleep Times	24	9	1	34
Stress	1	3	8	12
Temperature	0	1	2	3
Excessive Motion	1	6	7	14
Other	4	2	10	16
Total Responses	41	41	32	114

A total of 114 responses for the leading causes of fatigue were recorded. Of the 114 responses, *lack of sleep* was selected most often as either the first, second or third choice as a reason for fatigue. Since participants selected three choices and ordered those choices, a process was developed to analyze the overall data set. The number one choice for each participant was given a weight of three. A two point weighting was applied to second choices and a one-point weighting was applied for each third choice. As shown in Table 4.1.5., the leading cause of fatigue after the weighting process was completed was *inconsistent sleep times,* followed by *lack of sleep.* All other categories received substantially lower scores.

Table 4.1.5. Weighted distribution of the leading causes of fatigue.

Weighted Leading Causes of Fatigue				
Answer Choice	**Number 1 Choice**	**Number 2 Choice**	**Number 3 Choice**	**Weighted Total**
Lack of Sleep	33	40	4	**77**
Inconsistent Sleep Times	72	18	1	**91**
Stress	3	6	8	17
Temperature	0	2	2	4
Excessive Motion	3	12	7	22
Other	12	4	10	26
Weighted Total	123	82	32	237

In summary, DWO's do feel fatigued while on watch but not at a very high level and/or not very often, which bodes well for safety. Also, there was not a statistically significant difference between age groups nor watch types and fatigue levels. This may be due to the human ability to adapt well to the environment. The DWO's included in this study appear to be able to manage their schedules such that they are receiving adequate rest as necessary to compensate for short term fatigue. Most participants indicated that the end of the voyage was when they felt most fatigued. These results do provide some indication of chronic long term fatigue. This is consistent with Sanquist's (2002) finding that fatigue occurs near the end of a tour with extensive sleep disruption. A possible explanation for the long term fatigue is that mariners adjust and do what they have to do for the short term but without any weekends or days off, the lack of sleep accumulates and results in DWO's generally feeling more fatigue near the end of a tour.

The leading causes of fatigue identified in this study are lack of sleep and inconsistent sleep times. The lack of sleep may be due to the fact that DWO's seldom sleep the recommended 7-9 hours because there is not enough time off between watches. As for the inconsistent sleep times, there are many factors that affect the ship's schedule that are beyond the control of the individuals that work on the vessels. Furthermore, the number of personnel available on a vessel to compensate for the fluctuating schedules is limited.

4.2. Sleep

Results related to the quality and quantity of sleep are summarized in this section. The number of hours spent sleeping, sleep consistency, sleep continuity, napping, time zone crossings, sleep environment, and the impact of ship motion were studied. Two questionnaire items related to sleep were used to determine if DWO's were able to get sufficient sleep while working on board vessels.

According to the NSF, most adults need between 7-9 hours of sleep each night for optimum performance, safety and health (NSF, 2004). The amount of sleep DWO's receive varies depending on whether they are in port or are at sea as illustrated in Figure 4.2.1. While in port, the majority, 60 percent of the participants, slept on the average between 5-7 hours per day. A slightly higher percentage, 67%, was able to sleep 5-7 hours per day while at sea. Overall, 42% of the participants slept 6-7 hours while at sea. This is consistent with previous studies that found mariners in the U.S. west coast trade slept an average of 6.6 hours (Sanquist, Raby, & Forsyth, 1997). Very few participants slept less than five hours at sea or more than eight hours at sea and in port. Some participants commented that being in port was often a busy time. When in port, participants felt that they must be awake to tend to the ship's business including overseeing cargo operations. It was while they were sailing or at sea that they would "catch up" on sleep.

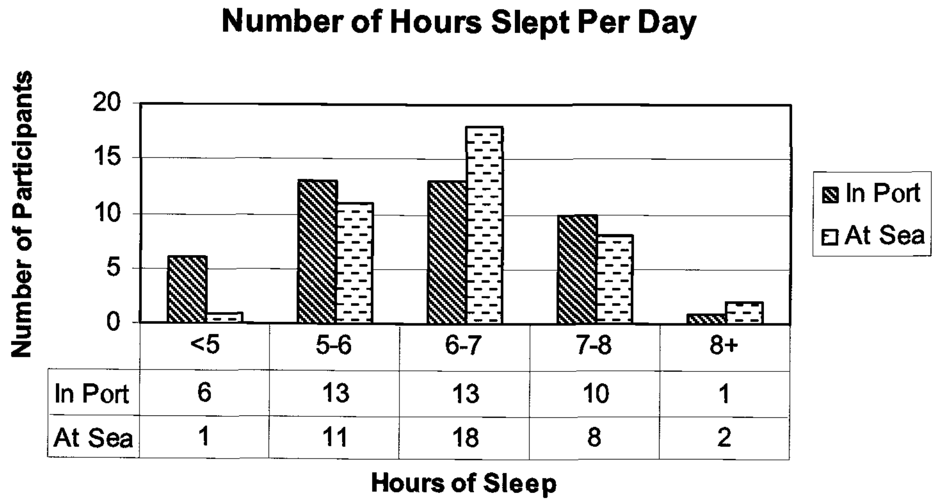

Figure 4.2.1. Average amount of sleep received per day while in port and at sea.

A second item was used to assess how often participants *received more than seven hours of sleep* per day. Most of the participants in this study seldom slept more than seven hours a day as shown in Figure 4.2.2. In fact, 54% of the participants responded that they slept more than seven hours only 0-20% of the time. These results are not consistent with the previous questionnaire item. When asked how many hours of sleep was obtained on the average, only 25% of the participants responded that they slept more than seven hours. It is therefore uncertain as to how many hours of sleep the DWO's actually received. These results do, however, confirm that most participants did not receive the recommended minimum 7-9 hours of sleep. It is unclear whether the participants did not receive the recommended amount of sleep due to 1) the work schedule 2) body clock/circadian rhythm or 3) personal choice of not wanting to sleep seven or more hours.

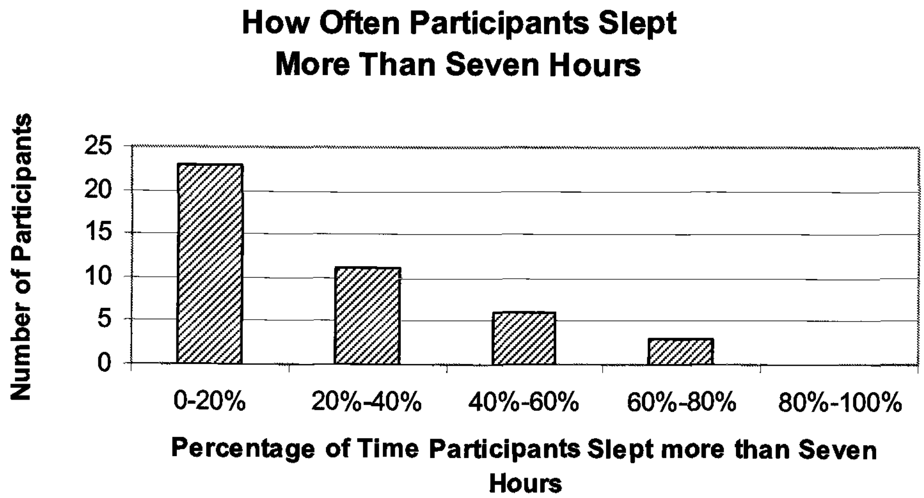

Figure 4.2.2. Frequency of participants receiving more than seven hours of sleep per day.

Participants were asked what hours they slept and whether or not it was continuous. When participants were asked what time they went to sleep, nearly all participants hesitated before giving an answer because there really was no regular or set time, it seemed to vary from day to day. Through the interviews, it was learned that variances in sleep time result from numerous situations but primarily depend on the state of the vessel: in port, approaching port, departing port, at sea, loading/offloading cargo etc. and the associated duties and responsibilities of the DWO's resulting from the vessel's state. A total of 43 participants responded, given these circumstances, with general sleep times and conditions. As shown in Figure 4.2.3., participants went to sleep anywhere from before 8 p.m. to after 2 .a.m., but most participants went to sleep between 11 p.m. and 1 a.m. Another large group, mainly those that work the mid-watch, went to sleep between 4 a.m. and 5 a.m.

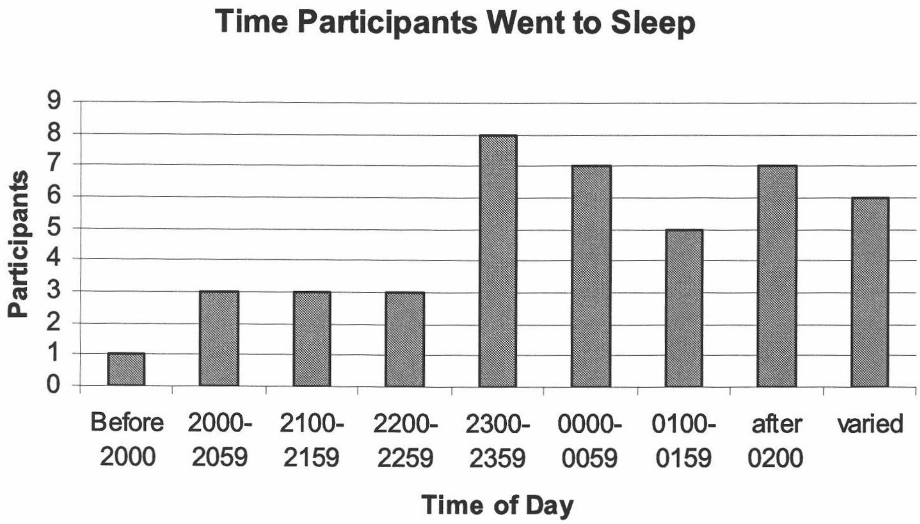

Figure 4.2.3. The time participants went to sleep.

Most participants, 72%, were able to sleep continuously, while 28% had two sleep periods, primarily those that stood the mid-watch (0000-0400). Many of those that stood the mid-watch would sleep for 2-3 hours before going on watch, then sleep again after getting off of watch for 3-5 hours.

Participants were also asked how often they were able to sleep regular hours. There were responses in all categories from zero to 100%, however, most participants were able to sleep during their normal sleeping hours 60 to 80 percent of the time. In other words, most participants were able to sleep during their normal sleep hours 4-6 nights per week. Nearly a third of the participants were able to sleep during their normal hours only 40 to 60 percent of the time as summarized in Figure 4.2.4.

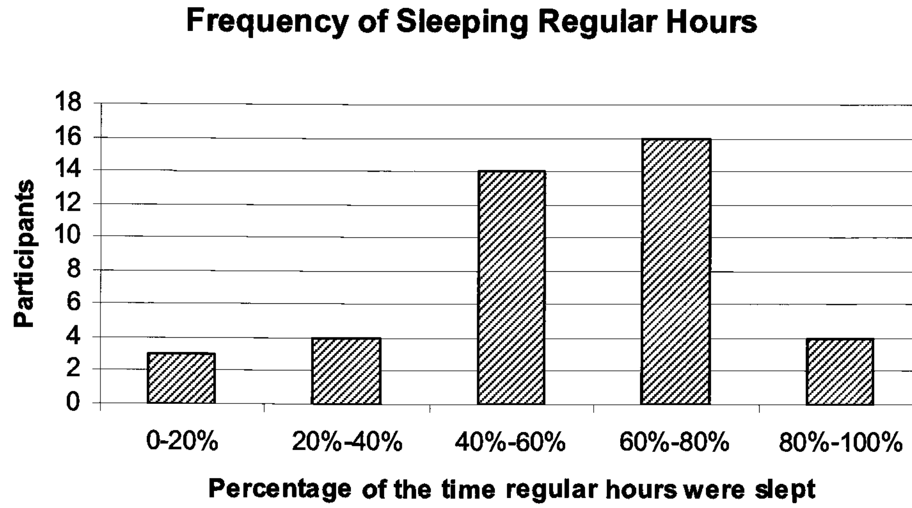

Figure 4.2.4. Frequency of sleeping regular hours.

Participants were asked how often they were woken up during their sleep period (due to alarms, emergencies, etc). For some participants, the answer was less than once per sleep period, however, instead of answering with zero, some gave a more descriptive response, such as once per week. All responses are summarized in Figure 4.2.5. and the responses ranged from never to as often as once per week.

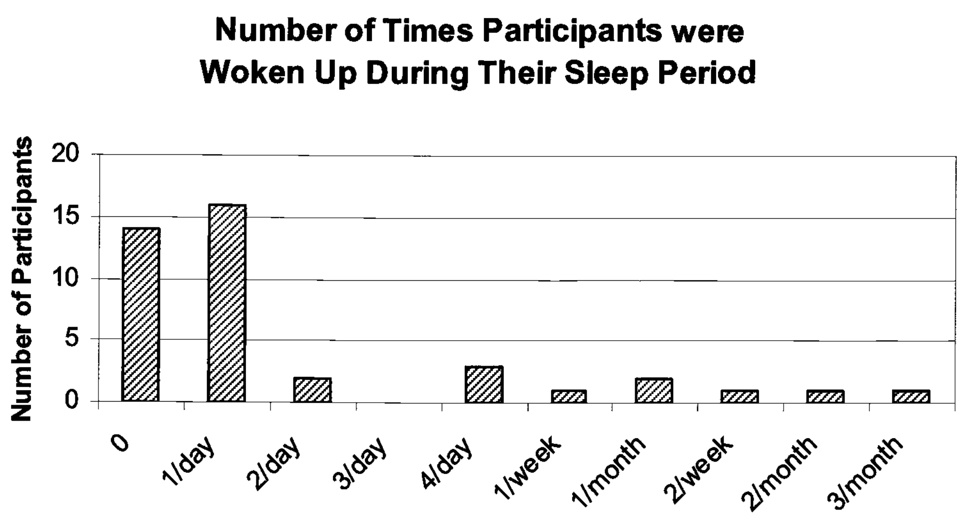

Figure 4.2.5. Number of times participants were woken up.

DWO's are not only shift workers but have work shifts that change constantly. Napping is essential and can be extremely effective at eliminating fatigue-related accidents and injuries (NSF, 2004). Participants were asked if they took naps, and 88 percent responded with yes. Naps do not completely make up for lost or disrupted sleep and many industries do not allow napping at work. However, it is fortunate that a large percentage of the participants do take naps regularly. Hopefully many others in the maritime industry are also taking advantage of napping to compensate for the irregularities in sleep times and schedules.

With the exception of the six participants that worked on the ferry vessels, all participants worked on vessels that cross time zones. As shown in Figure 4.2.6., many participants, 63%, were affected by times zone changes. For those that traveled along the West coast of the United States and Alaska, there was only one time zone to adjust for. However, for those that traveled across the Pacific Ocean or Atlantic Ocean to destinations such Asia and Europe, there were many time zones to cross, requiring internal body clocks to adjust in a relatively short time frame. Ships traveling on the routes to Asia from the West Coast of the U. S. could experience as many as nine time zones in one week. During the interviews, it was discovered that some crews adjust the ship's clock by an hour a day and for others, they would change the clock up to three hours in one day. These intense time changes can significantly impact DWO fatigue levels particularly when these changes result in reduced hours of sleep or advanced/delayed sleep, wake and work times.

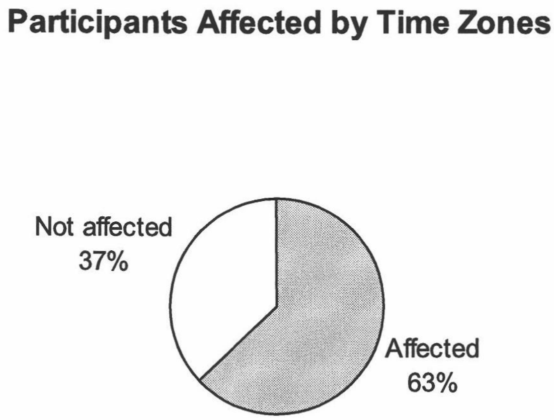

Figure 4.2.6. Percentage of participants affected by time zones.

The sleep environment is an important consideration in determining the quality of sleep. Six sleep environment categories were evaluated: darkness and lighting, mattress comfort, temperature appropriateness, noise, vibration and ventilation. Participants were asked to rate all six categories on a five-point scale. A response of five was assigned to ratings of *excellent* and a response of one was assigned to a rating of *very poor*. Two items under this section, *noise* and *vibration* were reverse coded. For the purpose of analyzing the results, the data was re-coded to maintain consistency with the other four categories. Table 4.2.1 shows the mean rating and standard deviation for each sleep factor for the entire set of participants.

Table 4.2.1. Mean and standard deviation values for sleep environment categories.

n=43	**Darkness & Lighting**	**Mattress Comfort**	**Temp.**	**Noise**	**Vibration**	**Ventilation**
M	3.40	3.40	3.28	3.44	3.98	3.40
SD	0.98	1.12	0.96	0.98	0.83	0.98

Participants were asked to rate the lighting/darkness of sleeping quarters and/or their ability to completely darken the room. Response choices ranged from very light to completely darkened. Depending on the watch schedule or geographic location of the vessel and time of year, DWO's may need to be able to darken their room to help them sleep during daylight hours.

The next two sleep factors addressed the comfort of the mattress and whether or not DWO's were able to adjust room temperature. The fourth and fifth sleep comfort items focused on the frequency of sleep disruption due to either noise level or vibrations. Depending on many factors such as ship design and materials used, noise and vibration can be very prevalent and significantly affect the quality of sleep. The last item related to sleep environment focused on ventilation adequacy. A questionnaire item addressing the affect of ship motion on sleep was also used in this section. Each question and the available choices are summarized in Appendix B.

The category with the highest mean response was vibration, followed by noise. These results indicate that for participants in this study, sleep disruption due to vibration and noise was minimal. The lowest mean response for all categories was temperature. Although 3.28 was the lowest mean response, many participants commented they had thermostats in their sleeping quarters, enabling them to adjust the temperature to their personal comfort level. Similar to temperature, participants also commented that they were able to darken their room to their satisfaction through the use of window coverings.

The overall mean response for all six categories and all participants was calculated to be 3.48. On a scale of one to five, 3.48 falls between "average" and "good." The overall assessment of the sleeping environment for the entire set of participants was that the sleeping environment itself was not problematic.

The sleep environment variables were also analyzed by age, experience, and gender to determine whether or not different populations of participants perceived the adequacy of the sleep environment differently. Two age categories were evaluated: 20-40 and 40-60. Also, two experience categories were evaluated: 0-19 and 20-40 years. The null hypothesis used was that the sleep environment is the same for all age groups, experience level and gender. The results are summarized in Table 4.2.2. and indicate that the sleep was not perceived differently for the different age groups, experience levels or for men and women.

Table 4.2.2. Mean, standard deviation and p-values of sleep environment by age and gender.

	Age			**Years of Experience**			**Gender**		
	20-40	**41-60**	**p-value***	**0-19**	**20-40**	**p-value***	**M**	**F**	**p-value***
	n=15	n=26		n=21	n=19		n=37	n=4	
Darkness & Lighting	3.73 0.80	3.27 1.04	0.162	3.62 0.97	3.26 0.99	0.237	3.44 1.01	3.50 0.58	0.914
Mattress Comfort	3.53 1.25	3.31 1.09	0.645	3.48 1.08	3.32 1.25	0.823	0.237 0.823	3.00 0.82	0.312
Temp-erature	3.47 0.74	3.15 1.08	0.416	3.10 0.89	3.47 1.07	0.120	3.34 0.97	3.50 0.58	0.790
Noise	2.53 1.06	2.50 0.95	0.918	2.52 1.08	2.53 0.90	0.759	2.50 1.02	2.25 0.50	0.704
Vibration	1.93 0.80	2.04 0.87	0.663	2.00 0.84	2.00 0.88	0.885	1.97 0.90	2.00 0.00	0.745
Ventilation	3.53 0.74	3.31 1.12	0.637	3.43 0.81	3.37 1.21	0.943	3.56 0.95	3.50 0.58	0.745

* Mann-Whitney Test

The next item addressed the affect of ship motion on sleep. As shown in Figure 4.2.7., most participants responded that ship motion does not have an effect on sleep. However, some commented that in rough sea conditions, sleep was affected in a bad way for obvious reasons. For some participants, motion affected sleep in a good way by "lulling" them to sleep.

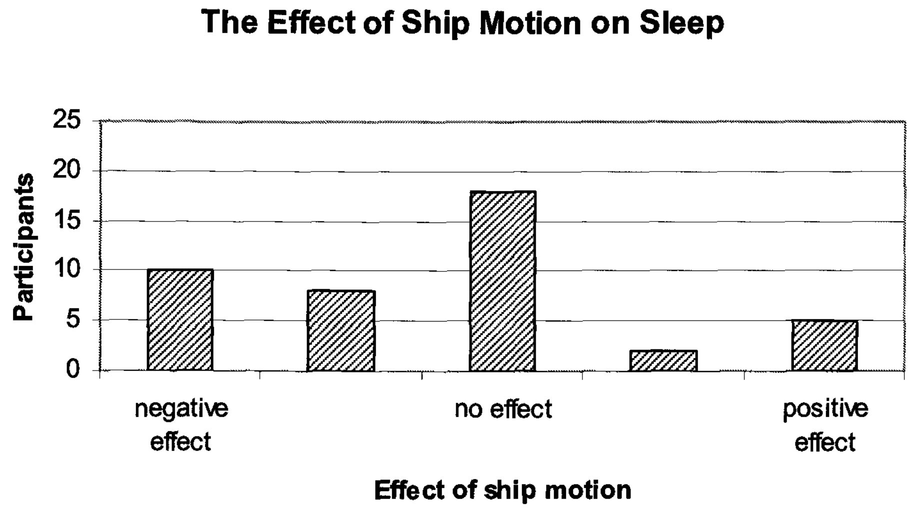

Figure 4.2.7. The affect of ship motion on sleep.

In summary, most DWO's do not receive the amount of sleep necessary for optimum performance but do take advantage of naps. Again, DWO's are adapting/coping with reduced sleep but as a result, they may not be performing at optimum levels. The quality of sleep was evaluated as good and does not appear to be a significant factor in causing fatigue. Temperature was rated the lowest, but it is the one factor that DWO's have the most control over. The sleep environment was not found to be significant when age or gender were factored in. Given the relatively high responses, the quality of sleep appears to be quite good which may be compensating for the quantity of sleep. Ship motion did not have a significant effect on sleep for most DWO's. This may be in part due to the infrequent storms experienced, the ability to adapt to the moving platform and the personal choice to work in this profession. The consistency and continuity of sleep was also analyzed. Most DWO's did not maintain the same bed and wake times each day but were able to sleep continuously.

4.3. Work

This section addresses aspects of work that affect levels of fatigue. Questionnaire items specifically addressed stress, mental versus physical demand, technology/electronics, and current regulations. Work includes not only watchstanding, which takes up a large majority of the working day for DWO's, but it also includes other duties and responsibilities such as administrative work, checking cargo and safety equipment on deck, and vessel maintenance.

Participants were asked whether they felt their work was more physically challenging or more mentally challenging. Figure 4.3.1. clearly illustrates how the work demands are much more mental rather than physical. Two thirds of the participants felt their work was more mental than physical.

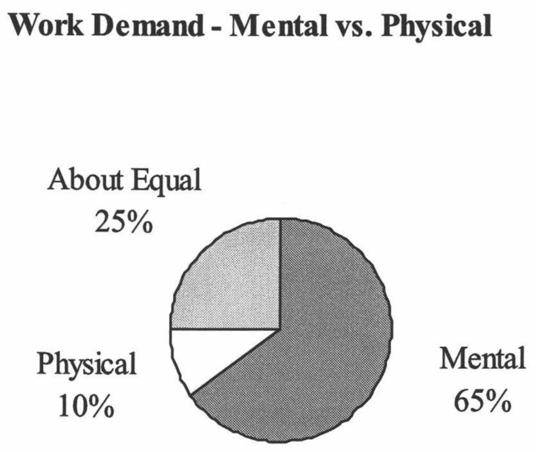

Figure 4.3.1. Percentage of participants' evaluation of the type of work demand.

Previous research that tested the fatigue levels or conversely, vigilance using radars (similar to ones used on ships today) found that performance decreased after only half an hour, indicating a rather rapid decrement in mental capabilities despite the extremely small amount of physical action required (Broadbent, 1977). With high mental demand required of DWO's on watch and the rapid decrement in mental capabilities from simply doing their job, particular attention should be given to ensure DWO's alertness levels do not degrade such that performance and safety suffer. A well-designed bridge with proper equipment and personnel with high proficiency in operating equipment are critical when mental workloads are high (Lee & Sanquist, 2000; Wheeler, Bolton & Sanquist, 1990; Tepas, 1994).

Participants were also asked to address their level of stress at work. As shown in Figure 4.3.2., the vast majority felt the level of stress was *average,* and few participants felt that their jobs were either *very stressful* or *not stressful* at all. Although stress plays a significant role in causing fatigue, the stress experienced by the participants was intermittent. As learned during the interviews, there are times when the level of stress is high, such as during periods of moving cargo or meeting schedules/deadlines. There are times, however, when the job has little stress, such as being on watch on the open ocean without anything in sight except for the sea and the sky. Therefore, it is not surprising that generally speaking, many participants felt the stress level was fairly average.

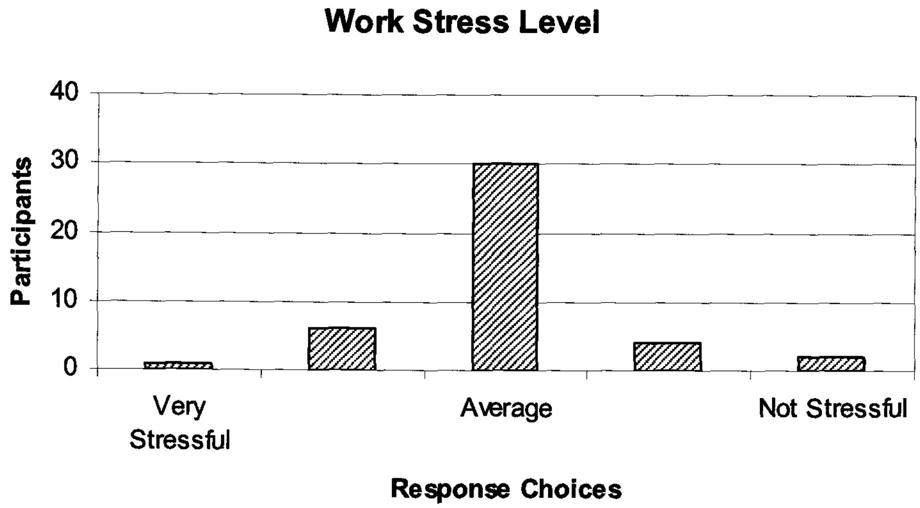

Figure 4.3.2. Stress level of work.

Participants were asked whether the use of modern technology such as automation and electronics made their jobs easier or more difficult during both routine and emergency situations. Contrary to previous research, many participants felt the use of automation and electronics made their jobs easier during both routine and emergency situations as shown if Figure 4.3.3.

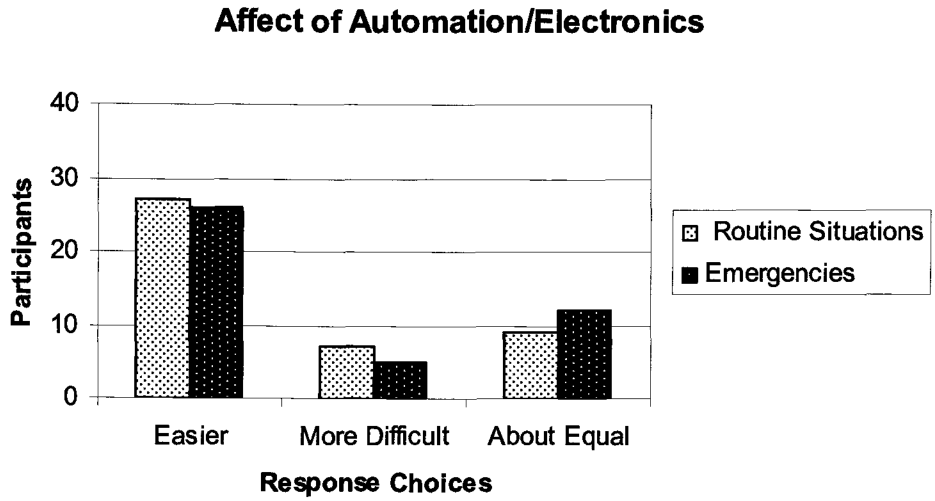

Figure 4.3.3. The affect of automation/electronics.

Current international regulations require shipping companies to ensure DWO's receive at least 10 hours of rest per 24 hours. Participants were asked whether or not ten hours of sleep is sufficient. Ninety percent of the participants answered that ten hours of sleep is sufficient.

Since the participants were required to work two four-hour watches or a rotating watch, having a continuous ten hour rest period was not possible. Participants also noted that they were not able to obtain a full ten hours of rest due to the work and watch schedule. For example, a master with 35 years experience commented "Ten (hours) would be good if you can get it." Further, he noted that he would be "...surprised if you get six" hours of sleep. When asked what recommendations he had to this address this issue, his response was that "more manning" was needed. Other participants shared similar comments with the researcher. The comments resulting from the questionnaire item asking whether or not 10 hours is sufficient are summarized in Table 4.3.1.

Table 4.3.1. Participants' comments on the sufficiency of ten hours of rest every 24 hours.

Is ten hours sufficient?	Comments
Yes,	-- I think it is more than sufficient because sometimes too much rest makes me more tired. -- allows your body to recuperate. -- in my experience, myself and others have operated safely with less sleep. -- 10 hours is sufficient (4)
Yes, with reservations	-- if you get ten hours (5). -- if the ten hours were continuous (4) -- as long as there is at least one six hour period of sleep. -- such that everyone can get eight hours straight. -- if people could really get it but they don't. Also it would be great if it could be all at one time. It is bad not to have ten (hours) in a row. It takes time to wind down, eat, get ready for work. Thanks for asking. --seldom, achieved successfully. Does not account for meal hours, prewatch calls, or emergencies. -- under optimum conditions (3). -- if sleep was undisturbed and uninterrupted like airlines. -- if vessel company complies. -- need more people.
No	-- and it's impossible for some people like the chief mate to get even that. -- 12 hours rest in 24. -- disturbed sleep for tie ups, drills and noise in port, make this a no.

In summary, because a large portion of the work demands for DWO's are mental, more attention should be given to factors that reduce or degrade cognitive abilities. On a positive note, many participants felt the use of electronics and automation made their jobs easier during both routine and emergency situations. This may be attributed to better design of equipment and increased proficiency of the navigators. Overall, stress levels were not particularly high or low, however it was learned that high stress levels are intermittent and include occasions such as cargo operations and staying on schedule. Based on the responses from the participants, the current hours of rest regulations for DWO's are adequate, however, organizational policies do not ensure that DWO's are receiving the full benefit of the regulation. Clearly, regulations alone are not adequate in reducing fatigue as previous research indicates (NRC, 1990).

5. CONCLUSIONS/FUTURE RESEARCH:

5.1. Findings

Fatigue continues to be a growing concern in the maritime industry. This study sought to reveal and clarify the factors that contribute to maritime fatigue by collecting and analyzing data from licensed professionals. The research focused on the topics of fatigue, sleep and work. The findings from this study are:

- Fatigue is prevalent in the maritime industry, particularly for watchstanders.
- Leading causes of fatigue are 1) inconsistent sleep times and 2) lack of sleep.
- The sleep environment (darkness/lighting, mattress comfort, temperature appropriateness, noise, vibration and ventilation) was not a factor in fatigue.
- In spite of the current regulations on hours of rest, DWO's are not receiving adequate rest.
- Although previous research suggests that electronics/automation could increase workload during emergencies, the data in this study suggest that electronics and automation made duties and responsibilities for DWO's easier during both routine and emergency situations.
- Fatigue levels do not vary as a result of gender, age or experience.

5.2. Conclusions and Recommendations

Ships are more sophisticated and reliable than ever with the advances in design and technology. However, the humans operating these vessels are still vulnerable, and are limited in their capabilities. The sleep environment does not appear to be a pressing issue, however, the quantity and consistency of sleep is a concern, particularly, during busy times. These busy times include when the vessel is entering and leaving port and when transiting through restricted waters. Safety practitioners, managers, and others in the maritime industry, need to continue working to improve shipboard work and living conditions in an effort to minimize fatigue.

Working in the maritime industry is very demanding. DWO's work long hours, live by schedules that change from day-to-day, and are away from loved ones for months at a time. As a result, mariners are fatigued, and of particular concern, is that they are fatigued while on watch. The level of fatigue was not found to be significantly different between age groups or watch schedules. Being fatigued while on watch can degrade cognitive ability which can result in injuries, accidents, and catastrophes.

The leading causes of fatigue for DWO's in this study were found to be lack of sleep and sleeping at inconsistent times. Because ships operate 24-hours per day, 365 days per year, DWO's must also work at all hours of the day. Also, the ship's clock changes as the vessel travels East or West, often at a rate faster than the body is able to adjust for. One way to address these concerns would be to increase number of available personnel to stand watch which would reduce the burden on DWO's. Another alternative is to alter the typical four-on eight-off watch schedule such that one of the two watch periods is lengthened. Lengthening one watch period would result in lengthening one rest period as well. This would enable DWO's to have a longer sleep period and allow for more consistent sleep times.

Although the sleep quantity was less than desirable, the sleep environment for most mariners was conducive for quality sleep. Darkness/lighting, mattress comfort, temperature, noise, vibration, ventilation and ship motion were aspects that were studied. Of the seven categories, vibration and noise were found to be the least disruptive to sleep and temperature was found to be the most disruptive to sleep. The sleep environment was also analyzed by age, experience level and gender. The results indicate that the sleep environment was not perceived differently for those over or under 40 years old, those with more or less experience, or men and women. In conclusion, all aspects of the sleep environment were found to have little to no affect on sleep quality and subsequently, little to no affect on fatigue.

Aspects of work, including electronics/automation, stress, and regulations were also studied. Participants were asked to evaluate their work demand. Two-thirds of the participants felt that their work was more mentally demanding rather than physically demanding and 25% felt the demands were about equal. Mariners today rely heavily on electronics for navigation an communication. Although previous research suggests that electronics/automation could increase workload during emergencies, the data in this study suggest that electronics/automation made duties and responsibilities for DWO's easier during both routine and emergency situations. Use of technology to make the job easier is desirable; however, consideration should be given to ensure the user is proficient, and boredom/monotony does not result from its use. Lastly, regulations on fatigue were evaluated. The international maritime regulations addressing fatigue by requiring minimum hours of rest seem to be adequate according to the participants in this study. However, as stated in previous studies, the regulations are difficult to enforce and regulations alone will not increase safety. Also, many design changes have been made to commercial vessels over the last century since the original hours of service regulations were first enacted. The current regulations need to be updated to reflect the significant change in working conditions on board modern vessels.

In conclusion, this study found that advances in technology have reduced the number of personnel on the bridge and subsequently, increased the workload for DWO's. With the multitude of duties and responsibilities DWO's have, current staffing levels are not adequate. Also, regulations should address dynamic schedules (due to times zones and port operations) and human physiology in addition to hours of rest.

Sleep is one of the most effective ways to reduce fatigue. Organizations interested in reducing fatigue should find innovative ways to increase the amount of sleep for DWOs. One recommendation is find alternatives to the traditional four-on eight-off watch schedules. Another recommendation is to conduct a cost benefit analysis on staffing requirements. Increasing personnel would increase costs, however, benefits include enhanced crew performance and reduced risk. A third recommendation is to develop methods to monitor the amount DWO's sleep and ensure stricter enforcement of hours of rest regulations.

5.3. Future Research

Many factors contribute to maritime fatigue. This study revealed a number of factors that cause fatigue, however, more research needs to be conducted to verify and extend on those causes of fatigue resulting from living and working onboard ships. The studies should take into account human limitations and capabilities.

Future studies should also include larger samples with a wider range of vessels. This study targeted DWO's on the West Coast, however, licensed engineering officers and non-licensed mariners and mariners from the East Coast and elsewhere should also be included. Written surveys that can be mailed would enable researchers to obtain larger and more diverse samples. Also, building on the information from this study, surveys should include more detailed questions with narrower response choices.

This study revealed that some factors have more of an impact than others. All of the factors identified should be addressed, however, the factors with higher impact and implications should take priority. Lack of sleep and inconsistent sleep times were identified as leading causes of fatigue. Additional research on the costs and benefits of increasing the number of watchstanding personnel may be helpful in finding methods to increase the amount DWO's sleep and reduce the inconsistencies in sleep times. Developing alternative schedules to the traditional four-on eight off schedule would also be beneficial not only to DWO's but also other watchstanding positions such as lookouts and quartermasters.

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APPENDICES

APPENDIX A

OSU
Oregon State
UNIVERSITY

Department of Industrial & ManufacturingEngineering
Oregon State University, 118 Covell Hall, Corvallis, Oregon 97331
Tel 541-737-2365 | **Fax** 541-737-5241

Informed Consent Document

I hereby give my consent to participate in a survey conducted by a graduate student, Vivianne Louie, under the supervision of Dr. Toni Doolen of the Oregon State University Department of Industrial and Manufacturing Engineering.

Purpose. This research survey is being conducted to gain a better understanding of the causes of maritime fatigue. Only a small sample of deck watch officers will be interviewed, so your participation is vital to the study. The rresults of this study will be made available to the Coast Guard for review and development of training materials. This research may contribute to establishing new regulations regarding hours of service.

Procedure. I understand that the survey questionswill be read to me and my answers will be recorded on an answer sheet. No information identifying me will be recorded. The total time to conduct the survey will be about 20-40 minutes.

Risks. I understand that the probability and magnitude of harm, inconvenience, or discomfort anticipated in this study are no greater than those encountered in daily life.

Benefits. I understand that I will receive no direct benefits from my participation in this experiment.

Compensation. I understand that I will not be paid for my participation in this experiment.

Voluntary Participation. I understand that my participation in this study is voluntary and I can withdraw from the experiment at any time without any kind of penalty. I have the right to decline to answer any question(s) at any time.

Confidentiality. I understand that the data collected in this study will be available to the research investigators, support staff, and any duly authorized research review committee. The data will be kept confidential to the extent permitted by law. The data will be kept for 56 years following the publication of the results (the usual time required for keeping original data and records).

I grant Oregon State University permission to reproduce and publish all records, notes, or data resulting from participation, provided there will**be no association of my name**with the collected data and that confidentiality is maintained unless specifically waived by me.

Questions. I understand that I will have the opportunity to ask questions and receive satisfactory answers from the graduate student conducting the survey. I understand that any further questions concerning this experiment should be directed to Dr. Toni Doolen at (541) 7375641, doolen@engr.orst.edu.

If I have questions about my rights as a research subject, I should contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, OSU Research Office, (541)737-3437, IRB@oregonstate.edu

My signature below indicates that I have read and that I understand the process described above and give my informed and voluntary consent to participate in this experiment. I understand that I will receive a copy of this consent form.

Signature of Participant________________________________ Date: __________

Printed Name of Participant ____

OSU IRB Approval Date: 07-08-04
Approval Expiration Date: 07-07-05

APPENDIX B

Questionnaire

Date:
Position:
# of years as licensed officer/DWO
Age:
Vessel Type/size/LOA:
Crew size:
Route:
Watch schedule: 4-8's, 8-12's, mid watch?
# of Months/years on this shift
# of Months/years on this vessel
Primary responsibility(s)

1. How often do you feel fatigued while on watch?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

2. When do you feel most fatigued during the voyage? During the...

Beginning	*Midway*	*Towards the end*
1	2	3

3. What do you consider to be the (top 5) leading causes of fatigue while underway?

_____ lack of sleep
_____ inconsistent sleep times
_____ stress
_____ temperature heat, cold
_____ excessive motion
_____ or something else

4. How many hours of sleep per day do you receive on average?

While in port?

Less than5	*5-6*	*6-7*	*7-8*	*more than 8*
1	2	3	4	5

While at sea?

Less than5	*5-6*	*6-7*	*7-8*	*more than 8*
1	2	3	4	5

5. How often do you receive more than seven hours of sleep?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

6. How would you rate your sleep environment?

a. Darkness/Lighting

Very light *Fairly light* *Dark* *Very dark* *Completely darkened*

1	2	3	4	5

b. Mattress comfort

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

c. Temperature appropriateness/comfort

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

d. Noise: Noisy enough to disrupt/prevent sleep

Never	*Occasionally*	*Fairly often*	*Very often*	*Always*
1	2	3	4	5

e. Vibration: Enough vibration to disrupt/prevent sleep

Never	*Occasionally*	*Fairly often*	*Very often*	*Always*
1	2	3	4	5

f. Ventilation adequacy

Very Poor	*Poor*	*Average*	*Good*	*Excellent*
1	2	3	4	5

g. Does ship motion affect your sleep?

In a bad way		*Doesn't affect your sleep*		*In a good way*
1	2	3	4	5

7. What hours do you normally sleep?

Is it continuous sleep? Yes No

How often do you sleep these hours (pulling into port, cargo ops) ?

0-20%	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*
1	2	3	4	5

Do you take naps? Yes No

8. How many times do you get woken up during your sleep period (due to alarms, emergencies)?

4 or more 3 2 1 0

9. Would you consider your job more *mentally* or *physically* challenging?

10. Is your job very stressful?

Very Stressful		*Average*		*Not at all*
1	2	3	4	5

11. Does automation/electronics make your job easier or more difficult ...

	easier	more difficult	about equal
during routine situations	1	2	3
during emergencies	easier	more difficult	about equal
	1	2	3

12. Are you affected by time zones? If so, how?

13. To reduce fatigue, STCW requires a minimum of 10 hours of rest every 24 hours. Do you think this is sufficient? Why or why not?