Phase IV of an ongoing program to develop strategies to reduce fatigue and risk on towing vessels and to improve the health of crewmembers operating vessels 24/7 (March 2011 – May 2012)

Large scale survey of sleep quality and general health in wheelhouse towing vessel crewmembers on American waterways

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A. Prologue

This Phase IV study represents the latest phase of studies that started in 2008 on issues related to fatigue and sleep in crewmembers on towboats on inland waterways. Phase I consisted of the preparation of a White Paper that was an analysis of published studies and data on schedules and fatigue of crewmembers 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 were often split into two periods of work over 24 hours (and thus two periods of rest per 24 hours) for maintaining 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 completion of the Phase I White Paper led the Northwestern University investigators to conclude that any viable strategy for an industry that has two crewmembers who must be on duty collectively for 24 hours over many days (i.e., crewmembers 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.

In order to develop a better understanding of the sleep-wake schedules and sleep amount of the crewmembers on board towing vessels that were using a 6 on: 6 off: 6 on: 6 off duty schedule, NU investigators rode on five towing vessels and collected data on crewmembers in Phase II studies supported by seven different towing vessel companies in 2009. In 2010, with support from the AWO, we carried out a Phase III study that collected sleep time and sleep duration data from crews on ten different towing vessels. The results of these studies are summarized in our Phase II and Phase III reports.

The results from the Phase II and Phase III studies were very consistent between the studies and gave us a clear understanding of 1) how many hours crewmembers were actually in bed during each of the six-hour sleep opportunities and 2) how much sleep time (based on actigraphy data) they were actually obtaining. It should be noted that such objective data on time in bed (TIB) and total sleep time has never been collected and reported before for crewmembers on inland waterway towing vessels.

Findings from the Phase II and III studies consistently indicate that while wheelhouse crewmembers appear to be spending an adequate time in bed each day, they are not able to obtain more than about 6.5 hours of sleep per 24 hours. While a strength of our previous studies was the objective measures used to determine sleep/wake times, it was not possible to study a large number of crewmembers over an extended period of time. In the Phase IV studies, we set out to examine a large sample of wheelhouse crewmembers (captains and pilots). Our previous
studies indicated that there is no difference in the sleep duration of crews on the front (Captains) and back (Pilots) watch. This was unexpected as the front watch crew had a rest period during the night 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 in our Phase IV work was that given the small number of wheelhouse crews previously studied (19 in Phase III), it is difficult to identify factors that may be impacting sleep in these wheelhouse crews. The aims of the Phase IV studies were to 1) determine and compare the sleep patterns of wheelhouse crews both when on extended vessel duty (21-28 days) as well as when at home for an extended period of time and 2) use online technologies to identify factors that may be influencing sleep quality in a large number of wheelhouse crewmembers. 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 crewmembers and to carry out follow-up analyses to determine the effectiveness of such constant (online) educational interactions for increasing total sleep time for crews on the front and back watch. In these Phase IV online studies we also obtained data on body weight and BMI and collected many more measures of sleep and fatigue levels using a number of scientifically validated tests (see Appendix B).
B. Executive Summary

B-1. Goals and study design

The primary aims of this study were to use online technologies to collect data on a large number of wheelhouse crewmembers to determine:

a) Sleep habits both when on duty and when at home

b) Levels of fatigue and subjective measures of sleep quality

c) Attitudes toward the importance of obtaining quality and sufficient sleep as well as barriers to obtaining sufficient sleep

d) Risk for sleep apnea and levels of obesity and to relate these indicators to sleep time and quality

In order to achieve these goals, 163 Captains and Pilots from 27 AWO membership companies were studied between June 2011-February 2012 for an approximately two-month period: one month at home (Session A) and one month on the vessel (Session B). By studying wheelhouse crewmembers (Captains and Pilots) both on the vessel and off, we were able to identify whether the individuals’ sleep is impaired in general due to some underlying reason (e.g., sleep disorder, stress, health, social factors, perceived need for sleep) or due to being on the vessels or the shift schedule.

To determine daily sleep duration and quality and to assess sleepiness/fatigue levels, wheelhouse crewmembers were asked to complete a number of sleep logs and fatigue scales after every sleep period during the first and third week of each section of the study. To determine general factors about sleep, sleep quality and sleepiness, crews were asked to complete a series of questionnaires relative to their time on the vessel and at home. At the end of the two-month period, crewmembers were provided with the educational materials developed during the Phase III studies.

B-2. Results

B-2a. Sleep on duty and at home

A major finding from the present study was that when on duty, crews on the Captain’s or Pilot’s watch reported similar time in bed (TIB) and sleep duration; these findings confirmed our objective measures of TIB and sleep duration based on actigraphy from our onboard Phase II and III studies. A second major finding was that there were no differences in reported sleep duration for crews when at home or on the vessel. Indeed, we found that crews spent
significantly more TIB when on duty than when at home, indicating that the 6:6:6:6 square watch schedule is allowing crews sufficient TIB. A third major finding was that while the TIB was similar in crewmembers when on duty in our onboard studies (Phase II and III) compared to our survey-based study (Phase IV), the crewmembers reported much longer sleep duration based on survey data when compared to our objective (actigraphy) data from studies in Phase II and III.

B-2b. Subjective assessment of sleep quality and fatigue

A major finding based on the Pittsburgh Sleep Quality Index (PSQI) was that crews on the Pilots’ watch reported that they slept worse than crew on the Captains’ watch. Importantly, a second major finding from sleep diaries was that on average, crews reported they slept worse while at home than on the vessel for the first seven days at each location. Both front watch and back watch crews reported poorer sleep quality, not sleeping long enough, not sleeping deeply and finding it more difficult to wake up while at home compared to on the vessel (p<0.03). Front watch crews also reported a greater number of awakenings at home, and back watch crews reported finding it more difficult to fall asleep at home (Figure 9) (p=<0.03).

In general, there were no differences in the levels of fatigue or sleepiness between the watches when on board. But there was a difference in sleepiness as determined by the Karolinska Sleepiness Scale prior to sleep when comparing crews on duty and at home. On average, both front watch (p=0.001) and back watch (p=0.03) crews were slightly more sleepy prior to sleep at home than when on the vessel but had similar levels of sleepiness after sleep. This difference prior to sleep is likely the result of the differences in time awake at home compared to on the vessel, since crews typically reported only one sleep period a day at home and two sleep periods a day while on the vessel.

B-2c. Determine attitudes and barriers for obtaining sufficient sleep and quality sleep

Much more analysis, including an evaluation of many different survey findings on an individual basis, is required before we can address these issues.

B-2d. Risk for sleep apnea and levels of obesity

Based on the sleep apnea risk questionnaire (the Berlin Questionnaire), 41% of the crewmembers were at a high risk for sleep apnea, which is higher than in the general population of similarly-aged males (32%). Importantly, the body mass index (BMI), an important health indicator for risk of cardiometabolic disease and sleep apnea, was in the obese range for a high percentage of crewmembers (47.9% vs. 33.8% of the normal population) while the level of morbid obesity (BMI>40) was nearly double that of the normal population (10.1% vs. 5.7%). Given the high percentage of crewmembers at high risk for sleep apnea, and that this disorder
carries a risk of both poor health and alertness outcomes, careful consideration of how to use the findings of this study to implement screening and risk mitigation strategies should be considered. Indeed, a proactive intervention by the industry in addressing this important risk factor is warranted. Further study is also needed to determine the correlation between obesity/sleep apnea and TIB and sleep duration and quality, as well as levels of sleepiness.

**B-3. Future Plans/Directions**

The data we have collected in Phases II and III when on board towing vessels, as well as the survey data collected online in Phase IV from a large number of crewmembers, represents a rich unprecedented set of data that is expected to lead to three to four full-length publications (we have already presented some of the results at scientific meetings and in abstract form). In addition, we believe these data now represent a foundation of knowledge that can be used to develop intervention strategies and a plan for the development of a scientifically based Fatigue Management Plan and System for the towing vessel industry. We recommend that in the future, further studies should involve:

a) A more extensive analysis (data mining) of the large datasets we now have access to,

b) Possible Phase IVa studies that could continue our efforts to collect data from the ~150 crewmembers who were fully engaged in the Phase IV study, and

c) Taking our present results to the next level and move from collecting data from crewmembers to intervention and fatigue management levels.

Possible future funding opportunities for further studies are described in section B-3d below.

**B-3a. Further analysis of Phase IV data**

Funding for the Phase IV studies allowed us to collect an enormous amount of data. While Drs. Reid and Turek will now be able to use the tables and figures in this Phase IV final report for reporting our initial results in the scientific literature, further funding would allow for a much more extensive analysis. For example, we are now in a position to go back into the data to determine if sleep time or quality relate to BMI or age of the captains and pilots. The current report outlines just a small portion of the data collected as part of this study of captains and pilots on American waterways.

In a sense, we have just scratched the surface of the data we only finished collecting in February 2012, and there is now an opportunity to hire statisticians and large dataset analysts to probe our unprecedented dataset.
B-3b. Extension of Phase IV studies

We have information on sleep, fatigue, health and age on 163 captains and pilots who participated to one degree or another in the Phase IV studies, and we are in a position to reconnect with these wheelhouse crewmembers for follow-up studies to determine if the educational materials and/or just participating in the Phase IV studies made the crewmembers more cognizant of the importance of obtaining sufficient sleep for health and performance and to manage their fatigue. Such information could be valuable for determining factors that could be incorporated into a Fatigue Management System and for the development of Fatigue Management Systems for the towing vessel industry.

B-3c. Development of a Fatigue Management System

Again, depending on funding levels, a number of steps could be taken to develop a plan that in 3-5 years would lead to a comprehensive scientifically based Fatigue Management System for all the members of the AWO. Such a plan would have as a goal for the AWO to be “out-front” of the regulators in developing a Fatigue Management System and could include, but not be limited to:

- Holding a two-day workshop with the leading scientists in the US who work in the area of sleep management, as well as health and safety officers of AWO companies and perhaps members of the Coast Guard. A major objective of such a workshop would be to come to a consensus on a 3-5 year Fatigue Management Plan that would involve research studies, development of countermeasures and individual fatigue and performance profiles that could increase safety and performance as well as the health of crews.

- Renewed attempts to measure how interventions affect actual performance in a real-world setting or in studies involving high-fidelity simulators. Such studies, would be particularly useful and important in comparing the effects on fatigue and performance for crews on different 2-watch schedules such as 6 on:6 off:6 on:6 off vs. 7 on:5 off:5 on:7 off vs. 8 on: 4 off: 4 on: 8 off. To date no such comparisons have been made in either real on board or simulated studies. A recent and in depth study (The European HORIZON Project) using simulators to compare the effects of different schedules on fatigue and performance in mariners only compared a 2-watch vs. 3-watch schedule.

- The implementation of a new industry-wide wellness program to combat the high levels of obesity (and presumably sleep apnea and associated cardiometabolic diseases) found in the maritime industry.
• Studies to determine if new technologies are feasible for use in the maritime industry that would allow individual crewmembers to track their own levels of fatigue and sleep habits in an attempt to change the culture in the maritime industry when obtaining sufficient sleep and making good health become as much a part of the everyday concerns of each mariner about their sleep and levels of fatigue as has occurred with issues surrounding safety. An example of such a new technology is a new portable, easy-to-use sleep- (EEG measurement) recording device made by Zeo. One of the latest versions of this device costs about $100 and can be used with an iPhone. It provides a great deal of information about the quantity and quality of one’s sleep, and there is evidence it is a motivational tool for making the obtainment of quality sufficient sleep time a high priority in the same way that blood glucose tracking devices motivate a large percentage of diabetics and even pre-diabetics (i.e., individuals showing signs of insulin resistance) to closely monitor and control their blood glucose levels in order to prevent or control their diabetic condition.

B-3d. Future External Funding Opportunities

While further funding from the AWO and/or individual towing vessel companies could be used for future studies and in the development and implementation of a comprehensive scientifically based AWO Fatigue Management System, in this section, we are or will seek external funding for future studies aimed to combat fatigue and adverse health due to insufficient sleep among mariners in the towing industry.

• National Cooperative Freight Research Program (NCFRP)

With the support of the AWO, the team at Northwestern submitted a proposed “Problem Statement” to the National Cooperative Freight Research Program (NCFRP) in August 2011. While this proposal has been approved for funding by the NCFRP, Congress has yet to pass a new Transportation Bill for over two years, so it is not clear if funds will ever become available. If funded, this NCFRP study would allow the Northwestern team to mine the unprecedented amount of real-world data we have obtained on the sleep habits and measures of fatigue in wheelhouse crewmembers in our Phase IV studies. In particular, the aims of the NCFRP study are: a) assess whether there were any changes in behavior in crewmembers following their participation and their receiving educational material in our Phase IV survey study, and b) implement recommendations for how best to use an anchor sleep/nap strategy for crews working split-shift schedules. The data collected from this study would be assessed in combination with data from the Phase IV study in order to determine whether there has been any change in behavior. It will also allow us to identify and categorize those who have and those who have not changed
behavior and to what degree. By identifying these groups of individuals it will be possible to tailor future programs for intervention. This approach could provide a model for other industries facing similar challenges.

- **Other external funding opportunities**

  There are a number of federal agencies that support research related to fatigue in the workplace. Our plan is to prepare new proposal to agencies such as National Institute of Occupational Safety and Health (NIOSH) and the Centers for Disease Control (CDC).
C. Goals and Study Design

The primary aims of this study were to use online technologies to collect data on a large number of wheelhouse crewmembers to determine:

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c) Attitudes toward the importance of obtaining quality and sufficient sleep as well as barriers to obtaining sufficient sleep

d) Risk for sleep apnea and levels of obesity and to relate these indicators to sleep time and quality

In order to achieve these goals, participating crews involving 163 Captains and Pilots from 27 AWO membership companies were studied over an approximately two-month period: one month at home (Session A) and the second month on the vessel (Session B). By studying wheelhouse crewmembers (Captains and Pilots) both on the vessel and off, we were able to identify whether the individuals’ sleep is impaired in general due to some underlying reason (e.g., sleep disorder, stress, health, social factors, perceived need for sleep) or due to being on the vessels or the shift schedule.

To determine daily sleep duration and quality and to assess sleepiness/fatigue levels, wheelhouse crewmembers were asked to complete a number of sleep logs and fatigue scales after every sleep period during the first and third week of each section of the study. To determine general factors about sleep, sleep quality and sleepiness, crews were asked to complete a series of questionnaires relative to their time on the vessel and at home. At the end of the two-month period, crewmembers were provided with the educational materials developed during the Phase III studies.
D. Background

The current project stems from two previous examinations of the sleep of crewmembers aboard towing vessels when NU investigators were on board a limited number of vessels to collect data. The hypothesis underlying those studies of towboat crews on a 6:6:6:6 square watch was that anchor and nap sleep strategies could be utilized that would allow crews on either the back or the front watch to obtain 7-7.5 hours of sleep per day. An educational intervention that introduced the concept of anchor sleep/nap sleep and sleep hygiene was developed, and the impact of this educational intervention was assessed as part of the Phase III studies. Of particular concern for this intervention were crewmembers on the Pilot (or back) watch who have sleep/rest periods from about 06:00-12:00 and 18:00-00:00 each 24 hour day—times when it is difficult to sleep for a prolonged period of time due to the circadian drive to be awake. An additional concern was our surprising finding from a small number of vessels in the Phase II and III studies that indicated the crews on the front watch were not obtaining more than 3.7 hours of sleep during the prime time for human sleep, i.e., between 24:00-06:00 hours.

This anchor sleep/nap sleep concept was derived from recent laboratory studies by Mollicone and colleagues 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). These studies published in 2008 and 2009 indicated that performance levels are dependent on the total number of hours of sleep per day. 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 (Mollicone et al. 2007 and 2008). The basic protocol for the Mollicone et al. studies included allowing individuals 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 of anchor sleep combined with a second “nap” sleep period at a different time of day (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 whether sleep occurred in one or two bouts per day (i.e., performance was equal when individuals slept 6.2 + 0 hours vs. 4.2 + 2 hours).

The previous Phase III study of crews from ten towing vessels from March until December 2010 revealed several interesting findings. While crew members spent approximately 8 hours in bed each day (about 4.6 hours in bed during the morning rest period and a further 3.4 hours in bed during the evening rest period), actual sleep duration was considerably less than this (the results from our Phase III studies were essentially identical to those obtained in our more limited Phase II studies). This of course raised the question: why is time in bed so much
longer than actual sleep time? This Phase III dataset, in part due to the small sample size, did not allow us to determine the factors that may be influencing sleep. A primary objective of this Phase IV study was to address this important question.

An additional important finding (found in both the Phase II and III studies) was that there were no significant differences in the sleep durations between wheelhouse and deckhand crewmembers on either the front or back watch. Thus, we have no data to support an intervention strategy that would involve attempts to phase shift the circadian clock of back watch crews so they would be sleeping in phase with their internal clock; something crews on the front watch are already doing. The fact that crews on both the front and back watch are able to be in bed for about 8 hours on both watches when using a 6:6:6:6 work schedule indicated that this square watch schedule does allow sufficient time for sleeping; the main issue is that sleep efficiency is low.

Crews on the front watch obtain about 6.4 hours of sleep per 24-hour day. This was not affected by our short (2-day) sleep education intervention (see Appendix A for a copy of educational materials) to encourage them to obtain more sleep. Crews on the front watch slept about 3.7 hours during the anchor sleep period from about 00:00-06:00, and they usually were able to obtain a 2-3 hour nap during the 12:00-18:00 sleep period. This is in line with the circadian propensity to sleep during the night and nap in the afternoon. However, surprisingly crewmembers on the front watch were only sleeping about 3.7 hours during the 6-hour anchor sleep period from 0000-0600, which is the prime time for human sleep. This finding makes it very unlikely that crews on a 7:7:5:5 or an 8:8:4:4 watch schedule would obtain close to 7 or 8 hours of sleep even when a sleep period coincided with a 7 or 8 hour rest period. Thus, it would appear that on a 7:7:5:5 or an 8:8:4:4 watch, crews would still have to develop a “napping” strategy as do crews on a 6:6:6:6 watch with less time (4 or 5 hours) for nap sleep.

Another important finding from the Phase II and III studies was that the crewmembers showed a great deal of interest in their sleep behavior and were compliant with the study. The data were very tight and repeatable from Phase II and III. The education intervention was clearly too short to have a meaningful impact and to change sleep behavior. Indeed, it is well known that to change human behavior, it often takes a long period of repeating the message (e.g., smoking cessation). This may be especially the case for the importance of sleep for long-term health outcomes. Even with most of the crews from the ten vessels participating in the Phase III study, our sample size was small, especially when the samples were broken into groups such as deckhand vs. wheelhouse; back watch vs. front watch. This type of break down is important since crews on different vessels often have a much different working environment even if on the same 6:6:6:6 square watch. An important issue that was not addressed in the Phase III study.
was that we did not have data on how sleep times while on the vessel compared to sleep time when the crewmembers were off the vessel and sleeping at home. For example, it may be normal to have a sleep efficiency of 80% at home as well as on the vessel, indicating that sleep quality may be an issue all the time, not just on the square watch. It is not unusual for older adults to have lower sleep efficiency than younger adults. Thus, an important component of the larger Phase IV study was to obtain data on the impact of age, BMI or health problems on sleep quality and duration.

All of the points outlined above highlight the need for the type of study conducted in the Phase IV trial. During Phase IV, we examined the sleep and health of over 150 wheelhouse crewmembers both at home and on the vessel, allowing the research team to answer some of the questions raised by the prior studies. The design of and results from this study are provided in this report.
E. Study Sample

Crews from twenty-three companies participated in this study, "Large scale survey of sleep quality and general health in wheelhouse towing vessel crewmembers on American waterways.” A list of the companies whose crews volunteered to participate in the study is provided below. Of the 629 potential wheelhouse crewmembers whose names were provided by staff from the AWO to be contacted to participate in this study, 282 agreed to participate, although only 163 actually participated to some degree in the study. Given that not all crewmembers participated to the same extent in all aspects of the study, for each of the outcome variables, the number of participants that contributed to various measurements is reported on individual tables as well as in the text.

To date, this is perhaps the largest study of its kind in the maritime industry and certainly the largest study of its kind in the American towing industry focusing on Captains and Pilots.

Companies with crews actively involved in the Phase IV research study (June 2011 – February 2012)

1. Ingram Barge Company
2. ACL
3. Kirby Inland Marine Transportation
4. Inland Marine
5. Lorris G. Towing
6. AEP River Operations
7. DeLoach Marine
8. Express Marine
9. Callais and Sons
10. K-Sea
11. Marquette Transportation Company
12. Canal Barge
13. Artco
14. Wasler
15. ADM
16. Blessey Marine
17. Amhurst Madison
18. Great Lakes Dredge and Dock
19. McAllister Towing
20. Buffalo Marine
21. Magnolia Marine
22. American River Transportation
23. Echo Marine
F. Methods, Procedures and Data Analysis

F-1. Metrics that were used for the online surveys

The NU investigative team has extensive experience using subjective measures of sleep-wake behavior in industry-based settings. Subjective questionnaires provide a great deal of information. Given the resources and the large scale of the Phase IV study, objective measures of sleep (e.g., use of actigraphy) were not used as in the more limited Phase II and III studies. The subjective survey items used in the Phase IV study are those that have been well validated, and the large number of participants strengthens the overall results and conclusions that can be made. Specifically, we collected extensive survey data on sleep-wake measurements, general sleep quality, subjective fatigue, general demographic, health (physical and mental), social information and work information. Details of the survey items and study procedures are outlined in this section (F), and a copy of each questionnaire can be found in Appendix B.

Sleep-wake measurements

A commonly used measure of sleep and wake behavior is a daily sleep log/diary that allows one to measure sleep-wake activity over an extended period of time, with little demand on the individuals being studied. Sleep diaries were completed at the end of each sleep period for the duration of the study and provide a subjective record of sleep and wake. Crews note the time they went to bed, how long it took to fall asleep, what time they woke up and the perceived quality of sleep. Additional questions were included to assess factors such as the ability to wake up and how refreshed they felt upon awakening.

- **Examples of sleep variables obtained by sleep diary:**
  - Bedtime: Time a subject goes to bed;
  - Wake-up time: Time a subject gets up in the morning;
  - Sleep latency: Time (in minutes) a subject takes to fall asleep;
  - Time in bed: Duration between bedtime and wake-up time;
  - Sleep duration: Duration between bedtime and wake-up time minus sleep latency.

General sleep quality questionnaires

We also used well established and validated sleep questionnaires to obtain subjective sleep data. Participants completed the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS) and Berlin Questionnaire. Below we summarize the key features of each questionnaire.
**Pittsburgh Sleep Quality Index (PSQI):** This self-rated, 21-item questionnaire assesses individual sleep habits (bedtime, morning rising time, sleep-onset latency and night sleep duration), insomnia and hypnotic use over a one-month time interval (Buysee et al. 1989). The PSQI has been widely applied in a variety of clinical settings and epidemiological studies in many countries because of its satisfactory psychometric properties. The PSQI was modified for the on vessel portion of the study. Since the original PSQI only has the option to complete the sleep timing and duration portion of the questionnaire for a single sleep period per day, the questionnaire was modified to include the option to complete this section for both of the sleep opportunities afforded by the 6-hour square watch schedule. A composite for the two sleep periods for this section was then calculated to allow for scoring of the PSQI according to standard criteria.

**Epworth Sleepiness Scale (ESS):** The ESS provides a measurement of a subject’s general level of daytime sleep propensity: it asks individuals to estimate the likelihood of dozing off or falling asleep in eight different sedentary situations (Johns et al. 1991 and 1992). The ESS correlates to some extent with mean sleep latencies on the objective Multiple Sleep Latency Test (MSLT) and with the degree to which people complain of sleepiness. The instrument has been used extensively as a subjective measure of daytime sleep propensity and sleepiness.

**Berlin Questionnaire:** This designed to identify adult patients who are likely to have sleep apnea (Netzer et al. 1999). It asks about snoring behavior, wake time sleepiness or fatigue, and the presence of obesity or hypertension. Scoring in the high-risk category predicts a respiratory disturbance index of > 5 with about 90% accuracy.

**Subjective fatigue**

We used the Karolinska Sleepiness Scale (KSS) questionnaires to assess subjective fatigue/sleepiness levels at the beginning and end of each sleep period and the beginning and end of each work period. The KSS is a 10-point rating scale in which participants describe their sleepiness as one of the following scores: 1 = extremely alert, 2 = very alert, 3 = alert, 4 = rather alert, 5 = neither alert nor sleepy, 6 = some signs of sleepiness, 7 = sleepy, but no effort to keep awake, 8 = sleepy, some effort to keep awake, 9 = very sleepy, great effort to keep awake, struggling against sleep, or 10 = extremely sleepy, falls asleep all the time. The KSS is widely used; it has been shown to be sensitive to sleep loss (Axelsson et al. 2004), and is closely related to performance (Horne et al. 1995) and physiological indicators of sleepiness (Kaida et al. 2006).
General demographic, health (physical and mental), sleep and social information

We used the *Standard Shift Work Index (SSI)*, which was developed after a request by the Scientific Committee on Night and Shift Work of the International Congress of Occupational Health for a standardized battery of questionnaires to assess issues related to shift work. Based on existing knowledge of the problems associated with working shifts, the measures chosen fall broadly into two categories: variables which are thought to modify an individual's response to shiftwork, such as individual circumstances (age, marital status or children to look after), personality variables (morningness/eveningness, extraversion/neuroticism, rigidity and vigour), and coping strategies; and personal outcomes for the individual, including physical and psychological health, sleep disturbances and social and domestic disruption (Shiftwork Research Team).

Work diary

During the onboard portion of the study, crewmembers were asked to report their daily work schedule in a diary. The diary includes simple questions about what time the shift started and ended.

*An example of all of the instruments used in this study is provided in Appendix B.*

F-2. General study procedures

Participant recruitment

Pilots and captains were contacted by the AWO to be invited to participate in the study. If they agreed, eligible individuals' email addresses and/or telephone numbers were provided by the AWO to the NU Research Team. The research team contacted participants initially via email if it was available or via telephone if only this information was provided. If there was no response to the initial contact, crewmembers were contacted up to an additional 7 times (usually at least 3 additional times) using email, telephone call and/or text messaging.

Participant characteristics

Inclusion criteria: At least 18 years of age and a pilot and/or captain of a towing vessel.
Study procedures

Consenting
Upon receiving email contact from wheelhouse crewmembers, a URL to a secure server was sent to them where they were asked to complete the consent form. The consent form outlined the reason for the study, study procedures, confidentiality and the risks and benefits associated with the study. All procedures and questionnaires were approved by the Northwestern University Institutional Review Board (IRB). In order to maintain confidentiality, all participating crews were assigned a unique study identification code that was used to track their data throughout the online survey process. Only NU research staff had access to these ID codes and knew whether specific individual crewmembers had participated in the study.

Timeline
The study schedule for each participant was divided into two approximately one-month periods, with one month of observation at home and the other month of observation on board the vessel. During each “month,” data was collected for up to 14 days. This approach was used to reduce the burden of daily/twice daily reporting and still allowed us to observe any changes in sleep/wake that may have occurred with the number of days either at home or on board the vessel. For example, crews may have difficulty sleeping during the first few days at home after being on the vessel for an extended time, and the longer they are on the vessel, the more fatigued they may become.

On board the vessel the participant received a sleep/work diary to be completed after every sleep period for two 7-day periods, days 1-7 and again on days 14-21. Sleep period refers to when the individual goes to sleep for more than ten minutes. In addition to the sleep/work diary, three questionnaires were distributed on the first day (Day 1) of data collection via a URL and were monitored by the research staff via the survey website to determine if they were completed within the desired time frame. Participants had 48 hours to complete the three questionnaires from the time the URL was opened. Study staff email addresses and telephone numbers were provided for questions or concerns regarding the surveys.

<table>
<thead>
<tr>
<th>Questionnaires</th>
<th>Day given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep/work diary (Day 1-7): 3 min each time</td>
<td>Day 1 (completed twice daily)</td>
</tr>
<tr>
<td>Sleep/work diary (Day 14-21): 3 min each time</td>
<td>Day 14 (completed twice daily)</td>
</tr>
</tbody>
</table>
At home participants completed a daily sleep diary after every sleep period longer than ten minutes. In addition, four questionnaires were distributed on the first day of the data collection period (Day 1). Participants had 48 hours to complete the four questionnaires from the time the URL was opened. Research staff monitored this via the survey website.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Day given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep diary (Day 1-7): 3 min each time</td>
<td>Day 1 (completed daily)</td>
</tr>
<tr>
<td>Sleep diary (Day 14-21): 3 min each time</td>
<td>Day 14 (completed daily)</td>
</tr>
<tr>
<td>Pittsburgh Sleep Quality Index (PSQI): 3 min</td>
<td>Day 1 (completed within 48 hours)</td>
</tr>
<tr>
<td>Berlin Questionnaire: 2 min</td>
<td>Day 1 (completed within 48 hours)</td>
</tr>
<tr>
<td>Epworth Sleepiness Scale (ESS): 2 min</td>
<td>Day 1 (completed within 48 hours)</td>
</tr>
<tr>
<td>Standard Shiftwork Index (SSI): 30-45 min</td>
<td>Day 1 (completed within 48 hours)</td>
</tr>
</tbody>
</table>

F-3. Data analysis

Data from the sleep diaries were averaged for the first seven days on the vessel and for the first seven days at home. Crews were required to have completed the diary for at least three of the seven days to be considered eligible for analysis. Missing days were imputed from the average of the completed days. Eleven percent of the sleep periods were imputed for the on board diaries and six percent for the at home diaries.

For the onboard portion of the study, data are reported for the 24-hour day, morning, evening, front watch (Captains) and back watch (Pilots). For the at home portion of the study, data are reported for the 24-hour day for front watch (Captains) and back watch (Pilots). Comparisons between morning and evening sleep periods and front watch (Captains) and back watch (Pilots) crews were made using independent sample t-test. Comparisons between individuals, for example, crewmembers who completed both the on board and at home portions of the study, were conducted using a paired t-test. Chi-square was used to determine whether there were significant differences between front watch and back watch crewmembers for high
risk for sleep apnea. Multivariate regression adjusting for age was used to determine whether there was an association between time in bed and measures of sleepiness and sleep quality.
G. Results

A summary of the findings from this large study is reported in this Results section. Given the scale of the study, the results from every question are not provided. However, the summary variables from the key questionnaires are provided for all crewmembers while on the vessel and at home.

This section is divided into the following headings: crew characteristics (Section G-1); sleep duration (Section G-2); sleep quality (Section G-3); sleep apnea risk (Section G-4); sleepiness (Section G-5) and other factors that may influence sleep (Section G-6). The analysis presented is aimed at addressing each of the primary aims of the study.

G-1. Crew characteristics

G-1a. All crews

A total of 163 crewmembers actively participated in this study. Not all crewmembers completed all the questionnaires, and some characteristics, like age, are not available for everyone (we are attempting to obtain this information from the remaining crewmembers). In general, there were twice as many front watch crewmembers as back watch crewmembers that participated in this study. Front watch crewmembers tended to be older (p<0.01) and have more years working on a maritime shift schedule (p<0.01) than back watch crewmembers (see Table 1).

G-1b. Crews on the vessel

There were 133 crewmembers who completed the sleep diary while on the vessel; of these, 85 were on the front watch and 48 were on the back watch.

G-1c. Crews at home

There were 135 crewmembers who completed the sleep diary while at home; of these, 90 were on the front watch, 42 were on the back watch crew and 3 individuals were not able to be classified as to their watch schedule.

G-1d. Crews studied both on the vessel and at home

There were 83 crewmembers who participated in the questionnaires portion of the study both at home and on board the vessel: 54 on the front watch and 29 on the back watch.

There were 105 crewmembers who participated in the daily sleep diary portion of the study both at home and on the vessel for at least three of the seven first days aboard the vessel or when at home.
Table 1. Characteristics of participants with questionnaire data.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>ALL (FW&amp;BW)</th>
<th>Front watch</th>
<th>Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>mean</td>
<td>std</td>
</tr>
<tr>
<td>Age (years)</td>
<td>124</td>
<td>48.31</td>
<td>8.92</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>119</td>
<td>32.33</td>
<td>5.76</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>124</td>
<td>(123males)</td>
<td></td>
</tr>
<tr>
<td># years on Maritime shift system</td>
<td>120</td>
<td>26.28</td>
<td>10.64</td>
</tr>
</tbody>
</table>
G-2. Sleep duration

The amount of time spent in bed (calculated from questions that asked what time the crewmember went to bed and woke up) and sleep latency was recorded daily in sleep diaries. In addition, participants were asked about their usual sleep schedule or sleep “need” questionnaires. The results of these sleep-related questions are presented below. Time in bed (TIB) was the duration between when the crewmember reported going to bed and waking up, while sleep duration (SD) was calculated as TIB minus sleep latency.

G-2a. Sleep diary

Time in bed (TIB) and Sleep duration (SD)

G-2ai. TIB and SD on board

The data presented for onboard crews represents seven days of sleep diaries from the first 7 days on board the vessel for 133 individuals (Figure 1). During the first 7 days on board the vessel, participants reported spending an average 8.3±1.3 hours in bed each day and had a sleep duration of approximately 7.9±1.3 hours. This difference between TIB and SD represents an average sleep latency of about 24 minutes.

Time in bed in this Phase IV study is similar to that observed in the Phase III study (1 minute difference), but sleep duration is considerably longer (78 minutes) in the Phase IV study compared to the Phase III study due to the methods used. Table 2 presents a comparison of results from 133 crew members in the current Phase IV study using subjective sleep estimates with the 19 crew members from the smaller Phase III study using both subjective and objective sleep estimates.

Table 2. Comparison of Phase III (N=19) and Phase IV (N=133) Time in Bed (TIB) and Sleep Duration (SD) in hours for all crews and for Phase III wheelhouse crews on the front watch (N=10) and back watch (N=9) and Phase IV Front watch/Captains (N=84) and Back watch/Pilots (N=48). The difference was calculated as Phase IV minus Phase III for TIB and SD.

<table>
<thead>
<tr>
<th>Phase Method Schedule</th>
<th>Phase III Actigraphy</th>
<th>Phase IV Actigraphy</th>
<th>Difference Actigraphy</th>
<th>Phase III Sleep Diary</th>
<th>Phase IV Sleep Diary</th>
<th>Difference Sleep Diary</th>
<th>TIB</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All crew</td>
<td>8.1</td>
<td>6.6</td>
<td>0.2</td>
<td>8.3</td>
<td>7.9</td>
<td>0.2</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Front watch/Captains</td>
<td>7.9</td>
<td>6.4</td>
<td>-0.4</td>
<td>8.3</td>
<td>8.0</td>
<td>-0.3</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Back watch/Pilots</td>
<td>8.5</td>
<td>6.9</td>
<td>0.9</td>
<td>8.2</td>
<td>7.8</td>
<td>0.4</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
On board sleep was split into two separate episodes morning (sleep occurring between approximately 11:30pm – 12am) and evening (sleep occurring between approximately 12:01am – 11:29pm). The average time in bed in the morning was 4.6±0.7 hours and the average sleep duration was 4.3±0.7 hours. When sleeping in the evening, time in bed was on average 3.7±0.9 hours and the average sleep duration was 3.2±0.9 hours. There was a significant difference in the morning compared to evening sleep periods for both time in bed (p=0.001) and sleep duration (p=0.001).

![Time in Bed and Sleep Duration](image)

**Figure 1.** Mean ± standard deviation for the first seven days on the vessel for all crew (N=133) for each sleep period and for each 24 hour period. *p=0.001

When the front watch (N=84) and back watch (N=48) crews were compared, there were significant differences between the groups for morning and evening sleep episodes. However, there were no differences between the front watch and back watch for the cumulated 24-hour sleep episodes (Figure 2). In the morning, front watch crews spent about 36 minutes longer in bed than back watch crews (p<0.001), and in the evening, back watch crews spent about 24 minutes longer in bed than front watch crews (p<0.01). For sleep duration in the morning, front...
watch crews also slept about 36 minutes longer than back watch crews, and there was a trend in the evening for back watch crews to sleep longer than front watch crews (p=0.06).

**Figure 2.** Mean ± standard deviation for the first seven days on the vessel for all front watch (FW, N=84) and back watch (BW N=48) crew for each sleep period and for each 24 hour period. *p<0.05 and p= 0.06
G-2aii. TIB and SD at home

The data presented for the time at home represents seven days of sleep diaries from the first seven days at home for 135 individuals (see Figure 3). During the first seven days while at home, participants reported spending an average of 7.6±1.1 hours in bed each day and slept approximately 7.3±1.1 hours of this time. This difference between TIB and SD represents an average sleep latency of about 18 minutes.

![Sleep at home][1]

**Figure 3.** Mean ± standard deviation for time in bed and sleep duration for the first seven days at home for all crewmembers.

G-2aiii. TIB and SD on board compared to at home

For both the front watch (N=67, p<0.001) and back watch (N=37, p<0.05), crewmembers' time in bed (TIB) was significantly longer when they were on the vessel compared to when they were at home (see Figure 4). This 30 minutes difference in TIB may be due to crewmembers having less competing activities (social and family activities for example) when on the vessel than at home. It should be noted that there was no corresponding difference in sleep duration, so while the captains and pilots spent longer times in bed on the vessel compared to at home, there were no differences in the amount of that time they spent sleeping.
Figure 4. Mean ± standard deviation for the daily time in bed and sleep duration for the first seven days at home and on the vessel for front watch (FW, N=67) and back watch (BW, N=37) crew that completed the study both at home and on the vessel. * p<0.05
G-2b. Questionnaire - Time in bed, sleep duration, sleep need

Participants were asked questions related to sleep duration on both the PSQI (referring to both the time on the vessel and time at home) and SSI questionnaires (referring only to their time on the vessel).

G-2bi. Pittsburgh Sleep Quality Index - Time in bed and sleep duration

Question 6.d from the PSQI asks, “How many hours of actual sleep did you get” for both on board the vessel and at home (Tables 3 and 4). Since on board the vessel there are typically two sleep periods per day, the PSQI was modified to allow crews to respond to this question for both sleep periods. These responses were then summed for each individual and presented as the mean ± standard deviation.

While on the vessel, crewmembers reported their actual amount of sleep as 7.2±3.6 hours (Figure 5). For those on the front watch, the actual amount of sleep was 7.2±4.2 hours, and for the back watch crewmembers, it was 7.3±2.1 hours (p=0.8).

While at home, crewmembers reported their actual amount of sleep as 6.5±1.4 hours. For those on the front watch, the actual amount of sleep reported while at home was 6.6±1.3 hours, and for the back watch crewmembers, it was 6.3±1.6 hours (p=0.3).

In addition to the specific question about the amount of actual sleep obtained, crewmembers reported their usual bedtime and wake time (on board they reported these times for both sleep opportunities). Time in bed was calculated from the PSQI questionnaire (the difference between the time that the participant has “usually gone to bed” (question 6a) and “usually gotten up” (question 6c)). The average time in bed when on the vessel was 9.2±6.1 hours (Figure 5) and 8.1±3.2 hours when at home. This extremely long TIB may be an artifact of summing the responses for both sleep periods while on board but does suggest that crews overestimate the amount of time they spend in bed when asked to give an average time for the past month. This long TIB is in contrast to the TIB calculated after every sleep period from the sleep diaries (8.3 hours).

G-2bii. Standard Shiftwork Index - Sleep need

For the SSI question 2.2 asks “how many hours of sleep do you need per day regardless of what shift you are on” (Figure 5). While on the vessel crew reported that they need 7.2±1.4 hours of sleep per day. Front watch crew reported that they needed 7.2±1.5 hours, and the back watch crew reported that they needed 7.2±1.1 hours (p=0.9).

G-2c. Sleep Duration Summary
For all the crews combined, the self-reported time in bed while on the vessel was on average consistently above eight hours a day, with estimated sleep durations between 7.2-7.9 hours a day.

The sleep duration reported here in the Phase IV study is longer than was reported in previous phases using objective measures like wrist activity monitoring (See Table 2). Unlike the objective measures, “sleep duration,” as calculated in Phase IV, does not take into account any wake time after falling asleep (WASO). Crews were asked to report whether they woke up after falling asleep, and if so, for how long on a scale from 1-5, with 1 being 0 minutes awake and 5 being more than 60 minutes awake for every sleep period. Given that the WASO is estimated in bins and would not allow the same degree of precision as with objective measures, it was decided to not include it in the calculation of sleep duration at this time. Future analysis will be able to take this time into account, which will ultimately shorten sleep time.

Since crewmembers were asked to report the amount of time spent sleeping in several different ways, a summary of these findings while on the vessel is provided below in Figure 5. What this figure indicates is that depending on how and when the question is asked, the response can be considerably different. Therefore, these methodological differences need to be considered when interpreting the results, when making comparisons between items within a study and when comparing data between studies. The questionnaire data presented in Figure 5 represents a recollection of sleep time for the past month, while the sleep diary is completed immediately following each sleep period and then averaged for seven days. This difference in methodology could explain the surprisingly long time in bed calculated from the PSQI questionnaire. It is likely that crewmembers over-report time in bed since it is a calculation based on reported bedtimes and wake times for both morning and evening sleep periods over the previous month. It is also interesting that self-reported “sleep need” and “usual amount of sleep” from two different questionnaires are basically identical at 7.2 hours. The difference between reported sleep amount and time in bed measures suggests that crewmembers are aware of sleep disturbances that would account for this difference.
There was a significant difference between the TIB reported at home compared to on board the vessel, with crewmembers spending more TIB on the vessel than at home, but there was no corresponding difference in sleep duration. The difference in TIB is likely due to the time required to participate in competing activities of daily living (social and family commitments, etc.) that are different between the vessel and at home, i.e., there are more competing activities when at home, much like the difference observed in sleep times between weekends and weekdays in other studies. Given the method used to calculate sleep duration (TIB minus sleep latency), this suggests that sleep latency is longer while on the vessel than while at home and requires further investigation.

The recommended amount of sleep for an adult is 7-8 hours a day, and many people in today’s society are not able to obtain this amount of sleep. The findings from the current study are consistent with average weekend sleep durations self reported in the general population, and are considerably longer than weekday sleep durations from the same studies. For example, data from the National Sleep Foundation 2005 Poll reports that average sleep durations were 6.8 hours during weekdays and 7.4 hours on weekends (National Sleep Foundation Poll, 2005).

G-3. Sleep quality

Sleep quality was assessed in several ways for each sleep episode and over the past “month” while on the vessel or at home. The quality of sleep for each individual sleep episode was assessed with a series of questions on the sleep diary, and the general quality of sleep was assessed using the Pittsburgh Sleep Quality Index (PSQI).
**G-3a. Sleep diary**

**G-3ai. On board**

In addition to questions about the amount of sleep obtained in each sleep period, crewmembers were asked to assess the quality of that sleep period. There were significant differences in average sleep quality between front watch and back watch crews while on the vessel (Figure 6). In general, front watch crews slept worse than back watch crews. Front watch crews generally woke too early, found it difficult to get up and felt they had not slept enough.

![Sleep Quality Questions](image)

**Figure 6.** Mean ± standard deviation of key sleep quality measures asked about every sleep episode. *p<0.05, ** p<0.01, p= 0.06

There were also significant differences in sleep quality when comparing the morning and evening sleep periods (Figure 7). For the morning sleep periods, crews reported finding it more difficult to fall asleep, poorer sleep quality, waking too early without being able to fall back to sleep, not sleeping long enough and not sleeping very deeply. Most of these differences for the morning group were accounted for by back watch crews, who reported finding it difficult to fall asleep (p=0.005) and poorer sleep quality (p=0.01). The front watch reported that they did not sleep as deeply (p=0.03).
Crews were also asked whether something special occurred that disturbed their sleep (question 17) and whether there was anything specific that caused them to wake up and ultimately get out of bed (question 18). There were no significant differences for any of the comparisons, although it is important to note that the most commonly reported issues for question 17 were “noise during sleep” and “the work hours” and for question 18, “noise or the like” and “the alarm clock (or the like)” (Figure 8).

Figure 7. Mean ± standard deviation of the first seven days on board for questions related to sleep quality for morning and evening shifts for all crew. * p < 0.05
Anything specific that caused you to wake

![Bar chart showing proportions of responses to each item listed in question 18: Was there anything specific that caused you to wake up and ultimately get out of bed?](chart.png)

**Figure 8.** Proportion of responses to each of the items listed in question 18: “Was there anything specific that caused you to wake up and ultimately get out of bed?”

G-3aii. Sleep quality on board compared to at home

When comparing sleep quality at home and on the vessel, both front watch and back watch crews reported differences. On average for the first seven days either at home or on the vessel, crews reported sleeping worse at home than on the vessel. Both front watch and back watch crews (Figures 9 and 10) reported poorer sleep quality, not sleeping long enough, not sleeping deeply and finding it more difficult to wake up while at home compared to on the vessel (p<0.03). Front watch crews also reported a greater number of awakenings at home, and back watch crews reported finding it more difficult to fall asleep at home (Figure 9) (p=<0.03). These differences in sleep quality were very small but significantly different; overall, sleep quality was quite good.
**Figure 9.** Mean ± standard deviation of the first seven days on board and at home for questions related to sleep quality for Front Watch/Captains. *p <0.05
Sleep Diary Quality Measures Back watch Home and Vessel

![Bar chart showing comparison of sleep quality between vessel and home for back watch.](chart)

**Figure 10.** Mean ± standard deviation of the first seven days on board and at home for questions related to sleep quality for Back Watch/Pilots. * p <0.05

**G-3b. Pittsburgh Sleep Quality Index (PSQI)**

**G-3bi. PSQI On board**

To place the findings from the PSQI questionnaire in context, it is important to note that a “poor sleeper” is considered to be someone with a score of greater than 5 on the PSQI. The mean PSQI score for all of the participating crew was 4.37±2.7, and there was a significantly (p=0.04) higher score for those on the back watch (5.2± 2.8) compared to those on the front watch (3.9±2.6). Overall, there were 28.5% of the crew who had a score greater than 5 on the PSQI, with a slightly higher percentage of back watch crews, but there was no significant difference between front watch (23%) and back watch crews (38%) (p=0.12). The overall average global score reported on the PSQI in this group is slightly lower than population based studies (5.7± 3.1) (Knutson et al 2006).
The PSQI also has seven component sub-scores assessing different aspects of sleep quality (see Table 3). There were significant differences between front watch and back watch crews on two of these sub-scores with the back watch having worse sleep latency \((p=0.01)\) and sleep duration \((p=0.01)\) sub-scores.

In interpreting the results from the PSQI on board the vessel, it is important to note that the questionnaire was modified from the original for this portion of the study. The original PSQI only has the option to complete the sleep timing and duration portion of the questionnaire for a single sleep period per day. Therefore, the questionnaire was modified to include the option to complete this section for both of the sleep opportunities afforded by the 6-hour square watch schedule examined in this study. A composite for this section was then calculated to allow for scoring for the PSQI according to standard criteria.

G-3bii. At home

While at home (Table 4), the PSQI global score was on average 5.5±2.8. There were no significant differences between front watch and back watch crews for the overall global score, but there was a significant difference for sub-score 4 with back watch crewmembers reporting slightly worse sleep efficiency than front watch crewmembers \((p=0.04)\).

G-3biii. On board compared to at home

There was no significant difference in the global PSQI score for crews who completed this questionnaire for both the at home and the on board portions of the study. However back watch crews did report sleeping significantly less (sub-score 3 for sleep duration, \(p=0.03\)) on the vessel than when at home (See Table 5).
Table 3. Pittsburgh Sleep Quality Index Global and sub-scores while on the vessel.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>ALL (FW&amp;BW)</th>
<th>Front watch</th>
<th>Back watch</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>mean</td>
<td>std</td>
<td>N</td>
</tr>
<tr>
<td>PSQI Global</td>
<td>98</td>
<td>4.37</td>
<td>2.73</td>
<td>64</td>
</tr>
<tr>
<td>sub score 1 - Sleep quality</td>
<td>119</td>
<td>0.94</td>
<td>0.68</td>
<td>77</td>
</tr>
<tr>
<td>sub score 2 - Sleep latency</td>
<td>118</td>
<td>1.03</td>
<td>0.94</td>
<td>77</td>
</tr>
<tr>
<td>sub score 3 - Sleep duration</td>
<td>117</td>
<td>1.05</td>
<td>1.06</td>
<td>77</td>
</tr>
<tr>
<td>sub score 4 - Sleep efficiency</td>
<td>107</td>
<td>0.64</td>
<td>0.94</td>
<td>71</td>
</tr>
<tr>
<td>sub score 5 - Sleep disturbance</td>
<td>112</td>
<td>0.96</td>
<td>0.60</td>
<td>71</td>
</tr>
<tr>
<td>sub score 6 - use of sleep med</td>
<td>119</td>
<td>0.28</td>
<td>0.84</td>
<td>78</td>
</tr>
<tr>
<td>sub score 7 - Daytime dysfunction</td>
<td>120</td>
<td>0.46</td>
<td>0.66</td>
<td>78</td>
</tr>
<tr>
<td>PSQI ques 6d</td>
<td>117</td>
<td>7.25</td>
<td>3.60</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 4. Pittsburgh Sleep Quality Index Global and sub-scores while at home.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>ALL (FW&amp;BW)</th>
<th>Front watch</th>
<th>Back watch</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>mean</td>
<td>std</td>
<td>N</td>
</tr>
<tr>
<td>PSQI Global</td>
<td>115</td>
<td>5.15</td>
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<td>73</td>
</tr>
<tr>
<td>sub score 1 - Sleep quality</td>
<td>125</td>
<td>0.80</td>
<td>0.66</td>
<td>80</td>
</tr>
<tr>
<td>sub score 2 - Sleep latency</td>
<td>125</td>
<td>0.98</td>
<td>0.81</td>
<td>79</td>
</tr>
<tr>
<td>sub score 3 - Sleep duration</td>
<td>125</td>
<td>1.23</td>
<td>1.00</td>
<td>79</td>
</tr>
<tr>
<td>sub score 4 - Sleep efficiency</td>
<td>124</td>
<td>0.44</td>
<td>0.88</td>
<td>78</td>
</tr>
<tr>
<td>sub score 5 - Sleep disturbance</td>
<td>121</td>
<td>1.02</td>
<td>0.46</td>
<td>78</td>
</tr>
<tr>
<td>sub score 6 - use of sleep med</td>
<td>126</td>
<td>0.24</td>
<td>0.73</td>
<td>80</td>
</tr>
<tr>
<td>sub score 7 - Daytime dysfunction</td>
<td>124</td>
<td>0.46</td>
<td>0.58</td>
<td>78</td>
</tr>
<tr>
<td>PSQI ques 6d</td>
<td>125</td>
<td>6.52</td>
<td>1.42</td>
<td>79</td>
</tr>
</tbody>
</table>
Table 5. Pittsburgh Sleep Quality Index Global and sub-scores while at home and on the vessel for those on the front watch and those on the back watch.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Vessel</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>N</td>
<td>mean</td>
<td>std</td>
<td>N</td>
<td>mean</td>
</tr>
<tr>
<td>Front watch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSQI Global</td>
<td>37</td>
<td>4.27</td>
<td>2.77</td>
<td>37</td>
<td>5.05</td>
</tr>
<tr>
<td>sub score 1 - Sleep quality</td>
<td>52</td>
<td>0.90</td>
<td>0.63</td>
<td>52</td>
<td>0.77</td>
</tr>
<tr>
<td>sub score 2 - Sleep latency</td>
<td>51</td>
<td>0.82</td>
<td>0.84</td>
<td>51</td>
<td>0.80</td>
</tr>
<tr>
<td>sub score 3 - Sleep duration</td>
<td>51</td>
<td>1.31</td>
<td>1.17</td>
<td>51</td>
<td>1.10</td>
</tr>
<tr>
<td>sub score 4 - Sleep efficiency</td>
<td>46</td>
<td>0.61</td>
<td>1.00</td>
<td>46</td>
<td>0.33</td>
</tr>
<tr>
<td>sub score 5 - Sleep disturbance</td>
<td>45</td>
<td>0.91</td>
<td>0.67</td>
<td>45</td>
<td>1.00</td>
</tr>
<tr>
<td>sub score 6 - use of sleep med</td>
<td>53</td>
<td>0.23</td>
<td>0.80</td>
<td>53</td>
<td>0.25</td>
</tr>
<tr>
<td>sub score 7 - Daytime dysfunction</td>
<td>51</td>
<td>0.41</td>
<td>0.61</td>
<td>51</td>
<td>0.53</td>
</tr>
</tbody>
</table>

| Back Watch                   |     |      |      |       |      |      |         |
| PSQI Global                  | 22  | 4.68 | 2.61 | 22    | 5.36 | 2.68 | 0.26    |
| sub score 1 - Sleep quality  | 29  | 1.00 | 0.71 | 29    | 0.86 | 0.69 | 0.21    |
| sub score 2 - Sleep latency  | 28  | 1.25 | 1.04 | 28    | 1.18 | 0.61 | 0.68    |
| sub score 3 - Sleep duration | 28  | 0.71 | 0.98 | 28    | 1.36 | 1.10 | 0.03    |
| sub score 4 - Sleep efficiency | 24  | 0.75 | 1.15 | 24    | 0.75 | 1.15 | 1.00    |
| sub score 5 - Sleep disturbance | 27  | 0.85 | 0.46 | 27    | 0.96 | 0.34 | 0.26    |
| sub score 6 - use of sleep med | 29  | 0.28 | 0.80 | 29    | 0.14 | 0.58 | 0.21    |
| sub score 7 - Daytime dysfunction | 29  | 0.34 | 0.61 | 29    | 0.38 | 0.56 | 0.77    |
G-4. Sleep Apnea Risk Questionnaire

During this study, the Berlin Questionnaire, a well-validated questionnaire, was used to assess the risk of sleep apnea. Sleep apnea is a sleep disorder in which there are brief pauses (at least ten seconds) in breathing, repeatedly throughout the sleep period. These pauses in breathing are associated with reductions in the amount of oxygen in the blood and cause brief arousals from sleep. Sleep apnea is often associated with excessive sleepiness. In addition, moderate levels of sleep apnea have been linked to an increased risk of cardiovascular health problems. Signs of sleep apnea include loud snoring, someone telling you they have noticed that you stop breathing in your sleep, being overweight (although “skinny” people can also have sleep apnea), and, for some people, excessive sleepiness.

G-4a Berlin Sleep Apnea Risk

Of the 116 participants that completed the Berlin questionnaire, 41% were at a high risk for having sleep apnea (Figure 11). This is higher than in the general population, where approximately 32% of men of a similar age are reported to be at high risk for sleep apnea (Hiestand et al. 2006). More (p=0.12) of those on the back watch were at high risk (51.3%) than those on the front watch (36.4%); it is unclear why there is this difference.

The proportion of the crewmembers (63%) who reported snoring (Figure 11) was similar to the percentage reported in the general population, where about 60% report snoring (National Sleep Foundation Poll, 2005 and Young et al. 2002). Of those that snore, 25.4% reported severe snoring, which is reported as snoring that is “louder than talking or very loud and can be heard in adjacent room.” 39.2% reported frequent snoring, which is reported as snoring “nearly every day and 3-4 times a week” (Figure 11). This is similar to the severity and frequency of snorers in the general population (National Sleep Foundation Poll, 2005 and Young et al. 2002). There is growing evidence that snoring may be an important contributing factor to elevated blood pressure and cardiovascular disease. (Young et al. 1996).

Of those that completed question 9 on the Berlin questionnaire (“Have you ever nodded off or fallen asleep while driving a vehicle?”), 29% reported having fallen asleep or nodded off while driving (Figure 11). This is less than what has been reported for the general population (37% of those with a driver’s license) (National Sleep Foundation Poll, 2005). Those on the back watch were 30% more likely to report having fallen asleep while driving than those on the front watch (OR 0.30 (CI: 0.13-0.71), p=0.002).

While the Berlin questionnaire is not a diagnosis of sleep apnea, it is a well-validated indicator of risk. Given the high rate of those at high risk for sleep apnea and that this disorder carries a risk of both poor health and alertness outcomes, careful consideration of how to use
the findings of this study to implement screening and risk mitigation strategies should be considered.

![Berlin Questionnaire chart](image)

**Figure 11.** Proportion (%) of crew for responses on the Berlin questionnaire.

**G-4b. Berlin Body Mass Index**

Height and weight are reported as part of the Berlin Questionnaire and allowed us to calculate body mass index (BMI), an important health indicator for risk of cardio-metabolic disorders. The average BMI for the crew is 32 kg/m², which is considered obese, and approximately 10% of the crew had a BMI of greater than 40 kg/m². Since BMI is used as a factor in calculating sleep apnea risk, it is not surprising that the proportion of the crew at high risk for sleep apnea is as great as it is. To put this into context, the risk of sleep apnea, as determined by the Berlin Questionnaire in this BMI range (BMI of 30-39.9), is about 56% (Hiestand, 2006). It is also striking that the proportion of obese and morbidly obese is substantially higher in the crew than in the general population (Table 6). Given that being overweight is a risk factor for cardio-metabolic disorders, the level of obesity in this group should be of great concern.

**Table 6.** The percentage of individuals by body mass index category for the general population (* taken from NHANES 2007-2008) and for crewmembers in this study; risk of sleep apnea as determined by the Berlin questionnaire for each BMI category.

<table>
<thead>
<tr>
<th>Category</th>
<th>BMI Range</th>
<th>% of Normal Population</th>
<th>% of Crew</th>
<th>Berlin Sleep Apnea Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight</td>
<td>25-29.9</td>
<td>34.2%</td>
<td>36.1%</td>
<td>17%</td>
</tr>
<tr>
<td>Obese</td>
<td>30+</td>
<td>33.8%</td>
<td>47.9%</td>
<td>57%</td>
</tr>
<tr>
<td>Morbidly Obese</td>
<td>&gt; 40</td>
<td>5.7%</td>
<td>10.1%</td>
<td>75%</td>
</tr>
</tbody>
</table>
There is discussion in some sectors of the transportation industry, in particular trucking, that suggests that anyone with a BMI of greater than 35 kg/m² be automatically referred for evaluation by a sleep specialist to determine whether they have obstructive sleep apnea or some other type of sleep disordered breathing.

**G-5. Sleepiness Questionnaires**

During this study, well-validated questionnaires were used to assess levels of general sleepiness, including the Epworth Sleepiness Scale (ESS) and the Karolinska Sleepiness Scale (KSS).

**G-5a. Epworth Sleepiness Scale (ESS)**

General levels of sleepiness were assessed using the ESS while on the vessel and at home (Figure 12). A clinically significant score on the ESS would be 12 or greater, and if 10 or greater then it is generally recommended that the person should talk to their primary care physician for follow up to determine if there is a problem. The average score on the ESS for this group was well below these recommended cut offs. It was also similar to that reported in population based studies (average ESS score of 7.4±4.3) (Knutson 2006).

On average, for all the crews who responded to this questionnaire (Figure 12), the level of sleepiness reported on the ESS while on the vessel was 7.8±4.0 (n=117); there was no difference (p=0.3) between those on the front watch (8.1±4.2, n=75) or back watch (7.3±3.4, n=41). While at home, the level of sleepiness was slightly lower 6.6±3.4 (n=122); there was a trend (p=0.09) for those on the front watch (6.9±3.6, n=78) to be more sleepy at home compared to those on the back watch (5.9±2.7, n=38).
Figure 12. Mean ± standard deviation of Epworth Sleepiness Scores (ESS) at home and on board for all crews and by watch.

There are no differences between front watch or back watch crews between the score on the vessels and at home when only those crews who completed the ESS both at home and on vessel are compared.

The interpretation of the results from the ESS maybe limited for the on board portion of this study, since by the nature of the questionnaire, it refers to some situations in which the respondent is unlikely to participate while on the vessel (e.g., in a car stopped at a traffic light for a few minutes). However, we believe the questionnai re is still valid, as this limitation can apply to the use of the questionnaire in general since not all people drive.

G-5b. Daily Sleepiness on the Karolinska Sleepiness Scale (KSS)

An average sleepiness score was calculated for the time prior to and immediately following each sleep episode for the first seven days on the vessel (morning, evening, 24 hours) and at home (24 hours). In general, the level of sleepiness was between 4-5.5 (a score of 5 is “neither sleepy nor alert,” see appendix for full nine point scale) and was higher prior to sleep than following.

G-5bi. KSS On board

For the first seven days on board the vessel, sleepiness prior to sleep was higher for the morning sleep periods than it was for the evening sleep periods (p<0.001). This difference is likely a reflection of the time-of-day since the sleepiness levels at this time would have been reported between about 11:30pm-6:30am when the circadian alerting signal is low. There was
also a trend for a similar difference for the level of sleepiness following the sleep period (p=0.07) (Figure 13).

**Figure 13.** Graphic representation of daily sleepiness level from the KSS prior to and following sleep for crews while on the vessel and while at home (n=133).

There was a trend (p=0.07) for the level of sleepiness for the back watch to be slightly higher following the sleep period compared to front watch crews (Figure 14).
**Figure 14.** Graphic representation of daily sleepiness level from the KSS prior to and following sleep for front watch (n=84) and back watch crews while on the vessel (n=48). † p=0.07

_G-5bii. KSS On board compared to at home_

Sleepiness was also assessed at home in comparison to on board the vessel for the 24-hour day (Figure 15). On average, both front watch (p=0.001) and back watch (p=0.03) crews were slightly more sleepy prior to sleep at home than when on the vessel but had similar levels of sleepiness after sleep. This difference prior to sleep is likely the result of the differences in time awake at home compared to on the vessel, since crews typically reported only one sleep period a day at home and two sleep periods a day while on the vessel.
Figure 15. Graphic representation of daily sleepiness level from the KSS prior to and following sleep for front watch (n=67) and back watch (n=37) crews while on the vessel and at home. * p=0.03, **p=0.001
G-5c. Sleepiness Summary

On average, there does not seem to be excessive sleepiness reported. As would be expected, sleeping reduces the level of sleepiness. Analysis was conducted to determine whether sleepiness levels at either bedtime or after waking were associated with time in bed, and on average, there was no significant association. Further analysis of this data is necessary to determine whether there is day-to-day variability that falls into the range of excessive sleepiness, and if so, how often and what conditions could explain the sleepiness.

The differences observed between sleepiness during the morning versus evening sleep periods and between sleepiness prior to sleep at home and on the vessel can be explained by circadian (time of day/circadian clock) and homeostatic (how long have you been awake) regulation of sleepiness. It is normal to be sleepier during the biological night compared to the biological day regardless of how long you have been awake, hence this difference between the morning and evening reporting periods. Crews may be reporting more sleepiness at home since they only report one sleep period per day, which means they have been awake for a longer period of time when they go to bed.

G-6. Other individual factors that may impact sleep

Crews completed the Standard Shiftwork Index (SSI), a questionnaire with hundreds of questions related to sleep, work, coping, circadian preference and health. Below in figures 16-18, we report the findings of some of the key questions in the SSI relating to health behaviors, sleep, sleep inertia and alertness. We have not been able to explore these findings fully at this time, but there does appear to be differences in some measures between front watch and back watch crews. Areas yet to be explored include general health, medical conditions and medications that may impact sleep and wakefulness, as well as circadian preference, mood and anxiety.

G-6a. Health behaviors

Crewmembers were asked to report the number of caffeinated and alcoholic beverages they consumed and the number of cigarettes smoked per day while on board the vessel and while at home (Figure 16). Stimulants, such as caffeine and cigarettes, are often used as a way to combat fatigue; the mean number of caffeinated beverages and cigarettes per day is presented in figure 16. The average number of caffeinated beverages per day was not excessively high, although given the standard deviation, there are some crewmembers who are consuming large quantities of caffeine on a daily basis. Further examination of the caffeine consumed prior to each sleep period or per day from the sleep diaries is required. Due to coding issues (crews
used different ways of reporting the units of caffeinated beverages), we have been unable to report these numbers from the sleep diaries at this time.

People consume alcohol for many reasons, but for the purposes of this study, we are interested in alcohol consumption since some people use alcohol as a way to help them fall asleep. Also, excessive alcohol use and consumption too close to bed time can result in disruption to sleep. While alcohol is banned from vessels, it appears that seven respondents reported consuming between 1-3 alcoholic beverages per day while on the vessel. We also asked crews whether or not they had consumed alcohol for every sleep period, and while on the vessel, no crew reported consuming alcohol. Given the difference between reporting methods, it is possible that the seven respondents for the questions from the SSI incorrectly reported alcohol consumption.

![Health Behaviours](chart.png)

**Figure 16.** Mean ± standard deviation of health related behaviors at home and on board for all crew (n=121).

**G-6b. Coping with organizational factors**

Crews were asked, “In general, to what extent does working shifts cause you problems with” different aspects of their work or personal life. They were also asked, “To what extent DO YOU THINK there are ORGANIZATIONAL problems at your work (e.g., the way your work is organized, staffing is arranged, or management decisions are implemented)?” and whether they have difficulty coping with these problems. On average, these factors did not seem to adversely impact the crew, however, further analysis of these factors in relation to sleep should be conducted since there is a large variation in responses to these questions.
Coping with shift schedule and organizational issues

![Bar chart showing the ability to cope with shift schedule and organizational problems for all crew (n=121).](image)

**Figure 17.** Mean ± standard deviation of ability to cope with shift schedule and organizational problems for all crew (n=121).

**G-6c. Sleep related factors**

In question 6.2 of the SSI, crews were asked about 30 questions related to sleep, sleep inertia and alertness. How the crewmembers responded to these questions could be an important predictor of how they sleep and how they feel if their sleep is disrupted or too short.
Figure 18. Mean ± standard deviation of Standard Shiftwork Index responses to questions related to sleep, sleep inertia and alertness. Responses are on a scale from 1-5 with 1 = almost never to 5 = almost always.
H. Future Plans

The data we have collected in Phases II and III when on board towing vessels as well as the survey data collected online in Phase IV from a large number of crew members represents a rich unprecedented set of data that is expected to lead to three to four full-length publications (we have already presented some of the results at scientific meetings and in abstract form). In addition, we believe these data now represent a foundation of knowledge that can be used to develop intervention strategies and a plan for the development of a scientifically based Fatigue Management Plan and System for the towing vessel industry. In considering our future plans, in this section, we outline H-1) our plans for preparing the results for publication, H-2) our plans for a more extensive analysis (data mining) of the large datasets we now have access to, H-3) possible Phase IVa studies that could continue our efforts to collect data from the ~150 crewmembers who were fully engaged in the Phase IV study and H-4) what steps could be taken to take our present results to the next level and move us from collecting data from crewmembers to intervention and fatigue management levels. Possible funding opportunities for future studies are presented in H-5.

H-1. Publications

H-1a. Phase II and III results.

A manuscript in draft form has gone through a number of in-house revisions, and we hope to submit for publication a manuscript describing the results of our onboard studies by the end of June 2012.

H-1b. Phase IV results

Dr. Reid is in the process of contacting all the participating crewmembers who did not initially provide information on age, height, weight and gender during the data collection period. This will allow us to complete more detailed analysis controlling for age and body mass index, for example. These data will then be integrated into the final data set for all future analysis and for publication. At the present time, we are considering reporting sleep and health in wheelhouse crewmembers based on our survey data. The two tentative titles of these papers are:

1) Sleep of wheelhouse captains and pilots during a 24-hour bi-phasic work/rest schedule and at home in American Waterways Operators

2) Health predictors for poor sleep quality in American Waterways Operators
H-2. In-depth extensive (data mining) analysis of Phase IV survey data

Funding for the Phase IV studies allowed us to collect an enormous amount of data. While Drs. Reid and Turek will now be able to use the tables and figures in this Phase IV final report for reporting our initial results in the scientific literature, further funding (see H-5) would allow for a much more extensive analysis. For example, we are now in a position to go back into the data to determine if sleep time or quality relate to BMI or age of the captains and pilots. The current report outlines just a small portion of the data collected as part of this study of captains and pilots on American waterways.

In a sense, we have just scratched the surface of the data we only finished collecting in February 2012, and there is now an opportunity to hire statisticians and large dataset analysts to probe our unprecedented dataset.

H-3. Extension of Phase IV studies

We have information on sleep, fatigue, health and age on 163 captains and pilots who participated to one degree or another in the Phase IV studies, and we are in a position to reconnect with these wheelhouse crewmembers for follow-up studies to determine if the educational materials and/or just participating in the Phase IV studies made the crewmembers more cognizant of the importance of obtaining sufficient sleep for health and performance and to manage their fatigue. Such information could be valuable for determining factors that could be incorporated into a Fatigue Management System and for the development of Fatigue Management Systems for the towing vessel industry.

H-4. Development of a Fatigue Management System

Again, depending on funding levels, a number of steps could be taken to develop a plan that in 3-5 years would lead to a comprehensive scientifically based Fatigue Management System for all the members of the AWO. Such a plan would have as a goal for the AWO to be “out-front” of the regulators in developing a Fatigue Management System and could include, but not be limited to:

1. Holding a two-day workshop with the leading scientists in the US who work in the area of sleep management, as well as health and safety officers of AWO companies and perhaps members of the Coast Guard. A major objective of such a workshop would be to come to a consensus on a 3-5 year Fatigue Management Plan that would involve research studies, development of countermeasures and individual fatigue and
performance profiles that could increase safety and performance as well as the health of crews.

2. Renewed attempts to measure how interventions affect actual performance in a real-world setting or in studies involving high-fidelity simulators. Such studies, would be particularly useful and important in comparing the effects on fatigue and performance for crews on different 2-watch schedules such as 6 on:6 off:6on:6 off vs. 7 on:5 off:5 on:7 off vs. 8 on: 4 off: 4on: 8 off. To date no such comparisons have been made in either real on board or simulated studies. A recent and in depth study (The European HORIZON Project) using simulators to compare the effects of different schedules on fatigue and performance in mariners only compared a 2-watch vs. 3-watch schedule.

3. The implementation of a new industry-wide wellness program to combat the high levels of obesity (and presumably sleep apnea and associated cardiometabolic diseases) found in the maritime industry.

4. Studies to determine if new technologies are feasible for use in the maritime industry that would allow individual crewmembers to track their own levels of fatigue and sleep habits in an attempt to change the culture in the maritime industry when obtaining sufficient sleep and making good health become as much a part of the everyday concerns of each mariner about their sleep and levels of fatigue as has occurred with issues surrounding safety. An example of such a new technology is a new portable, easy-to-use sleep- (EEG measurement) recording device made by Zeo. One of the latest versions of this device costs about $100 and can be used with an iPhone. It provides a great deal of information about the quantity and quality of one’s sleep, and there is evidence it is a motivational tool for making the obtainment of quality sufficient sleep time a high priority in the same way that blood glucose tracking devices motivate a large percentage of diabetics and even pre-diabetics (i.e., individuals showing signs of insulin resistance) to closely monitor and control their blood glucose levels in order to prevent or control their diabetic condition. Another analogous tracking device to the Zeo sleep tracking one is the small pedometers that can be worn to track the number of steps one takes on a daily basis. Such devices have proven effective in motivating users to “move it.” The major point being made in this section is not to recommend a specific device in approach to tracking sleep, but rather it is important to begin to look for novel ways to engage the individual mariner in ways that will make their interest and participating an integral part to any AWO Fatigue Management System.
H-5. Future External Funding Opportunities

While further funding from the AWO and/or individual towing vessel companies could be used for future studies and in the development and implementation of a comprehensive scientifically based AWO Fatigue Management System, in this section, we describe two different opportunities to obtain external funding for future studies and plans to combat fatigue and adverse health due to insufficient sleep among mariners in the towing industry.

H-5a. National Cooperative Freight Research Program (NCFRP)

With the support of the AWO, the team at Northwestern submitted a proposed “Problem Statement” to the National Cooperative Freight Research Program (NCFRP) in August 2011. While this proposal has been approved for funding by the NCFRP, Congress has yet to pass a new Transportation Bill for over two years, so it is not clear if funds will ever become available. If funded, this NCFRP study would allow the Northwestern team to mine the unprecedented amount of real-world data we have obtained on the sleep habits and measures of fatigue in wheelhouse crewmembers in our Phase IV studies. In particular, the aims of the NCFRP study are:

- Assess whether there were any changes in behavior in crewmembers following their participation and their receiving educational material in our Phase IV survey study.
- Implement recommendations for how best to use an anchor sleep/nap strategy for crews working split-shift schedules.

The data collected from this study would be assessed in combination with data from the Phase IV study in order to determine whether there has been any change in behavior. It will also allow us to identify and categorize those who have and those who have not changed behavior and to what degree. By identifying these groups of individuals it will be possible to tailor future programs for intervention. This approach could provide a model for other industries facing similar challenges.

H-5b. Other external funding opportunities

There are a number of federal agencies that support research related to fatigue in the workplace. Our plan is to prepare new proposal to agencies such as NIOSH. However, it should be noted that funding from such efforts usually begins 9-12 months after submission if the application is successful. Thus realistically, it is unlikely that new external funding from federal agencies (except for the NCFRP proposal if the Transportation Bill is passed) would be awarded until at least 15-18 months from now.
I. References


Appendix A

Educational Materials Brochure and Booklet
Appendix B

Study Tools

1. Sleep/Work Diary (On Vessel)
2. Sleep Diary (At Home)
3. Berlin questionnaire
4. Modified Pittsburgh sleep quality index (At Home)
5. Pittsburgh sleep quality index (On Vessel)
6. Epworth sleepiness scale
7. Standard shift work index