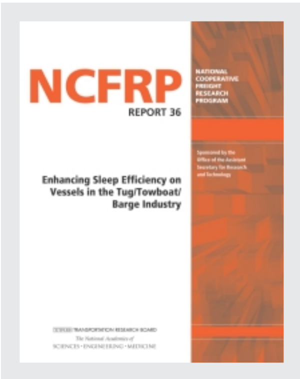

Enhancing Sleep Efficiency on Vessels in the Tug/Towboat/Barge Industry

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 36

Enhancing Sleep Efficiency on Vessels in the Tug/Towboat/Barge Industry

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

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Dr. Kathryn J. Reid, Research Associate Professor of Neurology at NU, was the Project Director and Principal Investigator. Dr. Fred W. Turek, Professor of Neurology and Neurobiology at NU, was the Co-Principal Investigator. Other individuals involved in carrying out the NCFRP Project 45 were Dr. Phyllis C. Zee, Professor of Neurology at NU and Co-Investigator; Dr. Greg Belenky, Research Professor at Washington State University and Consultant; Dr. Joseph Kang, Assistant Professor of Preventive Medicine-Biostatistics at NU and Research Assistant; Dr. Peng Jiang, Postdoctoral Fellow in the Center for Sleep and Circadian Biology at NU and Research Assistant; Mr. Eric Rowan, Consultant for NU and the project; and Ms. Katie Lind, Associate Research Administrator in the Center for Sleep and Circadian Biology at NU.

FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

NCFRP Report 36: Enhancing Sleep Efficiency on Vessels in the Tug/Towboat/Barge Industry provides best practices, including the use of anchor-sleep/nap-sleep strategies, to improve sleep and reduce fatigue in the United States inland waterway industry.

Human error related to operator fatigue is a major concern in all freight operations. The general consensus is that 7 to 8 hours of sleep per 24-hour day is required to maintain acceptable levels of alertness, minimize fatigue, and permit optimum performance. A long-standing and preferred practice of crews in the U.S. tug/towboat/barge inland waterway industry is to work/rest in alternating 6-hour shifts, commonly referred to as a square watch system. Each crew member has a total of 12 hours on duty with 12 hours off duty per 24 hours, and it has been customary for crew members to obtain sleep during both of their 6-hour off-duty periods. While there are no hours-of-service regulations beyond the 15-hours-on-duty limit, increasing uninterrupted sleep duration to a threshold of at least 7 consecutive hours in one of the two available off periods is being considered. Strict adherence to such a pattern would conflict with the most common work schedule in the tug/towboat/barge industry. Recent laboratory data suggest, however, that sleep can be obtained in more than one sleep period, referred to as anchor-sleep/nap-sleep, and that as long as the total duration is 7 to 8 hours, performance is comparable between a single sleep period and two separate sleep periods.

Under NCFRP Project 45, Northwestern University was asked to (1) identify and describe the metrics that could be used to evaluate current operational interventions (e.g., educational materials and programs; noise abatement; sleep disorders screening, especially sleep apnea; wellness and nutritional programs) for their effectiveness in improving sleep efficiency on tugs/towboats/barges; (2) evaluate the use of anchor-sleep/nap-sleep strategies on sleep behavior among personnel in the inland waterway industry; (3) identify barriers that inhibit waterway personnel from adopting good sleep management practices and propose ways to overcome the barriers; (4) develop a list of best practices that could be implemented by the waterway industry, companies, crews, or individuals to enhance sleep efficiency; and (5) develop a compendium of best practices for enhancing sleep efficiency in the U.S. inland waterway industry.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

SUMMARY

Enhancing Sleep Efficiency on Vessels in the Tug/Towboat/Barge Industry

Safety is a major concern in all freight operations with human error often being a key factor in incidents and accidents. Fatigue increases the risk for human error, which is why managing fatigue should be a key component of any safety management system (SMS). For many years the usual way to manage operator fatigue has been to limit work hours, and while there is still a place for a scientifically valid restriction on work hours to reduce operator fatigue, many industries view this as simply one element in what would ideally be a larger program, such as a Fatigue Risk Management System (FRMS).

A key premise that is used to justify the need to provide adequate rest intervals is the general consensus that 7 to 8 hours of sleep per 24-hour period is required to maintain acceptable levels of alertness, minimize fatigue, permit optimum performance, and maintain health. An element that is often missing from the discussion of adequate rest intervals in the maritime sector is that in order to obtain 7 to 8 hours of consecutive sleep, rest intervals may need to be as long as 24 hours (Roach et al. 2003). Rest intervals of this duration are unlikely to be feasible in any operational setting. So while the premise that sleeping for 7 to 8 hours per day is optimal and is not generally disputed, there have been several recent studies suggesting that a sleep episode may not need to consist of 7 to 8 *consecutive* hours in order to maintain adequate levels of performance. These studies suggest that even when sleep is split into more than one episode per day, often referred to as an anchor-sleep/nap-sleep strategy, that performance is comparable, and in some cases, better than when the same duration of sleep is obtained in a single sleep period (Mollicone et al. 2007, Mollicone et al. 2008, Jackson et al. 2014, Kosmadopoulos et al. 2014, Short et al. 2014).

While a long-standing and preferred practice of crews in the U.S. tug/towboat/barge industry has been to have work/rest schedules that alternate in 6-hour shifts, commonly referred to as a "square watch system," this new scientific data has important implications for managing fatigue in the maritime industry. Each crew member has a total of 12 hours on duty with 12 hours off duty per 24 hours, and it has been customary for crew members to obtain sleep during both of their 6-hour off-duty periods. In addition, other schedules that are employed when requiring two persons to be on duty constantly over a 24-hour period have involved rectangular watches (e.g., 7 on: 7 off: 5 on: 5 off; 8 on: 8 off: 4 on: 4 off) or watches that require 12 hours on duty: 12 hours off duty.

While there are no hours-of-service regulations beyond the 15-hours-on-duty limit, 46 United States Code (U.S.C.) 8904(c) gives the U.S. Coast Guard (USCG) authority to establish them. The USCG (*Federal Register*/Vol. 76, No. 155, August 11, 2011/Proposed Rules) stated that it was considering, "requirements to increase uninterrupted sleep duration to a threshold of at least 7 consecutive hours in one of the two available off periods. . . ." Strict adherence to such requirements would ban the most common work schedules in the tug/towboat/barge industry. There is currently no scientific data to support such a change in hours of service. However, there *is* good scientific evidence that it would not be possible to obtain 7 hours of uninterrupted sleep during a 7-hour off-duty period if sleep is attempted at a time when the internal 24-hour biological clock is in the "wake mode."

With these issues in mind, the primary goal of this project is to propose evidence-based best practices to improve sleep on schedules requiring a split-sleep period and reduce fatigue in crews working in the tug/towboat/barge industry in the U.S. A key part of achieving this goal is to determine the use and impact of anchor-sleep/nap-sleep strategies in this industry.

To this end, several approaches were used, including surveying crew and management in the tug/towboat/barge industry about practices related to enhancing sleep, mining previously collected sleep, health, and work data from crews working the 6:6:6:6 square watch, and reviewing related practices from other industries.

The results from data collected by the research team from crew members in the tug/towboat/barge industry indicate that in the over 200 crew members studied, an anchor-sleep/nap-sleep strategy was used 96% of the time and that the factors that predict sleep duration include time of day, stress, anxiety, discomfort, sleep disruption (noise being the most commonly reported), general health, and fatigue level. These are all factors commonly reported to impact sleep in other populations, but while the causes of sleep disruption may be universal, the practices that will need to be implemented to reduce the impact of these factors may in some cases be unique to this industry. In addition to examining sleep and health in crew members, the research team also surveyed management to determine the proportion of companies that use many of the practices suggested as part of this report. Results from these surveys indicated that, for the most part, companies were actively addressing factors that impact sleep, but that in some key areas, there was room for improvement and/or further research, as well as a need for tracking how effective company policies were in allowing crew members to obtain adequate sleep.

The best practices suggested here are drawn from the research team's research within the tug/towboat/barge industry and also from the experience of other transportation industries. A variety of sources, including government and private companies, were studied to gather information. Where appropriate, interviews with key personnel were conducted to garner further insight into the development and implementation of various practices that were not readily available from published sources. A key component of the research team's approach in this regard was to not "reinvent the wheel," but to determine which practices were likely to have the greatest impact, provide evidence of this, and discuss relevant issues that ideally would be considered in the implementation of these practices in the tug/towboat/barge industry.

Proposed Best Practices

The need for best practices related to sleep/fatigue in the tug/towboat/barge industry is not new; in fact, it has been 12 years since the USCG published the report *Crew Endurance Management Practices: A Guide for Maritime Operations* (Comperatore and Rivera 2003), and 10 years since an addendum (Emond et al. 2005) was published. The basic proposal was for tug/towboat/barge operators to establish a crew endurance management system (CEMS) that could be adopted across the industry to reduce fatigue on board vessels in order to reduce accidents that were due, at least in part, to fatigue. Many of the recommendations involved improving the work environment and scheduling changes that would enhance sleep quality and duration. While many of the recommendations were adopted by some parts of the maritime industry, surveys of 40 wheelhouse crew members and management from 46 companies have established that a CEMS is not well represented in the industry and there has been little attempt to measure if the recommended best practices in a CEMS actually increased sleep time or reduced fatigue. Furthermore, over the past few years a number of advances have been made in understanding the key role of split-sleep schedules and napping, in addition to new technologies and approaches, to control fatigue. These findings can now be incorporated into the best practices to enhance sleep duration and sleep efficiency.

Based on the findings of the current research and the investigators' experience and knowledge, the following best practices are proposed for implementation in the U.S. tug/towboat/barge industry.

- Develop and implement a FRMS.
- Develop updated educational materials and standardize dissemination and testing practices.
- Establish stress management policies/programs.
- Monitor and develop strategies to reduce the impact of excessive commute times.
- Implement fatigue reporting practices/fitness-of-duty requirements.
- Provide health and wellness programs.
- Consider establishing a registry of registered medical examiners.
- Initiate screening and guidelines for management of sleep disorders, in particular, obstructive sleep apnea.
- Develop programs for ongoing monitoring and review of all best practices.
- Provide access to good nutrition.
- Provide access to exercise equipment and resources.
- When applicable, utilize fatigue modeling.
- Enhance the sleep environment.
- Encourage and support split-sleep strategies when appropriate.
- Develop a process for crew to report missed sleep opportunities and practices to address any related fatigue.

The key that can link all of these practices is a well-developed FRMS that can be developed as part of a company's SMS. It will also be important to fully assess the implementation by tug/towboat/barge personnel of existing educational materials, such as the USCG *Crew Endurance Management Practices* site (http://www.uscg.mil/hq/cg5/cg5211/cems.asp) and other industry materials, to aid in the optimization of such strategies.

Future Directions

There are several key factors that still need to be addressed; these include further research on split-sleep schedules and alternate work start times in operational settings, monitoring and follow up on practices that are implemented to ensure that they are having the intended effect, and an assessment of the outcomes of these practices on safety. While not optimal, simulator studies may initially be a useful way of conducting studies to assess the impact on sleep; the limitations of such studies are that crew would not be sleeping on a vessel with all of the inherent noise, vibration, and other factors that are unique to vessel operations. Perhaps the biggest impact on sleep duration is time of day. Transportation requires crew to work 24 hours a day, which means that someone is always trying to sleep during the day. Simulation and/or fatigue modeling represent an important initial step to start examining the impact of scheduled work start and end times to minimize or distribute the impact of having to sleep at times when the circadian alerting signal is high. By knowing the times when risk is highest, tasks that are by nature more safety/fatigue sensitive could be scheduled to occur at times of lowest risk.

Another consideration is the widespread use of 12-hour shifts, the second most commonly used schedule in the tug/towboat/barge industry (reported to be in use by 20% of surveyed companies). There has been little research focused on the use of 12-hour shifts in this setting. Given the variety of ways that this schedule is operationalized, the use of individualized FRMS will be important and many of the recommendations in this report are also applicable to this schedule.

There is a need to provide guidance to individual companies for the development of an FRMS and to consider the size of and resources available to each company. This guidance could be developed by industry organizations such as the American Waterway Operators, as well as by government in collaboration with the industry and its workers.

Another area of need is the development of new, improved, and scientifically validated risk mitigation strategies that are appropriate for the type of work schedules in the maritime industry (two work and two rest periods/24 hours). A few example questions representative of this area of study follow:

- When crew are already using an anchor-sleep/nap-sleep strategy, what is the best way to use caffeine and naps, which are the most commonly proposed mitigation tools?
- Since not all currently proposed practices seem to be sufficient, are there better ways to reduce noise?
- What are the sources of stress for workers (personal/health and/or work related)? How can tools and strategies be developed within a company to deal with the source of the stress that is most common in their operations?
- What is the assessment of the utility of new technologies, such as personal fitness trackers, to aid crew in self-monitoring behaviors, including sleep, nutrition, and physical activity?

To achieve these goals, employees, companies, industry groups, and regulators will need to work together.

Final Thoughts

Prescriptive hours of service (HOS) are not likely to be the most effective way to increase sleep durations and improve sleep quality or to manage and reduce the impact of fatigue. Further research is needed to determine whether longer rest intervals are optimal or even required when schedules have more than 1 work and rest interval per 24 hours. The unique nature of many tug/towboat/barge operations makes these types of schedules necessary, for example, to avoid excessive time on task. Given new scientific data that suggests that anchor-sleep/nap-sleep schedules might actually be as effective or in some cases better than a schedule involving a single rest period per day due to a balance between homeostatic and circadian control of sleep and alertness levels, further consideration is needed before changes to the current HOS rules are initiated. As part of this process, an assessment and better management of the factors that impede optimizing sleep efficiency and the recuperative value of sleep should be undertaken.

CHAPTER 1

Background

1.1 Problem Statement and Research Objective

Human error related to operator fatigue is a major concern in all freight operations. The general consensus is that 7 to 8 hours of sleep per 24-hour day is required to maintain acceptable levels of alertness, minimize fatigue, and permit optimum performance. A long-standing and preferred practice of crews in the U.S. tug/towboat/barge industry when two crew members must provide 24-hour on-duty coverage (e.g., captain and pilot) is to work/rest in alternating 6-hour shifts, commonly referred to as a square watch system. Each crew member has a total of 12 hours on duty with 12 hours off duty per 24 hours, and it has been customary for crew members to obtain sleep during both of their 6-hour off-duty periods. In addition, other schedules that are employed when requiring two persons to be on duty constantly over a 24-hour period have involved rectangular watches (e.g., 7 on: 7 off: 5 on: 5 off; 8 on: 8 off: 4 on: 4 off) or a square watch of 12 on: 12 off.

While there are no HOS regulations beyond the 15-hours-on-duty limit, 46 U.S.C. 8904(c) gives the USCG authority to establish them. The USCG (*Federal Register*/Vol. 76, No. 155, August 11, 2011/Proposed Rules) stated that it was considering, "requirements to increase uninterrupted sleep duration to a threshold of at least 7 consecutive hours in one of the two available off periods. . . ." Strict adherence to such requirements would ban the most common work schedule in the tug/towboat/barge industry and, in some cases, might decrease total sleep time per 24 hours.

Recent laboratory data from a number of different investigators (Mollicone et al. 2007, Mollicone et al. 2008, Jackson et al. 2014, Kosmadopoulos et al. 2014, Short et al. 2014) have found that sleep can be obtained in more than one sleep period, referred to as "anchor-sleep/nap-sleep," and that as long as the total duration is 7 to 8 hours, performance is comparable between a single sleep period and two separate sleep periods.

Therefore, it is important to determine the impact of an anchor-sleep/nap-sleep strategy in the inland waterway setting. To aid in the optimization of such strategies, it is also important to assess the implementation by personnel of existing educational materials, such as the USCG *Crew Endurance Management Practices* and tug/towboat/barge industry materials.

The objective of this research is to develop a compendium of best practices for enhancing sleep efficiency on towboats in the U.S. tug/towboat/barge industry.

1.2 Previous Research

1.2.1 Sleep and Circadian Rhythms

The basic need or drive to sleep is a biological imperative, just as is the need for food, water, and oxygen. The sleep-wake cycle is regulated by two fundamental processes that are referred to as the homeostatic process and the circadian process. The scientific basis for these two processes is described below, as are some of the fundamental aspects and characteristics of the sleep-wake cycle. In addition, the behavioral and physiological consequences of sleep deprivation, as well as the consequences of sleeping or being awake at the wrong times of the circadian day, are also described.

1.2.2 Homeostatic Process Regulating the Drive to Sleep

This process refers to the fact that the longer one is awake, the greater the drive to sleep, i.e., the pressure to sleep becomes greater. This process is usually measured in humans by the amplitude of the delta waves in an electroencephalogram (EEG)—a measure of brain wave activity during non-rapid eye movement sleep. Thus, the longer one is awake, the harder it is to stay awake.

1.2.3 Circadian Process

It has been firmly established that a circadian (about 24 hours) clock in the brain regulates the sleep-wake cycle, as well as all 24-hour physiological and behavioral rhythms in mammals. The master circadian clock is located in the anterior hypothalamus, within two small nuclei referred to as the suprachiasmatic nucleus (SCN). For most people living on a normal day-night schedule, the low point (nadir) of alertness is between 03:00 to 07:00, which is also the time of the minimum of body temperature and when melatonin levels are elevated, two factors that contribute to the circadian drive to sleep. The 24-hour rhythm in sleepiness also reaches its maximum (to be asleep) at around 03:00 to 07:00. This low point in alertness, and maximum drive to sleep, coincides with when most accidents that are caused by fatigue occur in the transportation industry. The master circadian clock in the SCN regulates not only the 24-hour rhythms in the sleep-wake cycle and alertness, but also 24-hour rhythms in human performance and cognitive abilities, as well as all behavioral and physiological rhythms.

1.2.4 Cannot Override the Need to Sleep

While there is some belief that one can remain alert even when very tired by having the will power, the "right stuff" (i.e., the "Iron Man Syndrome"), this is not the case, and sleep can overwhelm even the strongest willed, most highly motivated person trying to stay awake. An extremely tired individual can fall uncontrollably into a microsleep, lasting only a few seconds, or into a full state of sleep, in which a total loss of function occurs—even while driving a car, truck, train, or while piloting a ship.

1.2.5 Timing of Sleep

Just as it is difficult to stay awake between 03:00 and 07:00, it is also difficult to fall asleep during the daytime for individuals living on a normal 24-hour light-dark cycle (Kryger et al. 2005). Individuals who work at night and attempt to sleep during the day are often only able to obtain 4 to 6 hours of sleep; the average person needs about 7.5 to 8 hours of sleep per 24-hour day to be fully rested and alert for the next day's activities [Office of Technology Assessment (OTA) 1991]. In addition, daytime sleep is less efficient and less recuperative than nighttime sleep is for many internal and external reasons (Monk 2005). When sleep is out of phase with the circadian clock, the sleep episode is shorter since the clock is telling the body and mind to be awake (Kryger et al. 2005). Furthermore, daytime environmental factors, including light, noise, and temperature make it more difficult to sleep during the day. Workers that routinely sleep during the day will have poorer sleep quality, leaving them less refreshed for work activities at night. The effects can be cumulative when individuals repeatedly attempt to sleep during the day, at a time their circadian clock is telling them to be awake (Van Dongen et al. 2003).

1.2.6 Duration of Sleep

The average human needs about 7.5 to 8 hours of sleep per night to be fully refreshed. Even a small reduction in sleep time, for example, from 8 hours to 6 hours, can impair performance [Carskadon and Dement 1981, Carskadon and Dement 1982, National Transportation Safety Board (NTSB) 1999, Van Dongen et al. 2003)].

1.2.7 Importance of Regularity of Timing of Sleep

Irregularity of the sleep-wake schedule means people are sleeping (and working) at different times of the day and night, often for multiple days in a row. The circadian system does not adjust instantly or even rapidly to a change in the sleep-wake schedule (Takahashi et al. 2001, Kryger et al. 2005). Indeed, it may take 5 to 7 days to re-adjust to a new fixed work-rest schedule, but if that schedule is constantly changing, it may never re-adjust, i.e., the worker is in a constant state of "jet lag."

1.2.8 Cumulative Effects of Sleep Restriction

It has been known for 25 years that alertness levels gradually decrease day after day if individuals repeatedly do not obtain sufficient sleep. For example, in one early study, alertness levels gradually were reduced each consecutive day when sleep was reduced to 4 to 5 hours per night over a 7-day period (Carskadon and Dement 1981, NTSB 1999). Quantitative studies have been carried out demonstrating that chronic sleep restriction to 4 to 6 hours per night over a 14-day period leads to cumulative, dose-dependent deficits in cognitive performance on a variety of different measures of cognitive ability. Indeed, for some measures of behavior, the adverse effects on performance of cumulative sleep loss in people sleeping 4 to 6 hours per night were similar to those observed in subjects totally sleep deprived for 24 or 48 hours (Van Dongen et al. 2003). Interestingly, sleepiness ratings for many of the subjects indicated they were largely unaware of their increasing cognitive deficits, which may explain why individuals who are in a chronic state of sleep deprivation think they can perform well. Their tiredness itself prevents them from recognizing their deficits in performance.

1.2.9 Adverse Effects of Fatigue and Disrupted Circadian Rhythms on Safety, Performance, Cognitive Abilities, and Ability to Operate Motorized Vehicles

Sleep and sleepiness are amongst the most basic of human behaviors (Mitler et al. 1997). While technological advances have eliminated many sources of accidents, sleep deprivation and fatigue continue to be a major cause of error and accidents in modern society. A study in Great Britain estimated that 27% of drivers who lost consciousness behind the wheel fell asleep, as opposed to fainting, having a seizure, or having a heart attack. However, this 27% accounted for 83% of the fatalities. Other investigators have also observed a high rate of fatality in sleep-related accidents. The increased fatality rate is probably due to the tendency for sleepy drivers to push on rather than stop and sleep, thereby allowing for unintended bouts of sleep to occur without warning. Once a driver has fallen asleep, there is little or no attempt to brake or otherwise avoid a collision (Mitler et al. 2000).

There is extensive literature going back many years demonstrating that prolonged wakefulness and/or the lack of sufficient sleep can lead to severe decrements in cognitive performance [for reviews see OTA (1991), Dinges (1995), Zee and Turek (1999), Harrison and Horne (2000)]. Particular attention has been paid to studies on the effects of prolonged periods of wakefulness and/or lack of sufficient sleep in the transportation industry due to the life-threatening aspects associated with fatigue and accidents in transportation operations, including the shipping, trucking, airline and railroad industries (Mitler et al. 1997, NTSB 1999, Lamond et al. 2001, Lamond et al. 2004). As noted below in the consensus statement published in *Sleep Research*: (Akerstedt 2000):

> It is the consensus of an international group of scientists who study human performance, safety, and prevention of accidents associated with work schedules, night activity, and inadequate sleep that:
>
> 1. The 24-hour society, with around the clock operational demands in all transportation modes, challenges the powerful and vital need for sleep. Sleep, alertness, and performance are fundamentally linked to the 24-hour biological clock.
> 2. The major causes of fatigue are (a) the time of day of the transport operation (e.g., night/early morning), (b) a long duration of wakefulness, (c) inadequate sleep, (d) pathological sleepiness (sleep apnea, etc.), (e) prolonged work hours (not necessarily operating the vehicle).
> 3. Fatigue (sleepiness, tiredness) is the largest identifiable and preventable cause of accidents in transport operations (between 15% and 20% of all accidents), surpassing that of alcohol or drug related incidents in all modes of transportation. Official statistics often underestimate this contribution.
> 4. Under-estimation of the impact of fatigue can lead to the underutilization of important countermeasures.
> 5. Public and environmental safety, health, and productivity are compromised by fatigue and sleepiness, with substantial financial costs to individuals and society.
> 6. Fatigue-related risk may be reduced through a variety of interventions, that include education (about sleep, the biological clock, sleep disorders, fatigue countermeasures), improved scheduling of work hours, and the judicial use of strategies and technologies.

Fatigue is recognized as an important cause of accidents. The consensus report cited above, written by a number of sleep researchers/experts, concluded that sleep loss and circadian influences are determinants of performance-related incidents and accidents, and are likely to compromise public safety. The critical importance for managing fatigue in the transportation industry led to the May 1999 NTSB Safety Report (SR) (NTSB/SR 99-01) titled, "Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue" (NTSB 1999).

- This NTSB report was a follow-up to a 1989 NTSB-SR that made three specific recommendations to the U.S.DOT: the third one being that all the transportation modes upgrade their governing HOS regulations to be consistent with the latest research on fatigue and sleep issues.
- The NTSB sponsored a watershed meeting in 1995 attended by more than 500 people from all modes of transportation on "fatigue" in the transportation industry.
- In 1999, the NTSB gave the USCG 2 years to come up with new "scientifically based hours-of-service regulations that set limits on hours of service and provide predictable work and rest schedules and consider circadian rhythms and human sleep and rest requirements" (NTSB 1999).

In addition to falling asleep while operating a motorized vehicle, sleep loss is associated with severe effects on cognitive performance and decision-making capabilities (Mitler et al. 1997, Philip et al. 2003). Sleepiness or fatigue can cause impaired reaction time, impaired judgment, impaired vision, problems with information processing, short-term memory loss, decreased mental and physical performance, loss of vigilance and loss of motivation (Dinges 1995, Harrison and Horne 2000). Indeed, impairments to the mental state associated with fatigue can be as severe, and even more severe, than being intoxicated (Dawson and Reid 1997).

1.2.10 Fatigue, Sleep, and Disrupted Circadian Rhythms in Marine Operations

Although not as extensive as for other industries (e.g., trucking and railroad), there have now been a number of studies documenting the impact of various work schedules on fatigue and performance in mariners in different environments (e.g., open sea vs. inland waterways). While some studies have been short term (e.g., a few days) in nature and others long term (e.g., a few weeks), and different studies have utilized different outcome measurements (e.g., subjective sleepiness, performance-based tests), almost all have reported adverse effects on crew sleep and/or performance that depend on length on duty and/or time of day on duty (or sleep time). It should be noted that the problems associated with "shift work," and the need to maintain 24/7 operations are not unique to the marine industry, as there is extensive literature on the adverse effects of 24/7 scheduling in other transportation industries (e.g., air, rail, trucking) on health, safety, and productivity. Between industries and within industries the operational demands are of tremendous complexity and diversity and the solutions are also not a simple "one size fits all." Therefore, the solutions for alleviating fatigue and decreased cognitive abilities due to sleep and circadian based problems associated with obtaining sufficient and quality sleep need to be addressed by using an integrated global approach as initially outlined in the *Crew Endurance Management Practices: A Guide for Maritime Operations* (Comperatore and Rivera 2003) report.

1.2.11 Napping Strategies to Reduce Fatigue

It is difficult to generalize the results from the "napping" literature because the design of such studies, the purpose of the studies, and the outcome measurements vary greatly between them, making it impossible to provide simple conclusions. Nevertheless, certain overall conclusions do emerge from both laboratory and field-based studies of various napping strategies, including:

- Naps (defined as being a period of sleep < 50% of main sleep period, or "anchor sleep") can be beneficial for reducing fatigue and improving performance, especially for individuals under restricted (voluntary or involuntary) anchor sleep, or when the nap is taken before or during a time the individual is attempting to work/be awake while their internal biological clock is attempting to induce sleep.
- Almost all initial studies examined the effects of short naps (10 to 60 minutes) by using various performance measurements over the next few hours (e.g., 30 minutes to 3 hours) following the nap. Most studies are short term in nature (1 day) and have addressed the immediate effectiveness of the nap on performance capabilities, not on long-term benefits of naps in conjunction with a fixed anchor-sleep time.
- Although many studies have been carried out to determine if and what kind of nap can improve acute performance in a sleepy or circadian-disrupted individual, surprisingly, until recently, the literature is almost *silent* on the question: How can one combine a regularly scheduled nap with regularly scheduled anchor sleep to minimize fatigue and maximize performance under chronic conditions? However, recent research has collectively come to the same conclusion: The beneficial effects of sleep on fatigue and performance are mostly dependent on the total amount of sleep achieved over any 24-hour period, and are not dependent on the consolidation of sleep into a single bout (Mollicone et al. 2007, Mollicone et al. 2008, Jackson et al. 2014, Kosmadopoulos et al. 2014, Short et al. 2014). Therefore, the key to any schedule for sleep and wake activities is to design the schedule so the individual can obtain 7 to 7.5 hours of sleep per 24 hours regardless of the timing of the sleep-work schedule.

1.3 Findings from Prior Research That This NCFRP Research Builds On

From 2007–2012, investigators have carried out research in the tug/towboat/barge industry (Preuss et al. 2010, Reid et al. 2012, Reid et al. 2013). As part of this work they interacted with hundreds of crew members on vessels from over 30 inland waterway companies to assess and quantify the amount of sleep the crews are obtaining on a two-watch system, as well as their levels of fatigue and overall health. This research enabled the research team to collect an unprecedented amount of data about the sleep habits and strategies of crew members attempting to obtain sufficient sleep while on the 6:6:6:6 square watch schedule for prolonged periods of time (e.g., 14 to 28 days), as well as their sleep and wake habits when off duty. Also collected were real-world data on fatigue, stress, health indices, and barriers to obtaining good sleep while on the vessel. Educational material was also distributed to 163 wheelhouse crew members. Together, these data allowed for research to determine what are the behaviors and characteristics of individuals that make up the best practices used by the "good sleepers," as well as the compendium of behaviors and characteristics of crew members who are not obtaining adequate sleep. The researchers have also been able to analyze the environmental factors that impact sleep-wake behaviors of crew members on board the vessel and in their home environments. These data enabled the development of models that will guide tug/towboat/barge operators and their crews to implement best practices on board vessels in the U.S. tug/towboat/barge industry, as well as in other industries (e.g., trucking) where sleep is often split into what is referred to as "anchor sleep/nap sleep" over a 24-hour period.

It should be noted that modern society's propensity to sleep during a single 8-hour period is a relatively recent phenomenon. There is historical evidence that sleep occurred in two sleep bouts, referred to as first and second sleep (Ekirch 2006), and there is evidence from modern clinical studies where humans lived for up to 30 days on a 10-hour light/14-hour dark day, that they also split sleep into two periods (Wehr et al. 1993). A major goal of this research was to understand and implement best practices that will allow tug/towboat/barge crews to obtain 7 to 8 hours of sleep split into two sleep periods while on a 6:6:6:6 square watch. The results from previous work on board towboats and with crew members while on duty and in the home environment, when taken together with data in the literature, especially data on the effects of split-sleep on fatigue and performance, have enabled the researchers to provide clear suggestions to improve current practices across the industry. The results of these studies have allowed the development of strategies for obtaining sufficient sleep on board tug/towboat/barge vessels that can now be implemented with and communicated to other stakeholders, including operators, crews, the USCG, and the NTSB. It is expected that the development of best practices strategies and educational materials will increase sleep and reduce human errors due to fatigue not only for crews on tugs/towboats/barges, but also in other industries that require the use of an anchor-sleep/nap-sleep strategy to maintain alertness and minimize fatigue during on-duty operations for individuals in 24/7 work environments. Many of the best practices suggested have already been implemented by a number of companies in the tug/towboat/barge industry, especially those that involve maximizing the environmental conditions that allow crew members to sleep efficiently; however, implementing the totality of the best practice suggestions will require that all stakeholders interact and work together so that recognition of the importance of sleep for safety and performance becomes part of the everyday culture of the entire industry.

Before starting work on this research, the research team completed four phases of research related to fatigue and sleep in crew members on tugs/towboat/sbarges. For Phase I, a white paper was prepared that provided a detailed analysis of published studies and data on schedules and fatigue levels of crew members on board vessels throughout the maritime industry (i.e., blue/open water, as well as inland waterways, where vessels must be maintained 24/7). Since it was apparent that the scheduled duty times in the maritime industry were often split into 2 periods of work over 24 hours (and thus, 2 periods of rest per 24 hours) in order to maintain vessel activities 24/7, the Phase I white paper also included an analysis of the scientific literature on the use of naps in association with anchor sleep (i.e., a split-sleep schedule) for reducing fatigue and optimizing performance. The conclusion from this analysis was that any viable strategy for an industry that has two crew members who must be on duty collectively for 24 hours over many days (i.e., crew members must be on duty and maintain high levels of vigilance for a total of 12 hours each 24-hour day) would require anchor-sleep/nap-sleep strategies to manage fatigue and reduce risk on towing vessels.

This white paper led to the design of a Phase II study with the objective of developing a better understanding of the sleep-wake schedules and sleep amount of the crew members on board towing vessels that were using a 6 on: 6 off: 6 on: 6 off duty schedule. The Phase II proposal was developed after the research team rode on two towboat vessels to obtain first-hand exploratory information on the lives of crew members in the barge industry. For the Phase II research, investigators rode on five towing vessels in 2009 and collected sleep-wake data on crew members. This work was supported by seven different towing vessel companies (Marathon, K-Sea, Canal Barge, Ingram Barge, American Commercial Lines, Kirby, and the Cenac Towing Co). In 2010, with support from the American Waterway Operators (AWO), the researchers carried out a Phase III study that collected sleep time and sleep duration data from crews on ten different towing vessels. The findings from these two studies were consistent and gave a clear understanding of (1) how many hours crew members actually spent in bed during each of the 6-hour sleep opportunities and (2) how much sleep time (based on wrist actigraphy data) they were actually obtaining. Findings from these two studies consistently indicate that while wheelhouse crew members appear to be spending an adequate time in bed each day (e.g., approximately 8 hours), they are not able to obtain more than about 6.5 hours of sleep per 24 hours (Preuss et al. 2010).

A strength of the Phase II and Phase III studies was the use of objective measures to determine sleep-wake times; however, given the resources available, it was not possible to study a large number of crew members over an extended period of time. Therefore, in the Phase IV studies (also supported by the AWO), online technologies were used that enabled the tracking of the sleep-wake behaviors of over 160 wheelhouse crew members (captains and pilots) for extended periods of time when on duty on a 6:6:6:6 square watch, as well as in their home environments. Crew on the front watch typically work between the hours of 06:00 to 12:00 and 18:00 to 24:00, while crew on the back watch typically work between the hours of 24:00 to 06:00 and 12:00 to 18:00, with rest intervals in the intervening periods. Previous studies indicated that there was no difference in the sleep duration of crews on the front (captains) and back (pilots) watches. This was unexpected as the front watch crew had a rest period during the night (24:00 to 06:00) when the circadian clock is signaling the body to sleep, and as such, it should be the best time to sleep. The rationale for studying only the wheelhouse crew members in Phase IV was that given the small number of wheelhouse crews previously studied (19 in Phases II and III), it was difficult to identify factors that may be impacting sleep in these wheelhouse crews. The major aims of the Phase IV studies were (1) to determine and compare the sleep patterns of wheelhouse crews both when on extended vessel duty (21 to 28 days) as well as when at home for an extended period of time and (2) to use online technologies to identify factors that may be influencing sleep quality in a large number of wheelhouse crew members. An additional aspect of this study was to take the opportunity to disseminate the education materials developed during the Phase III studies to a much larger number of crew members and, at a later time, to carry out follow-up assessments to determine the effectiveness of these educational materials (this research). As part of the Phase IV online studies, the researchers also obtained data on height and body weight in order to calculate body mass index (BMI) and collected a variety of measures of sleep and fatigue levels using a number of scientifically validated tests and questionnaires (Reid et al. 2013).

1.4 Scope of NCFRP Research

The overall approach for the NCFRP research involved:

1. An assessment of the use of split-sleep or anchor-sleep/nap-sleep strategies in the U.S. tug/towboat/barge industry for crew working on a 6:6:6:6 square watch schedule.
2. An assessment of whether there were any changes in behavior in crew members following their participation in the Phase IV study and after dissemination of the previously developed educational materials.

3. The identification of those groups of individuals who did or did not change their sleep-wake behaviors and to what degree and why.
4. The identification of the multivariate factors that enable some crew members to obtain adequate sleep (7 to 8 hours) per 24 hours and the factors that are associated with not obtaining sufficient sleep (<6.5 hours) per 24 hours.
5. The identification of best practices across other transportation industries (e.g., railroad, trucking, and aviation) for enabling individuals on unusual shift work schedules to obtain adequate and efficient sleep to develop models that could be used to advise supervisors and crews in their development of a fatigue management program that could be incorporated in their overall SMS.
6. To integrate the information obtained into a compendium of best practice.

The results from the NCFRP research, along with data in the literature and the collection of information on best practices from other transportation industry leaders, have led to proposed guidelines and best practices for obtaining sufficient sleep while on towing vessels to enhance safety and performance. Since a majority of the industry utilizes schedules that have crews working two shifts per 24 hours, the researchers have focused much of the work and best practices for crews who need to develop effective split-sleep or anchor sleep and nap-sleep strategies. It should be noted that research in the laboratory or field clearly indicates that individuals cannot obtain 7 to 8 hours of uninterrupted sleep when working a 6:6:6:6 square watch or 7:7:5:5/8:8:4:4 rectangular watches, especially when sleep is attempted at the wake phase of the circadian clock. Therefore, whether crews are on the square or rectangular watches, they will need to develop an anchor-sleep/nap-sleep strategy. While crews on a 12:12 watch might be able to obtain 7 to 8 hours of uninterrupted sleep when the sleep period is during the normal nighttime hours, it may not be possible when sleeping during the daytime. In addition, for many demanding jobs, such as operating towboats, 12 hours on duty may be too demanding of a work period, especially when the 12 hours on duty occur during the normal sleep time. In addition to proposing best practices, this research, as well as the research of others and previous work by this research team within the tug/towboat/barge industry, has enabled the research team to propose an implementation plan that will involve working collectively between the major stakeholders, including tug/towboat/barge management and operators, crews, relevant trade organizations, such as the AWO, and key federal agencies, especially the USCG and the NTSB.

CHAPTER 2

Research Approach

The overall objective of this research was to develop a compendium of best practices for enhancing sleep efficiency on towboats in the U.S. tug/towboat/barge industry. This chapter describes the research approach.

The research team has leveraged its prior work/experience with the U.S. tug/towboat/barge industry and the data collected in what it termed Phases I through IV, as well as a new assessment termed Phase V, to address the tasks proposed as part of NCFRP Project 45. A summary of these assessments is provided in Table 1, including the study phase, group(s) assessed, number of individuals studied, and the type of the assessment. Data from all five phases are used in this report, but particular focus is given to Phases IV and V.

2.1 Task 1. Kickoff Meetings

The first task (Task 1) of this NCFRP research was a teleconference with the NCFRP project panel. A separate stakeholder presentation was given at the AWO Combined Annual Meeting in January of 2014.

2.1.1 NCFRP Panel Meeting

At the initiation of the project, the three key members of the research team participated in a kickoff conference call with the NCFRP project panel. At this meeting, the research plan was reviewed.

2.1.2 Stakeholder Meeting

A stakeholder kickoff meeting was then held at the AWO Combined Annual Meeting of the Midwest, Ohio Valley & Southern Regions in New Orleans in January 2014. The NCFRP research plan was presented to the attendees and questions.

2.2 Task 2. Evaluate Current Operational Practices

Task 2 was to identify and describe the metrics to be used to evaluate current operational interventions (e.g., educational materials and programs; noise abatement; sleep disorders screening—especially sleep apnea, and wellness and nutritional programs) for their effectiveness in improving sleep efficiency on tug/towboat/barge vessels. In order to evaluate the current operational practices related to improving sleep efficiency, two main strategies were used:

1. Assess operational practices already in place across the industry using an online survey and structured interviews with key personnel involved in fatigue management, and

Table 1. Summary of research in American waterways, 2008 to 2014.

Phase	Who Assessed	# Assessed	Type of Assessment
I – White Paper: Split Sleep & Napping	NA	NA	• Review of literature
II - Assessment and Intervention of Anchor-Sleep/Nap-Sleep Strategy	All crew on vessel	50	• Actigraphy/sleep log • Questionnaire • Anchor-sleep/nap-sleep intervention
III – Develop Education Intervention and Assessment of Sleep	All crew on vessel	70	• Actigraphy/sleep log • Questionnaire • Education intervention
IV – Comparison of Sleep on Vessel and at Home	Captains and pilots only	161	• Sleep log and questionnaire • No intervention • Educational materials provided at conclusion of the study
V – Develop Best Practices	• Crew • Management • Other Industries • Government • Academics • Consultants	• N=40 • N=53 • N=6 • N=3 • N=11 • N=4	• Survey/questionnaire • Interview • Review of publicly available sources

2. Survey crew members from the previous Phase IV study to assess the impact of current operational practices on their sleep efficiency. This survey also included an assessment of the educational materials distributed as part of the previous Phase IV study.

While the assessments focused on key areas in the evaluation of current practices related to sleep efficiency, open-ended questions were also asked to elicit discussion about related practices that may be unique to a particular individual, company, or region within the U.S. tug/towboat/barge industry. The key areas included in the survey were:

- Noise abatement (ear plugs, white noise generators, quiet times),
- Sleeping quarters [e.g., light reduction, beds (size, mattress), sharing, sound proofing],
- Training/education related to sleep or sleep-related health factors,
- Screening for sleep disorders,
- Wellness programs,
- Stress management,
- Diet/nutrition,
- Exercise,
- Medical conditions that impact sleep,
- Medications that impact sleep, and
- Identification of other practices.

In addition to collecting information on current practices related to sleep efficiency, the research team asked the representatives of the companies whether they monitored the success of the practice, and in an attempt to determine whether these practices were successful, crew members were asked whether they thought the current fatigue management practices of their company influenced their behavior. This assessment was done as a Likert Scale to rate the practice from "very effective" to "not at all effective" in influencing sleep efficiency.

In addition, if a company had data they were willing to share on the effectiveness of current practices, the research team collected that information, assessed its validity, and, where appropriate, included it in this report.

The team also included a few key questions in the survey of crew members to determine whether they had taken advantage of the programs provided by their company, and, if so, what the perceived benefits or weaknesses of the program were, particularly in impacting sleep efficiency. Crew without access to these types of programs were asked to rate how likely they would be to use such a program and how beneficial they believe such a program would be if available to them.

2.2.1 Management Survey to Evaluate Current Operational Practices

With the aid of the AWO, the research team reached out to approximately 200 AWO member company representatives to complete an online survey (see Appendix B for full survey).

The research team then invited several of the representatives that completed the survey to participate in a phone interview. Representatives were selected for an interview based on their responses to the survey questions, including their willingness to participate in an interview, company size, primary shift schedule utilized, and whether they had various fatigue management practices in place. This selection process allowed the research team to interview representatives from a range of companies and to gather further information about specific practices and how they may have been implemented. See Table 2.

2.2.2 Crew Member Survey to Evaluate Operational Practices

For the second part of Task 2, 231 crew members who had previously consented to participate in the Phase IV study were approached. In the original Phase IV study sufficient data was received from 163 of the consented crew members.

Initially, crew who were determined from their Phase IV data to be short, moderate, or long sleepers were approached to participate; however, due to recruitment difficulty all Phase IV crew were invited to participate (N = 231). Crew members were contacted (up to a total of seven times). The crew members who agreed to participate were given a start date that coincided with their next rotation on the vessel. Crew participation in this research was between June and October 2014.

Table 2. Summary of the characteristics of the companies from the management survey respondents invited to be interviewed.

#	# Crew Employed	Primary Schedule	Secondary Schedule
1.	1078	6:6:6:6	
2.	126	6:6:6:6	
3.	262	6:6:6:6	
4.	225, 100, 550*	6:6:6:6	12:12
5.	40	4:8:4:8	
6.	149	6:6:6:6	
7.	152	6:6:6:6	12:12
8.	34	12:12	
9.	160	6:6:6:6	12:12
10.	900, 1250*	6:6:6:6	
11.	12	6:6:6:6	12:12
12.	100, 550*	6:6:6:6	4:4
13.	36	12:12	
14.	50	6:6:6:6	12:12

* Indicates that responses from multiple representatives of the same company (different operations of the same larger company) were received that included different total numbers of crew employed. All responses are listed.

There were two levels of participation for the crew. Level 1 was a survey only (see Table 3 in Section 2.4 for a summary of survey items and Appendix B for a full copy of the survey), which was given to all crew members who consented to be part of this research. Level 2 was a work and sleep diary that was to be completed at the end of each rest interval (see Appendix B for a copy of the diary). Those who were determined to be short, moderate, or long sleepers (based on sufficient data from Phase IV to group crew by average sleep duration; a total possible invitees was N = 136) were invited to complete this diary (see Section 2.4.1). The diary was to be completed for a total of 14 days, days 1 through 7 of rotation on the vessel and days 15 through 21 of rotation on the vessel.

2.3 Task 3. Evaluate the Use of Anchor-Sleep/Nap-Sleep Strategies

The completion of this task involved two main steps:

- Determining the proportion of crew who use anchor-sleep/nap-sleep strategies:
  - Re-analysis of Phase II to IV trials to identify crew members who used anchor-sleep/nap-sleep strategies,
  - Surveying all crew that participated in the Phase IV trial (for Phase V).
- Using mathematical models to predict performance based on actual sleep/wake and work schedule.

2.3.1 Determine the Proportion of Crew Who Use Anchor-Sleep/Nap-Sleep Strategies

For Phases II and III, sleep diaries and wrist actigraphy monitoring were completed by all participating crew on a total of 16 vessels for up to 12 days.

For Phases IV and V, sleep diaries were completed for up to 14 days for each sleep opportunity, regardless of whether the crew member slept or not (see Appendix B for a copy of the diary).

The analysis of the existing data set from the Phases II through IV trials specifically assessed the prevalence of the use of the anchor-sleep/nap-sleep strategies. In order to do this, a variable (yes or no) was created to identify whether a crew member is deemed to use an anchor-sleep/nap-sleep strategy. If a crew member consistently slept or attempted to sleep for more than 1 hour in both of the sleep opportunities per 24-hour period on at least 90% of the recorded days, they were deemed to use an anchor-sleep/nap-sleep strategy.

2.3.2 Use Mathematical Models to Predict Performance Based on Actual Sleep-Wake and Work Schedule

As part of the evaluation of nap-sleep/anchor-sleep strategies within the tug/towboat/barge industry, a currently available mathematical model was used to predict performance from sleep-wake history of actual crew members working in the industry. These models are a cost effective and scientifically valid way of predicting performance using a combination of sleep-wake and work history. There are many different models available, but most share the same mathematical "guts," the "two-process model." One such model, the Sleep, Activity, Fatigue, and Task Effectiveness/Fatigue Avoidance Scheduling Tool (SAFTE/FAST) model (Hursh et al. 2004), is in broad use by the commercial aviation and rail industries, as well as government organizations, including the USCG and the U.S.DOT.

The SAFTE/FAST predicts performance as the interaction of the linear decline in performance resulting from increasing time awake or the homeostatic sleep drive (Process H) and the sinusoidal variation in performance resulting from the circadian rhythm, the 24-hour rhythm in body temperature (Process C). This two-process model was originally developed to predict high-amplitude, slow electrical activity on the surface of the brain and, thus, is firmly rooted in brain physiology (Borbely 1982). It was later discovered that the same two-process model accurately predicted alertness, sleepiness, and performance.

As input, the SAFTE/FAST model takes the sleep-wake history of a study participant. The sleep-wake history derived from a wrist activity monitor (actigraph) or created from a sleep-work diary is a minute-by-minute record of whether the participant is awake or asleep, with waking typically coded as a "1" and sleep as a "0." Thus, a 10-minute sleep-wake history beginning at 08:00 with the participant awake for the first 5 minutes and asleep for the last 5 minutes would look like the following:

08:01 hours – 1
08:02 hours – 1
08:03 hours – 1
08:04 hours – 1
08:05 hours – 1
08:06 hours – 0
08:07 hours – 0
08:08 hours – 0
08:09 hours – 0
08:10 hours – 0

Taking this sleep-wake history as input, and estimating the position of the circadian rhythm relative to sunrise and sunset, the SAFTE/FAST model produces a performance prediction on a scale of 0 to 100, updated every minute. The model remembers the performance prediction from the previous minute and updates this prediction, decreasing predicted performance if, in the current minute, the person was awake and increasing predicted performance if, in the current minute, the person was asleep or awake as modulated by time of day to take into account the circadian rhythm. The model accurately predicts performance.

The SAFTE/FAST model was used to translate the minute-by-minute sleep-wake history into a minute-by-minute performance prediction, thus, interpreting the meaning of the sleep-wake history in terms of its effects on operational performance.

Figure 1 is an example of how a mathematical model (in this case, SAFTE/FAST) can be used to predict the performance of a single crew member. In the Phase IV study, sleep-wake histories were collected for both on-duty days and off-duty days using a sleep-work diary. Simply looking at a sleep-wake history provides limited information as one would like to know how this history translates into performance as modulated by circadian rhythmicity (Process C) and homeostatic sleep drive (Process H).

Another approach is to directly measure performance using, for example, a psychomotor vigilance task (PVT). A PVT takes at least 5 minutes to complete and needs to be executed at regular and frequent intervals, and the tester must be focused on the test; thus, the PVT is too obtrusive and not flexible under the research conditions. An alternative (as described above) is to take the sleep-wake history and use it as input to a mathematical model using homeostatic sleep drive (Process H) and circadian rhythmicity (Process C) to predict minute-to-minute performance. Modeling in this way predicted performance using the sleep-wake histories from the sleep-work diary of a captain who participated in the Phase IV study across approximately 1 week while on board. The results of this modeling are depicted in Figure 1 and is presented here as an example of how the SAFTE/FAST model can be used to predict performance based on sleep-wake history and circadian phase.

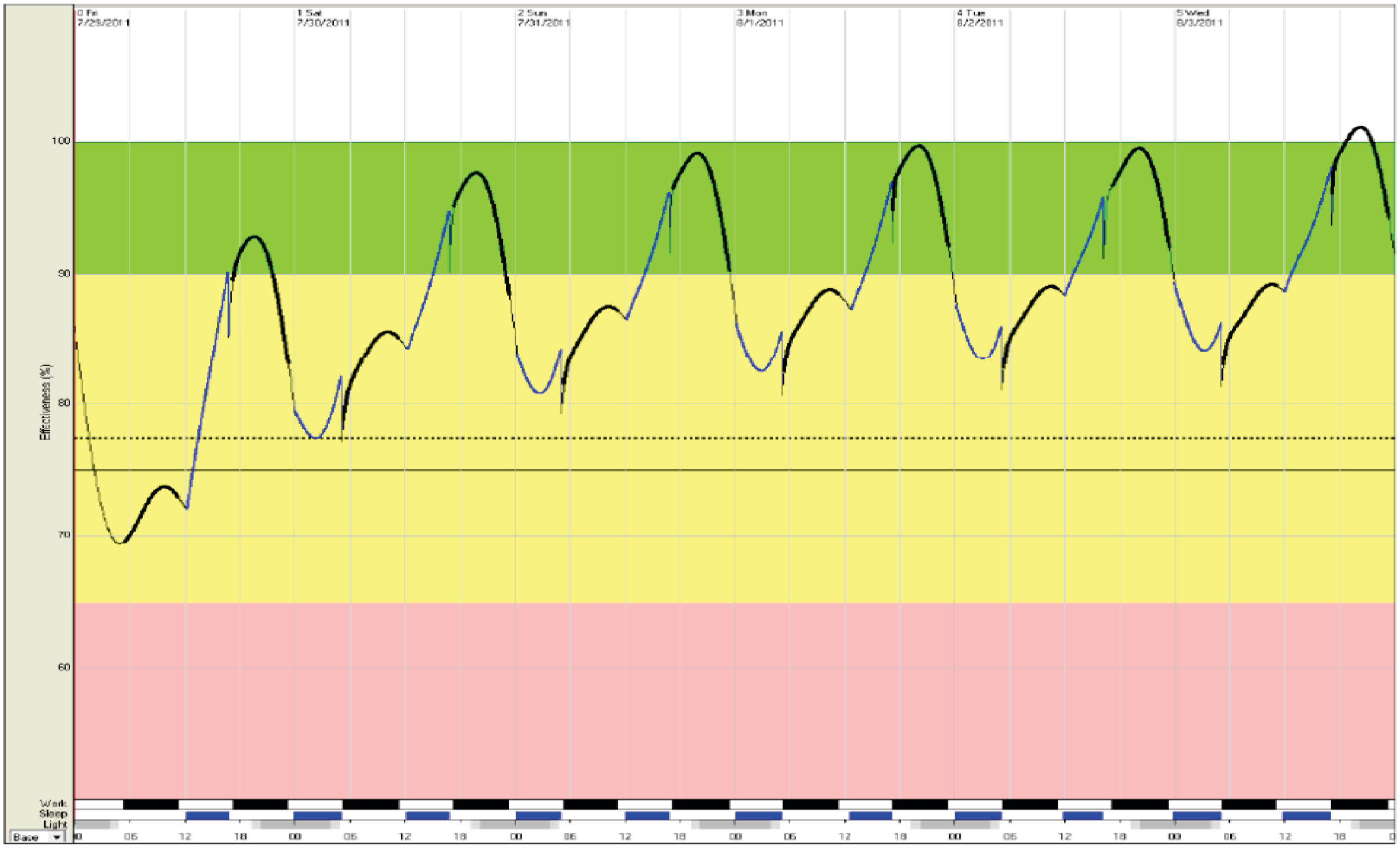

Figure 1. Participant 134 (Captain) spending 1 week on board at work.

In Figure 1 nighttime is indicated by gray bars, sleep by blue bars, work shift by black bars, and predicted performance by black (waking) and blue (sleeping) curved lines. The X-axis indicates times (days and hours) and the Y-axis indicates predicted performance. The background colors (green, yellow, and red) indicate increasingly impaired performance. In this model, a night of sleep is missed and the effect of this can be seen by a dip in performance. As the week progresses, however, the participant gets sufficient sleep and performance improves. There are troughs in performance in the early hours of the morning and peaks in the evening; this is due to the circadian rhythms produced by the internal circadian clock. Good performance is maintained throughout the week despite the participant splitting their sleep into two periods over each 24-hour period.

2.4 Task 4. Identify Barriers to Adopting Good Sleep Management Practice and Develop Practices to Overcome These Barriers

The completion of this task involved four main steps:

- Identifying factors that predict the 20% best and 20% worst sleepers.
- Identifying crew members who changed sleep behaviors since the Phase IV trial.
- Evaluating current best practices.
- Using the identified factors to model changes in sleep-wake and then using mathematical modeling to predict performance.

In order to identify barriers that inhibit tug/towboat/barge personnel from adopting good sleep management practices and then develop best practices to overcome these barriers, extensive analyses were conducted of the new data collected as part of this research and relevant data from prior studies were re-examined. As part of these efforts, those groups of individuals who did or did not change their sleep-wake behaviors were identified, the degree determined, and why. By identifying the multivariate factors (see Table 3) that enable some crew members to obtain adequate sleep (7 to 8 hours) per 24 hours, and the factors that are associated with not obtaining sufficient sleep (<6.5 hours) per 24 hours, the research team was better able to prepare the list of best practices and assess the effectiveness of practices already in place.

Table 3. Summary of factors that can impact sleep that were used in various statistical models to determine best (and worst) sleep practices in crew members.

FACTOR	MEASUREMENT	NOTES
Age *	Date of birth	
BMI*	Self-report height and weight	
Sleep apnea risk	Berlin* STOP Bang	
Caffeine use*	Standard shiftwork index* Sleep diary*	
Smoking status*	Standard shiftwork index* Sleep diary*	
Years on maritime schedule or other shift work*	History	
Physical health*	Standard shiftwork index*	
Mental health*	Standard shiftwork index*	
Job satisfaction*	Standard shiftwork index*	
Sleepiness*	Epworth Sleepiness Scale* Karolinska Sleepiness Scale* Samn Perreli	Single administration Repeated at each start and end of work period
Sleep duration	Time in bed* Total sleep time* Modified Pittsburgh sleep quality index*	For each rest interval and per 24-hour period Typical sleep period
Sleep quality*	Sleep diary*	Sleep latency, wake after sleep onset, self-reported sleep quality
Noise*	Sleep diary* Survey	
Vibration	Survey Sleep diary*	
Family burden*	Standard shiftwork index*	
Stress*	Sleep diary*	
Sleep disorders	Identified risk or known diagnosis Survey	Obstructive sleep apnea, restless leg syndrome, insomnia, narcolepsy
Medications*	Standard shiftwork index* Sleep diary*	Prescription, over-the-counter, supplements
Techniques used to improve sleep	Survey	White noise, ear plugs, relaxation techniques, etc.
Gender*	Survey	
Commute time*	Standard shiftwork index*	

* These items were used in the Phases II-IV research on crew members on towing vessels. All sleep diary factors are available for each sleep period.

2.4.1 Identify Factors That Predict the 20% Best and 20% Worst Sleepers

Using daily sleep data, the average daily sleep amount for each subject was first calculated and then all subjects were ranked based on their daily sleep amount. The top 20 percentile of the subjects as long sleepers (the daily sleep amount is longer than 8.6 hours) and the bottom 20 percentile of the subjects as short sleepers (the daily sleep amount is shorter than 6.6 hours) were defined. Subjects who slept on average 6.6 to 8.6 hours a day (i.e., the remaining 60% of the subjects) were thus defined as moderate sleepers.

To identify the factors that correlated with short or long sleep, various statistical approaches were used in the analysis of a number of different measures listed in Table 3. Repeated measures analysis with linear mixed-effect models were used to investigate how sleep durations during each sleep opportunity are influenced by sleep factors of interest. A univariate model was used to select sleep factors that are associated with sleep durations, and significant factors ($p < 0.1$) were then entered into a full model that models the linear combination of multiple sleep factors. In order to identify the factors that predict long and short sleepers, the 20% longest and 20% shortest sleepers were also directly contrasted. A conventional generalized linear regression model (GLM) was used to assess the multivariate associations of the factors influencing sleep with the sleep outcomes. Similar to the mixed-effect model, each of the factors influencing sleep was entered into the GLM as a main-effect term. In the GLM, coefficients of all factors influencing sleep were tested and their standardized values were ordered so as to evaluate the relative importance of the factors influencing sleep that are predictably related to sleep outcomes.

The originally proposed GLM, generalized boosted model (GBM), and marginal structural model (MSM) do not handle the longitudinal (measures over several consecutive days) sleep duration measures. The longitudinal feature of the data set via linear mixed-effect models, which is better suited for reporting the factors that are related to sleep duration, was also addressed.

2.4.2 Identify Crew Members Who Changed Sleep Behaviors Since Phase IV Trial

Assessment of the changes in behavior included asking crew members whether they had changed any behaviors since the previous assessment, and to provide details of the changes. Questions included (1) Following your participation in the previous sleep research study, did you change any of your usual behaviors to improve your sleep and (2) Can you provide examples of the behaviors you have changed (e.g., reduced caffeine intake close to bed, ear plugs, eye shades) as a consequence of your participation in the sleep research study?

2.4.3 Evaluate Current Best Practices

In order to evaluate current best practices, both crew members and management were separately surveyed (see Section 2.3 for general approach).

As part of the crew survey, participants were asked to list practices related to sleep that they currently used or have been educated about and to rate their effectiveness on a Likert Scale.

Examples of the questions used included (1) Have you ever received CEMS training; and (2) If so, how was the CEMS training received (i.e., did you have a course for a day, online, handouts, etc.); (3) Did you find the CEMS training useful; and (4) If you found the CEMS training useful what aspects of the training did you find the most useful?

For a complete copy of questions related to current best practices, see Questions 1 through 7 in the crew survey provided in Appendix B.

As part of the management survey the research team asked respondents to rate the effectiveness of a particular practice if their company had it in place. The research team also followed up with selected respondents by conducting interviews (see Section 3.2.1.1) to determine whether they had data that they would be willing to share that quantified the effectiveness of the practice.

2.4.4 Use the Identified Factors to Model Changes in Sleep-Wake and Then Use Mathematical Modeling to Predict Performance

Following the multivariate regression modeling, key factors that impact sleep duration and sleep efficiency were determined. Once done, these factors were used to predict sleep duration and then this information was used to create predictions of fatigue using mathematical models to predict performance as modulated by circadian rhythmicity and homeostatic sleep drive (SAFTE/FAST model). This is similar to the example provided in Figure 1.

2.5 Task 5. Prepare a List of Best Practices That Could Be Implemented by the Waterways Industry, Companies, Crews, or Individuals to Enhance Sleep Efficiency

The development of the list of best practices was approached in three ways:

- Determining current best practices with proven success from other industries that may either be tailored to the tug/towboat/barge industry or be directly transferable.
- Determining practices/interventions already in place in the tug/towboat/barge industry that have been successful.
- Proposing new best practices based on the findings of this report.

As part of this task, some suggestions for the implementation of the best practices were suggested.

In order to achieve the goals of Task 5, the research team utilized the findings from Tasks 2 through 4, and also conducted an extensive review of the literature related to best practices aimed at improving sleep already available from other industries, including the trucking, airline, motor coach and railroad industries (see Table 8 in Chapter 3 for a summary and Appendix A for a Bibliography).

2.6 Task 6. Prepare a Compendium of Best Practices for Enhancing Sleep Efficiency on Towboats in the U.S. Inland Waterway Industry and a Report Documenting the Results of the Research

Section 3.5 presents a compendium of best practices for enhancing sleep efficiency on towboats in the U.S. tug/towboat/barge industry. This report documents the results of the completed research.

CHAPTER 3

Findings and Application

3.1 Task 1. Outcome of the Kickoff Meetings

3.1.1 NCFRP Project 45 Panel Meeting

At the initial kickoff meeting, the NCFRP Project 45 panel provided further clarification on their suggested changes to the research approach.

3.1.2 Stakeholder Meeting

The stakeholder kickoff meeting was held at the AWO Combined Annual Meeting of the Midwest, Ohio Valley & Southern Regions in New Orleans in January 2014. At this meeting, the research team made a presentation and received valuable feedback from the attendees on how to best address the issue of enhancing sleep efficiency in tug/towboat/barge operations, how to establish best practices, and how to implement these best practices in the towing vessel industry.

There was an overall positive response to the session and several company representatives indicated their willingness to participate and to be interviewed. There were also questions related to whether the research would include different types of operations and watches, in particular 12-hour shifts. The research team indicated that all attempts would be made to represent the industry as a whole, including different operations and watch schedules, and that as part of the survey, these differences should be included. The research team also asked whether these companies would be willing to be involved in aiding with the development of the implementation plan for the different operations; the response to this was also positive.

3.2 Task 2. Results of the Evaluation of Current Operational Practices

The overarching goal of Task 2 was to identify and describe the metrics that would be used to evaluate current operational interventions for their effectiveness in improving sleep efficiency on towboats.

3.2.1 Best Practices/Interventions in the Tug/Towboat/Barge Industry

This section summarizes the work conducted to evaluate current operational practices in the tug/towboat/barge industry. To do this the research team surveyed representatives from AWO member companies and followed up with several of those representatives who completed the survey with a phone interview. The research team also interviewed other individuals identified throughout the project who provided information on specific issues related to obstructive sleep apnea, wellness and education/training. In addition, crew from the Phase IV study, who agreed to participate, were given an online survey. The findings from these surveys and interviews are summarized in the following subsections.

3.2.1.1 Evaluate Current Operational Practices— Management Survey and Interviews

The online survey of management from the tug/towboat/barge industry was completed with a total of 46 companies represented. Because of the varied operations represented by some companies, there were seven additional surveys that were completed by multiple representatives of the same companies, as such there were a total of 53 surveys completed. This represents a response rate of approximately 25%. The AWO considered this to be a good response rate in comparison to other surveys they have previously conducted with their membership.

Given the broad range in size of the companies surveyed, the data in this section are presented based on the number of crew that the company employs. While it is understood that there are certainly other methods of dividing the respondents, the research team chose to separate the data into these groups since smaller companies may not have the same resources and infrastructure in place as the larger companies and the team was interested in determining whether this had an impact on the responses related to different practices. This also allowed the team to determine whether there was a broad range of respondents that represented the industry, not just a certain sector of the industry. A summary of the number of respondents based on company size is provided in Figure 2.

In addition to the survey, managers from ten companies were interviewed over the phone to gather further details of their survey responses. In order to protect confidentiality, company/manager names will not be used in this report, but a summary table of the characteristics of the companies of those actually interviewed showing size of company and work schedule is provided in Table 4.

For clarity, the data for both the survey and interview responses will be presented together based on the categories outlined here. For the complete summary of the management survey responses see Appendix C. The categories include operational factors (i.e., work schedules); work-sleep environment; health; education; reporting of sleepiness and health-related factors; and other. Further interviews were conducted with representatives from various companies and outside organizations based on specific education, health, and sleep-related programs.

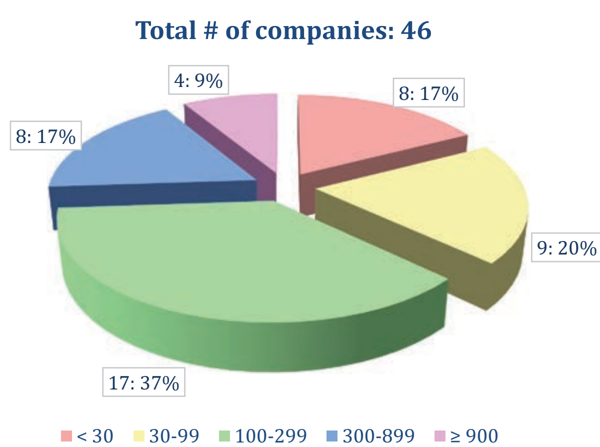

Figure 2. Chart of the proportion and number of companies that completed the management survey, divided by the number of crew the company employs. *Red: <30 crew; yellow: 30–99 crew; green: 100–299 crew; blue: 300–899 crew; pink: ≥900 crew.*

Table 4. Summary of the characteristics of the companies from the management survey respondents actually interviewed.

#	# Crew Employed	Primary Schedule	Secondary Schedule
1.	1078	6:6:6:6	
2.	126	6:6:6:6	
3.	262	6:6:6:6	
4.	225, 100, 550*	6:6:6:6	12:12
5.	40	4:8:4:8	
6.	149	6:6:6:6	
7.	152	6:6:6:6	12:12
8.	34	12:12	
9.	160	6:6:6:6	12:12
15.	410	6:6:6:6	12:12

* Indicates responses from multiple representatives of the same company (different operations of the same larger company) were received that included different total numbers of crew employed. All responses are listed.

3.2.1.1.1 Operational Practices Identified from Survey and Interviews. As part of the survey several operational factors were considered, including primary work schedule, number of vessels a company has, whether they use standby to load and unload, and, if they do, for how long, and do they change the schedule at these times. A full summary of the survey responses can be found in Appendix C.

- *What is the primary watch schedule used by your company?*

There are a variety of schedules and operations in the tug/towboat/barge industry. Results from the survey of management (Figure 3) indicate that the predominant schedule is the 6:6:6:6 square watch (70% of respondents), but several other schedules are also quite common. The 12:12 schedule is the next most common with 20% of respondents using this schedule. Of particular note, all the companies surveyed with less than 30 or more than 900 employees primarily use the 6:6:6:6 square watch schedule.

In the follow-up interviews the research team was able to solicit more details and comments from companies that use the 12:12 schedule to determine typical rotations so that these schedules could be modeled using SAFTE/FAST (see Section 3.3.5.2). For the 6:6:6:6 schedule, start times were typically between 23:00 and 24:00, 05:00 and 06:00, 11:00 and 12:00, and 17:00 and 18:00 hours, with rotations on and off duty usually being between 14 and 30 days long, with crew remaining on the same watch throughout the 14 to 30 day schedule. In contrast, the 12:12 schedules ranged from 5 to 30 consecutive days and in some cases, crew members switch

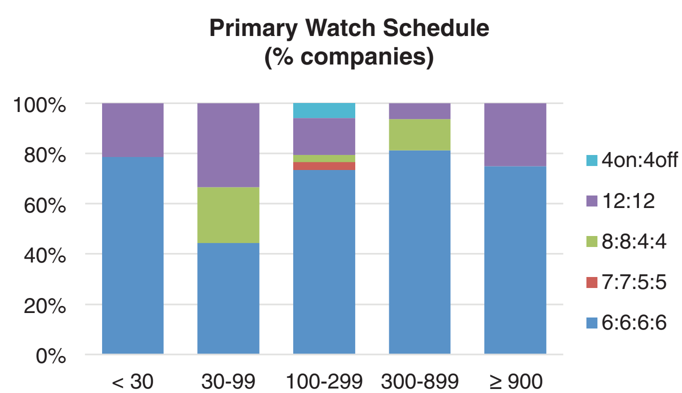

Figure 3. Responses for the question: "What is the primary watch schedule used by your company?"

from front watch to back watch after a few weeks. In this report, "front watch" is a term used to describe those crew working predominately during the day and with at least one rest interval during the nighttime hours. While "back watch" is a term used to describe those crew working predominately at night with at least one rest interval during the normal waking day. What became clear is that the 12:12 schedule is used in a greater variety of situations than the 6:6:6:6 schedule. This variability in schedule requires further considerations when developing a FRMS, since there are additional factors to consider. It also means that tools such as fatigue modeling could be particularly useful in determining which types of schedule variations are more problematic than others.

Since there is no one single schedule and that some operations crew live on the vessels, while others they return home each day (a practice which is not uncommon for the 12:12 shift schedule), best practices that might work for crew living on the vessels will be different than for those crew who are working on the vessel and returning home at night. The manner in which commute time is addressed in relation to fatigue/safety is likely to be very different for crew that commute just once a month as opposed to crew that commute every day. Companies do manage commute time in various ways, including providing transportation or accommodations close to the work place. So even though crew on a 12:12 schedule have a single consolidated period of potential rest, factors such as commuting and other competing daily activities, such as child care, home maintenance, and social activities, may be a factor for crew who sleep at home but are unlikely to impact those on the 6:6:6:6 watch.

By design, the current study only included crew working the 6:6:6:6 square watch. However, the investigators have been able to use information from the management surveys and interviews about current practices and challenges in regard to these other schedules. There is also much written on 12:12 shift schedules in other industries (Smith et al. 1998, Tucker et al. 1998, Reid and Dawson 2001, Baulk et al. 2009, Ferguson and Dawson 2012). Of note is that the 12:12 schedule requires a greater time on task; however, given that the type of work those on the 12:12 perform is often not the same as on the 6:6:6:6 square watch, concerns in regard to time on task may not always be relevant.

3.2.1.1.2 Work-Sleep Environment Practices. The majority of companies surveyed had made improvements to sleeping quarters (Figure 4), with only four smaller companies indicating that they had not made improvements. However, even for the companies that have made

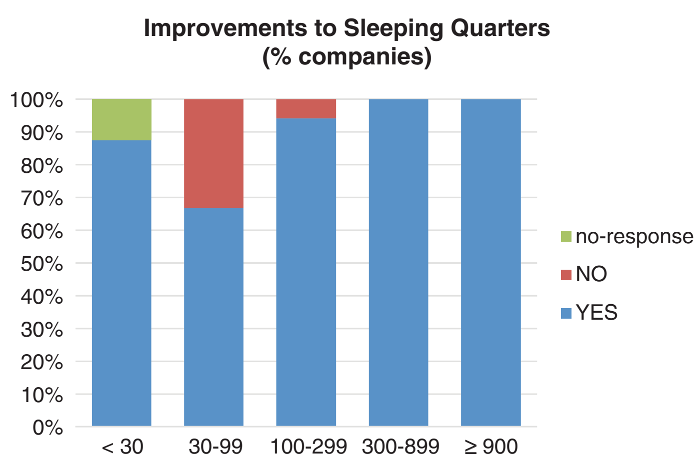

Figure 4. Responses for the question "Does your company provide improvements to sleeping quarters [e.g., light reduction, beds (size, mattress), sound proofing]?"

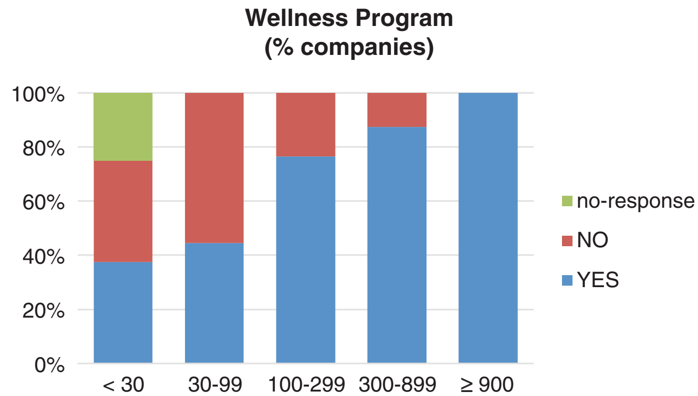

Figure 5. Responses for the question "Does your company offer a wellness program?"

sleeping environment a priority, there may still be room for improvement for some vessels as indicated in the crew survey (Section 3.4.3).

3.2.1.1.3 Health-Related Programs. Given the importance of health and well-being to good quality sleep, management was asked several questions about health-related programs. Many of the larger companies offered a wellness program (Figure 5).

However, there were fewer companies that offered screening or education for sleep disorders (see Figure 6).

A surprising response was the limited number of companies that had a program to ask crew about medical conditions or medications that might impact sleep (Figure 7). Based on follow-up, it seems that many companies relied on reporting at physical exams.

3.2.1.1.4 Practices Related to Education on Sleep and Health. Education is a key component of any FRMS and the ability for stakeholders to understand the importance of sleep and sleep-related health factors. Given the importance of education, several questions focused on this issue, including the use of existing education programs, sleep-related health, sleep disorders, medical conditions, and medications impacting sleep.

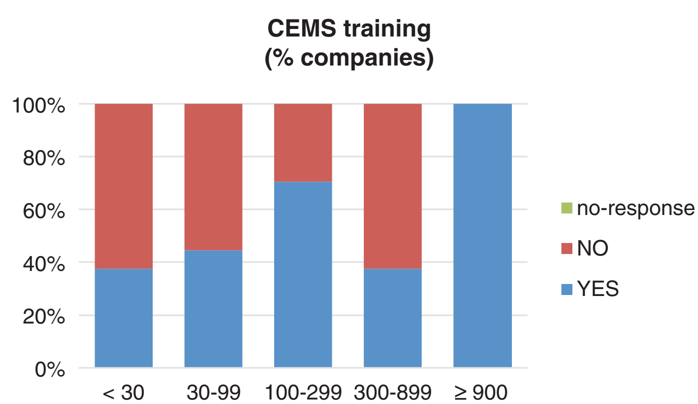

Figure 6. Responses for the question "Does your company provide CEMS training?" The overall positive response was 57% of companies.

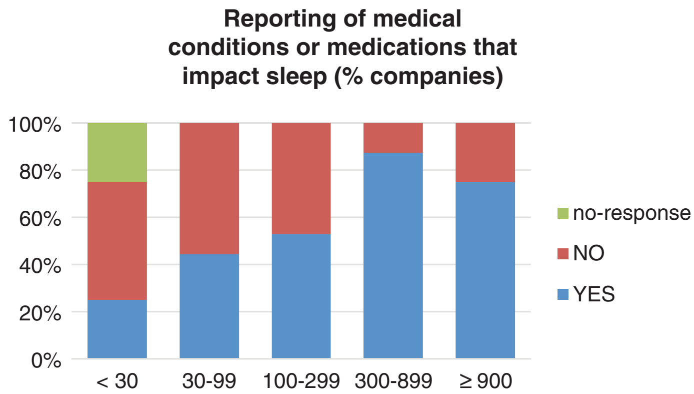

Figure 7. Responses for the question "Does your company have a program that asks crew about medical conditions and medications that impact sleep and fatigue?"

As part of the Phase III trial, the research team did a simple assessment of whether towboat crew members had received CEMS training and assessed their knowledge related to sleep/fatigue from this program. The section of the questionnaire that assessed whether they had received CEMS training included three questions; the section assessing CEMS knowledge included seven questions; and the section specific to sleep had five questions. This survey was completed by 73 crew members as part of the Phase III study and results are summarized in Table 5. As part of the Phase V research, the research team obtained more information about the use of CEMS educational material.

- *Does your company provide CEMS training?*

While education and training is considered a key element of any fatigue management system, it seems that a large proportion of companies (see Figure 7) do not provide the training outlined by the USCG CEMS.

Follow-up interviews revealed that even for companies that provide CEMS training there is a variety of ways that the training is implemented in regard to frequency (e.g., whether it be every 4 years or that the company rolled it out one time several years ago but did not maintain any follow-up) and how the training is given (classroom setting, onboard the vessel, etc.). Some companies also provide an alternate form of education in relation to sleep, circadian rhythms and fatigue as a part of other health-related activities such as wellness programs and health screenings.

A suggestion based on the findings is for the creation of new material or the updating of materials already provided to the industry (CEMS), so that education can be tailored and modules selected based on operational needs. For example, requiring 7 to 8 hours of uninterrupted rest is not possible on a 6:6:6:6 square watch, but would be on a 12:12 watch. Several companies

Table 5. Mean and standard deviation of responses on CEMS assessment questionnaire.

	CEMS Training (out of 3)	CEMS Knowledge (out of 7)	CEMS Sleep Knowledge (out of 5)
Mean (± stdev)	1.4 (0.9)	4.1 (1.6)	3.4 (0.9)
% correct	45% had one correct	15% had four correct	30% had four correct

Note: stdev = standard deviation.

indicated that if the overall message is lost, training might be less effective than it would be if it is tailored to the specific type of operations.

- *Does your company offer screening, training, or education on sleep disorders?*

Only a few companies (Figure 8) reported that they provide specific screening, training, or education on sleep disorders. However, most of the respondents indicated that they would be quite likely to do so. For those companies with sleep disorder screening programs in place, the research team was able to collect additional information from the follow-up interviews. The responses to these management interviews indicated that the way in which sleep disorders screening is done varies considerably. Some companies consider the licensing medical exams to be a screening, while others have more proactive screening programs in which all wheelhouse crew at risk (based on a BMI cut off) are screened with a clinical sleep study. To date, there does not appear to be any quantitative data available to suggest that such a screening program improves safety in this industry. If screening for sleep disorders was an industry best practice, then the research team would suggest that such data be collected. A detailed best practice related to sleep disorder screening programs and sleep disorders awareness is included in Section 3.5.8.

- *Does your company offer stress management training?*

Based on the finding from the Phase IV data that the ability to deal with conflict and stress is a significant predictor of short sleep duration (See Section 3.4.1), the research team suggests that resources be provided to crew in helping to deal with stress. Based on the management survey (Figure 9), 28% of the respondent companies provide training in stress management. From interviews it seems that the ways that this resource is provided varies from 24/7 hotlines with access to personal care to more simple training sessions or informational material.

- *Does your company offer training on diet and nutrition?*

Given the high rate of obesity in wheelhouse crew reported in the Phase IV trial, it is important that there be education on diet and nutrition. Only 52% of companies offered training on diet and nutrition (Figure 10), and the majority reported that they thought the training was somewhat effective. For those companies that did provide such training and resources, what they provided ranged from having weekly, monthly, or annual meetings; providing cooks with training; providing education as part of the wellness program; providing BMI charts and portion size guidelines; and even providing or encouraging crews to select healthier high-quality foods.

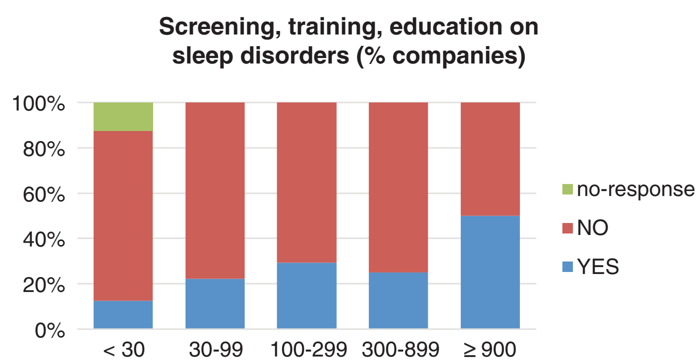

Figure 8. Responses for the question "Does your company offer screening, training, or education on sleep disorders?"

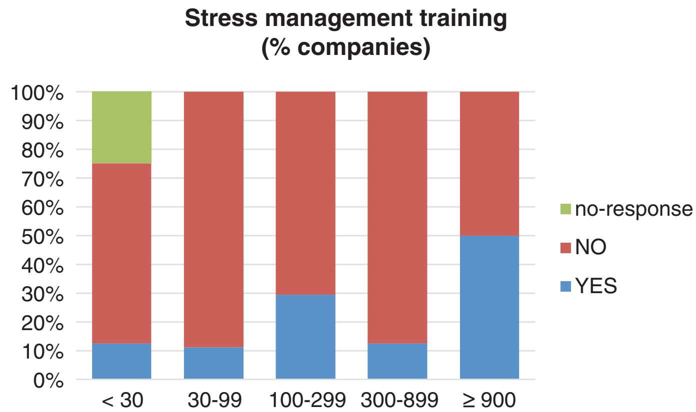

Figure 9. Responses for the question "Does your company offer stress management training?"

- *Does your company offer training or education on exercise or give access to exercise facilities?*

Exercise is an important factor in maintaining a healthy weight and has been shown to improve sleep quality, mood, and well-being (Reid et al. 2010, Baron et al. 2013). All of the larger companies reported that they offered education on exercise and access to equipment, but this was not as common for smaller companies. Overall 65% reported that they provided training and resources (Figure 11). In the open-ended responses, some companies reported even providing new technology, such as activity trackers, to crew to encourage healthy behaviors.

3.2.1.1.5 Practices Related to Reporting of Excessive Sleepiness and Health-related Factors. If crew members reported being sleepy while working, the research team was interested in learning whether they were encouraged to report it (Figure 12), and, if so, how and to whom. Sixty-one percent of companies reported encouraging crew to report sleepiness. During follow-up interviews, there were several approaches used for reporting.

3.2.1.1.6 Other. In addition to the interviews and survey of AWO company representatives (Sections 3.2.1.1.1–3.2.1.1.5), the research team spoke to others from healthcare companies, consulting firms, or specific companies and their representatives because of a program(s) they

Figure 10. Responses for the question "Does your company offer training on diet and nutrition?"

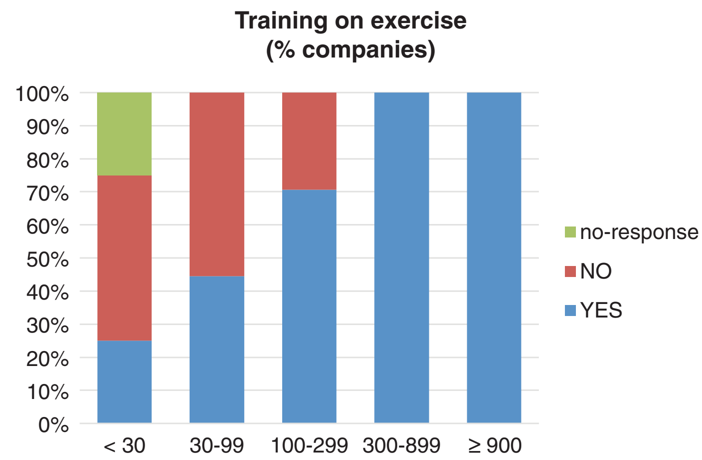

Figure 11. Responses for the question "Does your company offer training or education on exercise or give access to exercise facilities?"

have in place. A list of these meetings and interviews is provided in Table 6. The knowledge and information collected as part of these interviews is synthesized where appropriate into developing the best practice suggestions presented in Section 3.5.

3.2.1.2 Evaluate Current Operational Practices—Crew Survey

As part of the Phase V study (this research) the research team reassessed crew who had participated in the Phase IV study. There were 231 crew members invited to participate in the Phase V study. Forty crew members participated in the new Phase V assessment. In Phase V, 40 crew members completed the questionnaire portion and 14 crew members completed the 14-day sleep-work diary portion.

- *Crew Member Questionnaire*

The questionnaire portion of the study had two main sections: (1) changes in behavior and questions specific to the educational materials provided at the end of the previous Phase IV study

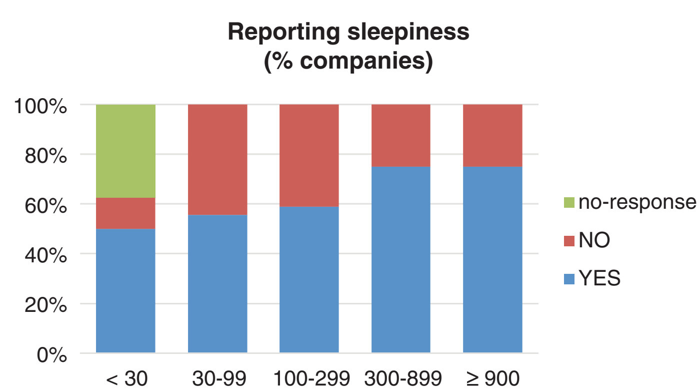

Figure 12. Responses for the question "Are crew members encouraged to report excessive sleepiness while they are working?"

Table 6. List of interviews with other tug/towboat/barge industry or related groups.

Group	Organization
Tug/towboat/barge	Moran Towing
Tug/towboat/barge	Ingram Barge
Tug/towboat/barge	Kirby Corp.
Occupational Nurse	Vanderbilt Dayani Center for Health & Wellness
Sleep Physician	Vanderbilt University
Consultant	Salyers Solutions, LLC

(see Appendix B for questions) and (2) standardized questionnaires (see Appendix B for a list of surveys).

Because the research team chose to increase recruitment by inviting all crew who consented to the Phase IV study to participate in Phase V, there were some crew members in the Phase V study who, although they consented, they did not actually complete Phase IV. The lack of overlap between Phases IV and V for all participants limits the ability to make the proposed comparisons between the two study phases, as well as limiting the statistical power to detect differences and to interpret the results. However, even with this limitation the research team was still able to accomplish the overall goal of the reassessment.

Table 7 provides a summary of some of the responses to questions related to current practices (for a summary of all responses see Appendix C). Interestingly, the majority of responding crew members had received CEMS training, indicating the training had made them more aware of the fatigue issues and, thus, had a greater willingness to participate in the Phase V study.

- *Sleep on the Vessel*

Details about sleep practices on the vessel can be found in Sections 3.3 and 3.4. Crew reported (92%) that there were practices in place to reduce disruption to sleep (Table 7); however, crew also listed noise as the most common reason for disrupted sleep and noise was also listed as one of the factors that they would like to see practices in place to reduce. This seeming disparity suggests that while there may be procedures in place to reduce noise, they appear to be ineffective or people are not consistent in using them.

Table 7. Phase V crew responses to questions related to current practices.

Question	N	No	Yes
Have you had CEMS training	40	17.5%	82.5%
Are there practices to reduce disruption of crew sleep	38	8%	92%
Are there procedures for reporting if not enough rest	40	80%	20%
Are there more practices you would like initiated	36	56%	44%
Are you interested in learning more about sleep CEMS	39	21%	79%

N = number of respondents for that question.

Table 8. List of interviews conducted in other industries/interest groups.

Mode/Group	Organization
Rail	Federal Rail Administration
Rail	Union Pacific
Aviation	United Airlines
Maritime	Southampton Solent University, HORIZON and MARTHA team members
Maritime	Australian Maritime Safety Authority (AMSA)
Trucking	Schneider National Inc.
Other, Academia	University of South Australia
Other, Academia	University of Central Queensland/Appleton Institute
Other, Academia	University of Sydney
Other, Consultant	Institute for Behavior Resources
Other, Consultant	Fatigue Science
Other, Consultant	Clockwork Research
Multi-modal/Aviation	FedEx
Other	Data Connect Corporation
Other, Academia	Universite de Bordeaux
Other, Navy	Office of Naval Research

3.2.2 Summary of the Assessment of Best Practices from Other Industries

Given that poor sleep efficiency and fatigue are common to many industries, the research team also sought to gather information from numerous sources outside of the tug/towboat/barge industry about their fatigue management and/or sleep issues. This section provides a list of existing literature, interviews with experts and industry leaders (Table 8), and a list of other documentation or regulations/rules (Table 9) conducted as part of this project.

3.3 Task 3. Anchor-Sleep/Nap-Sleep Strategies Amongst Personnel in the Tug/Towboat/Barge Industry

The overarching goal of Task 3 was to evaluate the use of anchor-sleep/nap-sleep strategies on sleep behavior amongst personnel in the tug/towboat/barge industry.

As part of this task, the research team was to identify whether crew use the split-sleep or anchor-sleep/nap-sleep strategy. Crew were deemed to have used the anchor-sleep/nap-sleep strategy if they slept at least 1 hour in each of the two daily sleep periods at least 90% of the time.

To determine this, objective sleep measures (wrist actigraphy) and self-reports (sleep diaries) were used in Phases II and III for at least 5 consecutive days. Sleep diaries were completed in both Phases IV and V for up to 14 days for each sleep opportunity, regardless of whether the crew member slept or not. The Phases II and III studies included all crew on the vessel, not just the wheelhouse crew (Phases IV and V included only wheelhouse crew). A summary of the findings of the

Table 9. List of regulatory and industry documents reviewed.

Mode/Group	Organization	Documents
Rail	Federal Rail Administration (FRA)	http://www.fra.dot.gov/Elib/Details/L01660 http://www.fra.dot.gov/eLib/details/L03200 See Bibliography
	Federal Aviation Administration (FAA)	http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-103A.pdf
	International Air Transport Association (IATA)	http://www.iata.org/publications/Pages/frms.aspx
	International Civil Aviation Organization (ICAO)	http://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/Doc%209966%20-%20FRMS%20Manual%20for%20Regulators.pdf http://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/FRMS%20Implementation%20Guide%20for%20Operators%20July%202011.pdf
Maritime	USCG	http://www.uscg.mil/hq/cg5/cg5211/docs/GuideForMaritimeOperations.pdf http://www.uscg.mil/hq/cg5/cg5211/docs/CEM_Addendum_Final.pdf http://www.uscg.mil/hq/cg5/cg5211/docs/CrewEnduranceManagement29Mar06.pdf
	AMSA	http://www.amsa.gov.au/forms-and-publications/Publications/AMSA494.pdf http://www.amsa.gov.au/seafarers_welfare/documents/11-fatigue.pdf https://www.amsa.gov.au/forms-and-publications/Publications/AMSA406.pdf
	International Maritime Organization (IMO)	http://www.imo.org/OurWork/HumanElement/VisionPrinciplesGoals/Documents/1014.pdf
Trucking	Federal Motor Carrier Safety Administration (FMCSA)	https://www.federalregister.gov/articles/2012/04/20/2012-9555/proposed-recommendations-on-obstructive-sleep-apnea http://www.fmcsa.dot.gov/research-and-analysis/research/north-american-fatigue-management-program
Medicine	Accreditation Council for Graduate Medical Education (ACGME)	http://www.acgme.org/acgmeweb/tabid/271/GraduateMedicalEducation/DutyHours.aspx
	American College of Surgeons (ACS)	http://bulletin.facs.org/2014/08/statement-on-peak-performance-and-management-of-fatigue/

use of anchor sleep/nap sleep from over 200 crew members is provided in Table 10. This analysis indicated that the majority of crew (over 95%) use an anchor-sleep/nap-sleep strategy at least 90% of the time. Further details of this analysis are provided in the following sections. Of note is the consistency in the average self-reported sleep durations across the Phases II through V studies, but when compared to actigraphy-derived sleep durations, sleep diaries may represent an over estimation of sleep duration. This mismatch between self-reported and actigraphy measures of sleep duration has been reported before in other studies (Lauderdale et al. 2008), highlighting the importance of adjusting interpretation of findings based on the techniques used to collect the data.

Table 10. Summary of the percentage of crew members on a 6:6:6:6 square watch using anchor-sleep/nap-sleep strategies and range of sleep durations from sleep diary data from all phases.

Phase	N	Crew Members Using Anchor Sleep/Nap Sleep	Daily Sleep Duration Range (hours)	Sleep Duration/Rest Interval Range (hours)
II and III	70	98%	4.1-8.9*	1.2-5.0*
			5.4-10	1.5-5.7
IV	134	94.7%	5.7-8.7	1.1-5.0
V	14	100%	5.9-8.8	1.1-6.0

Note: N = number of crew in analysis.

*Actigraphy recorded sleep duration.

3.3.1 Phases II-III Data on the Use of an Anchor-Sleep/Nap-Sleep Strategy

Using both sleep diary and wrist actigraphy monitoring from the Phases II and III trials, it was determined that all but one of the 70 crew members studied met criteria for using an anchor-sleep/nap-sleep strategy; that is they attempted to sleep in both of the rest opportunities each day on 90% of the monitored days. However, while almost all crew attempted to sleep in each rest opportunity, the wrist actigraphy data indicated that only 75% of the crew members actually managed to sleep in both sleep periods on 90% of days. For those who were unable to sleep in all the sleep opportunities, there was no difference between those on the front watch (27%) and those on the back watch (24%).

It is important to note here that only 5 days of data were included, so missing even just one sleep opportunity resulted in a crew member being deemed to not have met criteria for using the anchor-sleep/nap-sleep strategy. It also highlights the importance of having some type of objective measure of sleep.

3.3.1.1 Frequency of Members Not Sleeping During a Rest Interval

Since the research team objectively measured rest-activity rhythms in Phase II and Phase III, the team was able to accurately determine when a crew member did not sleep during a rest interval. To do this, the team examined the proportion of sleep opportunities that were missed as a function of all of the possible sleep opportunities. According to sleep attempts, regardless of whether the sleep period was in the morning or the evening, the front watch crew members missed less than 1% of the possible sleep opportunities (0.5%), and the back watch crew members missed 1.5% of the possible sleep opportunities.

When considering actual objectively measured sleep duration greater than 0 minutes, regardless of whether the sleep period was in the morning or the evening, the front watch crew members missed 0.8% of sleep opportunities, and the back watch crew members missed 2.7% of the sleep opportunities.

3.3.1.2 Mean Time in Bed and Objective Sleep Duration

Mean 24-hour objectively measured sleep durations from 70 crew members working the 6:6:6:6 square watch ranged from 4.1 to 8.9 hours, with each objective sleep duration for either of the sleep opportunities ranging from a mean of 1.2 to 5.0 hours in duration. The sleep diary mean 24-hour time in bed ranged from 5.4 to 10 hours a day, while time in bed for either sleep opportunity ranged from 1.5 to 5.7 hours. There were no significant differences in the sleep duration between the crew on the front watch and the back watch (Figure 13).

3.3.1.3 Phases II and III: Preference for Morning or Evening Sleep Periods

In order to determine whether crew had a preference for sleeping more in one rest period over another, the research team also divided crew into three groups: morning preference, neither preference, and evening preference. The groups were defined in the following way: morning preference were those who slept at least an hour more each day in the morning sleep period compared to the evening sleep period for >80% of recorded days; evening preference were those who slept at least an hour more in the evening sleep period compared to the morning sleep period for >80% of recorded days; neither were those who exhibited no preference either way. Average 24-hour sleep duration for the three preference groups is presented in Figure 14 for both the front watch and back watch crew. Results indicate that front watch crew did not typically sleep more in the evening sleep episode (approximately 18:00 to 24:00), and that back watch crew were represented in all three categories. The lack of preference for the evening rest interval in the front watch crew is likely due to sleep during this window being the most difficult from a circadian standpoint, as this period falls within the "forbidden zone" (Lavie 1986). The "forbidden zone" is a term used to describe the phenomenon that sleep is typically difficult to initiate between the hours of 20:00 and 22:00, due to the circadian alerting signal.

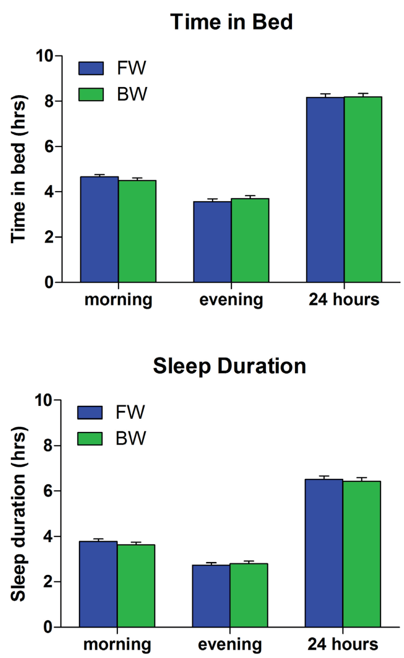

Figure 13. Mean ± standard deviation of Phase II and Phase III objective time in bed and sleep duration for the first 5 days on the vessel for all front watch (FW, N = 37) and back watch (BW, N = 33) crew for each sleep period and for each 24-hour period.

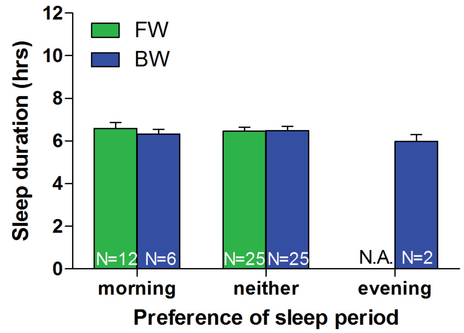

Figure 14. Mean ± standard error (SEM) of sleep duration from Phases II and III based on preference for sleeping more in either the morning or evening sleep period. *Number of subjects that fall into each group is indicated at the bottom of each bar.*

3.3.2 Phase IV Data on the Use of an Anchor-Sleep/Nap-Sleep Strategy

Phase IV used twice-daily sleep diaries to record various aspects of the sleep period, including time in bed and sleep duration. Data from the Phase IV trial indicated that 94.7% of the crew (127 out of 134 crew for whom sufficient data were available) used the anchor-sleep/nap-sleep strategy. Mean 24-hour sleep durations ranged from 5.7 to 8.7 hours, with each sleep duration for either of the sleep opportunities ranging from a mean of 1.1 to 5 hours in duration. In this assessment there were significant differences in the front watch and back watch crew in the time spent in bed for both the morning and evening sleep periods (Figure 15).

3.3.2.1 Phase IV: Preference for Morning or Evening Sleep Periods

As was done in Phases II and III, in order to determine whether crew members had a preference for sleeping more in one rest period over another, the research team divided crew into three groups: morning preference, neither preference, and evening preference. The groups were

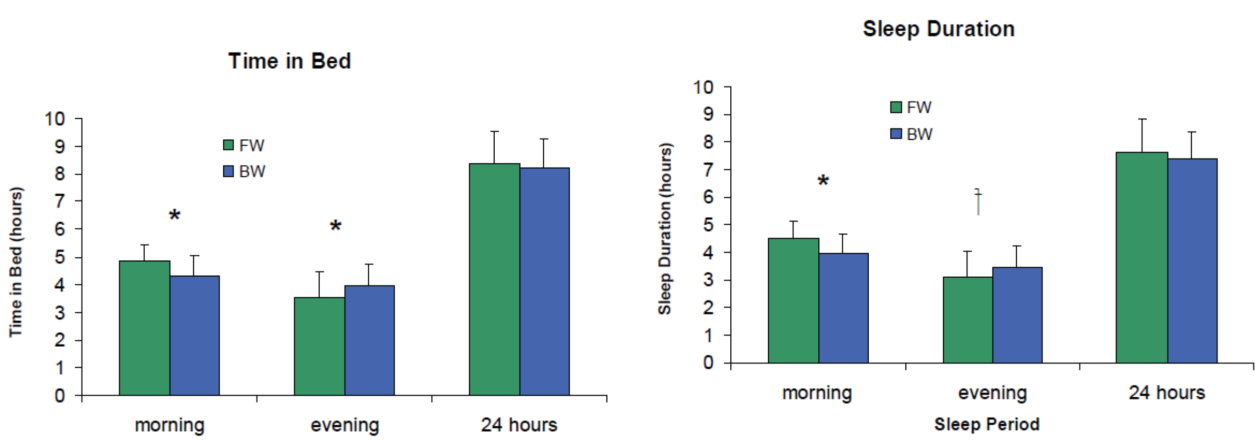

Figure 15. Mean ± standard deviation of time in bed and sleep duration for the first 7 days on the vessel from Phase IV for all FW (N = 84) and BW (N = 48) crew for each sleep period and for each 24-hour period. **p < 0.05 and †p = 0.06.*

defined in the following way: morning preference were those who slept at least an hour more each day in the morning sleep period compared to the evening sleep period for >80% of recorded days; evening preference were those who slept at least an hour more in the evening sleep period compared to the morning sleep period for >80% of recorded days; neither were those who exhibited no preference either way. Average 24-hour sleep duration for the three preference groups is presented in Figure 16 for both the front watch and back watch crew. There was a difference in the preference for sleeping either in the morning or the evening sleep period between the front watch and back watch. Results indicate that front watch crew did not typically sleep more in the evening sleep episode (18:00 to 24:00), and that back watch crew fell into all of the categories. As in Phases II and III, this finding in the front watch crew is due to sleep during this evening window being the most difficult from a circadian standpoint, as this period falls within the "forbidden zone" (Lavie 1986). Crew who had neither preference for morning or evening sleep periods had on average a small—but not statistically significant—benefit in sleep duration, which the research team interpreted to mean sleep as much as you can in whichever sleep period.

In the Phase IV study, the research team was also able to further explore whether there was a benefit to having a sleep strategy preference on the change in Karolinska Sleepiness Scale (KSS) score from the start to the end of the rest interval. Analysis indicated that there were no significant benefits to sleeping more in the morning or the evening for either watch (Figure 17).

3.3.2.2 Frequency of Disrupted Sleep

In order to determine whether there was more sleep disruption in the morning or the evening sleep period while on the front watch or the back watch, the research team also examined the frequency of disrupted sleep. To do this the team first aggregated day-to-day occurrences of disrupted sleep episodes into frequencies (i.e., percentage of sleep episodes disrupted) for each subject per sleep period (i.e., morning or evening). Crew reported sleep disruption on average for about 12% to 23% of their sleep periods depending on the watch and time of the sleep period. While there was no significant differences between front watch and back watch crew, the back watch crew reported disrupted sleep a little more often (Figure 18).

3.3.2.3 Reason for Disrupted Sleep

When all of the sleep periods are considered together, the primary cause of sleep disruption reported by crew members was noise during sleep (Figure 19).

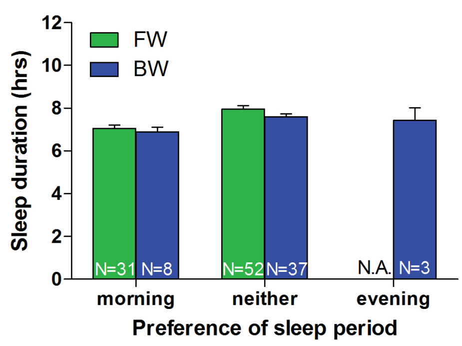

Figure 16. Mean ± SEM of sleep duration from Phase IV based on preference for sleeping more in either the morning or evening sleep period. *The number of subjects that fall into each group is indicated at the bottom of each bar.*

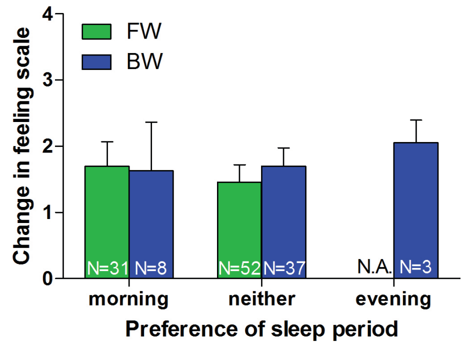

Figure 17. Mean ± SEM of change in KSS score from Phase IV based on preference for sleeping more in either the morning or evening sleep period. *The number of subjects that fall into each group is indicated at the bottom of each bar.*

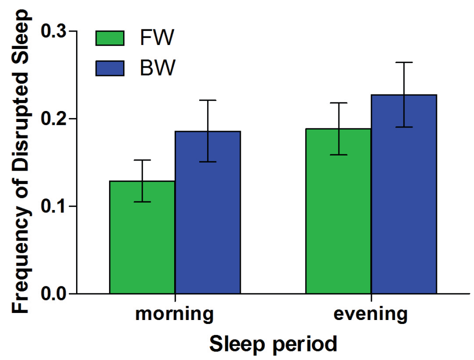

Figure 18. Mean ± SEM of the frequency of disrupted sleep episodes for crew on the FW and the BW for both morning and evening sleep periods.

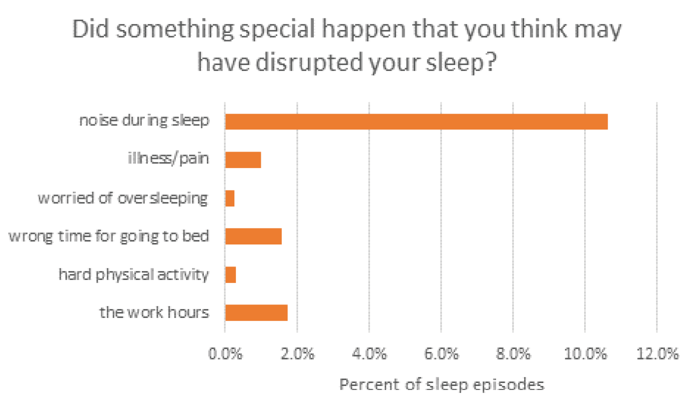

Figure 19. Reason for disrupted sleep as a proportion of all recorded sleep episodes from Phase IV captains and pilots.

3.3.3 Phase V Data on the Use of an Anchor-Sleep/Nap-Sleep Strategy

Data from the new Phase V assessment indicate that 100% of the crew (14 crew members) used the split-sleep strategy. Figure 20 shows the mean sleep durations for the group, categorized by morning and evening sleep period and for each 24-hour day. Mean 24-hour sleep durations ranged from 5.9 to 8.8 hours. With the mean sleep duration for either of the sleep opportunities (morning or evening) ranging from a mean of 1.1 to 6 hours in duration.

During the morning sleep periods (~24:00 to 12:00), front watch crew slept longer on average than the back watch crew (Figure 20). This is most likely due to the front watch crew sleeping at night, a time more conducive for sleep in relation to internal circadian timing. However, this did not result in more sleep over the 24-hour day.

Due to the small number of crew members who completed the Phase V onboard study, no further analysis was conducted for Phase V crew in relation to preference for morning or evening sleep periods.

3.3.4 Mathematical Modeling to Predict Performance Based on Actual Sleep-Wake and Work Schedule

As part of the evaluation of nap-sleep/anchor-sleep strategies within the tug/towboat/barge industry, the research team used a currently available mathematical model (SAFTE/FAST) to predict performance "effectiveness" level based on the work and sleep-wake history of actual crew members working in the industry. These types of mathematical models are a cost-effective and scientifically valid way of predicting performance using a combination of sleep-wake and

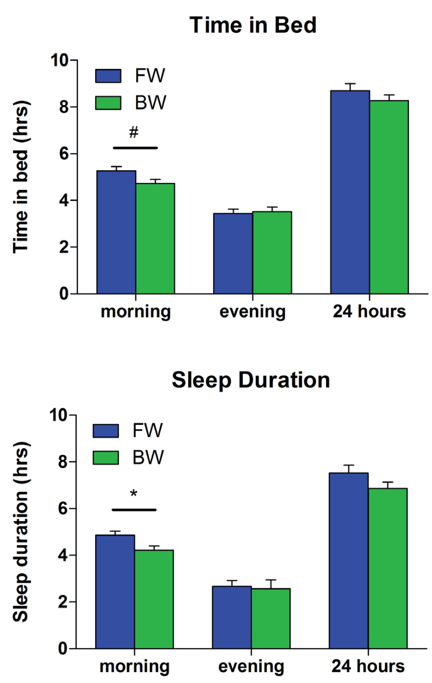

Figure 20. Mean ± SEM of self-reported time in bed and sleep duration from sleep diary for Phase V FW (N = 9) and BW (N = 5) crew for each sleep period and for each 24-hour period.
$*p < 0.05$ and $\#p = 0.067$.

work history. For a review and comparison of several of these mathematical models to predict fatigue see Mallis et al. (2004) and Van Dongen (2004). These manuscripts highlight the differences (work schedules, sleep time, or a combination of both) in the inputs used in the various models and compare them using different scenarios. While there are many different models available, the SAFTE/FAST model (Hursh et al. 2004) was recently mentioned by the USCG in the *Federal Register* (USCG 2011). This particular model is also being used extensively in the U.S. by other federal bodies, including rail (FRA) and aviation (FAA).

For the purposes of this report, the SAFTE/FAST model was used to illustrate comparative predicted "effectiveness" levels across shift types in several ways. For the 6:6:6:6 square watch, the research team modeled effectiveness levels using a work schedule with a 24:00 start time, with actual average sleep duration categorized as short, moderate, or long (see Section 2.4.1), and work schedules with shift start times of 23:00 or 02:00 with moderate sleep durations. The research team also modeled a schedule where at least one sleep period was skipped. A few examples of the output of the SAFTE/FAST modeled schedules are provided in this section to highlight key points (Table 11).

The model was also used to predict sleep duration and performance for 12:12 schedules. While the original focus of the project was on the 6:6:6:6 schedule, it was determined from the management surveys that the 12:12 schedule was commonly used (20% of respondents) as the primary watch schedule in the tug/towboat/barge industry. From the follow-up interviews conducted with companies reporting the use of the 12:12 schedule, it was determined that there were numerous ways in which the schedule was operationalized. While it was beyond the scope of this research project to collect actual sleep and performance data from crew working these 12:12 schedules, the SAFTE/FAST model does provide a "flavor" of the types of fatigue levels that would be found on various iterations of the 12:12 schedule. The research team has taken several approaches to modeling these 12:12 schedules: (1) using the auto-sleep function in the model to predict sleep and performance and (2) using predetermined sleep durations for the rest interval. For all schedules, the sleep start and end times are estimated and actual times may be different depending on operational and individual considerations, which ultimately will influence modeled outputs to various degrees.

For illustrative purposes the research team also modeled a version of the 8:4:4:8, 7:5:5:7 and 4:4:4:4 schedules; these schedules were reported to be in use by the surveyed companies.

While the research team used the SAFTE/FAST model to predict performance using actual sleep data from crew working in the tug/towboat/barge industry while working the 6:6:6:6 schedule (Phases IV and V), there are some caveats in the interpretation of the results generated by the model. The model allows for the entry of several parameters related to work schedule, time zone, and sleep duration and quality. If actual sleep data are not available, there is a feature called "auto-sleep," which can be used to predict sleep duration and quality. However, *the auto-sleep function does not account for the potential for two sleep periods per day*, so it only auto fills one sleep period per 24-hour day in the default mode. Given that the maritime industry commonly uses schedules with two rest intervals per day and that over 90% of crew use a split-sleep strategy, this is a limitation of this model for use in the maritime sector. This limitation can be "turned off" by setting the "forbidden zone" for sleep to start and end at 12:00 (in practical terms switching it to zero). The other caveat is that there appears to be an *under appreciation of the restorative value of sleep that falls in the evening rest intervals* (12:00 to 24:00 rest intervals in the 6:6:6:6 square watch); this is due to a well-documented difficulty sleeping between the hours of 13:00 to 19:00 hours due to the circadian rhythm of alertness. However, given that the research team has documented sleep (from wrist actigraphy) during this interval, it is surprising that predicted "fatigue" continues to decline during these sleep periods. The research team communicated with the developers of the model to discuss this issue. It was indicated that the

Table 11. Summary of work-sleep schedules modeled using SAFTE/FAST, including: watch, sleep duration, work start time(s), sleep quality, number of days in rotation, and mean effectiveness level (%) during work intervals.

Schedule #	and hours	Watch	Sleep Duration	Work Start Time	Sleep Quality Self-report	# Days	Mean % Effectiveness (work)
1	6:6:6:6	FW	Long (5.06 + 4.36 hrs)	6:00 and 18:00	Excellent	28	97.8
2	6:6:6:6	FW	Moderate (4.57 + 2.96 hrs)	6:00 and 18:00	Excellent/ Good	28	91.8
3	6:6:6:6	FW	Short (3.90 + 2.10 hrs)	6:00 and 18:00	Good	28	76.7
4	6:6:6:6	BW	Long (4.49 + 4.41 hrs)	24:00 and 12:00	Excellent/ Good	28	79.9
5	6:6:6:6	BW	Moderate (4.04 + 3.50 hrs)	24:00 and 12:00	Good	28	71.7
6	6:6:6:6	BW	Short (3.40 + 2.94 hrs)	24:00 and 12:00	Good	28	65.1
7	6:6:6:6	FW	Averaged, 1 skipped sleep	6:00 and 18:00	Good	14	82.9
8	6:6:6:6	BW	Averaged, 1 skipped sleep	24:00 and 12:00	Good	14	67.5
9	6:6:6:6	FW	Moderate	05:00 and 17:00	Good	28	87.2
10	6:6:6:6	BW	Moderate	23:00 and 11:00	Good	28	73.1
11	6:6:6:6	FW	Moderate	08:00 and 20:00	Good	28	84.7
12	6:6:6:6	BW	Moderate	02:00 and 14:00	Good	28	74.9
13	12:12	FW	7 hrs	06:00	Good	28	77.6
14	12:12	BW	5 hrs	18:00	Good	28	60.7
15	12:12	FW-BW	7-5 hrs	06:00 and 18:00	Good	FW, 21 (5 on/2 off) BW, 21 (5 on/2 off)	88.0 (FW) 69.8 (BW)
16	12:12	BW-FW	5-7 hrs	18:00 and 06:00	Good	BW, 21 (5 on/2 off) FW, 21 (5 on/2 off)	68.5 (BW) 86.4 (FW)
17	8:4:4:8	FW	4-2 hrs	12:00	Good	28	69.4
18	8:4:4:8	BW	4-2 hrs	20:00	Good	28	69.2
19	7:5:5:7	BW	4.1-2.5 hrs	12:00	Good	28	70.2
20	7:5:5:7	FW	3.6-3.7 hrs	19:00	Good	28	83.9
21	4:4:4:4 / 6:6:6:6	FW	Auto/ Moderate	06:00, 14:00, 22:00/06:00, 18:00	Good/ Excellent, Good	7/7	80.8 78.5/84.3*
22	4:4:4:4 / 6:6:6:6	BW	Auto/ Moderate	10:00, 18:00, 22:00/24:00, 12:00	Good/Good	7/7	74.7 78.8/69.2*

Hrs = hours, BW = back watch, FW = front watch.
*For schedules 21 and 22, the first effectiveness level listed is for the entire rotation modeled (inclusive of both watches), the second level is for the 4:4:4:4: schedule and the third level is for the 6:6:6:6 schedule.

model has been used in the maritime sector successfully and referred the research team to key publications with the equations used to calculate the fatigue levels (Hursh et al. 2004).

3.3.4.1 6:6:6:6 Hour Schedules

The most commonly used "primary" watch schedule in the tug/towboat/barge industry is the 6:6:6:6 square watch (70% of respondents). This schedule is used in several ways with typical start times ranging from 23:00 to 24:00, 05:00 to 06:00, 11:00 to 12:00, 17:00 to 18:00, and rotations from 14 to 30 days.

A mathematical model (SAFTE/FAST) can be used to predict the effectiveness or performance of a single crew member. Simply examining sleep-wake history provides limited information, as it doesn't show how this history translates into performance as modulated by circadian rhythmicity and homeostatic sleep drive. As mentioned previously one approach is to measure actual performance, using, for example, a PVT. A PVT takes at least 5 minutes to complete and needs to be completed at regular and frequent intervals, and the tester must be focused on the test; thus, the PVT is too obtrusive and not flexible under these research conditions. An alternative is to take the sleep-wake history and use it as input to a mathematical model using homeostatic sleep drive and circadian rhythmicity to predict minute-to-minute performance. In the Phases II through IV studies, sleep-wake histories were collected for on-duty days using a sleep/work diary.

The sleep data that was used in the model was collected from actual crew working the 6:6:6:6 square watch. The distribution of sleep times from across the Phase IV study was divided into three groups based on average sleep durations during the 2-week assessment period. Cut points for the groups were based on the average reported sleep durations for each individual and includes crew on the front watch (work 06:00 to 12:00 and 18:00 to 24:00) and the back watch (work 24:00 to 06:00 and 12:00 to 18:00). A short sleeper has a sleep duration in the shortest 20% of sleep durations and a long sleeper has a sleep duration in the longest 20% of sleep durations; moderate is the remaining 60% of individuals. Average sleep durations were: short (less than 6.6 hours in bed/day), moderate (6.6 to 8.6 hours in bed/day), and long (8.6+ hours in bed/day). Sleep quality for input into the model was based on the self-reported sleep quality for the same sleep periods.

For illustrative purposes an example of the scheduling grid entered into the SAFTE/FAST software is provided in Figure 21. This figure represents the first modeled schedule for a long sleeper on the front watch with a 06:00 and 18:00 shift start time and excellent self-reported sleep quality.

The SAFTE/FAST output (Figures 22 through 27) is designed to provide an easy-to-understand graphical image of SAFTE/FAST predictions. In the examples provided here effectiveness level is provided on the left axis and a blood alcohol equivalent performance levels is provided on the right axis. There is also a criterion line (dashed line) for which the default is 77.5%—equivalent to the effectiveness of a person during the day who has lost one night of sleep.

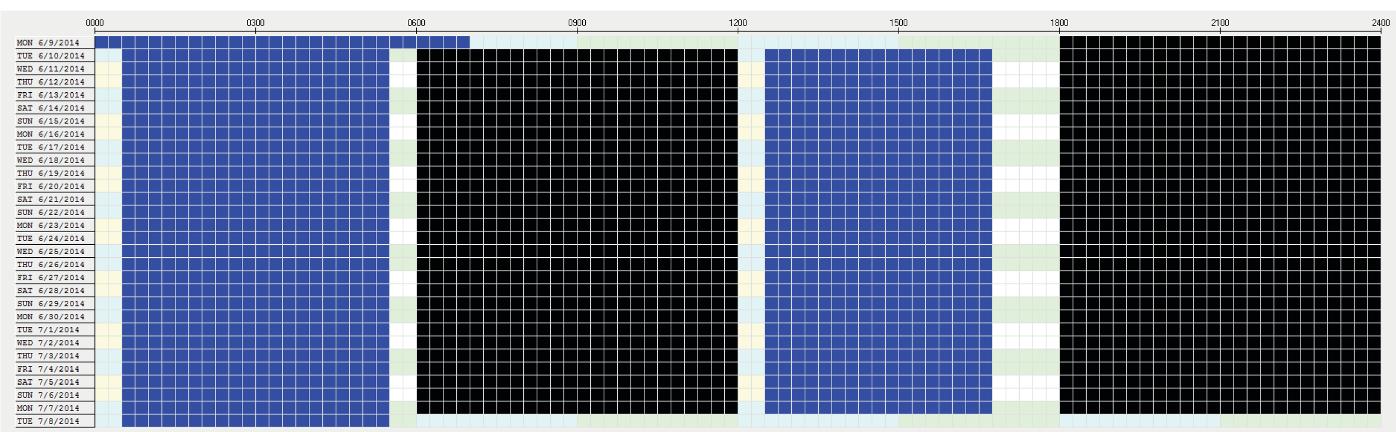

Figure 21. SAFTE/FAST model scheduling grid for an "average" crew member on a 6:6:6:6 schedule for the front watch with long sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods (06:00 to 12:00 and 18:00 to 24:00 daily for 28 days) are indicated by black squares; sleep is indicated by blue squares; and leisure time is indicated by white and green squares. The sleep duration for the day was 564 minutes (9.4 hours), divided between two rest intervals, one being 303 minutes (5.05 hours) (rest interval 24:00 to 06:00, excellent quality) and the other 261 minutes (4.35 hours) (rest interval 18:00 to 24:00, excellent quality).*

The SAFTE/FAST output is also divided into zones based on color. The green zone on the output (default setting is 100% to 90%) is the range of performance during a normal daytime duty period following an 8-hour period of excellent sleep at night. The yellow zone (default setting is 90% to 65%) is the range of performance during the 24-hour period after missing one night of sleep. According to the program output, it is difficult to avoid dropping into this zone during the early morning hours (24:00 to 04:00). The output also shows that countermeasures such as naps may be used to keep performance in the top half of the yellow zone/above the criterion line. The red zone (defaults setting is below 65%) indicates performance that is below the level that is acceptable for operations. The red zone represents performance following sleep deprivation of 2 full days and a night. Reaction time in the red zone is more than double normal.

3.3.4.1.1 6:6:6:6 Front Watch: Long Sleeper [daily sleep duration 564 minutes (9.4 hours)]. The predicted effectiveness (left axis) and blood alcohol equivalent (right axis) for the long sleeping [564 minutes (9.4 hours)/**day** of sleep] crew member on the front watch is provided in Figure 22. The **SAFTE/FAST** output utilizes three color coded "zones" of effectiveness level. The green zone is the most effective and indicates a range that is considered "safe." The yellow zone indicates when effectiveness levels are within a range that is less than optimal and countermeasures should be used. The red zone indicates a range in which the developers suggest operations are unacceptable. The criteria of these zones can be modified within the software; the default settings are used in this report. The level of effectiveness is always in the green for this 6:6:6:6 front watch schedule. The average effectiveness levels across the work shift for this schedule is 97.8% and is provided in Table 11.

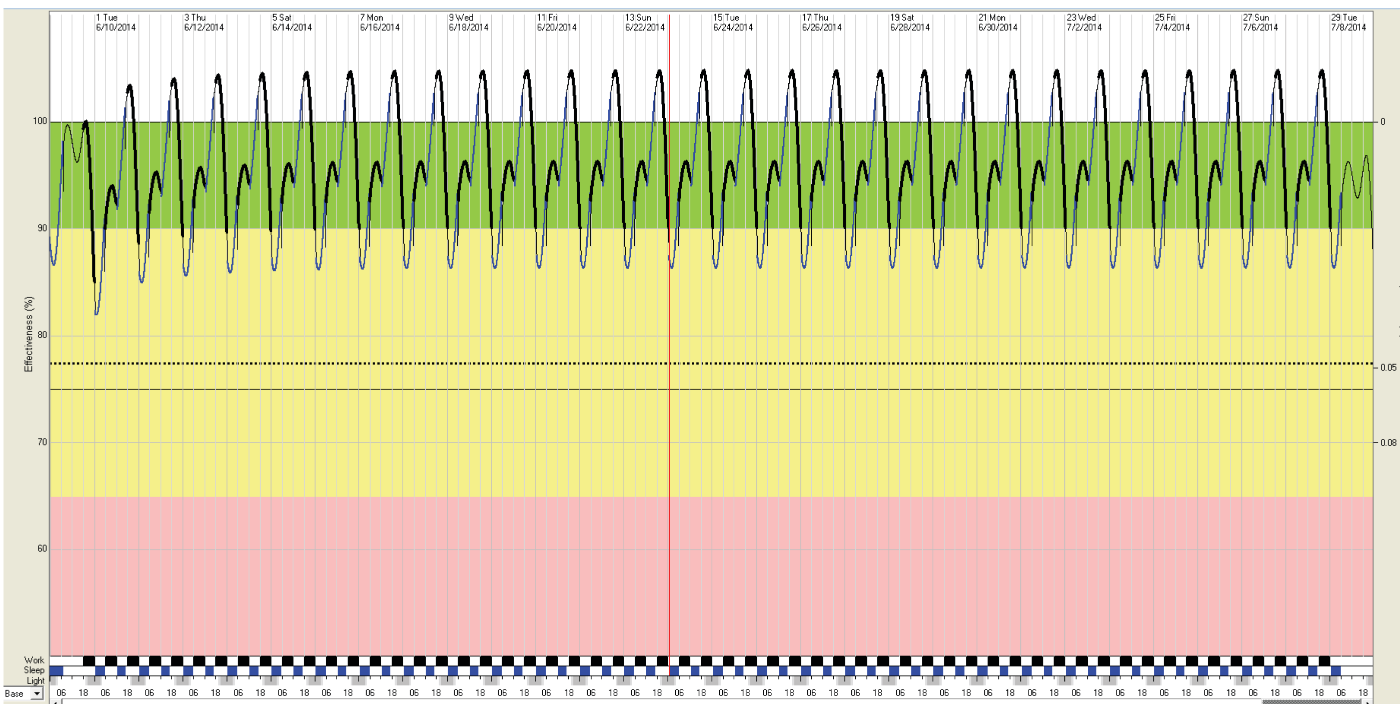

Figure 22. SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the front watch with long sleep. *Work periods (06:00 to 12:00 and 18:00 to 24:00 daily for 28 days) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 564 minutes (9.4 hours) divided between two rest intervals, one being 303 minutes (5.05 hours) (rest interval 24:00 to 06:00, excellent quality) and the other 261 minutes (4.35 hours) (rest interval 12:00 to 18:00, excellent quality).*

3.3.4.1.2 6:6:6:6 Front Watch: Short Sleeper [daily sleep duration of 360 minutes (6 hours)]. In contrast to the long sleeper, the effectiveness level for a short-sleeping [360 minutes (6 hours)/ **day** of sleep] crew member on the front watch is provided in Figure 23. The average effectiveness levels across the work shift for this schedule is 76.7% and is provided in Table 11. For most of the 28-**day** rotation effectiveness levels are below recommended limits.

3.3.4.1.3 6:6:6:6 Back Watch: Long Sleeper [daily sleep duration 535 minutes (8.9 hours)]. The predicted effectiveness (left axis) and blood alcohol equivalent (right axis) for the long-sleeping [535 minutes (8.9 hours)/day of sleep] back watch crew member is provided in Figure 24. The average effectiveness levels across all the work shifts for this schedule is 79.9% and is provided in Table 11. The level of effectiveness is sometimes in the green for work scheduled between 12:00 to 18:00. But for work performed between 24:00 to 06:00, the effectiveness level is often below recommended levels.

3.3.4.1.4 6:6:6:6 Back Watch: Short Sleeper [daily sleep duration 380 minutes (6.3 hours)]. The predicted effectiveness (left axis) and blood alcohol equivalent (right axis) for the short-sleeping [380 minutes (6.3 hours)/day of sleep] back watch crew member is provided in Figure 25. The average effectiveness levels across all the work shifts for this schedule is 65.1% and is provided in Table 11. The level of effectiveness is never in the green for work scheduled between 12:00 to 18:00. While the effectiveness level for work between 24:00 to 06:00 is always below recommended levels.

3.3.4.1.5 6:6:6:6 Front and Back Watches: Skipped Sleep Period. Figures 26 and 27 illustrate how dramatically estimated effectiveness level can drop with a single skipped sleep period.

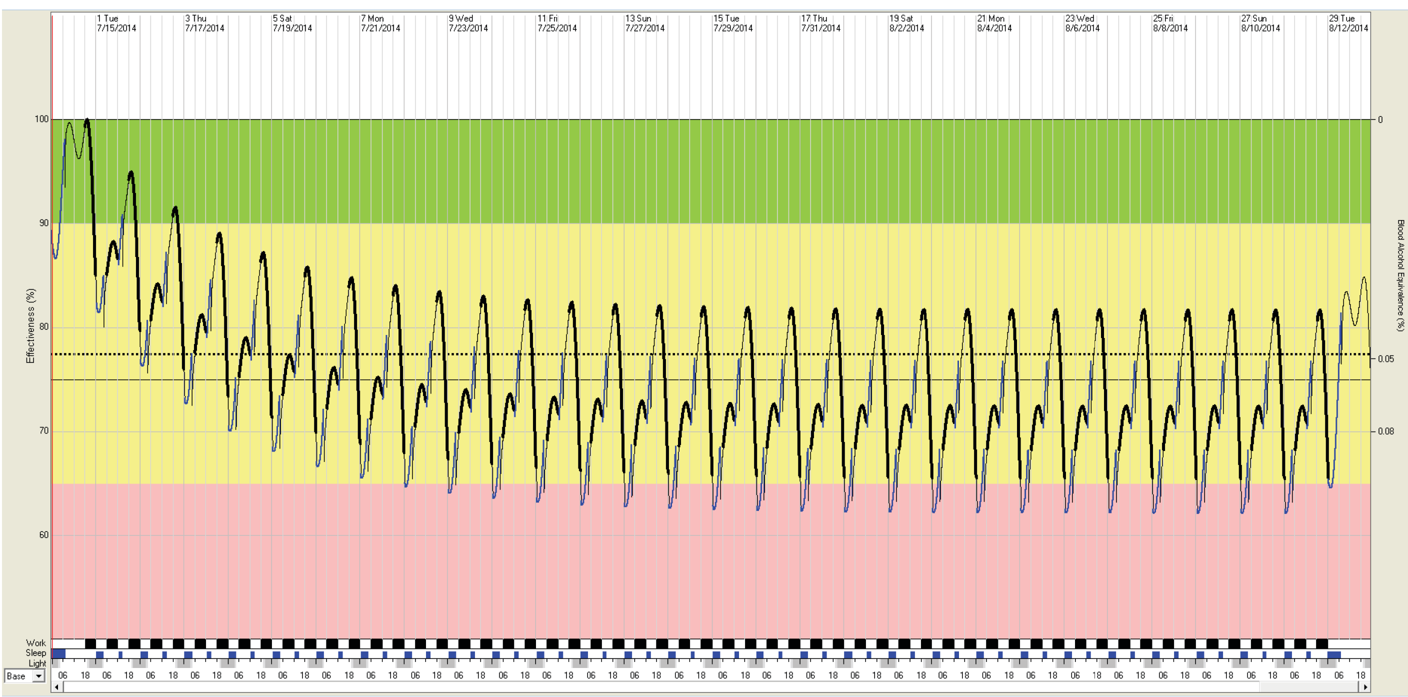

Figure 23. ***SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the front watch with short sleep.*** *Work periods (06:00 to 12:00 and 18:00 to 24:00 daily for 28 days) are indicated by black bars/ thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 360 minutes (6 hours) divided between two rest intervals, one being 234 minutes (3.9 hours) (rest interval 24:00 to 06:00, good quality) and the other 126 minutes (2.1 hours) (rest interval 12:00 to 18:00, good quality).*

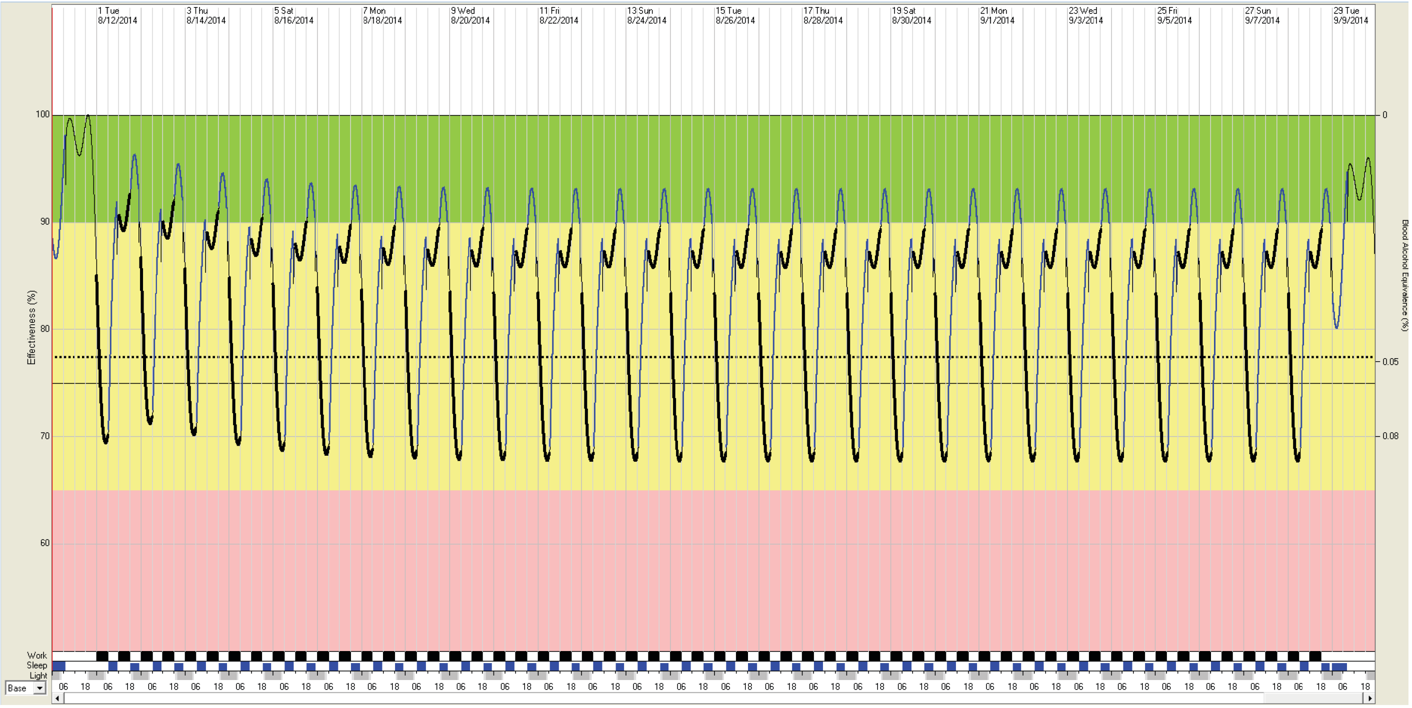

Figure 24. SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the back watch with long sleep. *Work periods (24:00 to 06:00 and 12:00 to 18:00 daily for 28 days) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 534 minutes (8.9 hours), divided between two rest intervals, one being 269.4 minutes (4.49 hours) (rest interval 06:00 to 12:00, good quality) and the other 264.6 (4.41 hours) minutes (rest interval 18:00 to 24:00, good quality).*

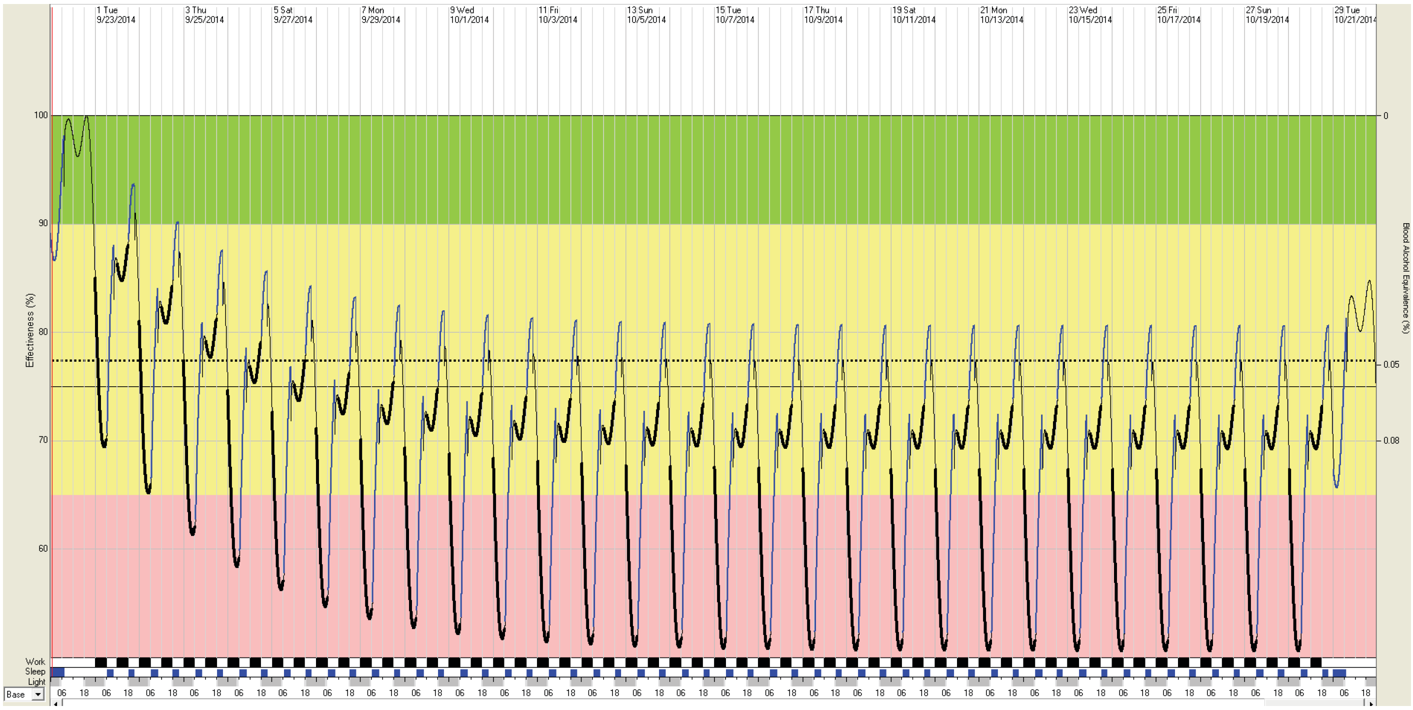

Figure 25. SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the back watch with short sleep. *Work periods (24:00 to 06:00 and 12:00 to 18:00 daily for 28 days) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 380 minutes (6.3 hours) divided between two rest intervals, one being 204 minutes (3.4 hours) (rest interval 06:00 to 12:00, good quality) and the other 176 minutes (2.93 hours) (rest interval 18:00 to 24:00, good quality).*

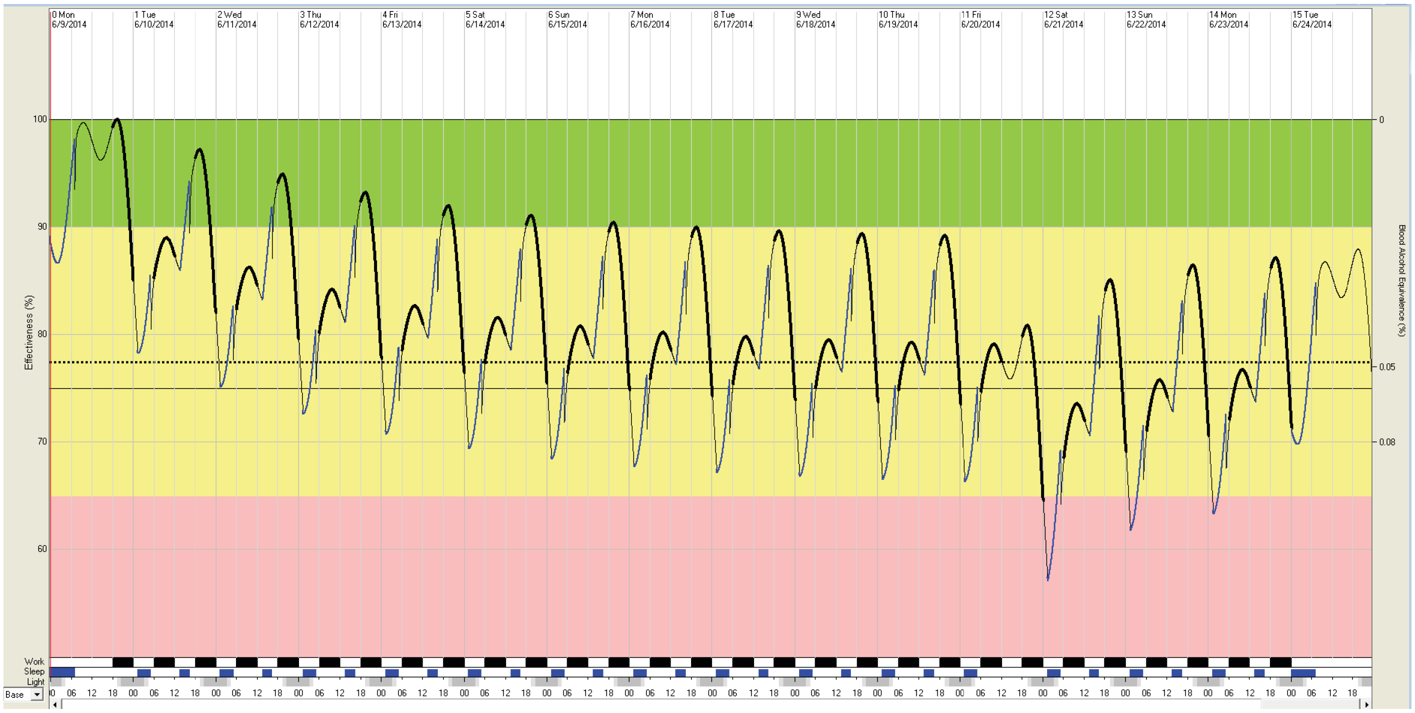

Figure 26. SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the front watch with a skipped sleep period. *Work periods (06:00 to 12:00 and 18:00 to 24:00 daily for 15 days) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines.*

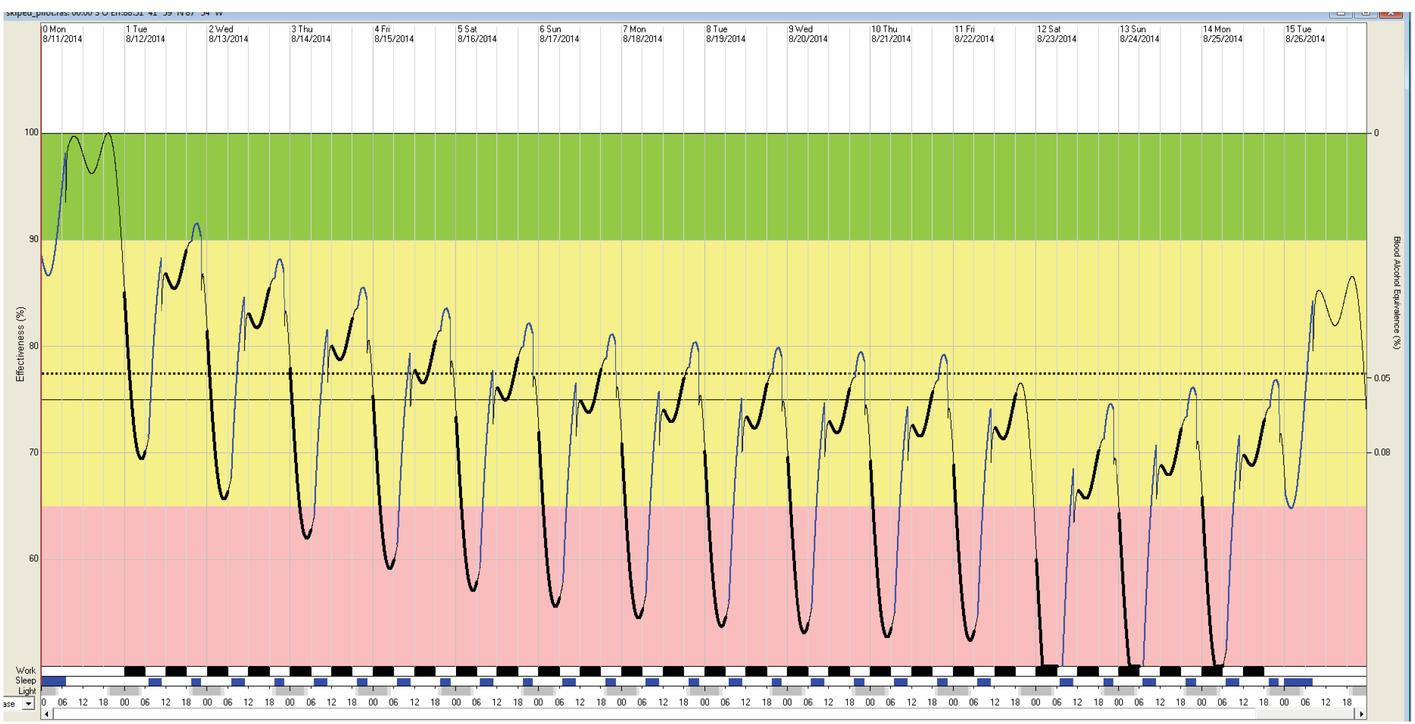

Figure 27. SAFTE/FAST model output for an "average" crew member on a 6:6:6:6 schedule for the back watch with a skipped sleep period. *Work periods (24:00 to 06:00 and 12:00 to 18:00 daily for 15 days) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines.*

3.3.4.2 Other Reported Schedules

Several other schedules were reported by management to be used as the primary watch schedule. This section models a few examples of these reported schedules.

3.3.4.2.1 12:12 Schedules. Twelve-hour shifts are commonly used throughout the tug/towboat/barge industry. As part of the management survey, 19% of companies reported using a 12:12 schedule as the primary watch schedule. The way in which the 12:12 schedule is used varies considerably in regard to start/end times and the number of shifts in a rotation; in addition, crew may live on vessel or commute home each day. Start times that were reported in interviews include 05:00, 06:00, 07:00, and 24:00, and the number of shifts in a rotation reported range from 7 to 30 days.

Several variations of the 12:12 schedule were modeled for this report using SAFTE/FAST (Table 11 and Figures 28 through 31). Sleep durations used in the model were based on average sleep durations commonly reported on 12:12 schedules, 7 hours of sleep for day shifts and 5 hours of sleep for night shifts (Akerstedt 2000).

3.3.4.2.2 12:12 Front Watch: 28 Days on Duty. The 12:12 schedule depicted in Figure 28 was reported to be in use by one of the surveyed companies. In this schedule crew could work up to 30 consecutive days on the front watch or back watch. This schedule was in use by a company that operated on a primarily seasonal schedule, so in order for crew and the company to make the most of the limited work season (~6 months of the year) crew worked on the same schedule over many consecutive days but did not necessarily live on the vessel. This company expressed an interest in learning more about how to optimize schedules within safe parameters. The figures provided here are for crew working between 06:00 to 18:00 (front watch) for 28 days. There were also crew who worked from 18:00 to 06:00 (back watch) for 28 days, this schedule is not depicted here but a summary of the level of effectiveness is provided in Table 11.

For this 12:12 schedule, the SAFTE/FAST model estimates that crew would have acceptable levels (green) of fatigue during the first work period (thick back lines) with only some gradual reduction of effectiveness levels over the first 9 to 10 days of the schedule (Figure 29).

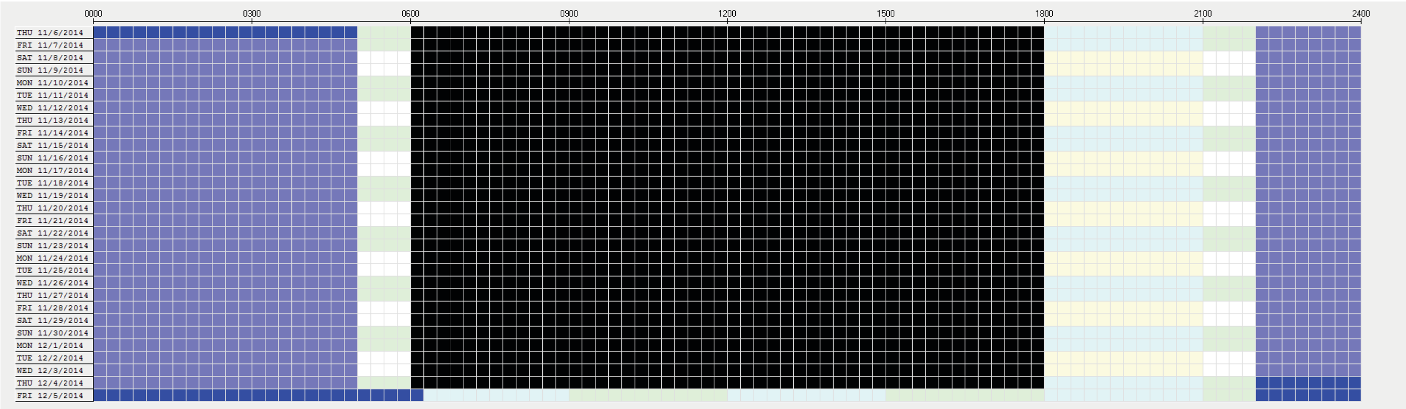

Figure 28. SAFTE/FAST model scheduling grid for a crew member on a 12:12 schedule for the front watch with average sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods (06:00 to 18:00 for a 28-day rotation) are indicated by black bars; sleep is indicated by blue bars (light blue = good sleep quality, dark blue = excellent sleep quality); and leisure time is indicated by white bars. The sleep duration for the day was 7 hours on work days with good quality.*

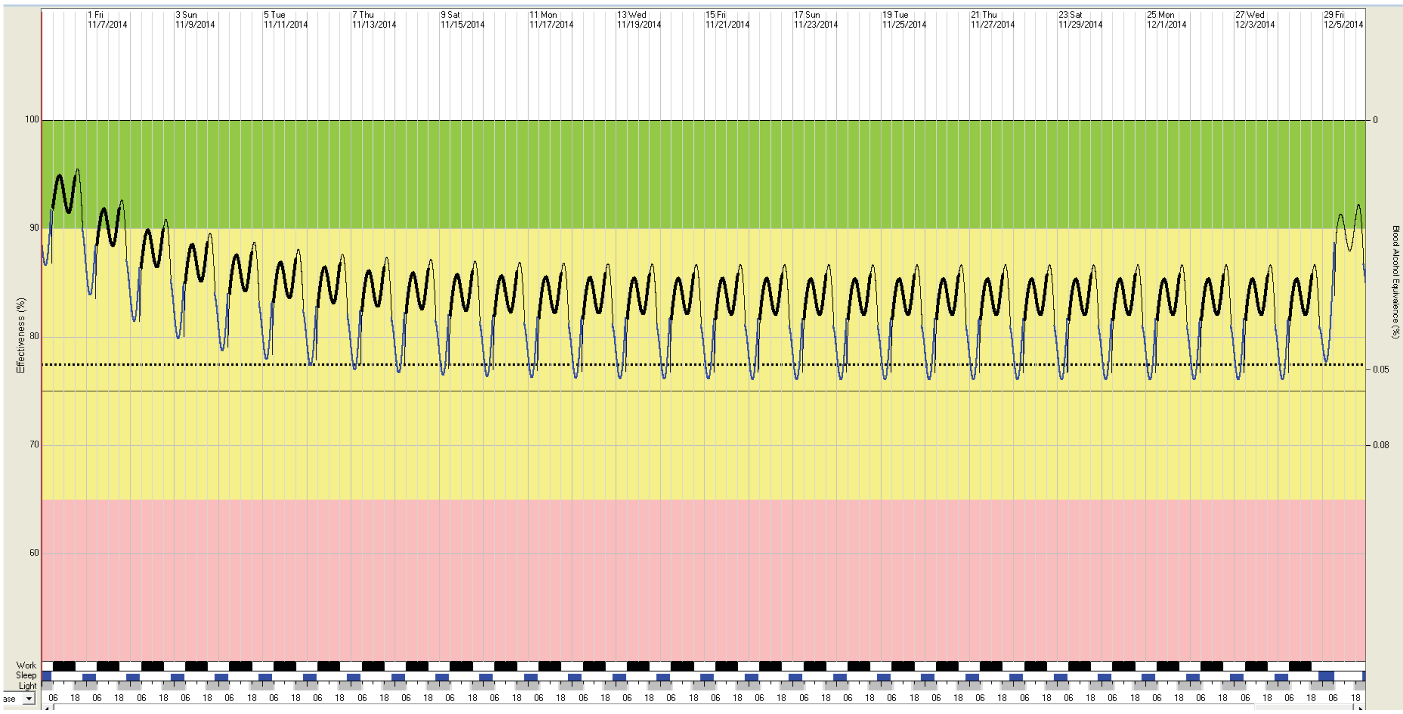

Figure 29. SAFTE/FAST model output for an "average" crew member on a 12:12 schedule for the front watch with average sleep. *Work periods (06:00 to 18:00 for a 28-day rotation) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 7 hours on work days with good quality.*

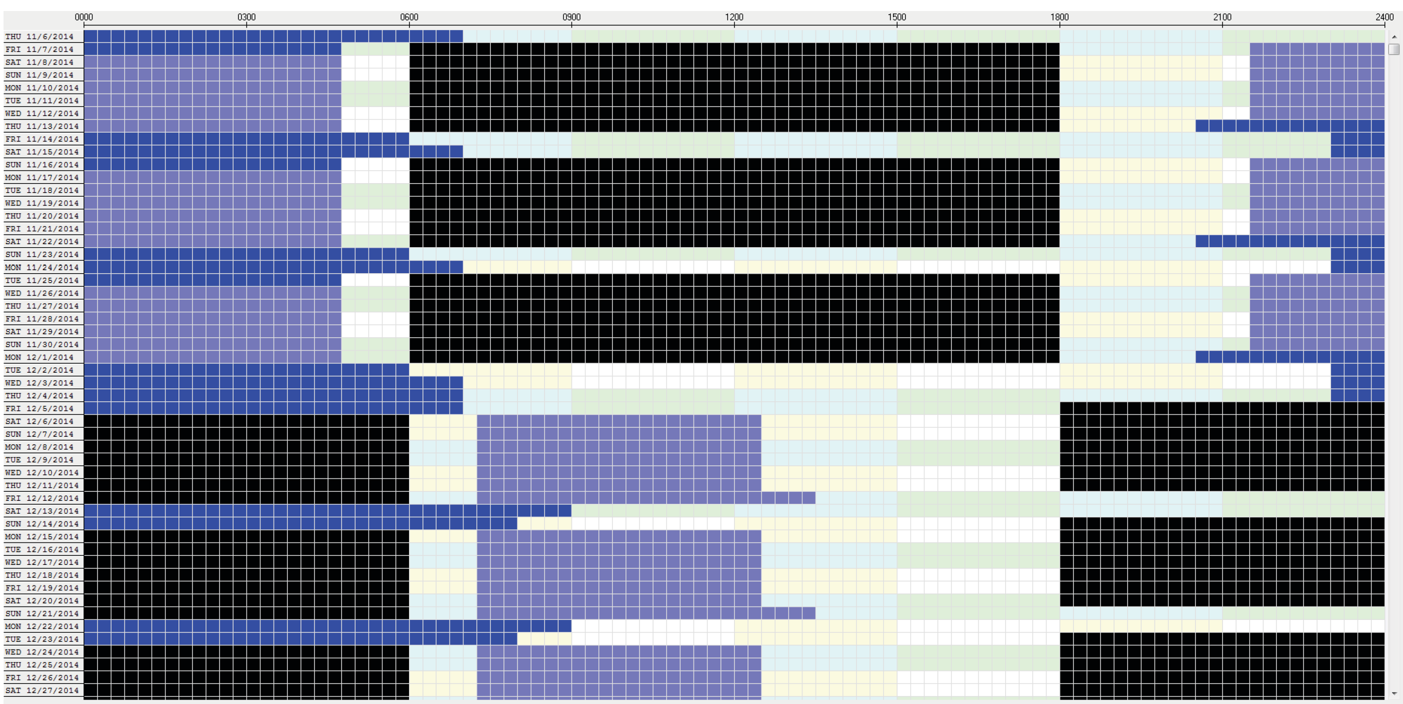

Figure 30. SAFTE/FAST model scheduling grid for a crew member on a 12:12 schedule for the front and back watch with average sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods [06:00 to 18:00 and then 18:00 to 06:00 with a 3-week 7-day rotation (figure truncated on last week of rotation)] are indicated by black bars; sleep is indicated by blue bars (light blue = good sleep quality, dark blue = excellent sleep quality); and leisure time is indicated by white bars. The sleep duration for the day was 7 hours on front watch work days and 5 hours on back watch with good quality.*

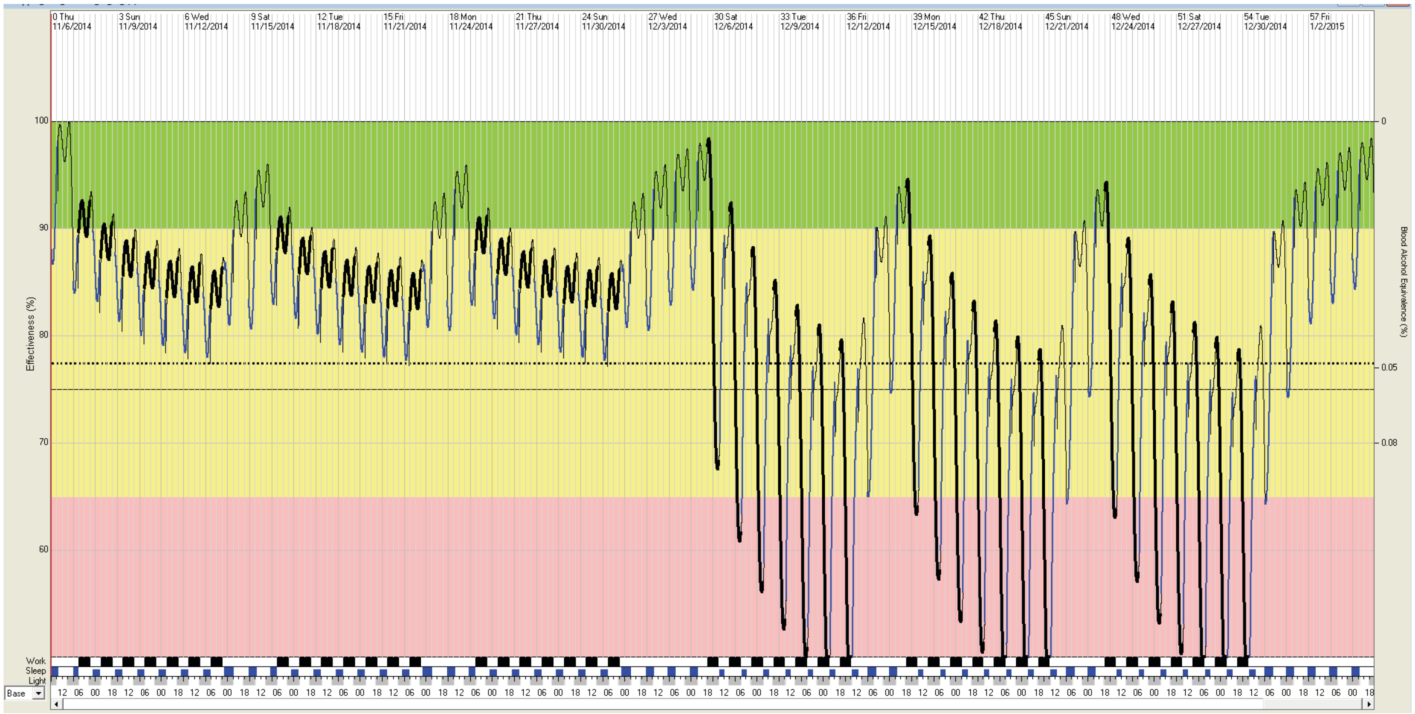

Figure 31. SAFTE/FAST model output for an "average" crew member on a 12:12 schedule for the front and back watch with average sleep. *Work periods [06:00 to 18:00 and then 18:00 to 06:00 with a 3-week 7-day rotation) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 7 hours on front watch work days and 5 hours on back watch with good quality.*

3.3.4.2.3 12:12—21-day Rotation, 5 Days on/2 Days off, Front and Back Watch. The 12:12 schedule depicted in Figure 30 was reported to be in use by one of the surveyed companies. In this schedule crew worked a 21-day rotation on the front watch with 5 days of work followed by 2 days off, then after 21 days switched to the back watch. The figures provided here are for crew working between 06:00 to 18:00 (front watch) for 3 weeks, then between 18:00 to 06:00 (back watch) for 3 weeks. There were also crew who worked from 18:00 to 06:00 (back watch) then switched to 06:00 to 18:00 (front watch) for 3 weeks, this schedule is not depicted here but a summary of the level of effectiveness is provided in Table 11.

For this 12:12 schedule the SAFTE/FAST model (Figure 31) estimates that crew would rarely have acceptable levels (green) of fatigue during the work periods (thick back lines). The average effectiveness levels during work for the first 3 weeks is 88%. While on the front watch there is some degradation of effectiveness levels over each 5-day work week period, in contrast, for the 5 days of work on the back watch, effectiveness levels are often below acceptable levels, with average effectiveness levels during work of 69.8%. Towards the end of the 5-day work week crew are almost always in the red zone for effectiveness level at the end of each night shift. This could be of particular concern for crew who are commuting home after a night shift.

3.3.4.2.4 8:4:4:8 Schedules. As part of the management survey, 8% of companies reported using the 8:4:4:8 schedule as the primary watch schedule. This schedule has been proposed as an alternative to the 6:6:6:6 square watch since it allows for at least one opportunity per day to get an extended duration of sleep (8-hour rest interval). In the tug/towboat/barge industry the

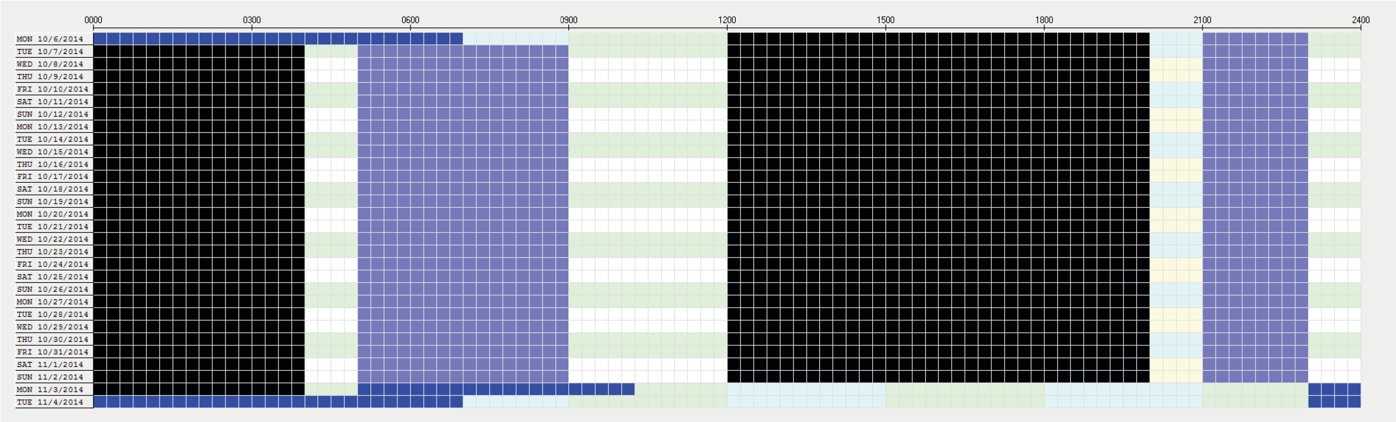

Figure 32. SAFTE/FAST model scheduling grid for a crew member on an 8:4:4:8 schedule with 6 hours of good sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods (12:00–20:00 and then 24:00–04:00) are indicated by black squares; sleep is indicated by blue squares (light blue = good sleep quality, dark blue = excellent sleep quality); and leisure time is indicated by white squares. The sleep duration for the day was split into two periods with one 4-hour sleep period and one 2-hour sleep period with good quality.*

8:4:4:8 schedule is typically a two-crew member operation. The 8:4:4:8 watch was not used as widely as in other maritime operations that have a three watch system. An example of both a front watch and back watch 8:4:4:8 schedule is modeled and summary results provided (Table 11, schedules 17 and 18, and Figures 32 and 33). The sleep durations of 6 hours/day in the example models were based on those reported for a three watch system so sleep durations are likely to be overestimated compared to a two watch system (Lutzhoft et al. 2010).

In this example of the 8:4:4:8 schedule, the 8-hour work period begins at 12:00 and the 4-hour work period starts at 24:00. Effectiveness levels are often below optimal levels during both the day and the night for much of the rotation even when there is only 4 hours of work at night. This is likely due to the limited amount of sleep (6 hours) while on this schedule. There is also progressive deterioration in effectiveness levels over the first 12 days of the rotation. On average, the effectiveness level during all work periods was 69.4%, which is only slightly better than on the 6:6:6:6 schedule with similar sleep durations (Table 11, schedule 6, average effectiveness level of 65.1%).

3.3.4.2.5 7:5:5:7 Schedules. The 7:5:5:7 schedule was reported as the primary watch schedule by 1% of companies. This schedule has been proposed as an alternative to the 6:6:6:6 square watch since it allows for at least one opportunity per day to get an extended duration of sleep (7-hour rest interval). An example of a front watch and back watch schedule were modeled and summary data provided (Table 11 and Figures 34 and 35). Sleep data for input into this model were taken from the average sleep durations recorded using wrist actigraphy (average sleep duration of 6.6 hours/day) from crew on a single vessel studied as part of the Phase III study.

In this example of the 7:5:5:7 schedule, the 7-hour work period begins at 12:00 and the 5-hour work period starts at 24:00. Effectiveness levels are often below optimal levels during both the day and the night for much of the rotation even when there is only 5 hours of work at night. This is likely due to the limited amount of sleep (6.6 hours) while on this schedule. There is also progressive deterioration in effectiveness levels over the first 10 days of the rotation. On average, the effectiveness level during all work periods was 70.2% which is similar to the 8:4:4:8 schedule and only slightly better than on the 6:6:6:6 schedule, which has slightly less sleep each day (Table 11, schedule 6; average effectiveness level of 65.1%).

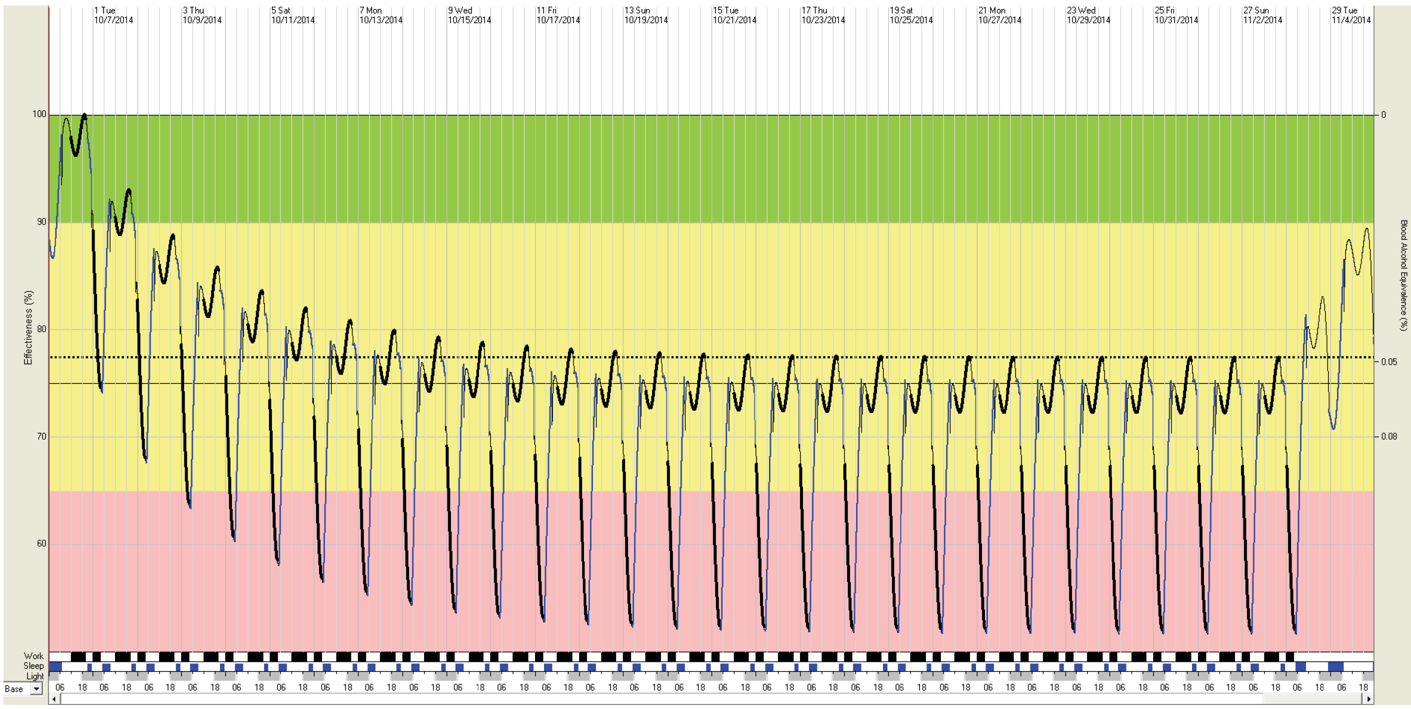

Figure 33. SAFTE/FAST model output for an "average" crew member on an 8:4:4:8 schedule with 6 hours of good sleep. *Work periods (12:00 to 20:00 and then 24:00 to 04:00) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 6 hours on work days with good quality.*

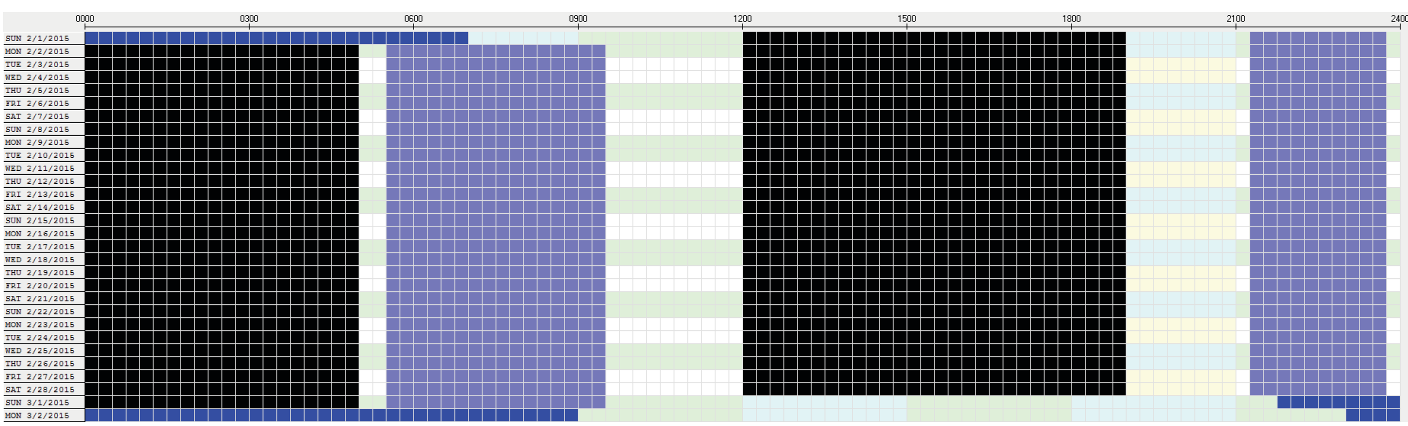

Figure 34. SAFTE/FAST model scheduling grid for a crew member on a 7:5:5:7 schedule with 6.6 hours of good sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods (12:00 to 19:00 and then 24:00 to 05:00) are indicated by black squares; sleep is indicated by blue squares (light blue = good sleep quality, dark blue = excellent sleep quality); and leisure time is indicated by white squares. The sleep duration for the day was split into two periods with one 4.1-hour sleep period and one 2.5-hour sleep period with good quality.*

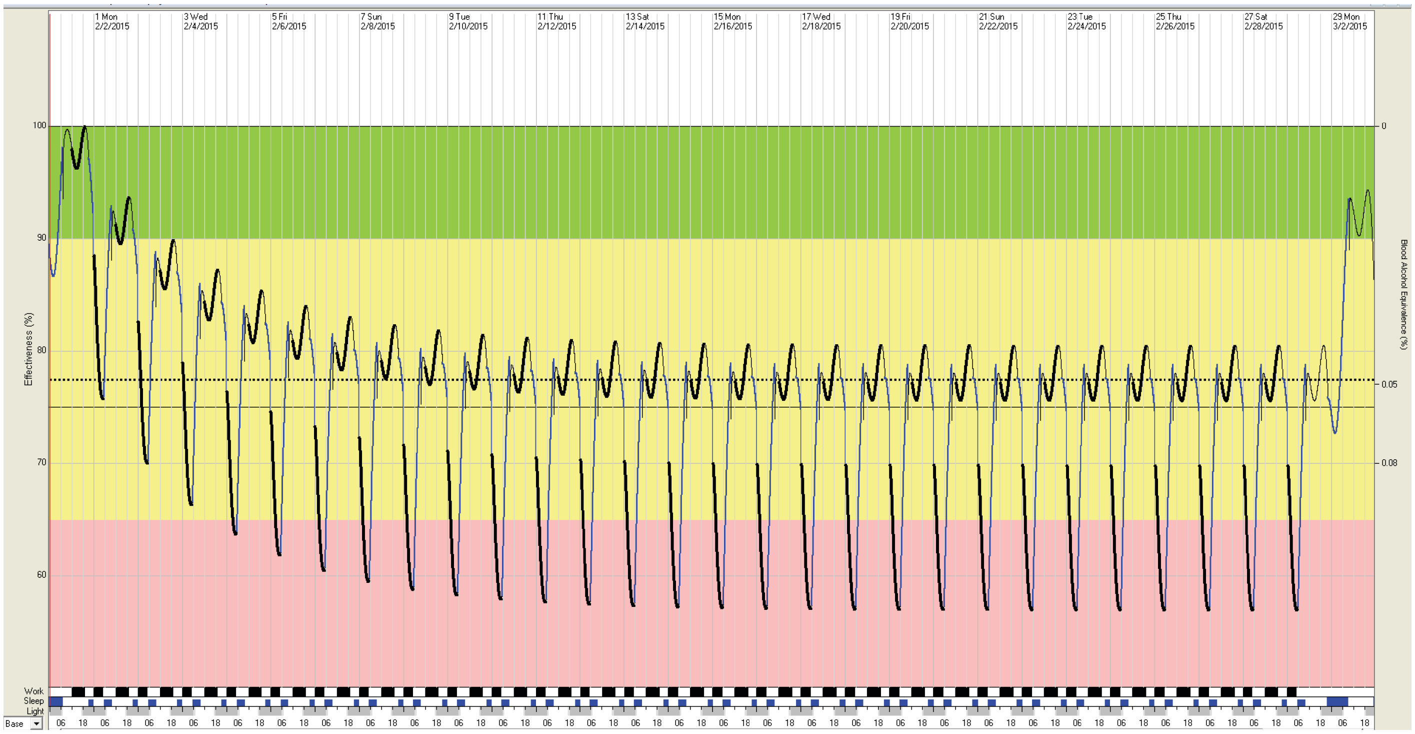

Figure 35. SAFTE/FAST model output for an "average" crew member on a 7:5:5:7 schedule with 6.6 hours of good sleep. *Work periods (12:00 to 19:00 and then 24:00 to 05:00) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines. The sleep duration for the day was 6.6 hours on work days with good quality.*

3.3.4.2.6 4:4:4:4 Schedules. A single company reported using a 4:4:4:4 schedule. Upon follow-up, they indicated that they used this schedule when not in port. In port they used a 6:6:6:6 schedule and then switched to a 4:4:4:4 schedule. Based on the information to date in regard to this schedule, a SAFTE/FAST model was generated using the auto-sleep function and a summary of results is provided (Table 11 and Figure 36).

The SAFTE/FAST model indicates that mean effectiveness levels are almost always at sub-optimal levels on this schedule (Figure 37). The average effectiveness level over the whole rotation was 74.7% (Table 11, schedule 22). The average effectiveness level while on the 4:4:4:4 schedule was 78.8% and 69.2% on the 6:6:6:6 back watch schedule.

3.3.4.3 Summary of Mathematical Modeling

Interpretation of the outputs from the SAFTE/FAST model suggest that it is possible to operate at acceptable "effectiveness levels" on a 6:6:6:6 split schedule with "moderate" amounts of sleep and that schedules allowing one longer rest interval such as the 7:5:5:7 and 8:4:4:8 do not necessarily offer additional benefits.

The outputs of the SAFTE/FAST model also suggest that the schedules that are commonly used in the tug/towboat/barge industry result in effectiveness levels that are below recommended limits for much of the night shift (conventional sleep time) and below recommended limits even for some schedules with shifts that occur during the day time (convention awake time) if there has not been sufficient prior sleep.

Since the research team was unable to directly monitor crew working on schedules other than the 6:6:6:6 schedule as part of this study, the use of the SAFTE/FAST model is of particular

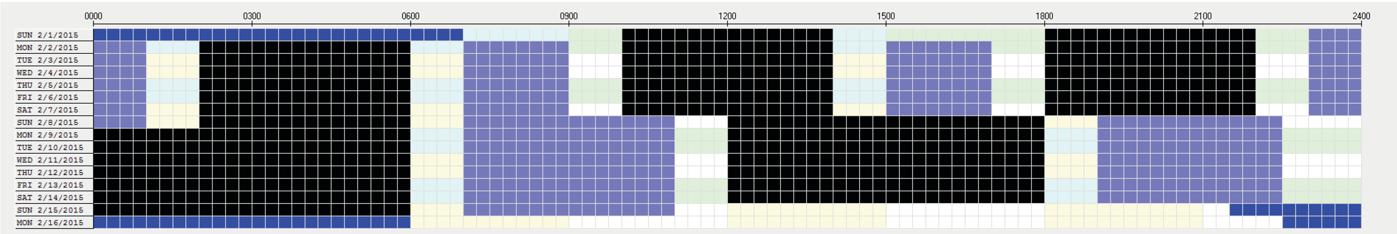

Figure 36. SAFTE/FAST model scheduling grid for 7 days on a 4:4:4:4 schedule with 6 hours of good sleep, followed by 7 days on a 6:6:6:6 schedule with 7.5 hours (moderate sleepers) of good sleep. *Each square on the grid is an increment of 15 minutes, and each row is a day. Work periods (start times: 10:00, 18:00, 02:00/12:00, 24:00) are indicated by black squares; sleep is indicated by blue squares (light blue = good sleep quality, dark blue = excellent sleep quality); and leisure time is indicated by white squares. The sleep duration for the day was split into three periods using auto-sleep, then into two periods with one 4-hour sleep period and one 3.5-hour sleep period with good quality.*

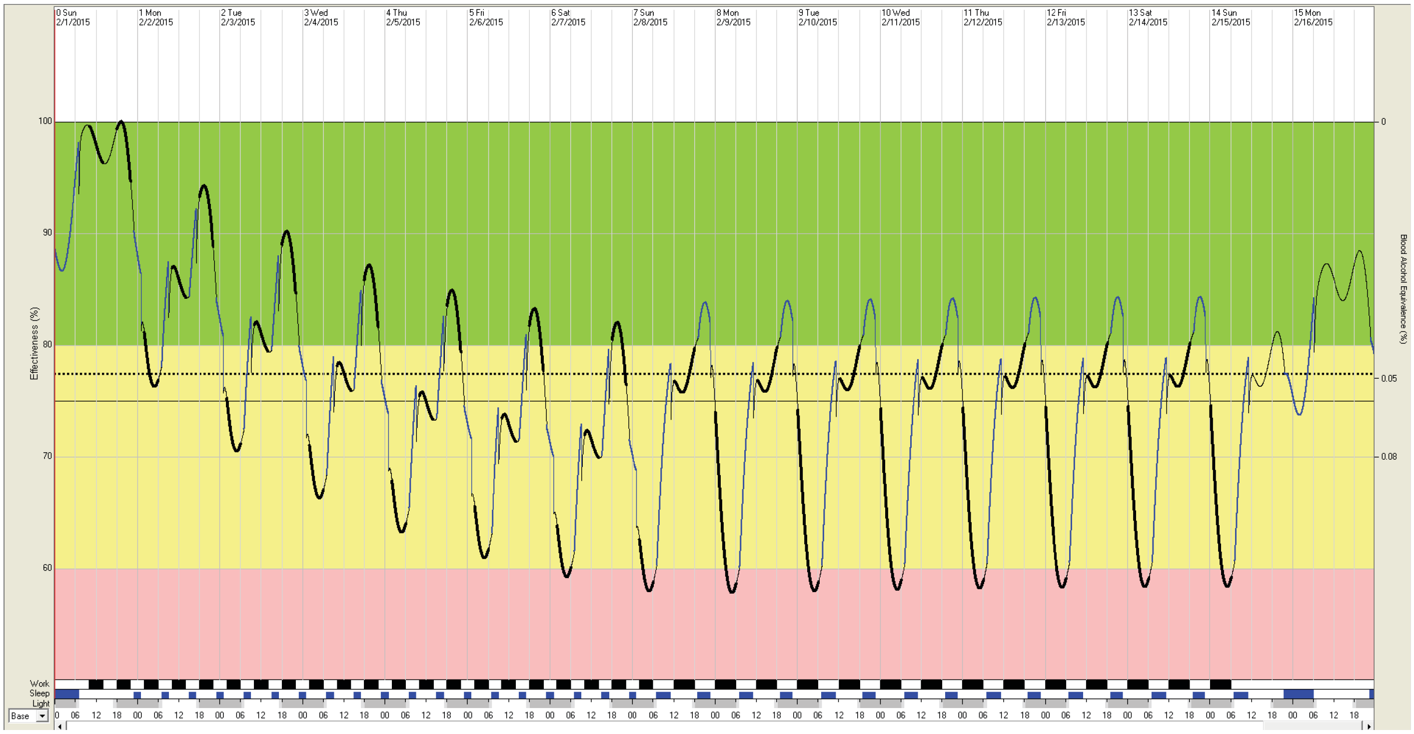

Figure 37. SAFTE/FAST model output for 7 days on a 4:4:4:4 schedule with 6 hours of good sleep, followed by 7 days on a 6:6:6:6 schedule with 7.5 hours of good sleep. *Work periods (start times: 10:00, 18:00, 02:00/12:00, 24:00) are indicated by black bars/thick lines; sleep is indicated by blue bars/lines; and leisure time is indicated by thin black lines.*

interest for these "other" schedules. The second most commonly reported schedule within the tug/towboat/barge industry was the 12:12 schedule, which was used in a variety of ways and varied by start time, number of consecutive shifts worked, rotation of the schedule, and whether the crew slept on the vessel or at home. The examples reported here suggest that during the daytime, effectiveness levels are within acceptable limits but that during portions of the night shifts, effectiveness levels drop to levels that would require monitoring. Since sleep times were only estimated, it would be useful for companies that want to assess the fatigue levels of their particular schedule to consider monitoring typical sleep durations of their workers to more accurately determine times of potential risk.

The cost of modeling software such as SAFTE/FAST may be a barrier to broad use in this industry. In addition, given the limited variation in schedules used in this industry, if companies wanted to do such modeling it might be more cost effective to work with the company that provides the software to model particular schedules rather than to purchase the model outright. Although no actual costs for such services were requested as part of this project.

The modeled schedules support the need to optimize sleep and to have practices in place to manage risk at times of low effectiveness (primarily at night). While there are limitations (i.e., auto-sleep function and forbidden zone) of SAFTE/FAST that are discussed in the introduction of Section 3.3.4, the program does provide relative insight into what times during a shift and across a rotation are potentially problematic.

Further validation using split-sleep schedules and adjusting model parameters (equations) based on new available data may be useful to improve the validity of this type of model for use in industries that have split-sleep schedules. This is of particular interest given recent data from laboratory studies that suggests the homeostatic component of sleep regulation may play a larger role than initially suspected under various conditions of split sleep (Jackson et al. 2014, Kosmadopoulos et al. 2014).

Given the potential limitations of the auto-sleep function under split-sleep conditions, the research team suggests the use of actual sleep durations rather than the use of the auto-sleep function. Sleep-wake schedules could be collected from self-report with a sleep diary or objectively estimated using wrist actigraphy. If self-reported sleep is used then it should be understood that there is likely to be a bias for an over estimation of sleep duration (see Table 10).

Since the use of models such as SAFTE/FAST are encouraged by both the FAA and FRA and the research team has demonstrated the practicality of this type of model in the tug/towboat/barge industry, the use of such models is included as a suggested best practice, under certain conditions (see Section 3.5.12).

3.4 Task 4. Barriers to Good Sleep

Several approaches were proposed to address Task 4, with two main parts: (1) to identify barriers to good sleep and (2) to propose practices to overcome these barriers (see Task 5). The following analysis of existing data and new data was conducted:

1. Identify factors predicting best and worst sleepers,
2. Identify those who changed sleep behaviors since Phase IV, and
3. Determine best practices crew would like to see initiated.

3.4.1 Identify Factors Predicting Best and Worst Sleepers

In order to identify factors that predicted best and worst sleepers, the research team utilized two main strategies. The first was to divide crew members into groups based on their average daily sleep duration. The second was to examine factors that predicted sleep duration on a sleep period-by-sleep-period basis over many days using regression modeling.

Table 12. The number of crew per sleep duration group, by watch.

	Short	Moderate	Long
Front Watch	17	50	21
Back Watch	11	30	7

p = 0.4793; Fisher's exact test.

3.4.1.1 Categorization of Long, Moderate, and Short Sleepers

Data collected as part of the previously funded AWO Phase IV studies were reanalyzed to determine factors that may predict average daily sleep duration. Crew members were categorized into three groups (long, moderate, and short sleepers) based on their average daily sleep duration. Groups were chosen based on overall group distribution (N = 136), with the lowest and highest 20% being either short or long sleepers (Table 12). This split (20% lowest and highest) provides similar proportions of captains and pilots per group.

The mean time in bed and sleep durations for long, moderate, and short sleepers is provided in Figure 38 and is divided by front and back watch and into morning, evening, and 24-hour sleep periods. Morning sleep periods are considered to be between 24:00 and 12:00 and evening sleep periods are those that occur between 12:00 and 24:00. On average, those considered to be short sleepers had less than 6.6 hours of sleep per day, moderate sleepers had 6.6 to 8.6 hours of sleep per day, and long sleepers slept greater than 8.6 hours per day.

There were differences in sleep duration between the front and the back watch crew members who were long or short sleepers but not for those who had moderate daily sleep durations. For

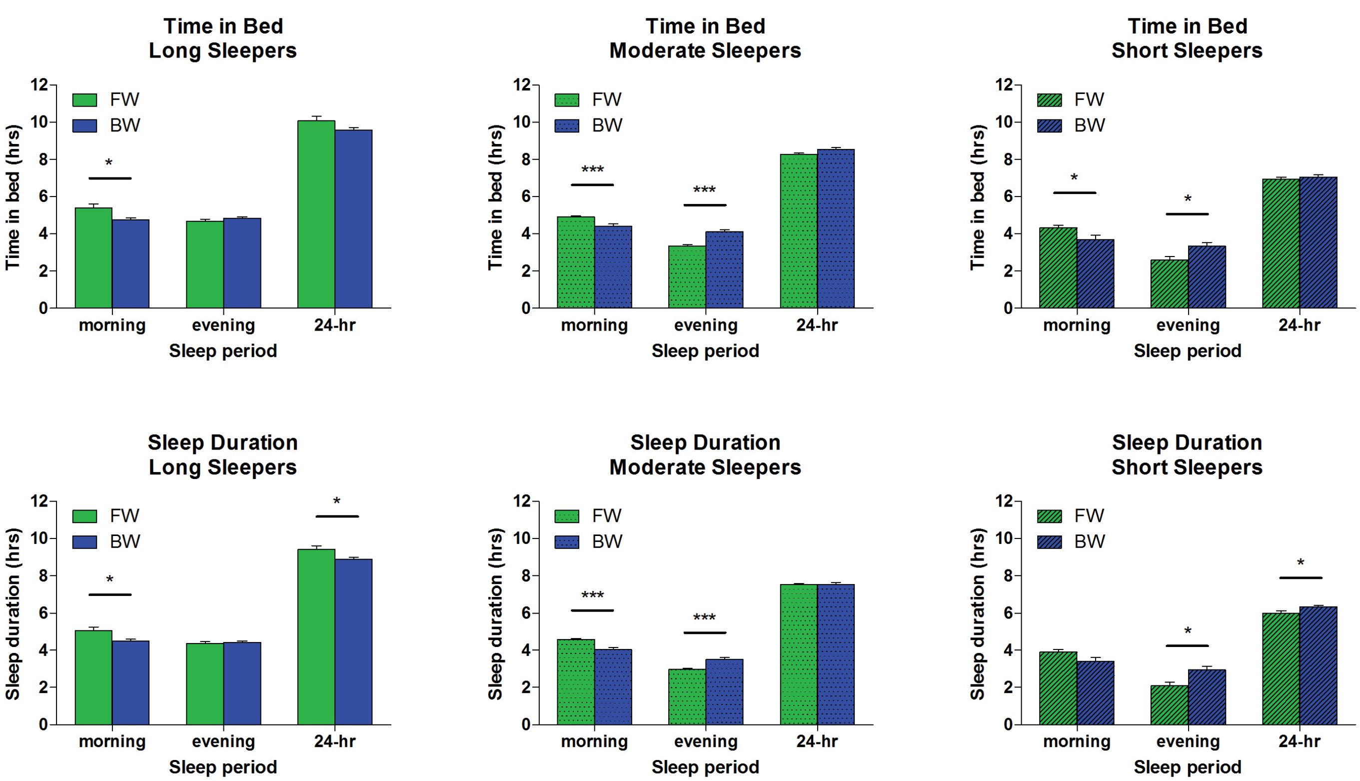

Figure 38. Mean ± SEM of time in bed and sleep duration for Phase IV captains and pilots, grouped into long, moderate, and short sleepers. **p < 0.05 and ***p < 0.001.*

long sleepers, those on the back watch slept slightly less than those on the front watch. However, the opposite was the case when considering short sleepers. For short sleepers, the back watch crew members tended to sleep slightly longer than those on the front watch.

There were also differences in the time in bed and sleep duration for the front watch and back watch crew members for sleep periods in the morning and the evening. Time in bed is defined as the difference between bedtime (time the person got into bed) and wake time (time that the person got out of bed). Sleep duration in this case is defined as time in bed minus sleep latency (how long it took to fall asleep).

For the moderate and short sleepers, those on the back watch tended to sleep longer in the evening sleep period (18:00 to 24:00) than those on the front watch during their evening sleep period (12:00 to 18:00).

This was not the case for the long sleeper group, where the only difference between front watch and back watch was for the morning sleep period, when those on the front watch slept longer in the morning (24:00 to 06:00) than those on the back watch (06:00 to 12:00).

3.4.1.1.1 Sleep Duration at Home Compared to Sleep Duration on the Vessel. In order to determine whether crew members were always long, moderate, or short sleepers, the research team also calculated the average sleep duration that they reported while at home (Figure 39). While at home, crew members typically slept just one time per day, rather than two, and slept at night between approximately 23:00 and 08:00. The short, long, and moderate sleepers (as determined by their on-vessel sleep durations) had basically the same sleep duration while at home—no significant differences. This suggests that sleep duration on the vessels is not determined by crew being inherently short or long sleepers per se, but instead is due to factors in the work environment.

3.4.1.1.2 Change in KSS Score According to Watch and Sleep Period and Average Sleep Duration Category. The research team was also able to examine whether there were differences in how restorative sleep was for those who were long, moderate, or short sleepers and whether this differed by watch. To do this the research team examined the change in KSS score between the start and end of a rest interval (Figure 40). There was a trend ($p = 0.053$) for those on the back watch in the moderate sleep duration group to have less of a change in KSS score in the evening rest interval, indicating that this sleep period was less restorative for this group.

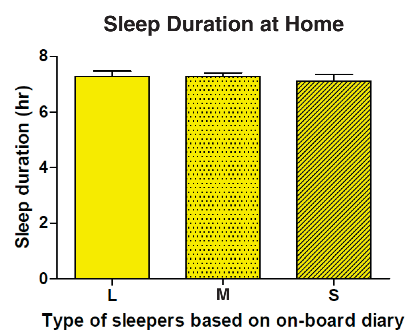

Figure 39. Mean ± SEM of sleep duration for Phase IV captains and pilots while at home, grouped based on sleep durations while on the vessel into long, moderate and short sleepers (L = long, M = moderate, S = short).

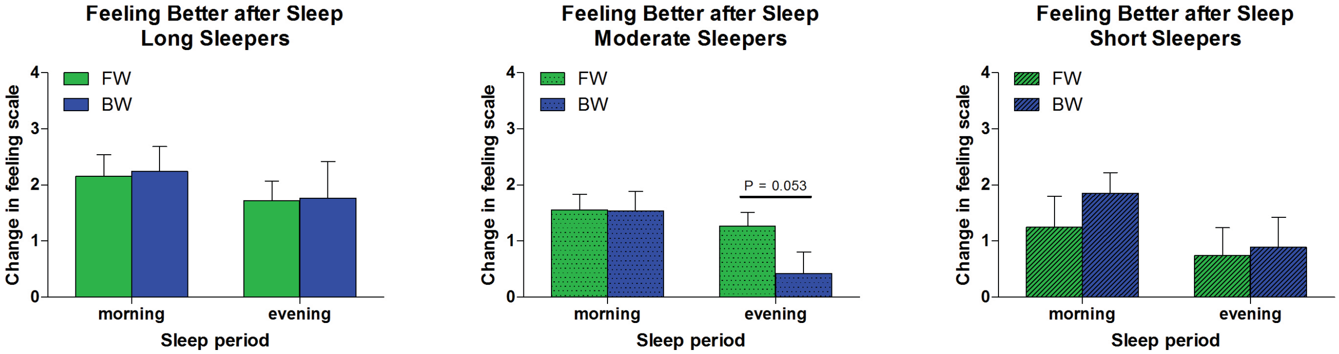

Figure 40. Mean ± SEM of change in KSS score between going to bed and waking for Phase IV captains and pilots, grouped into long, moderate, and short sleepers.

3.4.1.1.3 Other Factors That Are Different Between Sleep Duration Groups. Differences in the characteristics of the three groups (short, moderate, long) were analyzed in the following way. Several variables/factors that were considered to have potential for impacting sleep duration (based on prior analysis of the Phase IV data) were assessed for each group. Analysis of variance (three groups) and an independent group's student *t*-test (long vs. short) were used for continuous factors and Fisher's exact test were used for categorical factors, in order to determine whether there was a statistical differences between groups.

Characteristics that were significantly different between groups or are of particular interest are presented in Table 13. Analysis indicates that crew with short sleep are more sleepy [Epworth Sleepiness Scale (ESS)], report greater fatigue [Standard Shiftwork Index (SSI)], and have poor subjective sleep quality [Pittsburgh Sleep Quality Index (PSQI)], as would be expected. The crew with short sleep also report more somatic anxiety, worse general health, and more difficulty dealing with family stress related to their shift schedule (SSI). There is no significant difference in age, BMI, or risk for sleep apnea between sleep duration groups.

3.4.1.2 Regression Modeling to Evaluate Factors That Predict Sleep Duration

In order to evaluate factors that predicted sleep duration, the research team also took another statistical approach using mixed-effect regression modeling, using both univariate and multivariate regression. In such models, the team simultaneously considered the overall effects of predicting factors (i.e., the fixed effects) and the random variations of these effects amongst

Table 13. Characteristics of crew members from Phase IV with long, moderate, or short sleep duration.

	Long Sleepers		Moderate Sleepers		Short Sleepers		All Groups	Long vs. Short
	Mean	SEM	Mean	SEM	Mean	SEM	p value	p value
Domestic Conflict	4.19	0.19	3.67	0.14	2.76	0.30	0.00	0.00
Fatigue	18.40	1.75	21.53	0.94	23.89	1.38	0.08	0.02
Sleepiness (ESS)	6.75	0.75	7.19	0.58	9.35	0.79	0.08	0.02
General Health	18.86	0.51	21.47	0.49	21.47	0.99	0.04	0.03
Somatic Anxiety	10.31	0.88	9.42	0.50	8.17	0.43	0.19	0.04
Sleep Quality (PSQI)	3.42	0.69	4.08	0.37	5.63	0.78	0.07	0.04
Body Mass Index	33.89	1.85	32.73	0.71	32.12	1.47	0.68	0.46
High Sleep Apnea Risk %	25%		51.7%		42.1%		0.17	0.48
Age (years)	47.88	2.10	47.30	1.22	49.38	1.50	0.65	0.56

individual subjects (i.e., random effects). In simple terms, the goal of this analysis was to determine which factors predicted sleep duration or change in KSS score in any given sleep period. Factors included in the model were sleep duration, sleep diary measures (i.e., stress level and sleep disturbance) available for every sleep period, and other factors taken from questionnaires that were considered to be important.

3.4.1.2.1 Univariate Regression Analysis.

- *Factors predicting sleep duration univariate analysis*

In the initial analysis, 27 candidate variables were examined in a univariate fashion against sleep duration for each sleep period in a mixed-effect repeated measures model. In Table 14, significant factors are highlighted in red and include the time of the sleep period, sleep quality, special sleep disruption, and discomfort. The coefficients from the analysis are also reported, which estimates the average changes in hours of sleep duration when the predictive factor changes by one unit. In this table the sleep period between 24:00 and 06:00 was used as a reference.

Table 14. Univariate regression analysis for repeated measures sleep duration in each sleep period, with the 24:00–06:00 sleep period as a reference, significant p values highlighted in red.

Predictors	Coefficient	p-value
6:00-12:00 sleep period	-1.23	0.00
12:00-18:00 sleep period	0.22	0.07
18:00-24:00 sleep period	-0.40	0.00
Anxious or stressed	0.15	0.00
Hard to fall asleep	0.34	0.00
Sleep disrupted	0.16	0.00
Sleep depth	0.43	0.00
Special disruption	-0.53	0.00
Age	-0.01	0.34
BMI	0.00	0.95
Berlin OSA (obstructive sleep apnea) high risk	-0.15	0.17
Pittsburgh Sleep Quality Index	-0.05	0.04
Epworth Sleepiness Scale	-0.03	0.02
Discomfort	-0.04	0.01
Health	0.00	0.84
Fatigue	-0.02	0.01
Caffeine use	0.01	0.11
General feeling	-0.01	0.53
Anxiety cognitive	-0.01	0.52
Anxiety somatic	0.02	0.24
Anxiety total	0.01	0.43
Shift work problems	-0.01	0.31
Organizational problem	-0.04	0.37
Coping	-0.16	0.06
ME active	0.10	0.09
Morning type	0.12	0.33
Evening type	-0.47	0.35

p = 0.00 indicates a $p < 0.0001$.
Note: ME = morning/evening.

- *Factors predicting change in KSS score in the univariate analysis*

A regression analysis similar to what was done for predicting sleep duration was also conducted to examine factors that predicted a change in KSS score from the beginning to the end of the rest interval. There were some factors that were similar to those that were predictive for sleep duration in this model. However, there were also other factors that significantly predicted change in KSS (indicated in red in Table 15) that were not predictive of sleep duration, for example BMI, age, and shiftwork problems. The best predictor of change in KSS was the time of the sleep period and sleep duration itself.

3.4.1.2.2 Multivariate Regression Analysis. The factors that had their p-value < 0.11 in the univariate model were included in the multivariate repeated measures analysis with a mixed-effect model, which considers all possible predicting factors and thus adjusting potential biases.

- *Factors predicting sleep duration in the multivariate analysis*

In the multivariate repeated measures analysis, the research team was able to determine the number of minutes of sleep that each factor contributes to the total sleep duration in a sleep period. The factors that predict sleep duration in this multivariate model are presented in Table 16. The factors that seem to cause more than 1 hour difference in sleep duration are related to the time of

Table 15. Univariate regression analysis for repeated measures change in KSS for each sleep period, with the 24:00 to 06:00 sleep period as a reference.

Predictors	Coefficient	p-value
Sleep duration	0.31	0.00
6:00-12:00 sleep period	-0.21	0.10
12:00-18:00 sleep period	0.91	0.00
18:00-24:00 sleep period	-1.04	0.00
Anxious or stressed	0.32	0.00
Hard to fall asleep	0.74	0.00
Sleep disrupted	0.24	0.00
Sleep depth	0.44	0.00
Special disruption	-0.45	0.00
Age	0.04	0.04
BMI	0.09	0.00
Berlin OSA high risk	-0.65	0.08
Pittsburgh Sleep Quality Index	-0.23	0.00
Epworth Sleepiness Scale	-0.05	0.24
Discomfort	-0.16	0.01
Health	0.04	0.29
Fatigue	-0.10	0.00
Caffeine use	-0.01	0.49
General feeling	-0.22	0.00
Anxiety cognitive	-0.08	0.09
Anxiety somatic	-0.05	0.35
Anxiety total	-0.04	0.16
Shift work problems	-0.15	0.00
Organizational problem	-0.13	0.37
Coping	0.10	0.70
ME active	0.24	0.23
Morning type	0.18	0.66
Evening type	-2.00	0.27

Table 16. Multivariate regression modeling for repeated measures sleep duration in each sleep period, with the sleep period from 24:00 to 06:00 as the reference.

Predictors	Coefficient	Std. Error	DF	t-value	p-value
(Intercept)	3.31	0.69	724	4.81	0.00
6:00-12:00 sleep period	-1.65	0.17	724	-9.52	0.00
12:00-18:00 sleep period	-1.12	0.21	724	-5.35	0.00
18:00-24:00 sleep period	-0.96	0.26	724	-3.74	0.00
Anxious or stressed	0.08	0.05	724	1.50	0.13
Hard to fall asleep	0.22	0.05	724	4.63	0.00
Sleep disrupted	0.02	0.06	724	0.37	0.71
Sleep depth	0.22	0.06	724	3.62	0.00
Special disruption	-0.27	0.15	724	-1.75	0.08
Pittsburgh Sleep Quality Index	-0.02	0.04	28	-0.44	0.66
Epworth Sleepiness Scale	0.01	0.02	28	0.40	0.69
Discomfort	-0.08	0.03	28	-2.83	0.01
Fatigue	0.02	0.01	28	1.39	0.17
Coping	0.00	0.10	28	-0.03	0.97
ME active	0.13	0.09	28	1.40	0.17

DF = degrees of freedom.

the rest period. For example, when the 24:00 to 06:00 rest period is considered as the reference, sleeping in the 06:00 to 12:00 rest period is predicted to result in 1.6 hours less sleep.

- *Factors predicting change in KSS score in the multivariate analysis*

In addition to sleep duration, the research team also ran the multivariate regression analysis on the change in KSS score. Similar to the analysis for the sleep duration, those factors that were significant in the univariate analysis were included in the multivariate analysis. Results of this analysis are provided in Table 17. The best predictor in this analysis was sleep duration as would

Table 17. Multivariate regression modeling for repeated measures change in KSS for each sleep period, with the 24:00 to 06:00 sleep period as a reference.

Predictors	Coefficient	Std. Error	DF	t-value	p-value
(Intercept)	-3.40	2.05	1060	-1.66	0.10
Sleep duration	0.30	0.08	1060	3.85	0.00
6:00-12:00 sleep period	-0.02	0.18	1060	-0.13	0.90
12:00-18:00 sleep period	0.57	0.45	1060	1.26	0.21
18:00-24:00 sleep period	-0.07	0.46	1060	-0.16	0.88
Anxious or stressed	-0.31	0.16	1060	-1.98	0.05
Hard to fall asleep	0.52	0.10	1060	5.11	0.00
Sleep disrupted	0.10	0.10	1060	1.01	0.31
Sleep depth	0.21	0.07	1060	2.83	0.00
Special disruption	0.28	0.16	1060	1.73	0.08
Age	0.01	0.02	44	0.37	0.71
BMI	0.11	0.03	44	3.11	0.00
Berlin OSA high risk	-0.75	0.49	44	-1.54	0.13
Pittsburgh Sleep Quality Index	-0.19	0.10	44	-1.93	0.06
Discomfort	0.05	0.07	44	0.75	0.46
Fatigue	-0.01	0.03	44	-0.41	0.69
General feeling	-0.03	0.10	44	-0.26	0.79
Anxiety cognitive	-0.11	0.05	44	-2.14	0.04
Shift work problems	-0.02	0.05	44	-0.39	0.70

be expected, but factors related to difficulty sleeping (hard to fall asleep and sleep depth), anxiety, and BMI were also associated with the change in KSS score.

3.4.1.3 Phase V Data—Identify Factors Predicting Best and Worst Sleepers

A total of 40 crew members participated in the new Phase V study.

The total recruitment for this study was not what had initially been proposed (N = 60). Several of the crew who completed the Phase V survey either did not complete Phase IV, or changed schedule from Phase IV to V (i.e., changed from front to back watch); thus, there was not a sufficient amount of data to complete all of the proposed analysis. While the research team ran the originally proposed analysis, the investigators are not confident on the validity of the results and therefore they are not included in this report.

Given the data the research team was able to collect in Phase V and the considerable amount of data collected in the Phase II through IV trials, the investigators do not consider this a major issue for the completion of this task or for the conclusions of the project overall.

The lack of recruitment in the Phase V trial was not due to a lack of effort on the part of the investigators. In addition to the multiple (up to seven) contacts with crew directly, other attempts were made to recruit crew members throughout the project. Representatives from the companies who had crew members who previously participated were contacted and asked to encourage their crew to participate in this new study. Two presentations were also made at two AWO events. At these meetings it was requested that companies with crew who participated in the Phase IV trial reach out to their employees to encourage them to participate in the new assessment.

3.4.2 Identify Those Who Changed Sleep Behaviors Since Phase IV

Crew who completed the survey in Phase V were asked whether they used the educational materials from Phase IV to change behavior and also, in more general terms, had they changed behaviors as a result of participating in Phase IV. Of those crew members surveyed, 35% said they had changed behavior since participating in the previous study (Table 18). Of particular interest was whether the crew had used the educational materials given to them at the end of Phase IV and if they had, how useful were they. Fifty-eight percent of the crew members reported using the educational materials and on average crew reported finding the Phase IV educational materials very useful.

In addition to identifying those who changed behavior, the research team was also interested in determining what type of practices that they changed. To do this, crew members were also asked open-ended questions about the behaviors that they had changed. These open-field responses are summarized in the following subsections.

Table 18. Crew survey responses related to changes in behavior between Phase IV and Phase V.

Question	N	No	Yes
Did you read education material	39	54%	46%
Did you use the education material	17	42%	58%
How useful did you find the material*			1.8 (0.7)
Did you change any behavior	40	65%	35%

*1 = very useful to 5 = not at all useful.

3.4.2.1 What Practices Did You Change?

The research team specifically asked crew to provide examples of the type of practices that they had *changed* since participating in the Phase IV study.

- Caffeine consumption: By far the most reported factor was caffeine use. Primarily consumption was reported as avoiding caffeine close to bedtime/end of watch, but in some cases crew said they avoided caffeine altogether.
- Light management: Light management was mentioned in several ways, including reducing light in the sleeping environment, going to bed before sunrise on the back watch, and a general comment that just mentioned "light exposure."
- Meals: Aspects of meals and nutrition were mentioned by several crew members, including reducing portion size, not eating big meals before bed, eating light dinners, or often just listed as "nutrition."
- Exercise: Exercise was also mentioned several times but no details of how, when, or where they exercised was given.
- Noise: Noise was reported in several ways including the use of earplugs and keeping voices down in the hallway when crew are sleeping.
- Sleep environment: Responses included the use of blackout shades, ear plugs, and good bedding (mattress, pillow, and linens).
- Other factors: There were also factors that were mentioned by only one crew member: reducing screen time, using continuous positive airway pressure (CPAP) every day, travel time at crew change, started taking melatonin, getting extra sleep when possible like when at fleet or dock; one crew member reported shifting schedule to the 7:5.

3.4.2.2 What Practices Do Crew Use?

There were quite a few open-ended questions for the crew in regard to training that they may have received and practices that they *used* that they thought were useful in their day-to-day lives on the vessel that improve their sleep.

- Caffeine consumption: Avoid caffeine close to bedtime.
- Light management: Avoid light during sleep (blackout shades), avoid light at shift changeover in morning.
- Meals: Nutrition, when to eat and drink.
- Exercise: That they should exercise.
- Noise: Policies to reduce noise.
- Other factors: Learning how sleep affects their work, travel time reduced at crew change, watch change protocols, learning about circadian rhythms.

3.4.2.3 Practices Related to Reporting Enough Rest?

Crew were asked whether they had any reporting technique they or their company used to report whether they had enough rest—only 20% reported yes. They were also asked how they reported this. Reporting included calling the office, telling relief, emailing the operations safety team, referring to the CEMS annual plan, telling the port captain and filling out a work/rest log.

3.4.3 Practices Crew Would Like to See Initiated or Learn About

Crew were also asked about what type of practices related to improving sleep they would like to see initiated or were interested in learning more about. At least in general terms, these data give the research team some idea as to the type of practices crew members might be willing to use and that may not meet with resistance if they were to be implemented.

3.4.3.1 Practices Crew Would Like Their Company to Initiate

Crew were asked if there were practices they would like to see initiated, and 44% said yes. Practices that they would like to see initiated included diet regimes; good mattresses, beds and pillows; three-watch wheelhouse; 4:8 watch rotation; 7:5 watch rotation; more noise reduction around engine room; noise reduction through floors; individual thermostats in bunk rooms; stopping chipping and grinding (tie ship up to do that); train crew to be thoughtful of those sleeping; shorter work cycle; fixing vibration while in shipyard; and better light insulation in the bunk rooms.

3.4.3.2 Practices Crew Were Interested in Learning About

The research team also asked crew whether there were practices that they would be interested in learning more about to improve sleep. Eighty percent of crew were interested in learning more about how to improve their sleep. Specifically they were interested in learning more about managing stress, meditation techniques, bio-feedback, relaxation, detailed meal plans/nutrition, how to fall asleep quicker, and anything to improve sleep quality.

3.5 Task 5. Best Practices to Enhance Sleep Efficiency in the Tug/Towboat/Barge Industry

The overarching goal of this project was to provide a compendium of *best practices* related to improving sleep efficiency in the tug/towboat/barge industry in the United States.

For the purposes of this report, the following definition and description of *best practice* is being used: a best practice is a technique or methodology that, through experience and research, has been proven to reliably lead to a desired result (merriam-webster.com), in this case adequate sleep/sleep efficiency. Best practices are often used to maintain quality as an alternative to mandatory legislated standards and can be based on self-assessment or benchmarking.

The need for best practices related to sleep/fatigue in the tug/towboat/barge industry is not new; in fact, 12 years ago the USCG published *Crew Endurance Management Practices: A Guide for Maritime Operations*, and 10 years ago an addendum was published. The basic proposal was for tug/towboat/barge operators to establish a CEMS that could be adopted across the industry to reduce fatigue on board vessels in order to reduce accidents that were due, at least in part, to this fatigue. Many of the recommendations involved improving the work environment and scheduling changes that would enhance sleep quality and duration. As part of this effort there was also a demonstration project that concluded "companies and vessels that followed CEMS practices achieved measurable reductions in all fatigue-related risk factors" (United States Department of Homeland Security/USCG, 2005) While the research team investigations indicated that many of the proposed best practices were adopted by some parts of the maritime industry, the surveys of 40 wheelhouse crew and management from 46 companies have established that CEMS is not well represented in the industry and there has been little attempt to measure if the recommended best practices in CEMS actually increased sleep time or reduced fatigue since this demonstration project. Furthermore, over the past few years, a number of advances have been made in understanding the key role of split-sleep schedules and napping and in new technologies and approaches to control fatigue and these findings will ideally now be incorporated into the best practices to enhance sleep duration and sleep efficiency.

With this prior work in mind, the approach proposed in this report is similar to that initiated by the USCG 12 years ago, and one that has been implemented in many industries since—the integration of best practices into an FRMS, similar to the CEMS program. Here, the goal is to provide clear guidance on what should be included in a plan, how to implement a plan, and then how to maintain it over time. The research suggests that while there are a few companies that did an excellent job at implementing many of the CEMS recommendations, the original CEMS program was either not implemented or poorly implemented by many companies within the industry. This was particularly the case with the main audience of the program—the crew—since it suggested there be a change in work schedule to allow for 7 to 8 hours of uninterrupted sleep. This change in work schedule was not initiated by most companies since crew were unable to achieve the 7 to 8 hours of sleep on the 6:6:6:6 square watch.

There is another important element to consider when examining why the recommendation in CEMS to change to a schedule that allows 7 to 8 hours of consecutive sleep was not implemented: there is no scientific evidence to suggest that a schedule that allows 7 to 8 hours of uninterrupted sleep is better than one that allows for 7- to 8-hours of sleep in more than one episode. For example, to the best of the research team's knowledge, there are no data that directly compare a rectangular two-watch schedule of 7:5:5:7 or 8:4:4:8 with the square watch 6:6:6:6, which is the primary schedule used by the majority (70%) of the companies surveyed as part of this report. In fact the 12:12 schedule was more commonly reported (20%) as an alternate to the 6:6:6:6 for many operations. Furthermore, there is a great deal of science-based research that has shown that even if individuals are provided with a 7 to 8 hour period of uninterrupted sleep, they will not be able to actually sleep for 7- to 8-hours, especially when sleep is attempted at the wrong circadian time of day. Therefore, whether on a square or rectangular watch, crews will still need to develop an anchor-sleep/nap-sleep strategy if they are going to be able to obtain 7 to 8 total hours of sleep per 24 hours.

The full development and implementation of an FRMS is beyond the scope of this project; the goal therefore is to provide basic guidelines for an FRMS, evidence for the proposed best practices to be included, and a plan for the implementation of these proposed best practices. The implementation of an FRMS would need to be undertaken on a company-by-company basis.

It should be noted that, for several of the practices proposed, there is a need for further investigation into their validity and effectiveness. Some of these practices are in use, while for others, such as alertness monitoring, the technology may not be ready for full-scale implementation, but there is clearly a need to push the science in this area forward at a greater rate.

The rest of Section 3.5 provides a compendium of 16 best practices for implementation by the tug/towboat/barge industry that collectively would be beneficial for managing fatigue and decreasing the occurrence of accidents, as well as for improving the safety and health of crew members. There are two overarching foundations that underlie the 16 best practices: a report from the USCG published 12 years ago, with an addendum published 10 years ago, which was an excellent start in defining the best practices and many of the research team's proposals mirror what was in the CEMS document. However, the CEMS needs to be updated to take into account the latest scientific information about controlling fatigue and improving sleep as this information pertains to tug/towboat/barge crew members. Preparation of an updated CEMS should be undertaken in cooperation with highly respected leaders in the academic and government communities of sleep specialists who have experience in working with industries (transportation and otherwise) in which fatigue and operating in a 24/7 environment is pervasive. In addition, the preparation of an updated CEMS should take advantage of individuals within the industry who have become highly educated in and aware of the importance of managing fatigue and who have a great deal of working knowledge on what best practices could or could not be implemented by the industry. Furthermore, over the past decade a great deal has been learned regarding best practices in other transportation modes (e.g., air, rail, and trucking) and the expertise of these individuals should be utilized in updating the CEMS program.

In detailing the best practices in the following sections, the research team has provided an opening "big picture" best practice (Section 3.5.1)—the establishment of an FRMS—which would include many of the specific best practices discussed in Sections 3.5.2 through 3.5.16. For each best practice the following is given: a description of the practice; the proposed audience for that practice; current practice and improvements to a practice, and the practice's implementation readiness/plan/considerations. A summary of the 16 proposed best practices is provided in Table 19.

Table 19. Summary of proposed best practices for improving sleep efficiency and reducing related fatigue.

Section	Practice	Audience	Current Practice/ Improvements	Implementation Readiness Level
3.5.1	FRMS	• Management • Policy makers • Crew • Unions	43% of survey companies not using CEMS/100% of companies to have FRMS	1-4
3.5.2	Education (examples) • Sleep biology • Split-sleep schedules • Sleep hygiene • Caffeine • Napping • Nutrition • Exercise • Sleep strategies • Stress/anxiety management	• Management • Crew • Families • Healthcare providers	43% of surveyed companies not using CEMS, perhaps some other programs, 83% of crew had CEMS training/update programs to address split sleep and 100% crew training and training ongoing yearly	2-3
3.5.3	Stress Management	• Management • Crew • Families • Healthcare providers	28% of companies surveyed had a program/100% to have program, clear guidelines for a program	1-2
3.5.4	Commuting	• Management • Crew	Drivers, hotel rooms/even if being driven crew is probably still awake	1-2
3.5.5	Fatigue Reporting/ Fitness for Duty	• Policy makers • Management • Crew	61% of companies have system/100% to have system	1-2
3.5.6	Wellness Program	• Management • Crew • Families • Healthcare providers	Health screening for licensure/ongoing health and wellness programs	2
3.5.7	Registered Medical Examiners	• Management • Policy makers	NA/need for consistency	2-3
3.5.8	Sleep Disorders Screening	• Management • Crew • Families • Healthcare providers	NA, some companies screening/all at-risk crew to be screened	1-4
3.5.9	Monitoring and Review of Practices	• Management • Policy makers • Crew	4% of surveyed companies currently monitor/100% of companies to monitor	3
3.5.10	Nutrition	• Management • Crew • Families • Healthcare providers	Diet plans, education/ encouragement similar to smoking cessation	2
3.5.11	Exercise/Physical Activity	• Management • Crew • Families • Healthcare providers	Exercise equipment available/is it encouraged or used	1-2

(continued on next page)

Table 19. (Continued).

3.5.12	Fatigue Modeling	• Management • Policy makers	NA/could be useful	2-3
3.5.13	Sleep Environment	• Management • Policy makers • Crew	Most in place/still ways to go according to crew	1
3.5.14	Sleep Strategies	• Management • Policy makers • Crew	~98% of crew on 6:6 use split sleep/what about other schedules 12:12, 8:4	1
3.5.15	Duty Hours	• Management • Policy makers	15 hours per day/NA	1
3.5.16	Reporting Missed Sleep	• Management • Dispatchers • Crew	Not currently reported/ should be reported	2-3

Implementation Readiness Levels (1–4): 1 = most ready to implement, 4 = least ready to implement.

In addition, where applicable as part of the current practice the research team also provides a brief summary of the outcome of the assessment conducted as part of this project that was used to support each proposed practice.

3.5.1 FRMS

Description

Each company should have an FRMS that covers all aspects of their operations and is embedded within an overall SMS.

A FRMS is a methodology based on scientific principles that will allow operators to manage the fatigue-related risks particular to their types of operations and context. It provides a viable alternative to traditional prescriptive duty time rules. Advancements in sleep science have brought a better understanding of the correlation between fatigue and performance, as well as fatigue mitigation methods.

Each company, regardless of size, is likely to already have an SMS. The research team would suggest that every company, regardless of size, develop an FRMS, which would be a key element and embedded in their SMS. It is anticipated that each company would develop their own FRMS based on size and operational requirements, but that each plan should include each of the key best practice elements shown in Figure 41.

Common elements to most FRMSs are:

- Is adequate sleep opportunity provided?
  - HOS, watch schedules, work-sleep environment, resources (staffing for work demands).
- Is adequate sleep obtained? Are fatigue-related behaviors monitored?
  - Health and wellness.
  - Self monitoring.
- Are fatigue-related events reported and analyzed?

Audience

An FRMS should address all key stakeholders at multiple levels, including:

- Executives and Management: The success—or lack thereof—depends a great deal on obtaining the "buy-in" of the leaders of any given company, regardless of size. If the development

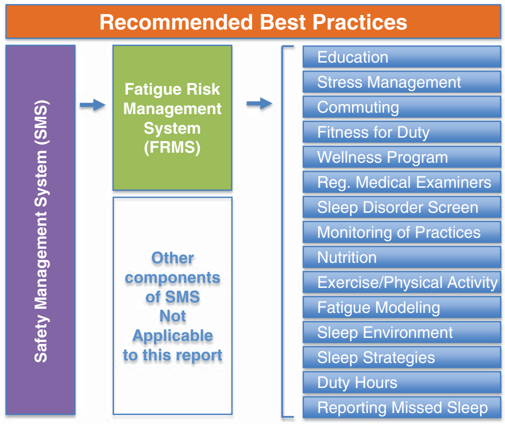

Figure 41. Diagram of the elements that an FRMS might include for the tug/towboat/barge industry.

of an FRMS is seen as the latest "fad" for advising all workers in a company about a new best practice, it will not be sustainable. There is a clear and consistent need to change the "culture" of much of the industry whereby fatigue management and obtaining sufficient and high-quality sleep becomes a standard operating procedure (SOP) in the way that wearing a lifejacket is an SOP when a crew member is on the vessel deck.

- Crew Members: All crew members, even those not on a watch schedule (e.g., engineers and cooks), should become knowledgeable about their company's FRMS so they can contribute to its success. Of particular importance is that the captains of each vessel are an integral component of the FRMS so they can lead their crews in its implementation.
- Physicians and Nurse Practitioners: These healthcare providers must recognize the importance of fatigue and sleep for the health and safety of the crews and they must reinforce this importance whenever they are examining and caring for the crew members, as well as other company employees.
- Human Resource/Safety and Dispatcher Personnel: It is critical that the FRMS be understood by non-crew members so they take into account the FRMS when overseeing the activities of the crews.
- Industrial Trade Organizations (e.g., AWO) and Policy Makers (e.g., USCG): These organizations need to be part of the tug/towboat/barge industry FRMS so they can provide input and assistance.

Current Practice and Improvements

After interviewing representatives from a number of companies ranging in size from 9 to 2,000+ employees, the research team found that there were few, if any, that reported having a formal FRMS. Many of the companies had many of the elements that would be included in a FRMS, but most did not have a formal written plan in relation to fatigue. Therefore, for many companies, there is a good foundation or base on which they can build a formal and clear FRMS, which can be continually improved and modified based on the individual company and workers' experience. Developing a formal FRMS will have the added benefit of engaging and exposing all company employees to the importance of sleep for health, safety, performance, and productivity. A key element for improving the pieces, as well as the whole of the FRMS, is for the entire industry to acknowledge that this cultural change in recognizing the importance of sleep and the development of best practices to improve it is good not only for workers' safety and health, but also for the bottom economic line of the company itself.

This is a very timely recommendation since the IMO is in the process of updating its guidelines on managing fatigue.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–4

The research team considers the readiness level for this particular best practice to be a Level 3 for most companies. In order to move this practice to implementation, there is need for agreement between regulators, unions, and industry on what an FRMS should include and what the requirements for successful execution would be. As noted in the introduction of this section, the base of the implementation plan should be an updated CEMS. However, since it is proposed that the CEMS be updated by a partnership of regulators, policy makers, sleep scientists, and knowledgeable industry leaders, the full development of an individual company's FRMS will probably take a few years. While the CEMS is being updated, many of the individual best practices discussed throughout this section can be advanced immediately.

The research team has used a range for readiness levels from 1 to 4 for the following reasons. Many companies could implement a fairly comprehensive FRMS now because they have many of the elements already in place. However, the complete implementation plan may need to wait for recommendations from the updated CEMS. In addition, other companies, which already have a few elements of an FRMS in place, may require more time to implement a plan. A clear guide to the implementation of an FRMS is required and should be developed to ensure consistency of implementation. Detailed documentation could be developed in conjunction with industry advocacy groups such as the AWO based on the present state of knowledge and could include an outline of this document. The AWO has already taken a lead role in this area, by supporting the research efforts of the research team and others in regards to improving sleep and managing fatigue.

It will be important to get as many companies within the industry and their management teams on board with developing and implementing an FRMS if it is to be successful. Possible explanations for the majority of survey respondents not answering "yes" to the question of whether there are any best practices related to improving sleep or fatigue management that they would like to see initiated are that they were not necessarily that interested in seeing new policies initiated (see Figure 42), or that they thought that their current polices were sufficient. The need for this kind of initial and ongoing buy-in can also be seen in the number of companies that did not provide CEMS training (only 43%).

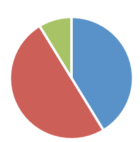

Figure 42. Responses for the question "Are there any best practices related to improving sleep (duration, quality and efficiency) or fatigue management that you would like to see initiated within your company?"

Labor unions were not consulted as part of this research, though input from the unions will be an important factor to be considered in the process of developing and implementing an FRMS. It should be noted that an FRMS should not be a one size fits all, rather an FRMS should be developed so that it fits the individual company's work environment. Indeed, for large companies that may have multiple modes of operations (e.g., some crews are on board vessels for continuous days while other crews return home after each duty of work), it may be necessary to develop tailored FRMSs that are appropriate for specific and different modes of operation.

3.5.2 Education

Description

Provide all stakeholders with education about the impact of poor sleep on fatigue, alertness, performance, health, and safety as well as provide details for fatigue mitigation strategies.

It would be preferable that there be a minimum standardized education curriculum or modules provided that are consistent across the industry. This should also be supplemented with additional education that is appropriate for different groups within the industry (e.g., management, crew, and families), different operations (e.g., harbor versus line, wheelhouse, or deckhand), age groups, and shift types.

Since there are new scientific discoveries and improvement in the understanding of sleep and fatigue, and development and validation of new fatigue mitigation strategies, education should be ongoing throughout employment. Continuing education on a regular basis could be as often as annually. This could also be supplemented with ongoing awareness programs that focus on a specific topic that occur on a weekly or monthly schedule.

Audience

Policy makers, companies, crew, family members, community, customers.

Current Practice and Improvements

Tug/Towboat/Barge Industry. Several approaches are taken on the issue of education related to sleep within the industry, including the CEMS developed by the USCG in 2003. The data collected as part of the current study indicates that there are some key needs in the CEMS and, in particular, in the way that the CEMS program is implemented. For example, CEMS training is not being provided by 43% of companies surveyed. There are also quite a few companies (39%) that do not have other practices, procedures, and/or training in place related to improving sleep (duration, quality, and efficiency) or fatigue management. Even in companies where CEMS is provided, the knowledge level of crew is poor (less than 50%, see Table 5).

Other Industries. Several other industries have developed guidelines for or sponsored the development of comprehensive education programs including, for example, the FRA, FAA, and the North American Fatigue Management Program. While review of these other programs are important in updating and developing programs within the tug/towboat/barge industry, the CEMS program forms a solid starting point for this industry.

Details of these programs can be found at:

- http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1020388
- https://railroadersleep.org/
- http://www.fmcsa.dot.gov/research-and-analysis/research/north-american-fatigue-management-program
- http://www.nafmp.com/en/

Based on the findings, the research team proposes that education and training materials related to improving sleep be updated based on current scientific literature and that the industry be provided with guidelines for how often crew should be given refresher training. Improvements could be made on several fronts in regard to education within the CEMS program, including updating content, updating delivery methods and format of materials, requiring knowledge acquisition standards, and requiring continuing education on an ongoing basis. Like all safety issues, repeated exposure to the importance of sleep for alertness, health, and safety will aid in conveying that it is important that the industry pays attention to this as an ongoing issue. Suggestions about strategies to improve sleep should be achievable, with the possibility of tailoring materials to specific operations. Some companies are doing this with the use of consulting firms to provide training, but it might be more efficient if guidelines and a curriculum and toolbox were put in place so that companies could deliver the training based on their needs and resources. It is also proposed that any new educational programs include tools to address differences in generational learning strategies, particularly since the safety critical positions tend to be held by those who are older and have more experience. While deck crew are also at risk of fatigue-related accidents, the barriers to good sleep are likely to be quite different than those for the wheelhouse crew. For example, deck crew tend to be younger and more likely to stay awake using mobile devices and playing video games, etc.

The goal of the education program is to provide students with sufficient information at an appropriate level to recognize and manage fatigue. Some of the key elements of an education program would include:

- Shared Responsibility [for crew to arrive to work fit for duty, for employer to provide adequate resources (i.e., bed, mattress, light control, strategies for noise and vibration reduction) and opportunity for rest].
- Sleep Biology.
- Sleep Strategies Such as Split-Sleep Schedules.
- Sleep Hygiene.
- Noise.
- Caffeine.
- Napping.
- Nutrition.
- Exercise.
- Sleep Disorders.
- Stress/Anxiety Management.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 2–3

It is the proposal of the research team that a new education program be developed, that includes clear guidelines on use, implementation, follow up, and ongoing training. While many of the elements required for a well-rounded education program are in place, there is a need to update these materials in both content and format. It will likely take some time to determine how this will occur and then to develop this new content. The research team suggests that a working group be brought together to develop a plan to do this; the group should include the USCG, industry partners such as the AWO, and key educators from some of the larger companies within the industry.

Education is simply one step in an FRMS and cannot be static or a one-size-fits-all approach. As such, the research team proposes that there be various levels of training depending on the audience with key elements of the education program that are included at all levels, but with other optional and tailored elements targeted to the audience. For example, basic education modules similar to the content in the CEMS (although this should be updated) could be developed and if a company requires a specific type of module they would develop the modules as part of their FRMS. Industry organizations such as the AWO could play a role in developing educational materials for the industry.

3.5.3 Stress/Anxiety Management

Description

A stress management program would provide support, training, guidance, and resources to crew on ways to handle both work and personal stress. Such a program could be provided via the company healthcare plan and, if this is not possible (small operations), then guidance of where crew could access these resources could be provided.

A specific practice related to stress is proposed since results from the current project suggest that stress in various forms negatively influences sleep duration. For example, stress related to health was associated with a short sleep duration. In addition, some crew expressed an interest in learning more about stress management and meditation techniques in the crew survey. Furthermore findings from the scientific literature clearly identify stress and anxiety as known contributing factors to poor sleep. There are also data to suggest that reducing stress and anxiety via various means results in improvements in sleep.

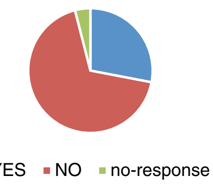

Figure 43. Responses to the survey question* "Does your company offer stress management training?" *as a proportion of all respondents.

Audience

Human resources personnel, management, dispatchers, crew members, family members.

Current Practice and Improvements

Tug/Towboat/Barge Industry. As part of the current study, management were surveyed about whether they offered stress management training, and the response to this question is provided in Figure 43. Only 28% of companies reported offering any form of training. From follow-up interviews it was determined that several companies offered resources that were available to crew 24/7 to deal with stress, using, for example, an Employee Assistance Program (EAP), which was confidential and provided crew with a toll-free number to call as needed; some companies considered the training provided in CEMS as adequate; and small companies reported that their constant communications with crew and close relationships allowed them to deal with stress on a more personal level. Techniques such as exercise were also reported as a way to manage stress, and companies provided equipment and encouraged crew to use it for this purpose in addition to the health benefits.

Given that only 28% of companies reported having stress management training and that stress and anxiety were identified as factors impacting sleep duration, there is a clear need for companies to address this issue and provide access and encouragement to use support services that may aid crew in dealing with stress from various sources.

Other Industries. The research team did not directly assess stress management programs within other industries. Many industries have a standard EAP provided as part of their employee benefits. For example, Northwestern University provides such an EAP (http://www.northwestern.edu/hr/work-life/nu-life-matters.html).

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–2

For some companies, this will be a relatively easy practice to implement. Information about the impact of stress on sleep should be integrated into any education program related to sleep and fatigue.

For those companies that do not have such coverage, they could either have their human resources look into what would be required in setting up such a plan or they could provide their crew with information about local resources available in their area. At a minimum, they should have stress management as part of any education related to sleep and fatigue.

Companies could work with healthcare providers to determine whether this type of coverage is available in their healthcare plans and make sure that crew are aware of the program and how they may access these resources.

Crew would need to be aware that such a resource is available and feel confident that they could access such a resource without any penalty and with confidentiality. Some companies handle this by having programs that are completely independent from their company (EAP).

A major consideration is the source of the stress/anxiety. If the stress is a result of organizational or operational factors, then stress management techniques may well be able to help a crew member deal with the stress. However, these techniques may not deal with the root source of the stress. Determining the cause of an individual's stress and how this may be influencing sleep is potentially difficult to determine since there may be a multitude of factors that contribute to stress. For example, there is little a company can do to help with domestic conflict that may be causing stress, but they can deal with stress related to conflict on a vessel between crew.

Tired crew are also more likely to find it difficult to deal with conflict as sleep loss is known to influence mood, irritability, and professionalism, which may heighten tension. Education about the effects of sleep on stress and, conversely, the effects of stress on sleep, specifically in the context of interactions with others, could help crew manage tension from seemingly moody and cranky co-workers.

Given that some of the stress that crew members may experience is separation from family, it is important that family members also have access to these resources. So that family/friends can be mindful that interactions that they may have with crew members while they are away may impact sleep and ultimately safety, health, and well-being.

3.5.4 Commuting

Description

A best practice(s) related to commuting would aim to limit the impact of the commute on sleep and/or to mitigate the risks associated with driving after being awake for an extended period (more than 16 consecutive hours). "Commute" is defined as travel between home and the vessel.

For crew who live on the vessel, the commute is only an issue every 7 to 30 days depending on the speed of the schedule rotation. However, in this case commute times are likely to be much longer. For example, a crewmember could be awake for over 18 hours if they woke at 06:00, left home at 12:00, drove for 5 hours (17:00) to the vessel and then worked between 18:00 and 24:00.

For crew who commute daily (primarily crew on the 12:12 watch schedule), there is the potential for a commute time to have significant impact on the time available to sleep, especially if the commute is an hour or more each way.

Practices include but are not limited to:

- Require crew who travel a long distance between home and work, to sleep for at least 6 hours prior to beginning work or after completing work, if that commute, inclusive of work time, will result in 16 hours or more of prior wakefulness.
  - This would require providing access to facilities for crew members to sleep (hotel room, cabin, or barracks).
- Provide drivers or some other similar form of transport to crew members to get them home at the end of a rotation.

Audience

Management, crew members, human resources, families.

Current Practice and Improvements

Tug/Towboat/Barge Industry. In the tug/towboat/barge industry there are two different issues related to commute time: one is for those crew members who may commute daily

Table 20. Do you ever feel unsafe when traveling to and from work?

To/From Work	Almost Never	Quite Seldom	Quite Often	Almost Always
Arrival	78.7%	14.8%	4.1%	2.4%
Departure	73.8%	16.4%	5.7%	4.1%

(typically those on the 12:12 schedules); the other is for those crew who may commute less often on their way to and from home on a longer rotation on the vessels 7–30 days (twice per rotation on and off the boat).

In both Phase IV and Phase V studies, the research team asked crew members about commute times. For Phase IV (N = 124), the average commute time was quite long at 5.7 ± 0.3 hours. We also asked crew members how they commuted and whether they felt unsafe when traveling to and from work (Table 20). Crew members commuted to the vessel in various ways: 4% by public transport, 54% private, 12.9% private and public, 25.8% company. Note: many people used rental cars and indicated that they were paid for by themselves or by their company.

Crew may be adequately rested when they set out to commute to work, but depending on the commute time, they may not arrive rested and have been awake for extended periods.

Some companies provide accommodations for crew so that they can arrive early for shift changes and rest on site before boarding.

Commute times are of particular concern for operations where crew are leaving the vessel and commuting between the vessel and home every day. Many crew members working 12:12 schedules are in this situation. Even in laboratory conditions when individuals have no competing activities, such as commute time, they are limited in the amount of sleep they are able to obtain during the day. Further research should be conducted to determine how much of an issue commute time is for crew who return home each day to rest.

Multiple strategies might be able to be combined in this situation—such as napping.

Commute times were not covered in the survey to management, but during several interviews, this was raised as a topic of concern that companies addressed in various ways depending on the circumstances. For example, one company reported a case where a crew member left home at 02:00 for a 07:00 crew change.

While it seems that in most cases companies try to address the issue of commute time, there is always room for improvement. Education for all stakeholders to improve the understanding of the risks associated with commuting should be implemented. Companies should be aware of the commute times of their crew so that they can assess the risks and develop appropriate mitigation strategies accordingly.

Other Industries. The research team did not directly assess programs within other industries that address the issue of commuting, since there was sufficient information available from the tug/towboat/barge industry to make a proposal.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–2

Most companies could easily and quickly implement plans to address commute time, so the research team considers this to be at a readiness level of 2. Based on the management survey and interviews, commute time practices are currently employed by many companies within the tug/towboat/barge industry. It would just be a matter of formalizing them into the FRMS and education programs.

Commuting practices would be included as a factor in the FRMS and be covered in the education component as well as having its own policies/practices. Companies would need to work closely with their crew members to conduct an assessment of the risks for each employee and to develop a mitigation plan based on the level of risk and the specific scenario.

There are several issues to consider when implementing commute time best practices. For example, crew may be eager to return home and not like the idea of being told that they are required to sleep for 6 hours prior to beginning their commute. To address this, companies could consider paying for the crew member to sleep before heading home. It is difficult for management to know when a crew member woke prior to starting their commute and so educating the crew about the risks in this case would be important so that they can make appropriate decisions and modify their behavior accordingly. Since there is the potential for many different scenarios, a rule cannot be made for all situations, but if management and crew are educated about how to assess the risks associated with commute time, they will be able to work together to mitigate the risks.

3.5.5 Fatigue Reporting/Fitness for Duty

Description

A key premise of a fatigue risk management plan is the idea that there is a shared responsibility of crew members to report fit for duty and for companies/policy makers to allow adequate opportunity for rest. For this to work there also needs to be the opportunity for crew members to openly report when they are fatigued without penalty (unless of course a crew member reports repeatedly unfit for duty).

Develop a policy and related procedures for crew to report when they have not been able to obtain adequate rest and/or are fatigued. Having such a reporting policy requires that there be procedures and guidelines for what the crew member and management are to do if crew report being at risk.

There is some overlap in the best practices related to fitness for duty and those for health/well-being. There are many reasons a crew member could be fatigued to such a degree that they are considered unfit for duty, if they have an underlying health issue(s) that impacts sleep (sleep disorders, pain, stress, medication, mood disorders), for example. This type of issue should be determined in their medical exams for licensure. However, given that changes in health/well-being can occur more frequently than these exams, this should be an ongoing consideration.

Audience

Management, captains, crew, human resources, dispatchers.

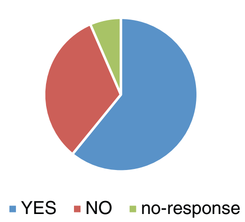

Figure 44. Responses to the survey question "Are crew members encouraged to report excessive sleepiness while they are working?"

Current Practice and Improvements

Tug/Towboat/Barge Industry. There is no evidence to suggest that the tug/towboat/barge industry has any requirements for crew to report if they are fatigued. However, based on survey responses and interviews, it seems that some companies do have procedures in place or at least encourage crew to report if they have excessive sleepiness (Figure 44). While 61% of surveyed companies indicated that they encourage reporting, there was not always a clear policy that they could point to on how this was to be handled. There are also reports that a captain can choose to manage such situations on a case-by-case basis, but that there may not be a clear procedure in place.

Some companies reported that their captains have the authority to monitor rest times and provide additional rest where necessary; another reported have a “floating” crew member who could cover when necessary.

The research team also interviewed managers from companies that had open water operations and, in these cases, companies had crew report whether they were working or resting in 15-minute increments across the day on a spreadsheet, although it was unclear from the interview what they did with this information if crew members reported not sleeping or what the criteria were for intervention.

Other Industries. Perhaps the best example from another industry is the aviation industry. The FAA requires that pilots report fit for duty (FAA 2012) (http://www.faa.gov/about/office_org/headquarters_offices/agc/pol_adjudication/agc200/Part117/Part117_General/media/Final%20Flight%20Duty%20Rule.pdf).

As defined, “fit for duty” means physiologically and mentally prepared and capable of performing assigned duties in flight with the highest degree of safety.

FAR 117.5 Fitness for duty.

(a) Each flightcrew member must report for any flight duty period rested and prepared to perform his or her assigned duties.
(b) No certificate holder may assign and no flightcrew member may accept assignment to a flight duty period if the flightcrew member has reported for a flight duty period too fatigued to safely perform his or her assigned duties.
(c) No certificate holder may permit a flightcrew member to continue a flight duty period if the flightcrew member has reported him or herself too fatigued to continue the assigned flight duty period.
(d) As part of the dispatch or flight release, as applicable, each flightcrew member must affirmatively state he or she is fit for duty prior to commencing flight.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–2

The concept of fitness for duty may need to become part of the safety culture within the tug/towboat/barge industry. While key elements (reporting at boarding of medical issues, medications) of such a program are in place as part of many SMS, a formal program with dissemination to all stakeholders would be beneficial.

As mentioned above, some companies have crew members report changes in their medical condition and medication at boarding and disembarking from the vessel as part of their SMS; however, fitness for duty should be assessed at every shift change and, for crew who live on the vessel, an assessment at the beginning and end of their rotation may not be adequate.

Adequate resources need to be available; therefore, each company would need to develop a plan of how to handle situations where a crew member reported fatigue. Given the multitude of operational settings, there may not be a single clear solution for how to manage a crew member requiring more rest. For example, if a captain reported that he had been unable to sleep at the time of shift start and was too fatigued to start, would the pilot be able to extend his/her shift to allow the captain more time to sleep. This is not an uncommon practice. If this was the case then is the pilot now at greater risk of fatigue and if so who will make that assessment?

A company may want to monitor this type of reporting so that it can determine whether it has operations or crew that may be more prone to fatigue reporting. For example, particular stretches of river that require greater concentration, weather conditions, or other factors may lend themselves to instances of reduced rest. With this information, the company would be able to act proactively to implement changes to current practices to reduce the instances of fatigue reporting; for example, changing schedules, sending crew for health screens or treatment, and being prepared with replacement crew.

3.5.6 Wellness Program

Description

Provide access to wellness programs that promote physical and mental health within the industry.

Improving health is likely to have significant impacts on sleep and fatigue. Given the complex relationship between sleep and health, such that health status can impact sleep and that poor sleep can have negative effects on health, the promotion of healthy behaviors and access to medical care would be a key element in any FRMS. This is particularly true for shift workers who are at a higher risk of many cardio-metabolic disease risk factors (obesity, elevated blood pressure) as well as diseases/disorders including diabetes, cancer, and mental health issues (Wang et al. 2013, Brum et al. 2015). This increased risk is thought to be the result of a combination of chronic circadian disruption and sleep loss.

This is such an important issue that the Office of Disease Prevention and Health Promotion has objectives for educational and community-based programs. The Office of Disease Prevention and Health Promotion's "Healthy People 2020" included a goal of increasing the number of workplaces that offer health promotion programs and increasing the number of employees who participate in them (http://www.healthypeople.gov/2020/About-Healthy-People).

Audience

Policy makers, management, crew, human resources, families.

Current Practice and Improvements

Tug/Towboat/Barge Industry. As part of the management survey, the research team determined that 67% of companies reported that they indeed did have a wellness program. The team also spoke with two occupational nurses that worked with larger companies within the industry to discuss the type of programs that were offered. These included nutrition, exercise, sleep disorder screening, tracking medications, and conditions that may impact workers' ability to safely do their jobs.

There are several initiatives to encourage crew to quit smoking; for example, some companies incentivize employees to not smoke.

They also provide access to mental health services, meal plans, and ongoing encouragement to lead a healthier lifestyle.

Other Industries. The research team did not directly assess wellness programs in other industries, since there was sufficient information available from our review of the literature and the tug/towboat/barge industry to make a proposal.

The recent report "Promising and Best Practices in Total Worker Health™: Workshop and Summary" from The National Academies of Sciences, Engineering, and Medicine is a summary resource on the latest information on workplace wellness (IOM 2014).

In the report, the authors suggest that most workplace programs can be divided into four main categories, which follow. The research team has included examples that are relevant to the tug/towboat/barge industry for each of these categories and propose including them in a wellness program to improve sleep quality.

- Support health behaviors—for example, provide access to health screening and promote a healthy environment such as healthy food options and exercise equipment.

- Prevent work-related illness and injuries—for example, control typical workplace hazards and provide adequate sleeping quarters.
- Reduce work-related stress—for example, encourage social support between workers, and work-family balance.
- Provide work-related resources and opportunities—for example, medical benefits.

Similarly the article "Implementation of a Worksite Wellness Program Targeting Small Businesses: The Pinnacol Assurance Health Risk Management Study" (Newman et al. 2015) identified sleeping problems, chronic fatigue, and cardio-metabolic health measures as key factors that could be modifiable by such programs (http://journals.lww.com/joem/Fulltext/2015/01000/Implementation_of_a_Worksite_Wellness_Program.3.aspx).

It is unclear whether all companies monitor the success of their wellness program to any degree.

More could be done to work with crew with chronic health conditions to manage and optimize medication regimes given the constant transition in the work schedule between day and night, as well as altered eating patterns etc.

Given the health risks associated with shift work, it will be important to provide these programs to all crew members. For example, a goal of such a program may be to slow the trajectory of obesity in this industry; the research indicates that the wheelhouse crew tend to be older and have a higher prevalence of morbid obesity placing them at greater risk of OSA and cardio-metabolic disease. Since the average number of years of employment on the split schedule of the wheelhouse crew that were surveyed is about 26 years, there is a lot of potential to work that can be done with younger crew members to reduce morbid obesity in older age and maintain a healthier potentially more productive workforce.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–2

For a large portion of the industry with wellness programs in place, this best practice has a readiness level of 1. For companies without wellness programs, it could be relatively easy to implement and these companies could be considered to be at a readiness level of 2. Costs of such programs are always a consideration (as in who will be responsible for covering the cost).

3.5.7 Registered and Certified Medical Examiners

Description

Require registered/approved medical examiners for compulsory medical examinations for licensure.

This issue has been raised on several occasions in relation to sleep disorders, excessive daytime sleepiness, and other ways that health problems related to sleep, fatigue, and alertness could be addressed in a systematic fashion.

Audience

Policy makers, management, human resources, crew members.

Current Practice and Improvements

Tug/Towboat/Barge Industry. Medical examinations are required for licensure.

According to the USCG's National Maritime Center (NMC), current requirements are that "the medical provider completing the required examination must be a physician, physician assistant, or nurse practitioner who is licensed in the United States or one of the U.S. territories." However, there is no requirement for a medical provider to have any other special training or certification to complete the required health forms. (http://www.uscg.mil/nmc/medical/default.asp)

The AWO and one of its working groups on Mariner Licensing & Medical Standards, in collaboration with the NMC, has developed recommendations for both companies and mariners.

The recommendations of the AWO working group for companies can be found at:

http://americanwaterways.com/sites/default/files/Best%20Practices%20Companies.pdf

Other Industries. There is certainly precedence for requiring examination by a registered or certified medical examiner for licensure in other modes of transportation.

- FMCSA: https://nationalregistry.fmcsa.dot.gov/NRPublicUI/home.seam
- FAA: https://www.faa.gov/pilots/amelocator/

The suggestion would be for the use of registered, qualified, and trained medical professionals to conduct licensure medical examinations.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 2–3

The creation of a registry of qualified and trained medical examiners, similar to that recently created by the FMCSA, would need to be established. This brings with it the issue of availability of such trained professionals.

Given that there is currently no such requirement for the tug/towboat/barge industry and that changes to policy may take a long time, it could prove to be beneficial for a company to have consistency in who examines their crew. This means that a company could have their crew examined by the same physicians. In fact, some companies have all of their crew examined at a particular location often as part of a larger wellness program.

Although the research team recognizes that for some groups there is certainly the opportunity for conflict if a company dictates a particular physician(s) do the medical examinations for their crew.

There are arguments both for and against using registered medical examiners, which will not be dealt with in this report.

3.5.8 Sleep Disorders Screening

Description

Those at risk for OSA should be identified and screened by an American Academy of Sleep Medicine (AASM) accredited program, and appropriate treatment should be initiated and monitored for compliance.

Initial focus for screening could be given to wheelhouse crew due to the potential for high risk—based on age and prevalence of obesity (Table 21). However, it would be useful for all at-risk crew members to be screened.

Audience

Policy makers, companies, and crew members.

While there is certainly precedence for rulemaking related to the detection and treatment of OSA by policy makers (e.g., FAA), there is debate on what such a "rule" would look like.

In order to address this issue in a timely manner, there could be some alternatives to such a regulator rule. For example, companies or the individual crew could take on the responsibility of dealing with this issue and be out front of the regulator. Companies could require screening of at-risk individuals for sleep disordered breathing as part of their eligibility for employment, or

Table 21. The percentage of individuals by BMI category for the general population (*taken from National Health and Nutrition Examination Survey 2007–2008) (www.cdc.gov/nhanes/search/nhanes07_08.aspx) and for crew members in this study; risk of sleep apnea as determined by the Berlin questionnaire for each BMI category.

Category	BMI Range	% of General Population	% of Crew	Berlin Sleep Apnea Risk
Overweight	25-29.9	34.2%	36.1%	17%
Obese	30+	33.8%	47.9%	57%
Morbidly Obese	>40	5.7%	10.1%	75%

an individual could choose to be screened and treated based on self-interest, given the scientific evidence and consensus of the medical community for the benefits to health and well-being of addressing sleep disorders.

Current Practice and Improvements

Tug/Towboat/Barge Industry. Based on the survey of management, 26% of companies already offered "screening, training, or education on sleep disorders." In fact, there are also some companies that already have screening programs for OSA in place and others that are planning to initiate such a program. As part of this project, the research team spoke to several key personnel involved in these programs about the details of the program and the decision-making processes involved in implementing these programs (Tables 6 and 8).

The company spoken to with the most developed OSA screening program was screening wheelhouse crew with a BMI ≥40. At the time of the interviews, they had expressed plans to move the BMI criteria to a BMI ≥35 once they had been able to screen all of those wheelhouse crew with the higher BMI.

Data from the Phase IV study of wheelhouse crew indicated that 10% of those surveyed had a BMI ≥40, while 48% had a BMI ≥30 (Table 21), and 28.8% had a BMI ≥35. Given the high rate of obesity in this population compared to population norms, there are a large number of crew members and companies that such a program/policy would impact.

Other Industries. Within other transportation sectors attempts have been made at rulemaking in relation to OSA. The NTSB has recommended that rules be made in several industries. To date, the only sector that has a clear rule is the FAA. However, several other regulatory organizations have proposed rules, both the FRA and the FMCSA (https://www.federalregister.gov/articles/2012/04/20/2012-9555/proposed-recommendations-on-obstructive-sleep-apnea) and have met with various degrees of controversy, primarily related to the lack of scientific evidence that diagnosis and treatment of OSA will impact accident risk.

A joint task force including the ACS, American College of Occupational and Environmental Medicine, and the National Sleep Foundation published a statement in 2006 on sleep apnea and commercial motor vehicle operations (Hartenbaum et al. 2006). Then, in 2008, the FMCSA Medical Review Board held a meeting that recommended that the FMCSA require screening for OSA in all drivers with a BMI over 30 (http://www.mrb.fmcsa.dot.gov/documents/Final_Meet_Min_Jan28_2008_MRB_Meet_Revised_Upd_2-19-09.pdf). This was followed up in 2009 by the NTSB with a Safety Statement (http://www.ntsb.gov/safety/safety-recs/RecLetters/H09_15_16.pdf) in regards to OSA that indicated no action had yet been taken on this issue. More recently, in 2015, there was a follow-up to the 2006 statement with a letter to the editor (Hartenbaum 2015) that included a link to a bulletin from the FMCSA related to OSA (https://nationalregistry.

fmcsa.dot.gov/NRPublicUI/documents/OSA%20Bulletin%20to%20MEs%20and%20Training%20Organizations-01122015.pdf).

There are some companies even within the tug/towboat/barge industry that have been ahead of the regulators and developed their own sleep disorders screening programs. Within other sectors of the transportation industry, Schneider National Inc. is considered by many to have the gold standard for programs to manage OSA in the transportation sector. The research team spent some time with representatives from Schneider National Inc. to discuss their programs for screening for OSA and managing fatigue. There were two interviews with representatives from Schneider.

Representatives from Schneider National Inc., a large truckload carrier in Green Bay, Wisconsin, described the programs that they have related to dealing with the issue of OSA. Using data from 4 years of truck accidents at Schneider, they conducted a causal factor analysis and determined that fatigue played a role in 36% of high impact crashes. In 2004, they used an OSA questionnaire to provide a preliminary assessment of possible OSA in drivers, which was followed up with polysomnographic testing. Now they have a fleet-wide program and have data to indicate that crash rate and severity are down as are healthcare costs. In 2014, it is estimated that Schneider National Inc. had 2,300 CPAP users in their company. They also mentioned that they had a fatigue management system that included training and awareness of fatigue, health and wellness coaching, and ongoing training.

The research team also visited Schneider National Inc. and had a day of in-person meetings with Schneider representatives. During this in-person meeting, the Schneider National team spoke about the impact and effectiveness of their sleep apnea screening program (e.g., reduction in incidents/accidents, improvements in sleepiness, reduction in body weight, other factors to be identified). If compliance (CPAP use for 4 hours a night, up to 70% of nights) to treatment of OSA is considered a measure of effectiveness, then Schneider reports that they have excellent compliance with greater than 80% of drivers with OSA being compliant. They also report that they spend approximately 4 million dollars a year on this program, but that the benefits include savings in healthcare cost of $250/driver/month, a 30% reduction in accident rates, and a 48% reduction in median cost of crashes. Another important factor to consider is that they are also able to retain drivers with OSA longer than other drivers, and the drivers report improvements in quality of life with treatment. A factor that they believe is helpful in the success of their program has been the use of a driver mentor program, which involves providing any newly diagnosed driver with a driver mentor who also has OSA. They also indicated that they believe that there needs to be greater consensus in the sleep medicine field for defining diagnoses and treatment of OSA and delivering what are the important cut-offs for the severity of OSA that requires treatment.

Much of the debate related to the creation of a rule to screen for OSA comes from a lack of clear scientific evidence that such a program will impact safety in respective industries. This is further compounded by the lack of consensus in the sleep medicine field on who should be screened (BMI only or BMI + other criteria such as neck circumference, elevated blood pressure), what degree of OSA [apnea hypopnea index of >5 (mild) or >15(moderate)] puts someone at risk of accidents, and who will benefit from treatment. This could even be extended to the type of treatment; while CPAP is the standard treatment, there are other options including upper airway surgery and oral appliances.

In addition, when is someone considered to be adequately treated? Does there need to be improvements in sleepiness and if so what test should be used to determine sleepiness?

In fact, this lack of consensus by the sleep medicine community was perhaps one of the most important points that the research team took away from their meetings with Schneider.

Having data on whether OSA is a factor linked to safety in the tug/towboat/barge industry would be useful, but may be difficult to get since there does not appear to be systematic monitoring or reporting.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–4

The readiness level for this particular best practice could be considered to range from 1–4 depending on how it is to be implemented. It could be considered to be at a Level 1 for individual crew members, since they are able to make the decision themselves. In addition, some companies within the tug/towboat/barge industry are already at a Level 1, because they already require such screening as part of company policy. Depending on whether a company had the infrastructure in place to roll out a companywide policy, individual companies could be at a Level 2 or Level 3.

However, policy makers could be considered to be at a Level 4. A recent bill (H.R. 3095) passed and signed into law that "authorizes the Secretary of Transportation (DOT) to implement or enforce a requirement providing for the screening, testing, or treatment of individuals operating commercial motor vehicles for sleep disorders (including OSA) only if it is adopted pursuant to a rulemaking proceeding" (https://www.govtrack.us/congress/bills/113/hr3095/summary).

There is considerable debate associated with rulemaking in regards to screening for OSA. However, there is enough evidence that diagnosis and treatment of clinically significant OSA is beneficial for health and not just work safety. Therefore, it is in an individual's best interest to be tested if they are at risk and to work with their physician to determine the best treatment options.

From the policy makers' standpoint, the requirements for creating and implementing a rule related to sleep disordered breathing is at multiple levels. Such screening could become part of the medical exams required for licensure.

Similar to policy makers' companies will need to have a clear rule that includes who will be screened (i.e., BMI ≥35) and where they should be screened (i.e., any accredited program/ board-certified physician or whether a specific program/physician).

In order for crew to take the initiative to be screened for sleep disordered breathing or other sleep disorders, they need to be aware of the risks and benefits of being screened and treated. More importantly, they need to be aware of the risks/benefits of not being screened and treated. Therefore, it would be important for there to be a clear and consistent message and process for disseminating information and providing education to crew members, across the industry as a whole.

Many crew belong to a union and therefore it will be important to engage the unions in any planned action.

Given that many crew members work for up to 30 consecutive days and sleep on a split schedule (twice/day) with sleep periods during the day and the night time, when should crew members have their screening polysomnographic testing? Traditionally the screening is done during conventional sleep hours. However, there is some evidence to suggest that OSA severity may be influenced by the time of day that a person is sleeping (Paciorek et al. 2011). The severity of OSA when sleeping during the day is greater than when measured at night in the same person. This also has implications for treatment, since if the severity of OSA is greater during the day, perhaps CPAP would need to be tailored to when the person is sleeping, although this is less of a concern with self-titrating machines.

The idea of what is the most appropriate time of day for crew members to be screened for OSA is further supported by data from the Phase IV trial indicating that 41% of wheelhouse crew members scored as high risk for having OSA using the Berlin questionnaire. Pilots/back watch were more likely to be at high risk for OSA (51.3%) than captains/front watch (36.4%), although this difference was not significant ($p = 0.12$). In addition, as part of the Berlin questionnaire, the research team asked respondents, "Have you ever nodded off or fallen asleep while driving a vehicle?" And if yes, then "How often does it occur?" No clarification was given to the crew members as to the type of vehicle being operated. Falling asleep or nodding off while driving a vehicle was reported by 29% of the participants on the Berlin questionnaire. Pilots/back watch were at 3.4 times increased odds (95% CI: 1.5–7.7) of reporting falling asleep while driving than captains/front watch (Reid et al. 2013).

There is a need for further research on the effects of OSA on health and safety in the tug/towboat/barge industry. A key part of this research should be to provide better delineation of the benefits, whether they be for financial, health, or safety reasons, to all stakeholders.

3.5.9 Monitoring and Review of Practices

Description

As part of the FRMS, there should be regular monitoring and review of each practice against an agreed-upon metric. This will provide information in order to assess the success of a particular practice and determine whether it needs to be modified.

Audience

Policy makers, management, human resources, and even the crew members themselves.

Current Practice and Improvements

Tug/Towboat/Barge Industry. When asked as part of the management survey whether their company had any concrete way of assessing the impact of their current practices related to sleep and fatigue management, the overwhelming response was "no" or "no response" and only two companies responded "yes" (see management survey responses, question 55, Appendix C).

Although anecdotally, the management that were surveyed reported that on average many of the practices they had in place were "somewhat effective" (see Appendix C). In addition, the management that were interviewed often mentioned that because they had long-standing relationships with their crew and that they often interacted with them daily, they knew which practices were working or not and could intervene where necessary.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 3

The premise of this proposal is that it may be counterproductive to implement a practice and then never assess whether it is working or whether it requires modification. In addition, since the science of sleep and fatigue is an ever-developing field, the integration of new evidence to support modifying or even rejecting a particular practice should be considered on an ongoing basis. A good example for this is fatigue mitigating strategies.

Not every practice is going to be perfect for every situation and one size does not fit all, within an organization there may be trial and error so there should be an expectation that there may need to be modifications and improvements made to practices based on individual and operational requirements.

This can be illustrated with an example from aviation. While for some operations the current HOS rules base maximum hours of work on where the pilot sleeps, there is no rule to require the pilot to sleep in that location. For example, a sleeping space where the pilot can lay down in private is valued more for rest and allows the pilot to work longer than if they rested in a business class seat, but crew may prefer to rest in the business class seat. However, since the private space is available, the pilot is able to work the longer hours, which seems counterproductive to the intent of the original rule. Another example from the aviation industry occurs when flight operations go outside the current HOS rules. Each company is able to provide evidence against an agreed-upon standard to indicate whether a particular operation is as safe as another similar operation that does fit within the rule.

Decision makers should also be open to review and modify rules when it would improve safety. Circumstance change and management of the risks associated with fatigue require some flexibility in the system within certain predetermined parameters and with guidance.

The idea of flexibility also applies at the crew level. For example, it would be preferable if crew were open to try new strategies and to assess for themselves whether a practice works for them rather than either blindly following a recommendation if it is not working for them or even detrimental to their ability to rest.

3.5.10 Nutrition

Description

The importance of good nutrition for health and sleep is covered in the CEMS, and the importance of a healthy diet for sleep is well recognized.

Audience

Management, crew members (especially cooks), human resources, and family members

Current Practice and Improvements

While some companies may provide educational materials on the importance of nutrition, all should. In addition, some companies provide healthy food options for their crews; there is little reason why all companies cannot provide at least *some* healthy meal options.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 2

Providing crews with healthy food choices can easily be implemented, although getting crew members to select the healthy diet choices may be difficult. But all companies can immediately put in place this best practice. Although the possible increase in food costs might be a barrier, the overall benefit (e.g., decrease in medical insurance costs) of a healthy diet for the workers, as well as for the economic health of a company, should outweigh this barrier if management and employees are educated. In any case, providing all crews with healthy food choices should be part of an overall FRMS.

Companies should assess themselves regarding whether or not their crew members are taking advantage of the provision of healthy food options and if they are not, more education and promotion about the importance of nutrition should be provided.

Wellness programs can provide access to dietary specialists who can help provide guidance on how best to make changes to dietary habits.

In the field of sleep and circadian rhythms, the impact of not only the macronutrient content (fat content, carbohydrates, etc.) of food but also the time that meals are consumed is being considered for development as interventions to reduce obesity and other poor health outcomes such as high blood pressure and poor glucose metabolism (Amani and Gill 2013, Grandner et al. 2013, Nedeltcheva and Scheer 2014).

Shift work and the associated disruption to eating schedule have long been considered to be a potential cause of many of the poor health outcomes in shift workers. However, surprisingly little has been done to develop test paradigms that might help workers optimize the schedule of their eating to work in tune with the timing of their internal biology rather than against it.

3.5.11 Exercise/Physical Activity

Description

Encouraging physical activity and providing the resources, both on and off the vessel, to exercise.

There is strong scientific evidence that exercise has a positive impact on sleep, health, and even on severity of sleep disorders such as OSA (Quan et al. 2007, Reid et al. 2010, Kredlow et al. 2015, Loprinzi 2015). There is a clear need for practices and even interventions related to increasing physical activity/exercise and reducing energy intake (Table 21) given the high rate of obesity (58 have a BMI >30) in wheelhouse crew in this industry.

Audience

Management, crew, human resources, family members

Current Practice and Improvements

Tug/Towboat/Barge Industry. There is no industry-wide practice for providing exercise equipment for crew members who are on the vessels for many days. Sixty-five percent of companies surveyed reported (see Section 3.2.1.1.4) providing training or access to exercise equipment to crew members. Providing at least some minimum exercise equipment or training on effective exercise routines to increase levels of physical activity that could be done on the vessel without equipment could readily be implemented.

At least two companies surveyed/interviewed reported that they had initiated a program in which they provided some of their crew members with physical activity monitors, and, in one case, several hours of a personal trainer as part of their policy to encourage greater levels of physical activity. It would be useful in future development of new programs to follow up with these companies to determine whether the introduction of these devices has made an impact on the physical activity/exercise by the crew.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1–2

While the research team recognizes that crew cannot be forced to increase physical activity levels, providing access and encouraging crew to do so is likely to be beneficial to sleep, health, and well-being. Education about the benefits of exercise is just one part of addressing the role of exercise in improving sleep. When possible, companies could not only provide access to exercise equipment or techniques to increase physical activity without equipment, but help crew manage their time in order to balance time for exercise and other leisure activities but still maintain an adequate sleep opportunity. Encouraging increased physical activity while off the vessel also has the potential to benefit health and sleep while on the vessel.

Consideration should also be given to current levels of physical activity since there are likely to be differences depending on what work the crew are doing. For example, wheelhouse crew are likely to be more sedentary than deckhand crew.

There should be realistic expectations based on available time and physical capabilities. Assessment of individual crew could be conducted as part of an integrated wellness program and used to determine what exercise plan works best at an individual level based on current physical capacity and activity level. For example, since it seems that a large number of wheelhouse crew are overweight, this may make it more challenging for them to exercise; they may need to be provided with access to personal trainers to build exercise programs tailored for them and their physical needs.

3.5.12 Fatigue Modeling

Description

Using scientifically validated models to predict fatigue/risk/performance levels based on work schedule and the amount and timing of sleep could be a useful tool for the tug/towboat/barge industry to identify and manage fatigue risk.

Audience

Management, human resources, policy makers.

Current Practice and Improvements

Tug/Towboat/Barge Industry. During our studies with the tug/towboat/barge industry, the research team has not come across a company who reports using any type of fatigue modeling software.

Other Industries. There are many other industries that use fatigue modeling software within their operations. There are even regulators that encourage the use of such models [e.g., aviation and rail (https://federalregister.gov/a/2011-20290)].

Companies such as FedEx have elected to collect their own sleep, performance, and alertness data on flightcrew and to integrate that with several different models including SAFTE/FAST, Washington State University's model, and their own model (Rangan et al. 2013, Rangan and Van Dongen 2013).

There are also models that propose to not only determine fatigue levels in real time but to also offer countermeasure solutions in real time such as the Predictive Risk Intelligent Safety Module (PRISM).

A key factor that the research team found while using the SAFTE/FAST model in this project was that it was validated using data from the rail industry and that some of the assumptions inherent in the two-process model do not account for the split-sleep schedule common to the tug/towboat/barge industry. It is also unclear how many of the fatigue models deal with continuous operations for up to 30 days, and whether various aspects such as sleep banks are taken into account. MARTHA (http://www.warsashacademy.co.uk/about/our-schools/maritime-research-centre/horizon-project/martha.aspx) is a program that is in development as part of Project HORIZON (http://www.warsashacademy.co.uk/about/resources/final-horizon-report-final-as-printed.pdf). A potential limitation of the MARTHA model is that it seems that it was validated using subjective data when objective EEG data are available.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 2–3

While the research team proposes fatigue modeling as a best practice, caution should be used in how any specific model is applied and how the data generated from it is interpreted. The research team would suggest that if companies are going to use these types of models, then the person using them should be qualified to do so. It should also be noted that the team does not endorse any specific product discussed in this report, but simply introduces those that were assessed as part of the project.

For implementation of this practice, there would need to be some guidance on which models/program would be acceptable and consideration as to whether further validation of these models needs to be undertaken with schedules that require more than one work/rest interval per 24 hours in mind.

In addition, the various models require different inputs. Some caution should be used when using these types of models since the algorithms may not account for recent advances in knowledge in regard to splitting sleep into more than one period per 24 hours.

3.5.13 Sleep Environment

Description

Provide adequate sleeping quarters and a general work environment that is conducive to sleep. In addition, where possible, optimize the work environment to reduce fatigue.

Audience

Policy makers, management, crew, ship builders, engineers.

Current Practice and Improvements

Tug/Towboat/Barge Industry. In the addendum to CEMS (Emond et al. 2005), there are many best practices for modifying the sleeping quarters that would allow for better and less disrupted sleep. These include:

- Using blackout shades to ensure that sleeping areas are totally dark when crew members are attempting to sleep.
- Sound insulating the doors and baffles over cabin door louvers.
- Improving air conditioning.
- Improving the quality of mattresses and pillows.
- Instituting courtesy policies for sleeping crew members such that non-sleeping crew members reduce any excess noise, whether it is coming from radios, TVs, conversations, etc.
- Avoiding loud repair work around sleeping quarters whenever crew members display “Do Not Disturb” sleeping signs.

In order to determine the type of modifications to sleeping quarters and the work environment that have been implemented in the tug/towboat/barge industry, both management and crew were surveyed/interviewed. Details from these surveys and interviews can be found in Sections 3.2.1, 3.4.2, 3.4.3 and Appendix B. In summary, 89% of management report that their company provided improvements to sleeping quarters, and many of the crew surveyed reported courtesy policies, blackout shades, etc., but there were also those who did not have such initiatives or for whom practices were not effective on the vessels on which they worked.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1

While there is widespread use of this practice, there seems to be room for improvement based on crew survey responses and other companies that have not implemented such practices (see above). Although crew consider these to be important practices/policies based on the survey, there is still only limited data to determine with any certainty whether there are differences in sleep as a result of these practices.

One approach could be to make this an element in the company’s FRMS so that it could be tailored to specific vessels (older versus newer vessels, or vessels under construction) and operations (for example, for crews who return home to sleep the focus would be on the work environment rather than the sleeping quarters—although napping facilities could be a consideration).

Other considerations include simple things such as determining the cost effectiveness of purchasing 100 mattresses for $300 each or a better-quality mattress at $1,500 each. The $300 mattress may be cheaper initially but need to be replaced more often so in the long run costs more. Similarly, during extensive interactions with hundreds of crew members, the research team often asked what would be a best practice for improving the sleep environment and often received the response: better mattresses and pillows: a best practice that is ready for implementation.

3.5.14 Anchor-Sleep/Nap-Sleep Strategies

Description

The beneficial effects of sleep on fatigue and performance are mostly dependent on the total amount of sleep achieved over any 24-hour period and are not dependent on when sleep occurs or on the consolidation of sleep into a single bout. Therefore, the key to any schedule for sleep and wake activities is to design the schedule so the individual can obtain 7 to 8 hours of sleep per 24 hours regardless of the timing of the work schedule.

In order to obtain 7 to 8 hours of sleep over a 24-hour period on either square or rectangular watches, an anchor-sleep/nap-sleep strategy must be employed. In addition, individuals working the night shift on a 12:12 watch may also need to employ a split-sleep strategy when they are attempting to sleep in the circadian wake zone. All crew members will ideally be educated on how this strategy would involve them; for example, crews on a split schedule would be sleeping for 4 to 5 hours during their anchor-sleep opportunity and 2 to 3 hours during their nap-sleep opportunity.

Audience

Management, crew.

Current Practice and Improvements

Tug/Towboat/Barge Industry. The majority of crews working split-sleep schedule (i.e., square or rectangular watches) are presently attempting to sleep during both of their sleep opportunities (see the introduction to Section 3.3). However, the research team data and data from other investigators indicate that crews on either the captain or pilot (front and back) watches are only obtaining about 6 to 6.5 hours of total sleep per 24 hours. While there are no data in the literature to indicate that crews would obtain more total sleep if on a rectangular (7:7:5:5 or 8:8:4:4) or a square (6:6:6:6) watch, it has been suggested that the desired goal of any work schedule on vessels being operated 24 hours a day is to implement a two-watch schedule (i.e., sufficient qualified personnel, with each crew member being available 12 hours per day) that will allow for a certain number of hours of *uninterrupted* sleep, such as 7–8 hours, to reduce the rate of injuries or accidents. While it is indeed desirable to obtain 7 to 8 hours of sleep per 24 hours to maintain optimal performance, no data are available to indicate that crew members would obtain 7 to 8 hours of sleep if they were provided with an uninterrupted 8-hour period of time to sleep. Indeed, it has been consistently demonstrated that shift workers who work 8 hours and have 16 hours off to sleep only obtain 5 to 6 hours of sleep when sleep occurs at the "wrong" circadian time (OTA 1991).

Just as it is difficult to stay awake between 3:00 am and 7:00 am, it is also difficult to fall asleep during the daytime for individuals living on a normal 24-hour light-dark cycle (Kryger et al. 2005). Individuals who work at night and attempt to sleep during the day are often only able to obtain 4 to 6 hours of sleep (OTA 1991). Data in several papers [including Harma et al. (2008) and Lutzhoft et al. (2010)] also show that even when crew members are given an 8-hour period to sleep, they cannot achieve 8 hours, or even 7 hours, of uninterrupted sleep. In interpreting the findings of these studies, the argument is often made that an 8-hour rest interval is better than a 6-hour rest interval on the 6:6:6:6 versus the 4:8:4:8 watch. However, this comparison is not really valid when comparing a two-watch versus a three-watch system. A more in-depth analysis of the data in the cited Harma et al. (2008) paper reveals that even if the pilots/captains have two 8-hour periods of rest per 24 hours, the amount of previous sleep length in the preceding 8-hour window before going on duty for 4 hours ranged from 3.7 hours to 5.6 hours.

The differences between 3.7 to 5.6 hours are due to when the 8-hour rest period fell in the circadian day. The conclusion is that crews are getting, at a maximum, 5.6 hours of time in bed and, at a minimum, 3.7 hours during an 8-hour period of "uninterrupted" sleep opportunity. This runs contrary to the assumption that if an 8-hour period of uninterrupted sleep is allowed, the crew will obtain 8 hours. It has been shown that they will not get 8 hours of sleep, and for some shifts, they will only obtain 3.5 to 4 hours of sleep during the 8-hour rest window and then only have a 4-hour rest time for a nap on a rectangular two-watch 8:8:4:4 schedule. In the text of their paper, Harma et al. (2008) present the average sleep time in the previous 6-hour sleep opportunity period on a 6:6:6:6 watch as 4 hours and 6 minutes. For the 8-hour time off, it is 4 hours and 50 minutes with no statistical significance between them. Such findings indicate that crew will need a split-sleep anchor-sleep/nap-sleep strategy on either a square or rectangular watch. On a 6:6:6:6 schedule, there are 6 hours for a nap period; on an 8:8:4:4 schedule, there is only a 4-hour window for the second sleep period.

A similar conclusion arises from another study by Lutzhoft et al. (2010)—the total sleep per 24 hours on a 6:6:6:6 schedule was found to be actually *more* than on an 8 on, 4 off, three-watch schedule, *despite* the fact that the crews on the 8:4 schedule had a total of 16 hours to sleep versus 12 hours for those crews on a 6:6 square watch (see Figure 45).

Thus, allowing 8 hours of uninterrupted sleep time during the circadian day *will not* lead to 8 hours of sleep. As noted by Lutzhoft et al. (2010), "what the effects of split sleeps are in a maritime setting should be further investigated." Certainly, there is a need for such studies. This is particularly the case since it is not at all clear if an 8:8:4:4 rectangular watch would lead to more

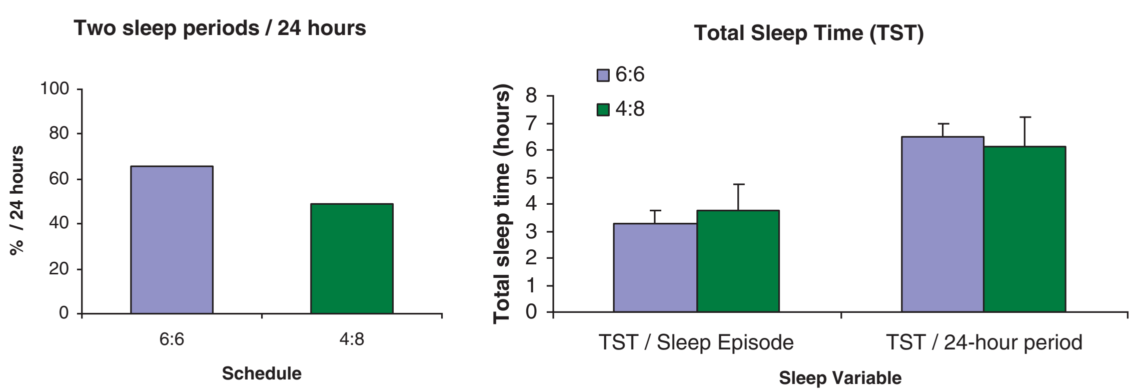

Figure 45. More sleep occurs on a 6:6:6:6 schedule than a 4:8 schedule. *The graph on the left is a representation of results from Lutzhoft et al. (2010) showing that 66% of sleeps in the 6 on 6 off system were split into two sleep episodes during 24 hours, whereas on a 4 on 8 off schedule, sleep was split into two episodes 49.1% of the time. The graph on the right is a representation of results from Lutzhoft et al. (2010) for mean total sleep time for each sleep episode and for each 24-hour period as determined using actigraphy. Note that crew members on a 4:8:4:8 schedule actually slept less (no statistical difference) than those on a 6:6:6:6 schedule despite having two 8-hour opportunities every 24 hours. Such results do not support the hypothesis that mariners would be able to sleep uninterrupted for 7 to 8 hours if given an 8-hour sleep opportunity. Data from both of these panels are from 15 crew members working a 4 on 8 off schedule and 15 crew members on a 6 on 6 off schedule. Data redrawn from Lutzhoft et al. (2010).*

or less sleep over 24 hours compared to a square 6:6:6:6 watch given that the sleep opportunity during the second rest period of an 8:8:4:4 watch is only 4 hours.

Other Industries. It is also noteworthy that other studies in which mariners worked a 4:8:4:8 schedule have also reported that crew members are not obtaining 8 hours of "uninterrupted sleep" despite having 8-hour sleep opportunities. For example, Sanquist et al. (1997) found that mariners on a 4:8:4:8 schedule averaged 6.6 hours of sleep per 24 hours with sleep occurring in bouts of less than 5 hours in duration.

Recent data on human performance capabilities in individuals obtaining their total sleep during a single sleep period, or during two sleep periods per day (i.e., an "anchor" sleep period and a "nap" sleep period), have indicated that performance levels are dependent on the *total* number of hours of sleep per day (Mollicone et al. 2007, Mollicone et al. 2008, Jackson et al. 2014, Kosmadopoulos et al. 2014, Short et al. 2014, and responses from interviews conducted with practitioners from other industries). That is, individuals obtaining the same total amount of sleep, whether during a single sleep period, or two sleep periods, have similar levels of performance. In one such study, individuals were allowed to sleep from 4.2 to 8.2 hours per day during a single "nocturnal anchor-sleep"period or 4.6 to 7.4 hours per day when the sleep times were divided into two bouts, i.e., nocturnal anchor sleep and diurnal nap sleep. The overall conclusion from these studies was that performance levels were better when total sleep time was increased, but performance levels were similar when told sleep time was the same, for example, when an individual slept 6.2 + 0 hours vs. 4.2 + 2 hours (Mollicone et al. 2007, Mollicone et al. 2008). More recently, Jackson et al. (2014) reported that a split-sleep schedule resulted in more sleep and less fatigue compared to when sleep was allowed to occur during a 10-hour uninterrupted sleep time when sleep was only allowed during the day. Thus, the hypothesis that 7 to 8 hours of "uninterrupted" sleep is better than 7 to 8 hours per 24 hours obtained by a split-sleep schedule is not supported by recent scientific literature. Of particular note are the data in Figure 38, which show that the longest sleepers (top 20%) were those who spent more time in bed and, thus, made more of an effort to obtain sufficient sleep. In contrast, those crew members who slept the least (lowest 20%) were not making the same level of attempt to sleep since they spent about 2 hours less in bed than the long sleepers.

Education on the need to sleep, and that split sleep leading to 7 to 8 hours of sleep in two episodes allows a person to obtain increased levels of alertness and performance and reduce levels of fatigue in the same way as when sleep occurs in a single period, has important implications for changing the culture of the industry. This cultural change could improve safety and performance in the way that other culturally accepted interventions within the maritime industry have improved safety (e.g., maintaining use of life vests and steel-toed boots while on tows).

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 1

Best practices are discussed on this topic in Section 3.5.15. There are now five papers in the literature (three authored in 2014) that indicate that combining an anchor sleep with a nap sleep can be as effective in maintaining performance as obtaining the same total number of hours of sleep in one single sleep period (Mollicone et al. 2007, Mollicone et al. 2008, Jackson et al. 2014, Kosmadopoulos et al. 2014, Short et al. 2014). It is essential that this information become readily known across the maritime industry, both for management, crew members, dispatchers, and other stakeholders. More than once crew members said that, since it is not possible to obtain 8 hours of uninterrupted sleep in a 6-hour (or even 7- or 8-hour) rest period, especially during the time of the circadian drive to be awake, there was lack of interest in following a program that could not be completely implemented. Educating the crew members and other stakeholders about the latest scientific research behind the use of a split-sleep strategy for maintaining high levels of attentiveness and reducing fatigue would result in crew members making a better attempt at obtaining more sleep using the anchor-sleep/nap-sleep strategy.

The use of anchor sleep/nap sleep as a best practice is considered at a Level 1, because well over 90% of crew seem to already adopt this practice. However, since the split sleepers on the pilot's or captain's watch are only obtaining approximately 6.5 hours of sleep per 24 hours, the research team proposes that within any education program, the science behind the benefits of an anchor-sleep/nap-sleep practice be presented and that crew be encouraged to sleep as much as possible in both of their rest intervals. The research team also proposes that crew be provided with guidance on how to best balance taking care of personal matters (meals, hygiene, leisure time, exercise, etc.) and making sleep a priority.

An anchor-sleep/nap-sleep strategy may also need to be implemented for crew members on a 12:12 schedule when the 12-hour sleep opportunity is occurring during the circadian wake zone, when it may not be possible to sleep 7 to 8 hours in a single bout. Studies examining this strategy with 12:12 shift schedules are underway. Furthermore, it is proposed that companies set up a fatigue management system that uses fatigue models and other tools to determine the impact of various schedule options on fatigue and sleep given the particular demands of their operations.

3.5.15 Duty Hours Regulation

Description

At the present time, the only duty hour regulations that the USCG applies to this industry is that crew members must not work more than 15 hours per every 24 hours or more than 36 hours in any 72-hour period unless in an emergency [46 U.S.C. 8104(c)].

There is not sufficient scientific evidence to suggest that there needs to be major adjustment to the duty hours within the tug/towboat/barge industry.

Audience

Management, crews, and employees responsible for scheduling duty time, as well as the USCG and policy makers.

Current Practice and Improvements

Crews do not work more than 15 to 16 hours per day, and in most cases, they work approximately 12 hours per day.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: NA

No proposal in regards to duty hours is offered.

3.5.16 Reporting Missed Sleep Opportunities

Description

Require crew members to report when they have missed a sleep period (whether due to extended work, inability to sleep, or no attempt to sleep) and provide real-time strategies to assess and minimize risk.

Audience

Management, crew, human resources, dispatchers.

Current Practice and Improvements

Tug/Towboat/Barge Industry. While it seems that missed sleep opportunities are rare (introduction to Section 3.3), the impact that just one missed sleep opportunity can have on predicted performance (SAFTE/FAST) warrants that procedures be in place to address this as an issue (see Table 11 and Figures 26 and 27).

Given the importance of sleeping during both rest opportunities to overall daily sleep duration while working on the split work schedule used in the tug/towboat/barge industry there should be a requirement for reporting when a sleep opportunity is missed, so that adequate monitoring or assessment of risk can be made in real time.

Other Industries. The research team did not directly assess the reporting of missed sleep episodes in other industries, since there was sufficient information available from the tug/towboat/barge industry to make a proposal.

Implementation Readiness/Plan/Considerations

- Implementation Readiness Level: 2–3

This practice has been rated at a 2–3 since it may be relatively easy to implement the reporting requirement; however, it is less straight forward to implement the assessment of risk and clear guidelines on how to do this would need to be developed and even tested.

An algorithm similar to that proposed in an article by Dawson and McCulloch (2005) could be used to quickly assess risk. The prior sleep-wake model allows the user to determine fitness for duty using an algorithm that has three simple calculations that include prior sleep in the past 24 hours, past 48 hours, and duration of wakefulness from awakening to end of work.

They suggest that each industry would need to assess thresholds based on the risk associated with the tasks the person is performing, but that a person who has slept less than 5 hours in the past 24 hours and less than 12 hours in the past 48 hours and is awake longer than 12 hours would be impaired.

For a crew member on a 6:6:6:6 schedule who had slept 7 hours in the past 24 hours split over the two rest intervals and 14 hours in the last 48 hours (slept 7 hours the previous day) is unlikely to be impaired since that crew member would have only been awake for 8 hours by the end of their shift. Further research is needed to examine this type of simple rule in relation to new data from split-sleep schedules, since the rule may not be appropriate for those who have two work and two rest intervals per 24-hour day.

3.6 Task 6. Compendium of Best Practices for Enhancing Sleep Efficiency on Towboats in the U.S. Inland Waterway Industry and a Report Documenting the Results of the Research

Section 3.5 provides a compendium in simple terms of the best practices to improve sleep efficiency and reduce fatigue in the U.S. tug/towboat/barge industry. Details of the best practices are provided, including readiness level and considerations for implementation (also see Table 19 for a summary).

CHAPTER 4

Conclusions and Suggested Research

4.1 Conclusions

This report provides a compendium of 16 best practices to improve sleep and reduce fatigue in the tug/towboat/barge industry. While it is beyond the scope of this project to fully develop, implement, test, and monitor the effectiveness of the proposed best practices, there is guidance on a number of pressing elements. This information could aid in the decision-making process about which practices to prioritize for implementation in order to improve sleep efficiency and reduce fatigue and fatigue-related accidents within the inland waterways. To improve sleep it will be important for all stakeholders, including policy makers, regulators, industry, labor groups, customers, and crew and their families to work together in the final development and implementation of these best practices.

While the industry takes safety very seriously, a further goal could be to change the overall safety culture specifically in relation to sleep and fatigue so that there is a high value placed on sleep and that the fatigue-related risks associated with the work schedule can be managed in an appropriate manner. A major challenge is the diversity of the operations (harbor, line, seasonal, etc.) and company size (3 to 2,000 employees). Similar challenges face other transportation-related industries, such as trucking and aviation. As such, a one-size-fits-all FRMS is not proposed and while some prior recommendations from CEMS will ideally be considered in any FRMS, CEMS might be only one component of a well-developed FRMS program. A system in which companies used a revised/updated version of CEMS (to develop their own FRMS could be implemented on a case-by-case basis. This paradigm is currently in practice with the FAA for flight schedules that do not meet current minimum flight duty standards. Companies are able to provide an FRMS and evidence that a particular schedule does not pose a risk beyond a currently approved standard, or in this case, similar sleep duration and quality.

In general, the research team suggests that any best practice be monitored and reviewed with appropriate metrics on a regular basis so that modifications and improvements can be initiated when necessary. Much like other areas of safety, such as advances in life preservers, there are new developments in the area of sleep/fatigue research all the time and so the issue of sleep and fatigue may be a moving target for implementing best practices. It is clear from this project that there needs to be clear communication between all stakeholders to determine the minimum standards, what the best way to achieve the goals of the program will be, and to determine and agree upon what could be considered the metrics for success.

Based on the operations studied to date, the crew are sleeping on average similar to, or in some cases, more than population norms (McClain et al. 2014). They do, however, seem to be at greater risk for various health conditions indicated by the high prevalence of morbid obesity. The current research project has only just touched the surface of health-related issues. Future research will also need to determine what best practices are working and which ones are not or even simply to determine whether companies are implementing programs at all.

In some industries, policy makers/regulators are often required to provide the "push" necessary to get all stakeholders on board with the overall goal, in this case, to minimize risk and avoid incidents and accidents related to poor sleep. It should be noted that within the tug/towboat/barge industry this is often not the case, as many companies are "out front" in that they are already addressing many of the best practices listed as part of this project. A long-term goal would be to get all companies to address these best practices in an appropriate manner for their operations. In past years, the NTSB has had addressing human fatigue on the top 10 most wanted list of important issues to tackle. At the time of this research, it is not on the list (http://www.ntsb.gov/safety/mwl/Documents/MWL_2015_brochure.pdf), although the NTSB did include "requiring medical fitness for duty." Given the importance of health for sleep and vice versa, this is very much in line with many of the research team's proposed best practices (Sections 3.5.3, 3.5.6–3.5.8, 3.5.10, and 3.5.11).

4.2 Proposed Research

As part of the efforts on this study, the research team spoke to a variety of individuals and groups that work in the field of fatigue management, in both the tug/towboat/barge and other transportation industries. The scope of scientific literature that reports on fatigue in the maritime sector is limited compared to other modes of transportation such as trucking, rail, and aviation. There was a general consensus from those working in the field of fatigue management in the maritime sector that there is a lot of scientifically based research that still needs to be conducted. Indeed, only limited research is being conducted, and it appears difficult to secure funding for this necessary research. It is also unclear whose role it should be to fund this type of research: regulators/policy makers, industry, or some combination? Therefore, the research team suggests that as implementation of the proposed best practices is carried out, funding for research could also be a consideration. This could take the form of the collection of outcomes within the company, as well as the collaboration of researchers outside of the industry with relevant expertise.

4.2.1 Practices Requiring Further Investigation

While it is the opinion of the investigators that the practices listed in Section 3.5 are at present the best practices for mitigating the risk of fatigue and improving sleep, there is limited data to support most of these practices, i.e., there is little quantitative data to support the benefits in the tug/towboat/barge industry. Most of the evidence is either from other industries or is subjective at this time.

In the next section, the research team suggests practices that could benefit from further research. These include practices recommended by the investigators in this report and practices that have been put forward by others including policy makers and regulators.

4.2.2 HOS Rules to Allow for an Uninterrupted 7 to 8 Hours of Sleep

Evidence suggests that the only schedule that would allow for 7 to 8 hours of uninterrupted sleep is one that allows at least 10 hours off between consecutive shifts (depending on the time of the rest interval). Even given this extended off-duty period there are other factors that impact the amount and quality of an individual's sleep that are not accounted for in such a simple HOS rule such as time of day, sleep disorders, stress, health, and environmental factors related to the sleep environment. HOS rules are not able to address these other factors and should therefore only be used in tandem with other practices that address them. There has been some progress on the issue of time of day and sleep environment in HOS regulations, and the FAA has taken a lead in adjusting duty hour requirements based on the time of day the shift starts (FAA 117) and the type of rest facilities available. These rules are relatively new (effective January 2014) and time will tell if they have a measureable impact on safety and health.

In determining the impact of any proposed changes in HOS requirements in the tug/towboat/barge industry, it will be important for there to be direct comparisons made between various two-watch schedules (i.e., 6:6:6:6, 7:7:5:5, 8:8:4:4, and 12:12). These head-to-head studies could be either under simulation or, preferably, under real-world field conditions. Limited data suggest that sleep durations are not significantly different between the 6:6:6:6 square watch and a 7:5:5:7 watch (single vessel), but more extensive studies need to be performed before any definitive conclusion can be made about sleep obtained on various watch schedules.

4.2.3 Shift Start Times

There is little data on how altering shift start times might impact sleep and fatigue. However, there is some evidence from the SAFTE/FAST modeling (Section 3.3.4) and recent research on split shifts (Jackson et al. 2014, and responses from interviews conducted with practitioners from other industries) that suggests that optimizing start times for the current schedules may be beneficial.

4.2.4 Impact of Education Programs on Improving Sleep and Safety

While it is clear that education is a key component of any FRMS, not all education is created equal and not all people learn in the same way. Consideration could be given to generational learning issues and the intended audience, as there are likely to be different approaches needed for policy makers, management, crew and their families, and physicians. Research to determine whether education programs are having any tangible impact on sleep, health, behavior, attitudes, or safety may also be beneficial, as would programs to determine what would be the best approaches for continuing education, for example, how often should individuals have refresher training in order to maintain effectiveness?

4.2.5 FRMS

There is little, if anything, published on the impact of FRMS on sleep and safety; most information comes from consultant reports that are not usually published in the scientific literature. Given the effort and cost that goes into the creation and maintenance of an FRMS, it will be important to involve researchers, economists, safety experts, and others to assess the benefits of any proposed practices in a scientific and unbiased manner.

4.2.6 Medical Examiners

It is unclear whether there is a problem with the current practice of allowing any licensed medical professional to conduct licensure physical examinations. While the research team proposed having registered examiners, there could be research conducted to determine whether there would be any measurable benefit to determine if such a change is warranted.

4.2.7 Sleep Disorders

There is a need for further research on the impact of sleep disorders, in particular OSA, in the tug/towboat/barge industry. Research could not only examine the risk of OSA in this industry but also the benefits for addressing this health and safety concern, including not only the benefits to the individual but the benefits to the companies and the community as a whole. This could be approached in several ways: one would be to examine the impact in other industries such as aviation where there is a rule, or another would be to further examine cases within the trucking and/or the tug/towboat/barge industries were companies already have programs, even though there is no rule requiring them to do so.

4.2.8 Other Considerations

Even if crew are obtaining sufficient sleep, there are still factors related to the work schedule and operations, such as working away from home and during the nighttime (circadian low of alertness) that should be considered in relation to overall health, well-being, and safety. Compared to other transportation sectors, there appears to be much less turnover in crew, which makes it particularly important for maintaining the health and well-being of crew over their careers, which could provide savings in healthcare and lost work time. Given this, it could be beneficial for companies to monitor the health of their workers over their careers.

One aspect of the inland waterway industry that is important to take into consideration is that schedules are in general very regular. Unless there are some unforeseen circumstances, schedules remain fairly static. This allows management and crew to plan accordingly. For instance, when there are unforeseen circumstances and a crew member works longer than planned or misses a sleep episode; basic policies and procedures would ideally be in place to mitigate the risks associated with these events.

Another relatively unique aspect of the schedules used in this industry is the number of days worked without a full 24+ hours off. This practice is most common in industries where travel to and from the work place is challenging, for example, maritime, remote mining, or offshore oil rigs. Each of these environments provides its own challenges and benefits in regard to optimizing schedules and balancing work and rest. While the use of 14- to 28-day rotations are common for some sectors of the tug/towboat/barge industry, the 12:12 schedule is also used and on this schedule, crew typically sleep at home daily. There is a need to monitor sleep and the buildup of fatigue while on these 12:12 schedules, particularly in the context of seasonal work where there is a benefit for both companies and crew to work as much as possible in the limited time available. The research team did some modeling of these schedules and the findings are presented in Section 3.3.4. It is also important not to jump to the conclusion that this type of schedule is automatically of higher risk than other split schedules where crew work for 30 consecutive days, since 30 days on a night shift might allow for greater circadian adaptation and therefore better sleep during the day and less fatigue during work. The research team suggests the need for further research on the impact of this type of schedule in the tug/towboat/barge industry.

4.2.9 New Technologies

An area for future development is likely to be the use of modern self-monitoring and cloud-based technologies that are now available for tracking physical activity, sleep, and fatigue. These technologies could be used to provide feedback to crew members about the status of their fatigue level and measures that should be taken to reduce and eliminate fatigue.

4.2.10 Why Are Some Practices Not Included?

There are other possible practices that were considered but that are not included in this compendium.

There is a multitude of other new technologies available to monitor fatigue/alertness or administer bright light, etc. While many of these technologies show promise, there is not necessarily a clear consensus on whether most of these devices/technologies are effective in improving sleep and reducing risk. Because of this, the research team has not included them in the best practices. This does not mean, however, that in the future with sufficient data that these technologies will not prove to be beneficial. Nor should this report deter companies from trying new technologies, but rather they should understand that they should not "rely" on these devices to safeguard them from the effects of poor sleep or remove the underlying causes of poor sleep.

4.3 Concluding Remarks

The best practices put forward in this report synthesize the findings of the research conducted by the research team in the tug/towboat/barge industry over the past 7 years and their broad experience in other areas of sleep and circadian research. While they are comprehensive, there is still considerable work required to bring them to practice within the tug/towboat/barge industry and to determine which best practices significantly improve sleep and reduce fatigue.

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Abbreviations, Acronyms, Initialisms, and Symbols

ACGME:	Accreditation Council for Graduate Medical Education
ACS:	American College of Surgeons
AMSA:	Australian Maritime Safety Authority
ATA:	American Trucking Associations
AWO:	American Waterways Operators
BMI:	body mass index
BW:	back watch
CEMS:	Crew Endurance Management System
CPAP:	continuous positive air pressure
EAP:	Employee Assistance Program
ESS:	Epworth Sleepiness Scale
FAA:	Federal Aviation Administration
FMCSA:	Federal Motor Carrier Safety Administration
FRA:	Federal Rail Administration
FRMS:	Fatigue Risk Management System
FW:	front watch
GBM:	Generalized Boosted Model
GLM:	Generalized Linear Regression Model
HOS:	hours of service
IATA:	International Air Transport Association
ICAO:	International Civil Aviation Organization
IMO:	International Marine Organization
KSS:	Karolinska Sleepiness Scale
MSM:	Marginal Structural Model
NCFRP:	National Cooperative Freight Research Program
NTSB:	National Transportation Safety Board
NU:	Northwestern University
OSA:	obstructive sleep apnea
PSQI:	Pittsburgh Sleep Quality Index
PRISM:	Predictive Risk Intelligent Safety Module
PVT:	psychomotor vigilance task
SAFTE/FAST:	Sleep, Activity, Fatigue, and Task Effectiveness/Fatigue Avoidance Scheduling Tool
SCN:	suprachiasmatic nucleus
SSI:	Standard Shiftwork Index
USCG:	United States Coast Guard

APPENDIX A

Bibliography

Many of the source materials reviewed as part of this project are available online. Below are links to access this publicly available information.

FRA

- Tools and software utilized by the FRA are offered via the Railroaders' Guide to Healthy Sleep: http://railroadersleep.org.
- Fatigue Status of the U.S. Railroad Industry: http://www.fra.dot.gov/eLib/details/L04320.
- Work schedules, sleep, fatigue, and accidents in the U.S. railroad industry: http://www.fra.dot.gov/eLib/details/L04272.
- Criteria and procedures for validating biomathematical models of human performance and fatigue: Procedures for analysis of work schedules (Docket No. FRA-2009-0043-0003). (Available at http://www.regulations.gov/#!documentDetail;D=FRA-2009-0043-0003.)
- Validation of FAST Model sleep estimates with actigraph-measured sleep in locomotive engineers: http://www.fra.dot.gov/eLib/details/L01288.
- Measurement and Estimation of Sleep in Railroad Worker Employees: http://www.fra.dot.gov/eLib/details/L01337.
- Analysis of the Relationship between Operator Effectiveness Measures and Economic Impacts of Rail Accidents: http://www.fra.dot.gov/eLib/details/L01301.
- Work Schedules and Sleep Patterns of Railroad Train and Engine Service Employees in Passenger Operations: http://www.fra.dot.gov/eLib/details/L01305 (Technical Report), http://www.fra.dot.gov/eLib/details/L01331 (Research Results).
- Procedures for Validation and Calibration of Human Fatigue Models: The Fatigue Audit InterDyne Tool: http://www.fra.dot.gov/eLib/details/L01308.
- The Railroad Fatigue Risk Management Program at the Federal Railroad Administration: Past, Present and Future: http://www.fra.dot.gov/eLib/Details/L04335.
- Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Final Report: http://www.fra.dot.gov/eLib/details/L04301.
- Fatigue Models as Practical Tools: Diagnostic Accuracy and Decision Thresholds: http://www.fra.dot.gov/eLib/details/L03026.
- Fatigue and Alertness in the United States Railroad Industry, Part II: Fatigue research in the Office of Research and Development at the FRA: http://www.fra.dot.gov/eLib/details/L03024.
- Passenger Hours of Service Regulation: http://www.gpo.gov/fdsys/pkg/FR-2011-08-12/pdf/2011-20290.pdf.

FAA

- http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-103A.pdf.

IATA

- http://www.iata.org/publications/Pages/frms.aspx.

ICAO

- http://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/Doc%209966%20-%20FRMS%20Manual%20for%20Regulators.pdf.
- http://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/FRMS%20Implementation%20Guide%20for%20Operators%20July%202011.pdf.

USCG

- http://www.uscg.mil/hq/cg5/cg5211/docs/GuideForMaritimeOperations.pdf.
- http://www.uscg.mil/hq/cg5/cg5211/docs/CEM_Addendum_Final.pdf.
- http://www.uscg.mil/hq/cg5/cg5211/docs/CrewEnduranceManagement29Mar06.pdf.

AMSA

- http://www.amsa.gov.au/forms-and-publications/Publications/AMSA494.pdf.
- http://www.amsa.gov.au/seafarers_welfare/documents/11-fatigue.pdf.
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IMO

- http://www.imo.org/OurWork/HumanElement/VisionPrinciplesGoals/Documents/1014.pdf.

FMCSA

- https://www.federalregister.gov/articles/2012/04/20/2012-9555/proposed-recommendations-on-obstructive-sleep-apnea.
- http://www.mrb.fmcsa.dot.gov/documents/Final_Meet_Min_Jan28_2008_MRB_Meet_Revised_Upd_2-19-09.pdf.
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North American Fatigue Management Program

- http://www.nafmp.com/en/.

ACGME

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ACS

- http://bulletin.facs.org/2014/08/statement-on-peak-performance-and-management-of-fatigue/.

NTSB

- http://www.ntsb.gov/safety/safety-recs/RecLetters/H09_15_16.pdf.

APPENDIX B

Surveys and Sleep Diary

Management Survey Materials

The management survey presented here was developed by the Northwestern University research team in collaboration with the American Waterways Operators.

Survey Information

Northwestern University is conducting a research study funded by the Transportation Research Board and the National Cooperative Freight Research Program to identify and assess Best Practices related to improving sleep (duration, quality and efficiency) and fatigue management on vessels in the Tug/Towboat/Barge Industry.

As part of this research, we would like to survey key stakeholders within the industry, such as yourself, about practices related to improving sleep (duration, quality and efficiency) and fatigue management that are currently in place within your company. Please note that any information you provide us with will be kept confidential and used anonymously.

Please complete each of the following questions where applicable.

The survey should take you approximately 10-20 minutes to complete depending on the level of detail you provide.

Contact and company information

Please complete each of the following questions where applicable.

1. What is the name of the company you represent?

Company: ________

2. What is your position title?

____

3. How many crew members does your company employ?

____

4. How many of these crew members are captains, pilots, or deck crew?

Captains ________

Pilots ________

Deck Crew ________

5. How many vessels does your company have? (if applicable)

____

6. How many barges does your company have? (if applicable)

____

7. What is the primary watch schedule used by your company? (Please choose all that apply if there is more than one shift schedule)

- ☐ 6-6-6-6
- ☐ 7-7-5-5
- ☐ 8-8-4-4

Other watch schedule (please specify)

____

8. Do you stand by to load or unload cargo?

- ☐ Yes
- ☐ No

9. If you stand by to load or unload cargo, do you alter your shift schedule?

- ○ Yes
- ○ No

10. How long do you stand by to load or unload?

Hours?

Minutes?

11. Does your company provide CEMS (Crew Endurance Management System) training?

- Yes
- No

12. Does your company have other practices, procedures and/or training in place related to improving sleep (duration, quality and efficiency) or fatigue management?

- Yes
- No

13. Rate the effectiveness of the practices, procedures, and/or training in place related to improving sleep (duration, quality and efficiency) or fatigue management

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

14. Please provide specific examples of your company's practices, procedures and/or training that are in place related to improving sleep (duration, quality and efficiency) or fatigue management?

Questions related to your company's current practices

15. How likely would your company be to initiate practices, procedures and/or training related to improving sleep (duration, quality and efficiency) or fatigue management?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

16. Does your company provide improvements to sleeping quarters (e.g. light reduction, beds (size, mattress), sound proofing).

○ Yes

○ No

17. Rate the effectiveness of the enhancements of sleeping quarters in improving sleep (e.g. light reduction, beds (size, mattress), sound proofing).

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

18. Please provide specific examples of the improvements to sleeping quarters (e.g. light reduction, beds (size, mattress) sound proofing).

19. How likely would your company be to initiate training on improving sleeping quarters (e.g. light reduction, beds (size, mattress) sound proofing)?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

20. Does your company offer training or education related to sleep or sleep-related health factors (e.g. effects of sleep loss on performance and health)?

○ Yes

○ No

21. Rate the effectiveness of this training or education related to sleep or sleep-related health factors?

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

22. Please provide specific examples of the training or education your company offers related to sleep or sleep-related health factors.

Questions related to your company's current practices

23. How likely would your company be to initiate training or education related to sleep or sleep-related health factors?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

24. Does your company offer screening, training or education on sleep disorders?

○ Yes

○ No

25. Rate the effectiveness of the screening, training or education that your company provides related to sleep disorders.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

26. Please provide specific examples of your company's screening, training and education related to sleep disorders.

27. How likely would your company be to initiate screenings, training or education for sleep disorders (e.g. obstructive sleep apnea)?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

28. If your company has a screening program for sleep disorders (e.g. obstructive sleep apnea), how do you manage and monitor this program?

29. Does your company offer a wellness program?

○ Yes

○ No

30. Rate the effectiveness of this wellness program.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

31. Please provide more information about your company's wellness program.

Questions related to your company's current practices

32. How likely would your company be to initiate a wellness program?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

33. Does your company offer stress management training?

○ Yes

○ No

34. Rate the effectiveness of this stress management training.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

35. Please provide more information about the training your company provides related to stress management.

36. How likely would your company be to initiate stress management training?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

37. Does your company offer training on diet and nutrition?

○ Yes

○ No

38. Rate the effectiveness of this diet and nutrition training.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

39. Please provide more information on the training your company provides related to diet and nutrition.

40. How likely would your company be to initiate diet and nutrition training?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

Questions related to your company's current practices

41. Does your company offer training or education on exercise, or give access to exercise facilities?

- Yes
- No

42. Rate the effectiveness of this training or education on exercise, or access to exercise facilities.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

43. Please provide more information about the training or education on exercise or access to exercise facilities that your company provides.

44. How likely would your company be to initiate training or education on exercise?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

45. Does your company offer information or training about medical conditions that impact sleep?

- Yes
- No

46. Rate the effectiveness of this training about medical conditions that impact sleep.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

47. Please provide specific examples of how your company offers information or training about medical conditions that impact sleep?

48. How likely would your company be to initiate education or training about medical conditions that impact sleep?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

49. Does your company offer information or training about medications that impact sleep?

- Yes
- No

Questions related to your company's current practices

50. Rate the effectiveness of this education or training about medications that impact sleep.

Very effective	Somewhat effective	Not sure	Somewhat uneffective	Uneffective
○	○	○	○	○

51. Please provide specific examples of how your company offers information or training about medications that impact sleep?

52. How likely would your company be to initiate education or training about medications that impact sleep?

Very likely	Somewhat likely	Not sure	Somewhat unlikely	Unlikely
○	○	○	○	○

53. Are there any other practices in your company that are related to improving sleep (duration, qualityand efficiency) or fatigue management and are not listed above.

○ Yes

○ No

54. Please list any practices in your company that are related to improving sleep (duration, quality and efficiency) or fatigue management that are not listed above.

55. Do you monitor or assess IN ANY CONCRETE WAY the effectiveness or benefit of any of the practices related to sleep/fatigue management that your company has in place?

○ Yes

○ No

56. How do you monitor the effectiveness or benefits?

57. Does your company monitor sleep-wake strategies used by crew members (e.g. do they sleep during each rest interval)?

○ Yes

○ No

Questions related to your company's current practices

58. Does your company do health screens of your workers?

- Yes
- No

59. Does your company have a program that asks crew about medical conditions and medications that impact sleep and fatigue?

- Yes
- No

60. If your company has a program that asks crew about medical conditions and medications that impact sleep and fatigue, how do you manage this?

61. Are crew members encouraged to report excessive sleepiness while they are working?

- Yes
- No

62. If your company has a wellness program would you be willing to share information about your wellness program with the study?

- Yes
- No

63. Do you have any additional information that you think would be useful for this research?

- Yes
- No

64. Please provide any additional information that you think would be useful for this research.

65. Are there any best practices related to improving sleep (duration, quality and efficiency) or fatigue management that you would like to see initiated within your company?

- Yes
- No

66. What are the practices related to improving sleep or fatigue management that you would like to see initiated within your company?

67. Are you willing to participate in a brief phone interview to follow up on your responses to this survey?

- Yes
- No

68. What is your availability to conduct said interview?

69. What is your email address?

Email Address:

70. What is the best phone number to reach you at?

Phone Number:

71. Are you willing to be contacted to aid in the development of a plan to implement the Best Practices identified as part of this project?

- Yes
- No

72. What is your email address?

Email Address:

Thank You

Thank you for your time in completing this survey

NU Sleep Team

Crew Survey Materials and Sleep Diary

Questions Related to The Previous Sleep Research Study

Please answer the following questions related to the previous study,"Integrating the Crew Endurance Management System (CEMS) with anchor sleep/nap sleep strategies to reduce fatigue and risk on towing vessels (Phase IV)".

Did you read the education materials provided at the end of your participation in the research study?

- ○ Yes
- ○ No

How useful did you find the Educational Material you received at the end of the study.

Very Useful	Somewhat Useful	Not Sure	Somewhat Not Useful	Not Useful
○	○	○	○	○

Did you use any of the information provided in those materials to improve your sleep or health?

- ○ Yes
- ○ No

If you did use the information provided what aspects of the educational materials were most useful and what practices did you employ?

Following your participation in the research study did you change any of your usual behaviors to improve your sleep?

- ○ Yes
- ○ No

Can you provide examples of the behaviors you have changed (e.g. reduced caffeine intake close to bed, ear plugs, eye shades) ?

New Best Practices

Please answer the following questions in relation to your current sleep practices/routines/behaviors.

Have you ever received Crew Endurance Management System (CEMS) training?

- ○ Yes
- ○ No

If you had CEMS training, how useful did you find the training you received in providing you information on ways to improve sleep and reduce fatigue.

Very Useful	Somewhat Useful	Not Sure	Somewhat Not Useful	Not Useful
○	○	○	○	○

If you found the CEMS training useful what aspects of the training did you find the most useful?

If you have had CEMS training, how was it received (i.e. did you have a course for a day, online, handouts etc)?

Does your company have any practices or procedures in place to improve sleep/reduce fatigue while on the vessel that you find personally beneficial – we are specifically interested in those that are NOT already outlined in CEMS, or the educational material you received at the end of the previous sleep study?

Are there any practices or techniques that you use to obtain good quality sleep while on the vessel?

Are there any practices or techniques that you use to make sure that when you are working you do not disturb the sleep of your fellow crew?

- ○ Yes
- ○ No

Can you provide details of the practices/techniques you use to make sure that when you are working you do not disturb the sleep of your fellow crew?

Is there any reporting techniques you use personally, or in place by your company to report whether or not you were able to obtain enough rest?

- ○ Yes
- ○ No

If there are any reporting techniques you use personally, or in place by your company to report whether or not you were able to obtain enough rest what are they?

Are there any practices that you would like to see initiated on your vessel to help improve your sleep or the sleep of your fellow crew members?

- ○ Yes
- ○ No

Can you provide details of the practices you would like to see initiated?

Would you be interested in learning more about how to improve your sleep?

- ○ Yes
- ○ No

Are there any specific techniques that you would be interested in learning more about in order to improve your sleep?

- ○ Yes
- ○ No

Can you provide details of the techniques you would be interested in learning more about?

What is today's date? (MM/DD/YYYY)

	MM		DD		YYYY
Today's date.		/		/	

What time did your shift begin and end? (please use military time)
EXAMPLE: Shift started at: 18:00
Shift ended at: 00:00

Shift started at:

Shift ended at:

Did you sleep in your time off shift?

- Yes
- No

1.) What time did you go to bed and wake up? (use military time)

EXAMPLE:
I laid in bed with the purpose of sleeping at: 23:00
I woke up at: 06:00.

I laid in bed with the purpose of sleeping at:

I woke up at:

Other:

2.) How long did it take for you to fall asleep? (In hours and minutes)

Hours

Minutes

3.) How did you feel upon going to bed and waking?

	Very alert		Alert		Neither sleepy nor alert		Sleepy, not straining to stay awake		Very sleepy, fighting against sleep
At bedtime:	○	○	○	○	○	○	○	○	○
When getting up:	○	○	○	○	○	○	○	○	○

4.) Did you feel anxious or stressed at bedtime?

	Not at all	A little	Some	Quite	Very
Amount of stress and anxiety	○	○	○	○	○

5.) Was it hard to fall asleep?

	Not at all		Quite		Very
Perceived sleepiness	○	○	○	○	○

6.) How did you sleep?

	Very well	Quite well	Neither nor	Quite badly	Very badly
Quality	○	○	○	○	○

7.) Was your sleep disrupted?

	Not at all		Some		Very
Disruption	○	○	○	○	○

8.) Did you wake too early without being able to fall asleep again?

	No		A little too early		Much too early
Choose the one that best represents your situation.	○	○	○	○	○

9.) Number of awakenings during your rest period.

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 or more

10.) If you woke during your rest period, how long were you awake?

	None	A couple of minutes	10-30 minutes	3/4- 1 hour	More than one hour
Choose the one that best represents your situation	○	○	○	○	○

10.1) How long in actual minutes were you awake during your rest period. (please enter your response in minutes e.g. 120 for 2 hours)

11.) Do you feel like you slept long enough?

	Yes, definitely	Yes, nearly enough	No, sightly too little	No, clearly too little	No, definitely too little
Choose the one that best represents your situation	○	○	○	○	○

12.) How deep was your sleep?

	Very light	Quite light	Neither nor	Quite deep	Very deep
Choose the one that best represents your situation	○	○	○	○	○

13.) How easy was it to get up?

	Very easy		Neither nor		Very hard
Choose the one that best represents your situation	○	○	○	○	○

14.) How rested do you feel?

	Completely		Quite		Not at all
Choose the one that best represents your situation	○	○	○	○	○

15.) Did you have any caffeine, energy drinks, or medication during the day? If so, what exactly; and how much?
(If none, enter a ZERO for each one that applies)

Coffee, amount in ounces: (example: 1cup=about 12oz) ________

Medication: ________

Sleeping Pills: ________

Pain killers: ________

Other: ________

16.) Have you had any alcohol during the night?

- ○ No, nothing at all
- ○ Yes, pint of beer/one glass of wine
- ○ Yes, normal dinner drinking (Equals 2 pints of beer/1/2 a bottle of wine)
- ○ Yes, I have been party drinking (More than 2 pints of beer)

17.) Did something special occur that you think might have disturbed your sleep?

If your situation is not properly represented by the choices given, please describe it in the "Yes, some other cause" section.

	No	Yes, the work hours	Yes, hard physical activity	Yes, wrong time for going to bed	Yes, worried of oversleeping	Yes, illness/pain	Yes, noise during sleep
Choose the one that best represents your situation.	○	○	○	○	○	○	○

Yes, some other cause: (please specify)

18.) Was there anything specific that caused you to wake and ultimately get out of bed?

If your situation is not properly represented by the choices given, please describe it in the "Yes, some other cause" section.

	Nothing special (spontaneous awakening)	Yes, the alarm clock (or the like)	Yes, noise or the like	Yes, needed to go to the bathroom	Yes, pain
Choose the one that best represents your situation.	○	○	○	○	○

Yes, other (please specify)

Is there anything you would like to add about the day or the sleep?

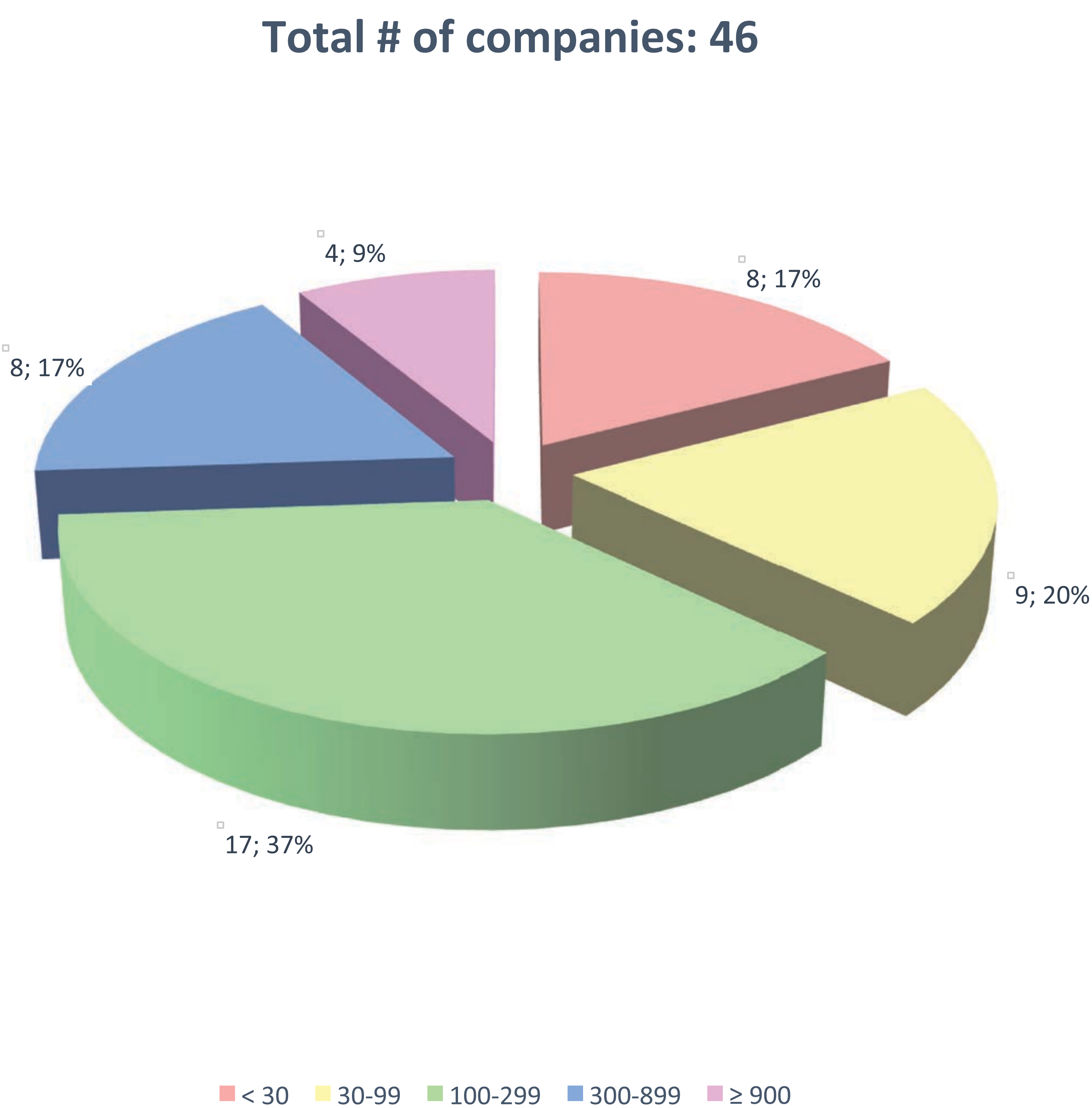
How much fatigue do you feel?

Fully alert, wide awake	Very lively, responsive, but not at peak	Okay, somewhat refreshed	A little tired, less than fresh	Moderately tired, let down	Extremely tired, very difficult to concentrate	Completely exhausted, unable to function effectively
○	○	○	○	○	○	○

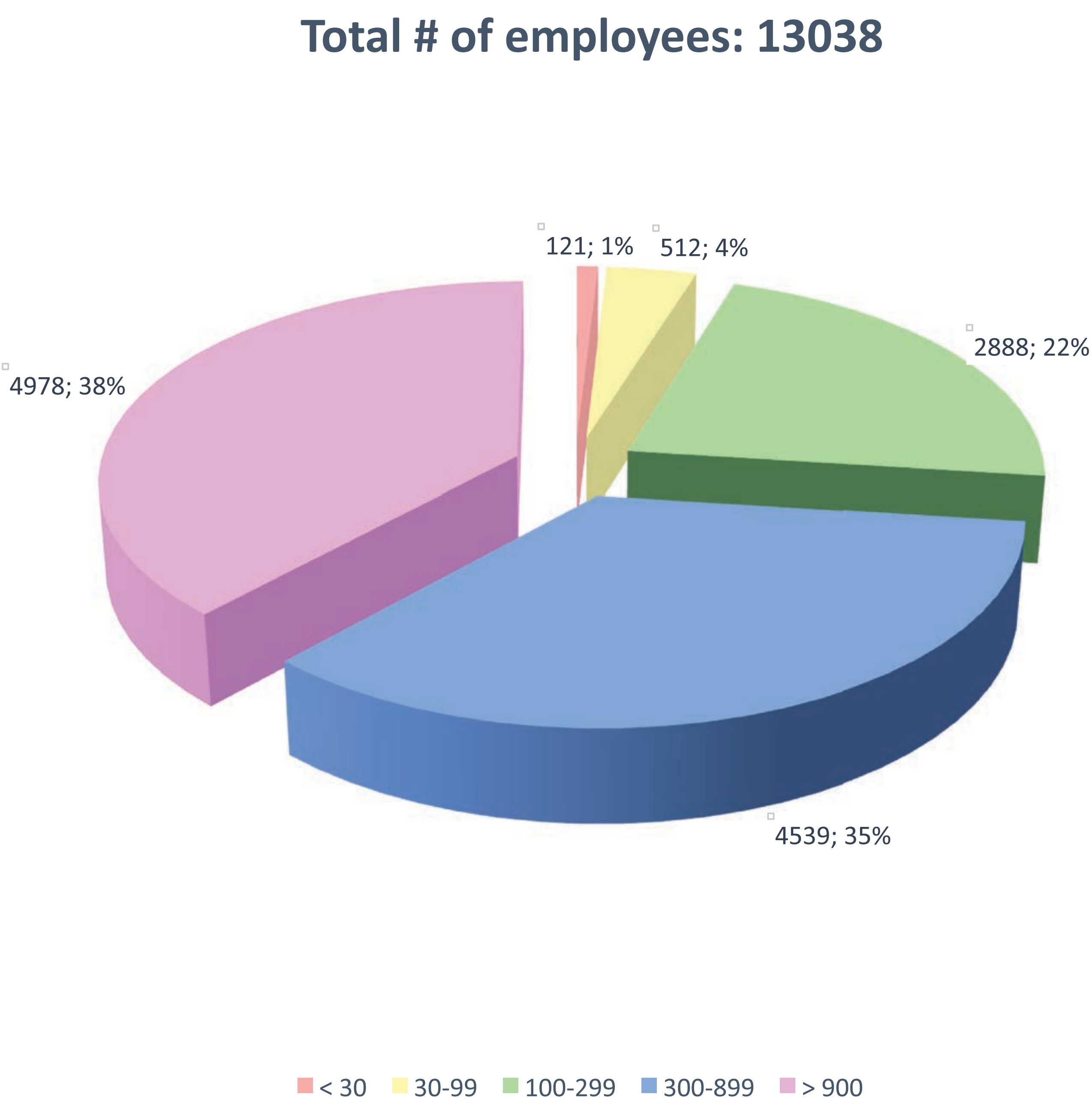
APPENDIX C

Management Survey Responses

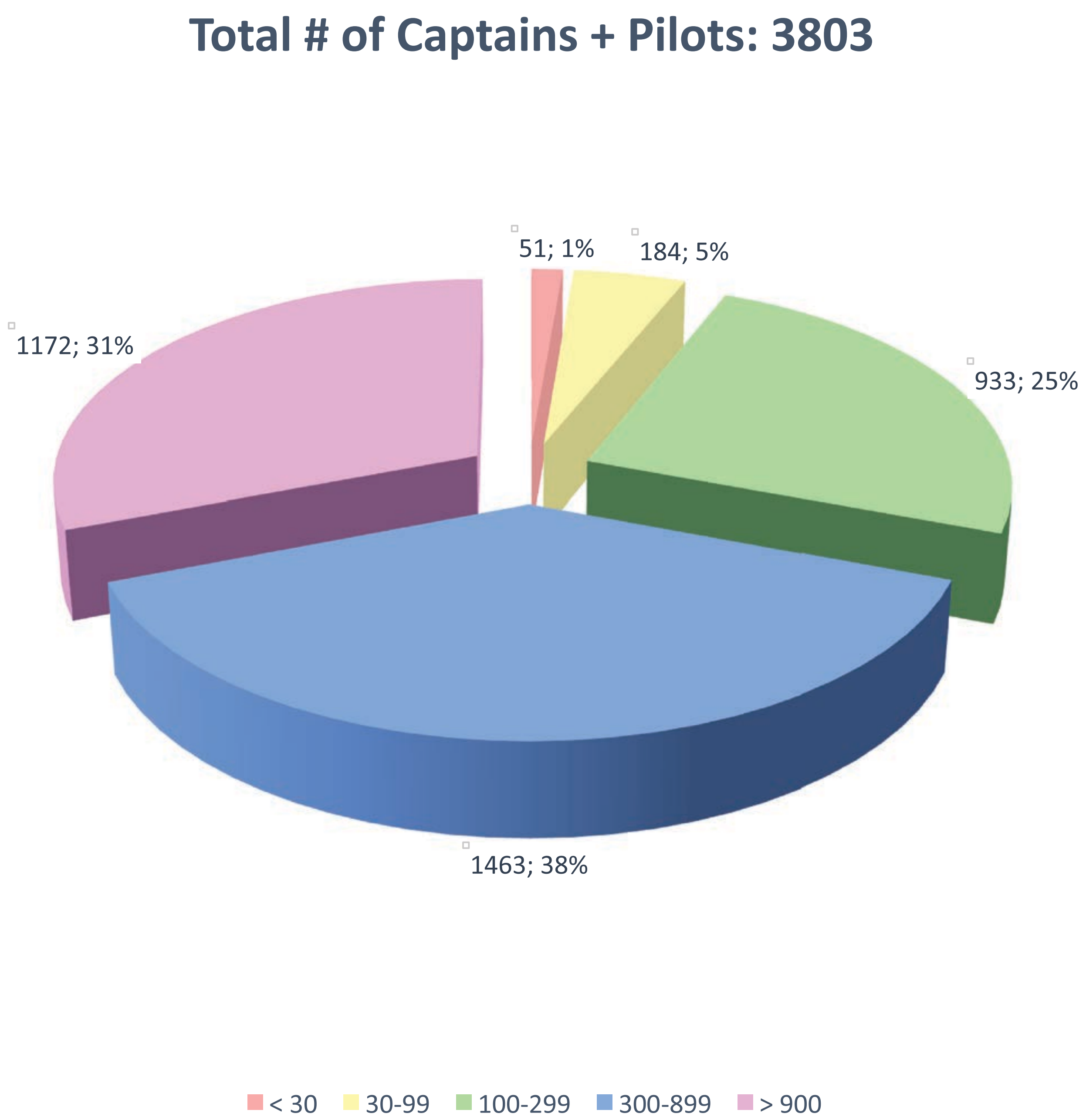
Company size



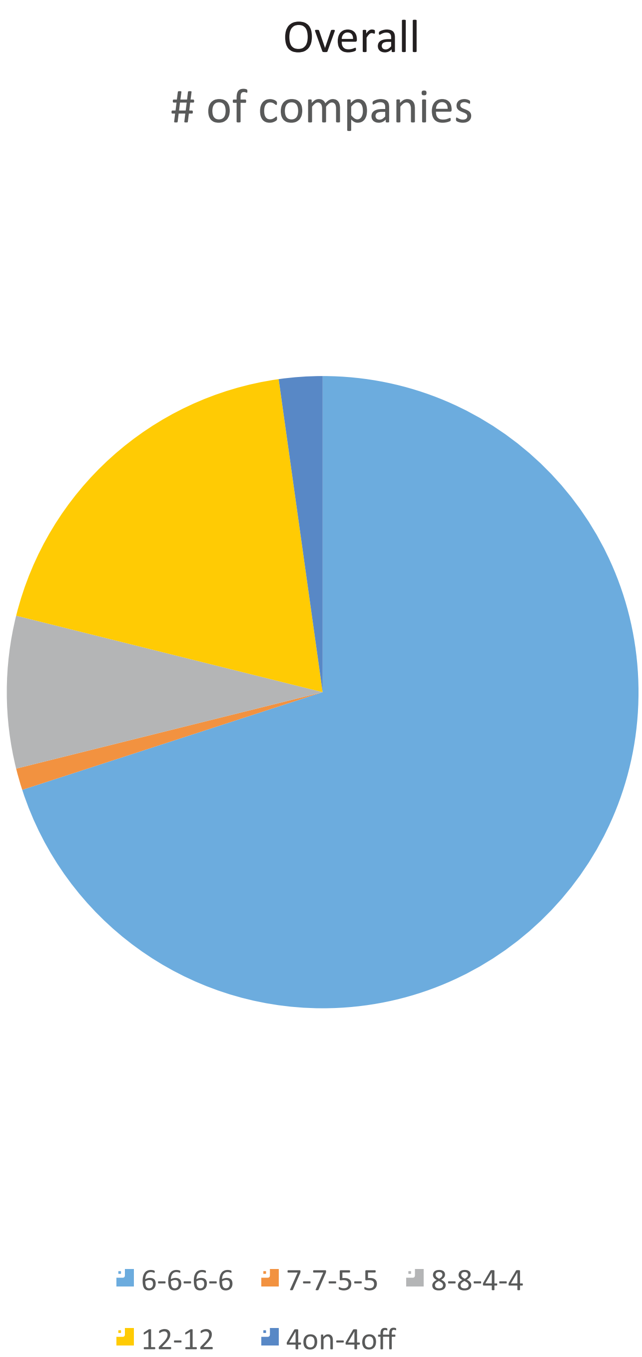
Employment by company size

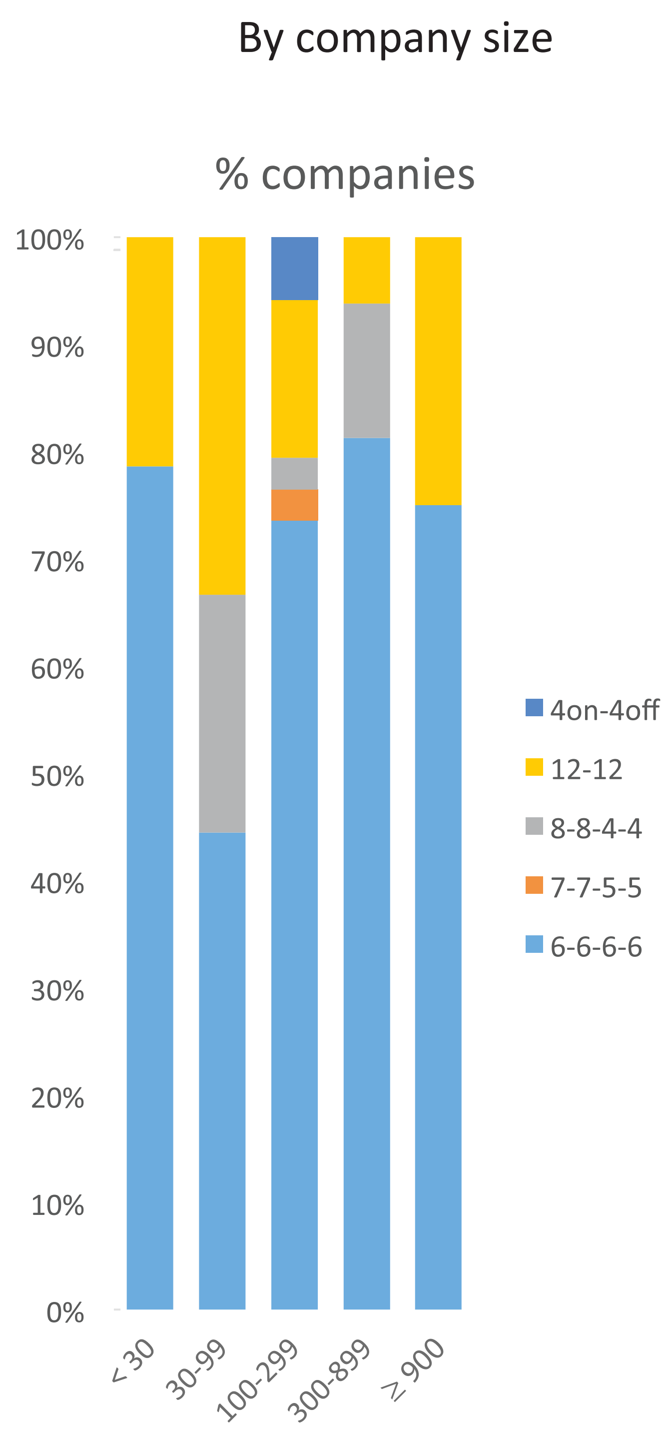


Employment by company size: Captain + Pilot



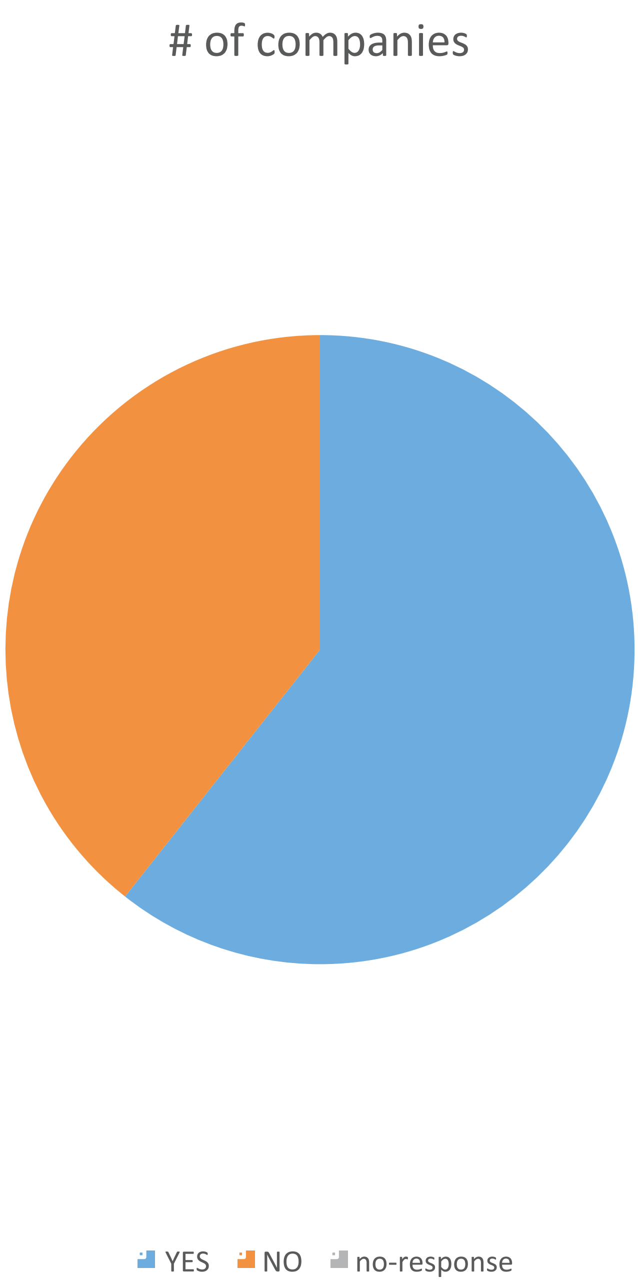
Q7. What is the primary watch schedule used by your company?



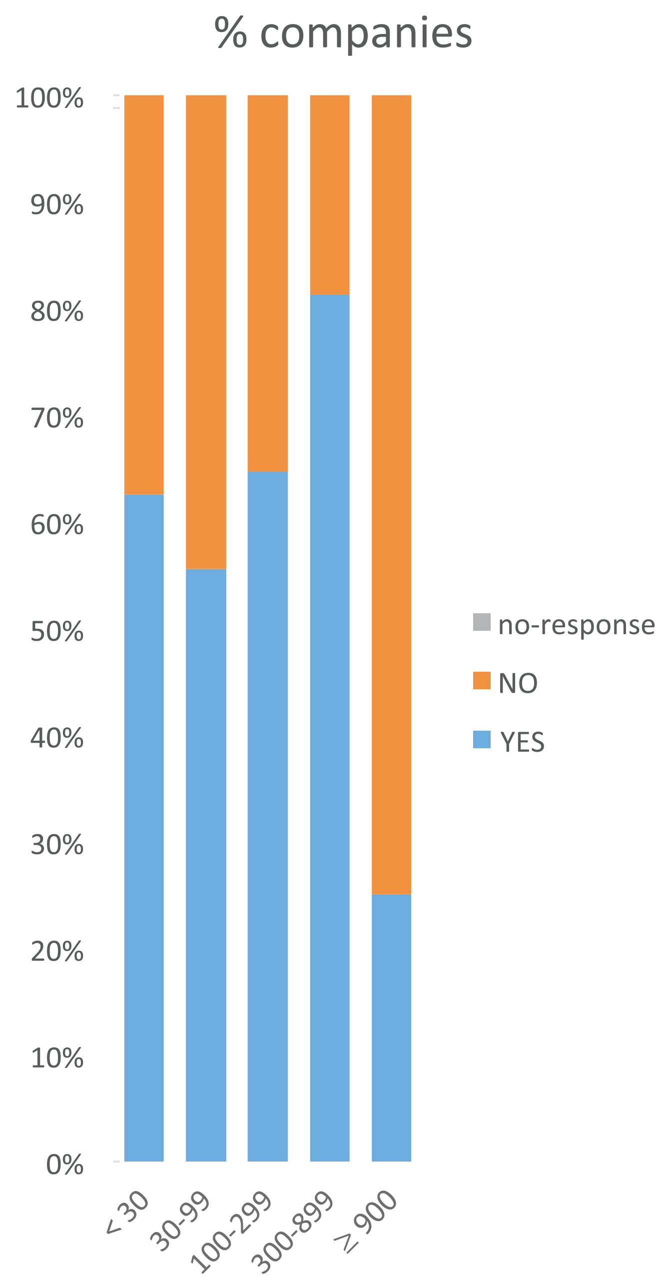


Q8. Do you stand by to load or unload cargo?

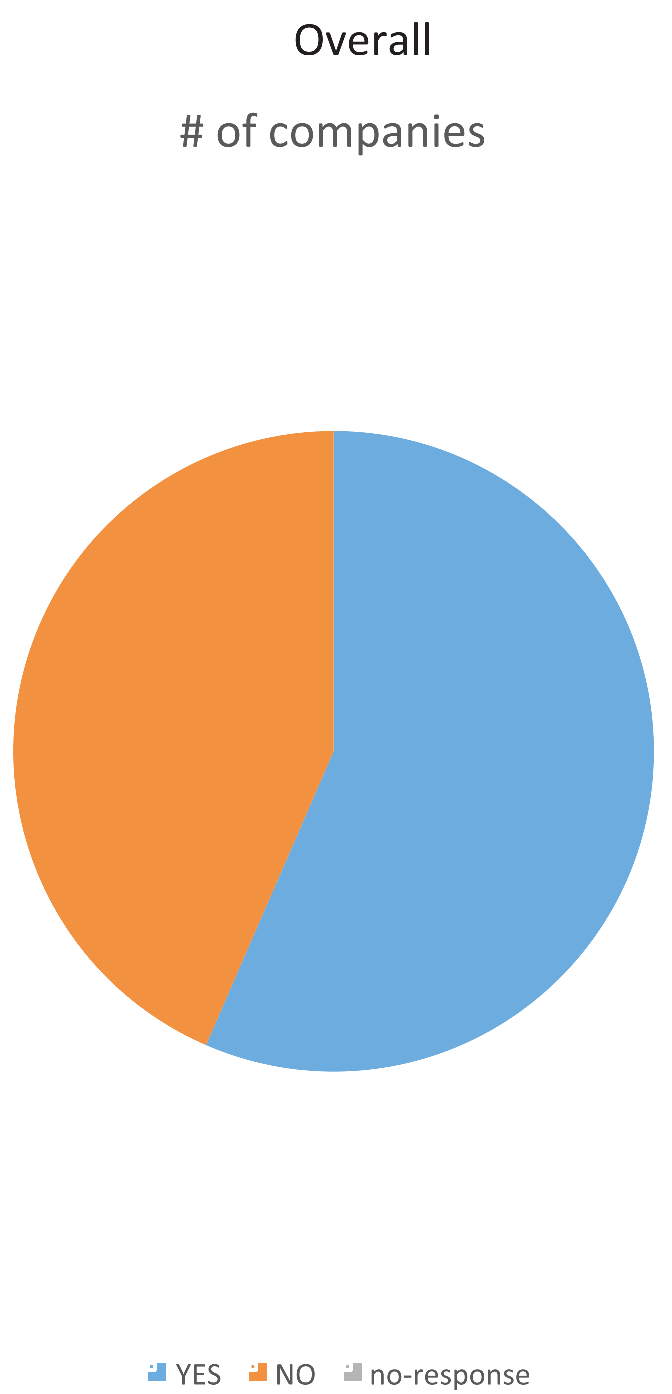
Overall

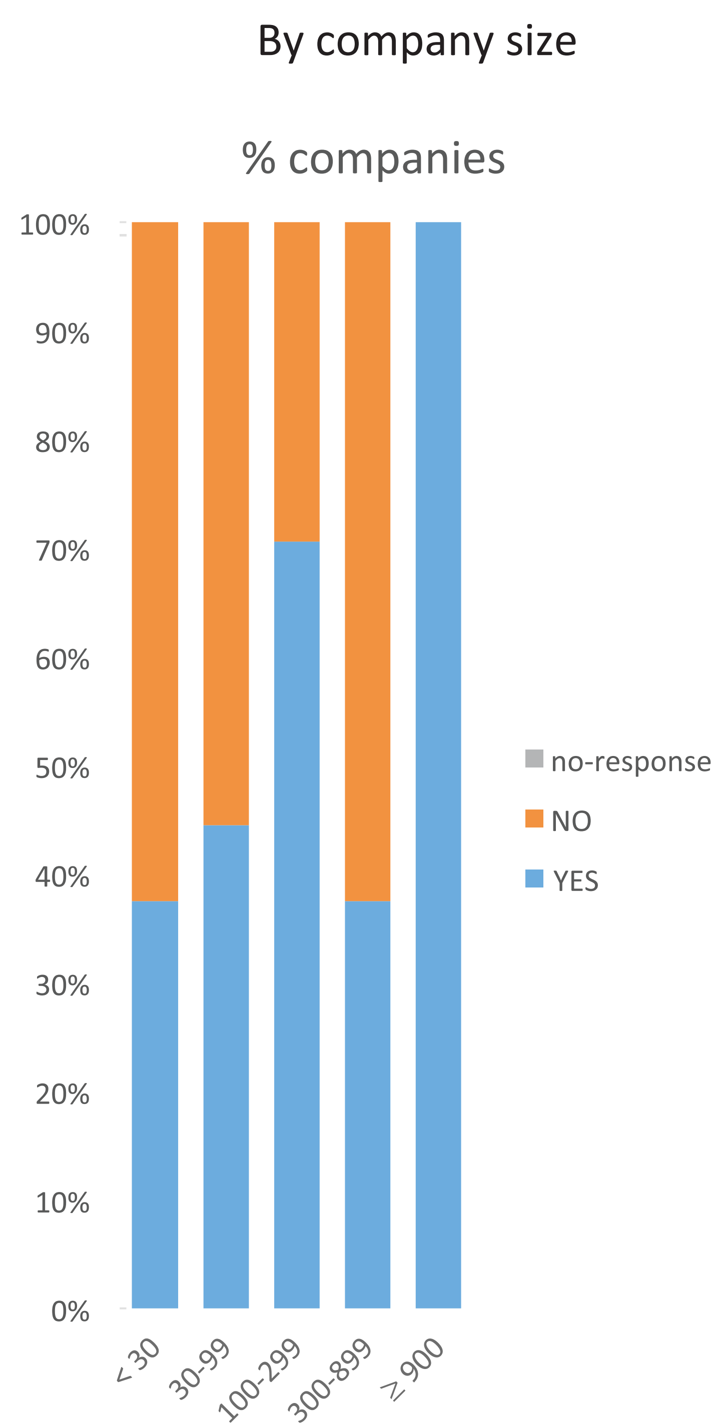


By company size

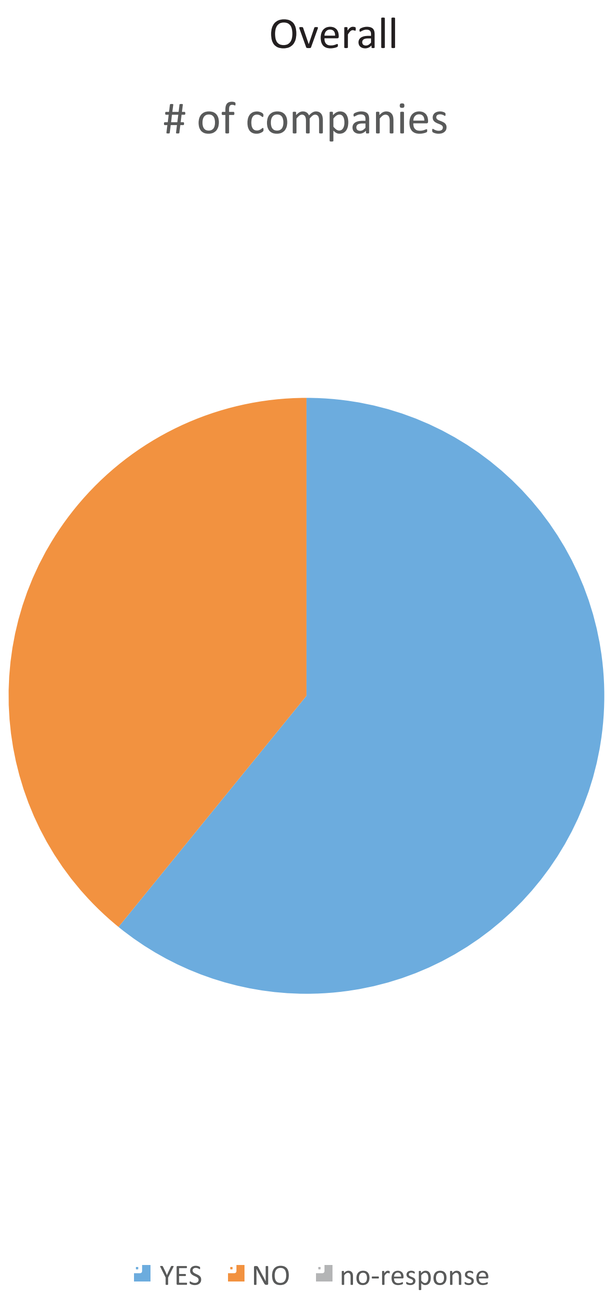


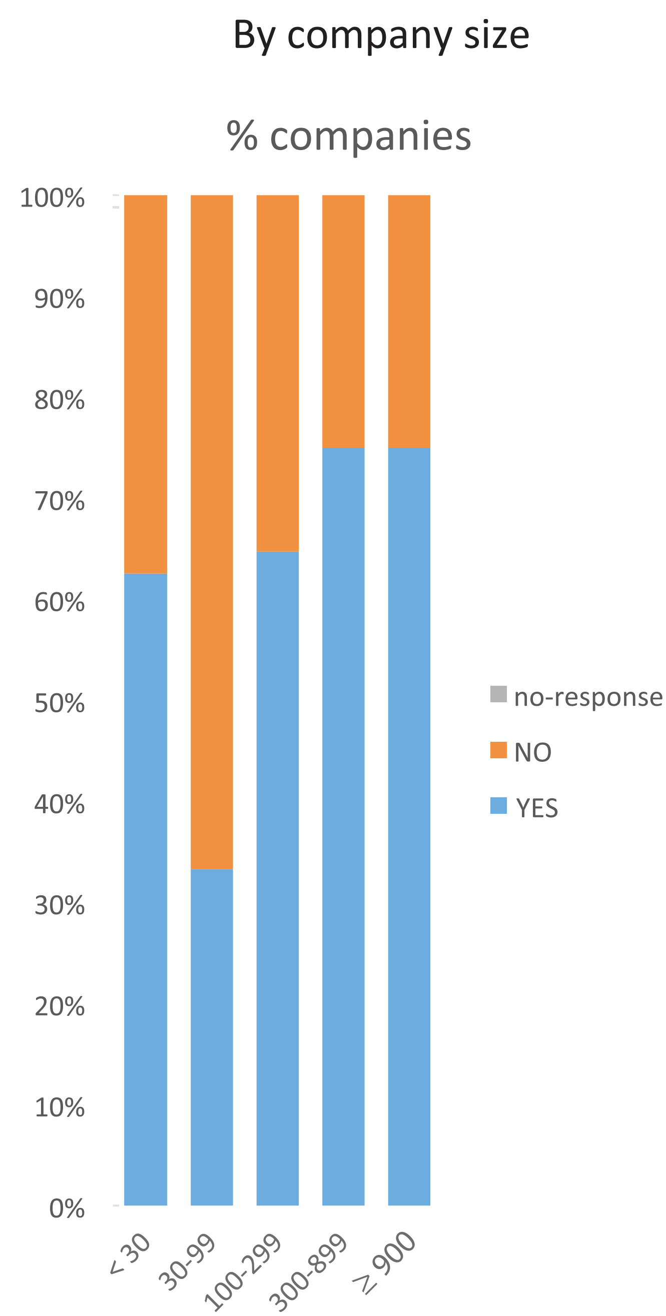
Q11. Does your company provide CEMS (Crew Endurance Management Systems) training?



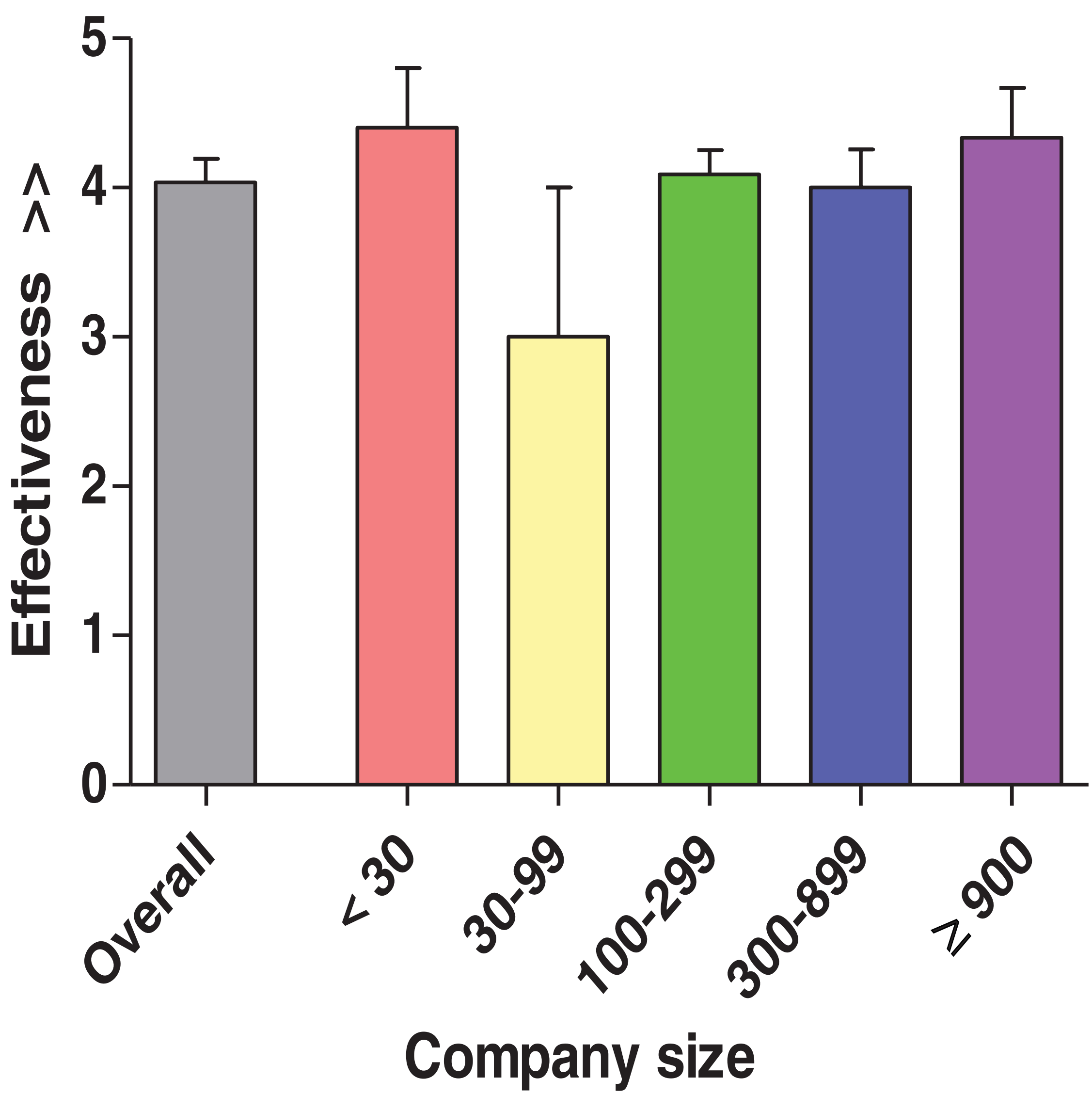


Q12. Does your company have other practices, procedures and/or training in place related to improving sleep (duration, quality and efficiency) or fatigue management?

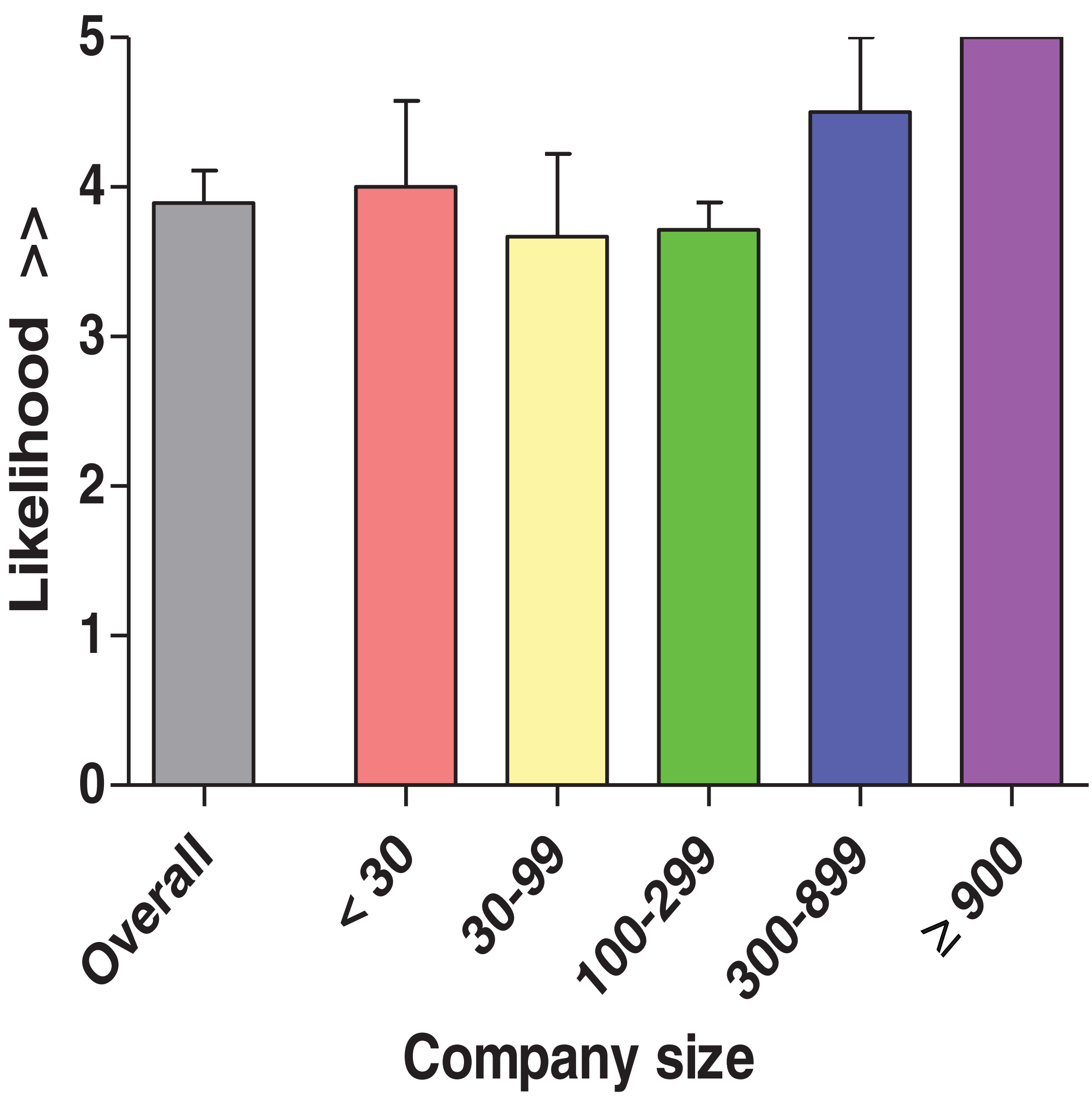




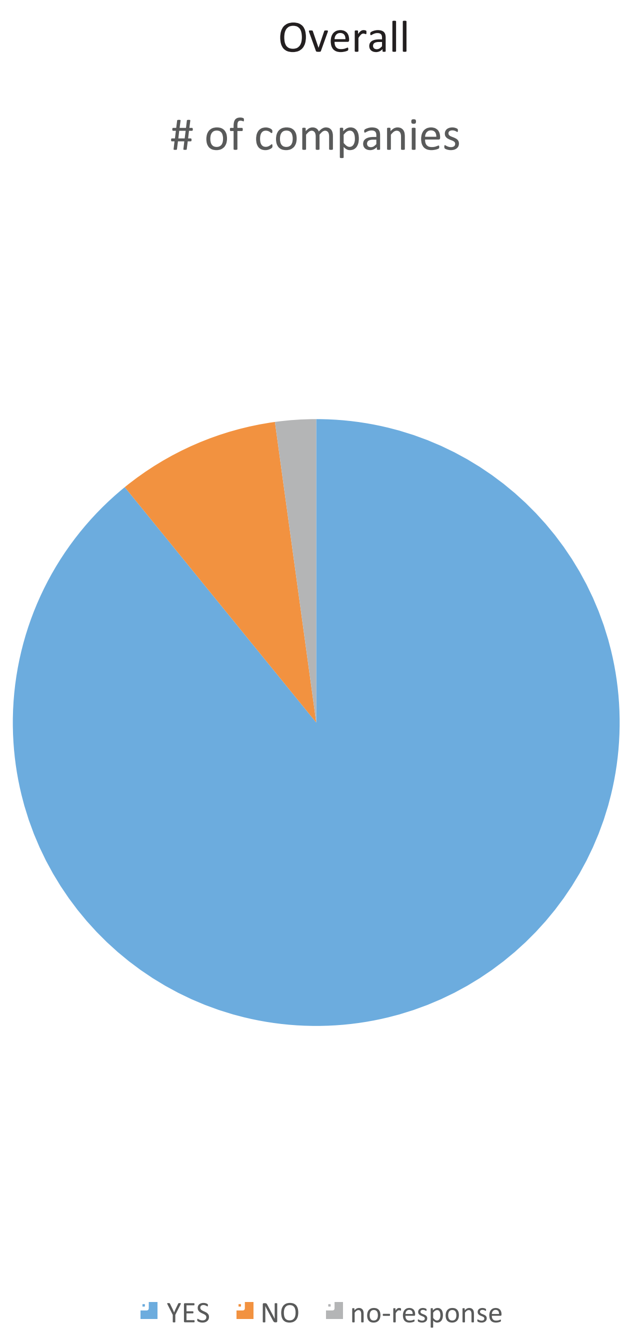
Q13. Rate the effectiveness of the practices, procedures, and/or training in place related to improving sleep (duration, quality and efficiency) or fatigue management

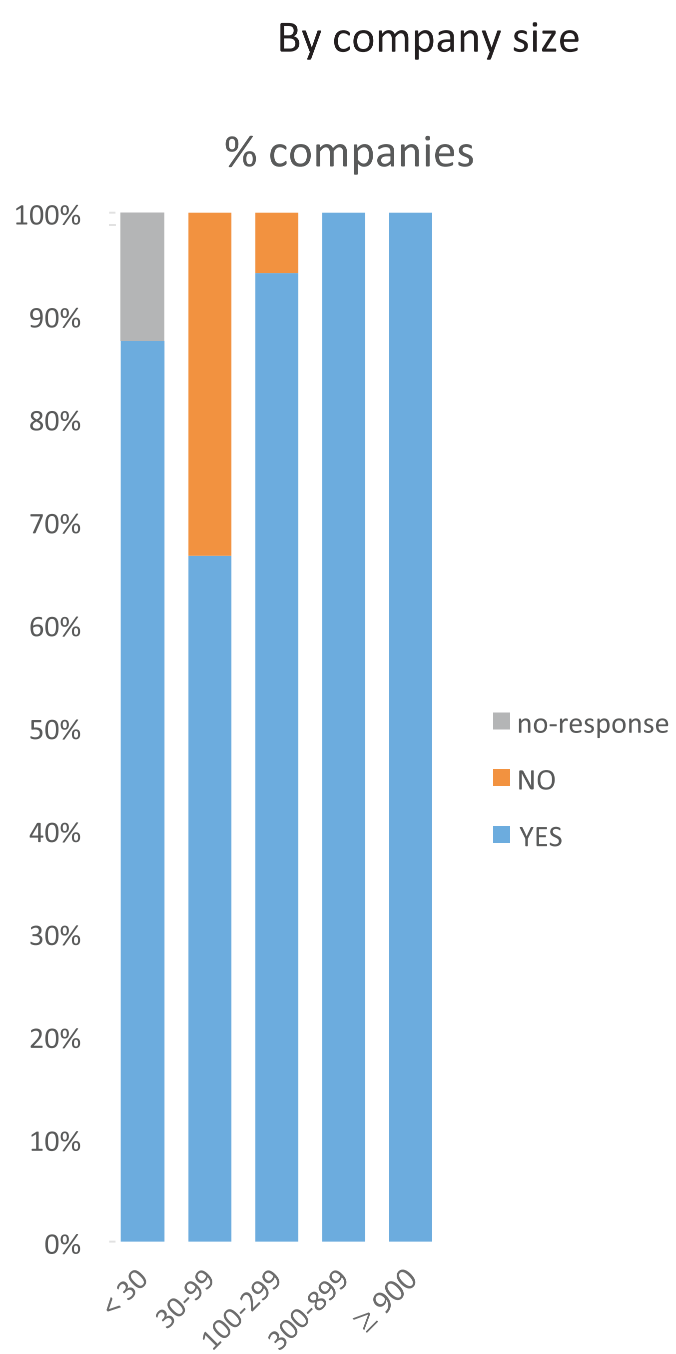


Q15. How likely would your company be to initiate practices, procedures and/or training related to improving sleep (duration, quality and efficiency) or fatigue management?

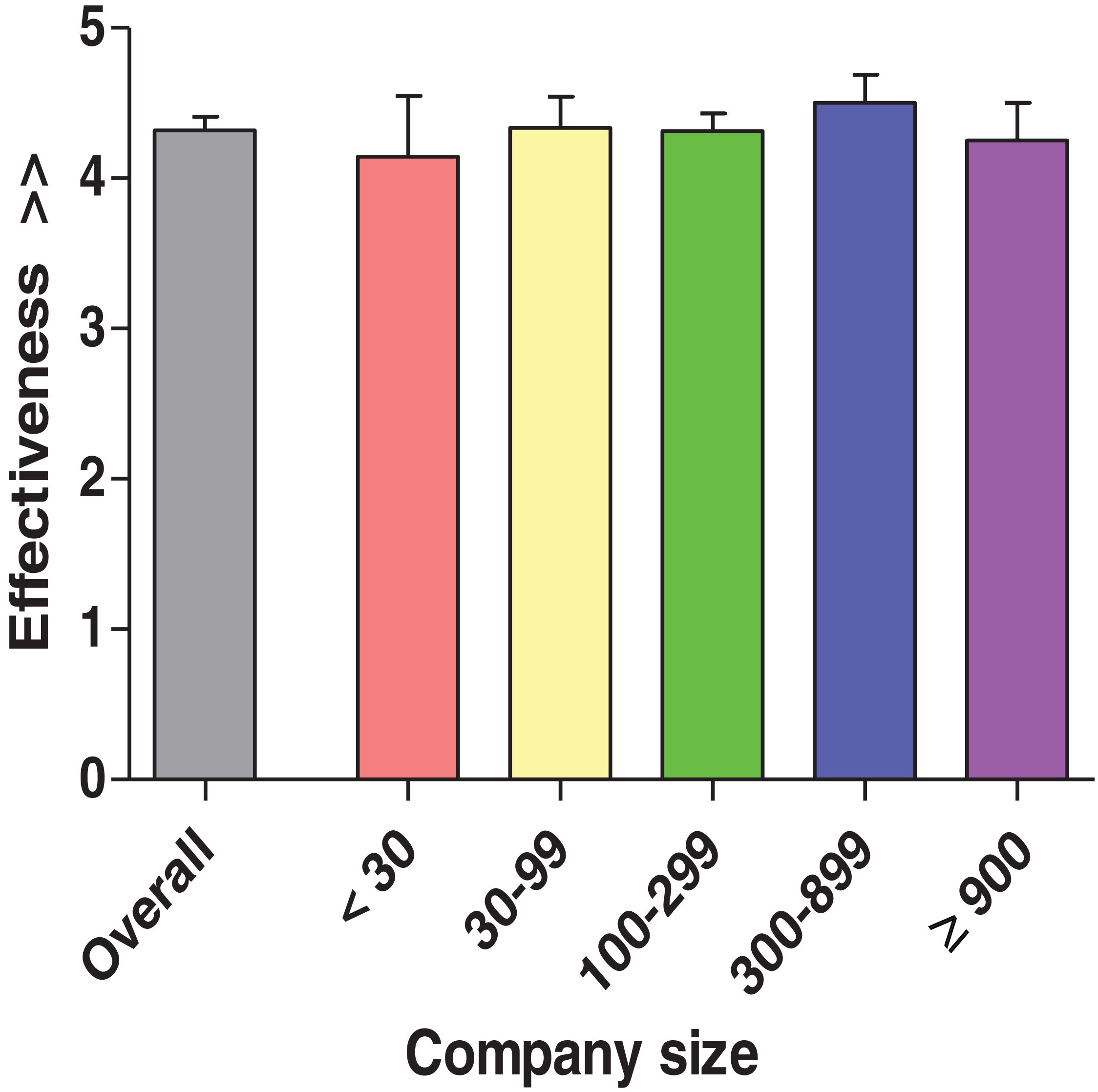


Q16. Does your company provide improvements to sleeping quarters [e.g. light reduction, beds (size, mattress), sound proofing]?

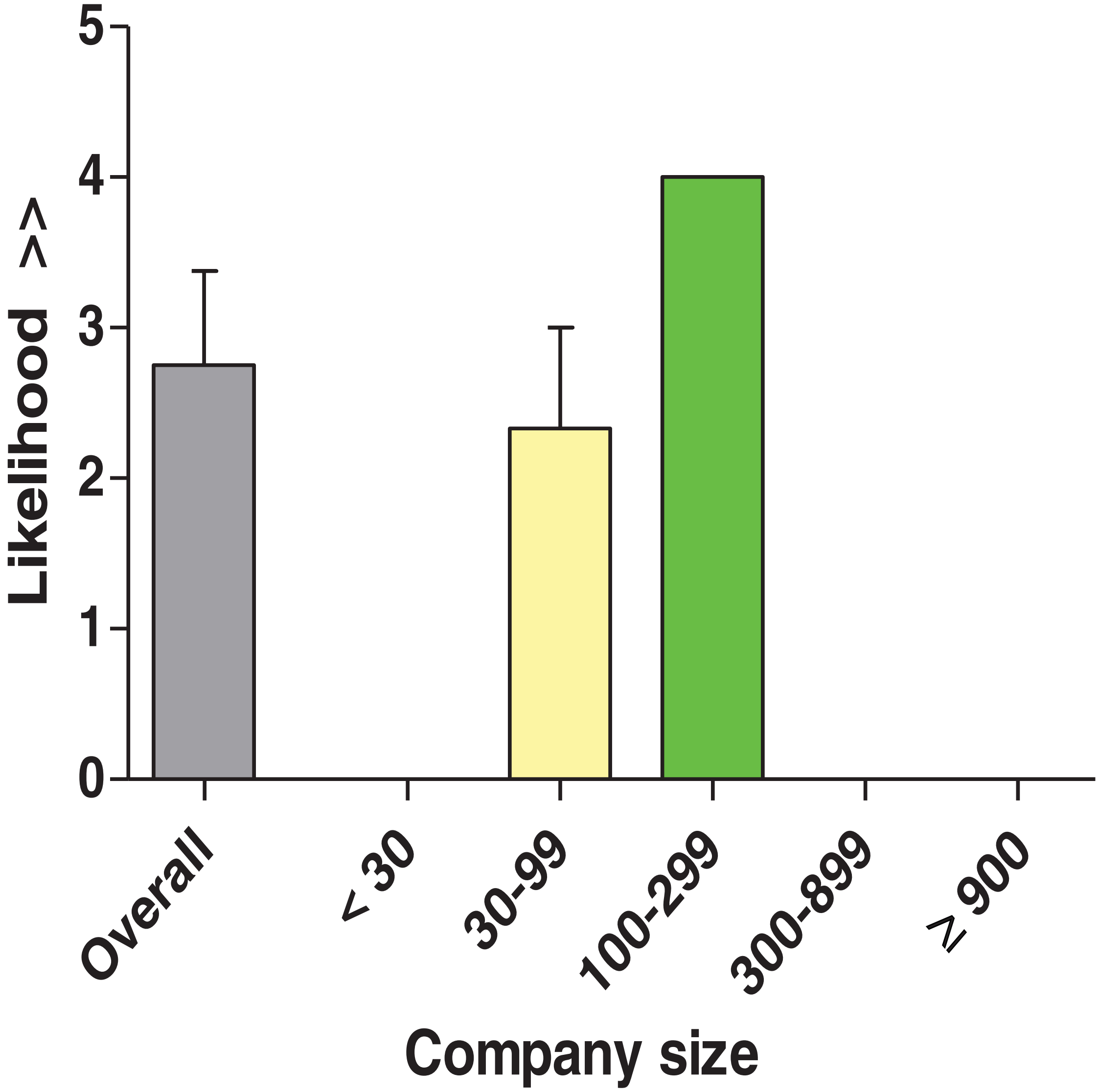




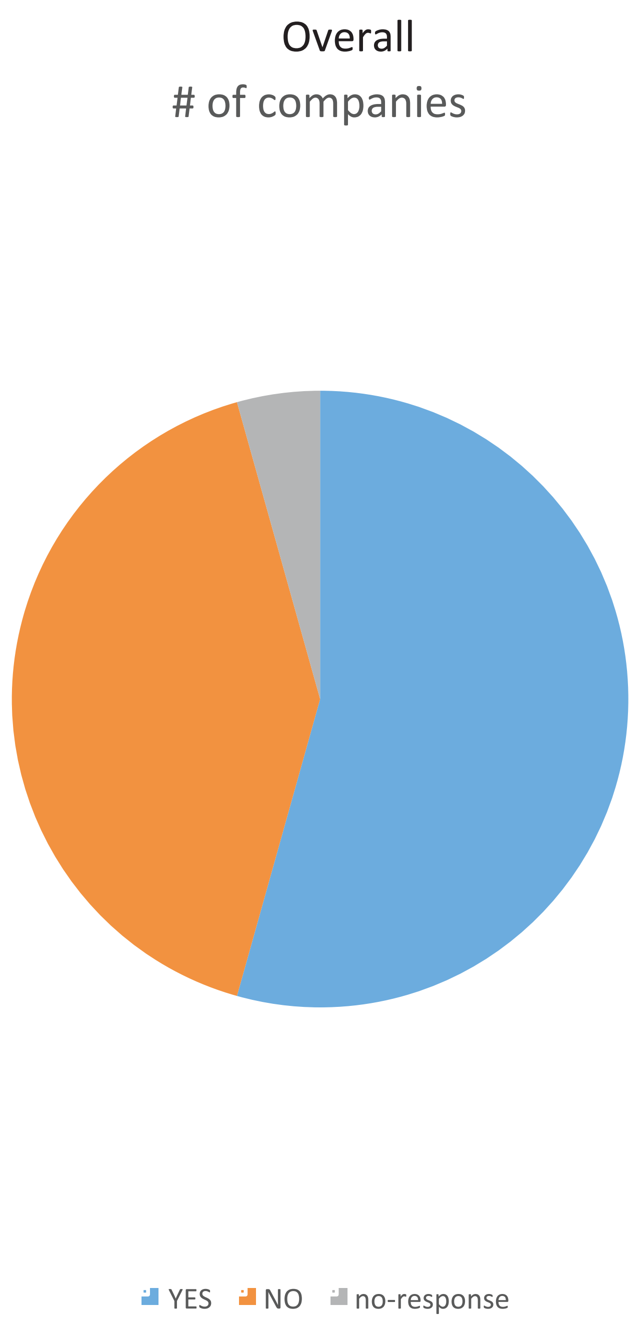
Q17. Rate the effectiveness of the enhancements of sleeping quarters in improving sleep [e.g. light reduction, beds (size, mattress), sound proofing].

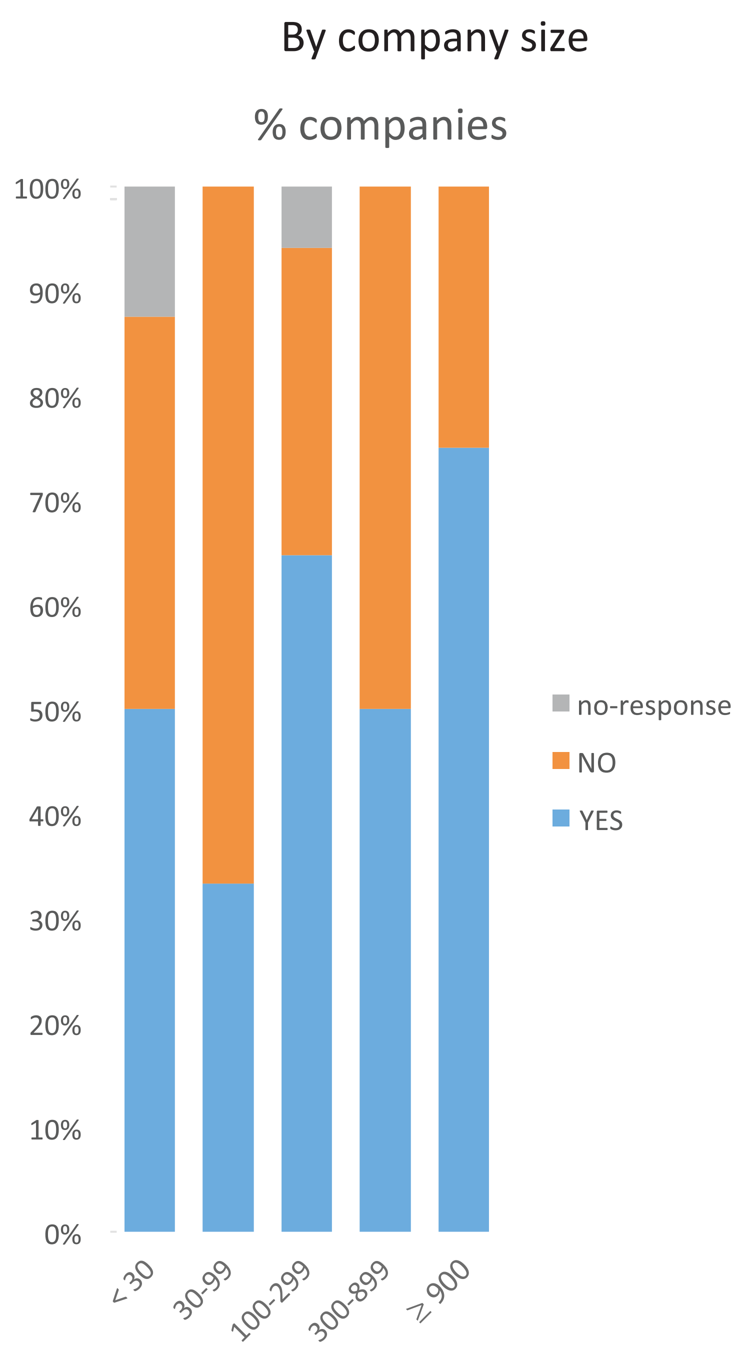


Q19. How likely would your company be to initiate training on improving sleeping quarters (e.g. light reduction, beds [size, mattress] sound proofing)?

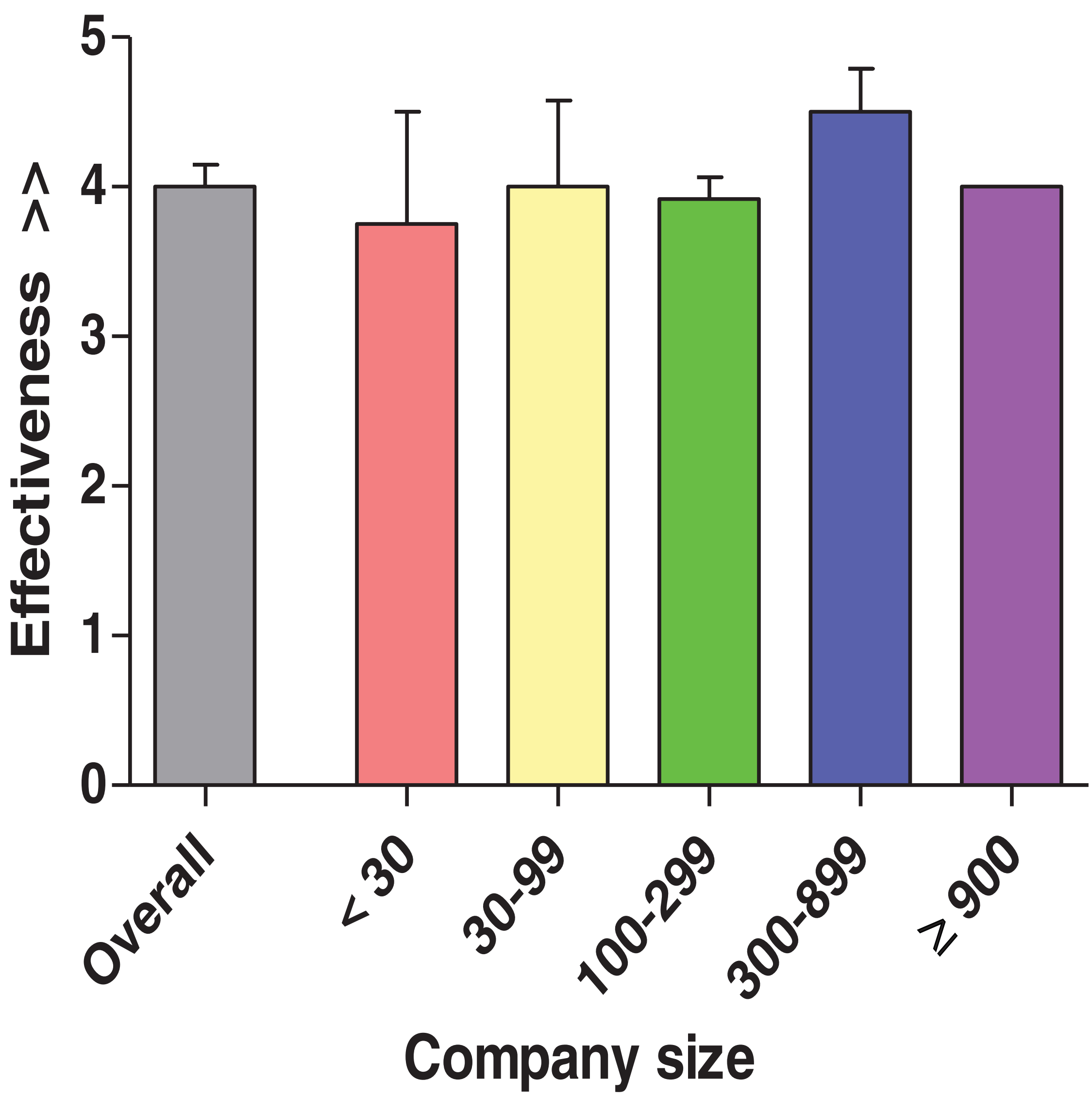


Q20. Does your company offer training or education related to sleep or sleep-related health factors (e.g. effects of sleep loss on performance and health)?

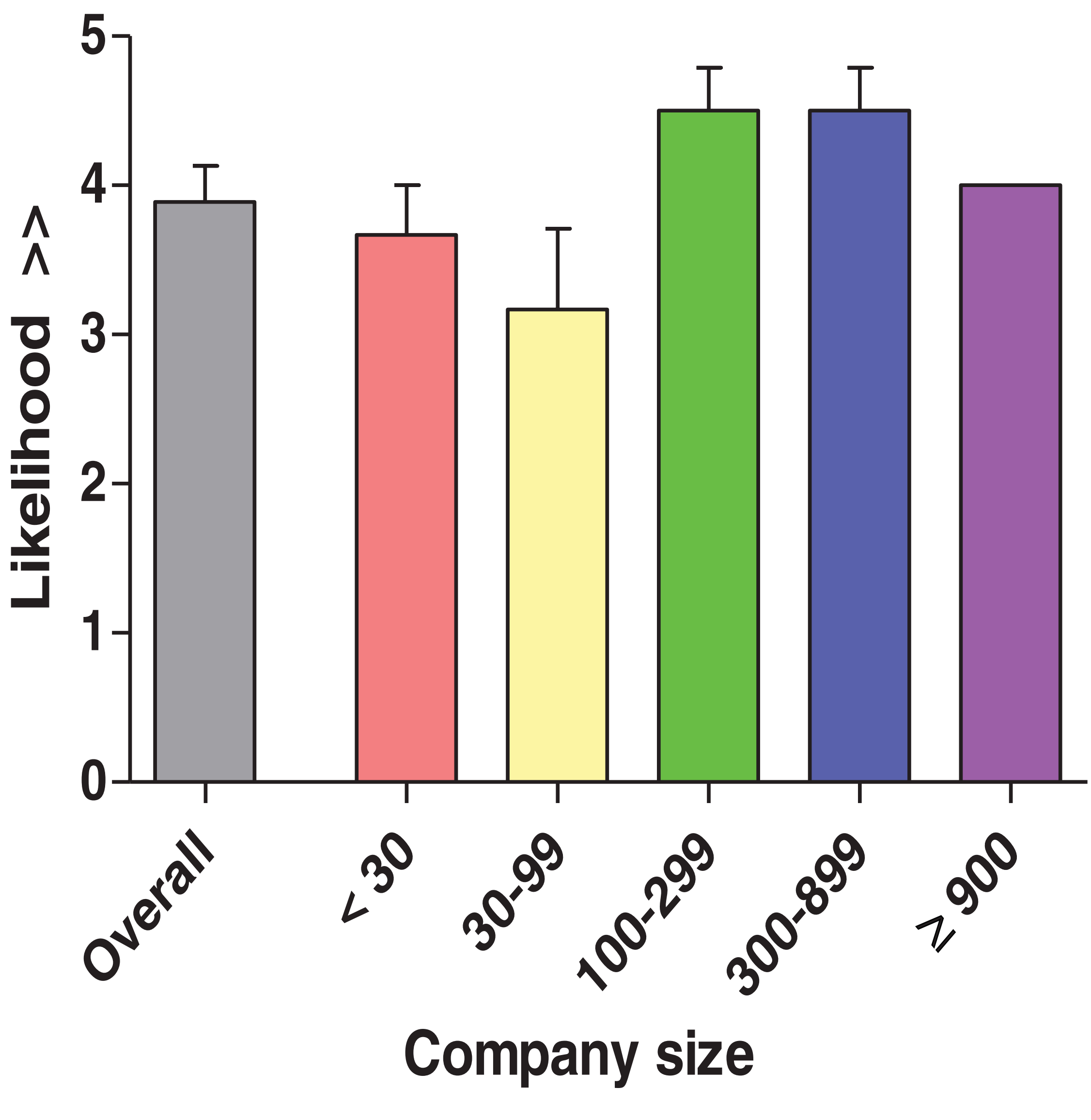




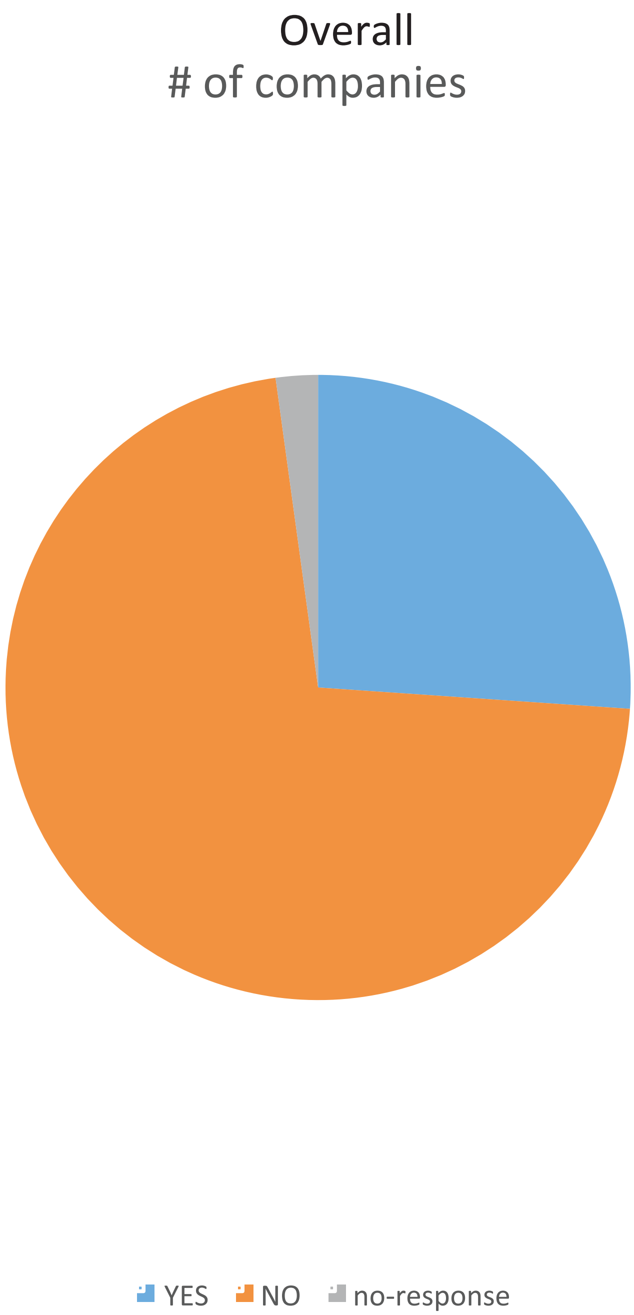
Q21. Rate the effectiveness of this training or education related to sleep or sleep-related health factors.

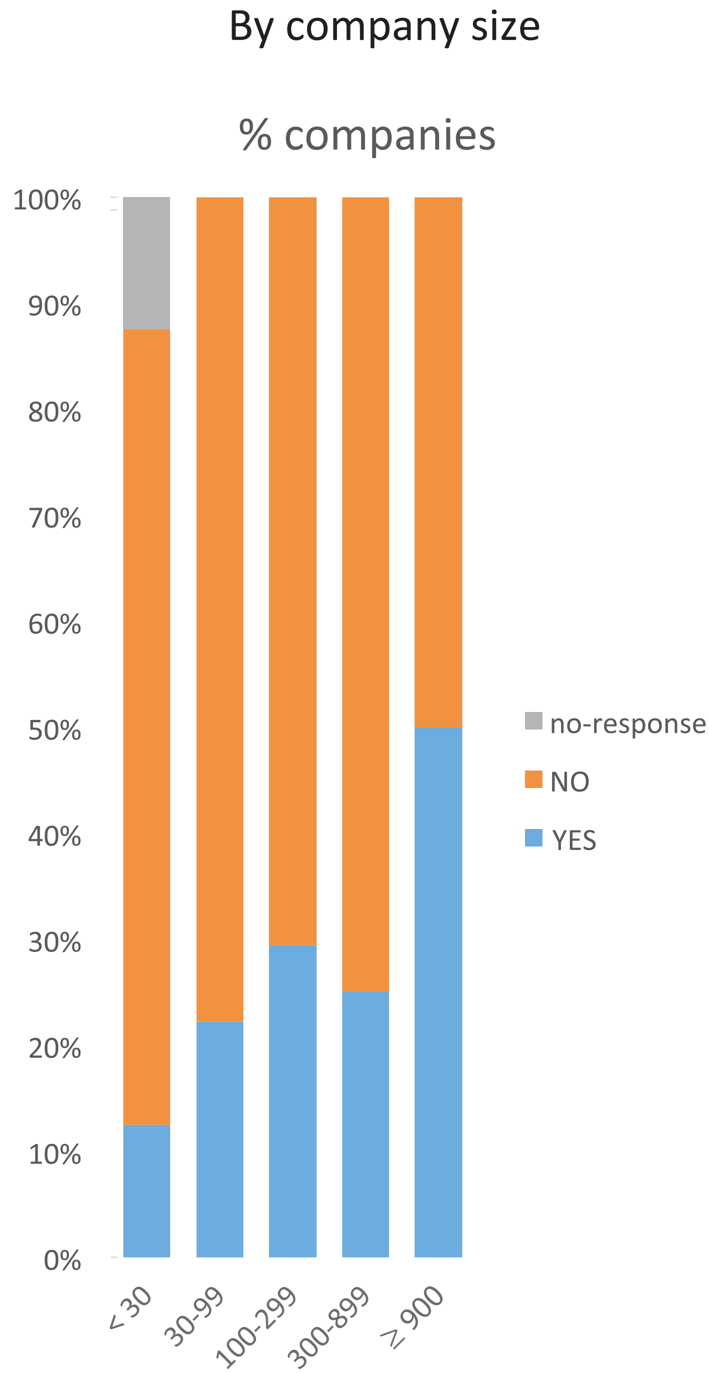


Q23. How likely would your company be to initiate training or education related to sleep or sleep-related health factors?

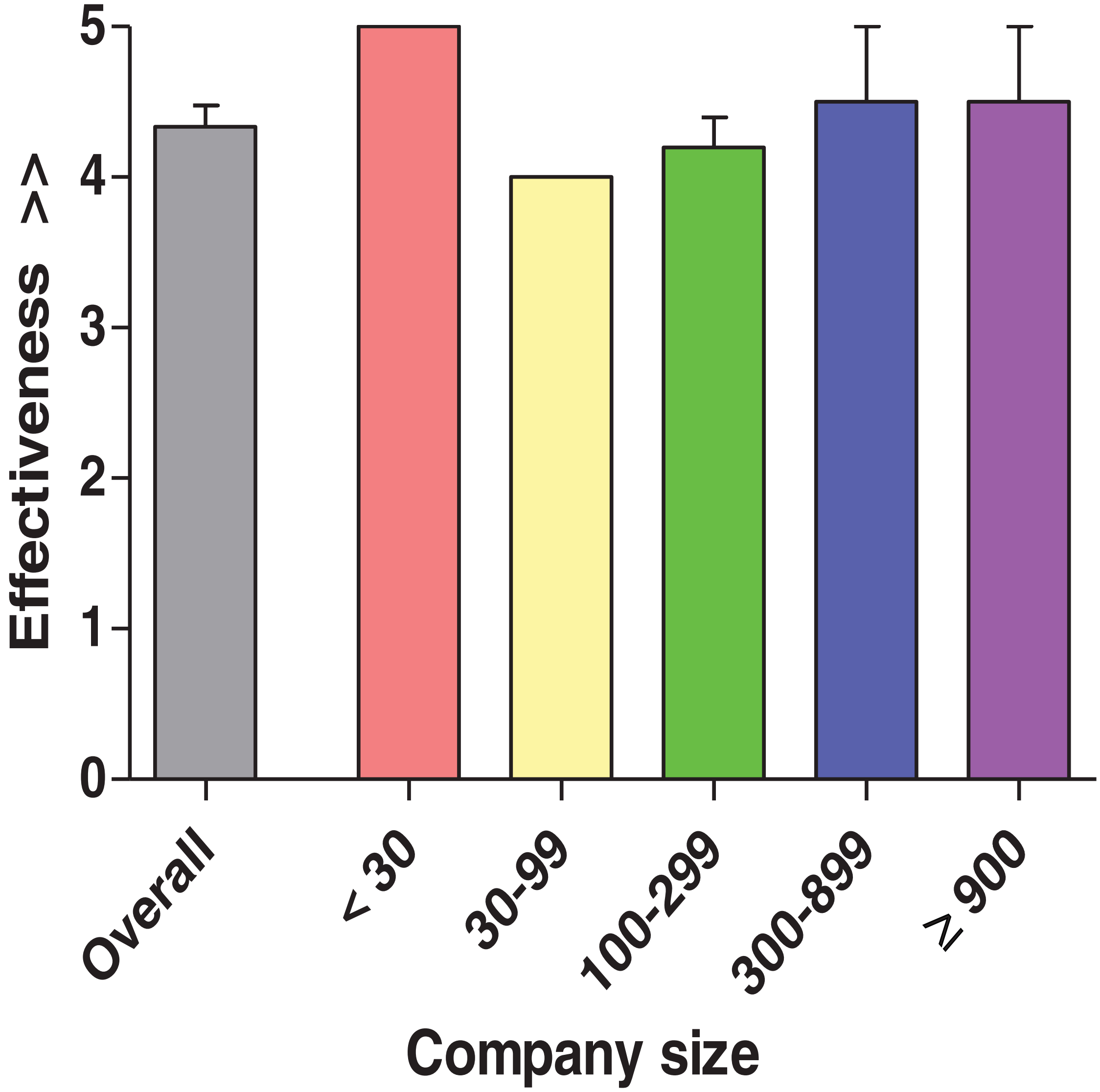


Q24. Does your company offer screening, training or education on sleep disorders?

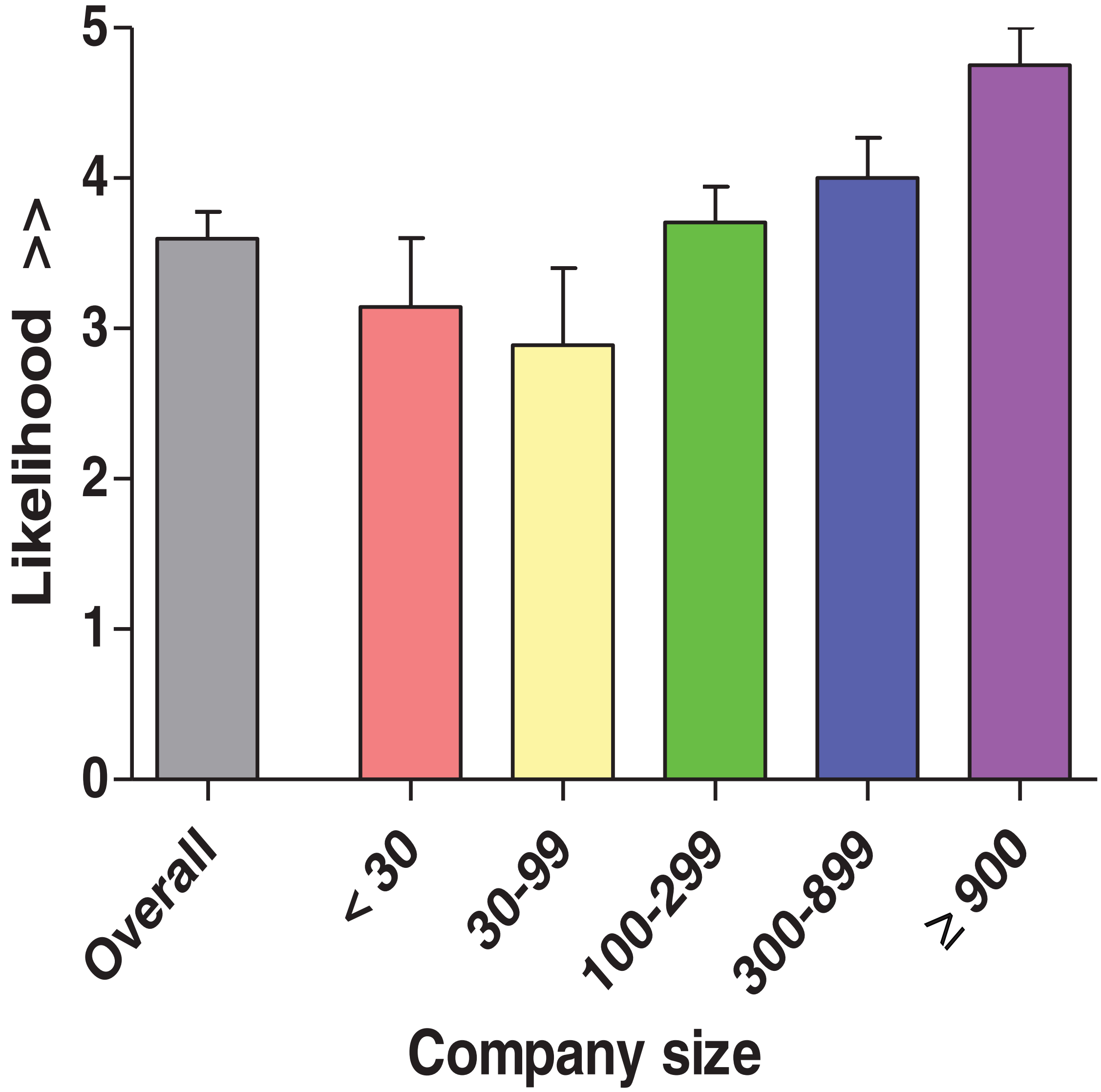




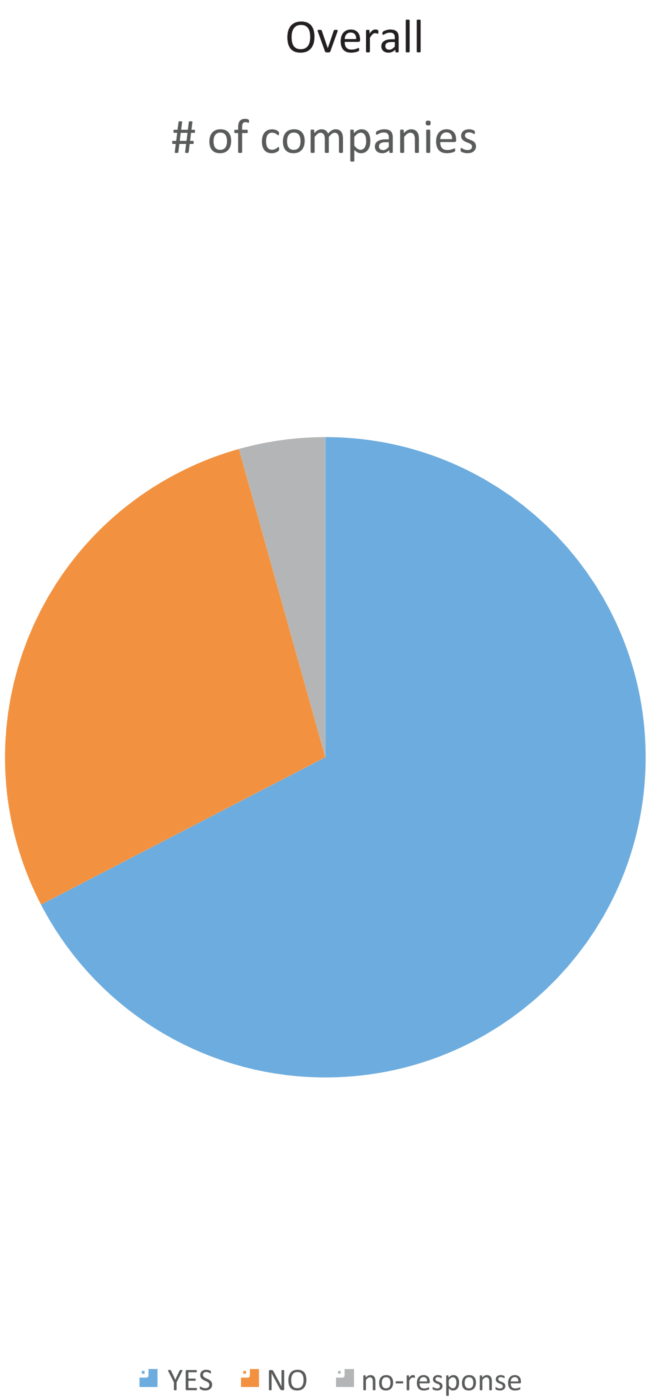
Q25. Rate the effectiveness of the screening, training or education that your company provides related to sleep disorders.

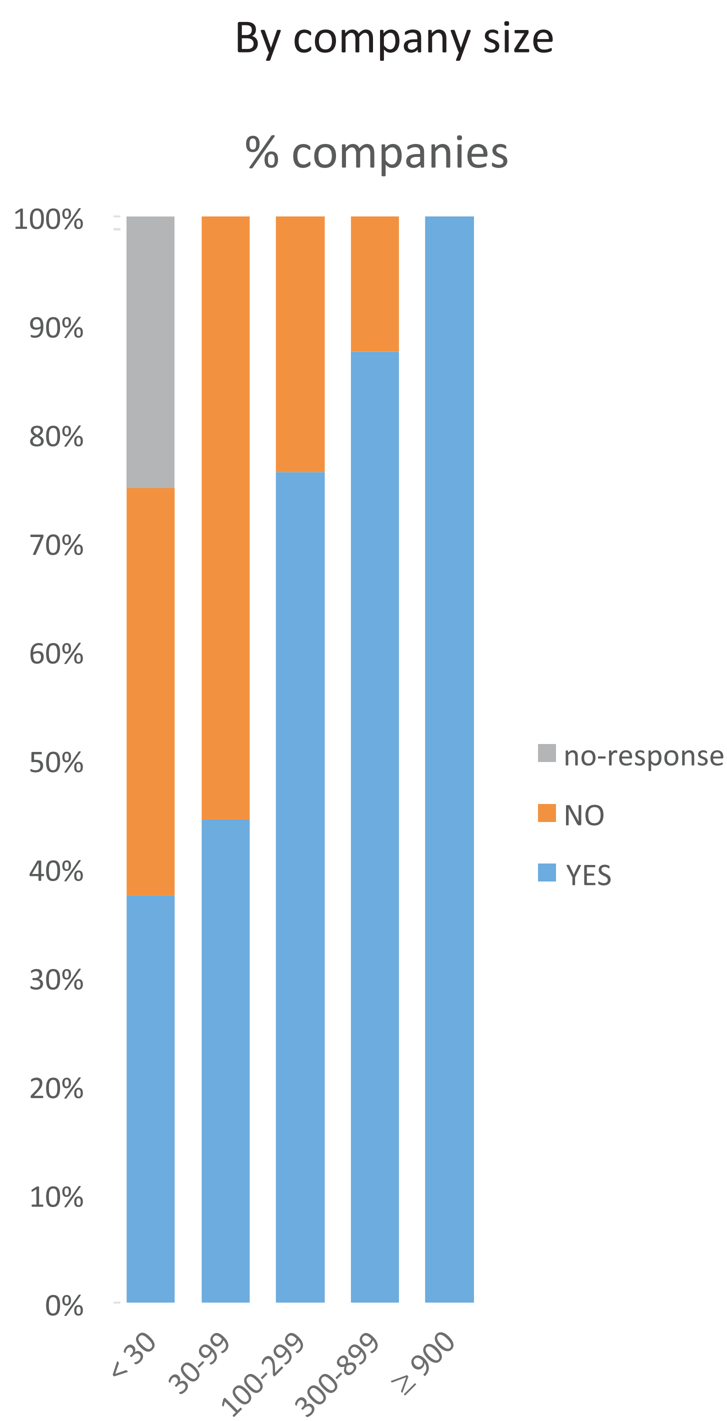


Q27. How likely would your company be to initiate screenings, training or education for sleep disorders (e.g. obstructive sleep apnea)?

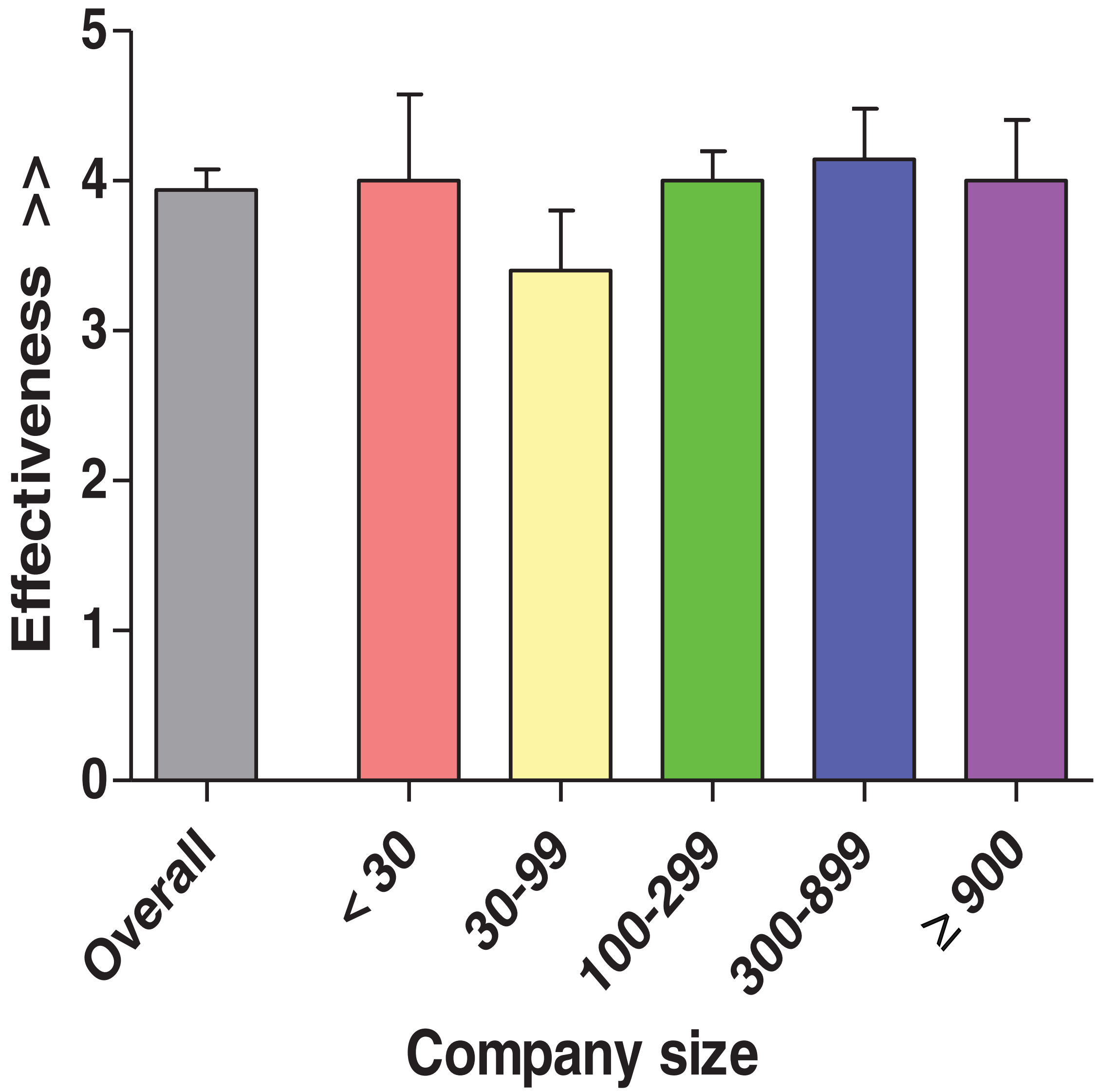


Q29. Does your company offer a wellness program?

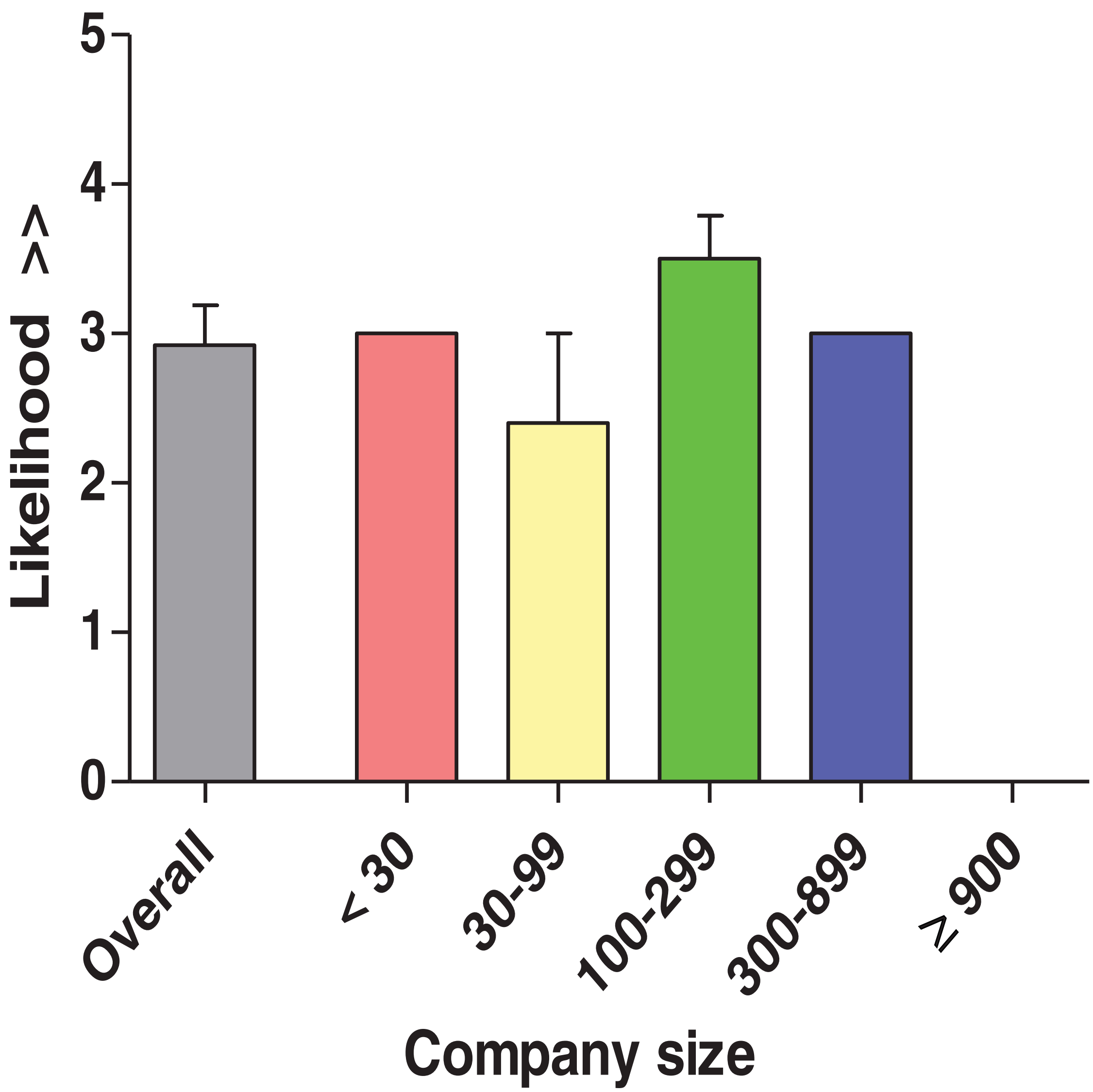




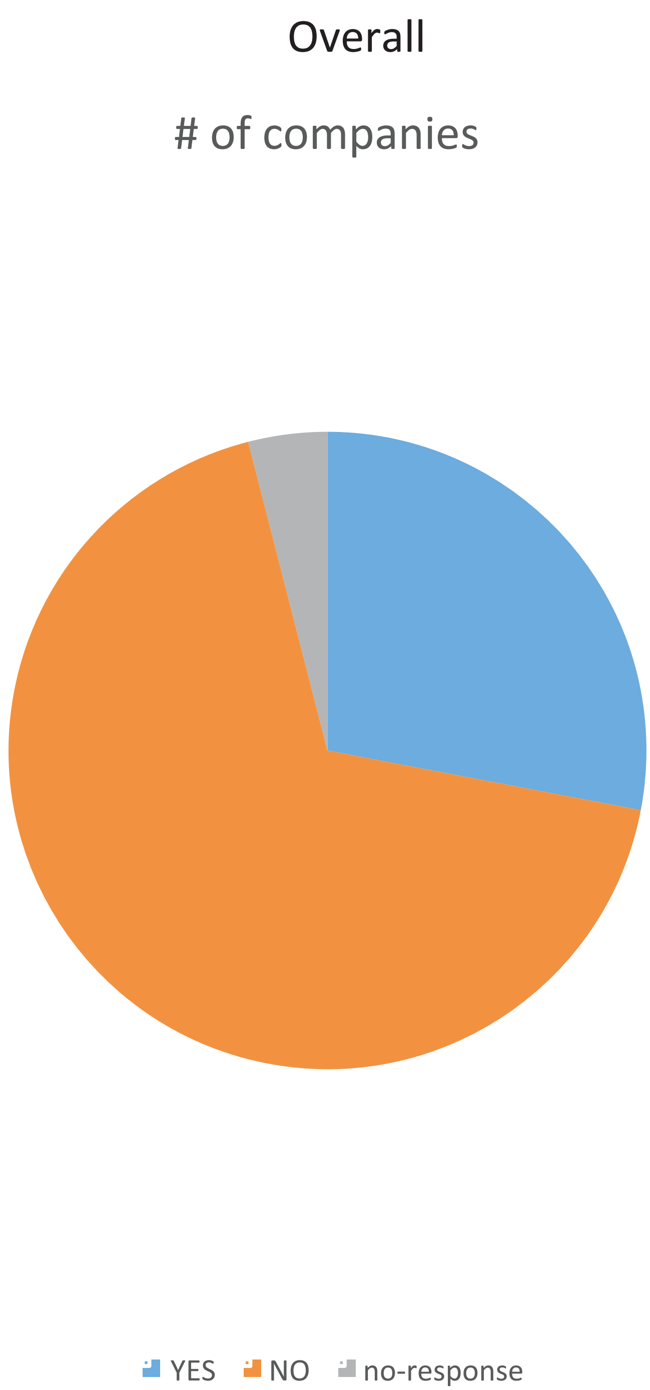
Q30. Rate the effectiveness of this wellness program.

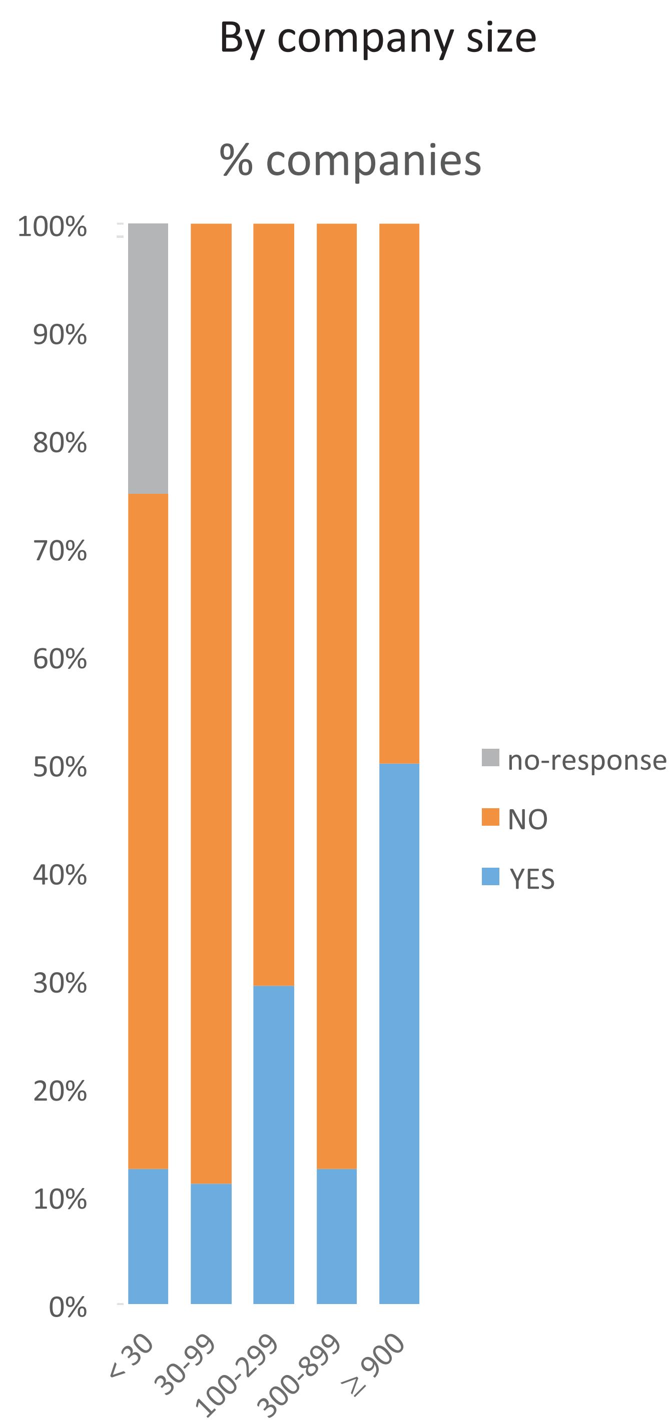


Q32. How likely would your company be to initiate a wellness program?

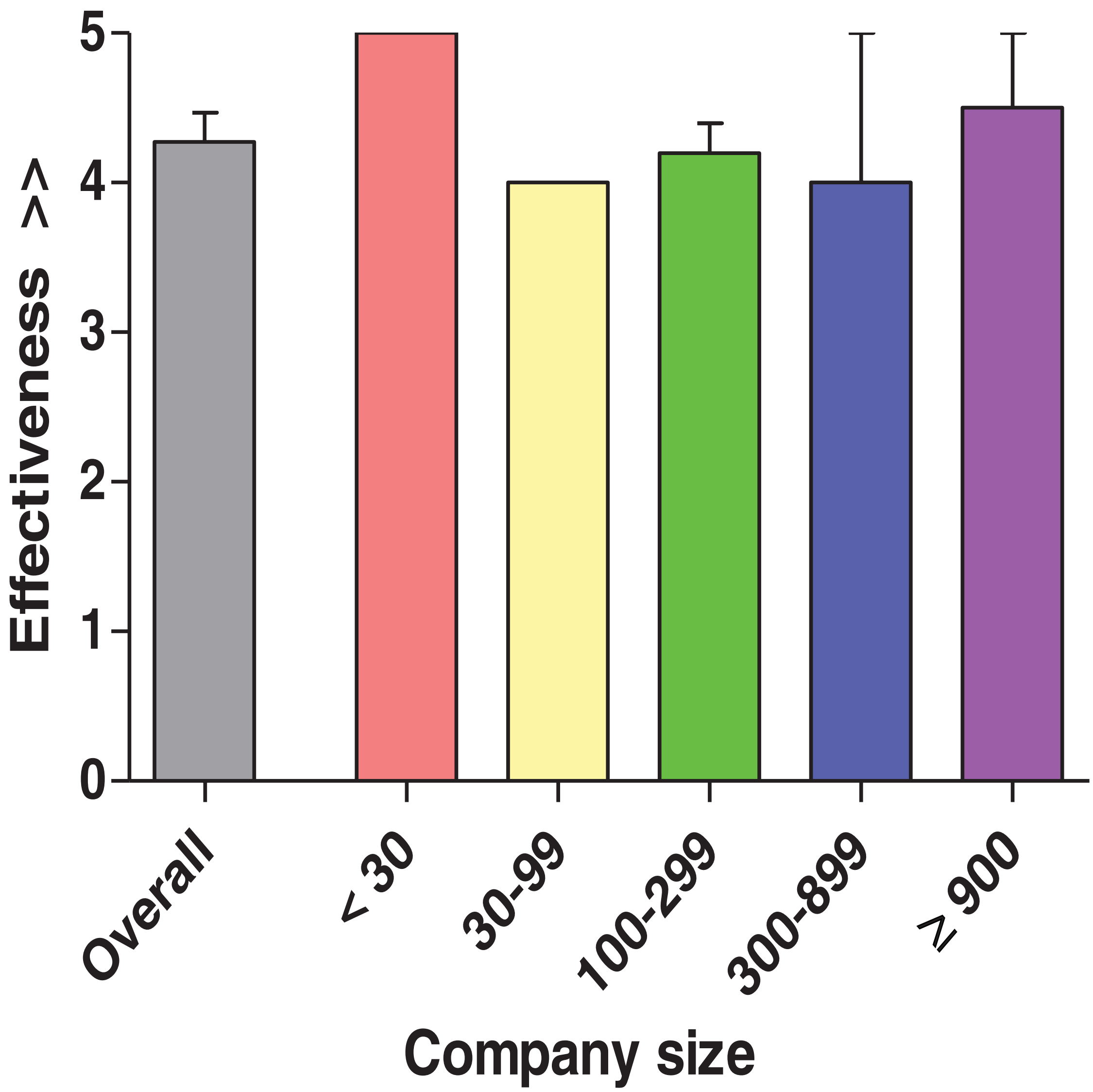


Q33. Does your company offer stress management training?

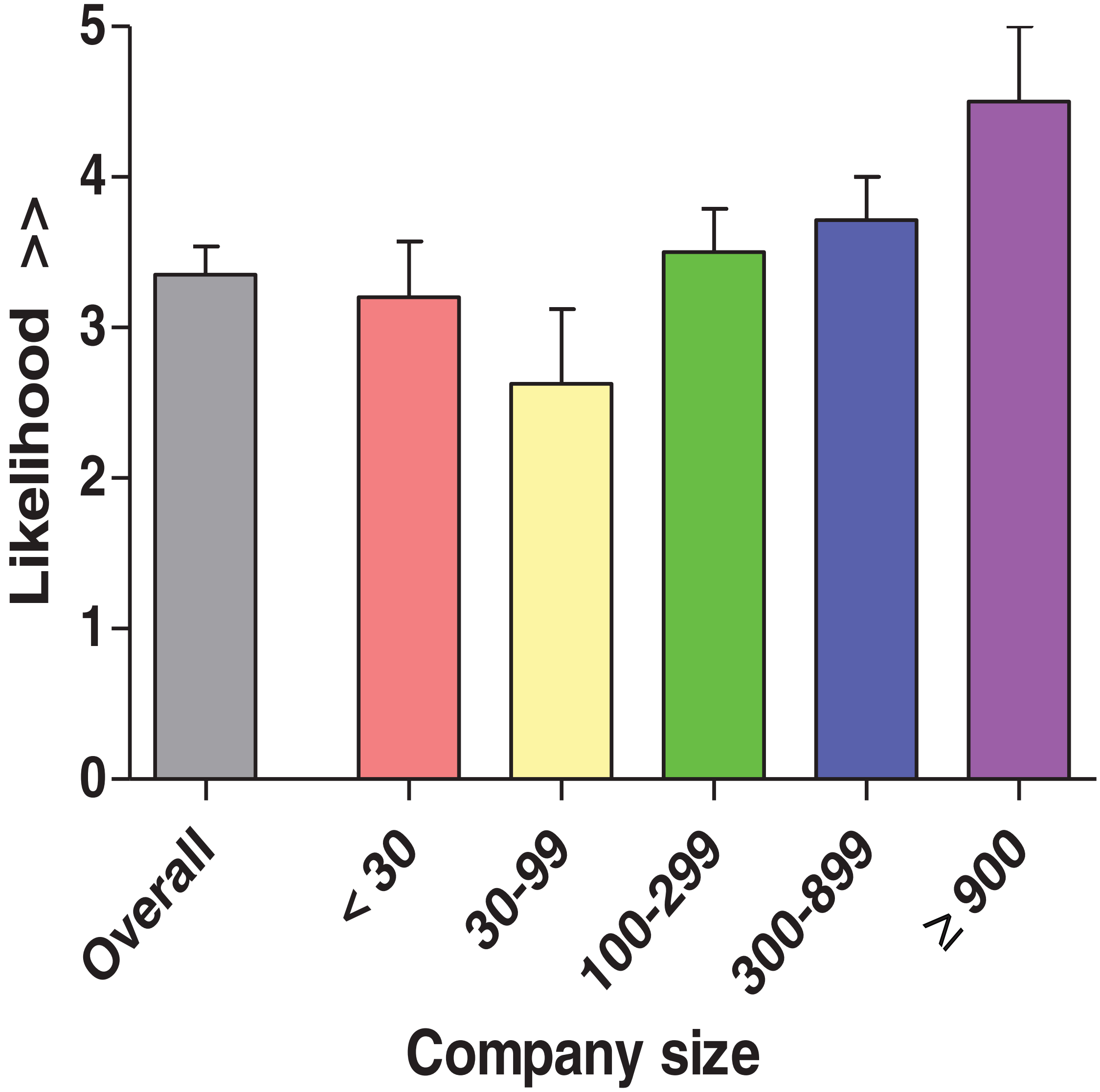




Q34. Rate the effectiveness of this stress management training.

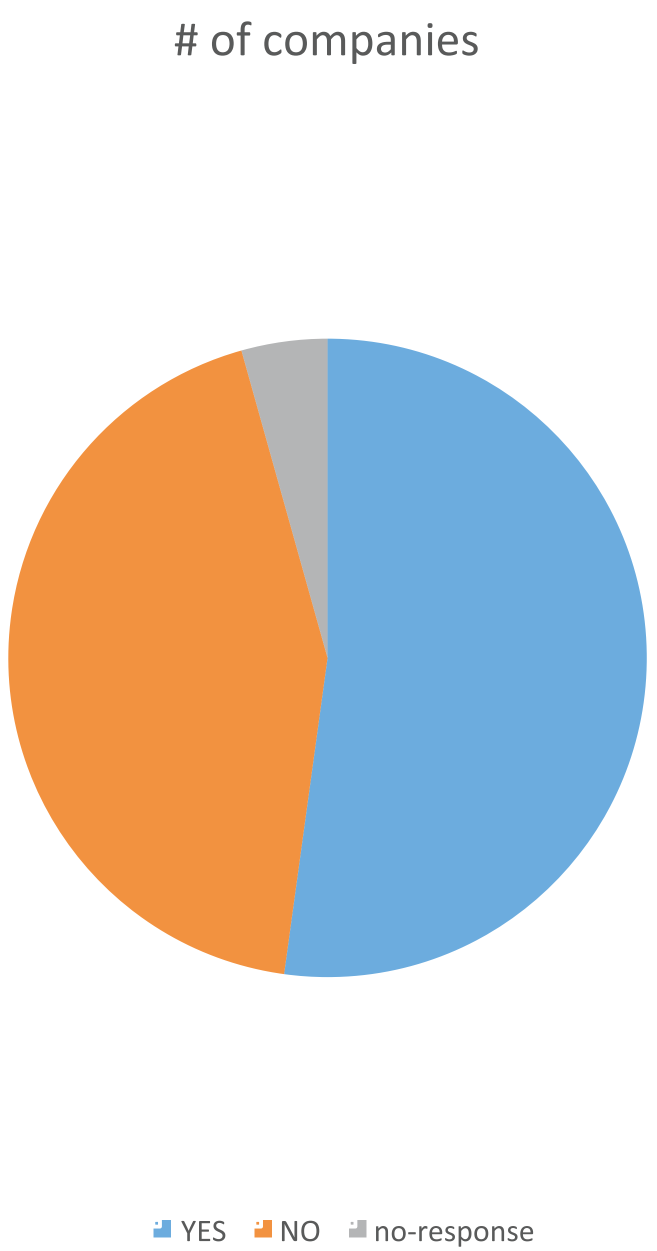


Q36. How likely would your company be to initiate stress management training?

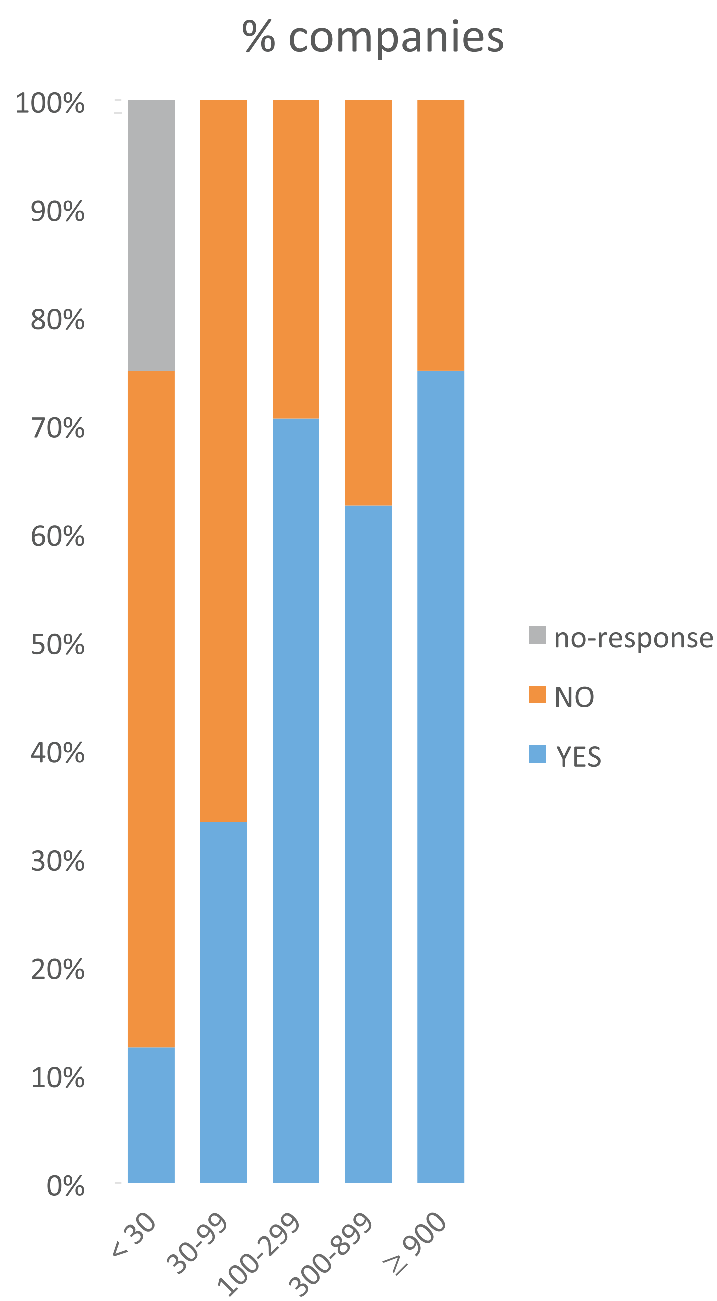


Q37. Does your company offer training on diet and nutrition?

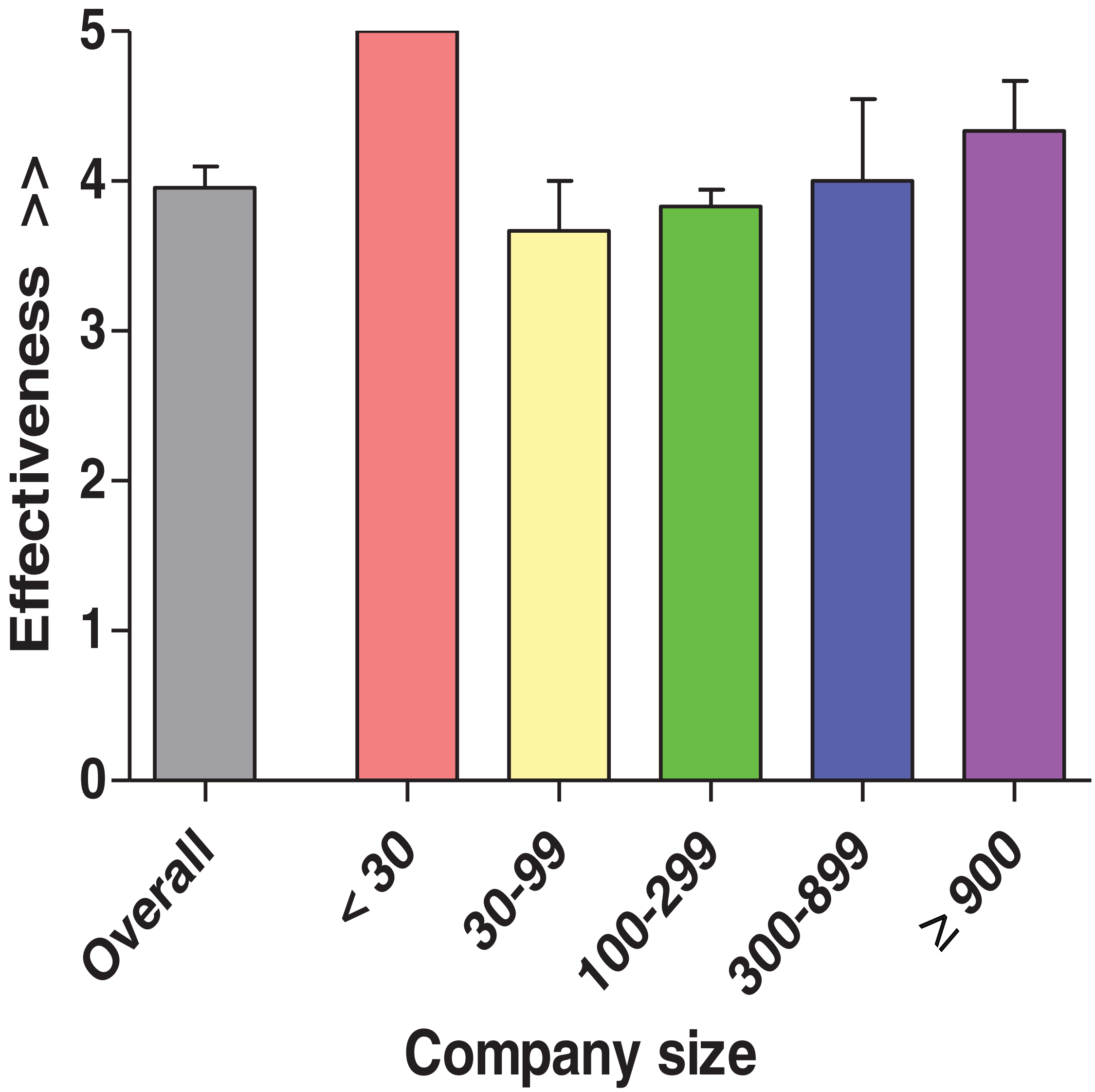
Overall



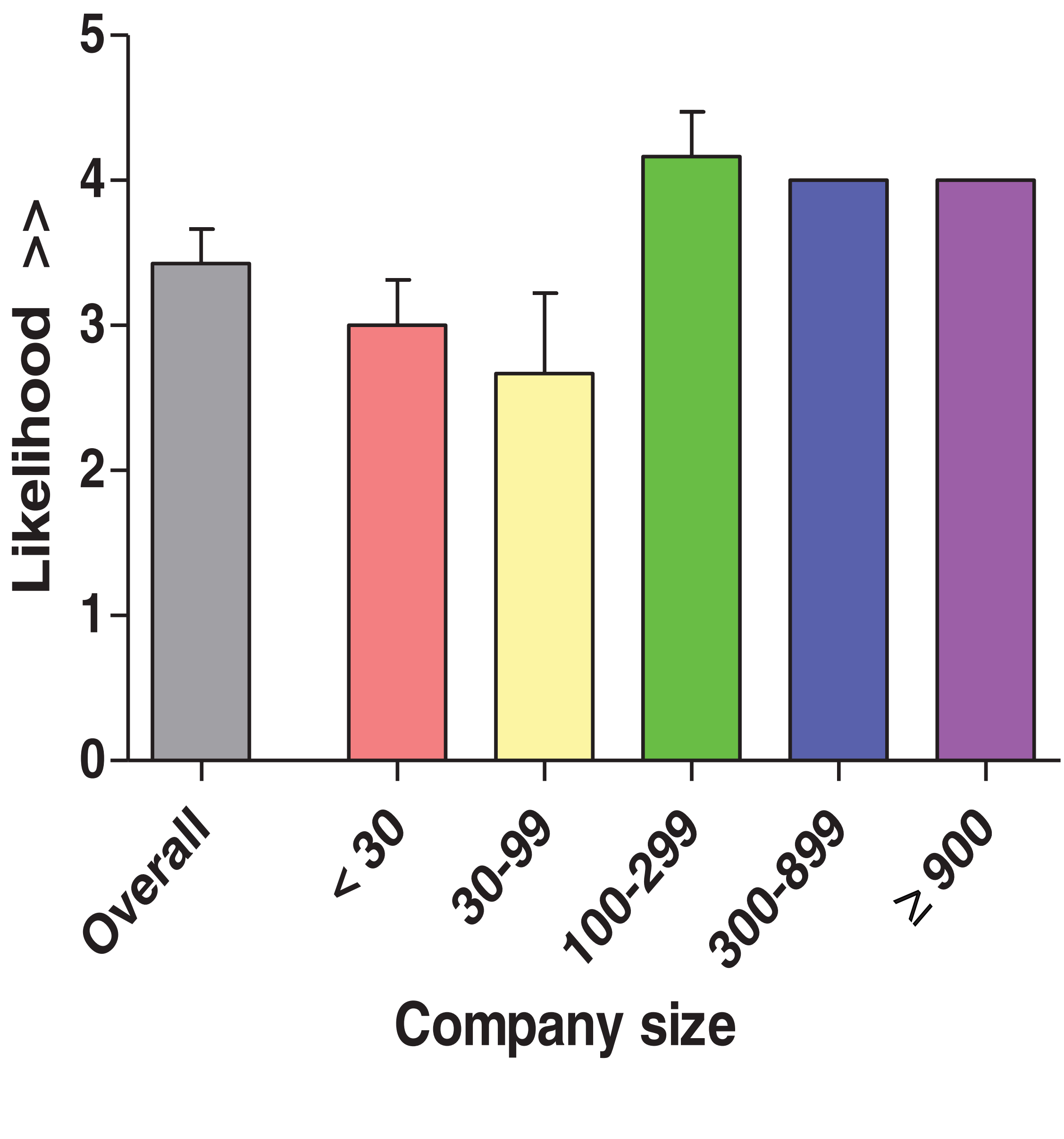
By company size



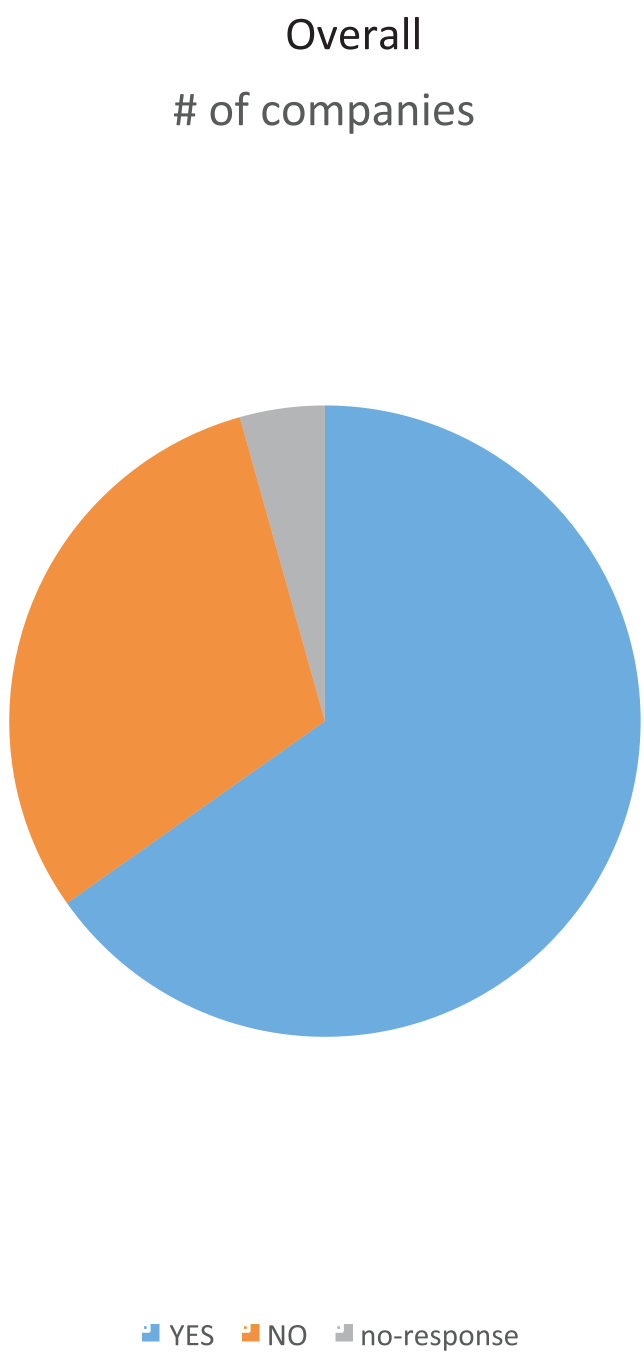
Q38. Rate the effectiveness of this diet and nutrition training.

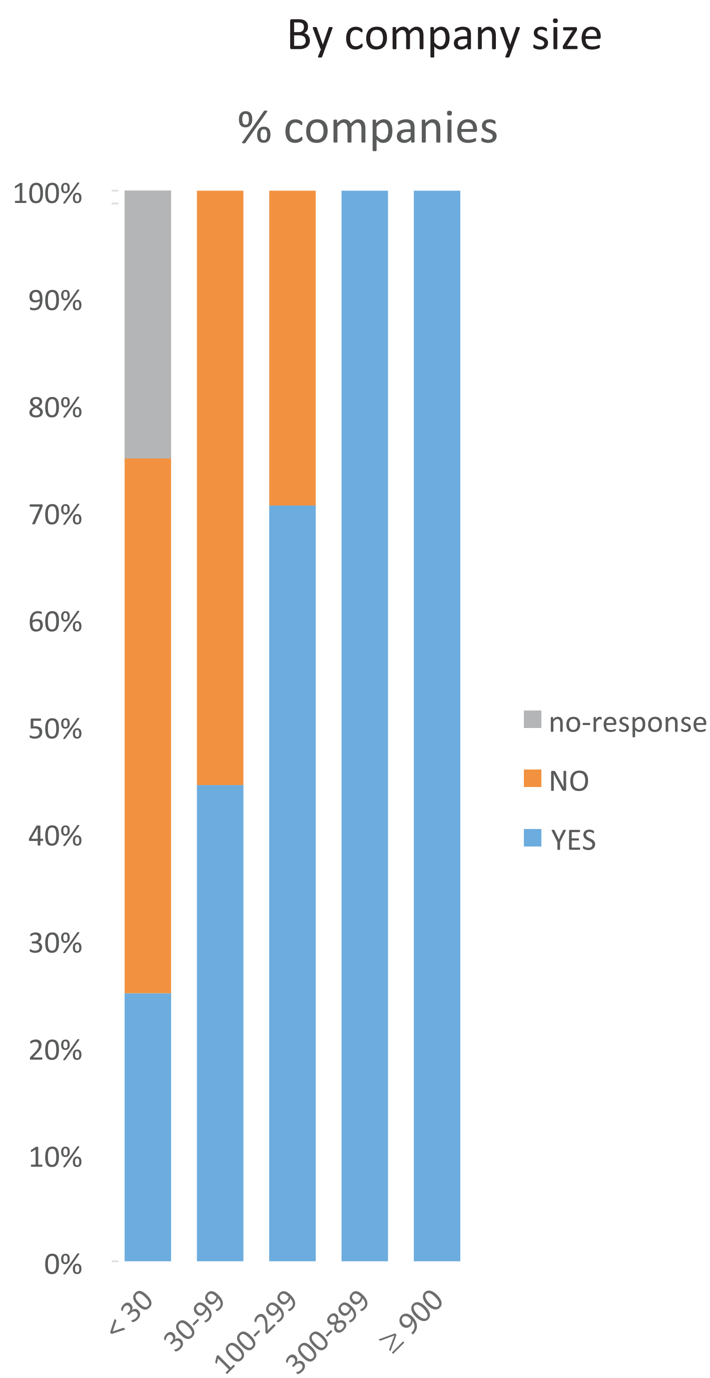


Q40. How likely would your company be to initiate diet and nutrition training?

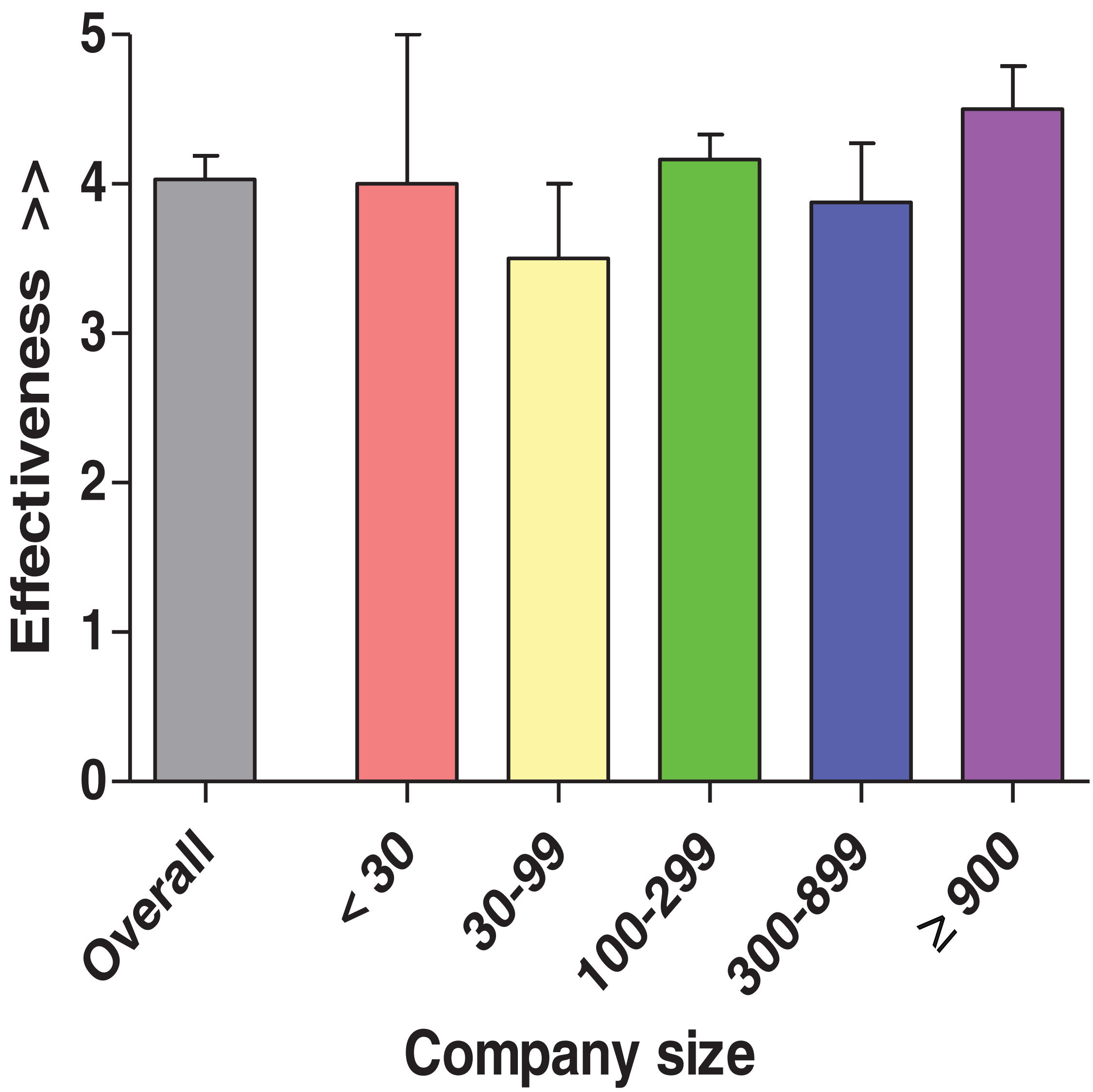


Q41. Does your company offer training or education on exercise, or give access to exercise facilities?

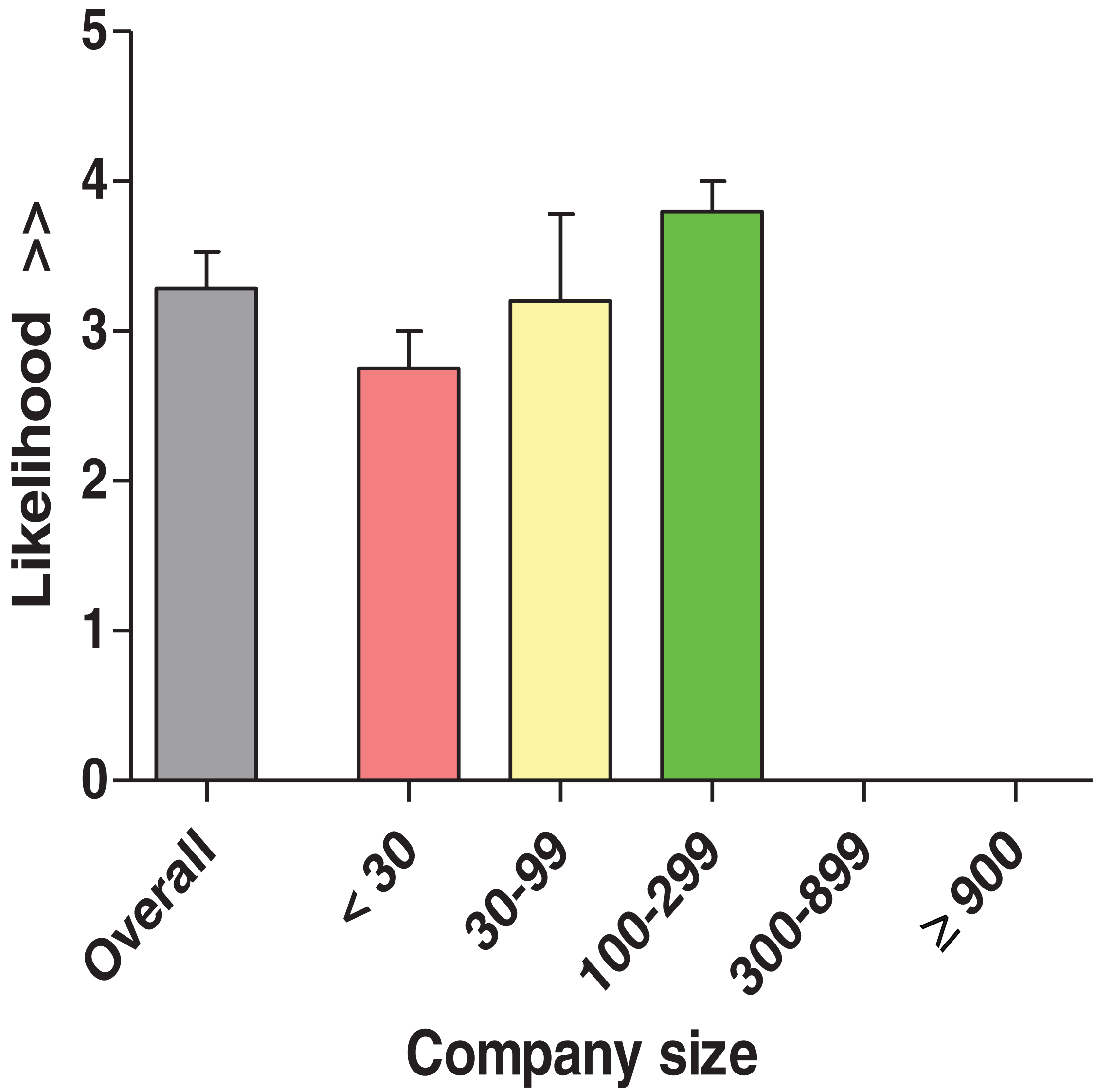




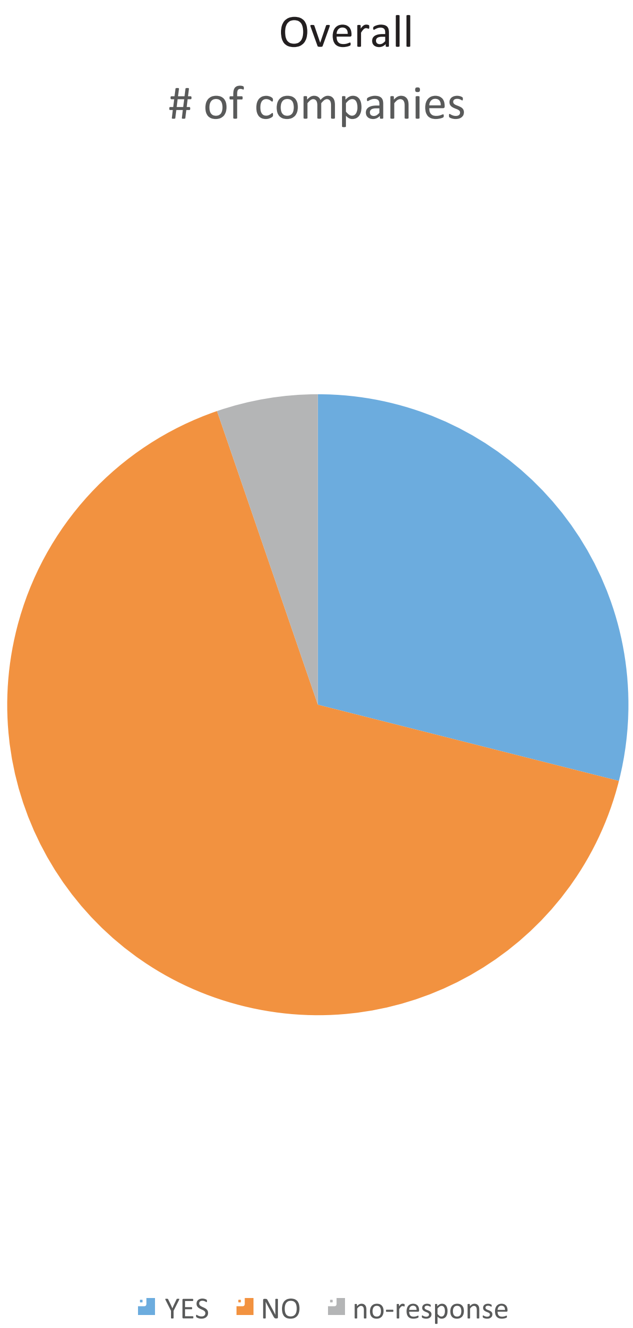
Q42. Rate the effectiveness of this training or education on exercise, or access to exercise facilities.

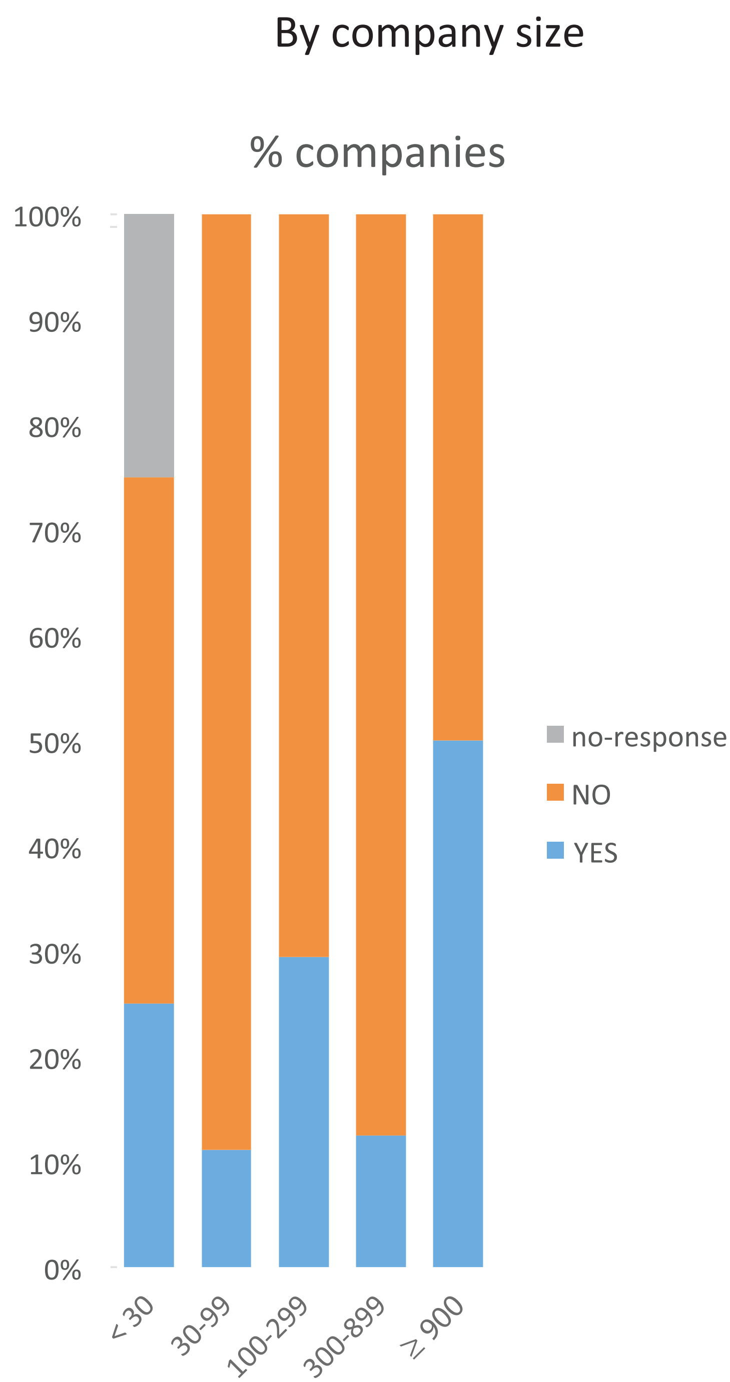


Q44. How likely would your company be to initiate training or education on exercise?

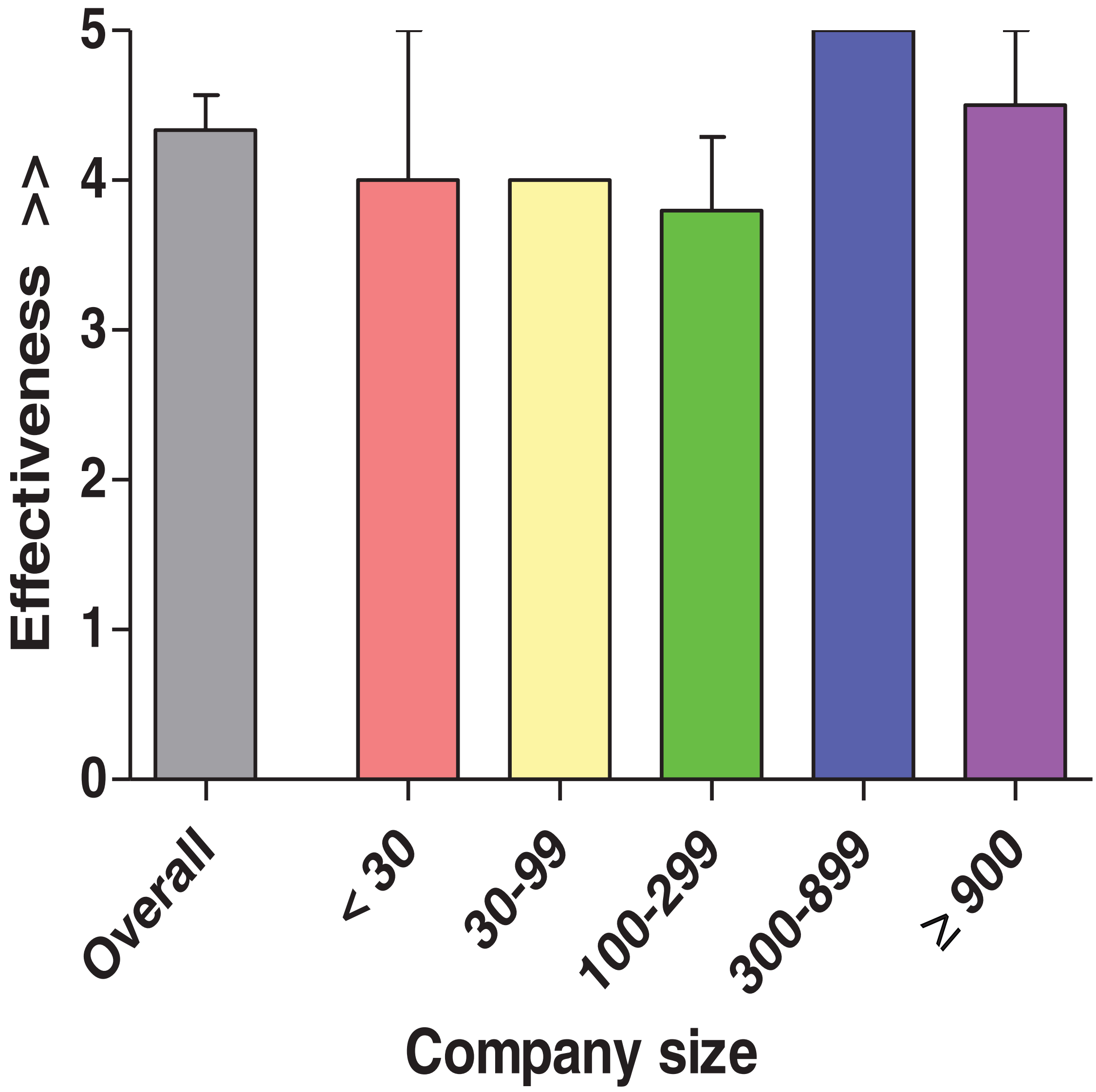


Q45. Does your company offer information or training about medical conditions that impact sleep?

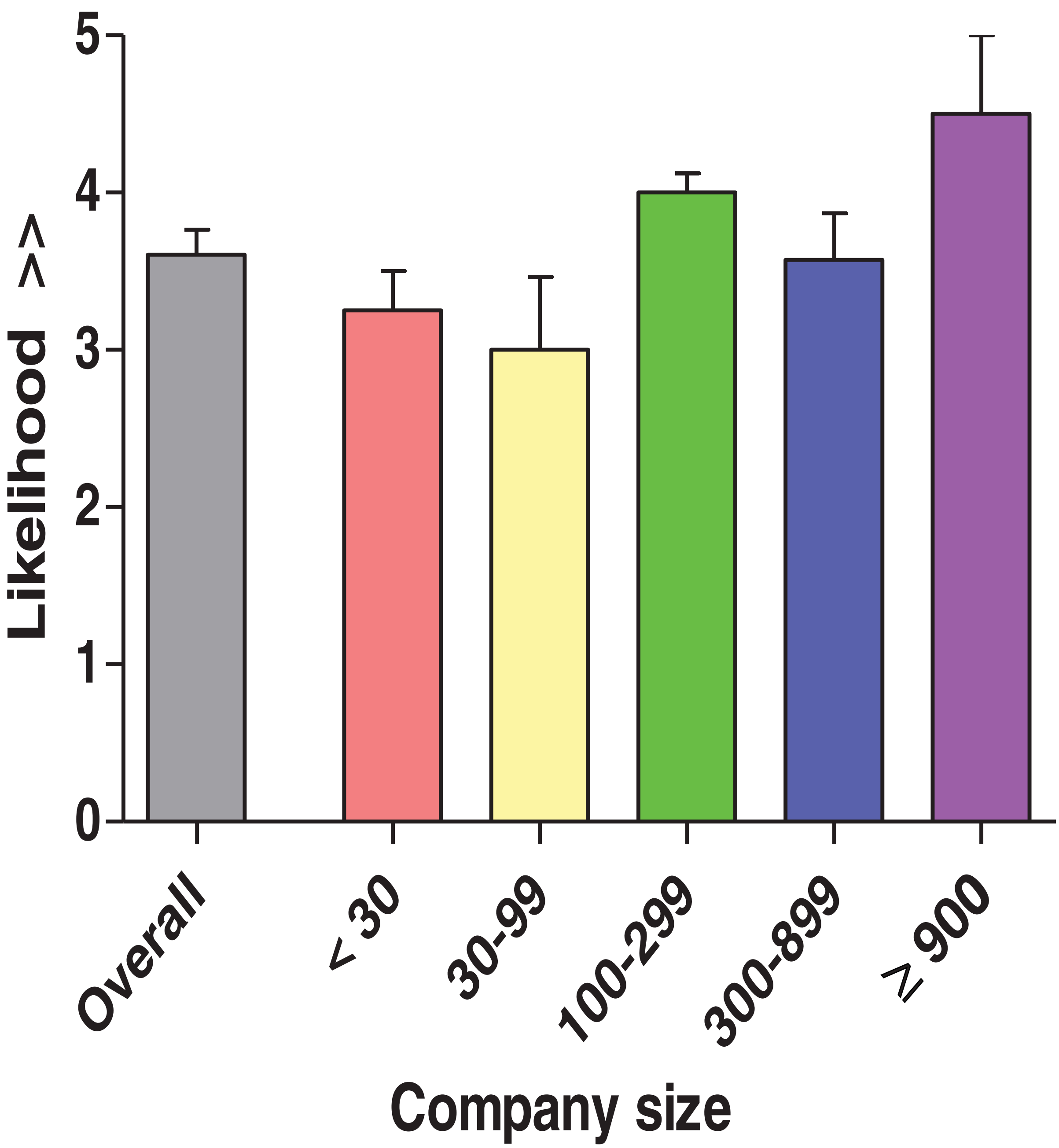




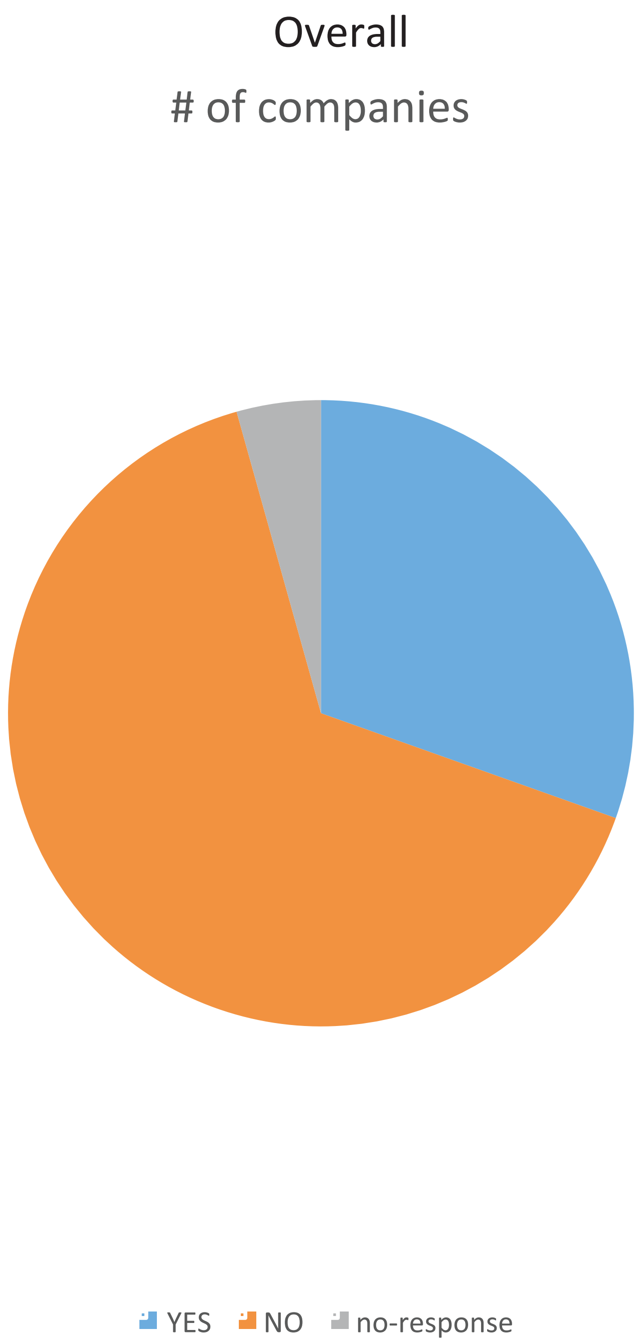
Q46. Rate the effectiveness of this training about medical conditions that impact sleep.

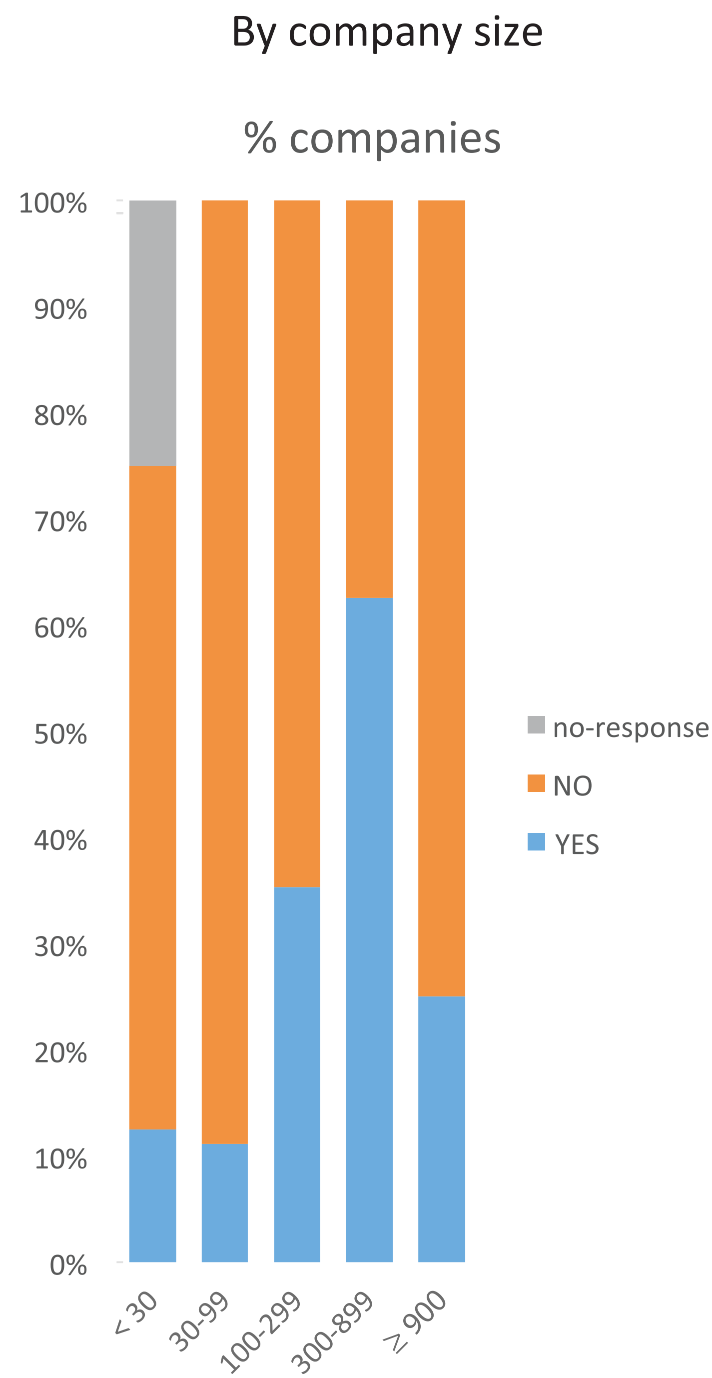


Q48. How likely would your company be to initiate education or training about medical conditions that impact sleep?

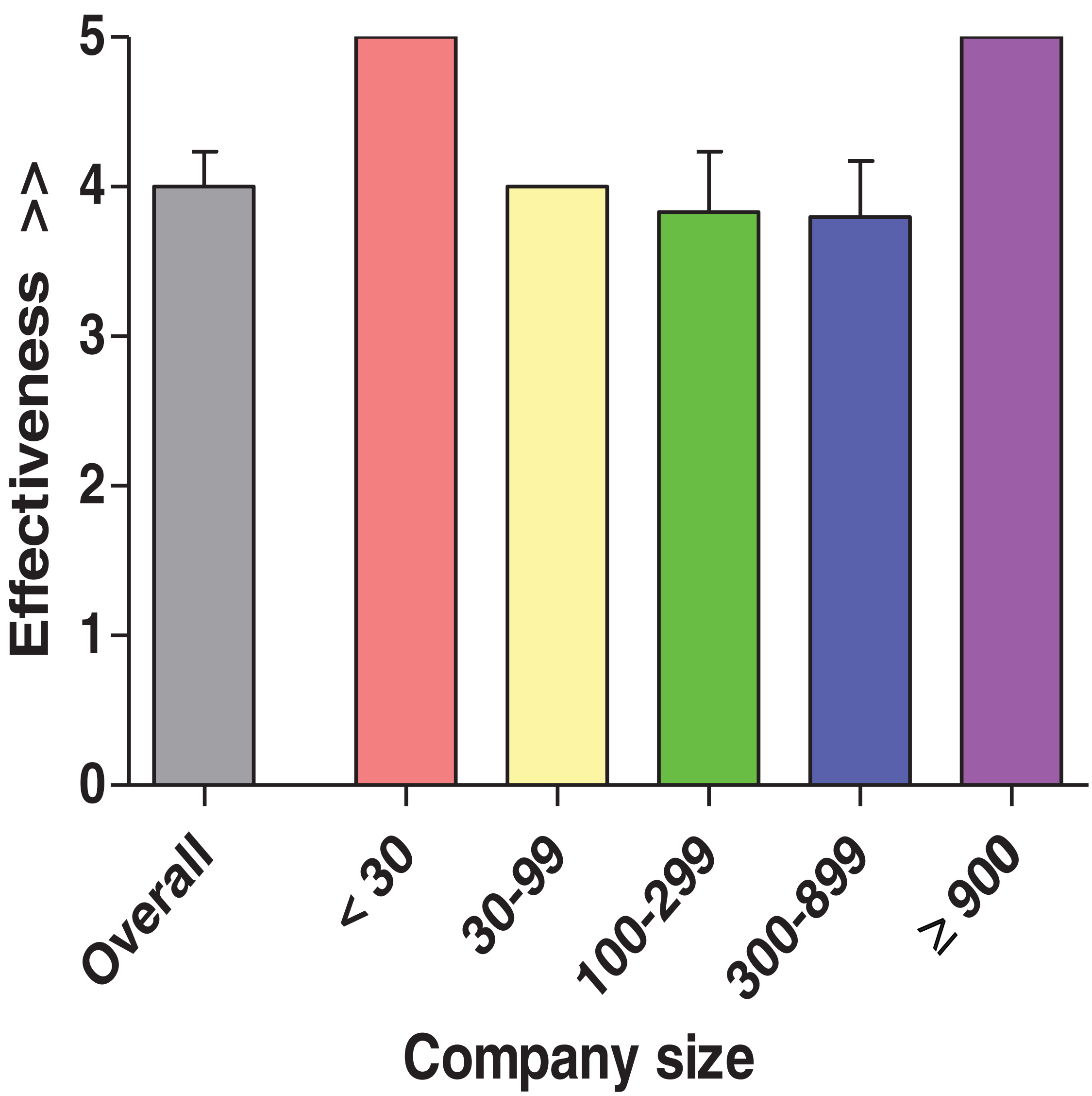


Q49. Does your company offer information or training about medications that impact sleep?

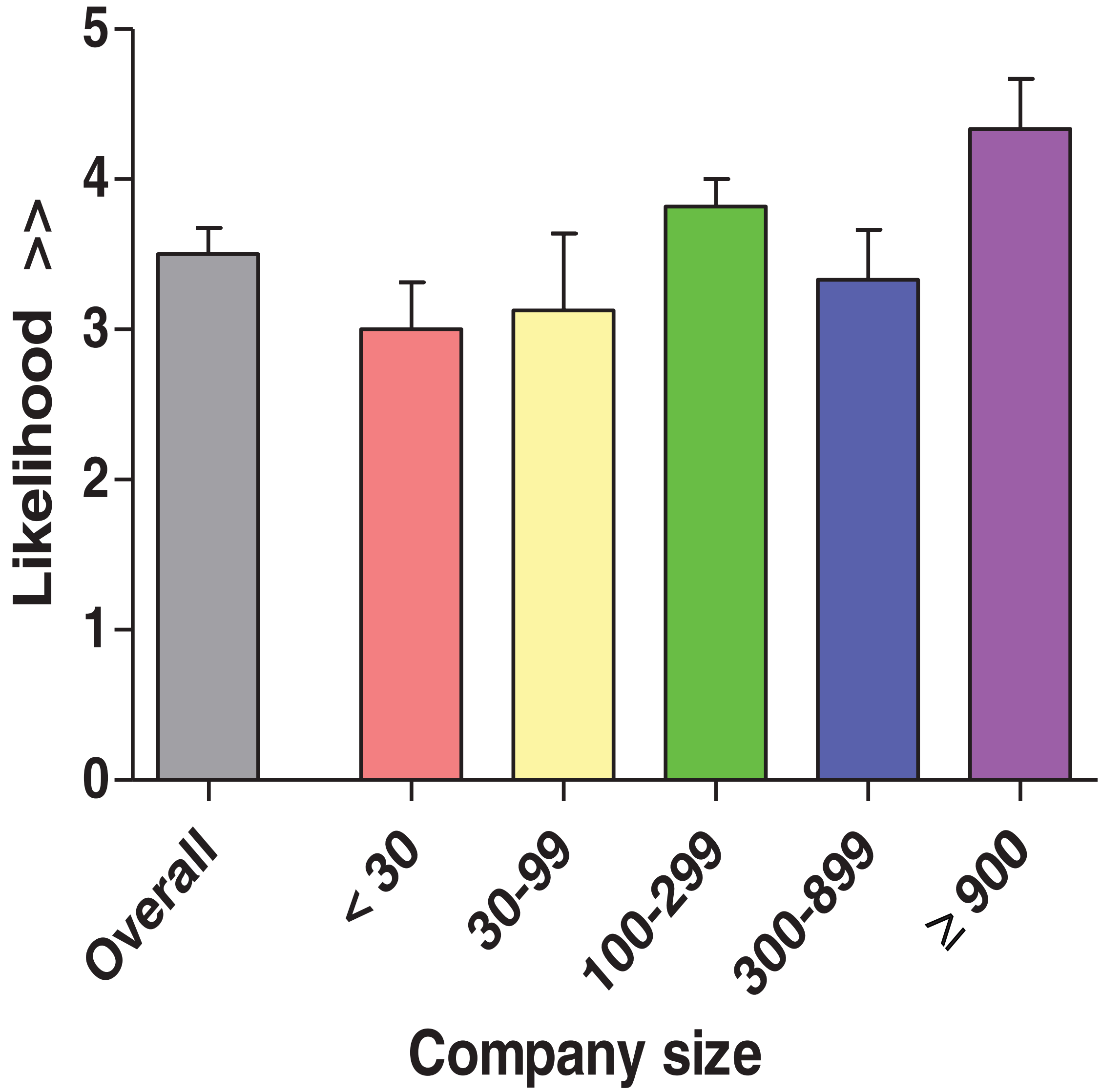




Q50. Rate the effectiveness of this education or training about medications that impact sleep.

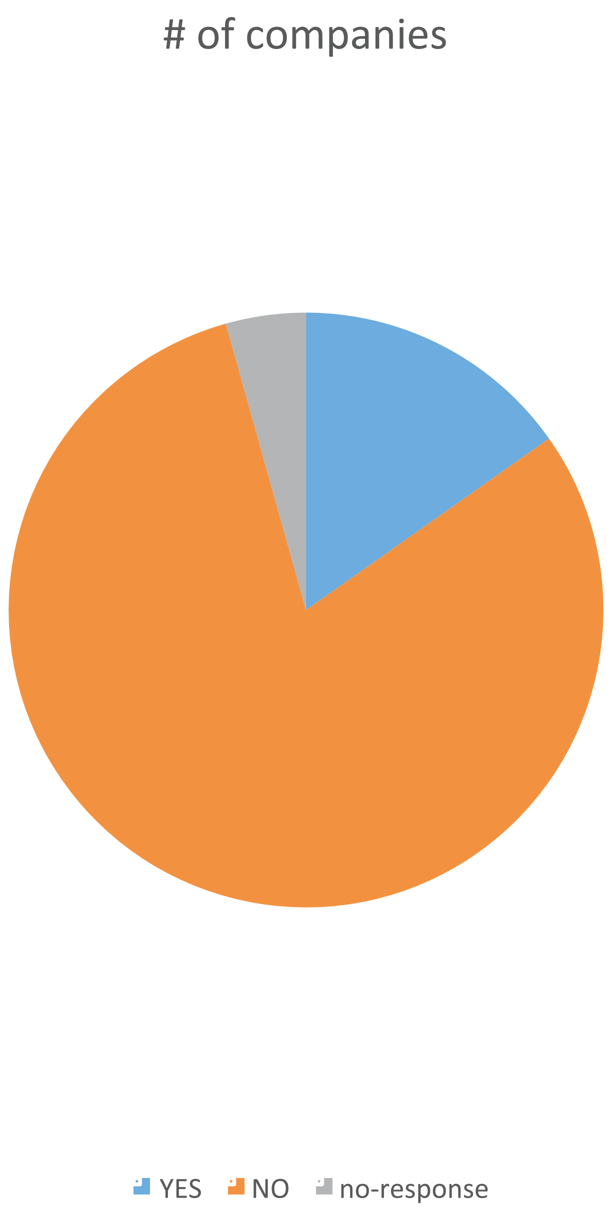


Q52. How likely would your company be to initiate education or training about medications that impact sleep?

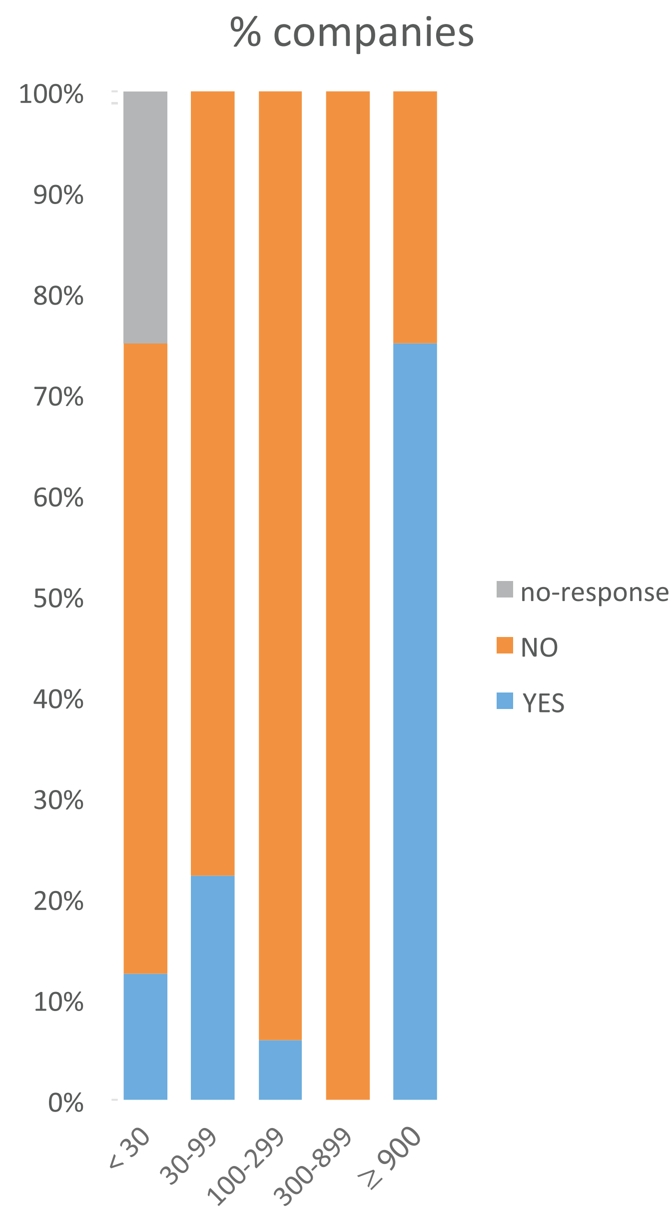


Q53. Are there any other practices in your company that are related to improving sleep (duration, quality and efficiency) or fatigue management and are not listed above.

Overall

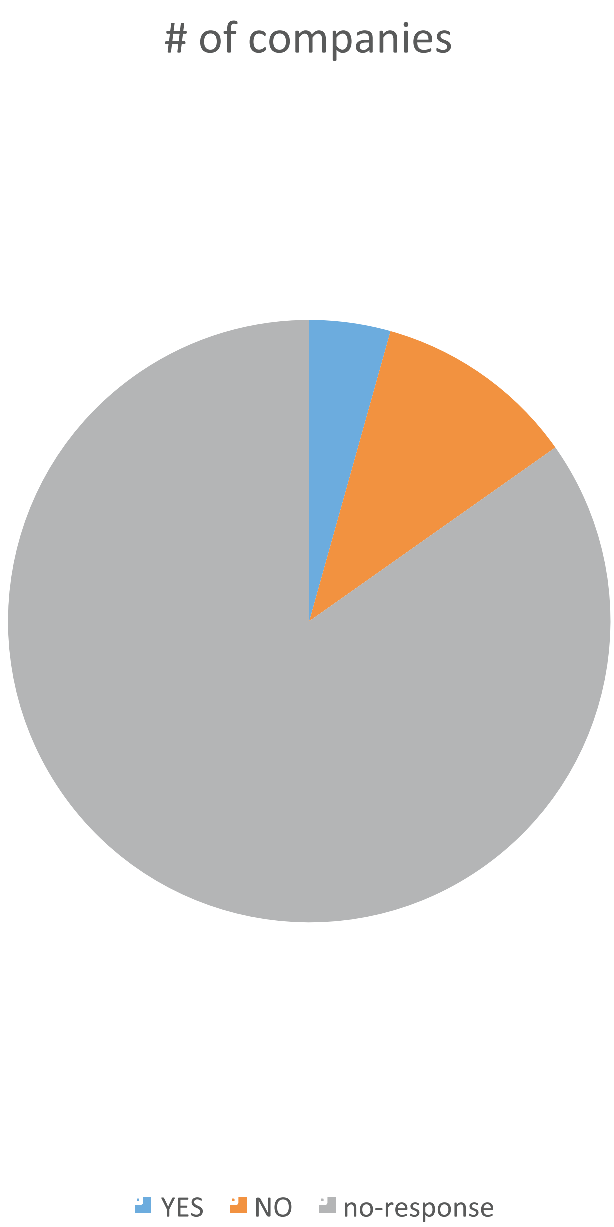


By company size

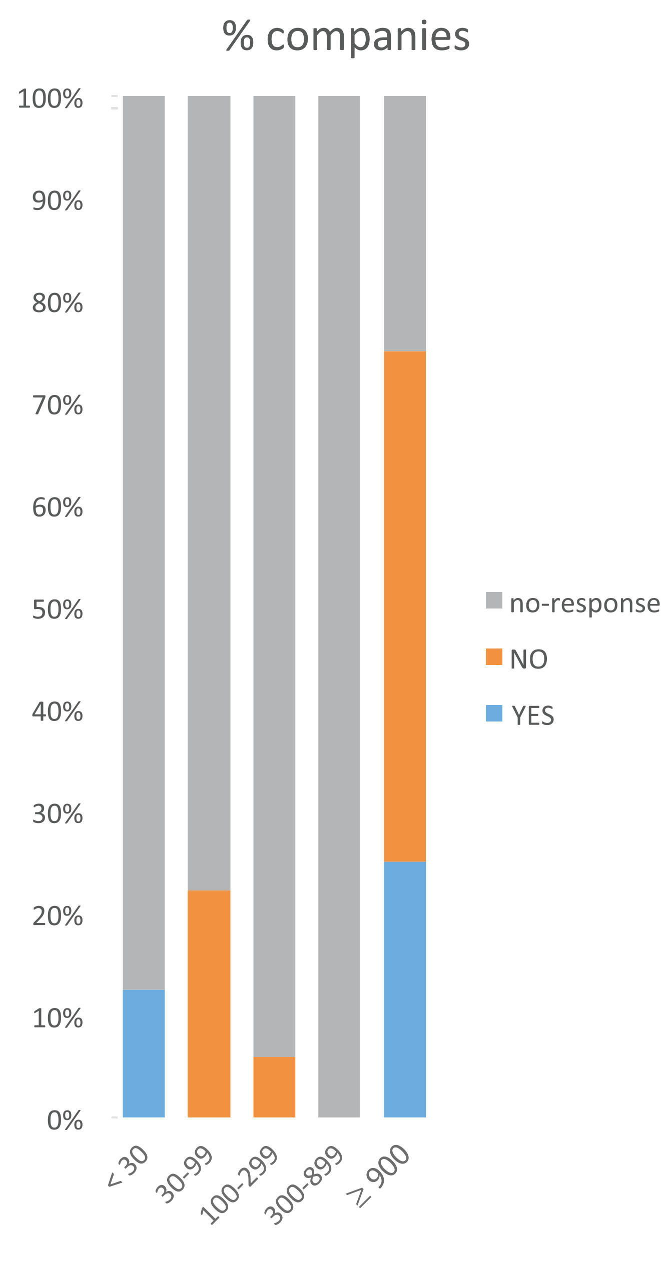


Q55. Do you monitor or assess IN ANY CONCRETE WAY the effectiveness or benefit of any of the practices related to sleep/fatigue management that your company has in place?

Overall

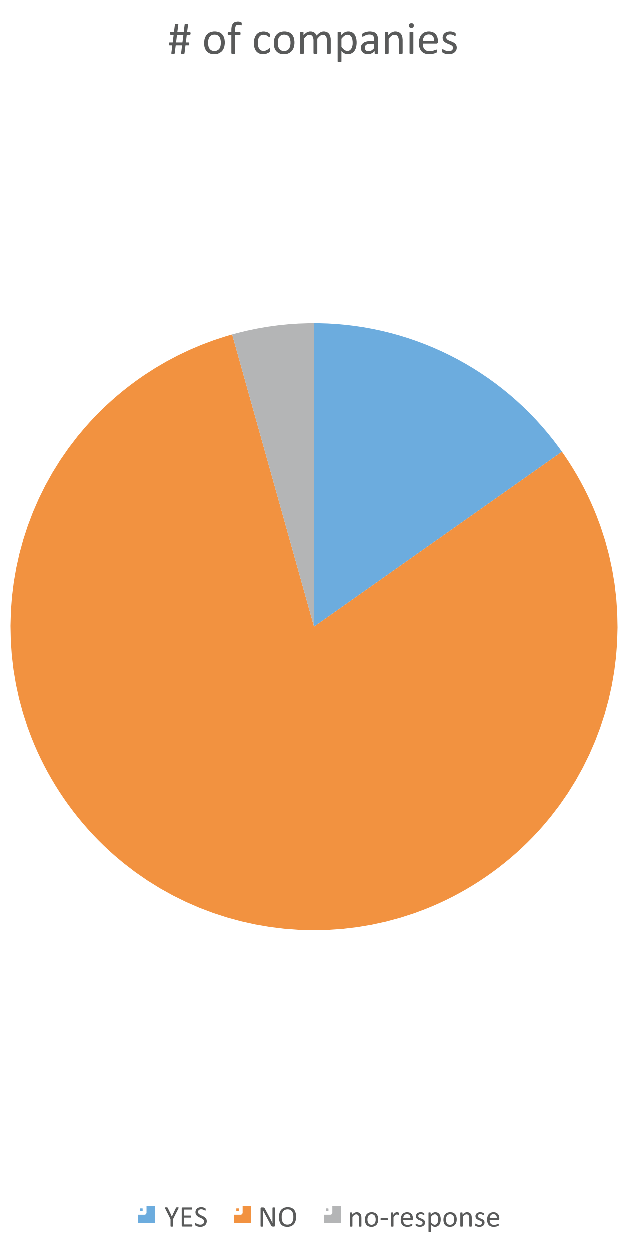


By company size

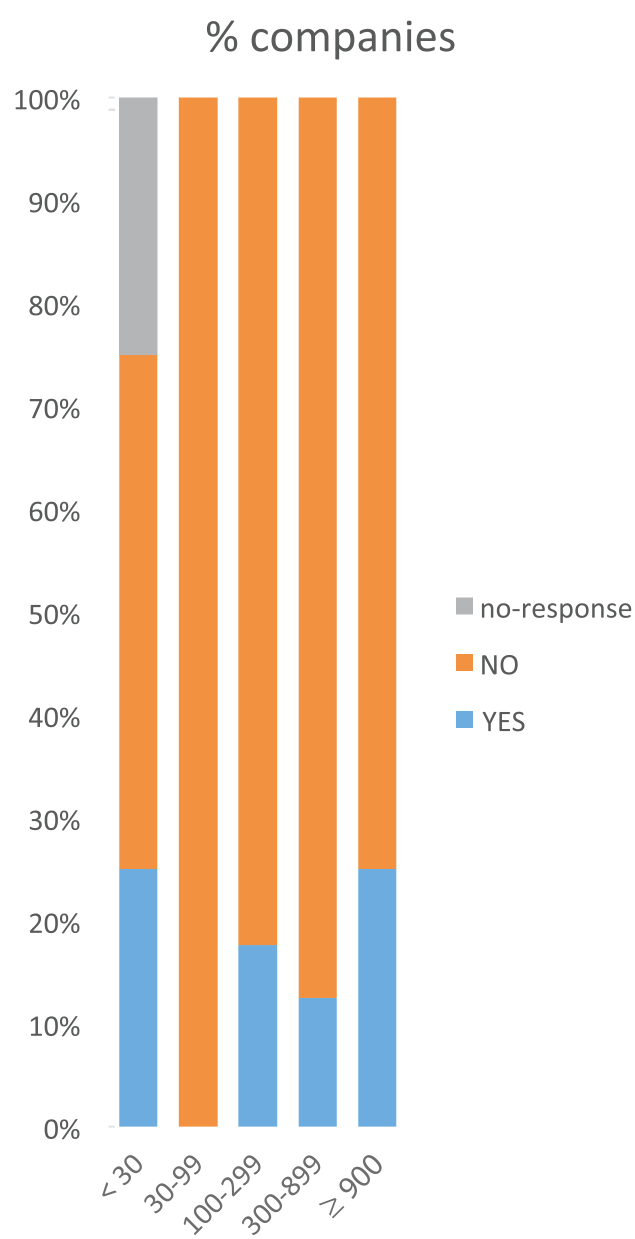


Q57. Does your company monitor sleep-wake strategies used by crew members (e.g. do they sleep during each rest interval)?

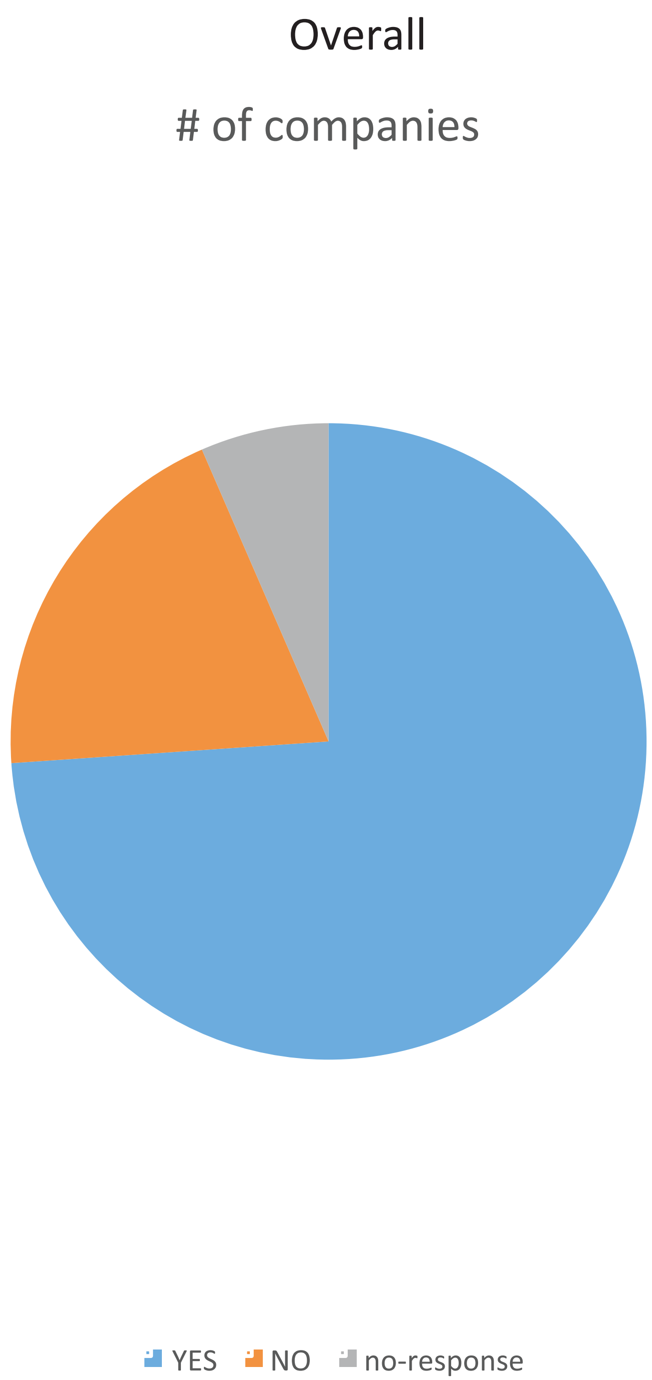
Overall

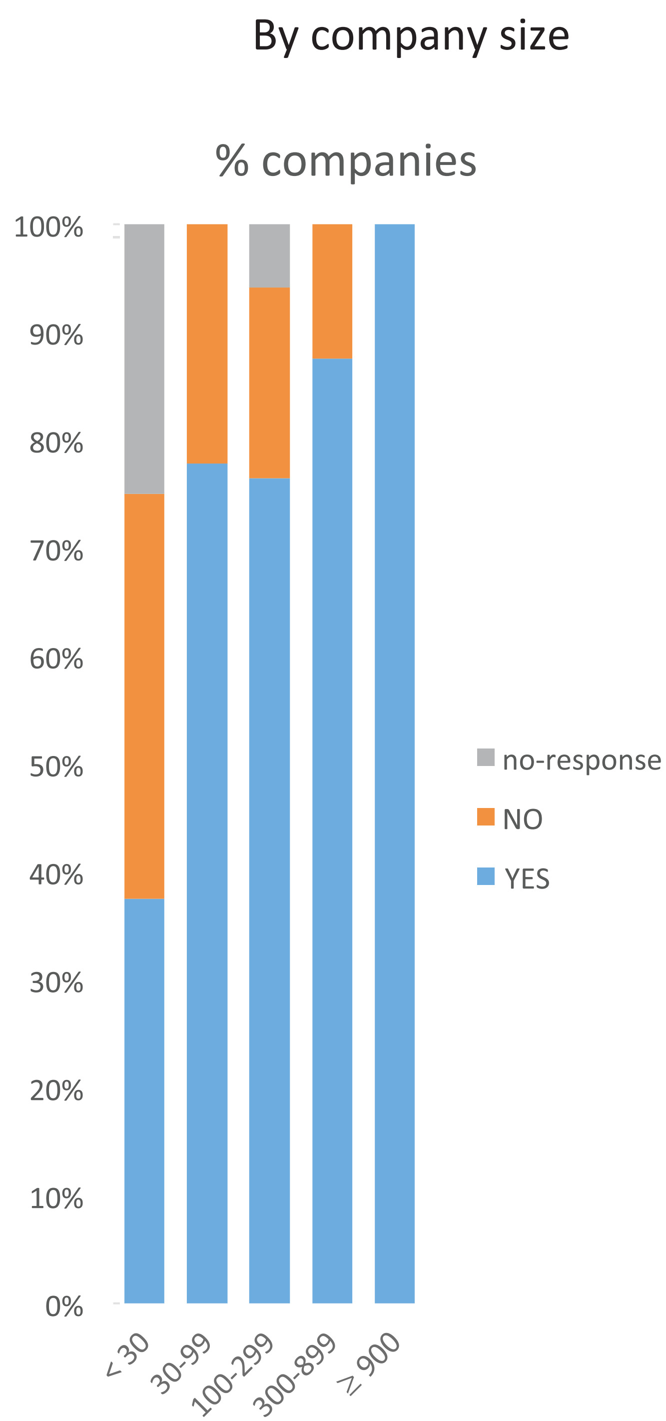


By company size



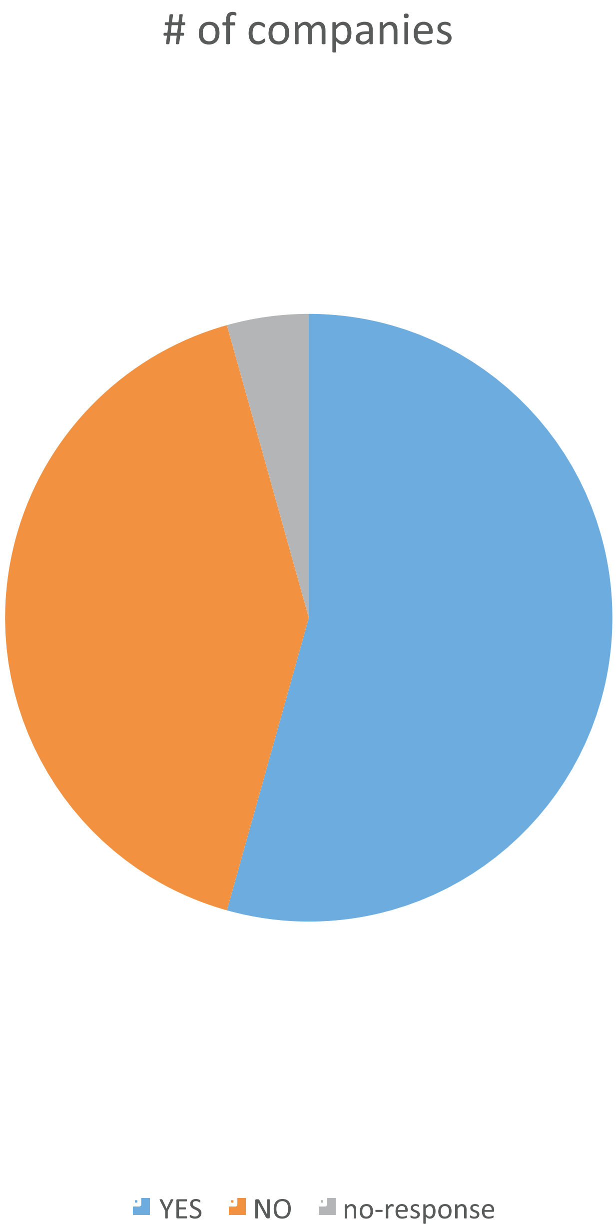
Q58. Does your company do health screens of your workers?



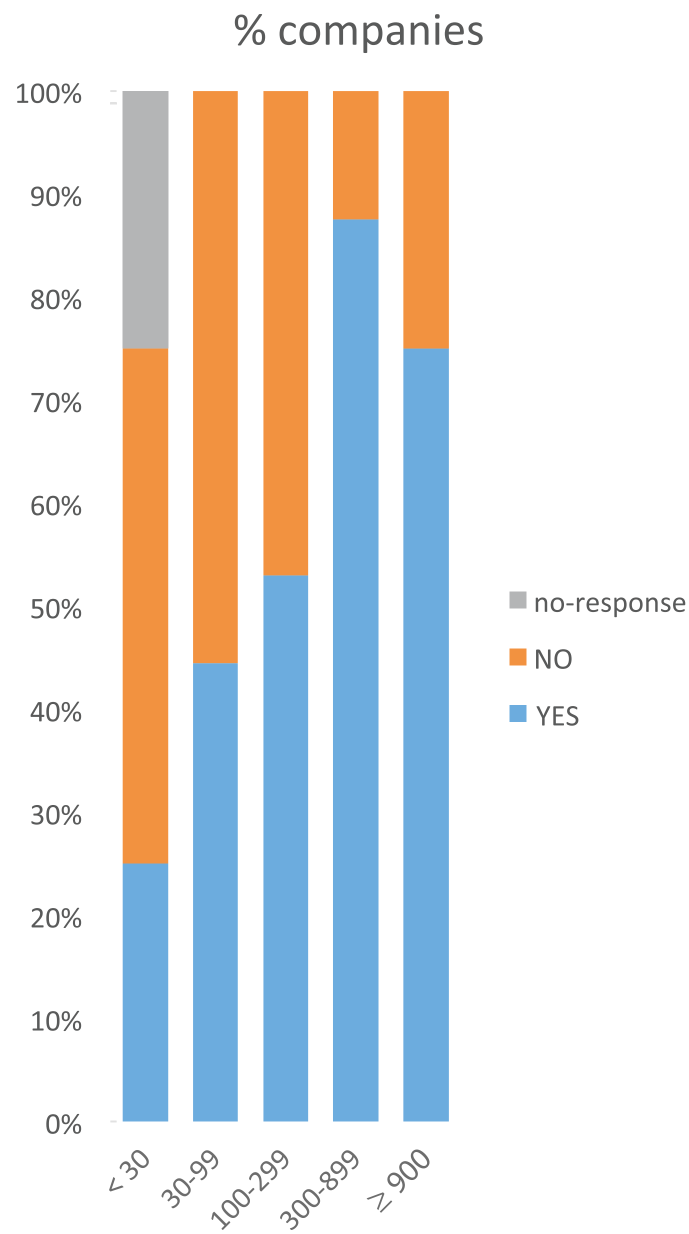


Q59. Does your company have a program that asks crew about medical conditions and medications that impact sleep and fatigue?

Overall

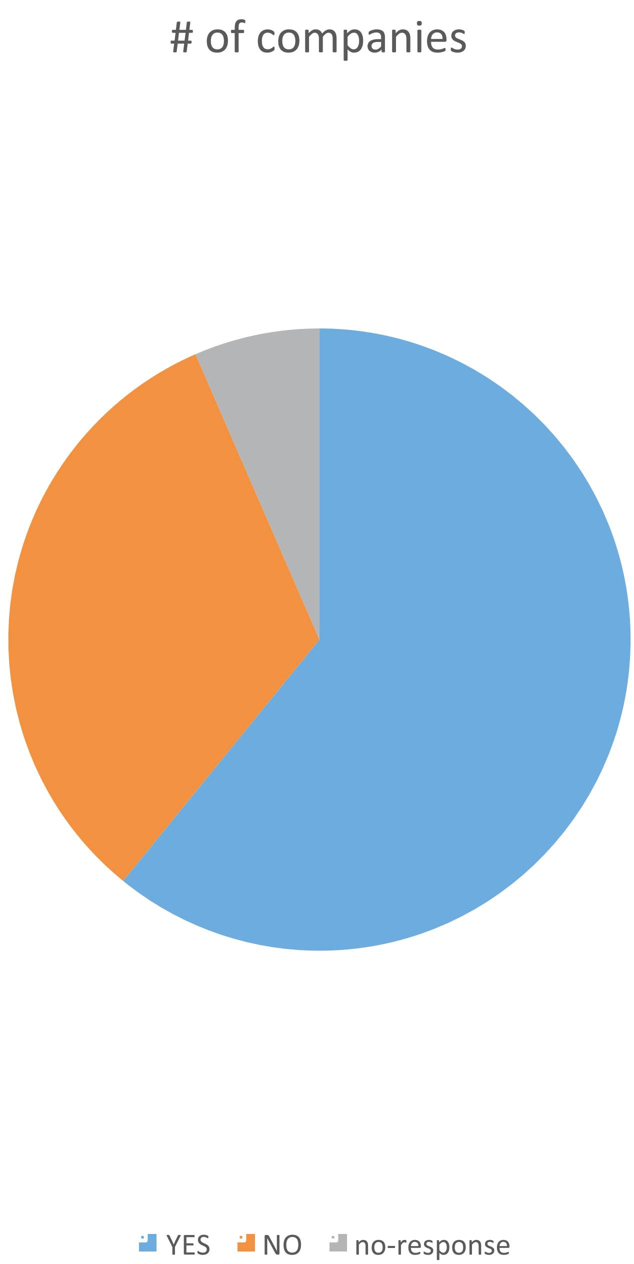


By company size

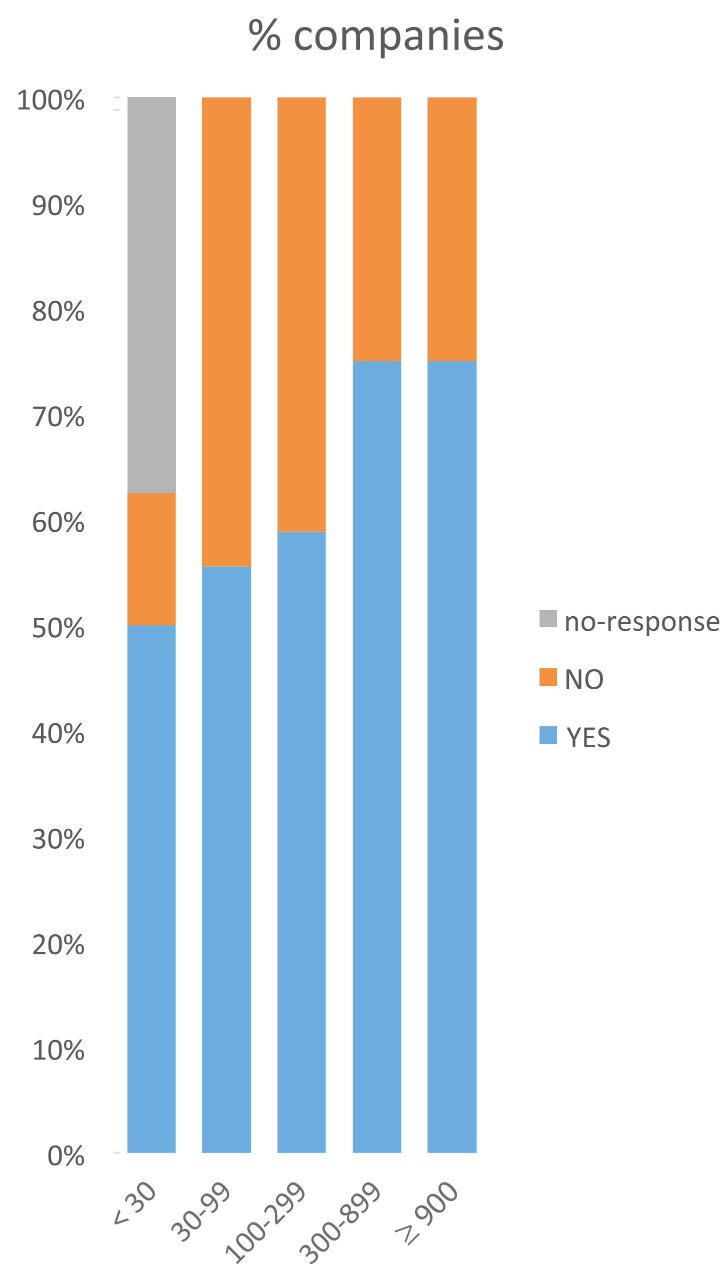


Q61. Are crew members encouraged to report excessive sleepiness while they are working?

Overall

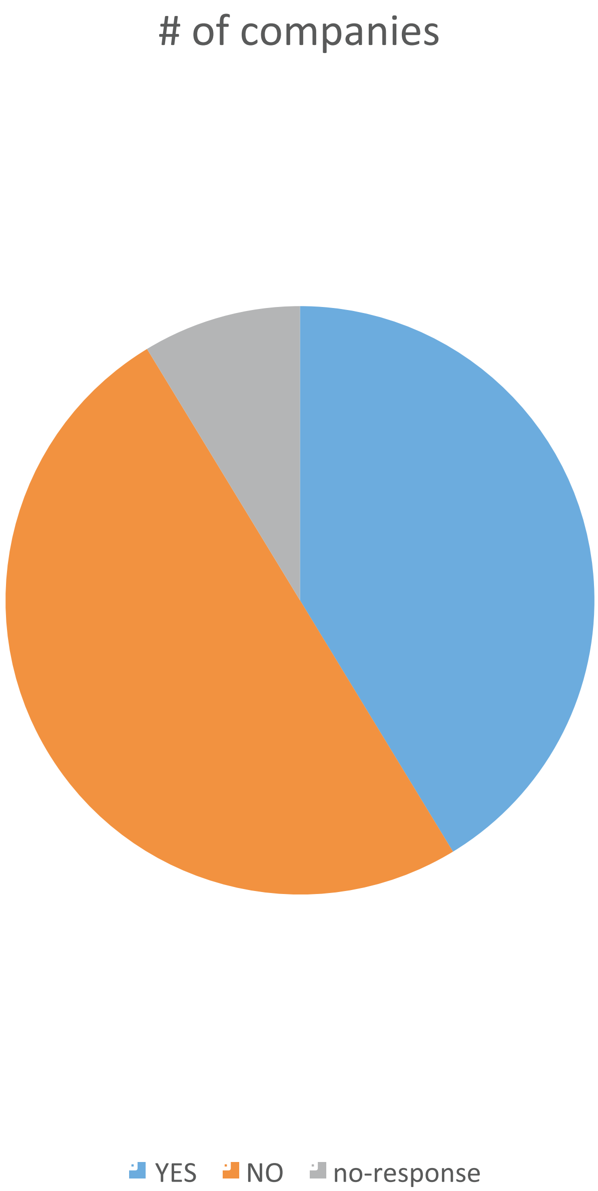


By company size

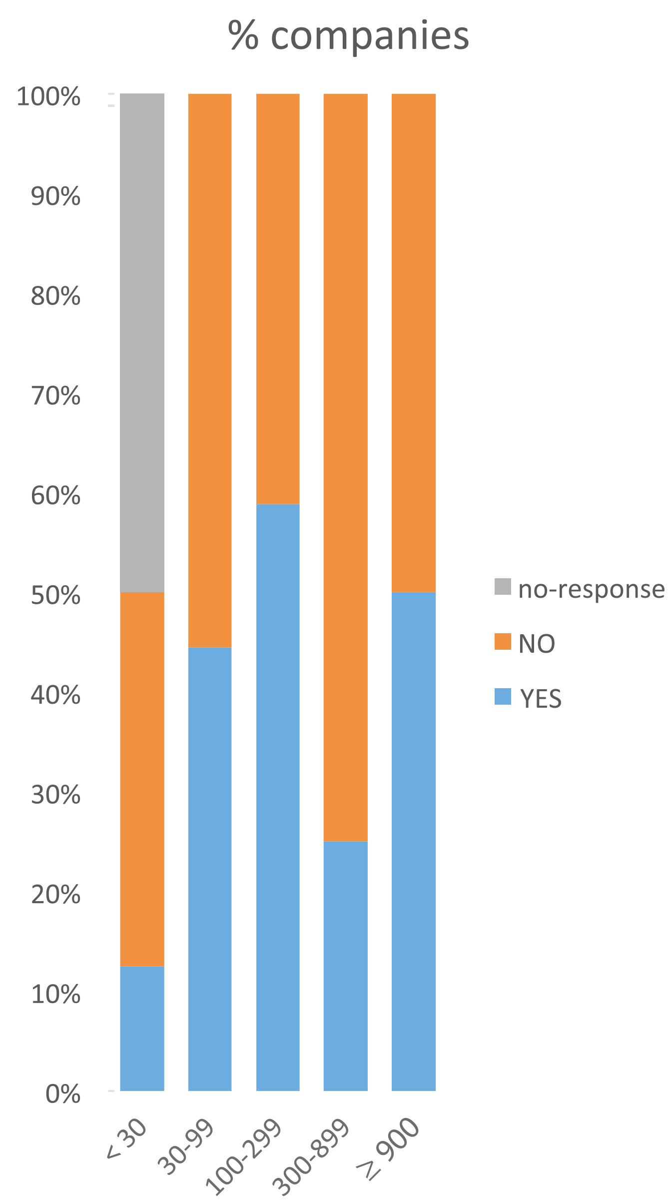


Q65. Are there any best practices related to improving sleep (duration, quality and efficiency) or fatigue management that you would like to see initiated within your company?

Overall



By company size



Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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