Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

MAR 29 2006

The Honorable Richard B. Cheney
President
United States Senate
Washington, DC 20510

Dear Mr. President:

Section 409 of the Coast Guard Authorization Act of 2004 (P.L. 108-293) directed the Coast Guard to report on the results of a demonstration project involving the implementation of the Crew Endurance Management System (CEMS) on towing vessels. The enclosed report also includes a description of the public and private sector resources needed to implement the CEMS on all U.S. flag-towing vessels.

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I appreciate your interest in the Department of Homeland Security, and I look forward to working with you on future homeland security issues. If I may be of further assistance, please contact the Office of Legislative and Intergovernmental Affairs at (202) 205-4412.

Sincerely,

Pamela J. Turner
Assistant Secretary for Legislative and Intergovernmental Affairs

Enclosure

Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

MAR 29 2006

Homeland Security

The Honorable Ted Stevens
Chairman
Committee on Commerce,
Science & Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

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MAR 2 9 2006

Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

The Honorable Daniel K. Inouye
Co-Chairman
Committer on Commerce,
Science & Transportation
United States Senate
Washington, DC 20510

Dear Senator Inouye:

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Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

MAR 29 2006

Homeland Security

The Honorable Harry Reid
Minority Leader
United States Senate
Washington, DC 20510

Dear Mr. Leader:

Section 409 of the Coast Guard Authorization Act of 2004 (P.L. 108-293) directed the Coast Guard to report on the results of a demonstration project involving the implementation of the Crew Endurance Management System (CEMS) on towing vessels. The enclosed report also includes a description of the public and private sector resources needed to implement the CEMS on all U.S. flag-towing vessels.

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Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

MAR 2 9 2006

Homeland Security

The Honorable Bill Frist
Majority Leader
United States Senate
Washington, DC 20510

Dear Mr. Leader:

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MAR 2 9 2006

Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

The Honorable Don Young
Chairman
Committee on Transportation
And Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Section 409 of the Coast Guard Authorization Act of 2004 (P.L. 108-293) directed the Coast Guard to report on the results of a demonstration project involving the implementation of the Crew Endurance Management System (CEMS) on towing vessels. The enclosed report also includes a description of the public and private sector resources needed to implement the CEMS on all U.S. flag-towing vessels.

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Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

The Honorable James Oberstar
Ranking Member
Committer on Transportation,
and Infrastructure
U. S. House of Representatives
Washington, DC 20515

Dear Representative Oberstar:

Section 409 of the Coast Guard Authorization Act of 2004 (P.L. 108-293) directed the Coast Guard to report on the results of a demonstration project involving the implementation of the Crew Endurance Management System (CEMS) on towing vessels. The enclosed report also includes a description of the public and private sector resources needed to implement the CEMS on all U.S. flag-towing vessels.

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Office of Legislative Affairs
U.S. Department of Homeland Security
Washington, DC 20528

MAR 2 9 2006

Homeland Security

The Honorable Nancy Pelosi
Minority Leader
U.S. House of Representatives
Washington, DC 20515

Dear Leader Pelosi:

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U.S. Department of Homeland Security
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Homeland Security

MAR 2 9 2006

The Honorable J. Dennis Hastert
Speaker
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Speaker:

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U. S. DEPARTMENT OF HOMELAND SECURITY

UNITED STATES COAST GUARD

REPORT ON DEMONSTRATION PROJECT:

IMPLEMENTING THE CREW ENDURANCE MANAGEMENT SYSTEM (CEMS) ON TOWING VESSELS

U.S. DEPARTMENT OF HOMELAND SECURITY

UNITED STATES COAST GUARD

REPORT ON DEMONSTRATION PROJECT:

IMPLEMENTING THE CREW ENDURANCE MANAGEMENT SYSTEM (CEMS) ON TOWING VESSELS

December 2005

EXECUTIVE SUMMARY

This report responds to a requirement in Section 409 of the Coast Guard Authorization Act of 2004 (P.L. 108-293), in which Congress directed the Coast Guard to report on the results of a demonstration project involving the implementation of the Crew Endurance Management System (CEMS) on towing vessels. The report also includes a description of the public and private sector resources needed to implement the CEMS on all U. S. flag-towing vessels.

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Traditionally, regulators in the transportation sector have addressed fatigue through hours of service or manning requirements. These regulations form an important part of our overall strategy to address fatigue. However, fatigue-related accidents have continued to occur because prescriptive regulations alone do not address the interrelated human factors that contribute to fatigue. Marine operators are exposed to a variety of operational risk factors, such as irregular work hours, extreme temperatures, heavy workloads, and extended separation from family members. In response to this situation, the Coast Guard has developed the CEMS, a set of tools and practices maritime operators can use to manage productivity and safety levels in their operations.

Through our Prevention Through People partnership, the Coast Guard and American Waterways Operators (AWO) chartered a working group to develop a plan to facilitate widespread implementation of Crew Endurance Management throughout the barge and towing industry. This plan included a demonstration project. Demonstration project participants included peers from various segments of the towing industry who would help build a solid understanding of CEMS principles by implementing CEMS themselves.

The purpose of the demonstration project was to show that CEMS is feasible, effective, and sustainable. Previous clinical and scientific analysis by the Coast Guard Research & Development Center has already proven that CEMS is effective in improving crewmembers' endurance. This demonstration project focused on how well companies and crewmembers were able to implement CEMS, and the real-world impact CEMS had upon the crew's energy, alertness, and ability to cope with endurance-related risk factors.

Although the demonstration project had participation from companies representing each of the three major towing segments (inland, coastal, and harbor), the available sample size of vessels was relatively small. Further, some of the data gathered is based upon surveys and subjective personal evaluation. Therefore, care should be taken when attempting to generalize these results. The results, however, show some very clear trends that accurately reflect the effectiveness, feasibility, and sustainability of CEMS.

The results of the demonstration project show that, when properly practiced, CEMS is effective in reducing fatigue-related risks. The demonstration project results indicate that companies and vessels that followed CEMS practices achieved measurable reductions in all fatigue-related risk factors. Companies that deviated from established CEMS practices (for example, by not having a certified CEMS Coach or acceptable alternative[i] on each vessel) were not able to demonstrate the same success.

Participant companies also demonstrated that CEMS is feasible to practice. Companies were able to implement many critical aspects of CEMS in a very short time. Most of the participating companies increased the number of onboard CEMS Coaches and provided CEMS training to the majority of their crewmembers. They made numerous improvements to the physical work and rest environments onboard their vessels. Companies also implemented significant policy changes and, in some cases, changed to an improved watch schedule. The fact that vessel crews and companies made these changes entirely on their own demonstrates the feasibility of CEMS in practical use by the towing industry.

To further illustrate this point, many participating companies extended the practice of CEMS to other vessels in their fleets. As seen in Figure 51 on page 66, CEMS was initially implemented on 59 vessels. Just six months later, the demonstration project companies expanded this number to 419 vessels. While it should be noted that each vessel's degree of implementation varies, these figures serve as an example of CEMS' exponential growth among not only the companies in this report, but companies *outside* the demonstration project, as well.

As indicated by these results and the Coast Guard's experience, CEMS also appears to be sustainable, something which the maritime community can support for the long term. First, CEMS Coaches Training is widely available, and the number of trained coaches industry-wide continues to expand. This has been made possible by a growing number of maritime training institutions and operating companies that have been accepted to train their own CEMS Coaches.

Second, despite normal employee rotation and turnover, companies in the demonstration project were able to increase the number of crewmembers trained in CEMS. While expending crew time for CEMS training is an investment, it is one that is manageable and sustainable.

Third, and most importantly, the continuous improvement nature of CEMS makes the process inherently sustainable. Companies in the demonstration project made numerous physical and policy changes, some of which were costly, many of which were not.

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[i] Anywhere the term "coach" is used in this document, it is meant as a trained Crew Endurance Coach or acceptable alternative. An acceptable alternative is someone who is capable of providing the onboard support, training, and CEMS expertise that a certified Coach would provide.

Companies identified their operation's highest risk factors and focused their investment of time and capital on those actions which produced the greatest overall reduction in risk. The companies were also able to time these actions so as to minimize undesirable impact to normal operations. Moreover, the companies that participated in the demonstration project show an interest in continuing CEMS implementation for the long-term.

While CEMS can require a substantial investment in resources by the public and private sector, this cost is manageable. Time and costs for a CEMS Coach and crew training were reported as some of the more significant private sector costs for CEMS. Each company that applied CEMS well found a way to train their crews that worked for them, both fiscally and culturally. The companies also demonstrated that physical changes and policy improvements do not necessarily have to be costly. Again, the continuous-improvement process of CEMS allowed companies to make changes that resulted in the greatest overall reduction in endurance-related risk, generally at the least cost.

CEMS was developed as a voluntary program as part of a joint industry-government partnership. Accordingly, it was carefully developed to minimize overhead for both parties. The Coast Guard's current management of the CEMS program leverages significant industry cooperation and third-party commercial ventures. Nevertheless, as this program expands throughout towing and other maritime transportation industries, we fully expect an increase in the public resources needed to oversee this program. Full implementation across the towing industry would require additional Coast Guard staff to manage the effort. The Coast Guard is including this information in its consideration of requirements for a "safety management system appropriate for the characteristics, methods of operation, and nature of service of towing vessels," as provided by Section 415 of the Coast Guard and Maritime Transportation Act of 2004 (P.L. 108-293).

Finally, the benefits of CEMS outweigh the costs. There are multiple benefits, most notably a decrease in the risk of accidents. However, CEMS can also help companies retain staff and keep employees healthy. Healthy employees have fewer sick days, perform better, and are able to stay working with the company longer. These are powerful motivators for companies facing a shortage of qualified crewmembers.

As shown by the results in this report, CEMS is effective, feasible, and sustainable. The Coast Guard believes that if towing vessel crewmembers and their companies implement CEMS, over time, the crew will become increasingly more alert and will make better decisions. Ultimately, fewer accidents may occur. These same practices and principles apply towards any maritime transportation operation. Accordingly, the Coast Guard recommends that all commercial vessels implement CEMS to reduce the risk of fatigue and endurance-related accidents.

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

Fatigue Happens

Fatigue is an issue for any 24-hour industry. Despite the use of lighting and other modern technology, the human body has a primal tendency to rise and set with the sun, according to its "circadian rhythm."[1, 2] For most species, disturbance of the circadian rhythm is physically disruptive.[3] If workers have not adjusted or "entrained" their bodies to a new sleep cycle, it can be dangerous to try to work feeling fatigued and disoriented. [4] [5] Once at work, they may stay awake, but not be able to think clearly, stay alert, or perform well. Worse yet, they may even fall asleep.[6] [7]

In the maritime industry, vessels have operated 24 hours a day, seven days a week since the days of the first ocean voyages. There are no rest stops on the open ocean. Even during the 18th century, the heyday of wooden ships and iron men, mariners were aware of fatigue issues. Legendary mariners like Captain James Cook and Captain William Bligh expressed concern regarding watch scheduling, crew rest, and diet.[8] Such concern continues today: in two separate studies, maritime operators cited fatigue as their number one concern.[9] In addition to experiencing shortened, interrupted sleep, mariners are exposed to many other operational risk factors. Elements such as extreme temperatures, separation from loved ones, and heavy workloads can also have negative impacts on productivity and safety.

Though towing vessels generally work closer to shore, the crews of these vessels are exposed to the same operational risk factors. By law, only a licensed crewmember is permitted to stand at the helm of a towing vessel.[10] Most towing vessels have two licensed operators who trade shifts throughout the day. The most common shift schedule is six hours on duty, and six hours off. Some harbor towing operations schedule twelve hours on duty, and twelve hours off. Whatever the schedule, operators must balance their duties in the wheelhouse with getting enough rest.

Fatigue Contributes to Accidents

Fatigue is a major contributing factor to casualties in all industries. In recent studies, researchers discovered that 25-75% of night workers experience sleepiness on every night shift, [11, 12] and half of night workers experience some kind of accident during their employment.[13] Risk of injury is 30% higher for night shift workers because alertness, performance, and metabolism all peak during the *day*.[14] These statistics are reflected repeatedly in accident reports. For example, in 1988, the cost of all sleep-related accidents, including accidents both inside and outside the workplace, was $56.02 billion, and 24,318 lives.[15] On May 16, 2005, the Federal Railroad Administration stated that fatigue was a contributing factor in a large number of human factor accidents.[16] Other experts have stated that fatigue is "the largest identifiable and preventable cause of accidents in transport operations." [17]

The maritime industry is no exception: studies indicate that fatigue contributed to 17% of U. S. marine accidents and 33% of U.S. marine injuries.[18, 19] This is not just a domestic problem. Many other countries have also concluded that fatigue threatens safety:

- In July 2004, the Marine Accident Investigation Branch in England reported that fatigued officers were the most common elements in a series of marine accidents.[20] The report explained that fatigue detracted from a watchkeeper's ability to complete duties, which, in turn, causes accidents.

- In a paper submitted to the International Maritime Organization (IMO), the Swedish Maritime Administration stated that in 2001, 87% of groundings in their waters were attributed to human factors, and the majority of accidents occurred during circadian dips.[ii] Sweden further explained that, in many cases, the operator's circumstances aboard the ship contributed to fatigue.[21]

Fatigue is More Than Falling Asleep

Fatigue contributes to accidents in many ways. In the most severe instances, vessel operators might become physically impaired or fall asleep. Fortunately, such cases are relatively rare. In the past 11 years, the Coast Guard recorded only 105 towing vessel accidents in which the level of fatigue was severe enough to be identified as an independent contributing factor. Of these, 26 were cases of acute fatigue, in which the operator fell asleep.[22] [iii]

Fatigue's more common, insidious contribution to accidents is that it impairs critical thought processes such as situational awareness, situational assessment, and decision-making. Accordingly, the Department of Transportation (DOT) has defined fatigue as "the degradation of human performance, the slowing down of … reflexes, and/or the impairment of the ability to make rational judgment…" The DOT definition goes on to include the causes of fatigue.[23] Similarly, the International Maritime Organization (IMO) states that fatigue impairs the ability to concentrate, the ability to make sound decisions, response time, and memory.[24]

According to the National Sleep Foundation, those who feel tired, fatigued, or otherwise not "up to par" are more likely to make errors at work at least once in a three-month period. [25] When long work hours cause fatigue, people's hand-eye coordination can deteriorate to the same degree as if their blood alcohol levels were .05 percent. [26, 27] Just

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[ii] Resulting from circadian rhythms, a low point in the normal daily rhythm (cycle) of body energy and wakefulness.

[iii] Gathering information to support a defendable determination that fatigue contributed to a casualty is resource-intensive and time-consuming. Accordingly, this kind of investigation was limited to casualties with more serious consequences or where there were strong indications that fatigue had a major contribution. Therefore, consistent with findings by other researchers, it is likely that there are many more instances where fatigue contributed to the cause of a casualty, albeit indirectly.

two hours of sleep loss has been shown to reduce Navy recruit test scores.[28] Fatigue was also found to impair the performance of some naval tactical aviators by up to 30%.[29]

Fatigue and Situational Awareness/Assessment

According to the American Bureau of Shipping (ABS), situational assessment/awareness is the dominant factor in failures of human performance. [30] They found that poor situational assessment/awareness was closely related to fatigue and task omission, and caused 60-70% of accidents attributed to human error in the U. S. , Canada, Australia, and the United Kingdom. [31]

ABS further explained that situational assessment/awareness is "a state of knowledge that directly relates a dynamic environment to the operational target goals. Situational awareness generally involves:

- Assessment of the environment;
- Identifying and updating immediate and long term goals;
- Planning, based on goals and the environment; and
- Predicting the results of plan execution." [32]

Other experts have also explained that there are three sequential levels of failed situational awareness:

- Failure to correctly perceive information;
- Failure to correctly integrate or comprehend information; and
- Failure to project future actions or state of the systems.[33]

To perform safely, operators must constantly perceive and assess situations, integrate old and new information, and accurately predict the consequences of their plans.[34] If operators miss any of these steps or perform them incorrectly, they may cause or be unable to prevent an accident. Fatigue has been proven to adversely affect an operator's ability to perform each of these steps.

Such information is currently used to reduce the risk of fatigue-related casualties. A joint Coast Guard – American Waterways Operators working group report concluded that 78% of U.S. towing vessel bridge allisions were caused by human error and, more specifically, by operator decision making. [35] The working group understood the relationship between fatigue and the cognitive processes described above. Consequently, they recommended requiring "the implementation of the CEMS throughout the towing industry as a means of improving decision-making fitness." [36]

Regardless of whether or not the contribution of fatigue is acute (where an operator falls asleep) or more subtle (poor decisions are made), costs can soar in terms of fatalities, injuries, and property damage. And while it may not be implicated as the primary cause of casualties, fatigue has featured prominently in a number of major incidents, including the *T/V EXXON VALDEZ.* [37]

Beyond Fatigue

As the IMO's "Guidance on Fatigue Mitigation and Management" circular describes, [38] there are many factors that affect fatigue: sleep, diet, physical condition, workload, circadian cycles, exposure to bright light, and extreme temperatures, among others. These factors are all interrelated. Therefore, any attempt to reduce fatigue must be considered as part of an interrelated system.

However, "reducing" fatigue implies setting some minimum "safe" level of it. Given the complex interrelations among so many individual factors, our extremely complicated human physiology, the competitive demands of maritime operations, and ever-changing world events, trying to establish some sort of "acceptable" limit would prove fruitless.

Instead, the Coast Guard Research and Development (R&D) Center focused on Crew Endurance: the ability to maintain performance within safety limits while enduring job-related physical, psychological, and environmental challenges. Rather than just reducing fatigue, operators manage endurance using the CEMS. This positive approach allows a company to improve safety and productivity while still accomplishing a primary mission.

II. THE SOLUTION

Traditionally, regulators have always dealt with fatigue issues through hours-of-service and manning regulations. Licensed masters and mates of most towing vessels are limited to twelve hours of service in any consecutive 24-hour period, as required by law. [39] More recently, IMO established requirements for minimum hours of rest as part of its Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code.[40] The IMO rules, which 46 CFR 15.1109 incorporated into domestic regulation, do not apply to most towing vessels.

While existing legislation and regulations form an essential foundation for protecting mariners and preventing casualties, they are not singularly able to address some of the cultural and systemic issues that cause fatigue. For example, even if crewmembers only work within time limits set by regulations, they may still be unable to sleep if their rest periods come at times when their bodies are used to being awake. Therefore, accidents may still occur because the regulations, by themselves, do not serve to prevent crewmember fatigue. CEMS is designed to address such cultural and systemic issues by addressing multiple factors simultaneously.

Scholars often reference similar versions of the belief that "there is no magic bullet to eliminate human fatigue in transportation operations …" [41] Instead, companies and their operators must educate, address scheduling, use countermeasures, and develop programs "to identify the signs of sleep-related error in vehicle operation and on the job, particularly in industries that have a responsibility to minimize accidents and error for the sake of public health and safety." [42]

Rather than promising a "magic bullet," CEMS is a systematic implementation process that addresses endurance holistically. CEMS is a formal program of proven practices that optimizes crew productivity and safety by managing a crew's period of lowest energy and alertness (their "Red Zone"[iv]) as well as its endurance risk factors. The implementation process is a basic, continuous-improvement cycle that enables an operation to address its relevant endurance risk factors incrementally.

The CEMS Process

The CEMS process is described in detail in *Crew Endurance Management Practices: A Guide for Maritime Operations* (Enclosure 1), its Addendum (Enclosure 2), and in a pamphlet entitled "Crew Endurance Management: The System" (Enclosure 3). However, a basic overview of the process is shown in Figure 1 on the next page.

[iv] Hereafter, the report may refer to the "Red Zone." This is the daily period of lowest energy and alertness, normally occurring between bedtime and sunrise.

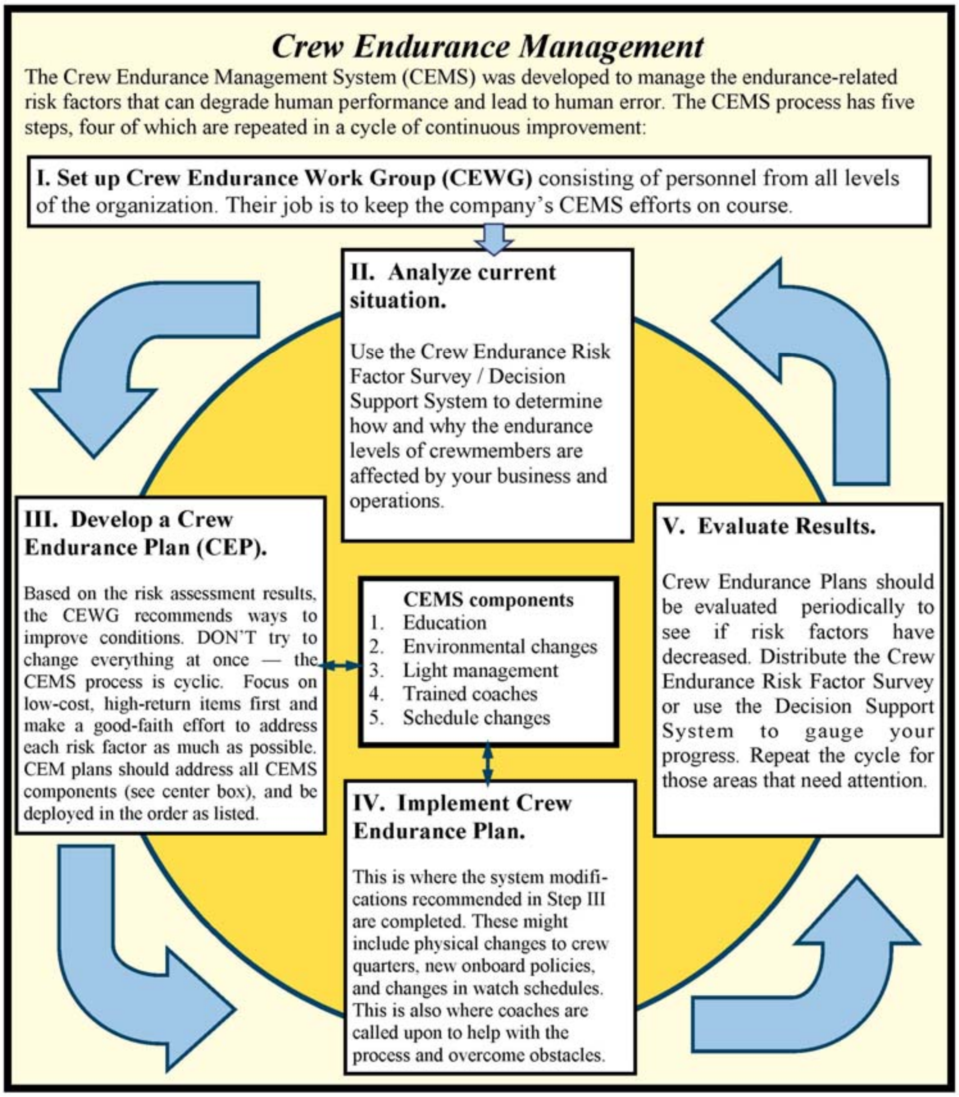


Figure 1. CEMS process diagram.

The implementing organization first forms a working group (Step 1 in Figure 1) that represents all levels of the company, from managers to crewmembers. Next, this working group assesses the risk factors known to affect crew endurance (Step 2). CEMS considers 15 endurance risk factor categories covering five general areas: sleep, work schedule/circadian rhythm, physical condition, work environment, and personal stressors. The working group then develops a Crew Endurance Plan, or CEP (Step 3), to address the risk factors they have identified as those most promising to reduce overall risk. After the CEP has been implemented (Step 4), the working group evaluates the results (Step 5), reassesses the risk factors, and the cycle continues towards a new round of improvement.

The Crew Endurance Plan includes five key components. With the exception of trained coaches, these components should be implemented in the same general order as listed below in order to create a successful system that will support the more difficult changes.

Education

Vessel crewmembers and other company employees learn about risk factors related to endurance, and then are encouraged to use recommended countermeasures, as well as finding their own countermeasures. They also learn about good sleep habits, the body's circadian rhythm and the "Red Zone," the effects of diet on sleep and energy levels, the importance of exercise, the effects of stress, and all other elements outlined in the CEMS Guide for Maritime Operations and its addendum.

Environmental Changes

The vessel company and crew make changes to the working and sleeping environments based on recommendations of the Crew Endurance Working Group (CWEG). Generally, these recommendations focus on achieving the greatest reduction in risk for the least cost. Some recommendations, such as implementing courtesy policies to respect the needs of sleeping crewmates, cost nothing at all.

Light Management

At its most basic, light management is about using ocular light input to keep the body awake and alert during watch, and avoiding the same input to help it fall asleep afterwards. Light management is the primary tool for shifting people's biological clocks so that their alertness peaks during work periods and their lowest energy levels occur during rest periods.

To practice light management, crewmembers are exposed to bright lights of 1000 lux for short periods of time throughout their shifts. Medical experts have discovered that, because sunlight suppresses melatonin production, exposure to lights of 1000 lux [43] or higher [44, 45] at a single pulse throughout the day, [46, 47] or up to three hours during the subjective circadian peak, [48] sufficiently signals the body to stay alert. [49, 50, 51] Bright light exposure has also been shown to help night shift workers make an effective circadian cycle shift from being day- oriented to night-oriented, [52, 53] while staying away from bright light at the proper times helped them to sleep during the day. [54] Because the medical advice is very specific as to when and how these lights should be used, the Coast Guard recommends that knowledgeable CEMS coaches discuss the use of light with crews.

To help night shift operators avoid light-induced circadian disruption during off-duty hours, towing vessel companies may also tint windows, install shutters, or otherwise keep sunlight from penetrating into sleeping quarters.

Light management needs support, such as that provided by the holistic CEMS process, to succeed. A recent study of night shift workers found that the use of light alone was insufficient to induce consistent circadian phase shifts, and that other adaptations should also be made, such as keeping a fixed wake/sleep schedule. [55]

Coach (or Acceptable Alternative)

As part of the continuous improvement process, each vessel should have a trained CEMS coach or acceptable alternative. Such coaches model good endurance management practices through their own personal behaviors, actively encourage crewmembers to follow these practices themselves, and monitor and reinforce adherence to the Crew Endurance Plan. Coaches also provide information to crewmembers on the science behind CEMS, including diet, exercise, caffeine use, environmental stressors, psychological conditions, sleep, and body clock management.

Schedule Changes

In this last step, watch schedules are changed to support proper light management and to allow crewmembers sufficient quality and quantity of sleep.

CEMS Philosophies

In order for CEMS to work, there must be "vertical alignment." Vertical alignment occurs when:

- The composition of the CEWG includes or represents varied employees who will be affected by CEMS implementation. This enables communication up and down the organization's hierarchy in the process of creating a Crew Endurance Plan;

- All members understand CEMS and are able to identify and mitigate their fleet/vessel's endurance risk factors;

- All members at all levels of the organization "buy into" CEMS, thus enabling progress; and

- Communication exists among all levels and members of the CEWG. It is important for crewmembers to communicate their experiences with daily risks up through the ranks. It is equally important for those at the upper levels of management to understand how important such risks are, and weigh how important it may be to fund or otherwise support CEMS prevention efforts.

One strength of the CEMS process is that it can be tailored to meet each company's specific needs and operation. Unlike prescriptive, one-size-fits-all regulations, CEMS allows a company to prioritize which risk factors to address and to progress at a pace suitable to its operation and capabilities. Ideally, to achieve all potential benefits of CEMS, every company would advance through the entire process from beginning to end. However, CEMS can immediately result in beneficial increased awareness and understanding of endurance and fatigue issues, even if a company has just begun to implement CEMS.

When properly implemented, CEMS provides a three-way win: operating companies get safer, more productive employees, the employees get safer, healthier workplaces and a better quality of life, and the Coast Guard and general public get an overall reduction in the risk of a fatigue-induced casualty. Overcoming hundreds of years of tradition and culture is no small feat. However, as demonstrated by the towing vessels in this report, the journey itself is worthwhile.

III. THE DEMONSTRATION PROJECT

As part of the Coast Guard's Prevention Through People program, the Coast Guard and AWO have maintained an active safety partnership since 1995, collaborating on a variety of human element issues. Examples of joint initiatives include the Safe Decks Campaign, the Crew Alertness Campaign, and Crew Endurance Management.

As with other transportation operations that operate around-the-clock, both parties have long recognized that maritime crewmember fatigue must be addressed in order to reduce the risk of accidents. Over the past decade, they have steadily increased their levels of commitment towards addressing this issue. In another joint effort, several AWO member companies participated in early studies and trials of the CEMS performed by the Coast Guard R&D Center. In 2002, the Coast Guard and AWO chartered a joint working group to develop a plan to facilitate widespread implementation of CEMS throughout the barge and towing vessel industry. [56]

A primary objective of the AWO/USCG CEMS Working Group was to build a solid understanding of the program amongst all segments of the towing community. To accomplish this, the group deployed a number of efforts, including presentations to company executives, this demonstration project, and publication of pamphlets, websites, and newsletters.

The demonstration project included participants from selected segments of the inland, coastal, and harbor towing industries. Its purpose was to show that CEMS is feasible, effective, and sustainable for many different types of vessel operations, and to provide concrete examples for mariners to follow. Section 409 of the Coast Guard and Maritime Transportation Act of 2004 directed the Coast Guard to report to Congress on its results.

Seven[v] companies participated in the demonstration project: American Commercial Barge Line LLC; Blessey Marine Services, Inc.; Moran Towing Corporation; Kirby Corporation; Penn Maritime Inc.; Marathon Petroleum, LLC; and AEP RIVER OPERATIONS Barge Line. These companies provided a total of 46 vessels to participate in the project.

[v] Six of the participating companies provided both vessel and crew measures. One company provided only vessel measures.

Participant Company Profiles

American Commercial Barge Line LLC (ACBL)

ACBL is an inland towing company that manages 64 river line towing vessels on the Western Rivers and Gulf Intercoastal Waterway. ACBL is an industry leader in transporting dry cargo, including coal, grain, steel products, and bulk ores. ACBL is the second-largest transporter of liquid cargoes, transporting petroleum and chemicals throughout the inland river system in both unit and integrated tow configurations.[57] Four ACBL vessels participated in the demonstration project.

American Electric Power (AEP) River Operations

AEP River Operations is a wholly-owned subsidiary of American Electric Power, and operates river line towing vessels along most of the U.S. inland and intercoastal waterways, from the Gulf of Mexico to Canada. AEP River Operations has a fleet of over 2200 hopper barges that move grain, coal, steel, ores, and other bulk products. In 2003, AEP River Operations moved over 57 million tons of dry bulk commodities, including grain, coal, steel, and ores. [58] Two AEP River Operations vessels participated in the demonstration project.

Blessey Marine Services, Inc.

Blessey Marine Services operates 84 tank barges and 42 river line towing vessels on the Western Rivers and Gulf Intercoastal Waterway. Blessey operates one of the youngest inland barge and towing vessel fleets in the country, transporting liquid bulk cargoes such as residual fuels, asphalt, lubricating oils, petroleum feedstocks, refined petroleum products, petrochemicals, and alcohols. [59] Eight Blessey vessels participated in the demonstration project.

Kirby Corporation

Kirby operates the Nation's largest fleet of inland tank barges and towing vessels, and moves petroleum products along the Gulf Intercoastal Waterway, the Mississippi River System, the Illinois River, the Ohio River, and many other western rivers and waterways. Kirby manages 885 inland tank barges and 235 towing vessels among five fleets. [60] Ten Kirby vessels participated in the demonstration project.

Marathon Petroleum Company LLC

Marathon Petroleum is one of the largest terminal operators in the country, primarily transporting petroleum and asphalt. Marathon has 7 inland waterway towboats, 2 harbor vessels, and 170 barges operating in the Mississippi, Tennessee, Illinois, Kanawha, and Ohio Rivers. The company's roots go back as far as the 1920s. One Marathon Petroleum vessel participated in the demonstration project.

Moran Towing Corporation

Over the past 150 years, Moran has grown from a small company providing only docking to operating tugboats all along the East coast and barges along the coast, the Great Lakes, and the Gulf of Mexico. Moran operates 83 harbor tugboats and 81 barges.[61]

Ten Moran vessels participated in the demonstration project. Seven vessels from the Norfolk Naval Base provided docking assistance to naval ships, as well as general base support, moving barges, cranes, and other equipment. The other three tugs operated out of Baltimore. Moran's Maryland territory extends from the C & D Canal, approximately four hours by tug, to the north of Baltimore. It continues south of the Port of Baltimore, approximately eight hours by tug, to the Potomac River.

Penn Maritime Inc.

Penn Maritime, the largest U.S. coastal transporter of heated asphalt products, operates 19 tank barges and 14 coastal tugboats.[62] Penn Maritime operates vessels in the Northeast, New Orleans, Texas, Florida, and Puerto Rico's waterways and has the capability to operate internationally in Canadian, Mexican, and Caribbean waters. Eleven Penn Maritime vessels participated in the demonstration project.

The Demonstration Project Process

The demonstration project utilized a risk-based approach called a "change analysis." Participating companies worked through the CEMS process and periodically reported on implementation progress and changes in levels of endurance-related risks. To quantify some of the CEMS-induced changes, we gathered baseline measures for each company in January 2005, then compared them to a final set of measures taken in July 2005.

Demonstrating the effectiveness of any endurance or fatigue management program is challenging. Ideally, we would like to demonstrate a clear-cut reduction in accidents. However, given the generally low accident rate among towing vessels, the small sample size of the vessels in the project, the short time period considered, and contributions of other factors besides fatigue, such analysis would be futile. Instead, the project measured changes in individual endurance risk factor levels. These risk factors, developed by the Coast Guard R&D Center, were used as part of the CEMS risk assessment process. Each risk factor is described in detail in Section IV.

To demonstrate the feasibility of CEMS, we gathered information on how quickly and well organizations were able to progress with its implementation. Given the relatively short six-month time period between the two sets of measurements gathered, we did not expect to see complete, beginning-to-end implementation. Instead, we were able to assess progress for companies in different stages of the process, from those who had already begun practicing CEMS well before the project, to those who only began shortly afterwards.

To measure the program's sustainability, we gathered information on the public and private resources companies needed to implement CEMS. These included training and implementation costs, investments of time by vessel crews and managers, necessary infrastructure (such as training schools), and governmental oversight. We also considered each company's ability to continue to practice CEMS after the first round of implementation effort, taking into account crew rotation, employee turnover, and other factors.

IV. MEASURES OF EFFECTIVENESS: INDIVIDUAL RISK FACTOR RESULTS

As previously described, the Coast Guard CEMS program manages risk factors that affect endurance. It considers 15 risk factor categories which fall under five general areas: sleep, work schedule/circadian rhythm, physical condition, work environment, and personal stressors. [vi] While the consideration of endurance risk factors is unique to CEMS, the factors themselves are well-established within the scientific and medical communities as indicators of fatigue. In this section, each factor, as well as its assessment, is described and followed by its measurements "before CEMS" and "after CEMS." There is also an analysis at the end of each of the five general areas to explain the meaning of the results.

1. Sleep

Sleep Duration

Medical research indicates that the average person needs eight hours of uninterrupted sleep per night, or one hour of rest per two hours awake.[63, 64] A lack of sleep can be devastating to performance.[65] Studies have shown that sleeping less than six hours a night impairs cognitive ability [66, 67] and performance enough to cause performance deficits. [68] This is because sleep deprivation causes:

- Daytime drowsiness;[69]
- Feeling overwhelmed, indecisive, and lacking motivation;[70]

[vi] This can be found on page 35 of the addendum to *Crew Endurance Management Practices: A Guide for Maritime Operations* (Enclosure 2).

- An unconscious slipping into brief or long episodes of sleep, reduced ability to handle complex tasks, and reduction in speed and ability to think logically or critically;[71] [72]
- Impaired memory;[73] and
- A reduction in motor skills and coordination.[74]

Everyone who experiences sleep deprivation, from medical personnel to airline pilots to operators and crews of towing vessels, is susceptible to these effects. In the case of towing vessels, an individual working alone may fall asleep or lose alertness. Sleep deprivation may also cause memory impairment, which in turn may cause an operator to forget a navigation route, as exemplified in some Coast Guard accident case files. Finally, such deprivation could cause crewmembers to experience a loss of coordination and motor skills, consequently impairing the ability to handle equipment.

For the purpose of the demonstration project, crewmembers were asked how many times per week they experienced insufficient daily sleep.[vii] As shown in Figure 2, the crewmembers reported that after practicing CEMS for six months, they attained sufficient hours of sleep more days per week. Only one of the seven companies, Company D, netted an increase in insufficient daily sleep.

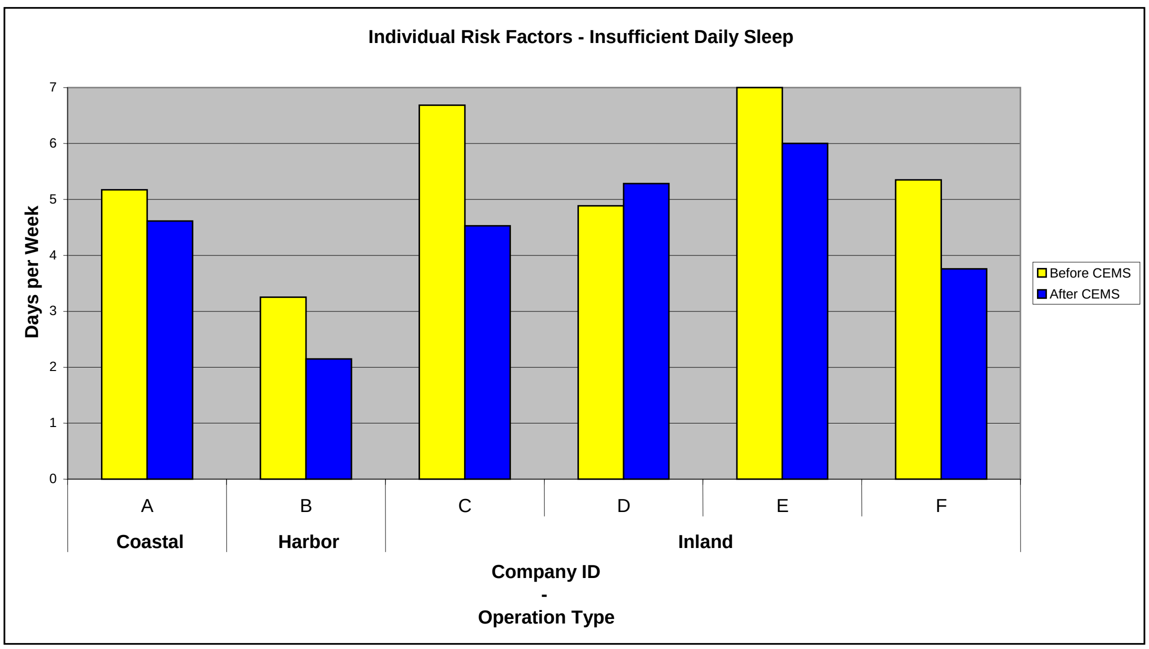


Figure 2. Individual risk factors – insufficient daily sleep.

[vii] Less than 7-8 hours of uninterrupted sleep in a 24-hour period.

Sleep Quality (Unintentionally Disturbed)

As stated in the last section, the average person needs 7-8 hours of "uninterrupted sleep" per night. "Uninterrupted" sleep means sleep not interrupted by *unintentional* disturbances (such as those described in this section) or *intentional* sleep fragmentation (a situation in which crewmembers break their sleep into periods shorter than 7-8 hours, described in the next section). An evaluation of these related categories serves to better address whether unintentional or intentional forces are behind poor sleep duration.

Factors and events sometimes prevent crews from sleeping, or cause their sleep to be disrupted. Depending upon weather and sea conditions, vessels are usually subject to motions that can interfere with sleep. Vessels need to maneuver to make up a tow, pass through a lock, change direction, dock, and conduct other ordinary activities. These maneuvers may cause sudden motions that awaken sleeping crewmembers. Noise and vibration are two common causes of sleep disruption.

Noise is an environmental stimulant that activates mental and physical reactions. It can disrupt sleep no matter how low the sound level is. [75] In various studies, scientists have discovered that any noise, ranging from a neighbor's radio [76] or road traffic [77] to aircraft noise,[78, 79, 80] can affect the quality and quantity of sleep a person gets each night. Noise can also affect the ability to fall asleep,[81, 82] causing sleep loss, or it can alter one's sleep stage or depth of sleep. [83, 84] Because the main engines, generators, and machinery are loud, noise levels in sleeping areas of some towing vessels are also loud. The noise travels to all parts of the vessel and affects crewmembers' sleep, especially when a vessel is small.

Vibration is another environmental factor affecting sleep and fatigue. In extreme cases, whole-body vibrations may be strong enough to create back pain, nausea, loss of balance, motion sickness, [viii] discomfort, a change in metabolism, decreased work performance, [85] and fatigue. [86, 87, 88, 89] Because vibration has such extensive effects on performance and physical health, whole-body vibration is considered a major risk factor in many industries.[90]

Depending upon the size, design, and layout of the towing vessel, crewmembers may experience various degrees of whole-body vibration caused by the main engine and other machinery. Clearly, vibrations that are strong enough to cause pain, nausea, and ineffective performance will also impair sleep, but poor sleep can result from lesser vibrations as well.

Noise and vibration may keep people awake, keep them from advancing to a more beneficial sleep stage, or wake them up. It is especially easy to disturb sleep when people are in the early stages of sleep, when they can be easily awakened. [91] If the noise and vibrations are so strong that people cannot get beyond these early stages of sleep, they

[viii] Motion sickness is one of the many health factors that impair alertness. See later in this report for more details.

will never reach the most important sleep stage – REM sleep. [92] Moreover, when noise or vibration disrupts sleep, it has the same impact as loss of sleep, because one needs to go through all stages and depths of sleep before becoming fully rested. [93, 94] The consequences of noise or vibration-induced sleep deprivation include fatigue, bad mood, poor health, [95] poor performance,[96, 97] and interference with mental ability. [98]

For the purpose of the demonstration project, crewmembers were asked how many times per week they slept poorly because of work-related awakenings or disruptions from environmental factors such as ship motion, noise, and vibration. As seen in Figure 3, crewmembers reported they experienced overall better quality sleep since implementing CEMS. Only one company's crewmembers, Company D, experienced a poorer quality of sleep.

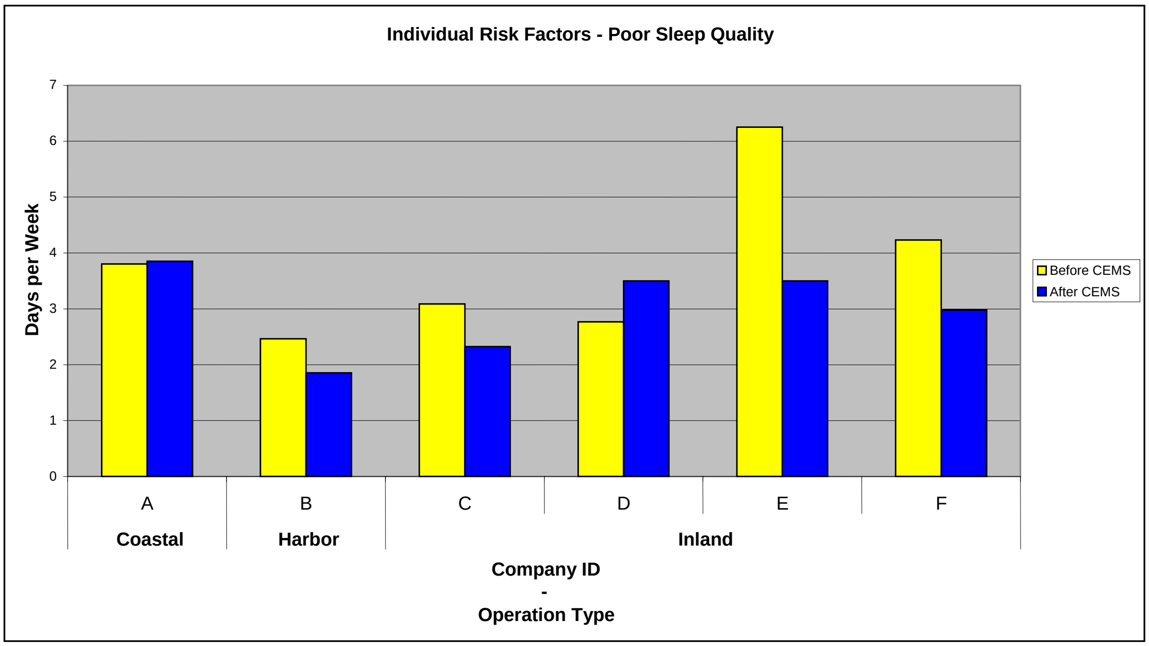


Figure 3. Individual risk factors – poor sleep quality.

Sleep Fragmentation

Sleep fragmentation occurs when an individual lacks a continuous, uninterrupted period of seven to eight hours of sleep and instead has a series of shorter sleep periods throughout the day. Though crewmembers may be able to nap off-duty to get additional sleep, this is merely a strategy for managing such fragmentation. Even if a person gets a total of seven to eight hours of sleep each day, the restorative effect of sleep is greatly diminished if that sleep is fragmented into shorter naps.

The body goes through different sleep cycles over time, and each sleep cycle serves a different purpose for our health. We start in Stage 2, the lightest level of sleep, then advance to Stages 3 and 4, which have physically restorative qualities. [99, 100] Stage 5, or REM sleep, comes last, and is most essential for preparing the mind for optimum daytime performance. REM sleep helps us with memory and concentration. However, we only get around to the longest REM cycle after the seventh hour of sleep.[101, 102] If we skip the last two hours of sleep, we won't get sufficient REM sleep. When people fragment their eight hours of sleep, they break the cycle that eventually leads them to a long REM sleep, and so fail to receive adequate rest needed to perform during the day. [103] Therefore, sleep fragmentation is considered as much of a crew endurance safety risk as inadequate sleep.

Sleep fragmentation occurs on towing vessels due to relatively short rest periods, cutting into scheduled rest periods to eat or take care of personal hygiene matters, and other circumstances of towing vessel life. Occasionally a crewmember's sleep might be disrupted for work-related reasons, such as drills or other operations requiring all hands.

For the purpose of the demonstration project, crewmembers were asked to indicate on a Decision Support System Worksheet how many times per week their sleep was fragmented. The worksheet further defined sleep fragmentation as sleep broken into multiple shorter periods, or naps, where the individual could not schedule a full seven to eight hours of continuous sleep. As seen in Figure 4, on average, crewmembers reported their sleep to be less fragmented after practicing CEMS. While most companies reported more days of continuous sleep, the crews of one company, Company D, reported fewer days of continuous sleep.

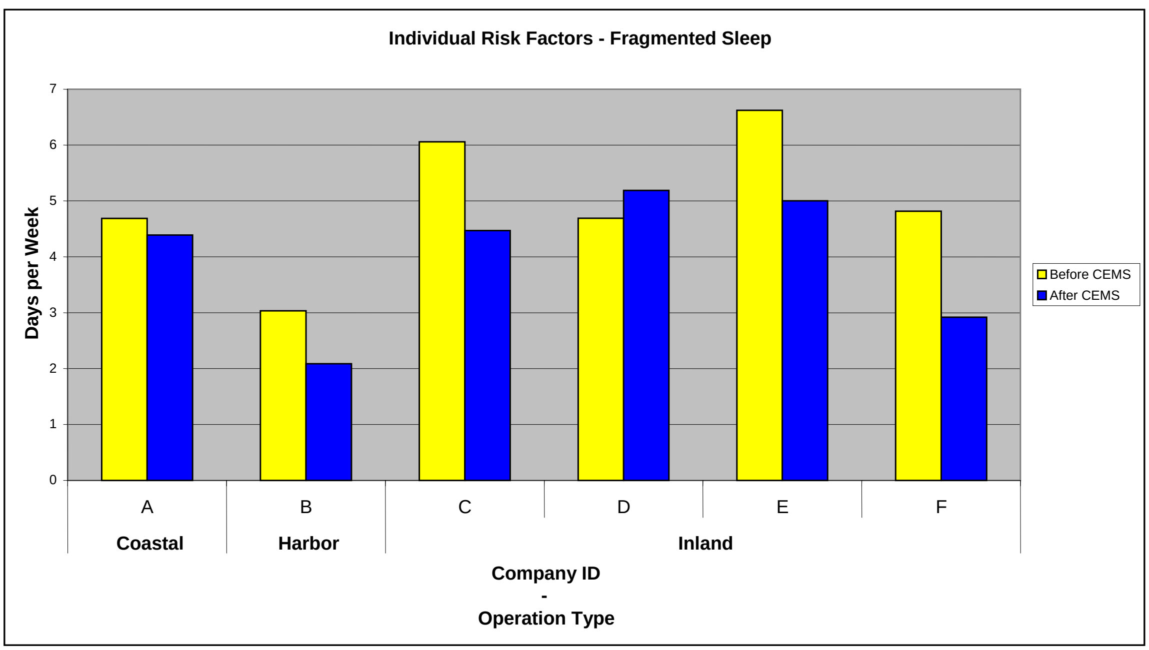


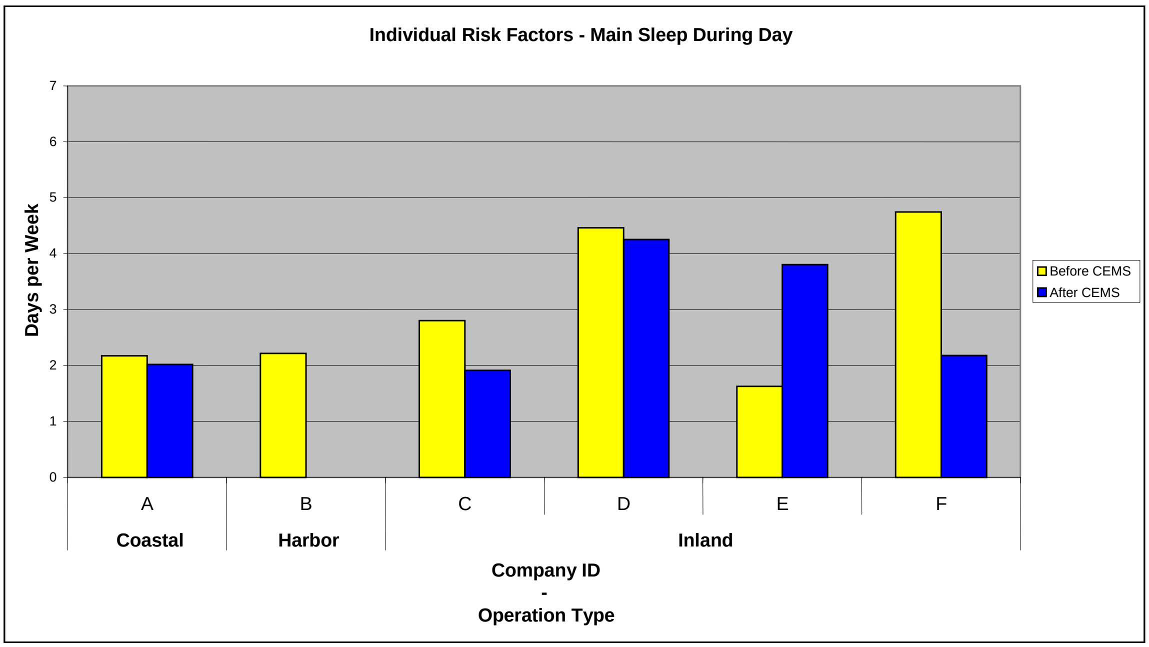
Figure 4. Individual risk factors – fragmented sleep.

Sleep Schedule Contrary to Circadian Rhythm

As mentioned in the introduction, circadian rhythms also affect crew alertness. Nearly all human physiological and behavioral functions occur on a rhythmic basis that makes a person feel more alert in daytime sunlight, and sleepier in nighttime darkness.[104, 105] This is because sunlight suppresses the hormone melatonin. Melatonin is a hormone which makes us sleepy or unwary. In sunlight, melatonin is suppressed, making us more alert. Without sunlight, melatonin is released, making us sleepy.[106, 107]

This becomes problematic for operators working night shifts because darkness causes feelings of sleepiness when they need to be awake.[108] Night workers would also normally experience a disruption in circadian rhythm [109] because daylight impairs sleeping during the day [110] by suppressing melatonin. Inexperienced shift workers, in particular, are likely to experience more difficulty with circadian inversion, [ix] but for all night workers, a long-term adjustment requires substantial dedication and a strict routine.[111] Until an adequate adjustment is made with the help of countermeasures, such as light management, circadian rhythm disruption is a risk factor.

For the purpose of the demonstration project, crewmembers were asked how many days per week their main sleep periods were scheduled during the day. For crewmen who were still “day oriented,” this provided an indicator of the level of circadian rhythm disruption. As seen in Figure 5, results indicated that the average crewmember’s main sleep period occurred during the day less often after practicing CEMS. Only Company E’s crews reported an increase in this measure.



[ix] Changing the biological clock or shifting the Red Zone.

Figure 5. Individual risk factors – main sleep during the day.

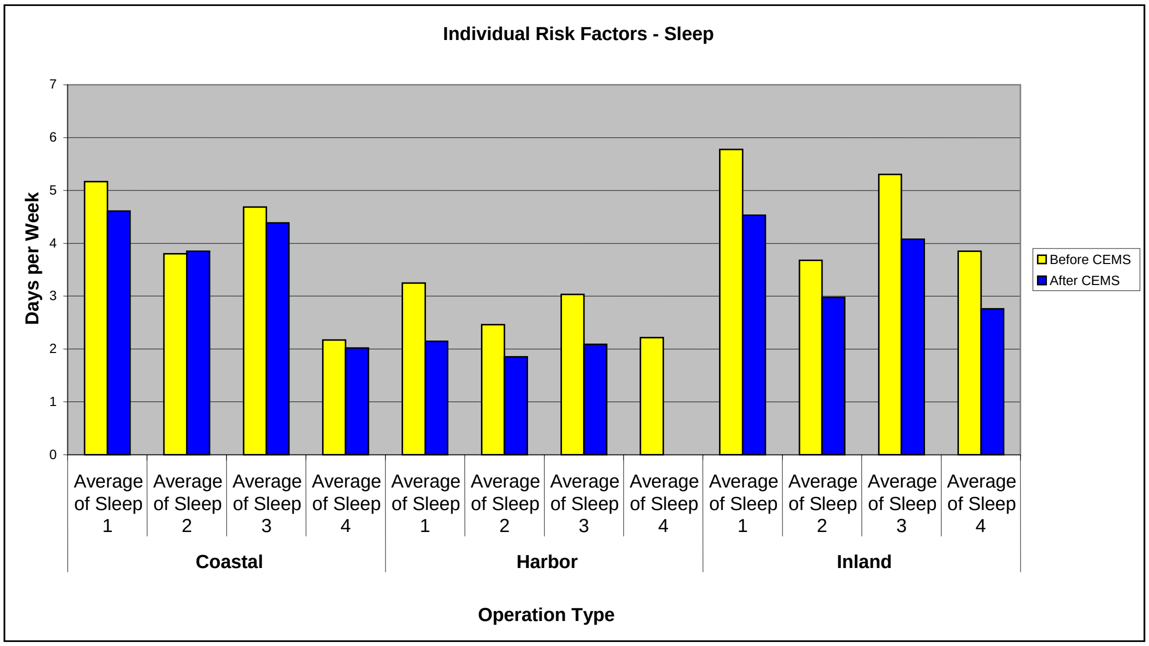


Figure 6. Individual risk factors – overall "sleep" results.

Analysis of Sleep Results

As seen in Figure 6, on average, every sector of towing – inland, coastal, and harbor – showed significant improvement on nearly every sleep risk factor. Given the relatively short six-month demonstration project period, these results are very encouraging.

Because harbor vessels are predominantly day operations, they displayed lower starting levels for sleep risk factors compared to coastal or inland operations. Harbor vessel crews generally go home at night and have better opportunities to get a good night's sleep. Their risk levels are comparable to those of the average American day-shift worker. Here, the harbor vessels' already-low levels were further improved by applying CEMS. This is likely attributable to education and improved awareness on the part of individual crewmembers, enabling them to make better, informed decisions about when to go to bed, their sleeping environment, and other elements involving their sleep at home.

The coastal operation's measurement of "sleep quality" risk ("Average of Sleep 2" in Figure 6) showed a very slight increase. This company had been practicing CEMS for some time before the demonstration project began, and so may be at a temporary equilibrium point on this factor. We learned from company interviews that they intend to make some major modifications to their vessels to reduce noise and vibration as part of a forthcoming maintenance period. This may result in improved sleeping conditions for the crew. Improvements such as these are an excellent example of the CEMS approach of continuous improvement.

As previously noted, only one company, Company D, experienced an increase in risk factors related to sleep duration, sleep quality, and sleep fragmentation. This company made the same types of environmental changes to its vessels as the other companies did. It had similar policies about napping, being courteous to sleepers off-watch, and alternate meal and shower times. It also improved the crew's diet and practiced light management, like the other companies. To examine why this company experienced an *increase* in risk, we studied Company D in comparison to two other inland towing companies whose crews experienced better sleep. Two differences were found – coaches and watch schedules.

Company D did not put coaches or acceptable alternatives on its vessels. Without such onboard support, crewmembers could not fully understand, practice, or embrace CEMS. They needed such a model to encourage self-discipline to follow good CEMS practices, such as establishing good sleep habits and practicing proper light management. They needed someone onboard to adequately assess the sleep environment. With no coach to ensure that these fundamental steps were completed and maintained, the crew could never be ready for CEMS' last step, a watch schedule change.

Figure 7, below, shows companies that incorporated onboard coaches. Companies B, C, and F, who had coaches, were able to show a greater reduction in sleep and other risk factors compared to those without them. Because the use of onboard coaches was one of only two factors differentiating Company D's practices from the other line towing companies, it stands to reason that if Company D had put a coach or acceptable alternative on every vessel, its crews would have demonstrated a reduction in sleep risk factors. Since completion of the demonstration project, Company D has decided to place a trained coach or acceptable alternative on each vessel.

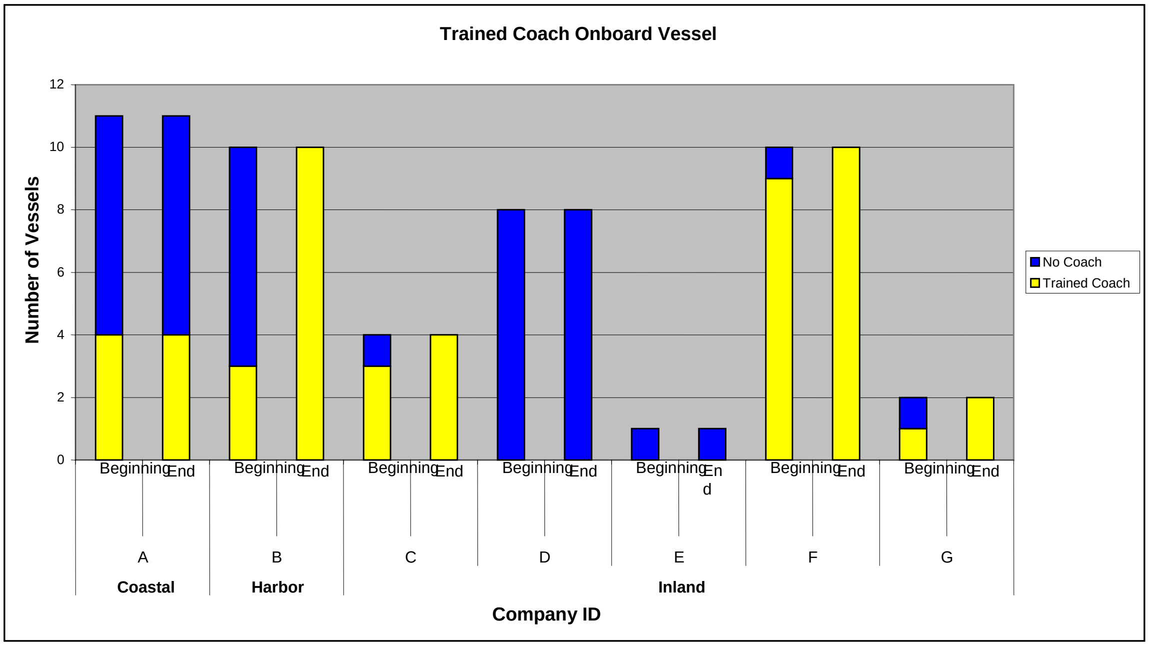


Figure 7. Trained coaches onboard vessels.

The other main characteristic distinguishing Company D's practices from other line towing operations was that it did not change its watch schedules. Given the status of its CEMS program and lack of coaches, we would not expect the company to be ready to make such a major change. However, their situation still provides an opportunity for comparison.

All line towing vessels in this project started with 6 on – 6 off watch schedules. Under this schedule (depicted in Figures 8 and 9), two watch standers take turns working six-hour watches, then taking six hours off, with each worker standing two watches in any 24-hour period. While some vessels made a change by the end of the demonstration project, Company D retained its 6 on – 6 off schedule for all of its vessels. It is clear they would retain their risk of inadequate sleep duration because, with a maximum of six hours off at a time, crewmembers can only obtain, at most, six hours or less of uninterrupted sleep.

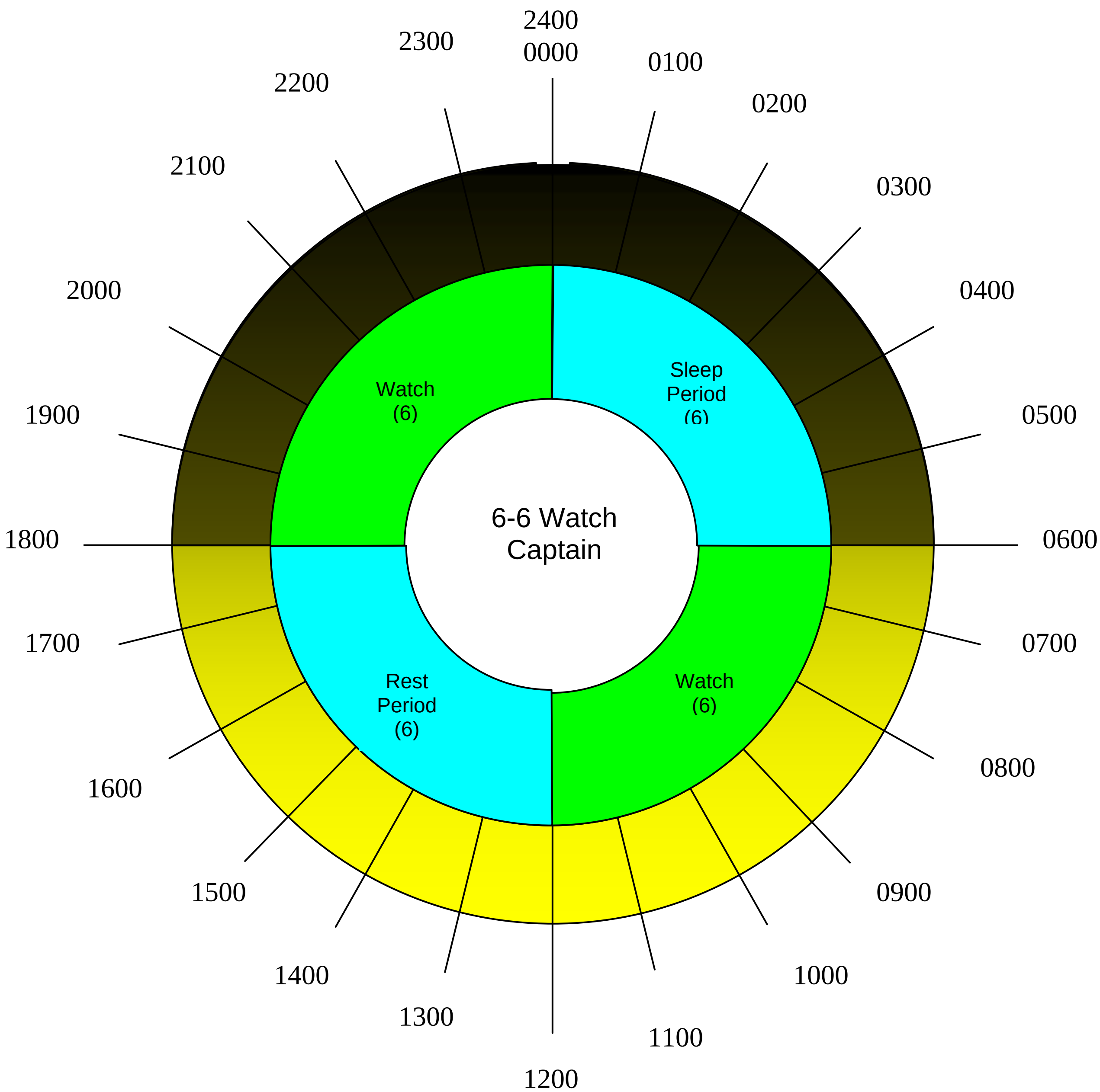


Figure 8. Six on – six off watch schedule for watch captain.

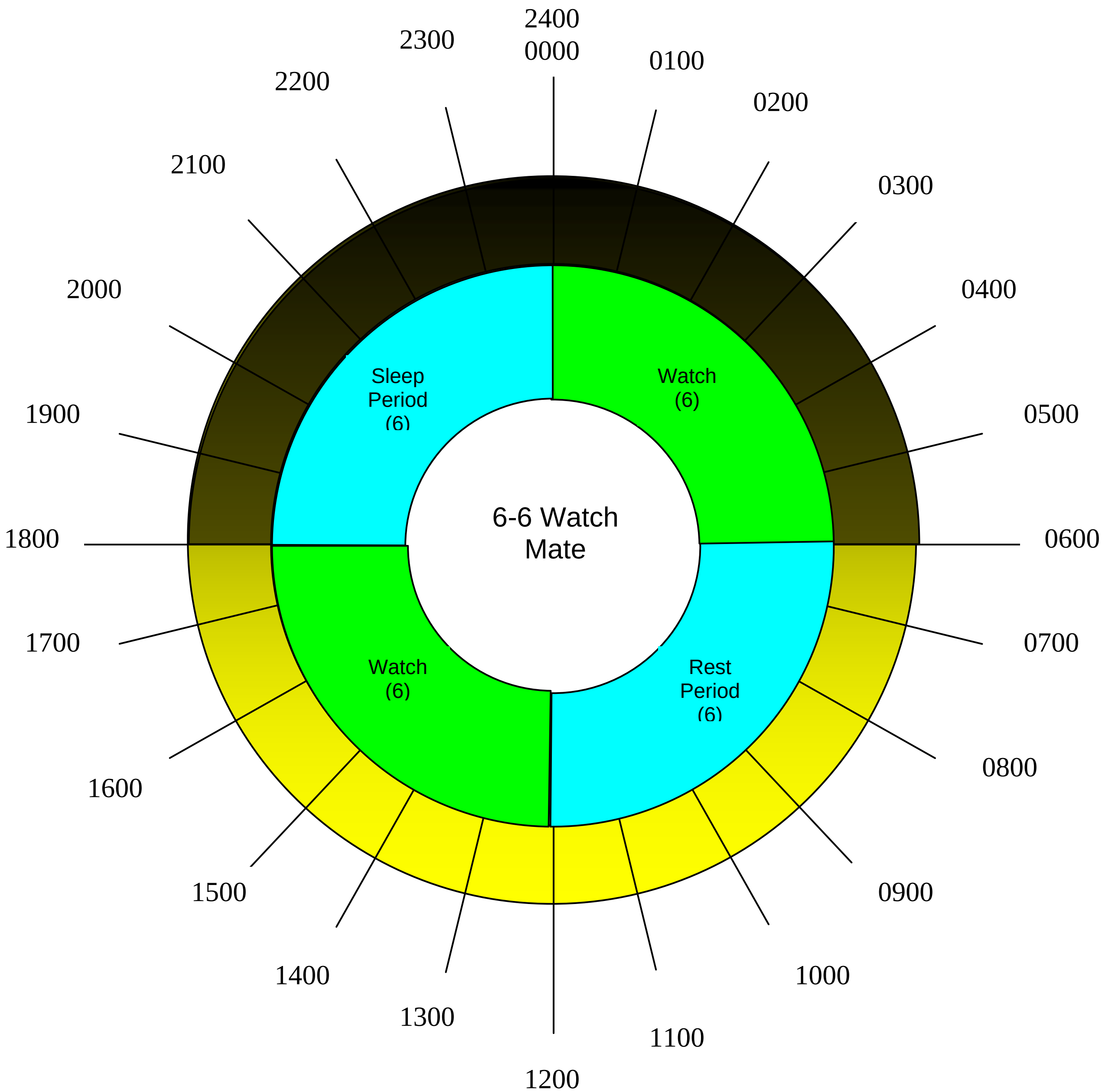


Figure 9. Six on – six off watch schedule for watch mate.

Other watch systems allow operators a longer period of uninterrupted rest. In a 7-7-5-5 watch system, each person works one 5-hour and one 7-hour watch, each separated by one 7- and one 5-hour rest period, as seen in Figures 10 and 11.

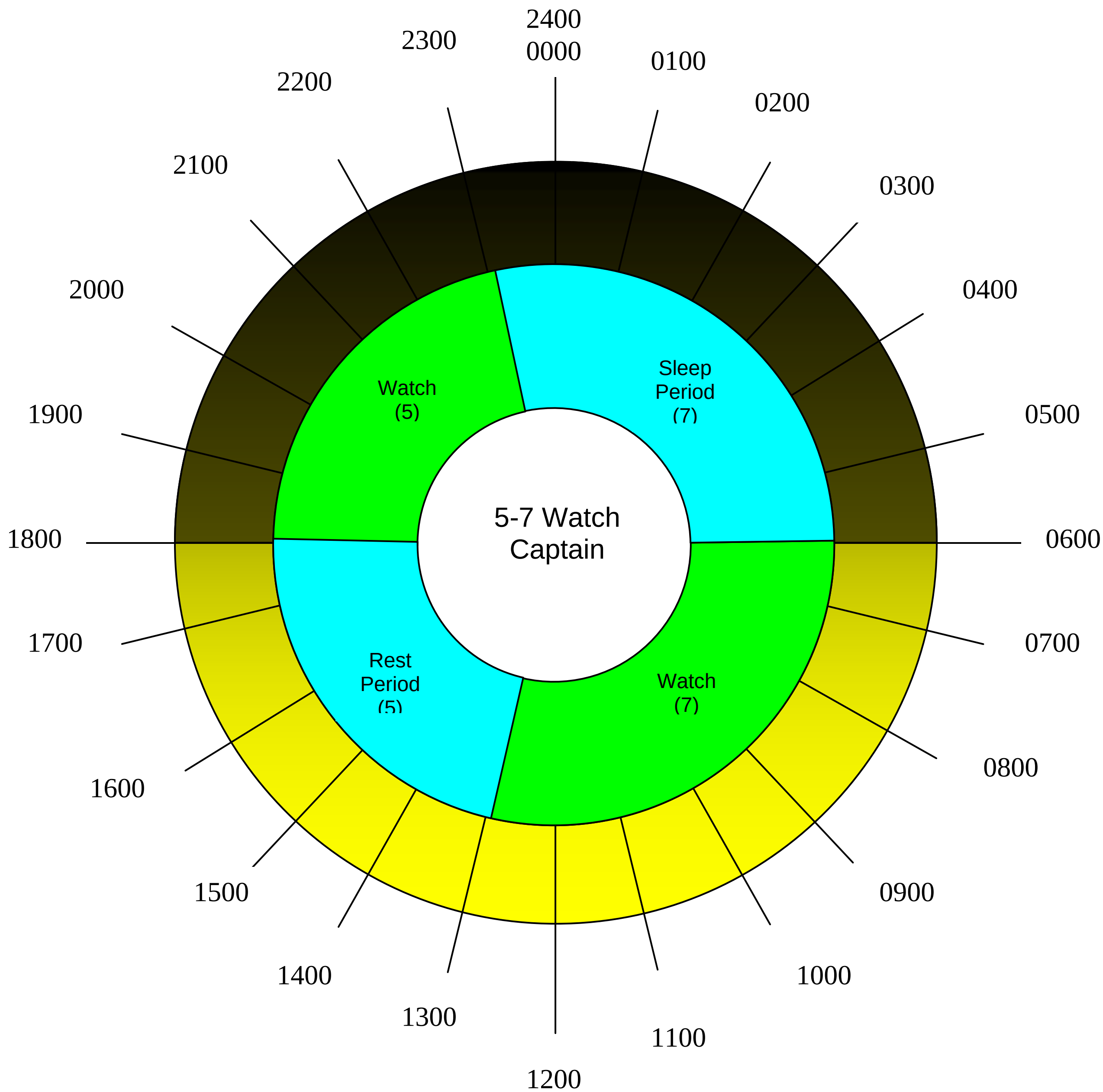


Figure 10. Five - seven watch schedule for watch captain.

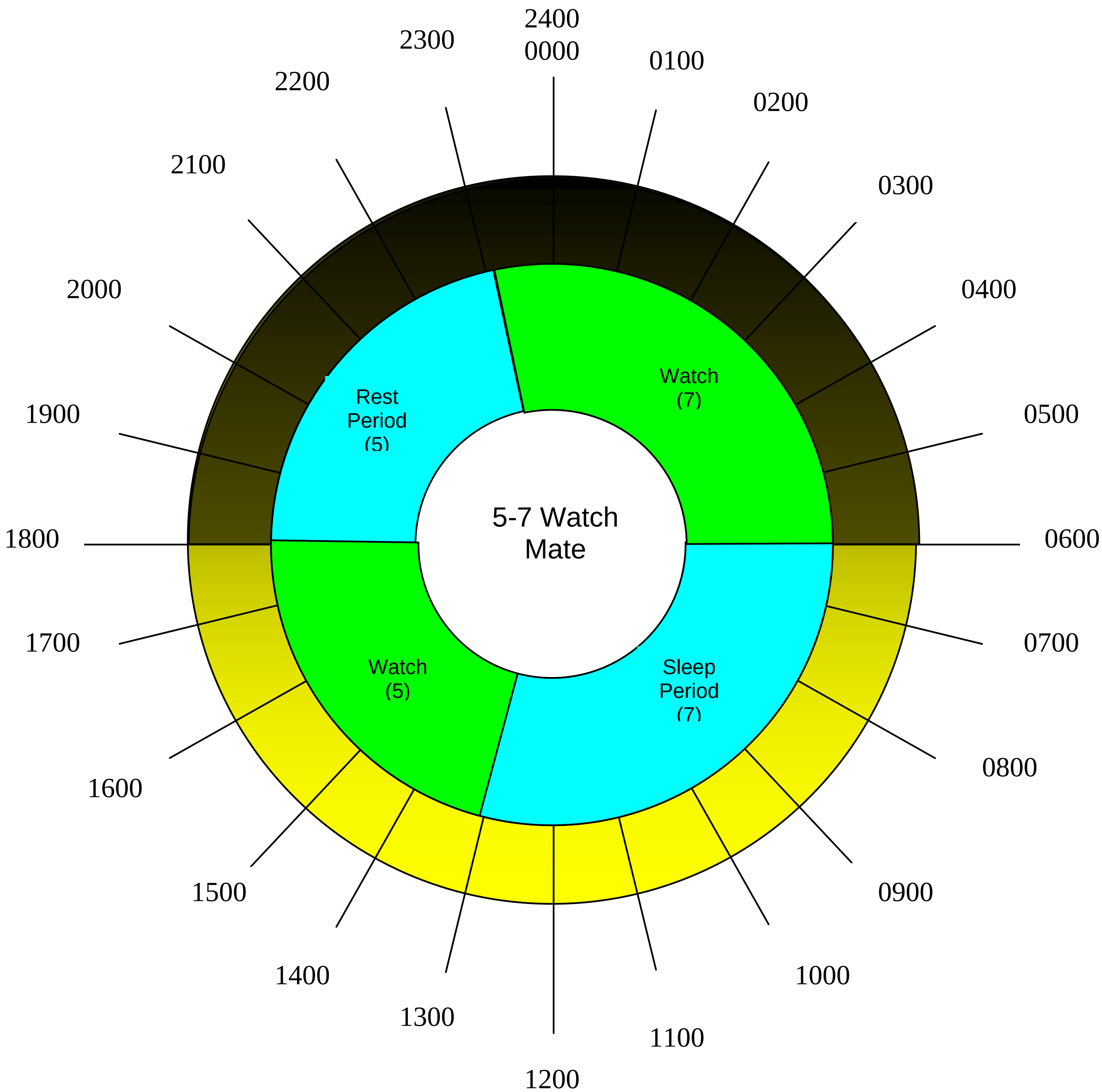


Figure 11. Five - seven watch schedule for watch mate.

Under the 8-8-4-4 system, each person works one 4-hour and one 8-hour watch, each separated by one 8- and one 4-hour rest period, as seen in Figures 12 and 13.

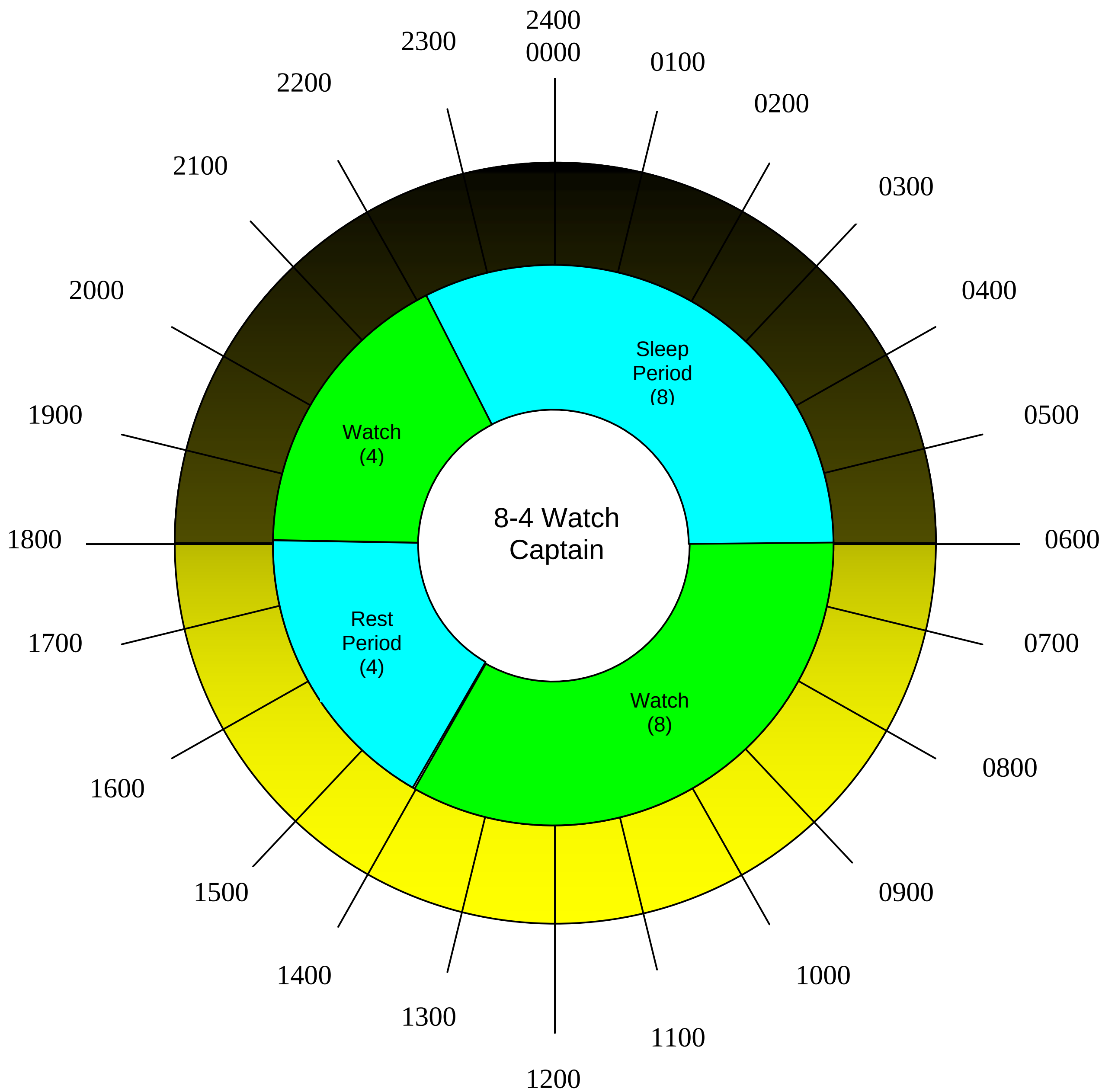


Figure 12. Eight - four watch schedule for watch captain.

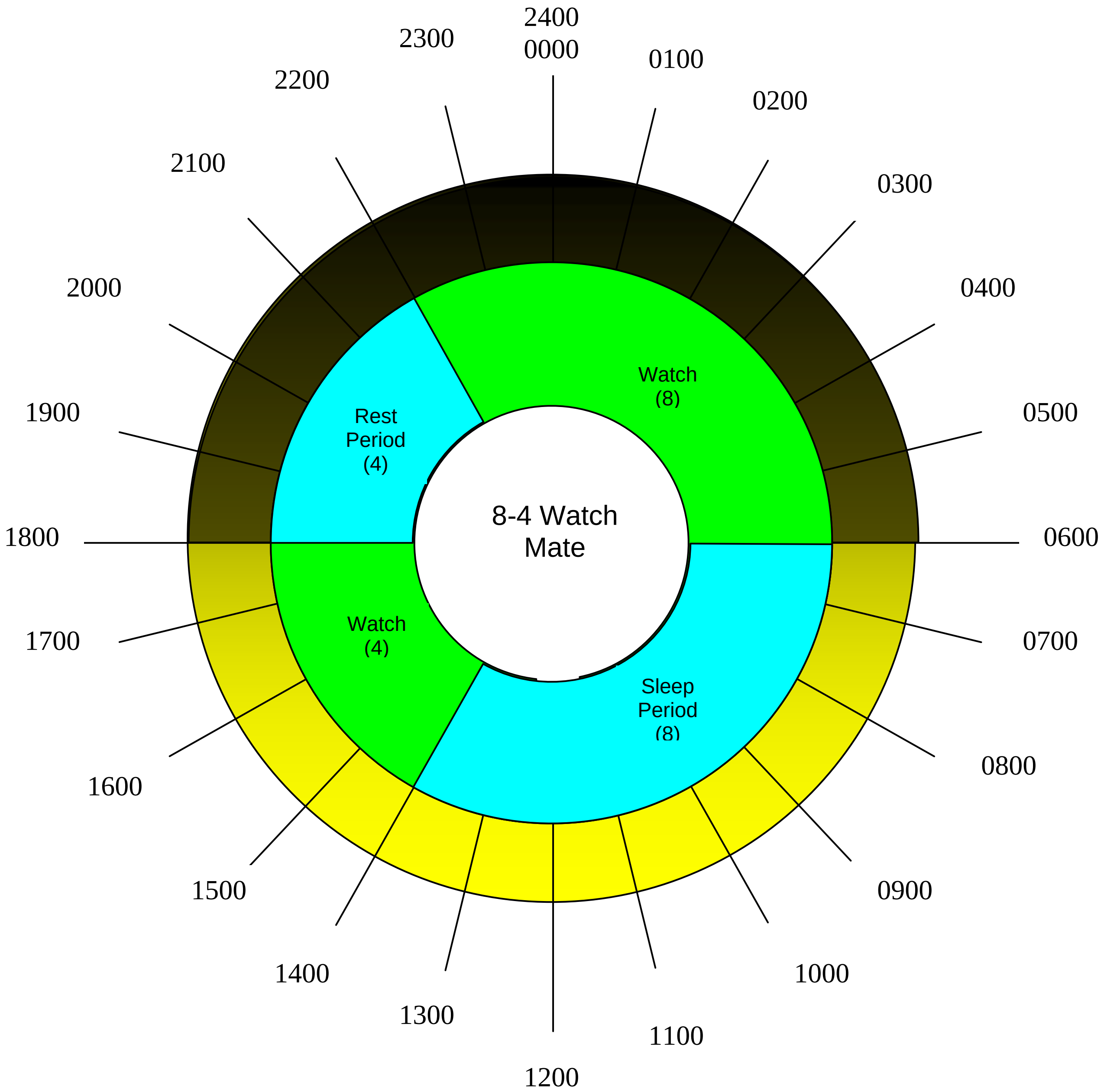


Figure 13. Eight - four watch schedule for watch mate.

As seen in Figure 14, Companies C and F were able to go to a 7-7-5-5, 8-8-4-4, or at least modify their current 6 on – 6 off schedule to ensure that watch relief times supported proper light management. Shifting to a different watch system is one of the factors that enabled Companies C and F to reduce these sleep-related risk factors when Company D did not.

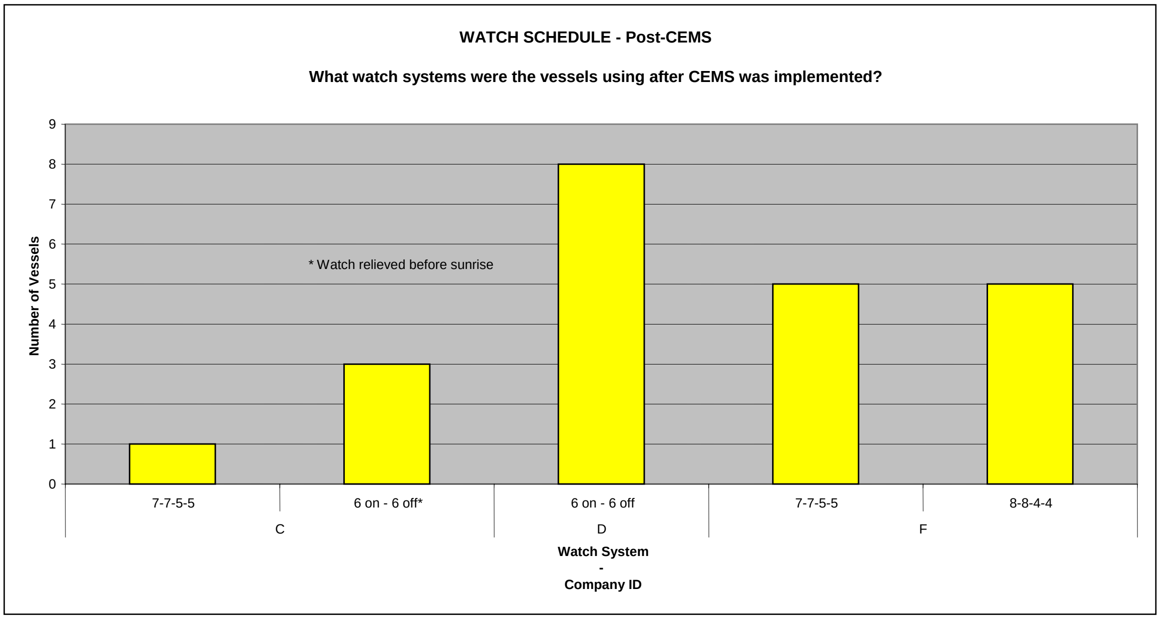


Figure 14. Post-CEMS watch schedules.

2. Work Schedule and Circadian Rhythm

<u>Irregular Hours and Changing Work/Rest Schedules</u>

In a 2002 study, the Canadian Marine Safety Directorate identified irregular hours as a top cause of fatigue. [112] "Irregular hours," in this case, refers to the absence of regular waking and sleeping times. This contributes to circadian disruption and impairs alertness and good decision-making. The constant shifting of work hours also affects the crew's ability to sleep. Unpredictable waking and sleeping hours confuse the body and have effects similar to those of jetlag.

These results may occur when a person scheduling shifts unknowingly creates schedules that don't allow people time to adjust to a new circadian rhythm, and/or rotates shifts earlier rather than later, which is harder to adapt to. [113, 114] Regardless of their causes, constant schedule changes become a safety risk.

Medical research has shown that shift schedules should remain consistent for two to three weeks. This allows people the recommended time period of about a week to acclimate to a new circadian rhythm, and lets them keep that schedule for awhile before making them do it all over again. [115, 116] In addition, when it is time to rotate the shift, the recommended approach is to schedule each worker's shift to start at approximately the same time of day [117] or later. [118, 119] This will work *with* the body's tendency to advance the biological clock over time, [120] rather than work *against* the body, as an earlier shift would. [121]

For the purpose of the demonstration project, crewmembers were asked how many days per week they experienced schedule changes. As seen in Figure 15, harbor and two inland towing companies indicated a general decrease in the number of days this occurred. All other companies showed an increase in risk measurements. The average of all crewmember responses indicated an overall, very slight reduction in this risk measurement. In any case, the original levels of this risk were small to begin with, relative to other risk factor considerations.

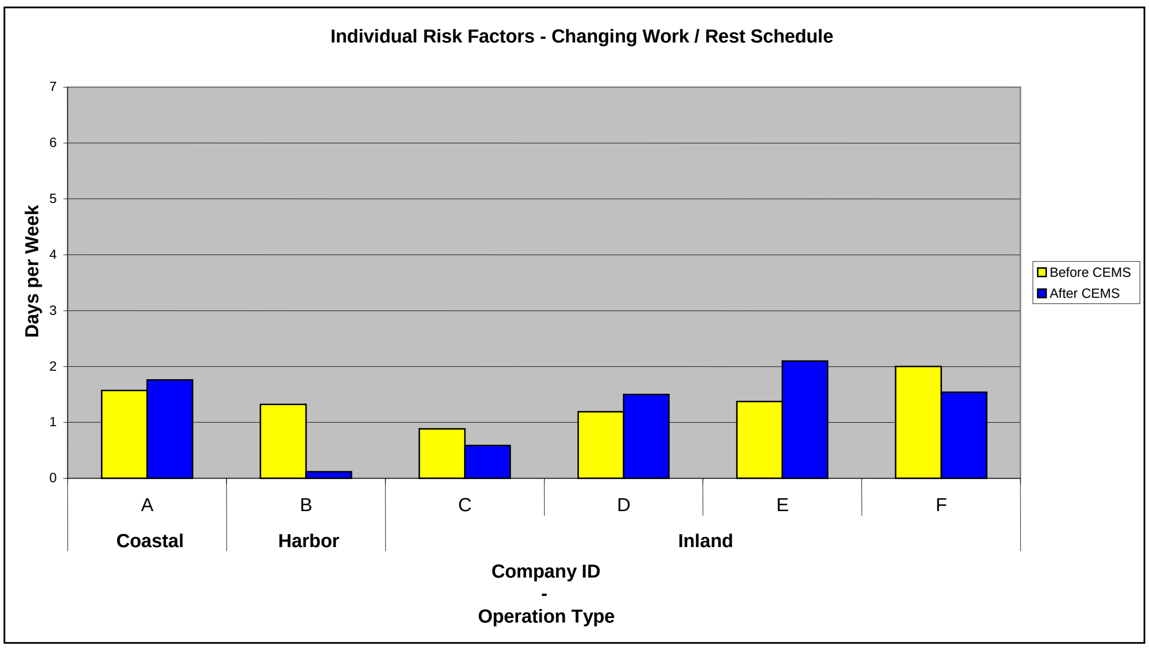


Figure 15. Individual risk factors – changing work/rest schedule.

Long Work Hours

The Centers for Disease Control and Prevention define extended work shifts as those longer than eight hours, and overtime as being more than 40 hours per week. [122] Research has shown that extended shifts of nine hours [123] or more cause more injuries, [124] [125] fatigue, poor health, [126] and errors. [127] A recent study also revealed that offshore oil riggers who worked 12-hour night shifts experienced decreased alertness and response time to task challenges. [128] Extended shifts have also caused nurses and construction workers to make more errors [129, 130, 131] and suffer car accidents driving home. [132] Nurses on extended shifts have reported they don't always have the stamina and mental alertness to deliver proper patient care. [133]

Those who work longer hours also have reduced cognitive ability, less energy to exercise, and less ability to plan and prioritize. [134] Finally, they may experience more disruption of their circadian systems and consequent declines in safety, performance, and productivity.[135]

Like other shift workers, towing vessel workers are vulnerable to fatigue, reduced performance, and decreased endurance, which is why long work hours are a safety risk.

For the purpose of the demonstration project, crewmembers were asked how many days per week they worked 12 hours or longer in a 24-hour period. The overall crewmember average showed a decrease in this risk factor. An overall decrease was also reported by three of the seven companies, as seen in Figure 16.

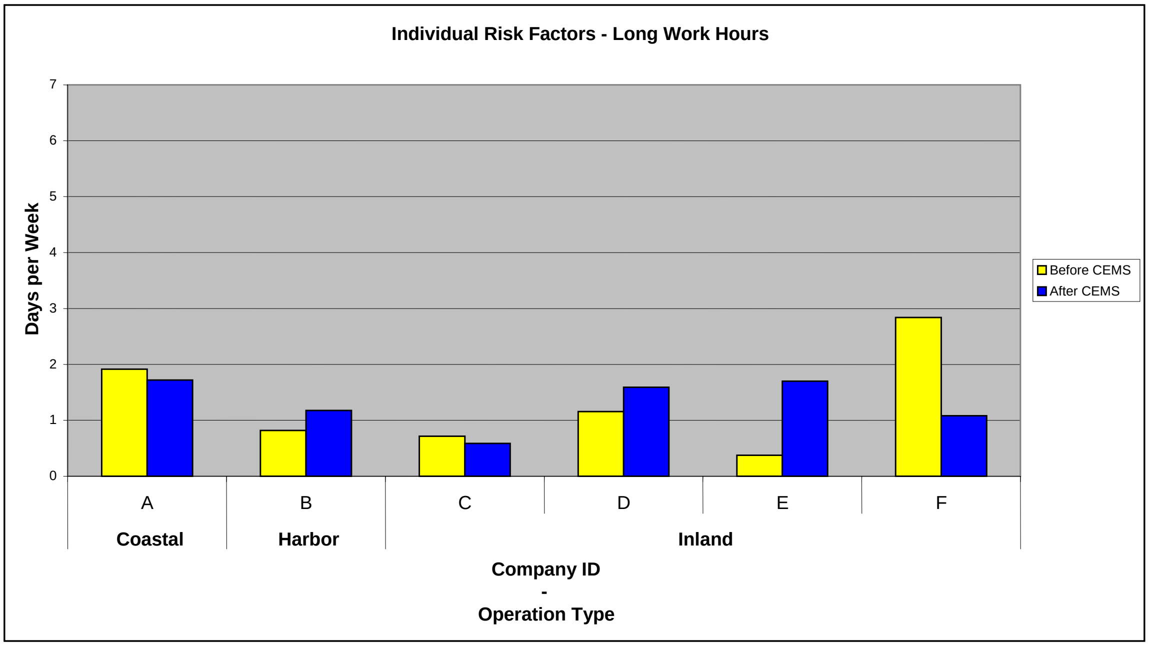


Figure 16. Individual risk factors – long work hours.

Naps

Towing vessel crewmembers and other shift workers are highly susceptible to sleep disruption. Their schedules interfere with their biological clocks and ability to sleep.[136]

Naps are an essential countermeasure to fatigue, exhaustion from long shifts, and sleep deprivation. Taken before or after an anticipated short night's sleep, brief naps improve performance and alertness, and delay fatigue-induced performance degradation. [137, 138]

Napping is such a popular solution to fatigue that transportation industries in the U. S. and Canada have recommended it to airline pilots as an answer to fatigue.[139, 140, 141] Naps should not last for more than 90 minutes. Otherwise, they might disrupt circadian rhythms and cause insomnia.[142, 143] After napping, experts recommend that workers take at least fifteen minutes between the nap and work to avoid sleep inertia[x] while working.[144, 145]

Not all crewmembers are able to sleep eight hours a night. Those who have no means of making up for this lack of sleep suffer an additional risk, because they have no other way to recover from sleep loss. Since it takes away an opportunity to increase endurance and alertness, a work schedule that does not permit napping is considered an additional risk factor.

For the purpose of the demonstration project, crewmembers were asked to indicate how many days per week napping was not possible. On average, crewmembers reported a greater opportunity to nap after starting CEMS, as seen in Figure 17. There was, however, one line towing company whose crewmembers said they experienced an increase in this measure.

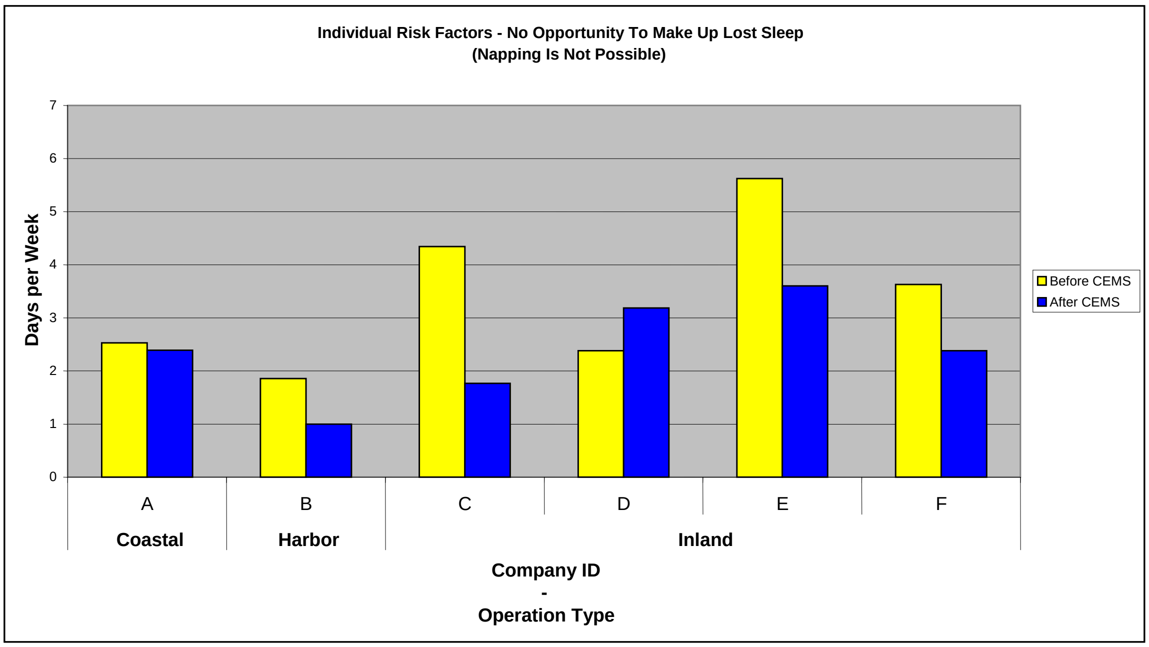


Figure 17. Individual risk factors – no opportunity to make up lost sleep.

[x] The tendency, after awakening, to feel sleepy and sluggish.

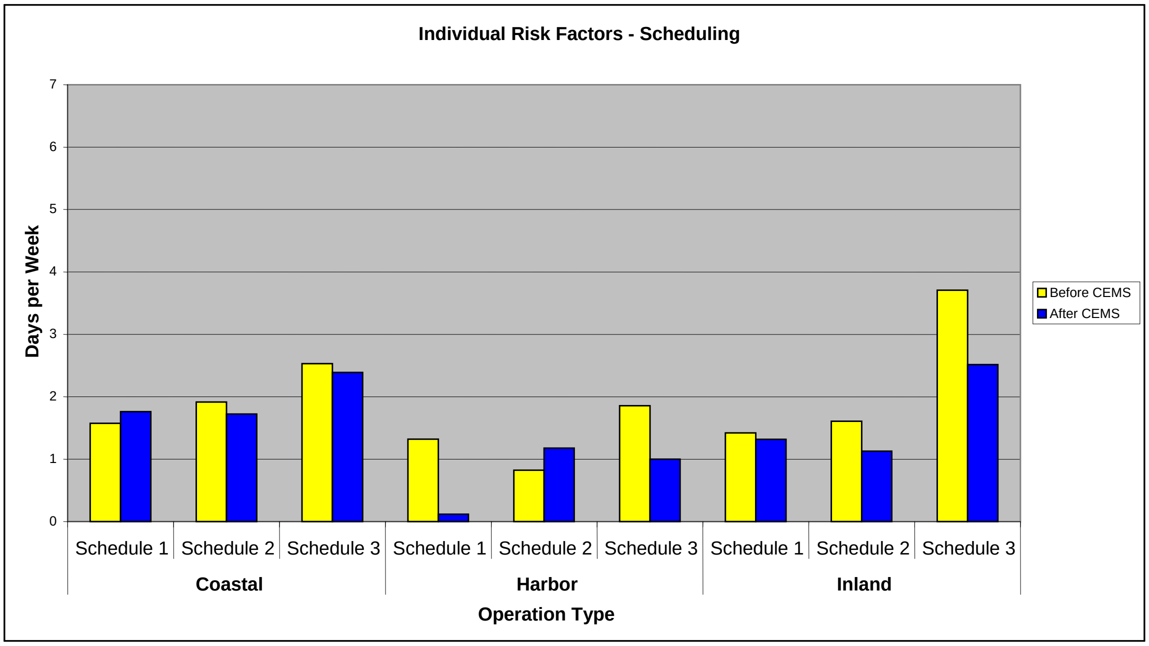


Figure 18. Individual risk factors – overall "scheduling and circadian rhythm" results.

Analysis of Scheduling and Circadian Rhythm Results

Overall, crewmembers from all three segments of towing reported either a reduction in schedule-related risks or that the risk factors remained relatively low throughout the project, as seen in Figure 18. While it is worth exploring the increase in some factors, the overall trend for these measures is encouraging.

Schedule Changes: As seen in Figure 15, one coastal company and two line towing companies showed a relative increase in the risk factor related to schedule changes. However, when you compare the relative value of this factor to their other reported risk factors, you will notice that their initial measures here were already fairly low. Therefore, it is likely these companies first focused their efforts in other categories, following the CEMS philosophy to address risks that can achieve the overall greatest risk reduction. Furthermore, given that the companies in this project generally keep crew members on the same watch schedule throughout their time onboard, the results are likely due to less common events, such as crew change-outs or operational scheduling changes for the vessels.

Long Work Hours: As seen in Figure 16, one harbor and two line towing companies reported an increase in the risk factor related to long work hours. Again, these factors started out at a relatively low level and therefore, consistent with the CEMS process, may not have been priority issues for these companies.

This measure is also highly susceptible to the temporal effects of operational surges for the day the survey was taken. For example, line towing crews may face high- or low-water conditions, which increases workload. Harbor tug crews periodically experience peaks of vessel activity when many vessels arrive or depart on the same day, or severe weather may hold docked vessels during high winds.

It is also worth noting that Companies D and E, the two line towing companies that experienced more varied schedules and higher frequencies of long work hours, did not follow CEMS-recommended risk management measures and were not as far along in the CEMS process as the others. For example, as seen in
Figure **7**, neither company had trained coaches onboard their vessels. Such coaches might have helped to better monitor the vessels' schedules and hours while providing positive guidance to the crew.

Nevertheless, given the relatively low initial levels of these two risk factors and the overall improvement when considering all respondents, these results are generally acceptable – even positive, in some cases.

Napping: As seen in Figure 17, only Company D's crew reported a higher risk of having no opportunities to nap. Although the company has an informal policy that allows napping when off watch, it is possible that the crew was hesitant to take naps without stronger support and encouragement. Company C, who experienced the greatest improvement in the ability to nap, reported they had much more success only after developing a formal, written policy.

This is also an area where a coach may have made a difference. A coach can monitor the situation, educate crewmembers on the utility of napping, and encourage them to nap as necessary.

3. Physical Condition

The crew's physical condition has related effects on their endurance. There are four physical risk factor categories considered under CEMS: diet, workload, stress, and extent of exercise. These factors affect people's ability to have sufficient energy, ability to fight sickness, likelihood of fatigue, endurance to withstand workplace stress, and ability to stay alert.

Diet

Diet is a factor that can strongly affect a crew's health and endurance. Unfortunately, shift workers have a tendency to eat poorly. Night shift workers, in particular, are prone to weight gain and bad eating habits. [146]

Despite the "kick" it gives people, caffeine can have detrimental effects on performance. Anyone who drinks more than three cups (24 oz) of coffee per day[147] [148] will find that caffeine continues to prevent sleep at bedtime, [149] shortening their total amount of sleep time. When caffeine keeps people awake, it also reduces the time they would spend in

REM sleep, the most important sleep cycle for learning ability, memory, and performance. Excessive caffeine impairs iron absorption and causes the body to lose calcium, magnesium, and B vitamins. [150] Finally, too much caffeine can cause dehydration, which is particularly bad when towing vessels are in an extreme climate, or if an individual on the towing vessel is seasick.[xi]

Consuming fatty foods also influences diet and performance negatively. Though fats do provide energy and serve other important functions for the body, Americans need to reduce the amount they consume. [151] Excessive fat intake causes obesity, cardiovascular disease, impaired work performance,[152 153] and heartburn. [154]

To support endurance and alertness, experts recommend a diet of high-protein, low-fat foods and well-chosen carbohydrates. Protein contains nitrogen, which helps repair and build tissue for all bodily functions. Nitrogen also provides nutrients to help endure stress. [155] Protein is also a source of amino acids, which are essentially responsible for cell regeneration. [156] These acids help run the brain: the neurotransmitters that they help build regulate cognitive and mental performance, [157] as well as emotional states and pain response. Carbohydrates provide fiber, [158] an essential nutrient that decreases risk of coronary heart disease. [159] Fruits and vegetables are common sources of carbohydrates and contain vitamins, minerals, and other essential nutrients. [160]

Adequate hydration is also necessary to keep the body functioning properly. Water, which makes up a majority of living tissue, [161] supports the health of all body systems, cushions the body's joints, fights environmental stressors, and carries oxygen to the body's cells. [162] If people lose as little as three percent of their body weight as water, their physical performance starts to suffer. When water loss occurs, a person experiences severe physical stress, mental stress, [163] and performance degradation. Water is essential for the body's cooling and heating systems, enhancing endurance, particularly in extreme climates. Moreover, water provides energy for thinking and it may expand the attention span. Finally, drinking water reduces fatigue. [164] Water is the only beverage that will promote endurance by carrying nutrients to the body's cells and dissolving them, making them accessible for the body's use. [165]

Figure 19. Some crews stocked more water to replace their soda and coffee consumption.

[xi] As the report will indicate, both conditions cause dehydration.

Besides knowing what to consume and what to avoid, the timing of meals is also important. Crewmembers should consume high amounts of protein at the beginning of a work shift to obtain the energy and amino acids necessary to do their work, stay alert, and make good decisions. After the first meal of the day, shift workers are better off eating lighter meals or snacks[166, 167] to decrease the risk of obesity[168, 169] and prevent digestive problems. Because bodies operate on a circadian rhythm, digestive systems that are not fully entrained to a night shift will more easily digest smaller meals than larger ones during the late-night to early-morning hours.[170, 171] It is also important to eat very little before sleeping, so as not to impede sleep.[172]

For the purpose of the demonstration project, crewmembers were asked how many days per week they experienced a poor diet. We defined this as the consumption of foods that are fried, high in fat, or high in sugar content. We also asked them about their caffeine and water intake.

As shown in Figure 20, five companies demonstrated improved crew diets during the project. Only one, the coastal company, showed a slight increase in this risk factor. Nevertheless, the initial and final levels for this risk factor were relatively small.

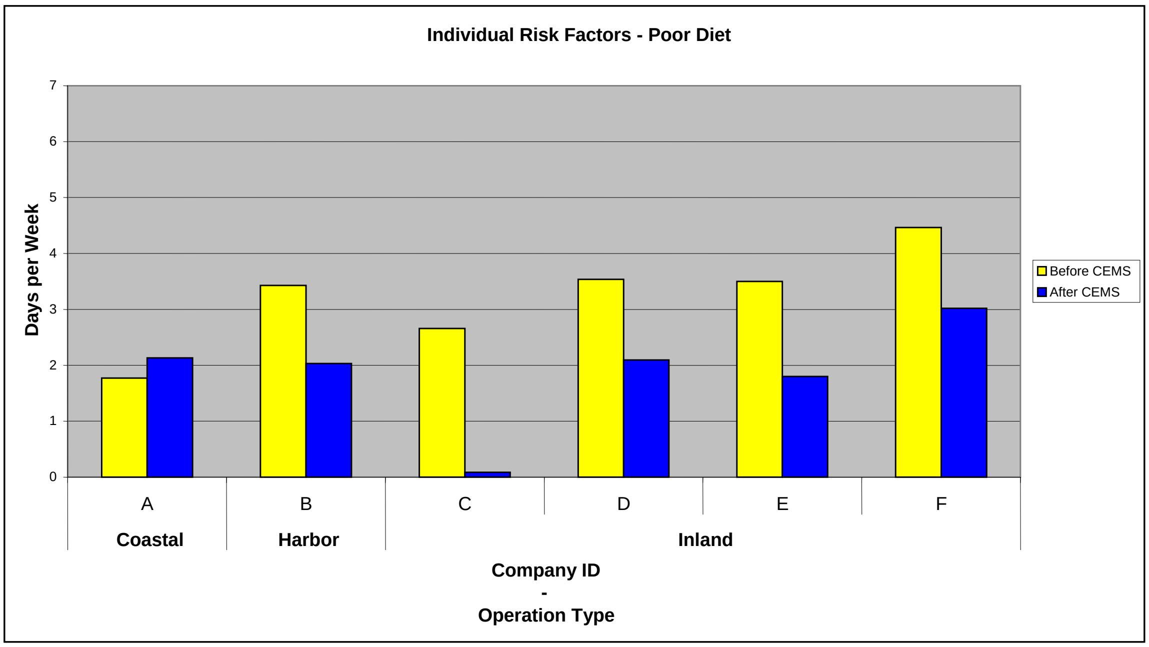


Figure 20. Individual risk factors – poor diet.

High Workload

An inappropriate workload is another risk factor. Both work overload and underload are considered sources of stress,[173 174] which is an additional endurance risk factor in its own right. Work overload triggers stress when an individual starts worrying about completing work on time, and feels too much pressure. If the work is physical, it fatigues the body and tires the crewmember. Work underload can be a problem when crewmembers get bored or feel disengaged,[175] [176] causing fatigue. [177]

We focused on work overload for the purpose of the demonstration project. Crew-members were asked how many days per week they put forth high levels of physical and/or mental effort. As seen in Figure 21, the results showed a decrease in risk of high workloads for the average of all respondents. All companies, with the exception of Company D, reported a decrease in this measure.

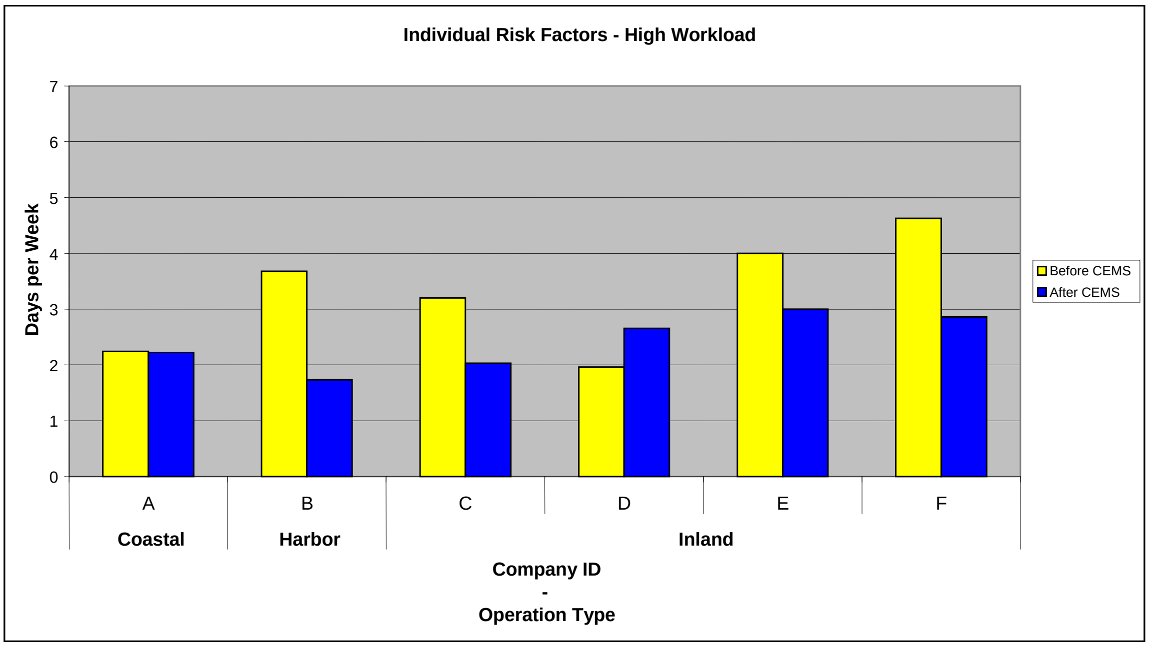


Figure 21. Individual risk factors – high workload.

High Stress

Crewmembers are subjected to physical and mental stressors from a variety of sources. Physical stress may come from sustained physical workload or extreme environmental conditions. Mental stress may come from sustained mental workload, being subjected to authoritarian leadership styles, social isolation, or other frustrating situations. A combination of physical and mental stress may occur due to poor task design, changes in the pace of operations, and rotating or changing watch schedules. Whatever the source, stress greatly affects endurance and is an important risk factor.

Stress depletes vitamins B and C, causing a person to be less alert, fatigued, slower to react, slower to think, confused, [178] and unable to concentrate. [179] These symptoms are conditions that impair decision-making and may contribute to accidents.

Work environment and stress are, to some degree, controlled by a company's culture and captain's management style. Rigid work practices and tyrannical supervisors induce stress by abusing power,[180 181] withholding support, [182] and being strict without being open to employee input. [183] Surveyed stressed employees reported the most common sources to be inadequate supervisor support, ineffective supervisor performance, and ambiguity about what is expected. [184] Another major source of stress is a general lack of control over the work environment or decisions. This is discussed further in the section entitled "Work Environment."

Social isolation is another stress factor that affects fatigue. When employees have the support of their colleagues, they are able to handle stress more easily and may receive help when overwhelmed. [185] Social support has also been shown to reduce vulnerability to colds by reducing stress hormone release,[186 187] reducing the sensation of pain, [188] and helping to keep the heart rate down during stressful situations. [189, 190] A lack of this support would create additional stress[191, 192] and reduce productivity. [193] Such a lack would also deprive crewmembers of the health-saving benefits of lower heart rates, stronger immunity against colds, vitamins that are essential to good decision-making, and possible task support.

For the purpose of the demonstration project, crewmembers were asked how many days per week they felt a high amount of stress. As seen in Figure 22, crewmembers reported a decrease in their risk of stress after six months of practicing CEMS. With the exception of Companies A and B, all others reported an overall decrease in their risk of high stress.

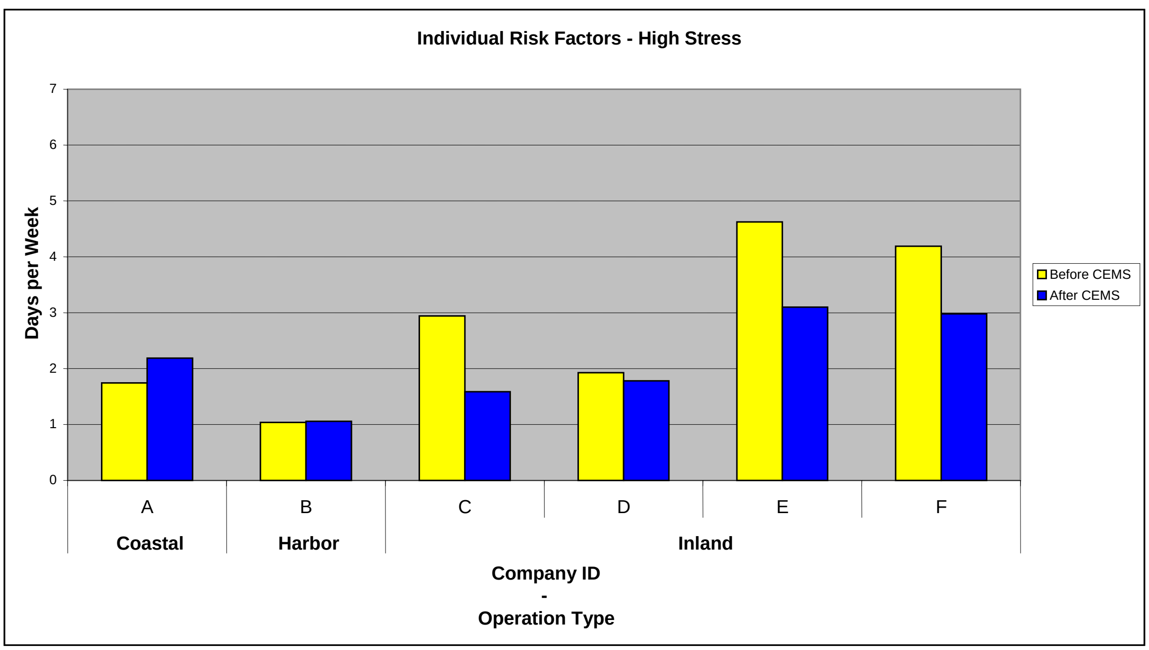


Figure 22. Individual risk factors – high stress.

Exercise

The inability to exercise is considered a risk factor because it takes away a crewmember's ability to increase endurance, enhance sleep, think clearly, and manage stress. Exercise increases physical endurance to sustain stressors such as motion, vibration, and extreme climates. [194] It also helps one adapt to a new circadian rhythm. [195]

Research also shows that physical activity enhances cognitive thinking. [196] According to one study, aerobic exercise performed for up to 60 minutes facilitated information processing and increased decision-making speed. [197] In contrast to quick thinking, slow decision-making has contributed to a number of maritime casualties.

Exercise is also known to enhance memory, problem-solving ability, concentration, [198] alertness,[199 200] and productivity. [201] This occurs because exercise enhances our ability to use oxygen to obtain energy for work. [202] Exercise can also help crewmembers to fall asleep and sleep well throughout the night. [203, 204] Finally, exercise helps to reduce stress and reset the circadian clock. [205, 206]

Figure 23. Examples of exercise equipment provided onboard demonstration project vessels.

Towing vessel operators and crewmembers can benefit from regular exercise. In addition to improving their health and well-being, exercise helps people to sleep, avoid circadian disruption, make better decisions, decrease stress, and increase endurance and alertness. The inability to access these benefits is considered a risk factor.

For the purpose of the demonstration project, crewmembers were asked how many days per week they had no opportunity to exercise due to a lack of equipment, facilities, or time. As seen in Figure 24, the vessels reported that after applying CEMS for six months, the average crewmember had an increased opportunity to exercise. Two companies, E and F, reported a decreased opportunity to exercise.

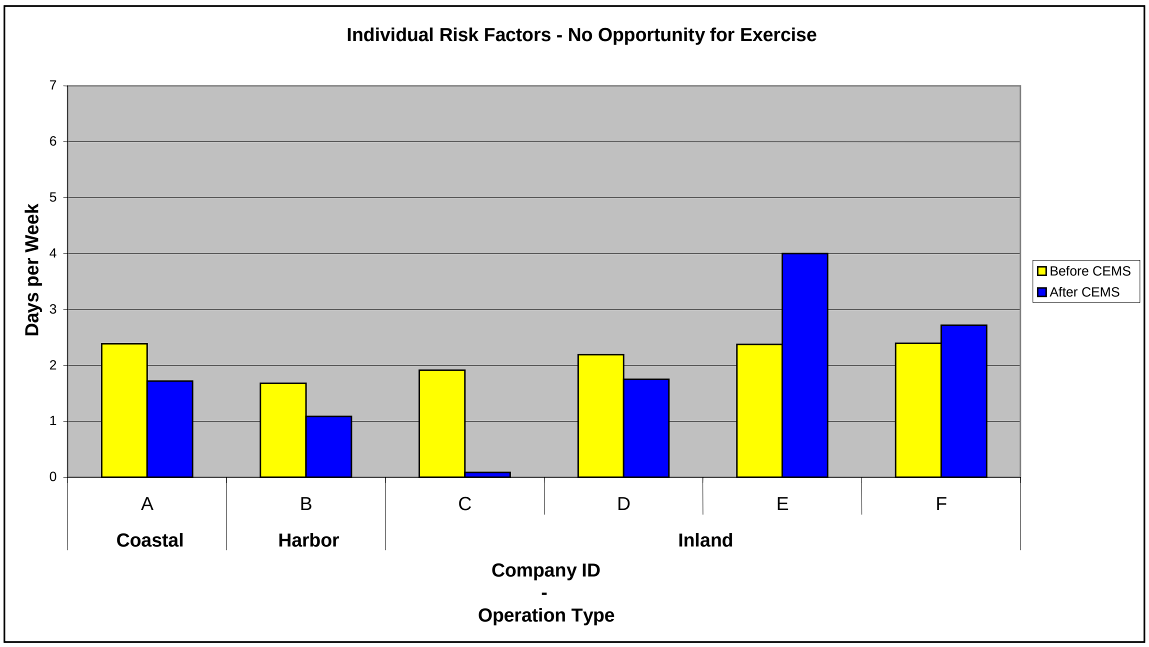


Figure 24. Individual risk factors – no opportunity for exercise.

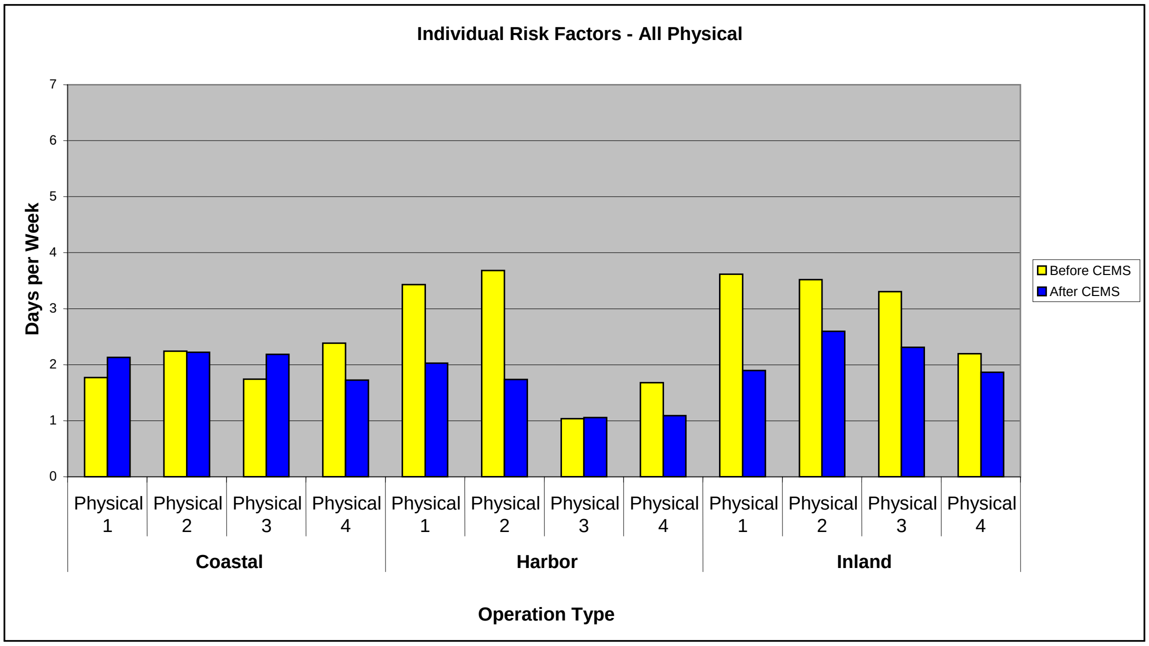


Figure 25. Individual risk factors – overall "physical stressor" results.

Analysis of Physical Stressor Results

As seen in Figure 25, on average, harbor and line towing company crewmembers reported reductions in measures of all physical risk factors. The coastal towing company showed improvement in only two of the four factors. However, the values reported by the coastal towing company were fairly comparable to those reported by line towing, and therefore may simply represent the current equilibrium level.

Diet: Most companies reported an improvement in crew diet, but there is still significant room for improvement. Many of the companies gave nutrition education to crews and distributed cookbooks and recipes to help the crews eat well. However, during site visits to the vessels, we observed varying degrees of conformity to a proper diet supporting CEMS. Overall, though, vessel crewmembers seemed to be making real improvements towards eating better, avoiding caffeine, and drinking more water.

Figure 26. While fruits (on counter) and vegetables (on table) are provided, sugary cookies (on counter) are still offered – an indication that there is still room for progress.

High Workload: Most companies showed improvement in this area. While this risk factor can be greatly influenced by external drivers, such as the current pace of operations or environmental conditions, this overall reduction in risk is encouraging. As seen in Figure 21, the company whose crew reported an increase in this workload risk factor is the same one that had no coaches on its vessels. It is difficult to make a clear correlation here, but it is possible that the crews aboard these vessels were lacking the guidance of coaches to help manage periods of high workload.

High Stress: As seen in Figure 22, all of the line towing companies reported a risk reduction with regard to the high-stress risk factor. Only the coastal towing company reported a significant increase. Two companies with very mature CEMS programs, C and F, showed considerable improvement.

Company A, the coastal towing operation, also has a mature CEMS program, but shows a different result. The result may be due, in part, to the nature of how its operation is run. It is involved in the voyage charter market, where units available for charter work are subject to an increase in operation pace. The market, rather than the company, will determine if and when the crew take a charter. By its nature, this kind of business creates an unpredictable and varied schedule, thereby inducing a certain amount of stress. In any case, the level of this risk factor is relatively low, and may not have required as much attention as other more significant risk factors.

Opportunities to Exercise: Even though they had relatively low levels of risk to begin with, four companies showed improvement in this category, as seen in Figure 24. These companies made investments in equipment and, through policy changes, provided time for their crews to work out.

Two companies' crews reported an increase in this risk factor (or a *decrease* in opportunity to exercise). Of the two companies, one reported it was a result of the company policy stating that crew must sleep during the longer time periods when the crew is off duty. Because crew shifts are usually a maximum of eight hours, and they need at least seven hours of sleep, the policy is wise. The crew is permitted to handle all other personal matters during their other rest period, which lasts from four to five hours. This shorter time period allows for exercise and other personal care matters. So, though this company reported less opportunity to exercise, the policy causing it was created to reduce sleep-related risk. This is a good example of the flexibility of CEMS, allowing a company to manage its highest risks as it sees fit. In this case, the company made a decision to focus on reducing the higher, more significant sleep-related risk by sacrificing what they view as a more minor trade-off, less opportunity to exercise.

The other company reporting similar results had only one vessel participate in the demonstration project. Thus, the results for this company may fluctuate more than others. This vessel had also just begun its CEMS program and did not have an onboard coach to provide necessary reinforcement and encouragement. This company and its vessel were able to show improvements in other areas, which are most likely attributable to the increased awareness provided in crew training.

4. Work Environment

Lack of Control Over Work Environment or Decisions

As previously mentioned with the "high stress" risk factor, one major cause of stress results from feeling a lack of control over one's work environment or decisions. Research indicates employees become stressed at work when they have little or no control over accomplishing their tasks. [207, 208] Stress becomes even worse if the job is very demanding. [209, 210] Stress is how the mind reacts to what it sees as an alarming situation, such as excessive workload, under constraints such as lack of time. Under such constraint, a certain amount of panic sets in, and logical thinking is cut off.

Shift work, such as watch shifts on towing vessels, is associated with decreased decision latitude [211] and more stress in general. Because towing vessel work schedules exist in shifts, these crewmembers are likely to be at risk of stress. The degree to which this risk factor affects crewmembers varies with the management styles of companies and senior vessel personnel, but may also be the result of contractual agreements with customers, regulatory requirements, and/or climate conditions. Although it is generally impossible to provide employees a complete sense of control in all cases, it is usually possible to provide them with opportunities to provide meaningful input to the decision-making process. This is one of the reasons behind establishing a CEWG as part of the CEMS process.

For the purpose of the demonstration project, crewmembers were asked how many times per week they felt they lacked control over their work environment or decisions. Though the initial levels of this risk factor were relatively low already, the average crewmember still reported a slight decrease. As seen in Figure 27, only two companies reported slight increases in this risk factor.

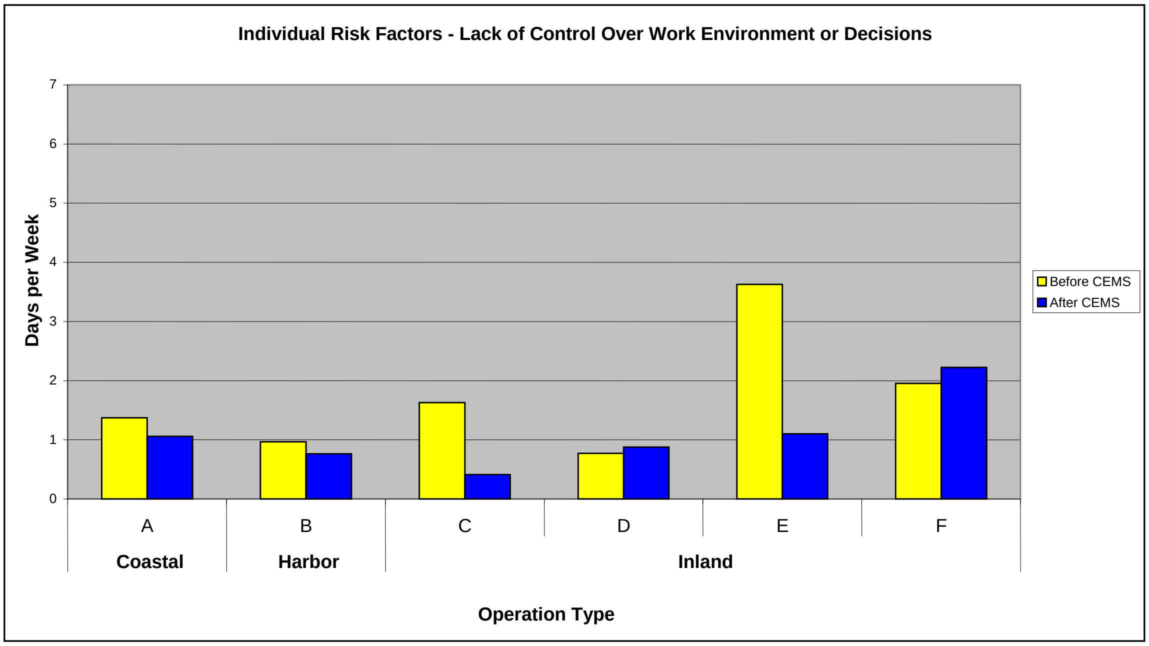


Figure 27. Individual risk factors – lack of control over work environment or decisions.

Extreme Environment

All mariners are occasionally exposed to extreme environments. Towing vessel operators are no exception. Vessels may operate in extreme climates. Very cold weather conditions can put crews at risk of hypothermia, while very hot conditions may put them at risk of heat illnesses, such as heat exhaustion.

Even when exposure to extreme climate is not severe enough to induce illness, extreme temperature, weather, or other working conditions can sap a crew's energy and endurance. Operators of towing vessels may be exposed to heavy seas and ship motions, depending on the operating environment. Some crews, particularly those working in machinery spaces, may be subjected to extreme noises or vibrations. Studies show that when employees work in conditions with such physical stressors, their tolerance for other stressors decreases, as does their motivation. [212, 213] Excessive exposure to these extreme environmental conditions is considered a risk factor because it can reduce endurance and impair judgment.

Cold weather is known to affect human performance. The U.S. Army found that the combined effect of a lowered core body temperature and dehydration contributed to reduced cognitive ability. [214] People exposed to cold weather over a period of time are also inclined to be in a bad mood or unhappy. [215] They may try to cope by thinking about other times and places, [216] causing a loss of situational awareness. Between the reduced cognitive ability and distracting elements, cold weather is a performance safety risk that should be guarded against.

The list of cold weather's effects grows with extended exposure, even to the point of hypothermia, which results from a lowered core body temperature. Chronic hypothermia occurs over a long period of time, lasting six hours or longer, and is a consequence of not wearing sufficient clothing to stay warm. [217] Very early in the process of cooling, an individual with hypothermia will experience impaired judgment due to mental incapacity. [218, 219] Specific mild conditions that are still cool enough to induce hypothermia include wind blowing on exposed skin, temperatures above freezing, and moisture. [220]

For towing vessel crews, that last condition is the most important. Rain, snow, or spray from the water lands on a person and evaporates. The evaporation uses body heat for vaporization, consequently lowering a person's body temperature. When people get their clothes wet, they lose body heat 25 to 30 times faster than if they were dry. If there is wind or a breeze, cooling occurs even more rapidly. [221, 222] At that point, chronic hypothermia may set in. Beyond affecting an individual's ability to work, if not treated immediately, hypothermia can lead to death.

Heat illnesses are most often caused by lack of preparation, working in the heat, and not being acclimatized. [223] The effects of heat usually start in the form of dehydration, which occurs when a person does not drink sufficient fluids to replace those lost through perspiration. Eventually, the body overheats due to lack of water for cooling. This may lead to heat exhaustion, but at the very least, it will affect the person's physical and mental performance.

Heat exhaustion occurs when the environment and activity level overwhelm the body's adaptive responses. [224] When this happens, muscular endurance is reduced and the metabolism starts to burn carbohydrates, which will only provide energy for a few hours. The end result is that a person will become weak, fatigued, dizzy, exhausted, and/or confused, all of which cause poor decision-making.

Motion sickness, or seasickness, is considered a risk factor because it impairs performance, and many medicines to treat it also impair performance. [225] Seasickness is caused by a conflict between the eyes, which perceive that the person is stationary, and the body, which feels motion. [226] A person who is fatigued is more vulnerable to motion sickness than other people, [227] which is yet another reason why adequate sleep is important. If a person is not already fatigued, seasickness may cause fatigue, [228] as well as symptoms such as nausea, dizziness, [229] visual problems including impaired night vision, and memory problems. [230]

Seasickness also has a direct impact on performance. [231, 232] Many crewmembers take over-the-counter or prescription medicines to prevent seasickness. The problem with taking them is, while they may eliminate nausea, they also cause drowsiness,[233,234, 235] so they do not eliminate the danger that a crewmember or operator may fall asleep or become unaware at the wheel. In fact, the danger of drowsiness is so strong that the Food and Drug Administration advises using caution when taking motion sickness drugs and operating a vehicle.[236]

Extreme noise and vibration also have serious effects on crew performance. In 1990, the Department of Transportation's Maritime Administration conducted a study in which long-distance driving was simulated. The study found that people experiencing high levels of noise for four hours performed significantly worse in a simulated emergency situation than people who were not subject to high noise levels. [237] Studies have also shown that whole-body vibration can affect human performance by blurring vision, causing misinterpretation of a situation, fatigue, [238] and accident-prone behavior. [239] Whole-body vibration also compromises the alertness of those operating equipment, especially during long work shifts. [240] Extreme noise and vibration are risk factors because they reduce an operator's situational awareness and ability to prevent accidents.

For the purpose of the demonstration project, crewmembers were asked how many times per week they experienced extreme work environments. As seen in Figure 28, after practicing CEMS and taking risk management measures, five companies either maintained or decreased their extreme environment risk factors. The only company to show an increase in this factor was a line towing company, and that increase was relatively minor.

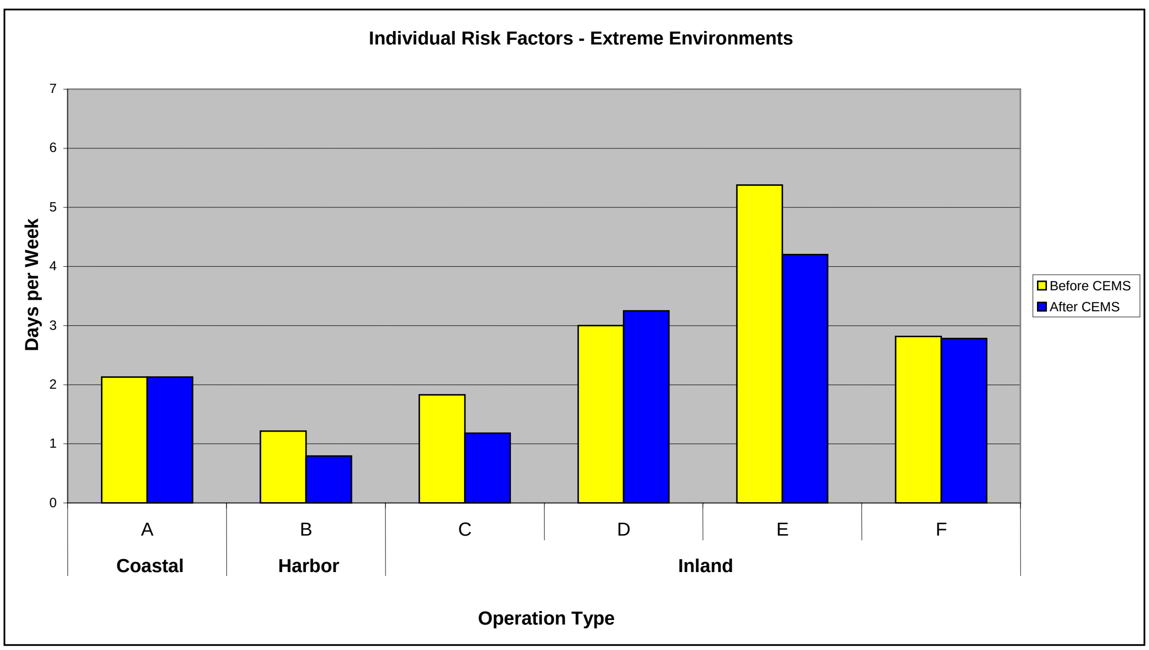


Figure 28. Individual risk factors – extreme environments.

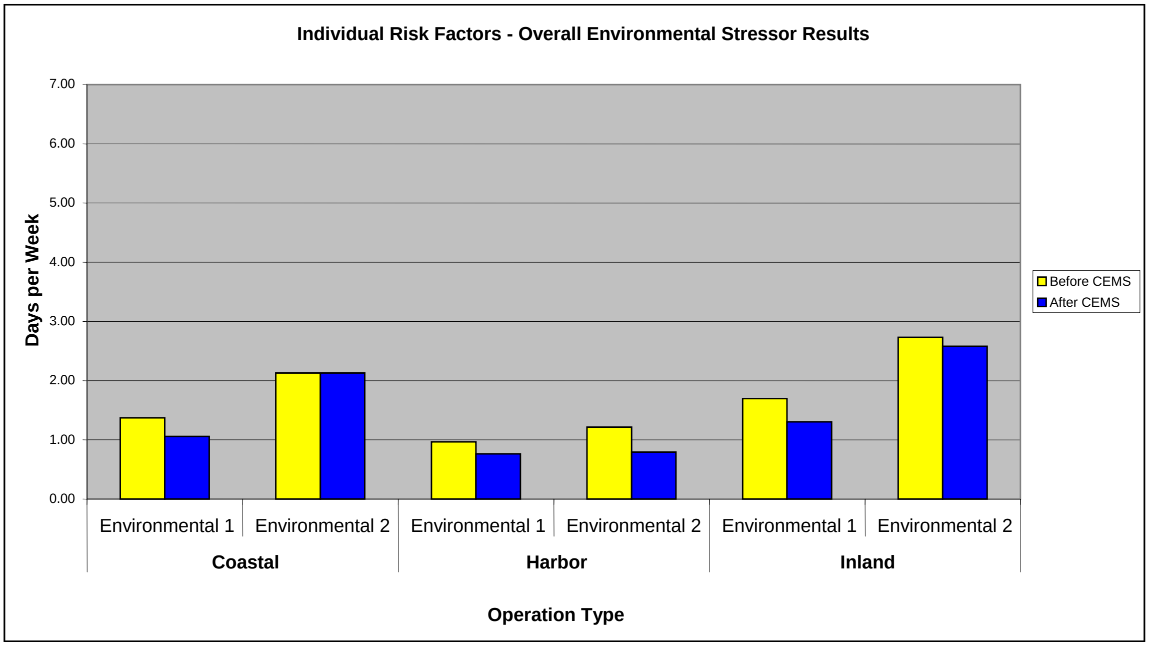


Figure 29. Individual risk factors – overall "environmental stressor" results.

Analysis of Environmental Stressor Results

Lack of control: As seen in Figure 27, most of the values reported at the end of the demonstration project were relatively low, possibly indicating that CEMS offered an opportunity for the crew to voice concerns about their work environment. Of the two companies that reported a slight increase in this risk factor, one did not have coaches onboard to promote communication of perceived risks. It is also worth noting that the coastal towing company that reported an overall increase in the "high stress" risk factor (see Figure 22) did not show an increase or large value for this risk factor. This may indicate that their stress is caused by something other than a sense of lack of control.

In addition, Company C specifically empowered its crewmembers to decide whether or not to attempt light management. The crew of one of their four vessels did not want to take this step and was permitted to hold off on this change. As shown in Figure 27, this company demonstrated a significant reduction in risk regarding lack of control.

Extreme Environments: Given that it is extremely difficult and, in some cases, impossible for a company to change their operating environment, the results seen in Figure 28 are expected. Overall, they are encouraging. While a given company may not be able to control their environment, gaining a better understanding of the endurance-related risks in those environments enables the company to mitigate those risks. Such risk mitigation may take the form of a physical improvement to the vessel (such as adding air conditioning), policy changes (allowing workers to take more frequent breaks in cooler areas during hot days), or simply by reinforcing CEMS practices (encouraging the crew to drink plenty of water, and less coffee or soda).

5. Family Stress and Isolation from Family

Stress from one's family life is just as distracting and likely to cause fatigue as work-related stress. Working on a towing vessel inherently involves traveling and being away from home for extended periods of time. This lifestyle imposes serious strain on crewmembers and their families. Stress stemming from loneliness, isolation, family conflict, and concern about family members can tire and distract vessel crewmembers, which is why family stress and family isolation are considered risk factors.

In 2000, 32% of men and 42% of women said their paid work interfered with their family life. [241] Families provide a source of intimacy, support,[242, 243] continuity, satisfaction, [244] and pride. [245] Vessel crewmembers that leave their homes for extended periods of time miss out on these benefits. In a recent study, families with husbands who worked irregular work hours and during weekends experienced more strain than families with a father that only worked weekdays. [246, 247] Long work hours are often associated with more conflict between work and family needs, and the effect worsens when a spouse must travel for his or her job. [248] In one report, many men expressed wishes to leave their jobs to spend more time with their families, or said they regretted taking a job that took them away from home because they missed watching their children mature. [249]

Another problem occurs when the absences and re-appearances of a traveling spouse become disruptive. The family dynamics have to change as often as the traveler comes and goes. [250, 251] With each departure and arrival, the family members' perceptions of their roles and household rules change, creating family stress. [252, 253] Other problems that arise from this situation are the conflicts that may arise when the spouses do not plan together. [254] If the traveler makes plans without consulting with the spouse, or vice versa, problems at home will likely result. Finally, job-related travel interferes with the traveling spouse's ability to help manage the household. [255] If the traveling spouse has responsibilities that are important to the survival of the family, such as paying the bills, then departures create highly stressful situations. The stress heightens if something goes wrong with anything the traveling spouse is responsible for.

These problems continue as traveling spouses worry about their family members and the impact their absence has on them. They feel guilty knowing that their at-home spouses feel lonely, miss the travelers, resent running the house alone, and worry about the travelers' safety. [256] While travel is a fact of life, it makes both spouses feel lonely because they have lost the benefit of mutual support. [257, 258] For some at-home spouses, the loneliness is so acute they become depressed[259, 260] and seek counseling. In fact, spouses of business travelers file more claims for psychological treatment than spouses of non-travelers. [261]

When a couple has children, both spouses worry about how the children cope with the situation. Traveling parents feel guilty about abandoning their children. [262, 263] Children tend to miss the traveling parent acutely, and they feel vulnerable because the traveling parent always leaves. They also miss having the traveling parent as part of their daily routines, feeling uneasy because of the unpredictability and uncertainty of that parent's schedule. Such maladjustment may be expressed as frequent crying, nervousness, clinginess, troubled sleep, argumentative and defiant behavior, and/or fear and concern over when the traveling parent will return. [264] Another problem is finding care for dependents. Even if spouses at home do not work, they still have to run the household, sometimes requiring dependent care. The logistics of ensuring this care around the clock are difficult because the care is not always available or affordable. [265]

Finally, the return home is often rocky. The traveling parent needs to renew bonds in his or her relationship with the spouse and children. Knowing this, he or she may be tense about the long absence and return home. [266, 267] During the first few days of the return, the family may want the traveler's attention, while the traveler needs to rest, creating a conflict of needs. [268] Some at-home spouses, feeling that their needs are not being met, [269] become difficult with the traveling spouse. On top of this, the traveling spouse often returns home to a heavy workload of household chores to be done. These stressful factors, if considered alone and not in conjunction with the joy of seeing loved ones again, can make the traveler stressed about his or her home life. [270] If traveling spouses feel they are not meeting their families' needs, they may also feel depressed and distressed. [271]

Some traveling spouses lack the knowledge and skill to sustain a marriage. For them, traveling may be an excuse to distract them from home life and escape family problems. However, the problems do not go away. They linger on and get worse from not being dealt with. For those whose marriages do not survive the stress of travel, divorce is ranked as a top life-stressful event,[272, 273] and heightens work stress. [274] If not kept in check, divorce can take a toll on an employee's health. [275]

Other significant events at home can contribute to a person's overall stress. One study found that drivers who experienced stressful life events such as personal conflicts, financial difficulties, illness, or bereavement were five times more likely to cause fatal accidents than drivers not subjected to stress. [276] The death of a loved one is one such significant event that contributes to stress and fatigue. In feeling grief, an individual may experience decreased concentration, sleep deprivation, dehydration, increased distractibility, mental fatigue, and memory loss. [277] All of these effects will detract from alertness and performance. In fact, many mourners are vulnerable to crises such as accidents. [278]

Clearly, family stress is an endurance risk factor. As with most mariners, when towing vessel crewmembers are underway, they are away from their homes for weeks at a time. They experience many of the same stressors as other traveling workers, in addition to a number of other stressors previously discussed. For the purposes of the demonstration project, crewmembers were asked two questions. The first (see Figure 30) regarded how many days a week they experienced family stress (such as that surrounding child or parent care, divorce, and finances). The second (see Figure 31) asked how many days a week they experienced isolation from family members (problems maintaining contact with family).

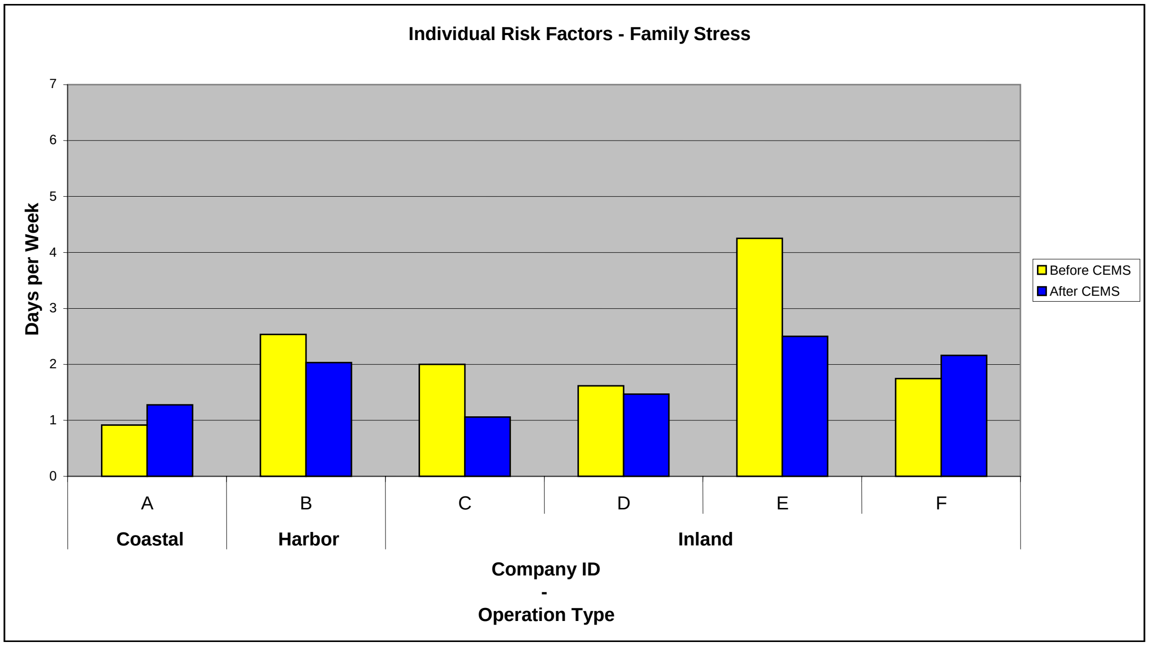


Figure 30. Individual risk factors – family stress.

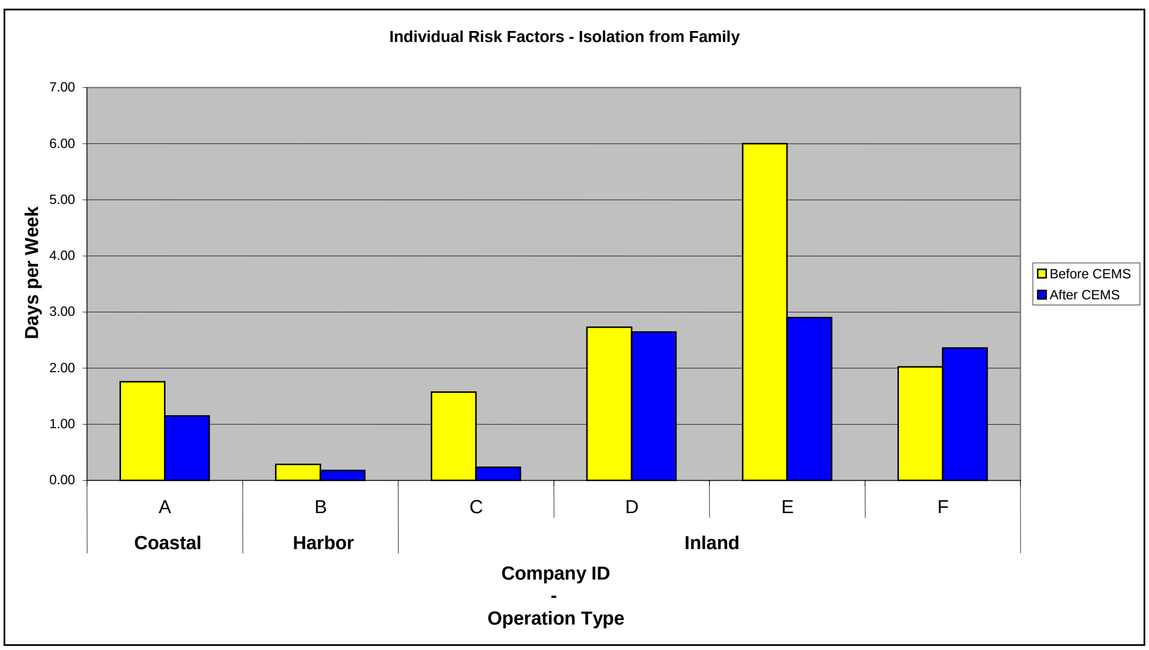


Figure 31. Individual risk factors – isolation from family.

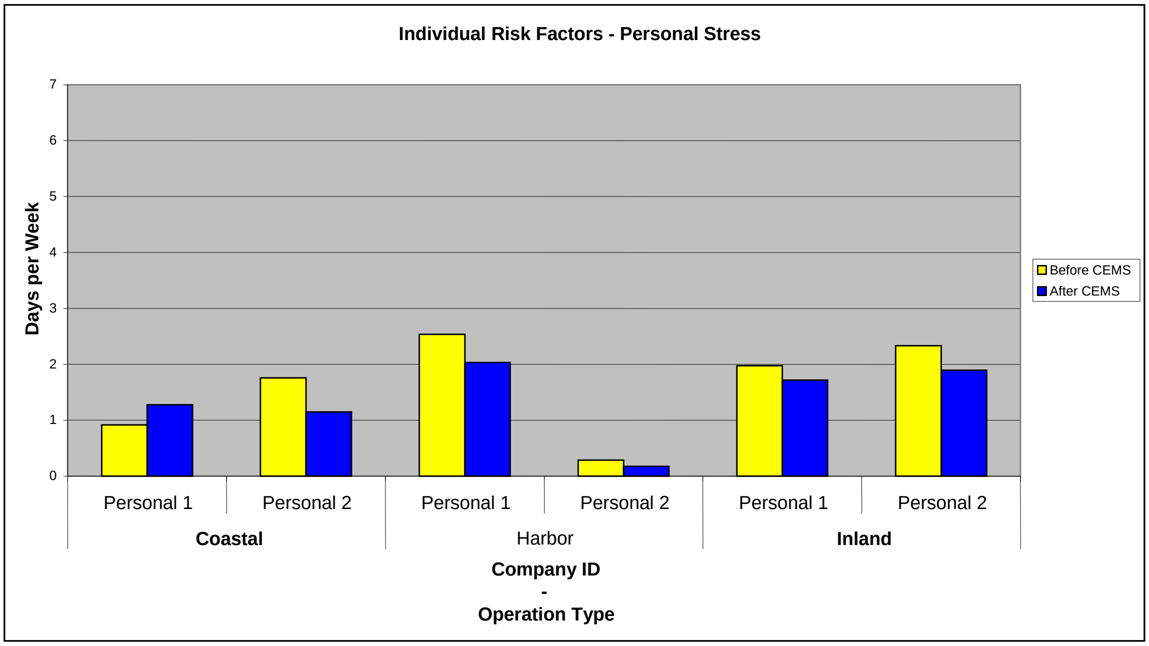


Figure 32. Individual risk factors – overall "personal stressor" results.

Analysis of Personal Stressor Results

As seen in Figure 32, there was an overall reduction in personal stressors reported after practicing CEMS. As seen in Figure 30 and Figure 31, most companies showed significant improvement with both family stress and isolation risk factors. Given that crewmembers have to be away from home to do their job and the fact that companies have little control over their crewmembers' personal lives, we should not necessarily attribute all results to the practice of CEMS. However, simply knowing the current status of their crewmembers' personal stress levels allows companies to provide support where needed. Some of the demonstration project companies already had employee assistance programs in place to provide this support.

One of the practices that may have contributed to improvement is the use of onboard E-mail. Many of the vessels reported they let crewmembers e-mail their families while on the vessels. While crewmembers may have avoided telephoning their families during early-morning shifts when they might be asleep, this new practice allowed the crews to be in touch with families regardless of their shift schedules.

V. MEASURE OF FEASIBILITY: IMPLEMENTATION PROGRESS RESULTS

The demonstration project companies' results clearly demonstrate that, when an organization follows the implementation process, CEMS can effectively address endurance-related risks. However, in order to be effective over the long term, CEMS must be something that every company can reasonably do – it must be feasible.

This section assesses CEMS' feasibility by reviewing how well the demonstration project participants were able to implement individual steps and components of the process. Our assessment compares how far along participants were at the beginning of the project to their status at the end.

One known limitation of this method is that it is difficult to accurately capture a company's progress over such a limited period of time. The demonstration project was only six months long, whereas full CEMS implementation can take several years. In addition, while some of the participants had already been practicing CEMS well before the beginning of the project, others were just getting started. Despite these limitations, this "before and after" snapshot of these companies at various stages of the program allowed us to gauge progress throughout the entire CEMS process.

To determine each vessel's extent of implementation, vessel representatives answered a series of questions related to the CEMS process and its key components (see Enclosure 4). As previously mentioned in Section II, "The Solution," the CEMS process involves forming a Crew Endurance Working Group (CEWG), analyzing the current situation, developing a Crew Endurance Plan, implementing the plan, and evaluating the results. The cycle then starts over again, with the CEWG analyzing the new situation.

Included in the Crew Endurance Plan are the components of CEMS that the company intends to implement: education, environmental changes, light management, trained coaches or acceptable alternatives, and schedule changes. Generally speaking, these components must be implemented in sequential order for a CEMS program to be successful. However, all aspects of each component need not be perfectly completed before moving on to the next step. For example, a company may first make some of the more cost-effective environmental changes identified by the CEWG and save other, more costly solutions for later. In general, a company can show progress by advancing through the CEMS process and by exerting a demonstrated good-faith effort to reduce relevant risk factors.

Coaches

While it is not required that vessels have a trained coach or acceptable alternative onboard each vessel at the beginning of the process, we began by gathering such information as a way of assessing where vessels were in the overall CEMS process. This told us whether or not there was onboard support for CEMS, and also gave us a general indication of the crew's depth of understanding the program.

Over the course of the demonstration project, as shown in
Figure **7**, four companies increased the number of coaches onboard their vessels, one stayed the same, and two obtained no coaches. Company B, a harbor tug operation, had just started CEMS at the beginning of the project, but was able to put a certified coach on every vessel before the end of the six-month period. In general, companies that had more coaches showed the greatest reduction of risk factors. As seen in Figure 33, the companies cumulatively trained 326 additional coaches (beyond those initially involved in the project) during the project's six-month period. Most of these were trained through two of the larger companies participating in the project.

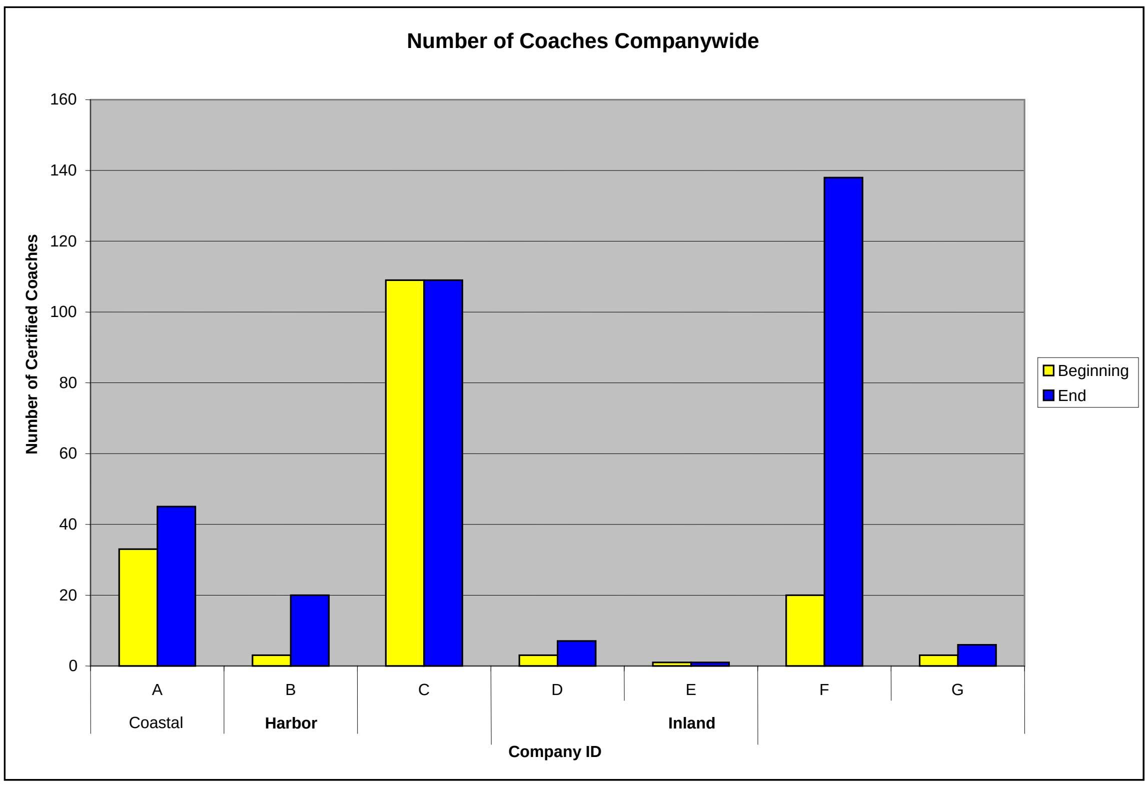


Figure 33. Number of coaches companywide at beginning and end of project.

Education

The first component of CEMS is crew education. This is how the crew learns the basics of improving their endurance. To assess company success in providing this training, we asked vessel representatives how many of the onboard crew were originally trained, and how many more were trained by the end of the project. These results are seen in Figure 34 and 35.

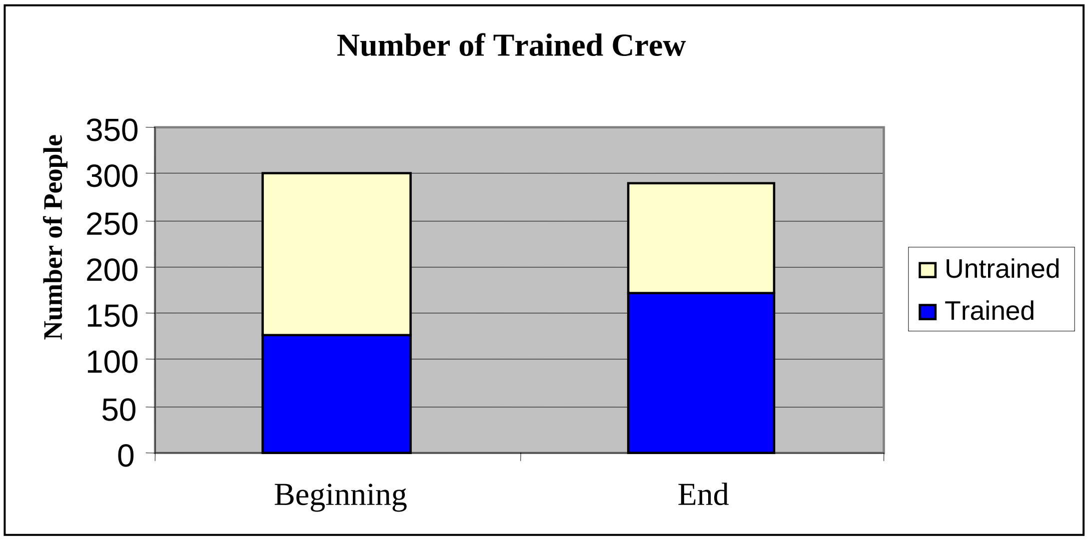


Figure 34. Number of crew trained in CEMS by beginning and end of project.

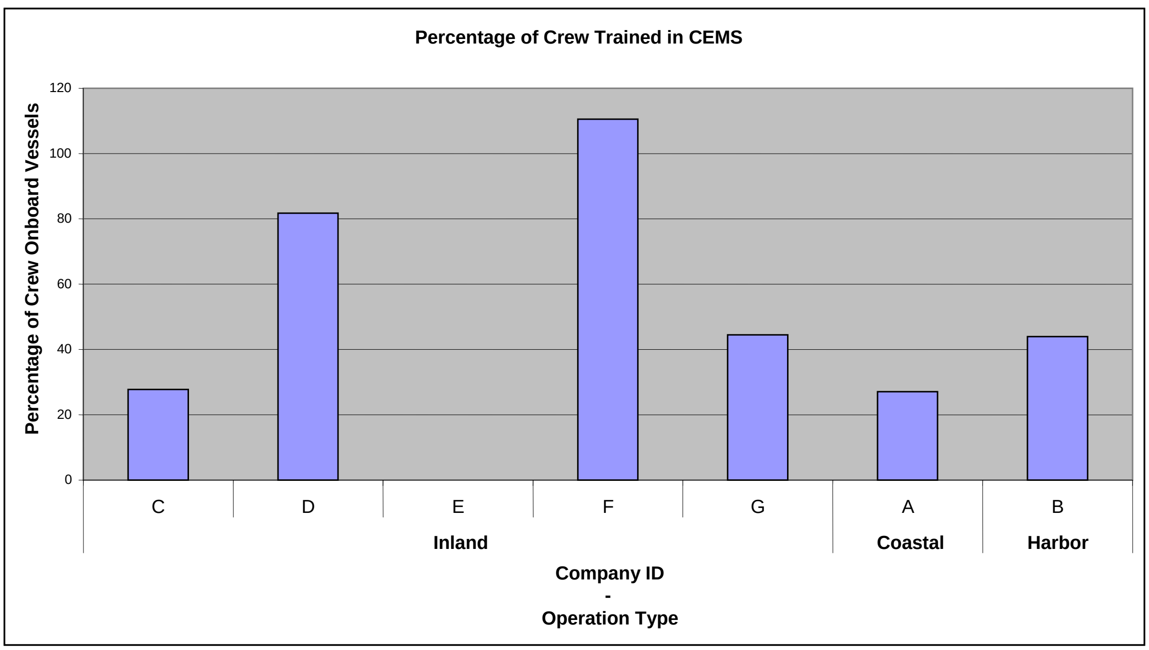


Figure 35. Percentage of crew trained in CEMS by end of project.

Averaging all companies, vessels, and crews, nearly 60 percent of all crewmembers received CEMS education, as seen in Figure 34. Figure 35 shows two of the companies were able to educate at least 80 percent of the onboard crew with CEMS training, four others trained less than 50 percent, and one trained no one. Given the typical rate of crew turnover and crew rotation onto vessels not practicing CEMS, this result is generally favorable. One company showed a training rate of over 120% due to the fact they were implementing CEMS fleet-wide, and therefore trained all crewmembers. The fact that a company with one of the largest towing fleets in the country can achieve this amount of training in such a short period of time proves that vertical alignment can have a strong impact on a program's success.

Participating companies were also asked how many hours of CEMS training the crew received during the project. As shown in Figure 36, on average, each vessel performed less than two hours of CEMS training per month. Companies C and F, the two companies that were most successful in implementing CEMS, performed over four hours of training each month. Given the fact that some of the other vessels were just getting started in CEMS and had more to learn, it would seem that they would require more training time. It is possible that more training would have helped these companies show better results in reducing their endurance risk factors. In any case, two to four hours a month is probably a feasible amount of CEMS training for most vessels.

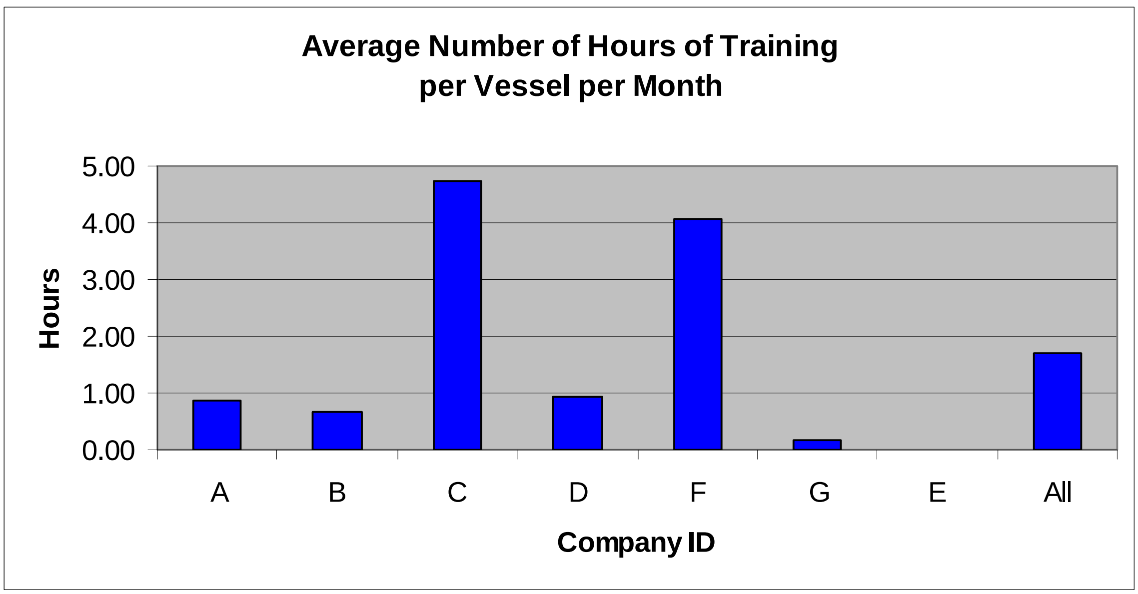


Figure 36. Average hours trained per vessel, per month, by end of project.

Crew Endurance Plan (CEP)

As previously stated in Section II, "The Solution," developing a CEP is a critical step in the CEMS process. As seen in Figure 37, Company B's increase in number of vessels with a CEMS plan was the only significant change here. Among the companies that reported the most success with reducing risk factors, all but one, Company C, reported having a CEP in place by the end of the project. However, Company C did have detailed, written plans for diet, light management, and other key elements of a CEP. All of the participating companies reported having a CEWG.

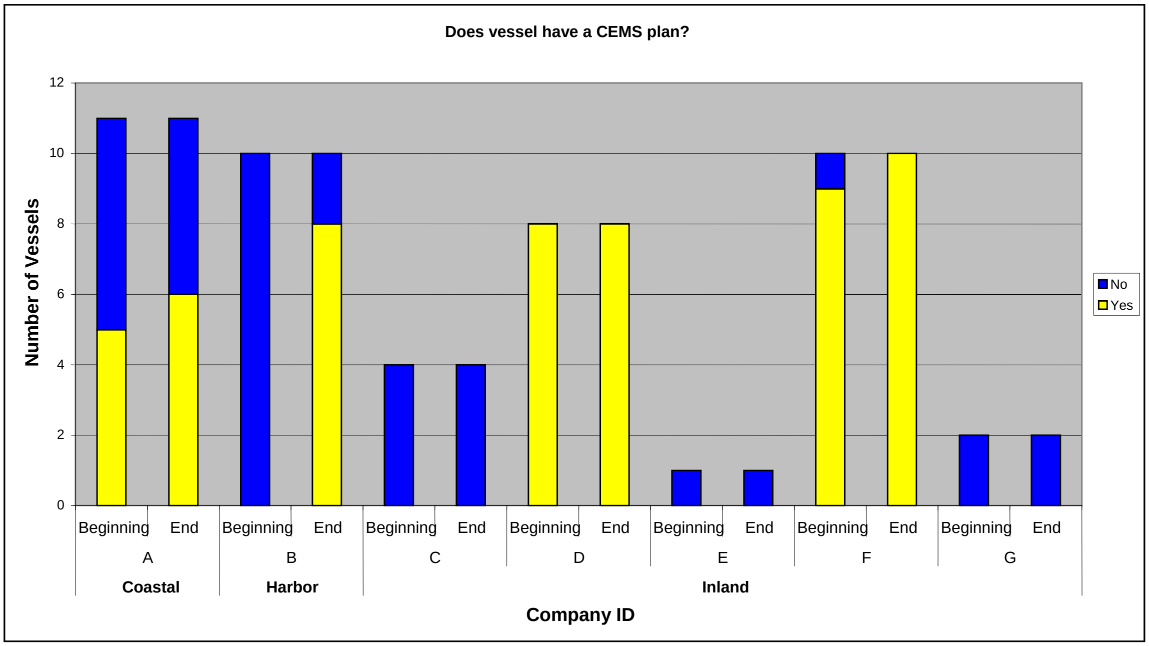


Figure 37. Number of vessels with a Crew Endurance Plan by beginning and end of project.

Environmental Changes

Another key component of CEMS involves making changes to the work and rest environments to improve endurance. Based upon an assessment of crew endurance risk factors and input from the CEWG, companies can decide to make physical changes to the vessel or change certain policies. The CEWG, in conjunction with the company, determines what changes to make. In general, however, they should focus on applying changes that have the greatest overall risk reduction for the least cost.

There are a number of changes that can be made to vessels to improve crew endurance, and some appear in one form or another on nearly every vessel. For the purposes of this project, we identified a number of common physical and policy changes and asked vessel representatives to assess, first, whether or not that improvement was needed on each vessel. We then asked them if improvements had been made to the vessel in these areas, regardless of whether or not the crew had identified the need for improvements in these areas.

Physical Changes

Sufficient Lighting: Participants were first asked whether or not the vessel initially had sufficiently intense lighting where required. This meant having sufficiently bright lights in work and common areas to support proper light management and to shift the crew's

Red Zone. Generally speaking, there must be at least 1000 lux of bright white light at eye level to affect melatonin secretion and circadian rhythm. More advanced options include the installation of 300-lux monochromatic green lights.

Of the 21 vessels that reported lighting was inadequate at the beginning of the project, two-thirds were able to make the necessary upgrades, as seen in Figure 38. The other 25 vessels in the project said that their initial lighting was adequate, and five of those went on to make improvements anyhow.

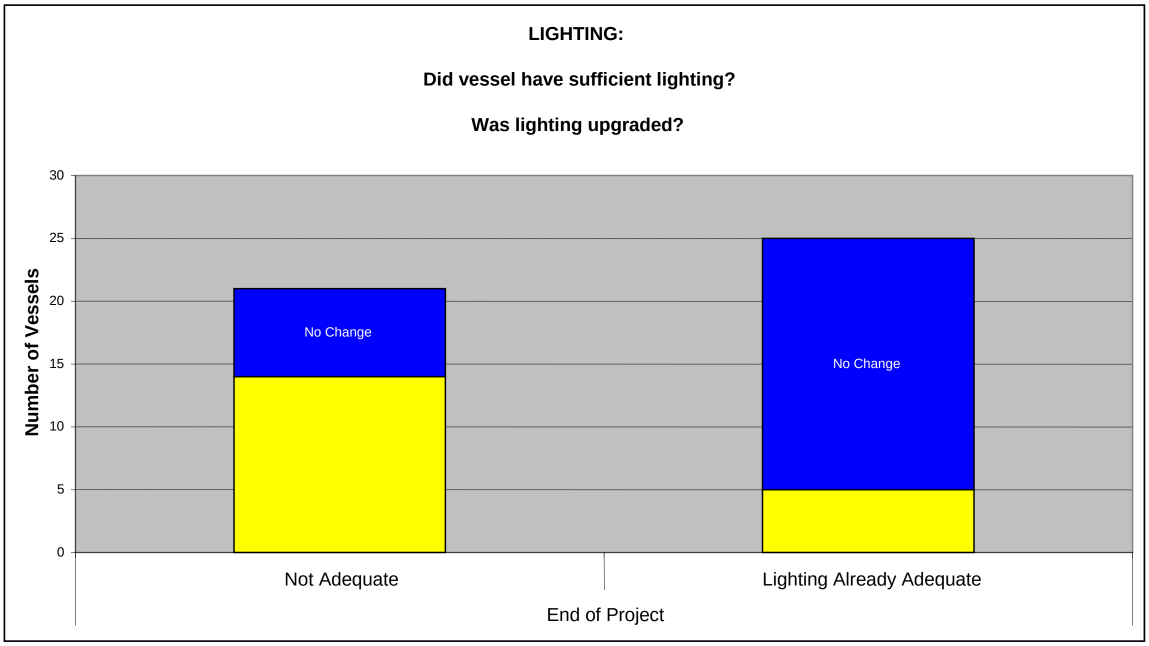


Figure 38. Number of vessels sufficiently lit by beginning and end of project.

Some who identified lighting as an issue indicated that their vessel's age and design may have been a factor. Some of the older vessels did not have adequate electrical wiring to permit upgraded lighting at the time. This may be resolved over time, as vessels go through normal renovations or are replaced by more modern vessels. Given that these changes can be fairly costly (as much as several thousand dollars per boat), it is encouraging that so many vessels chose to make the lighting modifications.

The installation of monochromatic green light to sustain crew alertness is not yet widespread amongst demonstration project participants. Some companies that have installed green lights have experienced difficulty obtaining the lights, problems with getting the crew to understand and accept their use, and challenges installing the lights in a way so as not to interfere with safe navigation. Although proper use of monochromatic green light has been shown to be effective for shifting the Red Zone, details of practical implementation of this technology are still being worked out. Many of these issues can and will be resolved as we gain more experience with this cutting-edge technology. In the meantime, we encourage those implementing CEMS to consider and deploy this technology with the understanding that this particular solution is evolving. Companies that are not willing to make this kind of investment can still achieve similar results by using 1000-lux white light, though it must be carefully used at night so as not to interfere with crewmembers' night vision.

Figure 39. Green light installed over doorway to prevent circadian rhythm disruption.

Sufficiently Dark Rest Areas: Other common physical improvements are those made to ensure the darkness of a crew's sleeping area. In general, the ideal sleeping atmosphere is one of complete darkness. Some vessels do not support quality sleep due to brightness coming from port lights, or other light pouring in through windows or doorways. As shown in Figure 40, all eleven vessels that identified the need for improvement in this area made modifications to improve the sleep environment. Also, over one-third of those vessels where conditions were already adequate made improvements anyway.

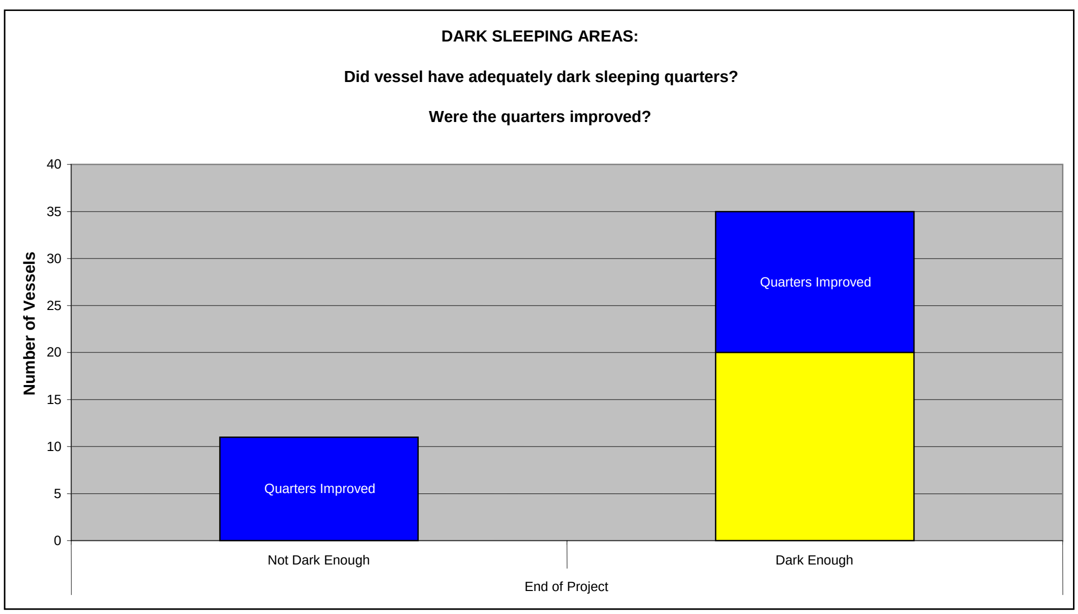


Figure 40. Number of sleeping areas sufficiently dark by beginning and end of project.

This result is not surprising, since it is usually very easy to keep sleeping quarters sufficiently dark using inexpensive measures, such as blacking out windows, installing window covers (as seen below), and installing night lights (also below).

Figure 41. Window cover and night light used to keep sleeping areas sufficiently dark.

Noise and Vibrations: The next two measures evaluated acceptable noise and vibration levels in sleeping areas. As previously described, excessive noise and vibration can easily affect sleep quality. While it may not be possible to create a perfectly quiet, vibration-free sleeping area onboard a small vessel like a towing vessel, there are still many measures a company can take to improve conditions.

As shown in Figure 42, only four of the 25 vessels on which noise was identified as an issue were able to make improvements. Eight vessels made changes even though their noise levels were initially deemed to be acceptable.

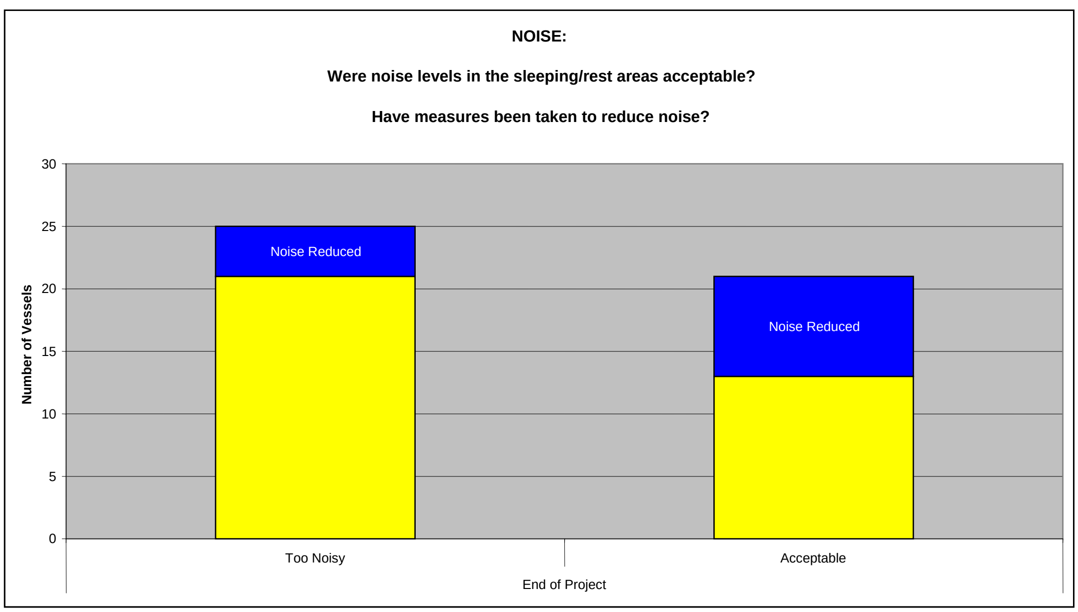


Figure 42. Number of sleeping areas sufficiently quiet by beginning and end of project.

Figure 43, nearly two-thirds of 24 vessels where vibration was identified as an issue were able to make improvements, and another 21 were able to make improvements even though vibrations were not initially identified as a problem.

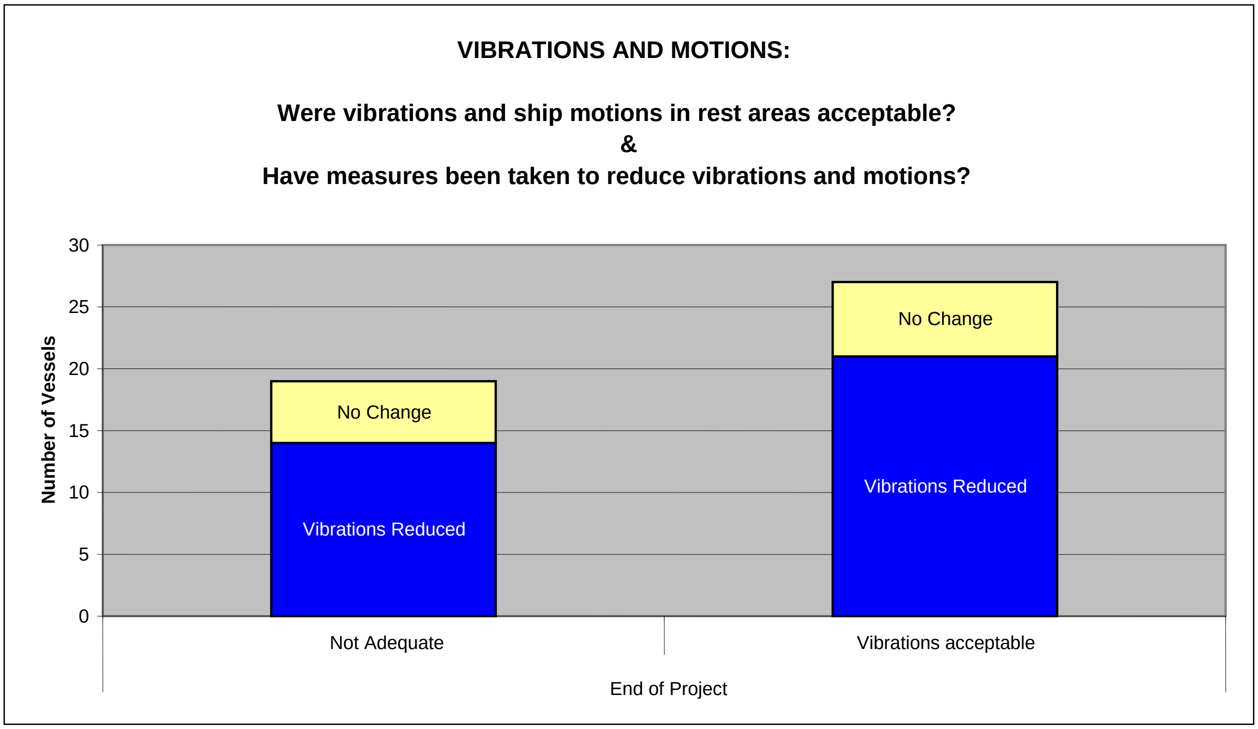


Figure 43. Number of sleeping areas with sufficiently reduced vibrations by beginning and end of project.

Several companies conducted load-testing on their vessels to evaluate vibration issues. For example, one company tested boats coming out of a major shipyard period on a calibrated pushpad to properly adjust vibration levels. Another company installed hospital-grade mufflers to reduce noise and vibration.

Given that noise and vibration are problems that can be difficult and expensive to resolve on an existing vessel, these results are encouraging. Since implementing CEMS, some of the participant companies have identified noise reduction measures they intend to perform as vessels go through renovations. These included plans to replace existing compressor and generator mounts with sound-deadening material and to add soundproofing insulation to floors and walls. Figure 44 shows two pictures of a compressor in which the existing mounts offer no reduction to noise and vibration communicated through the hull and structure. The company is planning to replace them with sound-deadening mounts.


Figure 44. One company intends to reduce noise and vibration by replacing these current compressor mounts with sound-deadening ones.

Air Quality: Air quality also affects crewmember sleep quality. Air temperature, humidity, odors, and fumes can greatly affect comfort and make it difficult for crew to sleep. In the case of demonstration project participants, only three vessels identified this as an issue, and one made necessary improvements, as shown in Figure 45. Some vessels reported installing additional filters and ducting during shipyard periods. Some boats requested and were permitted to install air filtering machines in crew quarters. Most modern towing vessels have air conditioning of some sort, so this result is not surprising.

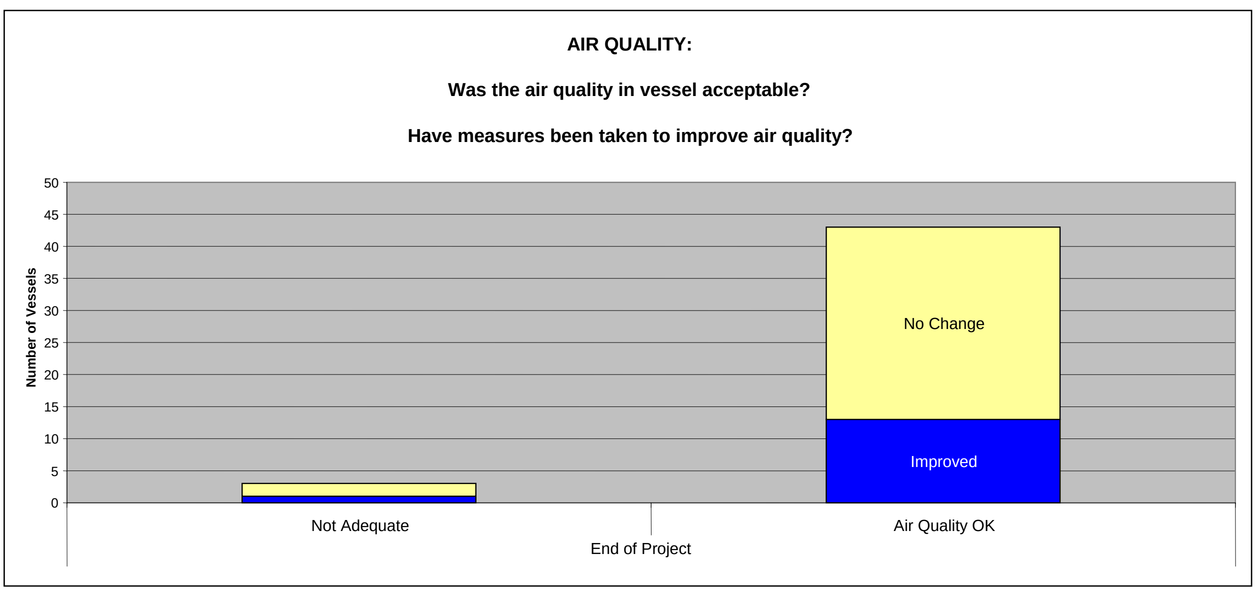


Figure 45. Number of vessels with acceptable air quality by beginning and end of project.

Diet: As previously mentioned, the crew's diet affects several facets of endurance. Good nutrition is important to energy and health, which ensure long- and short-term crew endurance. For the demonstration project, we asked vessel representatives whether or not the food provided onboard vessels conformed to recommendations in CEMS guidelines.

As shown in Figure 46, most of the vessels in the demonstration project improved the crew's diet, even those who reported that the original diet met CEMS recommendations. Correlating this with the individual risk factor data, we found that of the 32 vessels that reported either already having a proper diet or improving the crew's diet, 27 vessels (84 percent) showed a reduction in their "diet" risk factor. Three vessels reported an inadequate diet, did nothing to improve it, and reported an increase in their "diet" risk factor.[xii]

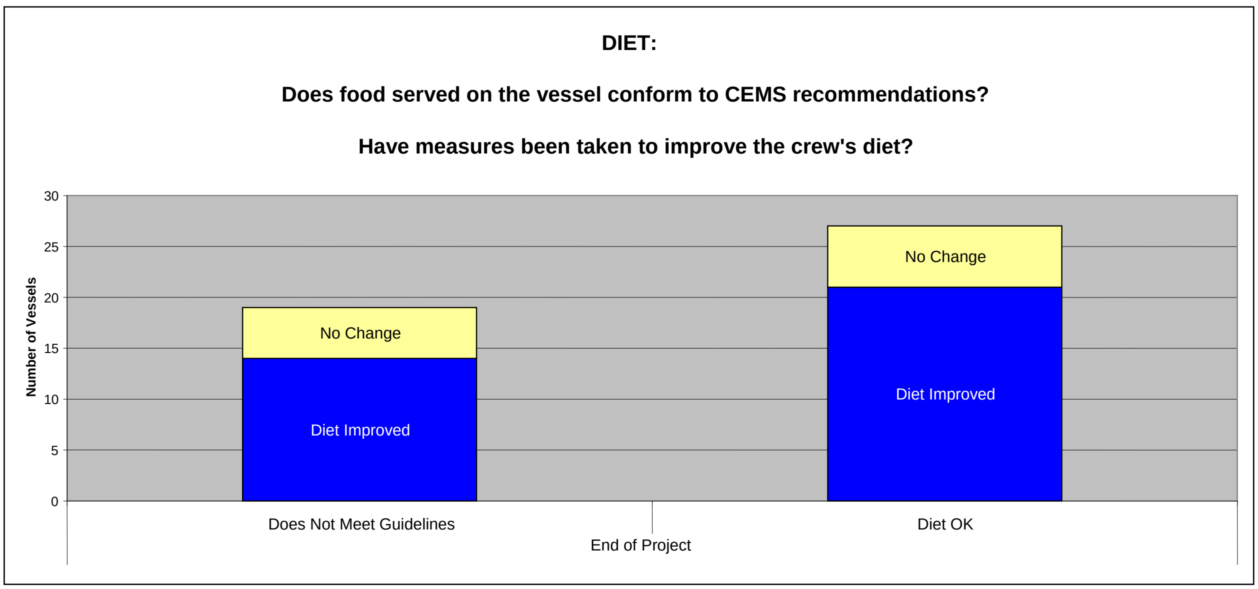


Figure 46. Number of vessels providing sufficient diet by beginning and end of project.

The extent to which diet was modified appeared to have been controlled, to a large extent, by how food was provided to the vessel and how crewmember meals were prepared. Some vessels had onboard cooks, allowing relatively easy adaptation to a good diet if the cook supported it, and a difficult adaptation if the cook did not. Some smaller vessels did not have cooks onboard, so food preparation was either a side job for one of the crew, or left to each individual. In that case, the quality of each crewmember's diet was largely a function of that individual's understanding of good nutrition and personal belief in the CEMS program.

[xii] Two vessels that reported inadequate diet and made no changes did not provide correlating individual risk factor data.

In any case, crewmembers can only make healthy choices if the food onboard supports them. Some companies allowed crewmembers to purchase and select their own foods. Here again, the nutritional quality of the food selected was a function of whether the person who bought the food understood and supported the importance of nutritional choices. Several companies had meal plans as part of their vessel management guidelines. Other companies report plans to move to a more standardized meal and food inventory plan.

These results are encouraging and also surprising; overcoming years of towing vessel tradition and cultural preferences is no small task. Such history tells us that towing vessel crews are firmly entrenched in diets of high-fat, high-carbohydrate food. As the results show, however, crews *can* be persuaded to make healthier choices.

Policies: Not all environmental changes require a physical change to the vessel. Some require a change to company policies or operational procedures. Many company policies directly or indirectly affect crewmember sleep quantity, sleep quality, and personal activities that promote or diminish crew endurance. Five policy areas that frequently need to be addressed are:

- *Courtesy* – Preventing noises or other activities that will unnecessarily disturb sleeping, off-watch crewmembers;

- *Alternate Shower Times* – Permitting crewmembers to take showers at times that enable them to maximize their sleep period;

- *Alternate Meal Times* – Permitting crewmembers to take their meals at times that enable them to maximize their sleep period;

- *Napping* – Permitting crewmembers to take naps during work shifts so they can make up lost sleep; and

- *Maneuvering* – Directing vessel operators to avoid the excessive use of throttle when maneuvering the vessel to reduce noise and shuddering.

Figure 47, vessel representatives stated that nearly every vessel either had a policy in place, or modified a policy to support CEMS. Given the fact that making these kinds of policy changes is relatively easy, the results are what we expected. The two vessels that belonged to a company just starting on their CEMS program did not yet have all necessary policies in place by the end of the study period.

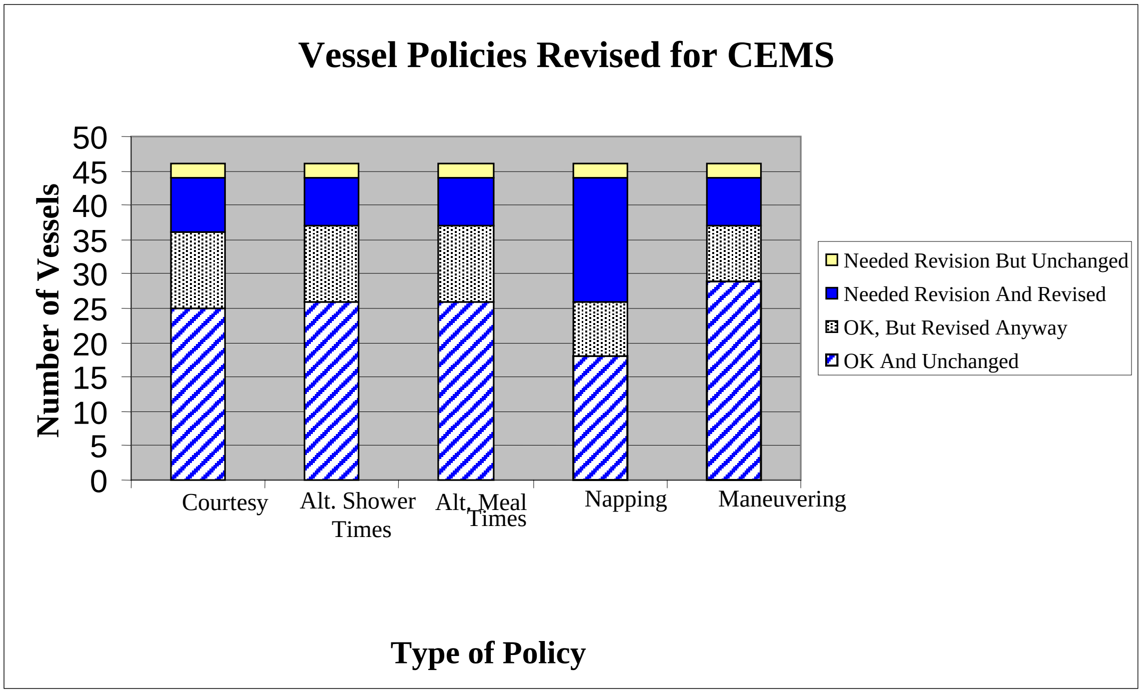


Figure 47. Number of vessels that revised policies.

Through the course of gathering information on policy changes, we learned that for some companies these policies are informal and unwritten. In some instances, this may have affected their ability to address endurance risk factors. This is particularly true for the companies that did not have onboard coaches to ensure consistent application of the policies. One of the companies that demonstrated consistent reduction of risk factors throughout the project attributes part of their success to establishing written policies.

Other Policies or Physical Modifications: We also asked the demonstration project participants for other modifications or policy changes that might support CEMS. Below is a list of some of the changes identified by the participants:

- Many upgraded mattresses on their vessels;

- One group of vessels identified a condensation problem, causing crewmember bunks to become wet. The bulkhead gathered condensation because the berthing area was adjacent to a fuel tank. The company decided to look into applying a paint-like insulation to the bulkheads to reduce or eliminate this problem;

- Some companies established non-smoking boats and provided incentives for crews not to smoke;

- Since some crews arrived at their vessels already fatigued after traveling several hours to get there, some companies adopted new commuting practices. One of the larger companies used centralized crew-change locations and transported crewmembers to vessels with a company van. The same company also arranged discount hotel rates for crewmembers arriving early to report to a vessel, and had company barracks at one of their major facilities. It also offered housing near a training center where crewmembers could stay;

- Some companies installed wheelhouse alerter systems designed to indicate when the vessel operator on watch was incapacitated or inactive. Most of these systems use sensors set up to monitor the entire wheelhouse. If the system detects no motion for 40 seconds, an alarm sounds in the wheelhouse. If the operator doesn't push a response button within 10 seconds, a general alarm sounds. There is also a panic button the operator can push to call for help. Both the response and panic button are located within easy reach of the operator. While such systems do nothing to prevent fatigue from occurring, and involve some trade-offs and limitations, they may provide an additional safeguard in the event a crewmember falls asleep or is incapacitated;

- Some companies installed satellite television systems on their boats to provide crew entertainment (and good morale) during rest times; and

- Some companies installed exercise equipment on their vessels.

Light Management

As previously mentioned, light management is a practice used to control exposure to bright light to re-synchronize circadian rhythms to an onboard work/rest schedule. This CEMS component requires a certain level of maturity in a vessel's CEMS program. Though essential for shifting a crewmember's Red Zone, to be implemented successfully, it is important that certain elements are already in place. The vessel must first have adequate lighting, and then needs a knowledgeable coach to help the crew reinforce the proper practice of light management.

Only five vessels were able to begin practicing light management if they had not already started to do so before the study period began. Those already using light management continued to do so, but some of the other companies did not get this far in the six-month time period as shown in Figure 48. The five additional vessels were from companies that had more mature CEMS programs, which may have helped to facilitate these changes.

It is important to note that nine of the vessels that reported not using light management were day operations. Though occasionally called upon to work late at night, particularly during their duty nights, the crews of these vessels were day-oriented. They were technically already practicing light management simply by exposing themselves to normal sunlight.

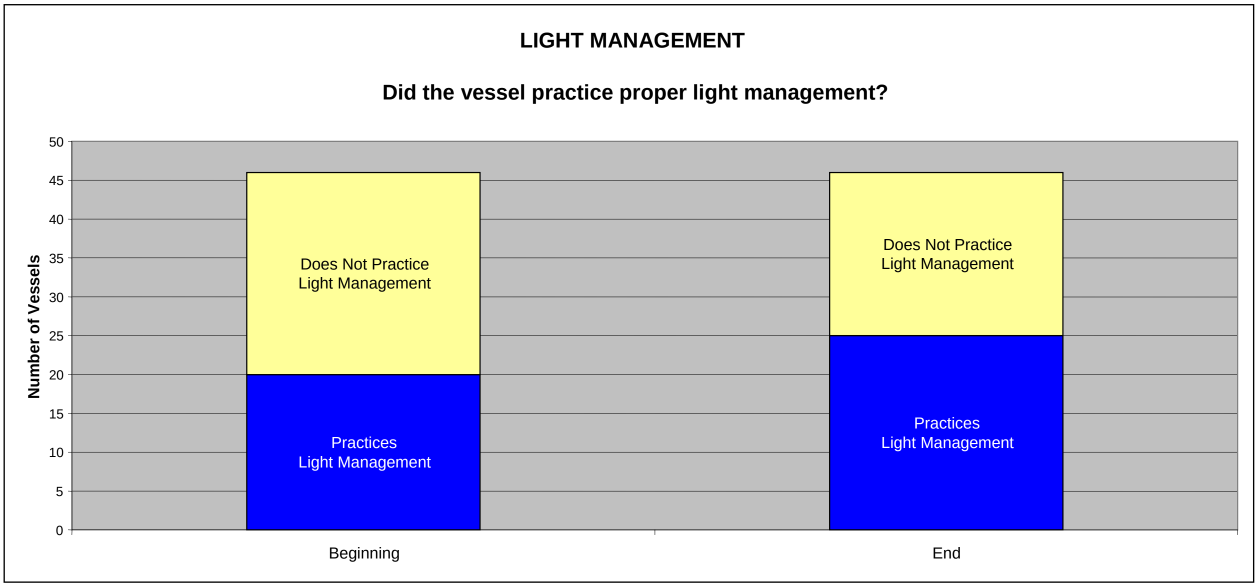


Figure 48. Number of vessels practicing light management by beginning and end of project.

Watch Schedule Changes

The final component of CEMS, watch schedule changes, is always applied after all other CEMS components are in place. It is essential to do this step last to ensure that the necessary elements of support are in place. Because this is the last component, we would not expect to see most vessels get so far in a short, six-month time frame. Nevertheless, some vessels did.

As shown in Figure 49, at the beginning of the CEMS project, most of the vessels reported a 6 on – 6 off watch rotation. This has been the standard watch system of the inland towing industry for decades. One of the endurance risk factors inherent in this watch system is that since two people trade watches every six hours, it is impossible to get seven to eight hours of continuous sleep.

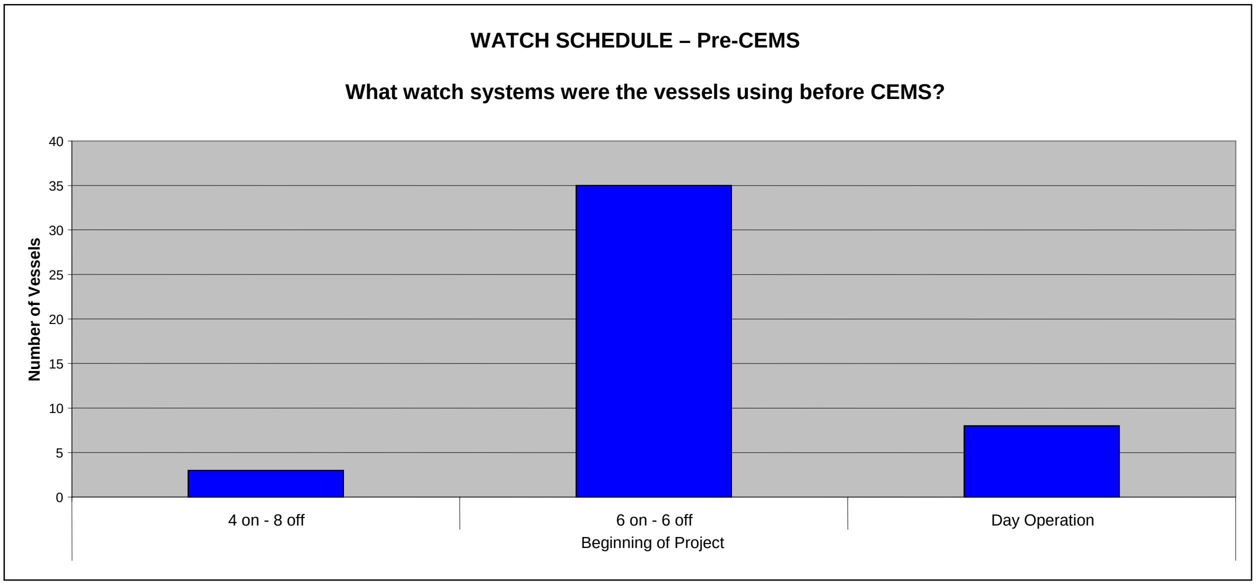


Figure 49. Vessel schedules at beginning of demonstration project.

As seen in Figure 50, by the end of the project, 13 vessels changed to either a 7-7-5-5 or 8-8-4-4 rotation. In addition, four of the vessels that retained a 6 on – 6 off schedule shifted their morning watch relief time to ensure that the off-going crew would not be exposed to morning sunlight. One company was very creative in its watch schedule change process. They made incremental changes over a period of time, with excellent success.

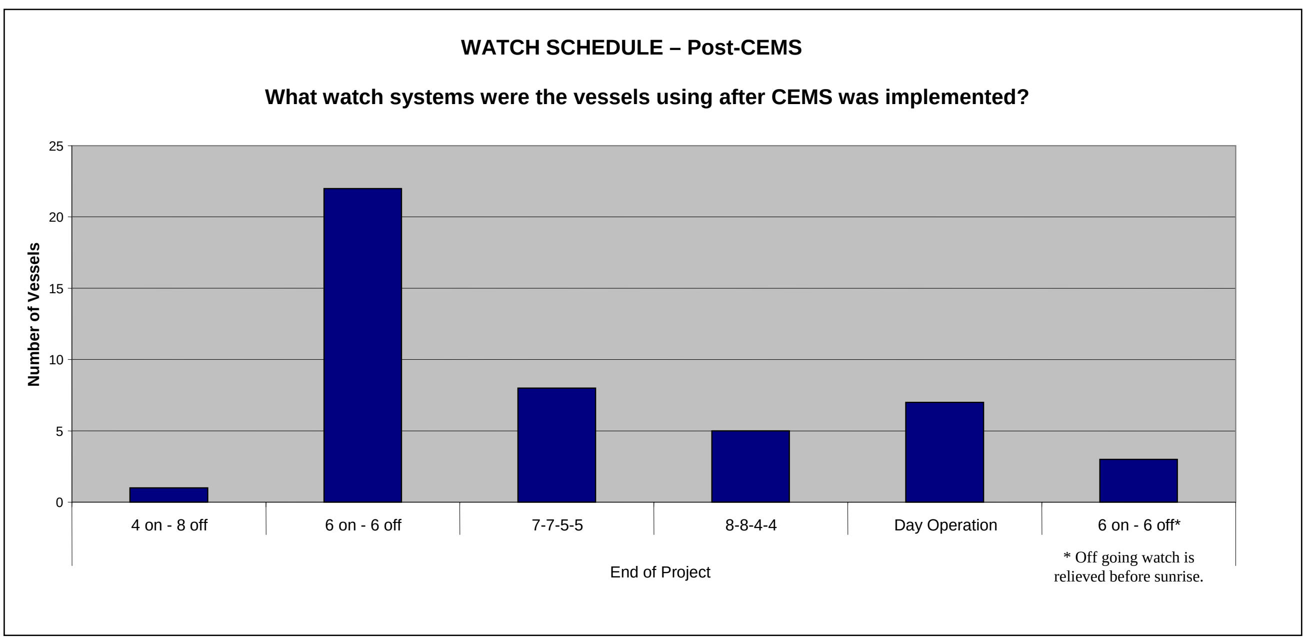


Figure 50. Vessel schedules at end of demonstration project.

These watch schedule changes demonstrate two important aspects of CEMS. First, the vessel crew and company themselves decide which watch system to use. CEMS only requires that the watch schedule support light management and provide the mariner a long continuous sleep period, ideally 7-8 hours.

Secondly, though the CEMS components should be applied sequentially, the overall CEMS process is one of continuous improvement. Those vessels that have not yet made schedule changes can continue to work towards them. For some vessels, this step may never be necessary, as in the case of the day operations. However, there are measures to improve endurance throughout the process, and those who participate in the process are able to reduce endurance-related risks.

Beyond the Demonstration Project

In addition to the vessels in the demonstration project, many participating companies have other vessels in their fleets using CEMS. We can see a massive increase in the number of vessels participating in CEMS in Figure 51. Within the demonstration project's time frame, the number of participating vessels increased from 59 at the beginning of the project to 419 just six months later. In fact, the final number of CEMS vessels for companies A, C, and F represents those companies' entire fleets.

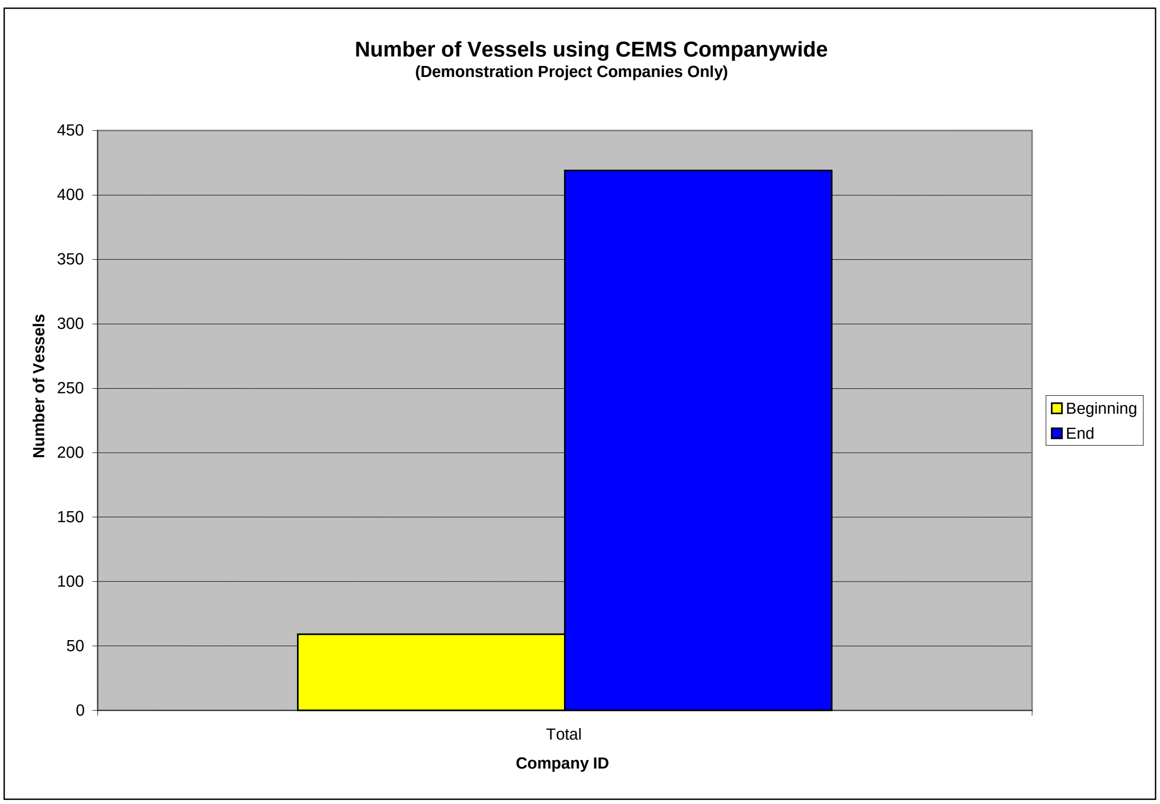


Figure 51. Demonstration project vessels using CEMS companywide.

Feasibility Measures - Overall Results

Taken as a whole, participants in the demonstration project showed significant progress with every step in the CEMS process, including each of the key CEMS components. This progress is all the more impressive given the relatively short time frame of the project and the voluntary, self-applied nature of the CEMS process. The extent to which each vessel was able to make progress was greatly influenced by the maturity of the company's CEMS program and the strength of its vertical alignment.

Attaining a mature CEMS program takes time. As previously stated, six months is an extremely short period to evaluate such a program. CEMS requires many cultural and organizational changes which can take years to fully establish. As the results have shown, obtaining buy-in from everyone in the organization, from crewmembers to senior executives, is essential and takes time. The companies that were able to make the most progress over the course of the project were those who have been working with CEMS for some time. As demonstrated by one of the project participants, establishing the necessary foundation for implementing CEMS can take many months.

Assessing the extent of a company's vertical alignment can be difficult, but company policies can be strong indicators. By officially allowing crewmembers time to take care of personal issues like meals and hygiene, companies send signals that they support CEMS. Similarly, they demonstrate commitment to CEMS by installing physical improvements like noise-reducing material in crew berthing areas. Companies demonstrating solid vertical alignment in this manner also showed the greatest reduction in overall endurance-related risk.

It should be noted that the demonstration project was entirely a volunteer effort, with minimal intervention by the Coast Guard. The companies identified areas for improvement and decided which to make without any direct oversight. Although the Coast Guard developed the CEMS process and the related supporting training, guidelines, and job aids, it was entirely up to the industry representatives to implement CEMS in their companies in their own way.

VI. MEASURES OF SUSTAINABILITY

The previous section gave us an indication of how feasible it is for an organization to work through the CEMS implementation process. This section looks at the long-term sustainability of CEMS for the complex system of maritime transportation companies, regulators, educators, customers, and vendors.

CEMS is a continuous-improvement process that companies must continue to follow for years to come. It is not a one-time fix, but a change that becomes part of an organization's safety management system and maritime safety culture. This section considers two areas that affect the long term sustainability of CEMS: the supporting infrastructure required; and resource implications for industry as well as government.

Infrastructure Required

Many of the elements necessary for long-term sustainability of CEMS have already been developed and deployed. The Coast Guard has produced a number of informational sources and job aids to assist organizations implementing CEMS. These include detailed guidelines for how to implement a CEMS program, software to support risk assessment and onboard training, a website and electronic newsletter to keep practitioners up-to-date, and a Coast Guard-approved Coaches Training program. Private training organizations, with oversight from the Coast Guard, have produced CEMS training videos and DVDs. Industry representatives have developed additional guidelines and share best practices with each other.

However, as reinforced by the results of this report, the effectiveness of CEMS is highly dependent upon the onboard support provided by a coach or acceptable alternative. Furthermore, each company implementing CEMS will ultimately require at least one trained coach to provide the technical expertise needed to set up a CWEG, assess the relevant risk factors, recommend effective solutions, and evaluate the results. Therefore, it is vital that Coast Guard-approved Coaches Training be readily available to those companies ready to practice CEMS.

Meeting the needs of the towing vessel industry in this regard, let alone the entire maritime industry, is a formidable challenge. There are as many as 650 towing companies and some 4,000 towing vessels of various types in the U. S. Without a robust training infrastructure, it would be impossible to provide a sufficiently large pool of trained coaches to support this need. Fortunately, the Coast Guard, members of the towing vessel industry, and numerous public and private training organizations have been working together to resolve this issue for some time.

Our primary strategy is to make coaches training available at more locations, and in forms that are most accessible by the industry. To do so, we established CEMS Experts Training, a train-the-trainer course conducted by the Coast Guard. Upon successful completion of this training, these personnel are qualified to teach and qualify other CEMS coaches. Some of those attending experts training are from maritime educational and training institutions such as the Massachusetts Maritime Academy and Seaman's Church Institute. Others are from third-party private training companies, and still others are representatives from the operating companies themselves. Certifying experts for these various types of organizations allows sufficient flexibility for nearly any operation to obtain coaches training in a way that works for that company.

Some companies, particularly the larger ones, prefer to have an in-house expert to serve as a coach trainer on staff. For other companies, particularly the smaller ones, it may not be as cost-effective to have their own expert. These companies might prefer to have their training done by a third-party contractor or a maritime training institution. There has been a lot of cooperation within the industry here. Frequently, certified experts from one company invite participation from potential CEMS coaches in another.

Since instituting the CEMS Expert Program, the number of available coaches has increased dramatically, as illustrated in Figure 52. As of July 2005, almost 600 people have passed coaches training.

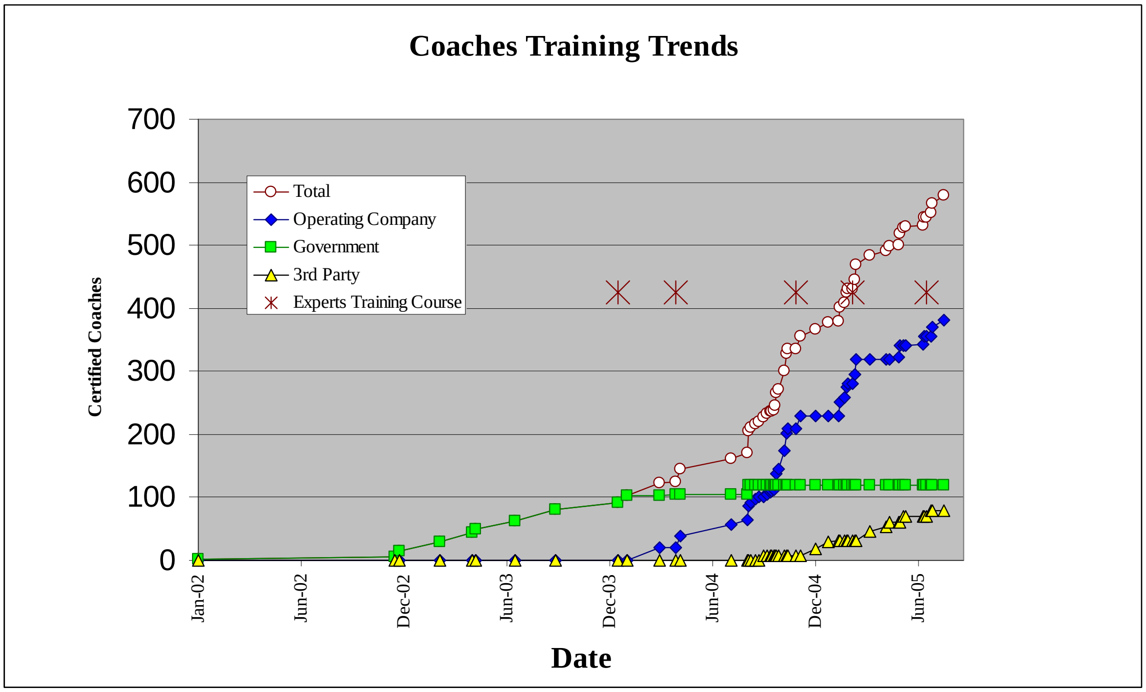


Figure 52. Coaches Training trends.

As shown in
Figure 53, the overwhelmingly preferred sources of training are the operating companies themselves. Two-thirds of all coaches receive their training from an expert provided by an operating company. The remaining non-government sources make up only 13% of training sources, but their numbers are growing as well.

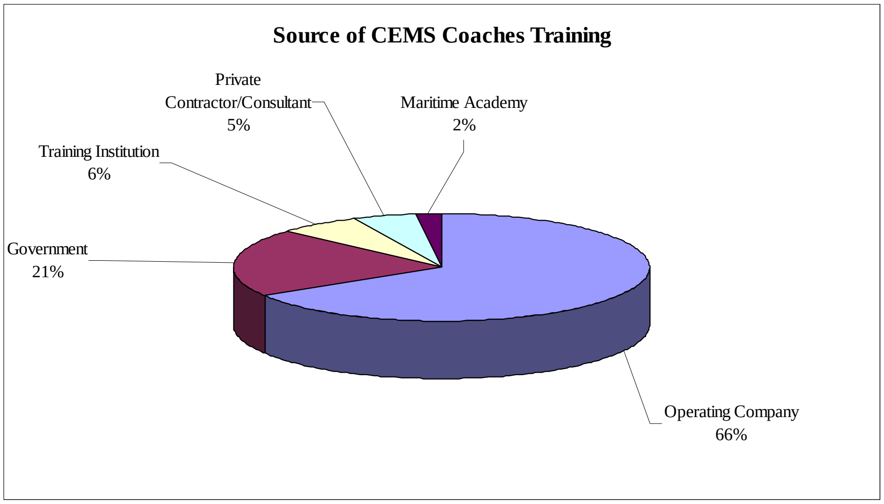


Figure 53. Sources of CEMS Coaches Training.

As CEMS becomes implemented industry-wide, a great many more qualified coaches will be needed. Our current strategy for developing experts allows us to rapidly expand availability as this demand increases. At the same time, we do not want to create such an excess of training resources that third-party trainers do not find it cost-beneficial to keep this training as part of their curriculum. So far, the third-party trainers have not been overloaded with requests for students, and some have even had to cancel classes due to lack of registration. Therefore, our current intentions are to build the availability of coaches training at a rate commensurate with demand.

Figure 54 shows, there are currently 57 certified CEMS Experts, 38 of whom are from operating companies. While the Coast Guard no longer trains coaches directly, the training and support of CEMS experts remains a full-time job. Some aspects of CEMS are scientifically complicated, and there are inherent pressures on third parties and company experts to qualify coaches. Because of this, the Coast Guard maintains an aggressive oversight of the Experts program, even after certification. This program includes reviews of tests administered by Experts and follow-up visits to observe coaches training. The Coast Guard also maintains a list of coaches certified by these experts and sends each new coach a letter welcoming them to the National Crew Endurance Training Team. As the number of certified experts and coaches increases, we expect this oversight workload to increase as well.

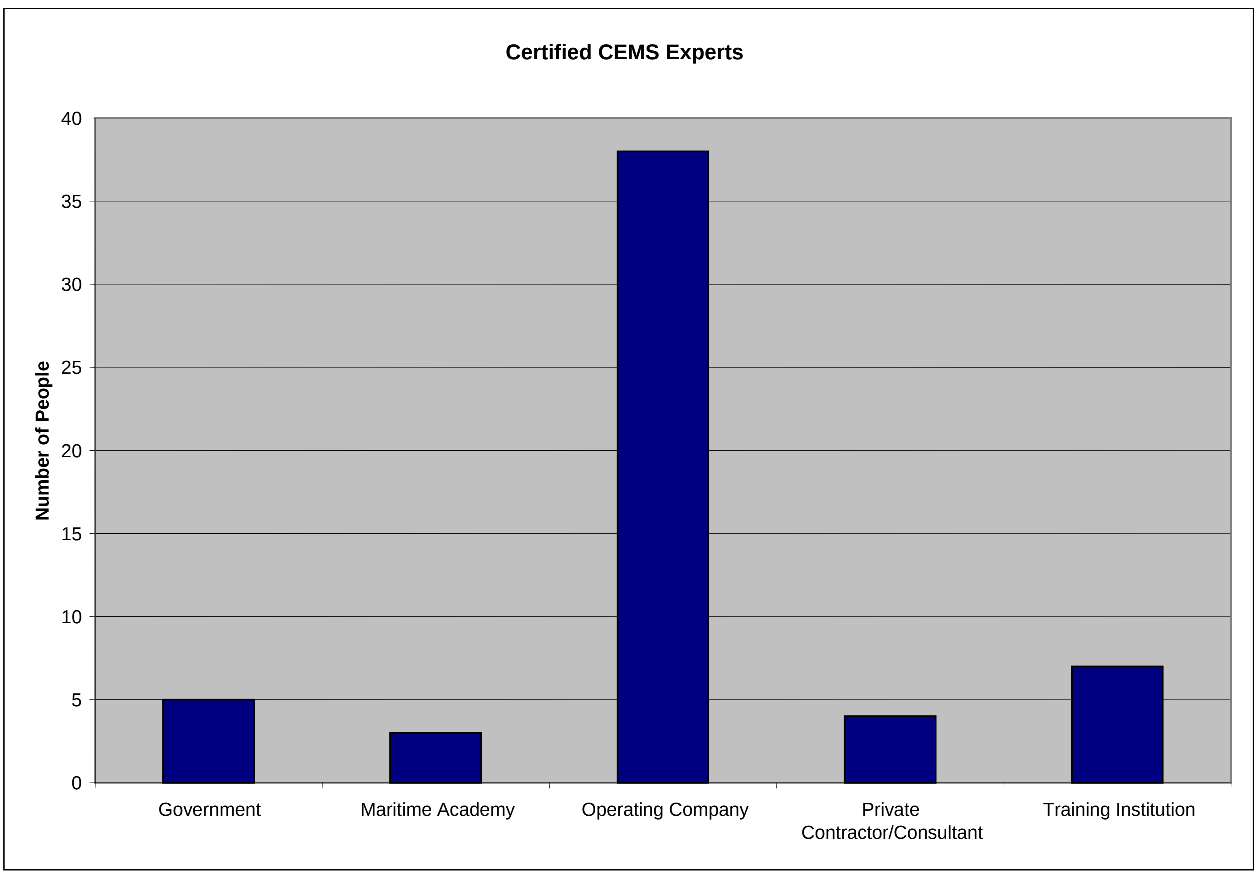


Figure 54. Certified CEMS Experts.

Resources Required

CEMS was developed and disseminated as a non-regulatory effort through a joint industry-government safety partnership. Because CEMS is voluntary, keeping the overhead associated with CEMS to a minimum is very important. Fortunately, there are many aspects of this program that support this aim. For example, CEMS works well within existing company safety management systems and crew training systems. The CEMS continuous-improvement approach allows a company to make improvements at an acceptable pace and cost. Nonetheless, there are resource requirements associated with CEMS for both the government and industry.

Within the Coast Guard

As the developer and main advocate of CEMS, the Coast Guard is the primary source of information about proper Crew Endurance Management and is ultimately responsible for the integrity of the program. Management of the CEMS program includes:

- Keeping the program up-to-date with current advances in scientific and medical research;
- Developing, supporting, and monitoring commercial and private CEMS training resources;
- Developing and maintaining program policies, guidelines, and information sources; and
- Monitoring the effectiveness of the program towards reducing the risk of fatigue-related accidents.

The administration of the CEMS Experts program described above is included in these duties. The experts program requires the Coast Guard to maintain its own cadre of experts to train new ones for the towing vessel companies and third-party training companies.

We anticipate that at some point there may be a need for a vetting of company CEMS programs. There are several possible sources to handle this need. Some chartering companies, insurance companies, and cargo owners have expressed interest in using CEMS as part of their vessel evaluation systems. Regardless of whether or not CEMS is incorporated into industry standards such as AWO's Responsible Carrier Program, included within a Coast Guard regulatory scheme, or remains a voluntary program like it is today, the Coast Guard will need staff to provide oversight to ensure that those claiming to practice CEMS are doing so in good faith. Most likely, this verification will take place through third-party CEMS Auditors. These Auditors would be individuals who visit the vessels and companies participating in CEMS to assess the extent of vessel and company participation. Training and administering these Auditors is another task for the Coast Guard.

Currently, Coast Guard administration of the CEMS program is a collateral duty for one employee. Nearly all of this person's time is spent in support of CEMS. Three other employees supplement this person's effort on a part-time basis. As previously stated, we expect this workload to expand as the application of CEMS expands throughout the maritime industry.

<u>In The Private Sector</u>

Administration: Companies participating in CEMS will have to make a certain investment of employee time in the form of a CEWG. This group will assess endurance-related risks, evaluate possible solutions, and develop a Crew Endurance Plan. The time commitment involved is largely up to each individual company's approach. Some companies may be able to leverage existing working groups or technology to minimize the impact on resources. In general, developing a useful Crew Endurance Plan should not be overly burdensome. Enclosure 5 is attached as an example of an existing plan.

Coaches: Companies practicing CEMS should expect to have a trained coach or an acceptable alternative on every vessel. Companies choosing to place a trained coach on every vessel can either send crewmembers to a third-party expert for training, or have one of their own certified coaches get certified as an expert, and have that person train their crews. The source of coaches training that is most cost-effective depends upon the company.

Having an in-house CEMS expert may make more sense for larger companies with more vessels and many coaches to train. There is no charge to attend the Coast Guard's Experts Training course, but the company must pay for travel and lodging. Experts training generally requires a full work week – two days for travel, and three days for the class (maximum travel/per diem estimated at $1,000, depending upon location of the attendee and training). Recurring costs for this option include the salary costs of the in-house trainer for time spent performing training and grading tests, as well as travel costs for the expert, if applicable. Using the in-house trainer strategy, one demonstration project company budgeted approximately $1,500 per vessel to train coaches and crew.

For smaller companies, or those sending a few people to training at a time, third-party Experts Training may be more appropriate. The cost for third-party training is set by the market and may vary with time and location. However, some experts are currently offering coaches training for $500 per person. Some towing companies have established cooperative arrangements with others that have their own certified expert. In this way, companies without an expert are able to obtain coaches training for free or at reduced cost. Over time, though, this may impose an undue burden on the company with the expert.

Whether a coach is trained in-house or by a third party, the person being trained will need to be away from work for up to four days – two for travel, and two for the class. In addition to salary costs, travel costs may be incurred (maximum travel/per diem estimated at $750, depending upon location of the attendee and training).

Regardless of whether or not the company decides to place a trained coach on every boat, it is vital that every company have at least one certified coach to guide the company through CEMS and serve as the company's CEMS Champion. Ideally, this person would complete both the Coaches and Experts Training at a total cost of ten working days.

For training institutions, maritime academies, and contracted third-party training, there is an investment required to become an expert, but it is not large, and generally is paid for after the first coaches training session held by that expert.

Education: In order to have a successful CEMS program, companies need to commit resources to train their vessel crews, as well as upper and middle management.

The cost of this training varies with the approach selected by the company. Costs vary depending upon whether the company holds this in conjunction with other training, and whether the training is held at the company facilities, offsite, or onboard.

Several training aids have been developed to support CEMS training:

- Training for vessel crews can be accomplished using computer training developed by the Coast Guard and the Ship Operators Cooperative Program, or SOCP ($20 for SOCP members, $100 for non-members);

- Knowledgeable presenters can put together CEMS training for vessel crews using computer-based training developed by the Coast Guard R&D Center. This "Self-Sustaining Workshop" Tool has no cost;

- Certified coaches receive instruction on how to educate vessel crewmembers on CEMS (cost included in Coaches Training);

- AWO and the Coast Guard have developed *CEMS Crew Endurance Management: Getting Started, Making It Work*. This implementation manual is aimed at company managers tasked with starting a CEMS program (no cost);

- AWO and the Coast Guard have developed an educational presentation for upper management (no cost); and

- Another company sells a DVD/videotape that provides an introduction to CEMS ($295 for SOCP members/$330 non-members).

As reported by demonstration project participants, crew time was the most significant cost of CEMS training. On average, project participants performed less than two hours of CEMS training each month. However, the companies that reported training for more than four hours were more successful overall. Some of the newer self-study tools may better facilitate obtaining necessary training.

Physical Changes: Companies that practice CEMS may also need to invest in physical vessel improvements. As indicated by demonstration project feedback, the costs can vary according to what actions are taken. Physical changes made to the vessels ranged from plugging in inexpensive nightlights to spending thousands of dollars abating noise and vibration issues. The key here is that the *company* decides what improvements to make.

To get a better understanding of the potential range of physical improvements, below are some of the more substantial measures taken by demonstration project companies. The first list of upgrades took place without having to take the vessel out of service, some occurring during normal loading of consumables:

- Replacing bedding with vibration-absorbing mattresses and pillows;
- Establishing a regular schedule to replace bedding – one company learned that their boats had not received new mattresses since the boats were built;
- Installing window treatments to block out light;
- Installing exercise equipment;
- Installing portable air filter equipment in berthing spaces; and
- Installing personal lamps in berthing spaces.

Other major modifications could only be completed when the vessel was not in service. These improvements, including major noise abatement projects, were scheduled to occur at times when they would not interfere with the normal operations cycle. The companies made these changes when the vessels were in the vessel yard for other major improvements. Some of the installed modifications were:

- Solid doors;
- Floating decks and insulation;
- Lighting modifications to raise vessel interior space lighting to CEMS levels;
- Vibration adjustments, including flexible machinery mounts and shaft couplings, wheel (propeller) tuning, and quieter mufflers; and
- Modified air intakes.

Some demonstration companies used CEMS criteria when making fleet changes. One company that acquired a number of new vessels incorporated CEMS improvements throughout the overhaul period before placing the boats in service. Another company downsizing its fleet used CEMS criteria as a factor in fleet disposition. The companies in the process of applying CEMS modifications across their entire fleets appeared to gain more significant reduction in crew risk factors.

The costs of the above modifications varied according to what modifications were made, and how. For example, when modifying windows, some companies hired contractors to make changes to the vessel, while others told the crewmembers to make the modifications themselves. Some companies used professional window treatments while others simply painted the windows black.

The demonstration project companies were unable to provide specific figures for the cost of these improvements, as they were part of overall modifications to the vessel. CEMS-related improvements were not identified as separate line items, so the cost could not be specifically quantified.

Policy Changes: Most policy changes cost little or nothing at all. This is particularly true of the policy to be courteous to those crewmembers sleeping off-watch.

Sustainability Measures – Overall Results

As demonstrated by the many towing companies voluntarily adopting the program, CEMS appears to be highly sustainable and resilient. Even as a voluntary program, it has flourished amongst hundreds of certified coaches and towing vessels. Just as importantly, the infrastructure necessary to support CEMS is largely in place and ready to expand as needed. Given the readily available training resources and the continuous-improvement approach of CEMS, this program is sustainable by any company or vessel with the will to see it through.

Benefits

Companies participating in CEMS can expect a return on their investment in several ways. First and foremost, we are reducing the risk that fatigue or poor endurance will contribute to an accident or pollution incident. This reduction can be measured using the fifteen endurance risk factors. Over time, as companies and crews identify and reduce risks, endurance-related incidents are expected to decrease.

However, even before a measurable reduction in risk occurs, participation in the CEMS process inherently builds awareness amongst employees. This in itself will improve crewmembers' ability to identify and understand endurance-related risks. As a result, they may make better personal choices, or at the very least, know when they are at risk.

Although the return on investment in CEMS may only be seen in the long run, some show immediate impact. For example, the crew of one vessel attributed a noticeable reduction in perceived fatigue to a series of vibration reduction measures, such as flexible engine mounts and floating floors.

Many CEMS environmental changes improve crewmembers' quality of life. This is important, not only for the short-term morale of the crew, but also for the long-term viability of the industry. CEMS can help companies retain their labor force by keeping the towing industry competitive with other places to work. The towing industry must compete for workforce entrants against conventional land-based industries. A company that has embraced CEMS will have vessels that are more appealing to the new employee and hopefully reduce employee turnover. For example, when new crewmembers joined one of the first boats to implement a new work schedule as part of its CEMS program, the new crewmembers were only familiar with the changed schedule, not the traditional 6 on – 6 off schedule. When transferred to a vessel that was not CEMS-oriented, these new employees either requested immediate transfer to a CEMS boat, or quit.

The benefits go beyond improving crew morale to improving personal health and safety. CEMS is also expected to help reduce the costs of health-related problems. Health care expenses and insurance premiums are spiraling for employers nationwide. Several demonstration project companies expect to reduce their health insurance premiums using CEMS as a key factor in keeping their workforce healthier, and have stated this goal in their business plans. This strategy is consistent with what some non-maritime companies have found – their insurance premiums are substantially lower if they have a program to address employee fatigue and alertness. [279]

There is also anecdotal evidence that CEMS can improve employee health. One company had CEMS boats where the crew cumulatively lost as much as 300 pounds. Another company's CEMS coach became fit enough to stop using hypertension medication.

Healthier crews also translate into higher retention of experienced crewmembers. Towing vessel operators, particularly those who are highly skilled and meet certain standards, can be expected to stay with the company if their health and safety risks are reduced. A forty- or fifty-year-old pilot who has gained his or her skill sets from years of hands-on experience in the wheelhouse may be motivated by CEMS training to lead a healthier lifestyle. If the pilot does, he or she may be better able to meet Coast Guard physical standards for a longer period of time, and, consequently, keep working longer. There is solid evidence that the CEMS has strong and positive impacts on companies and crews when the programs are applied properly. Companies can and will experience positive results from applying CEMS.

VII. CONCLUSION

As shown by the results of this demonstration project, the CEMS is effective in addressing known risks and factors that contribute to fatigue or endurance-related incidents. The degree of effectiveness depends upon the adherence to the process and principles of CEMS.

The results also show that CEMS can be effective for various segments of the towing industry. This is due, in part, to the fact that by beginning the process, an organization inherently raises awareness about endurance-related issues. We also see positive results because CEMS is flexible enough to be applied to any maritime transportation operation.

Just as importantly, CEMS is a program that towing vessel companies can practice successfully. CEMS is feasible. Implicit in this success is buy-in or vertical alignment among the company executives, middle-managers, and deck-plate mariners. Once a company achieves the necessary buy-in, the continuous-improvement approach of the process allows a company to address their highest risk factors in a manner suited to their operation and ability.

In many cases, the company can make many improvements at little or no cost. Other improvements may be expensive, costing thousands of dollars. In some cases, reducing a particular risk factor may not be feasible at a given time, or may conflict with a company's primary operational mission. The key here is that the company implementing CEMS should make a good-faith effort to reduce risk factors the best they can.

CEMS represents a significant investment for both the public and private sector. For the Coast Guard, this program requires considerable effort to build understanding, provide a supporting infrastructure, and assist companies implementing CEMS. We expect our workload to grow as more companies implement CEMS. The Coast Guard hopes to keep this workload manageable by leveraging support from our industry partners, such as the AWO. If the CEMS implementation scheme changes from the current voluntary program to one that is required, the Coast Guard would have to reassess the resources necessary for this effort.

In addition to the costs of making improvements to a vessel, CEMS asks companies to make a considerable but manageable investment of human capital, primarily in the form of time. In addition to additional duties placed upon the dedicated CEMS coach on each vessel, the company will also have to provide training time for crewmembers and others. Some company representatives have indicated that crew time is the largest constraint upon their CEMS program, particularly as it competes with other training that is required by regulation.

While the cost for this training is not insignificant, the availability of training resources for coaches and vessel crews is sufficient. New onboard training resources are produced frequently, and the Expert "train-the-trainer" program has created a variety of coach-training outlets across the country. This training infrastructure is readily expandable, based upon demand. The current pool of certified coaches is small compared to the towing industry as a whole. However, as demonstrated by some of the largest towing companies in the industry, a company can develop their own pool of coaches in a fairly short amount of time.

Unlike some safety initiatives, the benefits of CEMS are, for the most part, indirect. Our accident statistics tell us that many marine casualties and pollution incidents are caused by poor decision-making, situational assessment, and situational awareness. We know that fatigue and poor endurance impair these human factors. We know that endurance-related risk factors are present in every 24-hour, 7-day week transportation operation, and that the maritime environment imposes additional operational risk factors. Therefore, by addressing the root endurance-related risk factors, CEMS effectively reduces the risk of fatigue-related incidents.

Beyond decreasing the risk of accidents, there are other benefits for both the maritime employer and employee. Vessel crews practicing CEMS are likely to have more energy, and therefore be more productive. Companies practicing CEMS provide their crews a more healthy and hospitable lifestyle. This is likely to result in higher employee retention and healthier employees. Healthy employees have fewer sick days, perform better, and are able to stay working with the company longer. These are powerful motivators for companies facing a shortage of qualified crewmembers. Some companies even expect to see financial benefits in the form of reduced insurance premiums. The use of CEMS may affect a company's bottom line more directly. Some chartering customers have discussed the possibility of requiring companies carrying their cargos to use CEMS.

In short, CEMS works. It is something any company can do if they are truly willing. It is also something that can become part of the fabric of our maritime safety culture. It will take some work to get there, but in the end CEMS is a three-way win: vessel crews get better living and working conditions; operating companies get more efficient and safer vessels; and the Coast Guard and general public get cleaner, safer waterways.

The Way Forward

Section 415 of the Coast Guard and Maritime Transportation Act of 2004 (P.L. 108-293) adds towing vessels to the list of vessels subject to inspection under section 3301 of Title 46, U.S. Code, and provides that "The Secretary [of Homeland Security] may establish by regulation a safety management system appropriate for the characteristics, methods, and nature of service of towing vessels." At the time of drafting this report, the Towing Safety Advisory Committee (TSAC) was working on a task to assist the Coast Guard in developing the new inspection regulations. One of the many elements considered as a potential requirement of this regulation was the use of CEMS. The Coast Guard briefed TSAC on the results of this demonstration project so as to provide them an informed basis upon which to make a recommendation. In a meeting on October 12, 2005, TSAC approved the recommendation that the Coast Guard incorporate a safety management system as part of the towing vessel regulatory project. TSAC also recommended that crew endurance be a part of the safety management system.

While much deliberation will occur before the new regulations are completed, it is worth pointing out that the CEMS is well-suited for incorporation into a safety management system, the approach prescribed by the Authorization Act. In the meantime, the Coast Guard will continue promoting voluntary implementation throughout the towing industry and, as resources permit, other sectors of the maritime community. We will also share our experience internationally and, through the IMO, advocate the use of CEMS or CEMS-like approaches as part of our overall strategy against mariner fatigue. As CEMS implementation grows, we shall also support development of additional outlets for CEMS training and the development of additional onboard training resources.

We also intend to continue working through our Coast Guard/Industry Safety Partnerships to expand CEMS. CEMS was developed and tested with our towing vessel industry partners and would not be where it is today without them. Their assistance and cooperation continues to be a critical factor in the successful growth of CEMS across the industry.

END NOTES

[1] Martha Hotz, Vita Vitaterna, Joseph S. Takahasi, and Fred W. Turek, "Overview of Circadian Rhythms," National Institute on Alcohol Abuse and Alcoholism, p. 19.
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